第40届MATADOR智能制造与设计国际会议

40th MATADOR International Conference on Advanced Manufacturing and Design

摘要集
Abstracts

Manufacturing
Automation and Systems
Technology
Applications
Design
Organization and Management
Research

2019年7月8日-10日 / July 8-10, 2019

中国·杭州 / Hangzhou, China

Content

Keynote

FALM-1

FALM-2

LPAM-1

LPAM-2

MPT-1

MPT-2

DC-1

DC-2

FALM-3

FALM-4

LPAM-3

LPAM-4

MPT-3

MPT-4

WJ-1

WJ-2

FALM-5

FALM-6

LPAM-5

LPAM-6

MPT-5

LPRC

WJ-3

Poster

Keynote 1: Key Technologies and Applications of Digital Twin for Complex Equipment

Jianrong Tan

Zhejiang University, China

Abstract：

Realizing the interaction and integration of physical world and information world is one of key problems in the current intelligent manufacturing of complex equipment. Digital twin technology creates virtual model of complex equipment using digital way, and then it provides new ideas and technical means for intelligent design and manufacture of complex equipment by means of virtual-real interactive feedback, data fusion analysis and decision-making iteration optimization. The report systematically introduces the scientific connotation, current research status, key technologies and applications of the digital twin of complex equipment.

实现制造的物理世界和信息世界的交互和共融，是当前复杂装备智能制造需要解决的核心瓶颈之一。数字孪生技术以数字化方式创建复杂装备物理实体的虚拟模型，通过虚实交互反馈、数据融合分析、决策迭代优化等手段，为复杂装备的智能化设计制造提供了新的思路与技术手段。报告系统介绍了复杂装备数字孪生的科学内涵、国内外研究现状、关键技术及其企业应用。

Keynote 2: Creating Advanced Machinery for the 4th Industrial Revolution

Paul Shore

National Physics Laboratory, UK

Abstract：

Advanced production systems have seen dramatic changes during previous industrial revolutions. This presentation will highlight some of the critical production equipment developments that occurred since the first industrial revolution. It will go onto illustrate those expected and being developed through the emergence of the 4th digital manufacturing revolution. In conclusion, the application and changing form of robots will be considered.

Keynote 3: Quality Assured Smart Additive Manufacturing

Jyoti Mazumder and J Choi

University of Michigan, USA

Abstract：

This presentation describes paradigm-shifting approach for Additive Manufacturing(AM) by Laser Based direct writing and sophisticated on-line diagnostics with close loop control to monitor and control the material properties of the parts during fabrication. Our “Certify as you build”approach provide high level of reliability and robustness in manufacturing in general, thereby minimizing costly production downtime and rejection rate. The monitored signal includes the surface thermal radiation and the plasma spectrum generated during the laser-material interaction. Correlations have been developed successfully for in-situ detection of temperature, composition, defect and Phase transformation for both polycrystals and single crystal nickel-based super alloys. Due to the multitude of variables involved in the AM process, starting from process parameters to input materials, quality need to be interrogated continuously. Otherwise any defect in the single AM fabricated parts would be accumulated and one will reach the point of no return, at the expense of valuable materials, labor and time. Therefore, in-situ defect and properties detection is critical to accompany materials fabrication. This in situ diagnostics has the potential to correct the defect during the additive manufacturing process using feed back loop.

Keynote 4: Additive Manufacture of 3D Multi-Material and Functionally Graded Components using Multiple Jet Laser Powder Bed Fusion

Lin Li, Chao Wei, Xiaoji Zhang and Yuan-Hui Chueh

The University of Manchester, UK

Abstract：

In certain practical engineering applications, components with tailored material properties at different locations are desirable. It is difficult to realize this by using a single material. Despite the success in 3D printing of multiple polymer materials, it is challenging to print multiple material 3D components involving metals due to the high temperature requirement. Selective Laser Melting (SLM) is a powder bed fusion based additive manufacturing technique that has been demonstrated to be able print metal, ceramic and polymer materials. However, SLM currently can only print single material components or different materials across different layers, not within the same layer, limited by the powder spreading mechanism. In this presentation, we demonstrate 3D printing of multiple metallic and non-metallic materials over the same layer and across different layers in SLM. This has been realized by the integration of selective powder delivery, selective single layer material removal and the powder bed fusion. Specific system hardware and a software tool were developed to realize this capability. Printing of 2D and 3D functionally graded components is demonstrated. Process mechanisms, material characteristics and application potentials are discussed.

Keynote 5: History and Progress of Laser Intelligent Manufacturing

Voloymyr Kovalenko

National Technical University of Ukraine, Ukraine

Zhejiang University of Technology, China

Abstract：

Manufacturing is the source of human wealth. Product individualization and sustainable manufacturing are becoming urgent problems to be solved with the development of manufacturing. Laser manufacturing provides solutions for intelligent manufacturing and personalization, and have the characteristics of environmental protection, efficiency, energy saving, etc. Laser Intelligent Manufacturing (LIM), as an international research hot spot, has gradually transformed from fundamental studies into industrial applications. Current applications of LIM include laser cutting, micro/nano manufacturing, laser welding, 3D additive processing, surface modification, repairing & remanufacturing, etc. In this presentation, based on the review of the global research and application status on the LIM, the early exploration in the field of laser manufacturing in Ukraine and the recent research and application of LIM in China are introduced. Furthermore, recent research results in laser hybrid remanufacturing are introduced. The challenges and solutions of the LIM regarding the efficiency, the performance, the cost and the intelligentization are analyzed and discussed from the viewpoints of both fundamental research and industrial application. Finally, the future development trends of the LIM are prospected.

Keynote 6: A New Look into Abrasive Waterjet Machining Technologies

Jun Wang

The University of New South Wales, Australia

Keynote 7: Personalised Medicine through Additive Manufacturing

Paulo Bartolo

The University of Manchester, UK

Keynote 8: Implementation of "Internet of Things" Technology on Machine Tools from OT Layers

Wen-Yuh Jywe

President of National Formosa University, Taiwan

Keynote 9: Research Progress and Prospects of Laser Surface Engineering

Jianhua Yao

Zhejiang University of Technology, China

Abstract：

Laser surface engineering has the advantages including high flexibility, high quality and environmental friendliness, and have been widely used in energy equipment, mining machinery, metallurgical equipment, petrochemical industry and other fields. With the trend of diversification, on-site and high-quality in repairing, the laser manufacturing technology of single material, single performance and single energy field begins to develop towards composite materials, selection performance customization and multi-energy field assistance. As an important development direction and supplement of single laser technology, energy field assisted laser surface engineering can break through the bottleneck of single laser technology, and obtain more precise, more efficient and smarter processes. It will further promote the transform and upgrading of the manufacturing industry of China.

This report summarizes the research status of energy field assisted laser surface engineering around the world, and introduces the recent progress of the author's group on the manufacturing with laser/electromagnetic hybrid, laser/kinetic hybrid, laser/vibration hybrid and laser/electrochemical hybrid, etc. The advantages of laser hybrid manufacturing are analyzed in the aspects of material properties, microstructures and forming properties. The challenges and solutions on efficiency, performance, cost, and intelligence of the laser hybrid remanufacturing are discussed and analyzed from the perspective of fundamental study and industrial application. Finally, the future direction of the energy field assisted laser surface engineering is forecasted.

激光表面工程技术具有高柔性、高质量、环境友好等一系列优势，在能源装备、矿山机械、冶金装备、石油化工等领域得到了广泛应用。随着表面改性需求多样化、现场化、高质量的趋势，单一材料、单一性能以及单一能场的激光制造技术开始向复合材料、选区性能定制以及多能量场复合的方向发展。能场复合激光表面工程技术作为单一激光技术的进一步发展和重要补充，可突破单一激光技术的瓶颈，获得更精准、更高效、更智能的表面改性工艺，将进一步推动我国制造业转型升级。

本报告在综述国内外能场复合激光表面工程技术研究现状的基础上，结合作者团队在激光/电磁场复合、激光/动能场复合、激光/振动复合及激光/电化学复合等多能场复合制造领域的最新研究成果，从材料特性、组织结构、成形性能等方面剖析激光复合制造的优势，同时从基础研究和工业应用等角度对目前激光表面工程在效率、性能、成本以及智能化等方面存在的挑战和解决方案进行深入探讨和分析。最后，作者结合国内外研究现状对激光表面工程技术的未来发展趋势进行了展望。

Keynote 10: Innovation and Application in Han's Laser Smart Equipment

Yan Chen

Han's Laser Smart Equipment Group Co. Ltd, China

Abstract：

This report emphasizes the innovations and applications, including equipment development, automation production line, intelligent factory, to demonstrate the current state of the art of intelligent manufacturing of Hans Laser Smart Equipment Group.

本报告重点介绍大族激光智能装备的创新与应用，从产品研发，自动化生产线，智能化工厂展示公司智能制造发展情况。

Keynote 11: Thinking on talent training mode under the background of intelligent manufacturing

Jiansong Ye

Zhejiang Machinery and Electrical Group Co., LTD, China

Abstract：

Under the background of global manufacturing revolution, intelligent manufacturing has become the key for countries to gain competitiveness in the new industrial transformation. At present, there are still some problems in the field of intelligent manufacturing in China, such as the structural imbalance of talent training, the disconnect between the talent training mode and the actual intelligent manufacturing development, and the lack of openness and continuity in talent training system. In terms of current problems, it is necessary for us to change talent training strategies, construct the regionally integrated talent training pattern, innovate the talent training mode of the integration of industry and education, and establish a lifelong education system on the basis of studying the experience of the developed manufacturing countries represented by Germany, the United States and Japan, which could enable Chinese education to take on the new mission of building a manufacturing power.

在全球制造业革命性变革的背景下，智能制造已经成为国家在新的产业变革中获取竞争力的关键。目前，我国智能制造领域存在着人才培养结构性失调，人才培养模式与智能制造业发展实际脱节，人才培养体系缺乏开放性、连续性等问题。针对当前存在的问题，我们要在研究学习以德、美、日为代表的制造业发达国家的经验基础上，不断变革人才培养策略，构建区域一体化人才培养格局，创新产教融合人才培养模式，建立终身教育体系，使中国教育有力承担起建设制造业强国赋予的新使命。

Keynote 12: Nano-scale 3D printing of functional structures using blended resin mixtures

Yongfeng Lu[1], Peixun Fan[1],Ying Liu[1], Wei Xiong[2], Li Jia Jiang[1], Lan Jiang[3], and Jean-François Silvain[4]

[1]Department of Electrical and Computer Engineering, University of Nebraska-Lincoln, Lincoln, NE 68588-0511 (USA)

[2]Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, 1037 Luoyu Road, Wuhan 430074 (China)

[3]School of Mechanical Engineering, Beijing Institute of Technology, Beijing, 100081 (China)

[4]Institut de Chimie de la Matière Condensée de Bordeaux, Avenue du Docteur Albert Schweitzer F-33608 Pessac Cedex, (France)

Abstract：

Nanoscale 3D printing by two-photon polymerization (TPP) has been established as one of the most promising methods for achieving 3D fabrication in micro/nanoscales, due to its ability to produce arbitrary and complex 3D structures with subwavelength resolution. However, the lack of TPP-compatible and functional materials represents a significant barrier to realize functionalities of the fabricated structures devices, such as high electrical conductivity, high environmental sensitivity, high mechanical strength, and fast writing speed. To address these barriers, we have investigated the TPP 3D nanofabrication based on blended precursors. To unleash the full potential of TPP, it is essential to realize sufficient structural stability, high fabrication throughput, and fine linewidth. We introduced thiol-acrylate chemistry into TPP to improve all three of the factors simultaneously. Micro/nanofabrication by TPP was investigated using thiol-acrylic resins containing different amounts of tetrafunctional acrylic monomers and tetrafunctional thiol molecules. Compared with the pure acrylic resin, the thiol-acrylate resin (30 wt% of thiol concentration) can achieve higher writing speed, higher mechanical strength, finer linewidth, and lower percent of shrinkage in TPP fabrication. We also investigated a thiol grafting method in functionalizing multiwalled carbon nanotubes (MWNTs) to develop TPP-compatible MWNT-thiol-acrylate (MTA) composite resins. Significantly enhanced electrical and mechanical properties of the 3D micro/nanostructures were achieved. Microelectronic devices made of the MTA composite polymer were demonstrated. Similarly, we also realized metallic 3D micro/nanostructures with silver-thiol-acrylate composites via TPP followed by femtosecond laser nanojoining. Complex 3D micro/nanoscale conductive structures have been successfully fabricated with ~200 nm resolution. The loading of silver nanowires (AgNWs) and joining of junctions successfully enhance the electrical conductivity of the composites from insulating to 92.9 $s \cdot m^{-1}$ at room temperature. The nanomaterial assembly and joining method demonstrated in this study paved a way toward a wide range of device applications, including 3D electronics, sensors, memristors, micro/nanoelectromechanical systems (MEMS/NEMS), biomedical devices, and fuel targets for inertial confinement fusion.

Keynote 13: Cultural Effects on Manufacturing R&D in Japan - with Comparison with USA, China and Europe

Jiwang Yan

Keio University, Japan

Abstract：

Manufacturing is an important part of the economy of a nation, also a common base for supporting our human society. After three major industrial revolutions, the manufacturing industry has changed greatly and is now advancing toward a new era. In this lecture, after reviewing some recent trends of manufacturing industry in various countries and regions, the effects of cultures, traditions and other human factors on the manufacturing R&D activities will be compared and analyzed. Understanding these aspects helps young researchers to have a global vision of the relationship between manufacturing and the society, to identify new research directions, and to communicate/collaborate with people from other regions with different cultures, traditions, and ways of thinking.

Keynote 14: Engineers and the grand challenge of waste: Engineering the future

Paul Mativenga

The University of Manchester, UK

Abstract：

A current and future challenge and opportunity for engineers is to promote a sustainable world and to be the innovators and positive agents of change in a green and circular economy. This is a challenge for all engineers irrespective of their discipline. This talk will explore the challenge and opportunities and draw upon some examples to illustrate unanswered questions, research and business opportunities. The aim is to ignite a passion and mind-set and to stimulate innovation in a green economy.

Keynote 15: Intelligent Manufacturing Practice of Industrial Vehicles of Hangcha Group

Qipeng Li

Zhejiang University of Science & Technology, China

Abstract：

As one of the largest manufacturers of industrial vehicles in the world, Hangzhou Group has realized intelligent manufacturing, intelligent products and intelligent services for industrial vehicles by utilizing technologies including robotics, Internet of Things, big data, cloud computing, and thus has opened up a new model for the development of industrial vehicle manufacturing industry.

FALM-1: Research on the Interaction between Laser and Arc in the Process of two Heat Sources Hybrid Welding

Shi Yan

Changchun University of Science and Technology

Abstract：

The interaction between the two heat sources in the process of laser-arc hybrid welding was studied by means of high speed camera, welding analyzer, spectrometer, laser beam analyzer and so on. Through the study of the effects of laser plasma on arc characteristics, the action regulation of laser plasma on electron temperature and electron density, arc conductive mechanism, arc morphology, volt-ampere characteristics and droplet transfer characteristics of arc plasma are revealed. Through the effects of arc plasma on laser beam quality and propagation characteristics are obtained, The action regulation of arc plasma on laser focus position, spot shape, power and power density are obtained. The tow hot source matching relationship between laser and arc is explored, and the evaluation method of matching relationship between laser and arc is established.

FLAM-1: Microstructure and Properties of CoCrFeNiTi High Entropy Alloy by Laser Cladding

Wenpeng Gao[1], Hao Liua[2,*], Jingbin Hao[1], Haifeng Yang[1]

[1]School of Mechanical and Electrical Engineering, China University of Mining and Technology, Xuzhou, China

[2]Jiangsu Engineering Technology Research Center on Intelligent Equipment for Fully Mining and Excavating, Xuzhou, China

Abstract：

This work aims to develop a new high-entropy alloy (HEA) material system and to explore the effect of Ti on the microstructure and properties of CoCrFeNi high-entropy alloy. CoCrFeNiTi high-entropy alloy coating was prepared on the surface of 40CrNiMoA steel by laser cladding. The microstructure, microhardness, wear resistance and corrosion resistance of the coating were studied by X-ray diffractometer (XRD), energy spectrometer, scanning electron microscope (SEM), microhardness tester, friction and wear tester and electrochemical workstation. The CoCrFeNiTi HEA coating shows good metallurgical bonding with the substrate. The microstructure of the coating is typical dendritic structure. The CoCrFeNiTi coating is mainly composed of solid solution phase (Fe,Ni) with face-centered cubic, Cr-Fe-Ni enriched phase and intermetallic phase (Ti-rich). The microhardness of the coating reaches up to 791.5$HV_{0.3}$, and the average hardness is 2 times of the 40CrNiMoA steel substrate. Electrochemical tests show that the corrosion potential of the coating is -0.465V and the corrosion current density is 1.45×10-6 A/cm^2. The coating friction coefficient is stable between 0.38 and 0.43, and the wear rate is 2.11×10-7cm^3/(N·m). The high-entropy alloy coating was prepared on the surface of 40CrNiMoA by laser cladding, which has high microhardness and good corrosion resistance and wear resistance, and has a wide range of application prospects.

FALM-1: Design of Synchronous Coupling Device of Alternating Magnetic Field for Laser Refining and Remanufacturing

Zhifeng Yuan[1,2], Liang Wang[1,2],Yong Hu1,2, Shaozhuang Bai[1,2], Kejing Jiang[1,2],Jianhua Yao[1,2]

[1]Institute of Advanced Laser Manufacturing, Zhejiang University of Technology, Hangzhou 310014, China

[2]Zhejiang Provincial Collaborative Innovation Center of High-End Laser Manufacturing Equipment, Hangzhou 310014, China

Abstract：

Laser additive remanufacturing technology has many advantages over other remanufacturing technologies, such as fine cladding structure, strong adhesion between the cladding layer and the substrate, low dilution by the substrate, high cladding efficiency and small substrate deformation, etc. However, in the laser additive remanufacturing process, since the melting and condensation of the metal powder and the substrate are completed in a short period of time, the powder and the substrate are affected by the difference in thermal properties and the forming process, and the cladding is affected. In the layer, defects such as pores, cracks, and inclusions, and poor bonding of the cladding layer to the substrate are easily formed.

Additional alternating magnetic field assisted laser additive remanufacturing is a multi-energy field laser additive remanufacturing technology, which applies an alternating magnetic field to the laser molten pool, and generates an induced current inside the molten liquid metal in the molten pool. The variable magnetic field interacts to form a gradient Lorentz force that drives the flow of the liquid metal to regulate the melt flow in the molten pool, accelerate the bubble discharge in the molten pool, reduce the void defects in the cladding layer, and improve the quality of the cladding layer. Through the Comsol simulation software, the influence of material, magnetic field parameters and device structure size on the Lorentz force gradient of the molten pool was analyzed. On this basis, a synchronous magnetic field synchronous coupling device for laser additive remanufacturing was developed. The aluminum alloy coating was prepared on the surface of cast aluminum alloy by alternating magnetic field assisted laser additive remanufacturing. The results show that after applying the alternating magnetic field, the pore defects in the coating are significantly suppressed due to the action of the gradient Lorentz force.

FALM-1: Algorithm and Implementation of Consistent Overlap Ratio of Free-form Surface Laser Cladding

Su Hao, Shi Tuo , Shi Shihong , Fu Geyan

School of Mechanical and Eletric Engineering,Soochow University,Suzhou,Jiangsu 215021, China;

Abstract：

Path planning is a difficult point for laser cladding of any irregularly shaped freeform surface. Common methods are teaching method and equal-width slice based on three-dimensional contour point clouds. The generality of teaching method is not strong; since the curvature at different positions along the cladding direction changes, the equal-width slicing method will cause the overlap ratio of the front and rear melt channels to change, and the quality of the cladding is significantly reduced. This study proposes a trajectory generation method with equal overlap ratio. Using the depth camera Kinect V2 to collect the point cloud data of the surface and construct a model, finding equidistant points from machining points of the initial melting path along the cross-section of the vertical cladding direction and fit them to generate next track. Above steps are repeated to form a spatial curve type of cladding track family. The method can control the equidistance of each melt channel to obtain a curved cladding layer with overlap ratio tending to consistent, which can effectively improve the quality of the curved cladding layer.

FALM-1: Numerical Simulation and Experimental Study of Dense Weld Deformation of Thin GH3128 Plate in Fiber Laser-Welding

Zheng Cao

Beijing University of Technology, China

Abstract：

Active thermal protection components are mostly made of GH3128 superalloy, which have dense welds result in the greater trend of welding deformation. Therefore, it's difficult to control the shape and size of components. In this paper, the welding seam profile, temperature distribution and welding deformation of thin GH3128 plates welded by fiber laser are simulated by MSC·Marc software. Afterwards, the simulated results are verified by corresponding process experiments. The results show that the energy coupling behavior of fiber laser penetration fusion welding can be simulated by the combination heat sources of "Gauss surface heat source + cylinder heat source". With optimizing mesh generation and measuring GH3128 superalloy physical parameters (specific heat capacity, yield strength and modulus of elasticity), the simulated results, such as welding seam profile and temperature fields at different positions (perpendicular to the welding direction) are identical to the experimental results. On this basis, the residual stress and deformation of thin GH3128 plates (t=4 mm) welded densely by fiber laser are simulated. The influence of welding interval, welding sequence and other parameters on residual stress distribution and deformation are obtaining, and compared with the experiments.

FALM-2: Analysis of Hot Cracking in Laser Welded Ni Alloy and Platinum Foil Joints

Weiwei Dong[1], Jian Lin[1], Yongping Lei[1], Rongshi Xiao[2], Hangguang Fu[1]

[1]Institute of Materials Science and Engineering, Beijing University of Technology, Beijing, 100124, China;

[2]Institute of Laser Engineering, Beijing University of Technology, Beijing, 100124, China

Abstract:

Welded bellows of nickel-based superalloy plays an important role in the field of aerospace. At present, the common welding method abroad is mainly electron beam welding, while the domestic ones is mainly microbeam plasma welding, both of which have hot crack problem, which seriously affects the yield of bellows and increase the manufacturing cost. In this paper, aiming at the hot crack problem of nickel-based superalloy bellows, the adjustable clamping gap welding jig was used to clamp the foil, and pulse laser was used to conduct edge lap welding of GH4169 nickel-base alloy foils with a thickness of 0.2 mm. The relationship between the hot crack length of edge lap joint and laser welding process was studied and the mechanism analysis of the cause of hot crack and the process of eliminating hot cracks were discussed. The results show that pulsed laser welding can realize the edge lap welding of nickel-based superalloy foils. Good macroscopic forming welded joints that meeting the engineering size requirements can be obtained with the power of 60W ~ 240W and the speed of 10 mm•s^{-1}~ 30mm•s^{-1}. Crystallization cracks can be observed in the weld zone and the hot crack can be reduced to 6.7μm by controlling the laser power, welding speed, pulse duty cycle, clamping elongation and off-focus value. The crack originated from the sharp angle of the two foils and there were defects of impurities such as laves phase (γ'-Ni3（Ti，Al)、γ''-Ni3Nb)、oxide of Al and Ni-Ni2Mg which caused the crack to expand near the defects of impurities. Preheating 150°C can eliminate weld hot cracks.

镍基高温合金焊接波纹管在航空航天领域有着重要的地位，目前，国外主要采用电子束焊接，国内主要采用微束等离子焊接，均存在热裂纹问题，严重影响了波纹管的成品率，增加了制造成本。0.2mm 厚波纹管焊接接头的熔宽要求为 240μm～480μm，熔高要求为 400μm～600μm，测量得到成品波纹管的平均裂纹长度为 60μm。本文针对波纹管的热裂纹问题，利用可调夹持间隙焊接夹具装夹箔片，采用脉冲激光对 0.2mm 厚 GH4169 镍基合金箔片进行了边缘搭接焊。研究了边缘搭接接头的热裂纹长度与激光焊接工艺之间的关系，分析了热裂纹成因的机理并探讨了消除热裂纹的工艺方法。研究结果表明，脉冲激光焊接可以实现镍基合金箔片的边缘搭接焊，在功率为 60W～240W，速度为 10 mm·s^{-1}～30mm·s^{-1} 范围内可以获得成形良好且尺寸符合工程要求的焊接接头。焊缝区出现结晶裂纹，通过控制激光功率、焊接速度、脉冲占空比、夹持间隙和离焦量等参数，可以将热裂纹减小到 6.7μm。裂纹起源于两箔片的尖角位置，尖角附近存在 laves 相 (γ'-Ni3（Ti，Al)、γ''-Ni3Nb)、Al 的氧化物和 Ni-Ni2Mg 等缺陷杂质，导致裂纹在缺陷杂质处扩展。150°C 预热处理可以消除热裂纹。

FALM-2: Wear Performance of Laser Induced Arc Welding of High Boron and High Carbon Steel

李环，袁根福，郭百澄，杨富理

江南大学，无锡 214122

摘要：

目的为细化高硼高碳合金堆焊层中粗大硬质相，提高堆焊层耐磨性能。方法 以Q235为基材，选取高硼高碳焊条。通过OM初步观察，XRD与SEM分析验证，对比研究利用电弧堆焊和激光电弧复合堆焊层横截面的显微组织形貌；通过显微硬度测试和磨粒磨损试验，分别评价两种堆焊层的硬度和耐磨性。结果 发现单一电弧堆焊层截面中的硬质相多呈长条片状、六边形块状和规则四边形块状，显微硬度平均值为876.7HV，磨损量为0.36g；激光诱导下的堆焊层其硬质相尺寸明显减小，均匀弥散分布；显微硬度平均值为1030.6HV，磨损量为0.127g。由此可见，平均显微硬度提高了约154HV，磨损量减少了65%。结论 脉冲激光搅动熔池碎断粗大硬质相，细化了粗大的硼碳化物和硼化物，提高了高硼高碳堆焊层的硬度和耐磨性。

FALM-2: Gas Protection Characteristics of Ti-6Al-4V Alloy Induced by Laser Cladding in Open Environment

Gang Li

Soochow University, China

Abstract:

Titanium alloy has the characteristics of high strength, good corrosion resistance and good biocompatibility. It has a wide range of applications in aviation and medical industries. However, the titanium alloy has a large chemical activity and reacts strongly with oxygen, nitrogen and hydrogen in the air, causing a sharp drop in physical properties. In consideration of the serious oxidation phenomenon of titanium alloy induced by laser cladding under open atmosphere, a coaxial nozzle with inner main protection + outer auxiliary protection was designed, which achieves anti-oxidation by forming an inert partial protective atmosphere near the molten pool. The gas flow field of the inside-laser powder feeding nozzle was established by FLUENT software, and the oxygen mass distribution under different shielding gas flow rates was analyzed. Since various properties of the titanium alloy are not changed significantly at an oxygen concentration of less than 2000 ppm, a range in which the oxygen mass fraction is less than 2000 ppm is defined as an effective protection range. The effective protection range under different shielding gas flows is analyzed by numerical simulation. According to the simulation results, the laser cladding experiment of Ti-6Al-4V alloy in open environment was carried out. The oxidation of the single cladding layer was consistent with the simulation results. A circular single-layer experiment was carried out to verify the coaxial characteristics of the protective airflow, indicating that the protective nozzle still has a good protective effect when performing variable-direction cladding. A bulk experiment was carried out to obtain a block shaped part in which the upper surface was flat and each surface was silver-white. According to the tensile properties test, the ultimate tensile strength of the sample was 1144 MPa, and the elongation was 6.24%.

FALM-2: 304 Stainless Steel Foil Laser Micro Welding with Argon Gas Protection

杜伟哲，黄婷，肖荣诗

北京工业大学激光工程研究院 高功率及超快激光先进制造实验室 北京 100124

摘 要：

基模连续或准连续光纤激光器搭配扫描振镜系统的激光微焊接技术是当前的研究热点，具有广泛的应用前景。本文采用焦斑直径为 55 μm 的基模光纤激光器及振镜系统对厚度为 100 μm 的 AISI 304 不锈钢箔进行平板扫描焊接。研究了氩气保护、无气体保护对激光微焊接工艺参数的影响，建立了两种条件下的激光微焊接工艺窗口。研究表明施加气体保护不仅可以改善焊缝成型，得到鱼鳞纹细密且无表面氧化的焊缝表面形貌，而且可以消除热导焊向深熔焊转变时熔宽的不稳定分布，扩大工艺窗口的范围。对工艺窗口内不同工艺参数下的接头进行拉伸实验，焊缝最大抗拉强度均高于母材。

FALM-2: Numerical Simulation of Buckling Deformation of 3161 Ultra-Thin Plate by Laser Welding

ZHANG Jing-qi[1], LIN Jian[1], LEI Yong-ping[1], XIAO Rong-shi[1]

[1]Institute of Materials Science and Engineering, Beijing University of Technology, Beijing, 100124, China;

[2]Institute of Laser Engineering, Beijing University of Technology, Beijing, 100124, China

Abstract：

Based on the thermal-elastic-plastic finite element method and the thin plate stability theory using energy criterion, the stress field of surfacing welding of 316L ultra-thin plate with 0.07mm thickness is analyzed by using ABAQUS finite element analysis software. The distribution region and size of the inherent strain are obtained. By using the linear eigenvalue analysis method, the inherent strain can be equivalent to the thermal load in the weld zone to simulate the post-weld buckling deformation of the thin plate, and the welding deformation law of the ultra-thin plate is obtained. The effects of constraint type, weld length, plate width and heat input on the critical instability load and corresponding buckling mode of thin plate are studied and analyzed. The results show that by shortening the weld length and reducing the plate width, the critical instability load of the thin plate welded structure can be increased and the failure probability of structure can be reduced. With the increase of heat input, the width of the inherent strain zone increases, and the distribution of the inherent strain in the weld direction becomes more uneven, which will lead to the change of the buckling mode and the corresponding buckling eigenvalues of the thin plate. The buckling behavior affects the final form of welding deformation of thin plate.

FALM-2: Experimental Investigation on Picosecond Laser Induced Plasma Micromachining

Huang Yuke Xu Bin Ma Chenbin Li Chengyu Wang Xingsheng

College of Engineering, Nanjing Agricultural University, Nanjing 211800

Abstract：

Laser induced plasma micromachining (LIPMM) is a promising material processing method with the advantage of absorbing more energy. Micro-channels were firstly created by direct laser ablation and LIPMM to comparatively assess the machining ability of two processes. The results showed that LIPMM could create micro-channels with less heat affected zones, smoother surfaces, higher material removal rates and greater aspect ratios. On this basis, the influences of laser scanning speed, frequency and pulse energy on machining characteristics of LIPMM were investigated. The results showed that the machined depth increased with the increase of pulse energy and frequency, and reduced with the increase of scanning speed within the test range. The change of machining width was similar to that of depth, but with much less variation. The material removal rate increased with the increase of pulse energy, frequency and scanning speed.

LPAM-1：An experimental investigation into the laser drilling process of nitrile butadine (NBR) rubber under different wavelengths, pulse durations and drilling methods

Carlos Hernandez-Castaneda Juan[1,2], Guang Hui Lim[2], Yin Chi Wan[2], Hongyu Zheng[2]

[1]School of Mechanical Engineering, Shandong University of Technology, Zibo, China

[2]Singapore Institute of Manufacturing Technology, Singapore, Singapore

Abstract：

This paper explores laser drilling of nitrile butadine (NBR) rubber under different wavelengths and pulse durations. NBR has good resistance to oil and can withstand a range of temperatures from -40 to 108 0C. Therefore, it is widely used in the automotive and aeronautical industry to make fuel and oil seals. Drilling micron-size holes with controllable taper angle and thermal damage in rubber remains a challenge. We report a systematic study with a few types of lasers by trepanning and percussion drilling methods. The lasers employed include a Ti:Sapphire (λ=795 nm, τ=120 fs), an Nd:YAG (λ=1064 nm, τ=10 ps) and a third harmonic Nd:YAG (λ=355 nm, τ=30 ns). The drilling process was conducted under direct laser beam irradiation with an assistant Nitrogen gas stream. The drilled hole diameters, the thermal effect induced on the NBR rubber and the aspect ratio obtained under these laser drilling methods were analyzed. The laser pulse duration in the laser drilling process was quantified for the three laser wavelengths employed. Drilling by trepanning method accomplished through-holes but with larger hole diameters. An optimized laser percussion drilling method proved effective to reduce the hole diameter and to increase the aspect ratio. The third harmonic Nd:YAG laser (UV laser) achieved higher drilling speed with an aspect ratio of 35. The ultrashort pulse laser proved effective into reducing thermal effects on NBR rubber, and achieved aspect ratios of 10 on thin rubber (1.5 mm) and of 25 on thick rubber (5 mm) respectively.

LPAM-1：Advanced Stellite Alloys as Hardfacing Materials for Wear Resistance Applications

Rong Liu [1,2,] Yinping Ding [2,] Jianhua Yao [2,] Qunli Zhang [2,] Matthew X. Yao[3]

[1] Department of Mechanical and Aerospace Engineering, Carleton University,

1125 Colonel By Drive, Ottawa, Ontario, Canada K1S 5B6

[2] Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, No.18 Chaowang Road, Hangzhou 310014, China.

[3] Kennametal Stellite Inc., Belleville, Ontario, K8N 1G2, Canada

Abstract：

Stellite alloys are a range of cobalt-chromium alloys. They may also contain tungsten or molybdenum and a small (< 3 wt%) but important amount of carbon. Therefore, Stellite alloys are generally strengthened by the precipitation of carbides in the cobalt solid solution matrix. These alloys display a variety of wear resistance in both lubricated and unlubricated applications, and they also exhibit excellent retention of hardness at relatively high temperatures. The use of Stellite alloys spans a variety of industries from the oil and gas sector, to the medical industry. One of the most popular applications of Stellite alloys is hardfacing for surface wear-resistance improvement. Traditionally, Stellite 6 alloy has been selected as the hardfacing material due to its unique chemical composition (29%Cr, 4.5%W, 1.5%Mo, 1.2%C, Co balance, in weight) and excellent combined mechanical, anti-corrosion, anti-wear, and high temperature properties, but in recent years, many advanced Stellite alloys with combined better wear and corrosion performance than Stellite 6 have been developed, for example, 700 series Stellite 720 and Stellite 728, which contain high molybdenum. A Stellite alloy mixture hardfacing consisting of 70% Stellite 3 and 30% Stellite 21, is also created via laser cladding. The microstructure of the hardfacing is analyzed using SEM, EDS and XRD. The hardness, dry sliding wear resistance, cavitation-erosion resistance in NaOH solution and corrosion resistance in morpholine solution at pH 9.5 to simulate the amine environment of boiler feedwater service in power generation plants, are evaluated. The Stellite 6 hardfacing prepared with the same laser process parameters is analyzed and tested under the same conditions for comparison. The experimental results and real industrial test demonstrate superior performance of the Stellite alloy mixture hardfacing to the Stellite 6 hardfacing for control valve seat sealing application.

LPAM-1：Three-dimensional Mn/MnO_x electrode for supercapacitor

Mengya Cui, Ting Huang, Rongshi Xiao

Institute of Laser Engineering, Beijing University of Technology, Beijing, China

Abstract：

As one of the major energy storage devices, supercapacitors have attracted great attention over the past few years because of their high power density, long cycle life and fast charging-discharging rate. Manganese oxides have been considered to be among the most promising candidates for the active materials for supercapacitors owing to their high theoretical capacitance, natural abundance, low cost and environmental friendliness. In this study, 3D-Mn/MnO_x intergrated electrode for supercapacitor was reported. Femtosecond laser was used to generate 3D conductive network on metallic Mn surface (3D-Mn) which also served as the current collector. Mn_2O_3 and MnO directly formed on the 3D-Mn surface by the following chemical oxidation. With 6 M KOH electrolyte, the 3D-Mn/MnO_x electrode had significantly improved areal specific capacity and cycling stability in both cyclic voltammetry (CV) and galvanostatic charging-discharging (GCD) tests. There was almost 84% capacitance retention after 10000 cycles relative to that of first cycle, indicating superior long-term cyclability of the 3D-Mn/MnO_x electrode. With PVA/KOH solid electrolyte, the symmetric 3D-Mn/MnOx supercapacitor delivered the highest energy density of 11.1μW/cm² and the highest power density of 282.0 μW/cm². The enhanced performance is attributed to the unique periodic 3D-Mn/MnO_x architecture which largely increases the effective electrode surface area, shortens the electron/ion transportation distance, facilitates electrolyte permeation, and reduces the contact resistance between 3D-Mn and MnO_x.

LPAM-1：Optimization and metallurgical characterization of high-quality microchannel fabrication on Titanium by nanosecond fiber laser

Ashish Kumar Sahu, Sunil Jha

Indian Institute of Technology, Delhi, India

Abstract：

Laser beam micromachining have application to fabricate microchannel for various microfluidics devices for liquid fluid flow in medicine, aeronautic, automotive medical and other industries. Commercially pure titanium have application in biomedical, fuel cell oxygen generators and hydrogen generators. In recent years, nanosecond fiber laser micromachining has gained popularity due to its potential application, where product functionalities depend on microfeature dimension and surface structure.High quality microchannel is needed for better flow of fluids without interruption. Laser beam micro machining facing adversity because of poor quality and low aspect ratio. In LBM, higher MRR can be achieved at multiple scans which results in poor surface quality. Similarly at higher scanning speed gives better surface finish at cost of lower MRR.In this study, attempt has been made to optimize no. of scans, scanning speed, pulse repetition rate and assist gas pressure for better surface finish, higher MRR and lower taper of microchannel. The significant parameters have been selected based on analysis of variance (ANOVA). SEM and EDX analysis were carried out for metallurgical characterization. Surface

LPAM-1：Fabrication of the porous Si Architecture for SERS Platform by Laser Surface Remelting and Dealloying

Li Cao, Ting Huang, Rongshi Xiao

Beijing University of Technology, Beijing, China

Abstract：

Surface-enhanced Raman scattering (SERS) is a Raman spectroscopy technique with high detection sensitivity. The sensitivity can be improved by modifying the structure of SERS platform. In this study, the facile fabrication of three-dimensional (3D) porous Si/Au SERS platform with attractive SERS performances was reported. The developed method relied on laser-induced dendritic microstructure on the surface of Al-20Si (20 wt. %) cast alloy followed by dealloying Al from the laser treated surface, leaving a 3D dendritic-like porous Si substrate. By sputtering, the substrate was coated with Au film to form 3D porous Si/Au SERS platform. The as-fabricated platform showed ultralow concentration detection of rhodamine 6G (R6G) molecules down to 1×10^{-15} M with enhancement factor of 10^{11}-10^{12}. The lowest detection concentrations of crystal violet (CV) and malachite green (MG) are 10-14 M and 10^{-13} M respectively, indicating the superior sensitivity of the porous Si/Au platform. Furthermore, the structure of the porous Si could be effectively altered by controlling the laser energy input, which in turn affects the performance of the porous Si/Au platform.

LPAM-1：Quasi-continuous-wave laser additive manufacturing for tailored microstructures

Lijun Song, Simeng Li, Hui Xiao, Wenjia Xiao, Xingbo Liu

Hunan University, China

Abstract：

Laser additive manufacturing has been widely used in fabricating geometrically complicated functional parts. However, the microstructure of the fabricated parts exhibits typical columnar morphologies due to the epitaxial solidification, and therefore the tailoring of the microstructural morphology is challenging. In this report, we present a quasi-continuous-wave laser additive manufacturing approach to tailor the microstructural morphology. The transient solidification during the process is able to transform the columnar dendrites, grain and texture into equiaxed ones. The process is analyzed with transport phenomena theory, the solidification conditions are monitored by pyrometers, and the microstructures and the mechanical performance are analyzed. It is found that the solidification conditions and the multi-directional solidification behavior promote the columnar to equiaxed transformation. The quasi-continuous-wave laser additive manufacturing provides a simple and practical methods for microstructural control.

LPAM-2: Effect of Graphite Addition on Mechanical Properties of Direct Laser Deposited Al_2O_3 Ceramics

Yuan Xu[1], Chao Yu[2], Qiuyu Miao[2], Guangyi Ma[2]

[1]Huangshan uniersity, Huangshan, China

[2]Dalian University of technology, Dalian, China

Abstract：

In this paper, graphite-added Al_2O_3 ceramic materials were prepared by the direct laser deposition technology. The effects of different additions on the phase structure, microhardness and fracture toughness of Al_2O_3 ceramics were investigated at 3%, 6%, 9%, and 12% graphite mass addition. The results show that the direct laser deposition technology was beneficial to maintain the uniform mixing of graphite and ceramics, and could avoid the delamination caused by the difference of density. When the graphite added amount were 6% and 9%, there were fewer internal defects in the formed samples; and no obvious new phase was found after the addition of graphite. The microhardness was lower than that of pure ceramics, but it increased first and then decreased with different graphite addition. When the addition amount was 6% and 9%, it reached 18.84 GPa and 18.86 GPa, respectively, which was 99% of pure Al_2O_3 ceramics. When the addition amount was 12%, it dropped to 94% of pure ceramics. The change of microhardness was the same as the change trend of the number of defects, and it was confirmed that the forming defects number was the main factor affecting the microhardness; With the increase of graphite addition, the fracture toughness increased gradually, but the fracture toughness was 5.89 $MPa \cdot m^{1/2}$ at 12% graphite addition amount, which was higher than 4.82 $MP \cdot m^{1/2}$ of pure Al_2O_3 ceramics.

LPAM-2: Bicrystalline structure and its mechanical property regulation in Inconel 718 superalloy fabricated by laser hybrid manufacturing

Fencheng Liu, Feiyue Lyu, Fengrui Dong

Nanchang Hangkong University, Nanchang, China

Abstract：

Components fabricated by laser hybrid manufacturing are made up of two parts including the columnar crystal in the deposition zone and the equiaxed crystal in the substrate area. However, seriously micro segregation of alloying elements leads to the precipitation of brittle Laves phases in the inter dendrites in the manufacturing process. Aimed to improve the mechanical property of hybrid manufactured structure, Laves phase in columnar crystals of deposited area should be eliminated by post heat treatment, however, the high temperature solution treatment will coarsen the grain structure in forged or cast substrates. A novel post heat treatment procedure was adopted including δ phase aging and dissolving at 890°C and 1020 °C sequentially aimed to achieve the dissolving of Laves phase, in which the heat treatment temperature is much lower than the temperature of grain rapid growing. The results show that the fully precipitation of δ phase in deposited area can “cut” the Laves phase into small pieces and dissolve Nb element from Laves phase during the its growing. After solution treated at 1020°C for 30 min, all δ phase disappeared. The equilibrium volume fraction of Laves phase was measured as about 1% and microhardness was decreased gradually during the dissolution process. Meanwhile, the tensile strength tests show an increase of tensile strength by10.27%, as well as an increase in elongation and the reduction of areaat 31.38% and 52.71% after solution and aging treatments.

LPAM-2: Bonding mechanism and numerical simulation of Ti-6Al-4V alloy by supersonic laser deposition

Weilin Wang

Institute of Laser Advanced Manufacturing, hangzhou, China

Abstract：

Supersonic laser deposition technology is a new material deposition technology which synchronously couples laser heating into cold spraying. In this paper, Ti-6Al-4V coating was prepared on Ti-6Al-4V alloy (TC4) by supersonic laser deposition. The effects of laser irradiation temperature, carrier gas pressure, gas temperature and scanning speed on the bonding properties between particles and particle/matrix were studied. In theoretical research, Johnson-cook model of finite element ABAQUS software is used to select the reduced integral hexahedron element (C3D8RT) with thermal-mechanical coupling to study the morphological characteristics of particles after colliding with the substrate at different laser deposition temperatures and velocities, and to determine the optimum temperature and critical velocity of particle deposition. The thickness, microstructure, phase composition and porosity of the coating were characterized by SEM, XRD and Image J graphics analysis software. The experimental results show that the combination of particles and matrix achieves the best condition when laser irradiation temperature is 800 ℃, carrier pressure is 4 MPa, gas temperature is 500 ℃ and scanning speed is 15 mm/s. The simulation results show that the critical velocity of particles is 620 m/s when the laser irradiation temperature is 1000 ℃ and the gas temperature is 500 ℃. The critical velocity of particles decreases with the increase of laser irradiation temperature and gas temperature.

LPAM-2: Research on Force Measurement Intelligent Boring Bar system for Boring Process

Hui Chen, Zhibing Liu, Xibin Wang

Beijing Institute of Technology, Beijing, China

Abstract：

The straightness error affects the working performance and working life of the deep hole parts. In boring process, the boring force is an important factor to affect the straightness. It is an effective way to control the straightness error by monitoring the boring force, while it is difficult to measure the boring force in a real time. In view of the difficulty of real-time online acquisition and analysis of traditional force measurement methods, an intelligent boring bar system for measuring boring force in real time during boring process was developed. The strain gauge sensor was used to measure the boring force. According to the mechanical model and stress distribution of the boring bar, the position of the sensor was determined. Then, the annular groove structure of the boring bar which was used to mounted sensor was optimized. According to the spatial layout of the sensor, the stiffness of the boring bar and the sensitivity of the detection system, an optimized model of the annular groove structure was established. Used wireless signal transmission to transmission data of the sensor. The wireless transmission signal acquisition system which contains the signal acquisition module, power module and wireless signal transmission module was designed. The boring experiment was carried out with intelligent boring bar, and the dynamometer was used to measure the boring force. By comparing the data of the dynamometer and intelligent boring bar, the results show that the intelligent boring bar can effectively measure the boring force in real time.

LPAM-2: Cavitation Erosion Behavior of 17-4PH Precipitation Hardening Stainless Steel via Laser Soild Solution

Chenggan Xue, Liang Wang

Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, China

Abstract：

In order to improve the cavitation resistance of steam turbine blades, the surface of 17-4PH stainless steel was treated by laser solid solution and aging treatment. Ultrasonic cavitation tests were carried out in a simulated seawater environment to evaluate the cavitation resistance of the material and reveal the cavitation failure mechanism. The surface morphology and microstructure evolution after cavitation were analyzed by means of metallographic microscope (OM), scanning electron microscope (SEM), energy dispersive spectroscopy (EDS) and 3D ultra-depth-field microscopy. The hardness of the material was measured by microhardness tester. The results show that the hardened layer of 2 mm thickness can be obtained by the laser soild solution and aging treatment. The surface hardness of 17-4PH after laser surface strengthening is significantly improved. The maximum hardness of the strengthening layer is 491 $HV_{0.2}$, which is 116 $HV_{0.2}$ higher than the matrix. In the ultrasonic cavitation test, due to the dispersed strengthening phase ε-Cu, laser solid solution strengthening treatment has a longer cavitation incubation period, and the cumulative weight loss of cavitation after 40 h is 60% of the matrix. Combined with the analysis of the morphology and depth of the cavitation pit, the results show that the laser solid solution strengthening 17-4PH surface cavitation damage is lighter, the cavitation pit depth is shallower, so it has better cavitation resistance than the matrix.

MPT-1: Experimental Investigation on High-shear and Low-pressure Grinding Process for SLM Inconel 718 alloy

Yebing Tian[1], Lingguang Li[1], Bing Liu[1], Zenghua Fan[2], Qianjian Guo[1]

[1]School of Mechanical Engineering, Shandong University of Technology, Zibo, China

[2]School of Mechanical Engineering, Shandong University of Technology, Zibo, China

Abstract：

In this work, we reported a novel grinding method with high tangential grinding force and low normal grinding force using a specially developed abrasive tools made of flexible composites. The tools were fabricated with the principle of liquid body armor and the shear thickening mechanism of non-Newtonian fluid. During grinding, abrasive particles are capable of generating a “hydro-cluster effects” under reverse tangential load, which lead to the decreased normal grinding force and the increased tangential grinding force. Hence, workpiece materials are removed under high-shear and low-pressure grinding mode. A serial of grinding experiments were carried out on Inconel 718 specimens which were manufactured with selective laser melting (SLM). The influence of grinding parameters, i.e. wheel velocity and workpiece feed rate, on the grinding quality and tool wears were investigated. The results show that the new abrasive tool exhibits good grinding performance for the Inconel 718 specimens. The abrasive tool wear shows good characteristics within 120 min. The value of surface roughness of ground specimen decreased from 5.5 μm to 0.6 μm under the grinding conditions selected i.e. wheel rotational speed n=1000 rpm and workpiece feed rate V_w =8000 mm/min. The surface defects of the SLM Inconel 718 specimens were gradually removed while the uniformed grinding textures were generated with the high-shear and low-pressure grinding.

MPT-1: Process Monitoring of Micro Electrical Discharge Machining by Pulse Discrimination and Acoustic Emission Signals

Kanka Goswami, Samuel Gonumakulapalle Lodi

Indian Institute of Technology Madras, Chennai, India

Abstract：

Micro-Electrical Discharge machining (micro-EDM) is a random process where the interaction between the materials and the process parameters are difficult to understand. Monitoring of such process becomes necessary, to achieve the dimensional accuracy of the micro-featured components that are being manufactured. Thermo-mechanical erosion is believed to be the primary mechanism of the material removal during the process. Other postulates like Joule heating-melting-vaporization or electrostatic-stress-yielding provide a stronger argument rising ambiguity over the existing material removal process in the micro-EDM regime. It was found that the release of stress waves in the material occur during the machining process which indicates material removal by fracture mechanism. The stress waves generated by fracturing and spalling during micro-EDM is captured using the acoustic emission (AE) sensor. The pulses, captured by voltage and current measurement, were classified using gradient based pulse discrimination algorithm to identify the major categories of pulse and also to detect the duration of each pulses. The AE signal features were extracted and identifed by time-frequency distribution analysis. Mapping of the pulse instances was performed by neural network classification with the obtained AE signature. The mapped pulse data with the acoustic emission provides a better understanding of the material removal mechanism in the process. It also indicates the necessity for an alternative postulate for material removal in micro-EDM. The mapped model can be used for the in process monitoring for micro-EDM operation.

MPT-1: Elliptic Ultrasonic Assisted Fixed-Abrasive CMP of Si Wafer

Gengzhuo Li, Yongbo Wu

Southern University of Science and Technology, Shenzhen, China

Abstract：

As the most important and widely used approach to the surface finishing of Si wafer, chemical mechanical polishing (CMP) is encountering the bottleneck of low processing efficiency and high environmental cost due to the employment of loose abrasive slurries. On some occasions, such as thinning of Si wafers, a new, more efficient and environmentally-friendly way is strongly required to replace the conventional CMP approach. In this work, a resin-bonded abrasive pellet containing soft CeO_2 grains is employed to realize the fixed-abrasive dry CMP. With this method, a higher material removal rate can be obtained and the environmental pollution of alkaline slurry can be effectively avoided. The use of soft abrasives also greatly reduces the subsurface damage under the assistance of chemical reaction compared to the traditional fixed abrasive method like diamond grinding. However, the chip discharge problem still exists which limits the further improvement of processing efficiency. Consequently, an elliptic ultrasonic vibration is applied to the abrasive pellet during dry CMP. In order to perform the proposed novel method, an experimental setup is designed and constructed. On the basis of investigating the mechanism of mechanochemical reaction between abrasives and Si wafer experimentally, the composition of the polishing pellets is optimized to realize the high-efficiency coexistence of mechanical action and chemical action. It is found from experiments that the elliptic ultrasonic vibration has a catalytic effect on the chip emission compared with other vibration modes, which is more favourable for better surface quality, lower sub-surface damage and higher material removal rate.

MPT-1: Grindability Studies of Thermomechanically Processed Advanced High Strength Steel using Sol-Gel and Alumina Grinding wheels

Hari Srinivasa Rao Magham Magham, Arunachalam N, S Sankaran, L Vijayaraghavan

Indian Institute of Technology, Madras, Chennai, India

Abstract：

Advance high strength steels (AHSS) are used as structural as well as moving parts in automotive and power sectors due to their excellent strength to weight reduction ratio. The specific applications of these materials dictate the geometrical and surface quality requirement. Grinding is commonly used as a final machining process for most of the ferrous alloys to produce components with the required dimensional, form and surface tolerance requirements. Hence it is very much essential to develop a knowledge about the grindability of these materials. In this work, the grindability of the vanadium contained microalloyed steel with different microstructure are evaluated using fused white alumina and sol gel grinding wheel. The grindability characterizes such as forces, specific cutting energy, critical chip thickness, and surface roughness were observed under different cooling and lubrication regime. The influence of the microstructure of the workpiece and the role of type of abrasive grains on the grindability were investigated. The results of this study indicate the processing conditions, type of abrasive grains, cooling and lubrication regime suitable of grinding of these materials. This knowledge can be directly used by the industry for manufacturing of various components in automotive and other sectors.

MPT-1: Machining Induced Surface Integrity in the Drilling of CFRP/Ti Stacks

Vijayathithan M, Anil Meena

Indian Institute of Technology Madras, Chennai, India

Abstract：

The usage of the hybrid structure of carbon fiber-reinforced plastic (CFRP) and titanium (Ti) stacks in the aerospace industry has widely increased due to its superior mechanical properties and better structural functions. However, significantly different machining characteristics of CFRP and Ti materials formulate the drilling of stacks a challenging task. Inadequate chip removal and material characteristics lead to the delamination and disturbances in the surface integrity, especially in the inhomogeneous and anisotropic CFRP layer. The present study is, therefore, investigating the effects of cutting parameters on drilling performance and surface integrity characteristics of CFRP/Ti stacks using coated and uncoated carbide tools. The effects of coating and cutting conditions were evaluated from an analysis of cutting forces, delamination factor and machined surface topography. Scanning electron microscopy and optical microscopy has been performed to understand the influence of machining conditions (coating and cutting conditions) on machining-induced surface integrity and drilled hole quality. The obtained results indicated a significant correlation between the cutting forces, delamination factor, and machining-induced surface integrity.

MPT-1: Influence of the Variable Process Parameters in WEDM of High Conductive New Generation Aluminum Alloy

Kingshuk Mandal[1], Mukandar Sekh[2], Soumya Sarkar[1], Souren Mitra[1], Dipankar Bose[3]

[1]Jadavpur University, Kolkata, India

[2]Aliah University, Kolkata, India

[3]NITTTR, Kolkata, Kolkata, India

Abstract：

Wire electro discharge machining is a non-traditional machining process which is widely used to efficiently machine the new generation conductive metal and alloys. Using WEDM, intricate shapes can be made through difficult to machine electrically conductive components. The high degree of accuracy and the reasonable surface quality mark WEDM valuable. The appropriate selection of process parameters is the most significant aspect in WEDM for Al 7075 alloy. Al 7075 is the corrosion free and high temperature resistant high conductive new generation alloy. In the present study, effects of electrical and non-electrical parameters such as pulse on time (T_{on}), pulse off time (T_{off}), arc on time (A_{on}), arc off time (A_{off}), servo voltage (S_v), wire tension (W_t) and servo sensitivity (S_c) on the output responses have been investigated. Cutting performance of WEDM is measured by three major response parameters; namely machining speed, corner error and surface roughness. Taguchi's based design of experiment has been exploit to study the three machining criterion known as machining speed (V_c), corner error (C_e) and surface roughness (R_a). It has been found that the parameters setting for conventional steel and Al 7075 are not the same during machining. It is happening due to the different conductivity of the parent metal. It also has been found that the dimensional accuracy in terms of corner error and the surface quality both are depends on conductivity of the metal alloy and input parameter setting.

MPT-1: Influence of Spindle Speed Variation on the Chatter Stability Limits in High-Speed Milling

Vineet Paliwal, N Ramesh Babu

Indian Institute of Technology Madras, Chennai, India

Abstract：

Self-excited regenerative vibration or chatter limits the primary requirements like productivity, surface finish and dimensional accuracy of high-speed machining. It is the most critical factor that severely affects the tool-life and life of the machine tool. Out of the several methods followed for suppressing and avoiding chatter, stability lobes diagram is the most reliable way of selecting chatter-free machining conditions. Stability lobes diagrams are typically generated by the application of specific cutting force coefficients and tool point frequency response functions (FRFs). Inaccuracies in the estimation of tool points FRFs directly affects the certainty of stability lobes diagrams. As tool-point FRFs are affected by several factors such as gyroscopic effect, change in bearing dynamics, friction, etc. during operating condition, it is essential to consider the effect of these factors on tool point FRFs and stability lobes diagrams.In the present work, a novel approach is introduced for the estimation of tool point FRFs during operating condition by using output vibration signals. For the measurement of vibrations at the tip of end mill cutter at different spindle speeds, a non-contact laser vibrometer sensor is used. A comb filter is then applied to remove the tooth pass frequency and its harmonics from the measured vibration signals. Subsequently, FRFs are estimated by these filtered vibration signals with the application of operational modal analysis (OMA). And finally, stability lobes diagrams are drawn with the application of estimated FRFs at different spindle speeds and influence of spindle speed variation on stability lobes diagrams is analysed.

MPT-2: Comparison between Electric Arc Sweep Machining and Existing Technologies for Blisk Manufacturing

Ahmad Farhadi, Lin Gu, Wansheng Zhao

shanghai jiaotong university, shanghai, China

Abstract：

Blisk manufacturing is extensively used in aircraft industries. However, main challenges in fabricating these components are their intricate geometries and difficult to machine materials. Therefore, great attempt are attracted to enhance machining blisk as a key element in plane engines. Electric arc sweep machining (EASM) is a novel method for roughing open channels which are specifically used in blisk manufacturing. This method is a variant of blasting erosion arc machining (BEAM) which utilizes high pressure inner flushing to control plasma arc behavior. This research focuses on comparison between production efficiency of this technology and other alternatives such as EDM and milling. Based on findings, EASM has a great potential in manufacturing blisks and can improve machining efficiency in terms of material removal and cost reduction. Hence, electric arc sweep milling could be used as a promising technology to the existing alternatives for roughing blisks components.

MPT-2: Nanofinishing of Hemispherical Blind Hole Surface with A Newly Designed Magnetorheological Finishing Tool

Ankit Aggarwal, Anant Kumar Singh

Thapar Institute of Engineering and Technology, Patiala, India

Abstract：

Nano finishing is a property of the material surface which is highly required in industrial components for improving the functional operation. To achieve this requirement without defects in complex shapes such as internal hemispherical surface using conventional finishing processes is a difficult task. The aim of this present work is to finish the internal surface of the hemispherical blind hole workpiece with the help of a newly designed magnetorheological finishing tool tip surface. The simulation analysis and experimentation are performed to examine the performance of the present magnetorheological finishing process. The tool tip surface is designed as similar to the internal surface of the hemispherical blind hole workpiece. The simulation results indicate the efficacy of the designed magnetorheological finishing tool core tip surface. In present experimental work, the magnetorheological finishing tool will rotate in opposite direction to the rotation of the hemispherical workpiece. The experimental performance of the present process is determined in terms of reduction in surface roughness parameters with respect to time. The effectiveness of the process with the newly designed tool is analyzed by comparing the initial and final scanning electron microscope and mirror images. The reduction in surface roughness values at nanometer level and improvement in surface quality reveal the effectiveness of the present process with the newly designed tool. Thus, the present process with the newly designed tool can be used for nano level finishing of hemispherical blind hole surfaces for various applications such as hip joints in medical industries and other mechanical spherical joints etc.

MPT-2: A Research on the Incidence of Soft Abrasive Flow on the Surface of a Workpiece and its Machining Characteristics

Chen Li, Qingduo Xu, Liming Guo

Department of Quality and Safety Engineering, China Jiliang University, Hangzhou, China

Abstract：

To solve the problem of unable to calculate the particle velocity of the solid-liquid two-phase flow in high concentration while the particles are impacting on a surface, a model which can simulate the particle movement in boundary layer is proposed. Based on the simulated results of Mixture model and Realizable k-ε model, the incident velocity and the incident angle can be calculated by analyzing the particle velocity before the incidence, calculating the boundary layer thickness, establishing the velocity field in the boundary layer and analyzing the movement of the particles. We analyze the distributions of the dynamic pressure and the volume fraction of the abrasive particles impacting on the workpiece and compare two flow channels with different restrained structures to verify the correspondence between the simulated result and the machining effect. The experimental results can provide the basis for the design of the restrained module. Research results show that machining is directly affected by the incidence velocity and the volume fraction of the abrasive particles and the dynamic pressure on the surface of the workpiece, which are positively correlated with the removal volume of the workpiece. The initial value of roughness should be less than 0.2μm due to the machining parameters employed in this paper. Beside the characteristics of the flow field, the original machining marks should be also considered for the design of the restrained module.

MPT-2: High Speed Machining of Aluminium alloy using Vegetable Oil based Small Quantity Lubrication

Balakrushna Guntreddi, Amitava Ghosh

Indian Institute of Technology Madras, Chennai, India

Abstract：

In an attempt to investigate the effectiveness of vegetable oil based small quantity lubrication (SQL) assisted high speed machining of aluminium, current study finds that its usefulness is more significant in an intermittent process than in one where chip continuously flows on the rake surface of a cutting tool. In high speed turning, both uncoated and polycrystalline diamond-tipped WC inserts were used. Performance of both tools was enhanced by SQL (100 ml/hr) process but in the range of only 5-20% of cutting force reduction. The highest reduction was obtained when the turning velocity was raised from 700 to 1000 m/min. At low velocities, effectiveness of SQL was inconclusive. However, cutting force and surface roughness were substantially reduced by the application of SQL in high speed end milling. The order of reduction was at least 50%, among the different cutting speeds. The effect was more predominant when alloy 7075 was replaced by the pure 1050 grade. The required prevalence of the thickly filmed lubrication at the interface of chip and tool to minimize any possible diffusion of aluminium to tool material, could be remarkably realized only in the intermittent cutting where a cutting edge drew in fresh micro-droplets of lubricant before resuming its cutting in its next cycle of engagement with workpiece. Interestingly, the performance of SQL assisted uncoated carbide was found to be comparable to that of diamond tool. Chip morphology and traces of BUE formation was given due attention as evidential observations in support of the conclusion.

MPT-2: Implementation of Communication Protocol for Machine Tool in Reference Architecture of Fog Computing

Tai-Wei Chiu[1], Yung-Yi Huang[1], Hsiu-Fen Lee[1], Hung-Sheng Chiu[1], Yuan-Mao Chueh[2]

[1]Institute For Information Industry, Taichung, Taiwan

[2]National Chiao Tung University, Hsinchu, Taiwan

Abstract：

Implementation of Communication Protocol for Machine Tool in Reference Architecture of Fog Computing By far Machine Tool Industry has not unified standards of data access to cause difficulties in data analysis and industrial reform. International organizations of standards formulation such as OPC UA Foundation and MTConnect Institute, their presented communication protocols can solve problem of data disunity. This thesis introduced and implemented communication protocol architecture and introduced fog computing architecture which not only displays real-time status of machine tools but also provides solutions to mitigation of data process loading in the future.

MPT-2: Applications of Machine Learning for the Prediction of Stability Lobe Diagram and Surface Location Error during Milling

Dongqian Wang[1,2], Michael Löser[2], Steffen Ihlenfeldt[2], Xibin Wang[1], Zhibing Liu[1], Shuyao Liu[1]

[1]School of Mechanical Engineering, Beijing Institute of Technology, Beijing, China

[2]Institute of Machine Tools and Control Engineering, Dresden University of Technology, Dresden, Germany

Abstract：

During the process of material removal, stability and machined error are imperative indicators, i.e. stability lobe diagram (SLD) and surface location error (SLE), to evaluate the machining process. For the dynamic model, the delay differential equation of the system is mainly solved with two different methods: frequency domain or time domain, which needs specific models and high-precision parameters. In this paper, the machine learning method was employed to predict the SLD and SLE. The k-fold cross validation was used to prepare the acquired data from former cutting tests. Then the support vector machine (SVM) was applied to train these data with Nyquist stability criterion and establish the SLD and SLE. After that, the confusion matrix and receiver operating characteristic (ROC) curve were calculated to evaluate the model. Then different data acquisition methods with parameters uncertainty were compared with each other to find the best fitting of SLD and SLE with as little data as possible. Finally, the cutting tests were carried out with different cutting parameters. The experiments showed that the proposed method matched well with the experimental results, and it can be used to predict the SLD and SLE together.

DC-1: Free Sink Vortex Multiphysics Modeling and Vibration Characteristics in Ladle Teeming Process

Dapeng Tan

Zhejiang University of Technology, Hangzhou, China

Abstract：

For the continuous casting (CC) ladle teeming, the sink vortex with free surface can suck the liquid slag into tundish, and cause negative influences to the purity of molten steel. To address the issue, a two-phase fluid mechanic modeling method for ladle teeming is proposed. Firstly, according to the Navier-Stokes (N-S) equation and k-ε turbulence model, a dynamic model for sink vortex suction is set up, and the profile regulars of vortex flow field are acquired. Next, based on the level set method (LSM), a two-phase 3D interface coupling model for slag entrainment is build up. The LSM-based numerical solution method is proposed to obtain the two-phase 3D coupling evolution regulars in vortex suction process. The numerical results show that the vortex with higher kinetic energy can form an expanded sandglass-shape region with larger slag fraction and higher rotating velocity; there is a pressure oscillation phenomenon at the vortex penetration state, which is caused by the energy shock of two-phase vortex penetration coupling process. According to the dynamic characteristic at the vortex penetration state, a multiphysics model for vibration characteristics of sink vortex is established in combination with the solid-liquid coupling algorithm. The numerical results show that there is a transient vibration enhancement phenomenon at the vortex penetration state, and the main part of the transient enhancement signal is high-frequency signal. Finally, based on the simulation model, an experimental platform is set up to verify the accuracy of the subject. The result of the water-model experiment is accordant with that of simulation.

DC-1: Digital Technologies in Accurate Soft Tissue Reconstruction for Head and Neck Tumor Resection

Chao Chen[1], Yunfeng Liu[1], Jia Jie Xu[2], Xianfeng Jiang[1], Xingtao Dong[1]

[1]Zhejiang University of Technology Key Laboratory of Special Equipment and Advanced Processing Technology (Zhejiang University of Technology), Hangzhou, China

[2]Department of Head and Neck Surgery, Zhejiang Provincial People's Hospital, Hangzhou, China

Abstract：

The objectives of this study is to analyze the characteristics of the head and neck surface, and explore the surface segmentation and development method considering the flexibility of the soft tissue to get a accurate reconstruction plan and templates for transplating flap havesting. Extract the three-dimensional surface on head and neck of a standard human for Gaussian curvature analysis, in which the patch can be directly developed into a two-dimensional plane is marked Zone I.Perform the principal curvature analysis on the remaining surface, and consider the allowable extend of the soft tissue. By adjusting the normal section line of the surface, the patch that can reach the developable area will be marked Zone II.The area where the surface must be cut to meet the unfolding requirements is classified as Zone III. Reconstruct the three-dimensional model including the tumor with the CT data of the patient's head and neck, the surface area that needs to be resected is extracted. Then the surface patches are classified into zone I, II, and III, therefore the surface in defect area is expanded into a approximate plane, which could be designed into a template. The template is fabricated by 3D printing and used to havest flap with more accurate. The measurement results show that the converted surface is within 5% of the extracted surface area. The partitioning of the head and neck surface can more effectively obtain template, which can help doctors to improve the quality of surgery.Head and neck tumors; Surface segmentation; 3D printing

DC-1: Torque Coordinated Control for Distributed Drive Electric Vehicle Based on Hierarchical Control

Tao Zhao, Qiang Li

Zhejiang University of Science & Technology, Hang Zhou, China

Abstract：

Four-wheel independent drive electric vehicle(IEV) are more suitable for advanced control systems. By using the flexible distribution of torque of the distributed- driven electric vehicles, selecting the yaw rate and the slip rate as the control targets, and then the control strategy based on hierarchical optimal torque coordinated distribution is proposed. The control strategy consists of two layers of upper and lower controllers. The upper layer is the centralized controller with the yaw rate as the control variable. According to the current vehicle states and road conditions provided by the vehicle model, the total required torque to keep the car in stable operation is calculated and distributed to the driving wheels. By tracking the slip rate of each driving wheel, the layer controller revise the torque of each driving wheel to keep the slip rate near the optimal slip rate and improve the power performance of the vehicle. The simulation model was built in Matlab/Simulink to verify the simulation on joint road surface and split-μ road surface which have both high and low μ. Besides, there are also tests that are simulated with step and single shift line condition as the input. The results show the control strategy can make good use of the adhesion of the road surface and get less slip phenomenon when the vehicle starts, and improve the dynamic and the steering capability of the vehicle. In addition, excessive slippage during vehicle start-up is well suppressed.

DC-1: Pneumatic Soft Robotic Gripper Embedded with Multi-stable Structure

Xiangqi Ni, Chongjie Liao, Zheng Zhang, Huaping Wu, Shaofei Jiang, Guozhong Chai

Key Laboratory of E&M (Zhejiang University of Technology), hangzhou, China

Abstract：

Soft robotic gripper based on the pneumatic actuator have been studied actively, since it offers more flexible bending motion and a simple morphological structure. However, they require a constant pressure supply for retention of bending shape. This paper proposes a pneumatic soft robotic gripper integrated with a multi-stable carbon fiber reinforced polymer (CFRP) structure that can achieve reversible transition between multi-stable configurations without external force maintained. The gripper consists of a multi-stable structure and a cylindrical silicone rubber body that have a plurality of side chambers. Each air chamber can act as an actuator when injected with compressed air. By changing the air pressure in each air chamber, the silicone rubber body will be bent. Bending angle is determined by the difference of injected air pressure in the air chamber. The bending motion of gripper endows the multi-stable structure with the ability to snap from one stable configuration to another, ultimately achieving the gripping action for grasping objects of different size. The multi-stable structure supports gripper with a stable configuration when the internal air pressure is reduced to the initial state. Experiments and simulation results demonstrate that the soft robotic gripper can perform the action of gripping and unloading that combines the function of multipoint bending and the shape retention without continuous power supply.

DC-1: Surface Texture Characterization of Powder Bed Fused Ti-6Al-4V Components using Fractal Dimension Analysis

Akhil V, Raghav G, Arunachalam N

Indian Institute of Technology Madras, Chennai, India

Abstract：

The ingenious method of fabricating parts using powder bed fused Additive Manufacturing (AM) process has wide applications in medical, aerospace, defense and automotive industries. However, the implementation of AM processes in such a way to replace the conventional subtractive manufacturing processes in industry can only happen if the final products made using the process meets industrial quality standards with minimum post-processing. This clearly shows the need for better understanding and optimization of various attributes of the AM processes. One such attribute is the surface texture characteristics of the AM parts. This study demonstrates the surface characterization of Ti-6Al-4V parts made by Selective Laser Melting (SLM) using fractal dimension analysis of the surface images.The surfaces are characterized using the calculated fractal dimension and its relation with the measured 3D surface roughness of the components are studied using statistical analysis. The anisotropic nature of the surfaces of 3D printed Ti-6Al-4V components is also studied with the aid of rose plots obtained from the fractal analysis. The influence of major SLM process parameters, laser power, scanning speed, and hatch distance, on the anisotropic nature of surface is considered and it is found that the surfaces showed weak anisotropic characteristics at lower power, high scanning speed, and high hatch distance values. The developed fractal analysis can be utilized for process optimization, defect detection, and quality control in the real-time AM industry.

DC-1: Intelligent Monitoring System for Water leakage prevention of Public Facilities

Yongli Huang

Zhejiang University of Science and Technology, China

Abstract:

Water leakage in pipelines for shopping malls, schools, government buildings and other large public facilities are common phenomenon. So a intelligent monitoring system for water leakage prevention based on virtual instrument technology is presented, which perfectly integrates the hardware and LabVIEW software. A simulation system of valve failure and leakage of main pipeline is designed for monitoring and controlling the above mass flow and pressure intelligently. Intelligent measurement and control platform based on special sensor, data acquisition card and LabVIEW software are used to simulate the leakage of pipelines. The test results show that the above system can achieve the goal of real-time monitoring, draw real-time parameter curves, use PID algorithm and process data intelligently, immediately prompt leakage area, automatically alarm, automatically close the valves and save water resources.

DC-2: Systematic Analysis of Variable Stiffness Multistable Composite Structures and its Potential Application in Human Exoskeleton

Zheng Zhang, Hao Zhang, Yang Li, Huaping Wu, Shaofei Jiang, Guozhong Chai

Key Laboratory of E&M (Zhejiang University of Technology), Hangzhou, China

Abstract：

This paper presents a systematically study for the variable stiffness multistable composite structures. The aim of this paper is to explore the multistable shapes generated by changing various angle parameters that define a variable stiffness composite for elucidating novel morphing structures. The multistable shapes of such variable stiffness composite structures are predicted by theoretical method based on classical lamination theory and Rayleigh–Ritz method. This approach provides an efficient means to determine the stable solutions with reasonable accuracy. The out-of-plane displacement is required to check the accuracy of the theoretical method, the results of theoretical method for different stable states are compared with that of finite element analysis. The load-displacement for variable stiffness composite are investigated by the finite element analysis and experiment. Good agreement is obtained from the results of theoretical method, finite element analysis and experiment result. It is shown that the current approach can be successfully applied to predict the equilibrium configurations of a variable stiffness composite. The VS composite structures can reduce the elbow and knee bending torque in two stable states, which can be a good application in human exoskeleton at elbow and knee.

DC-2: A novel Solar Tracking Model Intergrated with Multi-stable Structure and Organic Solar Cell

Zheng Zhang[1], Kai Pei, Xiaochen Yu[1], Yang Li[1], Huaping Wu[1], Shaofei Jiang[1], Guozhong Chai[1]

[1]Key Laboratory of E&M (Zhejiang University of Technology), Hangzhou, China

[2]Key Laboratory of E&M (Zhejiang University of Technology), Hangzhou, Christmas Island

Abstract：

Solar tracking system has been studied actively, since it can increase efficiency compared to fixed solar panels, which however increase the complexity of the structure by using the mechanical structure. This paper proposes a novel solar tracking model integrated with a multi-stable carbon fiber reinforced polymer (CFRP) and organic solar cell. The main parts are multi-stable laminated shell, aluminum/steel bimetallic strip and organic solar cell. Multi-stable laminated shell instead of steering mechanism to reduce the number of parts in the solar tracking model. With the sunshine, the aluminum/steel bimetallic strip will bend and deform due to the influence of temperature depending on the shadow area. The bending motion of aluminum/steel bimetallic strip drives the multi-stable structure snapping from one stable configuration to another, which process is reversible. The change of multi-stable laminated shell shape holds the solar cell perpendicular to light to receive the maximum solar energy. Experiments and simulation results demonstrate that the deformation process of this solar tracking system is feasible. Due to the use of multi-stable CFRP, the quality of the solar tracking model has been greatly reduced. In addition, further developments to the design are critically evaluated in terms of complexity and benefit.

DC-2: Error Analysis of 5-PSS/UPU Parallel Mechanism Considering Ball Joint Clearance

Yanbiao Li, Taotao Xu, Hang Zheng, Zesheng Wang, Songyang Qin

Zhejiang University of Technology, Hangzhou, China

Abstract：

In order to improve the pose accuracy of the moving platform of the 5-PSS/UPU parallel mechanism, based on the kinematics model of the parallel mechanism, the error model of the parallel mechanism is modeled by the method based on the spatial closed vector chain. The mapping relationship between the pose error of the moving platform and each geometric error is established, and the compensation model of the pose error is proposed. The correctness of the compensation model is verified by simulation. According to the central limit theorem, the global sensitivity evaluation index of geometric error is introduced and the influence degree of each error source on the pose error of the moving platform is obtained after simulation. Finally, the screw theory is used to analyze the force of the branch, and the equivalent error model of the ball joint gap is established. The correctness of the model is verified by simulation, and the influence rule of the ball joint gap on the position and posture error of the moving platform is obtained, which provides a great reference value for improving the motion accuracy of the parallel mechanism.

FALM-3: 3D Printing of Metal Wires and Equipment Development

Weiming zhou

Shanghai Industrial Technology Institute

Shanghai Nanotechnology Promotion Center

Abstract：

Metal 3D printing technology mainly aims to develop and produce high-performance metal parts. Raw materials involved in this technology can be classified into two types: powder and wire. Metal wire feeding 3D printing technology has a great future in industry, especially in large-size parts manufacturing, due to its high printing efficiency, capability in printing large-size parts, no dust pollution, low cost in wire preparation and nearly 100% material utilization rate. This report studies the current status, industrial application and trend of metal wire-feeding 3D printing. Partial research progress and outcomes of the self-developed coaxial laser 3D printing machine are also included in this report.

金属 3D 打印技术主要以研究制造出高性能金属零部件为目的，其所用金属原材料分为粉材和丝材两种形式。金属送丝 3D 打印技术因其打印效率高，大尺寸零件打印，无粉尘污染，丝材制造成本低，且材料利用率接近 100%等优点，在工业中特别是大型零部件制造应用前景极大。本报告对送丝金属打印的现状、工程化应用以及发展进行展望，也报道了作者研制的同轴激光 3D 打印装备的部分阶段成果。

FALM-3: Numerical Simulation and Experimental Research on High Precision Forming Induced by Laser Shock Imprinting

Yang Haifeng[1,2*], Liu Kun[1], Wang Yan[1], Jia Le[1], Liu Hao[1], Hao Jingbin[1]

[1]School of Mechatronic Engineering, China University of Mining & Technology, XuZhou, 221116, China

[2]Jiangsu Key Laboratory of Mine Mechanical and Electrical Equipment, China University of Mining & Technology, XuZhou, 221116, China

Abstract：

Laser shock imprinting is a technique that can induce controlled ultrahigh-strain-rate plastic forming on the target surface by laser shock wave, thus obtaining high precision microstructures on the metal materials surface. Firstly, ABAQUS software was used to analyze the internal stress distribution, profile changes, and material thickness changes of formed microstructures under different parameters. Then, on the basis of the established experimental platform of laser shock imprinting, the forming law of metal microstructures was explored by adjusting the experimental parameters, including the forming scale, laser energy and target material. Besides, the influence principle of size effect and dynamic yield strength on the formed results was analyzed. Finally, on the basis of numerical simulation and experimental research, microstructures with high precision were obtained on metal surface by adjusting laser shock imprinting parameters. Therefore, due to the characteristics of high precision forming on metal surface, laser shock imprinting technology will have wide application prospects in the fields of microelectronics, sensors, optical device manufacturing.

激光冲击压印技术是通过激光诱导的冲击波作用在靶材表面，诱导靶材发生可控的超高应变率塑性变形，从而在金属材料表面得到高精度微结构。首先，采用 ABAQUS 软件分析不同参数下成型微结构内部应力分布、轮廓变化以及靶材厚度变化规律。然后，在建立的激光冲击压印实验平台的基础上，通过调控实验参数，包括成型尺度、激光能量、靶材材料，探究了金属微结构的成型规律，分析了尺寸效应和动态屈服强度对于成型效果的影响原理。最后，在数值仿真和实验研究的基础上，通过调控激光冲击工艺参数，在金属材料表面获得了高精度的微结构。因此，由于激光冲击压印技术在金属材料表面高精度成型的特点，其在微电子、传感器、光学器件制造等领域将具有广泛的应用前景。

FALM-3: Joining Mechanism of Dissimilar Aluminum/steel Joints by Laser Spot Welding

Yang Jin[1,2], Xiao Rui[1], Yuzhui shui[1,2], Zhang Zhenfu[3]

[1] Shanghai University of Engineering and Technology, 201620, Shanghai,

[2]Shanghai Collaborative Innovation Center of Laser Advanced Manufacturing Technology, 201620, Shanghai

[3]Shanghai Automotive Group Limited by Share Ltd Technology Center, 200041, Shanghai

Abstract：

Laser spot welding of Q235 low carbon steel and AA5754 aluminum alloy thin sheets was carried out in the key-hole welding mode. The influence of process parameters on the formation and the mechanical properties of joints was analyzed. Based on Taguchi method, it is found that welding time has very limited influence on the mechanical properties of joints, while defocusing amount, laser power and shielding gas have significant influence. When at high laser power, small amount of defocus and without shielding gas, welding defects such as burn-through and cracks are easily generated, and the weld formability is degraded. On the contrary, the penetration depth is too shallow to effectively bond the base metals. A sound weld appearance is obtained at 2.85 kW laser power, 22 mm defocusing amount and 3 s welding time after process parameters optimization. In this case, cracks are eliminated in the joints and an adequate penetration depth is obtained. The welding technique realizes the combined effect of metallurgical bonding and riveting which greatly improves the mechanical properties, and the maximum fracture load of the joint reaches 1737N.

本研究采用深熔焊模式进行了 Q235 低碳钢与 AA5052 铝合金薄板激光点焊搭接试验。重点分析了工艺参数对焊点成形及接头力学性能的影响规律。基于田口法分析发现，接头力学性能受时间影响最小，而离焦量、激光功率以及保护气对其皆影响较大。当激光功率过高、离焦量过小及无保护气时，接头极易形成焊穿和裂纹等缺陷，并降低焊缝成形性；反之，熔深则过浅，且连接强度较低。通过参数优化，当激光功率为 2.85 KW、离焦量为 22 mm、时间为 3 s 时，焊点成型良好，既避免了焊点宏观裂纹，又获得了一定的熔深。该焊接方法实现了接头冶金和铆接的耦合连接，大幅提升了力学性能，接头最大断裂载荷为 1737N。

FALM-3: Influence of Substrate Surface Inclination Angle on the Morphology of Iron-based Alloy Laser Cladding

Fang Zheng[1,2], Yang Gaolin[1,2], Lu Xiangang[1,2], Feng Liang[1,2], Fan Wen[1,2], Zhu Xudong[1,2], Zhang Qunli[1,2], Yao Jianhua[1,2*]

[1]Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, Zhejiang 310014,China

[2]Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, Zhejiang 310014,China

Abstract：

It is difficult to adjust the repaired area to the horizontal position when repairing large parts by laser cladding technology, so the repaired area needs to be repaired by multi-angle laser. In this paper, 2000W fiber-coupled semiconductor lasers are used to conduct laser cladding experiments on nodular cast iron QT400 and 700W fiber-coupled semiconductor lasers on 28CrNiMoV rotor axes, respectively, with laser cladding head vertically downward, base material and horizontal surface at different inclination angles, and with laser cladding head and base material perpendicular to each other, and base material and horizontal surface at different inclination angles. The experimental results show that the morphology of the cladding layer is obviously different under the two laser cladding modes of vertical down of the laser cladding head and perpendicular to the substrate at the same inclination angle of the substrate and the horizontal plane. Compared with the latter, the former has smaller cladding height, deeper penetration and wider cladding width. When the laser cladding head is vertical down, the morphology of the cladding layer tends to be flat with the increase of the tilt angle of the substrate. When the laser cladding head is perpendicular to the substrate, the morphology of the cladding layer is less affected with the change of the substrate inclination. This is because when the laser cladding head is vertical downward, due to the existence of obliquity between the base material and the horizontal plane, the spot does not match the spot and the spot is stretched at the same time. The powder distribution on the spot is different, which makes the cladding layer move downhill and the remelting zone move to the side of the uphill area. The cladding layer is not symmetrical. However, this problem does not occur when the laser cladding head is perpendicular to the substrate.

激光熔覆技术修复大型件时,由于难以将待修复区调整为水平位置，需要对待修复区进行激光多角度修复。本文采用 2000W 光纤耦合半导体激光器在球墨铸铁 QT400，700W 光纤耦合半导体激光器在 28CrNiMoV 转子轴上，分别在激光熔覆头竖直向下，基材与水平面在不同倾角的情况下和在激光熔覆头与基材保持垂直，基材与水平面在不同倾角的情况下进行激光熔覆实验。实验结果显示，在基材与水平面相同的倾角时，激光熔覆头竖直向下和熔覆头与基材保持垂直的两种激光熔覆方式下的熔覆层的形貌明显不同，前者相比于后者熔覆层的熔高和熔深较小，熔宽较大。在激光熔覆头竖直向下时，随着基材倾斜角度的增加，熔覆层的形貌的逐渐趋向于扁平状。而激光熔覆头与基材保持垂直的情况时，随着

基材倾角的变化，对熔覆层的形貌的影响较小。这是因为当激光熔覆头竖直向下时，由于基材与水平面倾角的存在，造成粉斑与光斑不匹配且光斑粉斑同时被拉长，光斑上粉末分布量的不同，使熔覆层往下坡区域移动，重熔区向上坡区域一侧移动。熔覆层不具有对称性。而激光熔覆头与基材保持垂直的时候却不会出现这种问题。

FALM-3: Analysis of Dilution Rate and Single Channel Morphology of High-speed Cladding Cr50Ni Alloy by Laser Inside-beam Powder Feeding Process

WANG Shu-guang[1], SHI Tuo[2], FU Ge-yan[1], WAN Le[1]

[1]Soochow University, College of Mechanical and Electrical Engineering, Jiangsu Suzhou, 215000;

[2] Soochow University, College of Optoelectronic Science and Engineering, Jiangsu Suzhou, 215000

Abstract：

High-speed laser cladding is a new green technology to replace wear-resistant and corrosion-resistant metal surface coatings by traditional electroplating, and has received great attention from the industry. Cladding dilution ratio and melt channel morphology are important performance indicators for high-speed cladding.The high-speed cladding process test was carried out using the "in-light powder feeding" coupling technology. A Cr50Ni alloy cladding layer was prepared on a 304 stainless steel substrate.The powder shading model under the condition of intra-light powder feeding was established, and the relationship between the powder feeding rate and the powder shading rate was obtained, and the laser energy density was positively correlated with the dilution rate.The effects of defocusing amount and powder feeding rate on the dilution ratio of the cladding layer were analyzed. The effects of different process parameters on the dilution ratio of cladding and the thickness of single pass cladding were investigated.The results show that when the scanning speed is 9m/min, the defocusing amount is +1~+2mm, and the laser power is 1.85 kW, the surface shape can be obtained with a thickness of about 121~452μm, a dilution rate of 75%~12.9%, and a hardness value of 280~320HV. A good appearance of the cladding layer.

高速激光熔覆作为替代传统电镀制备耐磨、耐腐蚀金属表面涂层的绿色新技术，受到了业界的高度关注。熔覆层稀释率及熔道形貌是高速熔覆关注的重要性能指标。采用“光内送粉”耦合技术开展高速熔覆工艺试验。在 304 不锈钢基体上制备 Cr50Ni 合金熔覆层。建立了光内送粉条件下粉末遮光模型，得出了送粉速率与粉末遮光率的关系，且激光能量密度与稀释率呈正相关。分析了离焦量和送粉速率对熔覆层稀释率的影响。考察了不同工艺参数对熔覆稀释率以及单道熔覆厚度的影响。结果表明，当扫描速度 9m/min、离焦量+1~+2mm，激光功率 1.85kW 时，可获得厚度约 121~452μm，稀释率 75%~12.9%，硬度值为 280~320HV 的表面形貌较好的熔覆层。

FALM-3: The Study on Plume Characteristics of 10 kW level Fiber Laser Welding

Han xue[1], Zou jinglin[2*], Xiao rongshi[2]

[1]High-power and Ultrafast Laser Manufacturing Laboratory,

[2]Institute of Laser Engineering Beijing University of Technology, Beijing 100124, China

Abstract：

In order to obtain a comprehensive understand about the welding characteristics of 10kW level fiber laser, this research carried out a comparative welding experiment with different welding parameters with YLS-15000, YLS-6000 and YLS-3000-SM Lasers, the whole welding process is recorded through a high-speed camera and then the final plume shapes and weld seams were discussed. Meanwhile, the contrast experiment of the plume controlled is also performed with the supersonic cross jet removing plume method and the laser arc hybrid welding method, respectively, to analyze the corresponding relationships between the 10kW level fiber laser welding plume and the weld seam shape. The results show that in the process of 10kW level fiber laser welding, the plume intensity is positive correlation with laser power. As the power is enhanced to a certain extent, the plume fluctuates slightly with a period around 0.7~0.9ms. Both the plume-controlling welding methods significantly improve welding quality, but differ in the effects on the elding bead profile. The supersonic cross jet removing plume method obtains the more remarkable penetration depth, as well as a decreased melting width. In contrast, laser arc hybrid welding increases the weld width comparing to the single laser welding. In the comparative welding experiments of three kinds of Lasers, when the welding is performed by YLS-15000 Laser with 2kW and 3kW power, respectively, the plume morphology shows a cluster without regular period, which is significantly different from the conventional view that plume is divided into two parts, and the penetration depth is the shallowest. As YLS-6000 and YLS-3000-SM Laser are used to weld at the same power, the plume morphology presents with two regions: bottom fluctuating plume and narrow plume, with a period about 0.7-0.9ms. The penetration of the former is much smaller than that of the latter but with the similar melting width. As the experimental results indicate that there are differences in the severity of plume fluctuation on the bottom in the 10kW level fiber laser welding, which has a one-to-one correspondence with the weld morphology. This phenomenon is attributed to the overflow of a large number of spatters. At the same time, the plume has a significant influence on the 10kW level fiber laser welding, plume controlling can significantly improve the welding quality. Compared to other Lasers, the differences are obvious in plume and weld seam shape under the same welding conditions due to the difference of focusing laser spot size.

为了进一步了解万瓦级光纤激光的焊接特性，本研究用 YLS-15000、YLS-6000 和 YLS3000-SM 三种激光器进行了不同工艺参数的对比焊接实验，并采用高速摄像拍摄焊接过程， 对羽辉形态和焊缝进行了分析；同时采用横吹气帘吹除羽辉法和激光电弧复合焊接法进行羽 辉控制对比实验，分析万瓦级光纤激光焊接羽辉和焊缝形态的对应关系。结果发现：万瓦级 光纤激光焊接过程中，

随功率升高，羽辉愈加剧烈，当功率提高到一定程度时，波动羽辉剧 烈程度反而有所下降，羽辉周期约为 0.7~0.9ms。两种去除羽辉的焊接方法均能提高焊接质 量，但对焊缝形貌的影响明显不同，横吹气帘吹除羽辉法使得熔深更为明显，熔宽减小，激 光电弧复合焊接法反而使得焊缝熔宽较单激光焊接时增加。三种激光器对比焊接实验中，使 用 YLS-15000 激光器在 2kW 和 3kW 功率焊接时，羽辉形态呈现为一簇，无明显周期，与 常规认为羽辉分为两部分有显著差异，熔深最浅；使用 YLS-6000 激光器和 YLS-3000-SM 激 光器在相同功率焊接时，羽辉形态为常规的两部分：底部波动羽辉和狭长形羽辉，周期约为 0.7~0.9ms，前者焊接熔深较后者小得多，熔宽相近。通过以上实验分析发现，万瓦级光纤激光焊接中，羽辉的底部波动羽辉剧烈程度存在差异的情况，与焊缝形态一一对应，是大量飞 溅的喷出引起的；同时羽辉对万瓦级光纤激光焊接有明显影响，除去羽辉能够显著提高焊接 质量；万瓦级光纤激光器与其他激光器对比焊接中，由于光斑大小的差异，导致相同焊接条 件下，羽辉和焊缝形态存在明显差异。

FALM-3: Simulation Analysis of Temperature Field and Process Optimization of Laser Cladding Based on Three-light-beams Internal Wire Feeding

Zhang Ji Ping，Shi Shi Hong*，Jiang Wei Wei

School of Mechanical and Electrical Engineering, Soochow University

Abstract：

Laser cladding based on three-light-beams internal wire feeding has the advantages of uniform wire heating, little influence of scanning direction, gentle wire feeding and so on. For the cladding process of it, the heat source model of three-beams light source was established, and the temperature field of the melting pool was simulated by Ansys. The effects of laser power, defocusing and scanning speed on the morphology of cladding layer were analyzed. Simulation and experimental results show that: the amount of defocusing has a great influence on the width of the cladding layer and the morphology of the dilution zone; the laser power has a small influence on the width and height of the cladding layer; but it has a great influence on the dilution rate of the cladding layer; and the scanning speed has a great influence on the height of the cladding layer. The experimental results were analyzed and the process parameters were optimized. The optimized parameters were selected for the cladding experiment, and the single cladding layer with good morphology was obtained.

三光束光内送丝激光熔覆具有丝材受热均匀，扫描方向性影响小，送丝平缓等优点。针对三光束光内送丝熔覆工艺，建立了三光束光源的热源模型，利用 Ansys 软件对熔池温度场进行了仿真，并结合工艺实验分析了激光功率、离焦量和扫描速度等工艺参数对熔覆层形貌的影响。仿真及实验结果表明：离焦量对熔覆层的宽度影响较大且影响着稀释区的形貌，激光功率对熔覆层的宽高影响较小，但对熔覆层的稀释率影响较大，扫描速度对熔覆层的高度影响较大。分析实验结果并对工艺参数进行了优化，选取优化后的参数进行熔覆实验，得到了形貌较为良好的熔覆单道。

FALM-4: The Advances of SLM Technology

Dongyun Zhang, Yang Gao, Lingshan Li, Songtao Hu, Xuping Wu

Beijing University of Technology, China

Abstract：

Laser selective melting (SLM) is one of the most promising metal additive manufacturing technologies. It has attracted much attention because it can be used to manufacture parts with complicated shapes, and the original data of manufacturing is from digital models, thus the manufacturing process is relatively less limited. SLM process is complex, involving laser-material processing, the performances of the processed materials, the design of the parts to be fabricated, the equipment to be applied and other factors. Therefore, the current research on SLM includes process simulation, material performance regulation, design optimization of parts, SLM equipment and its components, and so on. Because of the digital characteristics of SLM technology, the SLM team at 3d printing center at Beijing university of technology (BJUT) makes some researches such as digital simulation in SLM process, the design and performance evaluation of "digital" materials, performances adjusting of the SLM processed materials. What aims at the application of digital technology throughout the SLM technology, makes SLM process and material performances controllable, the design agrees well with the testing of new functional materials.

激光选区熔化(SLM)技术是最具潜力的金属增材制造技术之一，由于可以用于制造形状复杂的零部件，且制造的原始数据来自数字模型，制造过程受到的限制较低，因而备受关注。SLM 过程复杂，涉及激光加工过程、被加工材料的性能、待建零件的设计以及所用设备等因素，因而目前对 SLM 的研究包括过程模拟、材料性能调控、零件的设计优化、SLM 设备及其组件等内容。根据 SLM 技术的数字化特点，北京工业大学 3D 打印中心 SLM 课题组进行了 SLM 过程的数字模拟、“数字化”材料的设计与性能评价、SLM 加工材料的性能调控等研究，旨在把数字化技术贯穿于整个 SLM 技术中，打造过程可控、材料性能可控、设计与测试相吻合的新型功能材料。

FALM-4: Study on the Influence of Light-Powder Coupling Mode on Surface Roughness of Laser Cladding Forming

Mei Youzhu, Shi Shihong, Fu Geyan

Suzhou University, Jiangsu Suzhou 215021

Abstract：

For the laser synchronous powder feeding and cladding forming technology, the surface roughness of the formed parts is poor, which is close to the blank manufacturing. Based on the laser light internal powder feeding and forming technology, this paper realizes the true coaxiality of light, powder and gas in geometrical distribution, and achieves precise coupling, which makes the surface roughness of the formed part significantly improved. By adjusting the collimated gas pressure, the carrier gas pressure, the different powder tubes to adjust the powder concentration, and adjusting the defocus amount to adjust the spot diameter, different light powder coupling modes are formed. This establishes a model from a laser spot diameter smaller than the spot diameter to a laser spot diameter larger than the spot diameter. Then the surface roughness of different parameters was measured. It was found that the surface roughness gradually increased as the spot diameter was smaller than the powder spot to larger than the powder spot diameter. It was verified that the surface roughness of the laser spot was significantly higher than that of the powder spot.

针对激光同步送粉熔覆成形技术成形件表面粗糙度较差，接近于毛坯制造。本文基于激光光内送粉熔覆成形技术，实现了光、粉、气在几何分布上实现真正意义上的同轴，达到精准耦合，从而使得成形件表面粗糙度得到显著提升。通过调节准直气气压、载粉气压、不同粉管来调节粉末集束度，以及调节离焦量来调节光斑直径，形成不同的光粉耦合模式。以此建立了从激光光斑直径小于粉斑直径到激光光斑直径大于粉斑直径的模型。然后测量不同参数的表面粗糙度，分析发现随着光斑直径小于粉斑到大于粉斑直径，表面粗糙度在逐渐提升。验证了激光光斑大于粉斑时表面粗糙度显著提升。

FALM-4: Study of Coating Technology of Laser Cladding Single Layer of 42CrMo Bearing Steel with Large Thickness and Low Dilution Rate

Jiyu Du

Zhejiang University of Technology, China

Abstract：

Laser cladding technology was used to fabricate single layer of large thickness and low dilution rate cladding layer on 42CrMo bearing steel surface by semiconductor fiber coupled laser. By this method, single layer of large thickness, high hardness, low dilution rate, high wear resistance and high corrosion resistance were obtained. In the process of preparing cladding layer, the optimum technology of single channel laser cladding with large thickness and low dilution rate is explored through the changes of spot dispersion, the comparison of coaxial powder feeding and pre-laid powder laser cladding, and the method of laser cladding at different substrate temperatures. The temperature field is simulated by ANSYS simulation software, and the temperature gradient changes of different process parameters during cladding process are explored. Impact. The effects of laser cladding power, scanning speed and powder feeding amount on the morphology of single cladding layer were studied by orthogonal experiments. High power, medium and low speed laser cladding experiments were carried out by Z-axis lifting positive defocusing method, and the difference of the dilution rate of cladding layer obtained by preset powder was compared. The effect of matrix temperature on dilution rate and heat affected zone (HAZ) of 42CrMo bearing steel was studied by liquid nitrogen cooling matrix. The mechanism of the effect of substrate temperature on heat conduction of 42CrMo bearing steel was revealed, and the dilution rate and HAZ of laser cladding were controlled. The microstructure of the coating was studied by means of OM, XRD and SEM. The mechanical properties of the coatings were studied by Vickers hardness tester and wear tester. The results showed that the coatings were dense, without cracks and pore defects. The thickness of the coatings was over 3 mm, the dilution rate was about 5% and the heat affected zone was reduced. The coatings had good metallurgical bonding with the matrix. The average hardness of the cladding layer is about 810HV, which is about 2.3 times higher than that of the matrix. The wear resistance of the cladding layer is obviously improved compared with that of the matrix.

FALM-4: Effect of Laser Remelting on Al/Cu Diffusion Bonding Interface

Lin Luan, Li Cao, Ting Huang, Rongshi Xiao High-power and Ultrafast Laser Manufacturing Lab, Institute of Laser Engineering, Beijing University of Technology, Beijing,100124

Abstract：

Aluminum/copper connection is of great significance in the fields of electronic power, chemical industry, energy, etc. However, the physical properties of aluminum and copper differ greatly, and intermetallic compounds such as CuAl2 are easily generated during welding, which is not conducive to joint performance and is difficult to connect. In this paper, the study of laser remelting aluminum alloy/copper diffusion bonding was carried out to explore the effect of laser remelting on aluminum/copper bonding interface. Firstly, the surface of aluminum alloy was modified by laser, and the microstructure of remelted aluminum alloy was studied by changing parameters such as laser power and scanning speed. The results show that the microstructure of laser remelting area is fine and uniform, which is equiaxed crystal and dendritic crystal from the surface to the bottom. Secondly, the microstructure characteristics of diffusion bonding interface (thickness, composition distribution, precipitated phase) between remelted aluminum alloy and copper at different temperatures, times and pressures were studied. By optimizing the parameters, a good joint was obtained at 550℃, 90 min and 5 MPa.

铝/铜连接在电子电力、化工、能源等领域具有重要意义，但是，铝、铜的物理性能差异 较大，且在焊接过程中易生成 CuAl2 等金属间化合物，不利于接头性能，连接难度较大。本 文开展了激光重熔铝合金/铜扩散连接的研究，探究激光重熔对铝/铜连接界面的影响。首先， 利用激光对铝合金表面进行改性，通过改变激光功率、扫描速度等参数来研究重熔铝合金的 组织变化规律。结果表明激光重熔区域组织细小均匀，从表面到底部依次为：等轴晶、枝晶。 其次，研究了重熔铝合金和铜在不同的温度、时间、压力下扩散连接界面的组织特征（连接 界面厚度，成分分布，析出相） 。通过优化参数，在 550℃、90 min、5 MPa 得到了良好的接头。

FALM-4: Study on Temperature Control of Powdered Pool in Hollow Laser Light

Peng Cheng , Shi Tuo ,Fu Geyan

Suzhou University, Jiangsu Suzhou 215021

Abstract：

The stability of the bath temperature during laser additive manufacturing is an important indicator of the stability of the process. The purpose of this paper is to design a closed-loop feedback system suitable for controlling the temperature of the molten pool, so as to achieve the purpose of stabilizing the molten pool and improving the quality of the formed parts. Based on serial communication and Socket communication in C# programming software, the temperature value signal transmission between the infrared thermometer and the industrial computer, the industrial computer and the robot controller is realized, according to the linear relationship between the molten pool temperature and the laser power. The PID control algorithm is designed with a temperature controller. The results show that the system can realize the closed-loop control of the molten pool temperature in real time, and the system can be applied to the straight wall forming experiment, which can effectively eliminate the “mushroom cloud” phenomenon caused by the accumulation of temperature during the cladding process, and form The geometric accuracy of the parts is significantly improved, the microstructure difference is small, and the structure is dense and uniform.

在激光增材制造过程中，熔池温度的稳定性是表征加工过程稳定性的一个重要指标。本文研究的目的是设计一套适合控制熔池温度的闭环反馈系统，进而达到稳定熔池和提高成形件质量的目的。基于C#编程软件中的串口通信和Socket通信，实现了红外测温仪与工控机，工控机与机器人控制器之间的温度值信号传递，根据熔池温度与激光功率之间的线性关系，采用PID控制算法设计了温度控制器。结果表明，此系统能实时准确地实现熔池温度的闭环控制，将该系统运用于直壁墙成形实验中，能够有效消除由于熔覆过程中温度的累积而造成的“蘑菇云”现象，且成形件几何精度有显著提高，各处显微组织差异较小，组织致密均匀。

FALM-4: Study on surface quality of zirconia ceramics used for bearing grinding with diamond grinding wheel

HAN Guangtian[1], LI Songhua[1,2], SUN Jian[1], CHEN Wenzheng[1], WANG Kechong[1]

[1] School of Mechanical Engineering, Shenyang Jianzhu University, Shenyang 110168, China

[2]National-Local Joint Engineering Laboratory of NC Machining Equipment and Technology of High-Grade Stone, Shenyang Jianzhu University, Shenyang 110168, China

Abstract：

Aim to obtain a high quality surface in the grinding of zirconia ceramics, single factor experiments were usde to study the effects of grinding depth, grinding wheel linear speed and workpiece feed speed on the surface quality of zirconia ceramics in precision grinding and the material removal mechanism. The surface morphology of the grinded samples was observed by Ultra-depth-of-field three-dimensional microscope and scanning electron microscope. Orthogonal experimental carried out to optimize the grinding parameters and verify it. Results The grinding surface roughness increases with the increase of grinding depth. The grinding surface roughness first decreases and then increases with the increase of grinding wheel linear speed. The grinding surface roughness increases with the increase of workpiece feed speed. The optimal combination is grinding depth of 5 um, grinding wheel linear speed of 40 m/s and workpiece feed speed of 1000 mm/min. Conclusion Under the optimum combination grinding conditions, the average roughness of surface Ra is 0.3889 micron, 0.4170 micron, 0.4037 micron in the three groups of zirconia ceramics grinding experiments.

在氧化锆陶瓷磨削中为获得较高质量表面，采用单因素实验研究磨削深度、砂轮线速度、工件进给速度对氧化锆陶瓷精密磨削表面质量的影响规律及材料去除机理，通过超景深三维显微镜以及扫描电子显微镜，观察氧化锆陶瓷试件磨削后的表面形貌，最后用正交实验法进行优选并验证。结果表明：磨削表面的粗糙度随磨削深度、工件进给速度增大而增大,随砂轮线速度增大先减小、后增大。在磨削深度 5 μm、砂轮线速度 40 m/s、工件进给速度 1000 mm/min 的优化组合条件下，磨削三组氧化锆陶瓷的平均表面粗糙度 Ra 为 0.3889 μm、0.4170 μm、0.4037 μm。

LPAM-3: Fabrication of porous Si/Cu architecture for lithium-ion batteries based on laser microcladding and dealloying

Ting Huang

Institute of Laser Engineering, Beijing University of Technology, Beijing, China

Abstract：

Si anode for lithium-ion batteries (LIBs) has been intensively investigated to achieve high energy/power density due to its high lithiation capacity, environmental friendliness, and earth-abundant. However, the practical implementation of Si anode is impeded by well-known detrimental pulverization effect and conductivity fading during charge and discharge. The inhomogeneous volume expansion of Si during charge and discharge induces severe stress causing Si pulverization and peeling from the current collector, which results in the conductivity deteriorates continuously. Here, integrated anode with porous Si/Cu architecture was fabricated through laser microcladding and dealloying. First, a mixture of Al, Si and Cu powder was laser-cladded onto the Cu current collector to form a thin layer composed of Si, Cu, and Al-Cu compounds. Then, through dealloying, Al was selectively removed from Al-Cu compounds leaving porous architecture with Si particles and Cu skeletons. The specific capacity, capacity retention and Coulombic efficiency of the porous Si/Cu anodes fabricated with different parameters were compared and discussed in detail to evaluate the effects of laser microcladding and dealloying processes. Our results suggest that the as-fabricated porous architecture has enough space to allow for the large expansion of Si during lithiation. The Cu skeletons could prevent loss of electrical contact between pulverized Si and current collector.

LPAM-3: Optimisation of Laser Micromachining of multilayer coated cutting tools

Ahmed Alghamdi, Paul Mativenga

The University of Manchester, Manchester, United Kingdom

Abstract：

Laser surface structuring techniques have become widely used in research related to cutting tools improvement. However, the laser micromachining of multilayer coated carbide was found not to be thoroughly studied in the literature. Therefore, in this study, statistical analysis was employed to identify the critical process parameters to control the process of using laser technology for micromachining of multilayer coated carbide. The work includes the use of Nd: YVO4 nanosecond pulsed laser technology for surface structuring of multiple layers of Chromium (Cr), alumina (Al_2O_3) and titanium carbonitride (TiCN) coatings on a tungsten carbide-cobalt (WC-Co) substrate. The impact of different laser settings on the structures geometry and the multilayers of coating had been discussed in details. It addresses the effects on the micro-channels depth, width, and burrs height. Taguchi design of experiment allowed the identification of optimum settings for each parameter to achieve pre-set goals. The confirmation tests demonstrate that Taguchi results helped to control the micro-channels depth, width and burrs height.

LPAM-3: Structural Response of Femtosecond Laser Processed Silicon

Xin Zhang, Ting Huang, Rongshi Xiao

Beijing University of Technology, Beijing, China

Abstract：

Femtosecond laser is widely used in high precision micro-nanofabrication because of its very short pulse width and high peak power, which exhibits strong non-thermal effect when interacting with materials. In this study, the fundamental mechanisms governing material behavior under the femtosecond laser pulse are investigated. In order to provide a fundamental insight into the microstructural processes, high-resolution transmission electron microscopy (TEM), electron backscatter diffraction (EBSD), Raman spectroscopy as well as two-temperature numerical model were used to study structural response of silicon to laser pulse with a pulse width of 800 fs. Extensive microstructural examinations and numerical simulations showed that material behavior could be described in terms of amorphization and ablation. The structural response was found to be very sensitive to crystallographic orientation of Si surface. Specifically, the crystals with orientations close to beam direction exhibited a pronounced amorphization effect whereas no disordered material was detected at crystallographic orientations close to beam direction. This phenomenon was explained in terms of variation of penetration depth and concomitant activation of different solidification mechanisms

LPAM-3: Effect of Micro-textured Surface of Impact Needle on the Performance of Electronic Printing Nozzle under Sliding Boundary Conditions

Chao Guo[1], Qinghua Song[1,2], Zhanqiang Liu[1,2], Tao Zheng[1]

[1]Key Laboratory of High Efficiency and Clean Mechanical Manufacture, Jinan, China

[2]National Demonstration Center for Experimental Mechanical Engineering Education, Jinan, China

Abstract：

Jetting technology has been widely used in electronic fabrication due to its high operational flexibility and low production costs. To accurately investigate the effect of micro-textured surface and slip boundary of impact needle on the performance of electronic printing nozzle, a flow model between the jetting needle decorated by grooves of different geometric sizes and the wall of the ink reservoir is created in this paper. Considering the slip boundary conditions, the Reynolds equation is used to calculate the slip velocity near the boundaries, and the flow of printing ink is solved by Stokes and Energy conservation equation based on Galerkin finite element method. The influence of texturing geometry parameters and slip lengths on pressure and temperature of printing ink between needle and wall are investigated and discussed in detail. The results show that appropriate adjustment of different geometric parameters and slip lengths can achieve the same effect of pressure variation. Finally, micro-milling tools are used to machine grooves of different sizes, and sliding experiments are performed to confirm the method presented in this paper.

LPAM-3: Electro-active scaffolds for bone tissue regerenation

Boyang Huang, Paulo Bartolo

School of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester, United Kingdom

Abstract:

Characterization of bioactive electro-active scaffolds. Scaffolds were produced using an extrusion-based additive manufacturing system and different material compositions based onPoly (ε-caprolactone)(PCL) mixed with hydroxyapatite (HA), and multi-wall carbon nanotubes (MWCNTs) were investigated.Results show that the addition of MWCNTs and HA can significantly enhance the compressive modulus of PCL scaffolds. Biological results show that all scaffolds containing MWCNTs and HA are biocompatible (more than 80% cell viability), bioactive (60% increase for HA and 86% increase for MWCNTs) and osteoconductive (significant increase of ALP activity). Results also show that the addition of MWCNTs improves the osteoinductive properties and the presence of nano-sized HA improves the mineralization process. This research shows that PCL/HA/MWCNTs can be viable scaffolds for bone tissue engineering, providing a promising way for bone tissue regeneration.

LPAM-3: A comparative study on the fabrication efficiency of dental ceramics with high power pulsed laser and conventional diamond-based CAD/CAM milling

Peixin Hu[1], Zhengdi He[1], E.C. Ji[2], Lu Yao[1], Q.T. Lue[1,2]

[1]Shenzhen technology university, Shenzhen, China

[2]Han's Laser Technology Industry Group Co., Ltd, Shenzhen, China

Abstract:

In this paper, a non-contact method of glass ceramics fabricating with high power pulsed laser is investigated in detail based on CAD/CAM system. Aiming to improve the cutting efficiency of high power pulsed laser on glass ceramic blocks and the cutting precision to reduce the surface roughness and edge breakage, the interaction between pulsed laser and ceramics under nanosecond 1064 nm, 532 nm, 355nm lasers and picosecond 1030nm, 532 nm laser are thoroughly studied. After optimized laser parameters are obtained,10 groups of glass ceramic blocks are processed by pulsed laser and diamond-based3-axis CAD/CAM milling methods respectively. The average cutting speed of traditional CAD/CAM milling method is 0.0687mm^3/s(p3/s ($p<0.05$), 48.45±0.46μm ($p=0.05$) and 1.6±0.04($p>0.05$), 38.69±0.38μm($p=0.05$), respectively. The preliminary results show a great leap in the processing efficiency with pulsed laser while keeping the almost same processing accuracy. This study verifies the feasibility and practicability of ultrafast pulsed laseronmilling glass ceramic blocks. Pulsed-laser-based 5-axis CAD/CAM system is in great potential for shortening the dental restoration cycle and reducing the dental restoration cost. However, further study, such as the femtosecond laser milling, is necessary to improve the milling precision and reducing the surface roughness.

Keywords: high power pulsed laser, dental glass ceramics, CAD/CAM milling.

LPAM-3: Study on the element segregation and Laves phase formation in the carbon nanotube reinforced IN718 alloy fabricated by laser cladding

Yuan Chen, Qin Zhang, Jianhua Yao

Institute of Laser Advanced Manufacturing, Hangzhou, China

Abstract：

Nickel-based superalloy is widely used in the high-temperature application components, but the element segregation is inevitable during its rapid solidification, which decreases the mechanical strength of the alloy and helps the production of liquation cracking in the interdendritic region. In the present study, electroless plating of Ni was pre-treated on the surface of carbon nanotubes (CNTs). And then, CNTs reinforced nickel-based superalloy IN718 by laser cladding was manufactured. The structural evolution of CNTs was studied through the microstructural study by SEM and TEM. Attributed to the high energy laser beam irradiation and high-temperature molten pool heating, the tubular structure of CNTs is opened up, forming the graphene nanosheets (GNSs). The GNSs are further torn into lots of graphene fragments, which are found to be inter-bonded with the neighboring ones, resulting in the formation of large scale carbon nanoribbons (CNRs). Due to the high surface areas of the carbon nano products of GNSs and CNRs, the element segregation and Laves phase formation in the laser cladded IN718 superalloy are both suppressed. And with the increase of the thickness of the electrolessly plated Ni layer, the perfection of the graphene structure in the GNSs and CNRs is increased, and as a result, the depression effect provided on the element segregation and Laves phase formation of IN718 superalloy is improved dramatically. Attributed to the addition of the CNTs, significant improvements on the properties like hot cracking resistance, tensile strength and corrosion resistance are achieved.

LPAM-4: Hot corrosion behavior of laser deposited Inconel 718 alloy under different heat treatment conditions

Qunli Zhang*[1, 2], Jie Zhang[1, 2], Dong Li[1, 2], Jianhua Yao[1, 2]

[1] Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, 310023, P.R. China

[2]Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, 310023, P.R. China

Abstract：

Hot corrosion is one of crucial challenges of Ni-based superalloy operating at high temperature. In this paper, the hot corrosion behavior of laser deposited Inconel 718 alloy with different heat treatment conditions (solution + aging, direct aging and as-deposited) was investigated in salt mixture of 87.5 wt.% Na_2SO_4 + 5 wt.% NaCl + 7.5 wt.% $NaVO_3$ at 650 ℃. The weight gain made on the Inconel 718 samples at different heat treatment conditions during the experiments was used to determine the kinetics of hot corrosion. X-ray diffraction (XRD), field emission scanning electron microscope with energy dispersive spectroscopy and X-ray mapping were used to characterize the corroded products of the Inconel 718 alloy at different heat treatment conditions. Based on the corrosion compounds, the corrosion mechanism was also discussed. The experimental results show that the hot corrosion kinetics of the as-deposited Inconel 718 alloy obeys a parabolic law, and the element mapping results show that the corrosion products of as-deposited Inconel 718 can be divided into two layers, of which the outermost layer is mainly composed of Ni_2CrO4, Cr_2O_3 and Fe_3O_4, while the inner layer is mainly composed of NiS. It also indicates that the laser deposited Inconel 718 alloys with different heat treatment have different hot corrosion properties. The hot corrosion property of the solution treated samples is better than that of direct aging samples, while the direct aging samples have better hot corrosion property than as-deposited samples. On the basis of the experimental results and theoretical analyses, the physical hot corrosion mechanism of Inconel 718 at different heat treatment conditions was accordingly established to illustrate the oxidation behavior of as-deposited Inconel 718 alloy in salt mixture solution.

LPAM-4: ‘Bone Bricks’- cell-friendly, Low-cost and Easily Assembled Orthopaedic Treatment for Blast Injuries

Fengyuan Liu

University of Manchester, Manchester, United Kingdom

Abstract：

Blast injuries are common on the modern battlefield effecting both military personnel and civilians. A 2017 Handicap International report stated that 53% of injuries in refugees were due to the use of explosive weapons, among this 47% had fractures or complex fractures, including open fractures of lower and upper limbs. However, often the only feasible treatment for these injuries is limb amputation. Amputation has associated complications including loss of mobility, heart attack, slow wound healing, infection, and mental health issues. This project aims to create a medical device combining an internal scaffold structure with an external fixation device to treat large non-union bone loss in the lower limb for use by surgeons rapidly in traumatic situations. The internal scaffold prosthetic termed, ‘Bone Bricks’, is composed of modular porous blocks which are biocompatible and biodegradable polymer-ceramic composites manufactured using extrusion-based 3D printing. These will come in a variety of sizes and shapes allowing the surgeon to assemble the pieces, like Lego, to form a construct which will fit the damaged area. Once the ‘Bone Bricks’ have been fitted into place an antimicrobial ceramic paste will be injected into the blocks to prevent infection, a major cause of morbidity, and aid in bone regeneration. The combination of a 3D printed external fixation device incorporating electrical stimulation, internal porous and modular bioceramic blocks, and a antimicrobial paste will aid in the creation of stable bone union, long-term recovery of the patient, and saving of the effected limb.

LPAM-4: Generation of High-density, Self-organized Microcones on Reaction Bonded Silicon Carbide by Nanosecond Pulsed Laser Irradiation

Tushar Meshram, Jiwang Yan

Keio University, Yokohama, Japan

Abstract：

Silicon carbide (SiC) is heavily used in the industry due to its resistance to chemical wear and excellent mechanical properties such as high hardness and high stiffness. However, these properties make it difficult to produce micro and nanostructures on the surface of SiC by conventional methods. In this study high-density, self-organised (randomly aligned) microcones that protrude well above the initial surface have been fabricated by nanosecond pulsed Nd-YAG laser irradiation (λ = 532 nm) on reaction bonded SiC. In some case, the peak of cones was more than 10μm above the initial surface. Geometrically aligned cones were also fabricated by modifying the laser scanning path. Effect of different parameters such as pulse frequency, laser fluence was studied on the generation of conical microstructures. It is observed that the surface morphology of microcones is affected by the pulse width and beam overlap. The composition of cones was studied by X-ray spectroscopy and Raman spectroscopy, and it was found that the microcones were mainly composed of silicon. These results indicated that preferential melting of material occurred at grain boundaries initially and the molten material was pushed upwards by plasma pressure, forming microcones. At lower fluence, microstructures started to form in areas with smaller grain size and grain boundaries of large grains; at high fluence, whole surface was covered with cones. Formation of these structures made the surface superhydrophilic with a contact angle of ≈ 0°.

LPAM-4: Addition of Sawing Strategy for Microdrilling of Monel k500 Superalloy Sheet to Study Hole Characteristics with Low Power Pulsed Fiber Laser

Debal Pramanik, Arunanshu Shekhar Kuar, Soumya Sarkar, Souren Mitra

JADAVPUR UNIVERSITY, KOLKATA, India

Abstract：

Modern manufacturing industries make laser drilling of metals and alloys as a tool for the production of holes of different sizes and shapes. During recent years laser drilling of aerospace nickel superalloys is mostly done with the help of laser beam machining. Trepanning drilling process is to be an attractive choice in high-value manufacturing industries. But it is hardly complicated for 50-watt average power machine to achieve high-quality cutting of the metal sheet up to 2 mm thickness. A rear input parameter sawing angle acts as an important role in top and bottom diameter deviation in cutting monel k500 alloy sheet of 0.7 mm thickness in low power fiber laser beam machining. The present study deals with the effect of sawing angle with other process parameters like average power, duty cycle, pulse frequency and scanning speed on the diameter deviation for a monel metal sheet. Optimization of controllable process parameters help to obtain require diameter deviation which is validated in the proposed model. For prediction of the effect of independent process parameters on laser cut quality, a model has been developed with the help of regression analysis. As a result for low power fiber laser machine, laser trepan drilling with circular sawing strategy has become more suitable in cases of high dimensional accuracy and hole quality which are suitable quality characteristic for any manufacturing industries. Optimization of the laser input parameters can help to achieve high dimensional accuracy and hole quality.

LPAM-4: Effect of LSM Pretreatment with Different Energy Density on MAO-treated Ti-6Al-4V Alloy and Corrosion Resistance

Ye Wang[1,2], Guolong Wu[1,2], Min Sun[1,2], Danhua Lu[1,2],Jianhua Yao[1,2],Qunli Zhang[1,2]

[1]Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, China

[2]College of Mechanical Engineering, Zhejiang University of Technology, Hangzhou, China

Abstract：

In this paper, Ti6Al4V alloy was treated using duplex techniques of laser surface melting (LSM) and micro-arc oxidation (MAO) to improve its corrosion resistance and prolong the service life of it. The surface roughness and microstructure of samples were analyzed by 3D surface profiler and optical microscope (OM) respectively. The differences of micro-arc oxidation (MAO) coatings on Ti6Al4V alloy treated by LSM and untreated one were analyzed by scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS) and X-ray diffraction (XRD). The influence mechanism of LSM pretreatment on micro-arc oxidation coating was discussed. The results show that the melting layer mainly consists of α′ martensitic phase formed by rapid melting and cooling after LSM, and the refinement is more obvious with the decrease of laser energy density. In addition, the surface roughness of LSM-treated samples decreased firstly and then increase with energy density of LSM raised. The corrosion resistance improved during phase transformation on surface. At the same time, high volume fraction and crystal defects of microstructure in melting layer can provide more reaction channels and accelerate the diffusion of elements and promote chemical reactions during MAO process. Therefore, the MAO coating on Ti6Al4V alloy pretreated by LSM had refined micro-pores with uniform size and thicken than that on the surface of untreated sample. Potentiodynamic polarization are conducted in SBF‘s solution at 37℃, reveals that both MAO-and LSM/MAO-treated samples could significantly improve the corrosion resistance of TC4 alloy, and the latter one exhibited better properties than the former one.

LPAM-4: Modelling Plastic Deformation Induced by Laser Shock using 3D Discrete Dislocation Dynamics

Wangfan Zhou, Xudong Ren, Yu Yang, Zhaopeng Tong, Lan Chen

Jiangsu University, Zhenjiang, China

Abstract：

Laser shock peening is one of the most effective surface strengthening techniques, which uses laser shock induced ultra-high strain rate plastic deformation to optimize surface stress state and microstructures of target material. In this paper, dislocation dynamics simulation was used to investigate laser shock induced ultra-high strain rate plastic deformation of FCC and BCC metals. Molecular dynamics was employed to calculate dislocation mobility. Based on the obtained dislocation mobility coefficient, dislocation dynamics models of FCC pure nickel and BCC pure iron were established. Results show that the speed of dislocation movement increases as temperature decreases. Under ultra-high strain rate deformation, dislocation density of nickel increases while dislocation density of iron decreases as temperature rises. Moreover, iron exhibits thermal softening while nickel exhibits thermal hardening under laser shock loading. Plastic deformation dominated by dislocations is sensitive to loading direction, depending on the Schmidt factor of the slip system. The ultra-high strain rate induced by laser shock can effectively promote dislocation multiplication and suppress dislocation annihilation, thus significantly increase the dislocation density under the same strain.

LPAM-4: Microstructure characterization and Properties Evaluation on WC/Cu Composite Coating Prepared by Supersonic Laser Deposition

Xuanjie Huang, Bo Li, Weilin Wang, Lijuan Wu, Jianhua Yao

Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, China

Abstract：

Pure copper is widely used in power, metallurgy and other industrial fields owing to its excellent thermal conductivity, electrical conductivity and processing properties. However, low strength and hardness, together with poor wear resistance limit its widespread application. Therefore, it has been becoming a research hotspot to improve the hardness and wear resistance while ensuring copper's excellent performance.Due to its high hardness, good wear resistance, good electrical and thermal conductivity, tungsten carbide is often used as a reinforcing phase of ceramic-metal composite coatings to improve surface properties. Supersonic laser deposition (SLD) is a new material deposition method which introduces synchronous laser irradiation into cold spray (CS). The high-energy laser beam is employed to pre-heat and soften both the spraying particles and the substrate so as to modify their mechanical properties and impacting behavior. In this paper, WC/Cu composite coatings were prepared on the pure copper surface by SLD and CS respectively. The microstructure, phase composition, micro-hardness and wear properties of the as-prepared coatings were tested by SEM, XRD, EDS, Vickers hardness tester and wear tester. The results show that, compared to the CS coating, the SLD coating has better compactness and interfacial bonding, higher WC content as well as more even distribution of WC particles. The SLD coating still preserve the original microstructure and phase of the feedstock. The SLD coating has higher microhardness than the CS counterpart, and smaller friction coefficient, wear scar width and wear rate of the SLD coating indicates its better wear resistance.

MPT-3: Topological Optimum Design and 3D Printing for Artificial Mandibular Implant

Yun-feng Liu[1], Kang-jie Cheng[1], Russell Wang[2]，Xu Xu[3]

[1]Key Laboratory of E&M (Zhejiang University of Technology), Ministry of Education & Zhejiang Province, Hangzhou, Zhejiang, 310014, China

[2]Department of Comprehensive Care, Case Western Reserve University School of Dental Medicine, Cleveland, OH, 44106-4905, USA

[3]Department of Stomatology, People's hospital of Quzhou, Quzhou, Zhejiang, 324000, China

Abstract:

Mandibular segmental defects usually resulted from trauma, infection and surgical resection of tumors. A critical-sized mandibular defect requires surgical interventions to restore a normal appearance and functions using an implant, which is biocompatible, appropriate strength, bioactive and inexpensive. An artificial implants of metal alloy with solid structure generally is stiffer than natural bones, and it could lead to significant stress-shielding effects which causes bone resorption and eventual failure. To reduce stress-shielding, topological optimization could be used for porous structure design regarding optimal mechanical behaviors. Based on a 3D virtual mandibular model which was reconstructed from cone beam computed tomography images, a mimicked mandibular resection was segmented and reconstructed with an artificial implant. The implant includes internal structures designed by topological optimization, dental implants and implant-supported crowns. A second 3D virtual model reconstructed with a fibular graft and implant-supported crowns was used for comparison. The biomechanical behaviors within the two models were calculated by finite element method (FEM) under same boundary constraints and three loadings, which showed the maximum stresses and displacements of the topology optimized model were much lower than those of the model with fibular bone graft. To verify the validity of the topological optimal design method for artificial mandibular implant, a canine test was conducted. The artificial implant for a canine mandible with topological optimum structure was printed with titanium alloy, and was implanted into the canine mandible by surgery after post-process. The experiment showed the implant was integrated well with surrounded mandibular bone to supply stability for bone rehabilitation. PEKK/PEEK implant with optimal structure will be printed and experimented in future.

下颌骨缺损主要由创伤、感染和肿瘤手术切除引起。较大骨段的下颌骨缺损需要手术干预以重建患者的外貌和功能，即通过手术植入植入体实现，植入体需要具有生物相容性、合适的强度、生物活性和较低的成本。实心的金属合金植入体比骨的强度和硬度都更大，容易因为应力遮蔽而造成周围骨吸收和最终的失败。为了减少应力遮蔽，可以利用拓扑优化设计具有最佳力学性能的多孔结构来减小植入体的强度。基于 CT 图像重建的下颌骨三维虚拟模型，模拟设计了下颌骨的骨缺损，并通过设计具有内部拓扑优化结构的植入体进行下颌骨重建，该植入体中包含了牙种植体和联接的牙冠。第二个虚拟模型是用于数据比较的模型，其骨缺损与第一个模型完全一样，但用腓骨段进行重建。这两个模型用有限元方法在

完全相同的边界条件和加载方式下进行力学性能对比，结果表明具有拓扑优化结构的植入体其最大应力和位移比腓骨植入体要小得多。为了检验下颌骨植入体拓扑优化设计方法的有效性，进行了基于钛合金 3D 打印的植入体动物实验，初步验证了该植入体能够提供较好的骨重建的稳定性。将来，我们将进一步通过实验验证 PEEK/PEKK 植入体的效果。

MPT-3: Selection of Cutting Conditions Based on Both Minimum Cost and Energy

Haitham M Alswat, Paul T Mativenga

The University of Manchester, Manchester, United Kingdom

Abstract：

Selection of cutting conditions in machining has traditionally been based on quality, reducing cutting cost and/or maximising production rate. Strategies to reduce energy demand in manufacturing processes are becoming necessary due to the growing concern of carbon emissions and electricity prices. In this work, a methodology and software tool was developed using MATLAB GUI (Graphical User Interface) to select optimum cutting conditions by providing the user with both minimum energy and cost solutions allowing a trade-off in selection. Moreover, the maximum desired surface roughness has been considered in the methodology to find the best cutting conditions to achieve both minimum cost and energy criterion for roughing and finishing passes.

MPT-3: A Framework for Enhancing Machining Performance using Big Research Data Analytics

Kaustabh Chatterjee[1], Jian Zhang [2], Uday Dixit[1]

[1]Indian Institute of Technology Guwahati, Guwahati, India

[2]Shantou Institute for Light Industrial Equipment Research, Shantou University, Shantou, China

Abstract：

Machining is one of the most widely used manufacturing processes. However, often it is not carried out in an efficient manner, due to lack of proper knowledge and/or absence of proper methodology to impart and instruct the available knowledge at the shop floor. With the advent of Industry 4.0, there is a strong emphasis on using Big Data and analyzing it for optimizing the processes and resources. Big Data analytics offers a lot of promises for optimizing the machining process. In this work, a framework has been prepared for utilizing Big Data analytics in machining. Machining has been widely investigated by researchers and a lot of information about machining is available in the literature. However, there is still no reliable physics-based model thanks to the complexity of the process and its dependence on several factors. The proposed framework suggests to collect available research data, cluster it suitably and develop piecewise regression models for proper inference. One novel feature of the proposed framework is to estimate the dynamic reliability of developed regression models, which keeps on updating with available information. Further, it is proposed to augment the research data by big data from distributed manufacturing and cloud. It is highlighted that data analytics will optimize the process and will ensure proper utilization of the resources. The efficacy of the proposed framework is illustrated based on an example of proper cutting force estimation.

MPT-3: The Experimental Study of High Volume Fraction SiCp/Al Composites with Ultrasonic Drilling

Yang Liu

Beijing Institute of Technology, beijing, China

Abstract：

SiC_p/Al composite is a new type of composite material,with superior performance of low density, high specific stiffness, high specific strength, good fatigue performance, heat resistance,wear resistance etc, and the application prospect in the fields of aviation and aerospace. Due to its high internal hardness of the reinforcement SiC processing is difficult, which seriously hinders the development of this material. In this paper, the axial ultrasonic vibration is added to the drilling, and the high volume fraction SiC_p/Al is drilled by ultrasonic vibration. The orthogonal test method is used to drill the SiCp/Al test, and the different process parameters are analyzed. The influence of SiC_p/Al drilling force, surface roughness and surface topography, including drilling speed, drilling depth, feed per revolution, and discussion of the variation of drilling force after ultrasonic vibration assisted machining, the degree of wear of the drilling tool under different ultrasonic amplitude. The results show that the ultrasonic vibration assisted drilling process improves the wall roughness and the surface morphology of the hole wall. Ultrasonic vibration has obvious effect on reducing the axial drilling force. Ultrasonic vibration can effectively reduce the wear of the drilling tool and improve the drilling tool life.

MPT-3: Effect of Different Dielectric Medium on the Fabrication of High Aspect-ratio Micro-electrodes

Harish Kumar, Sunil Jha

Indian Institute of Technology Delhi, Delhi, India

Abstract：

Micro-electrical discharge machining (Micro-EDM) is a widely used non-conventional machining process for fabrication of micro size components with dimensions in the range of 1–999 μm. The concept of fabricating on-machine high aspect-ratio micro-electrodes arises from the need to fabricate small and deep micro-holes in Micro-EDM. In the present study, investigations were carried out on the fabrication of high aspect-ratio micro-electrodes in the different gaseous and liquid dielectric medium. The material removal rate of tool and workpiece in different dielectrics were comparatively studied. In this study Micro electrical discharge turning (Micro-EDT) a variant of electrical discharge machining process is used for the fabrication of high aspect-ratio micro-electrodes.

MPT-3: Design and Analysis of a Smart Milling Tool Holder for Milling Process Monitoring in Ultra-precision Machining

Jinqiu Pan[1], Zhibing Liu[2], Xibin Wang[2]

[1]Beijing Institute of Technology, No.5 South Zhongguancun Street, Haidian District, Beijing, China

[2]Key Laboratory of Fundamental Science for Advanced Machining, Beijing Institute of Technology, No.5 South Zhongguancun Street, Haidian District, Beijing, China

Abstract：

The machine tool industry is an important field of advanced machining. The monitoring of machining. status is a reliable guarantee to meet the requirements of high speed, high precision and high automation of cutting. Monitoring of force and vibration during machining is an effective way to estimate the state of the tool during the cutting process.This paper describes the design of an intelligent milling tool holder that monitors milling forces and vibrations in real time during milling. Monitoring of the milling process can detect and avoid instabilities. The tool holder uses piezo-film sensors for real-time monitoring of milling forces during precision milling, and piezoelectric accelerometers for real-time measurement of milling vibration. Since the piezoelectric sensor is subjected to strain during processing, an electrical signal is generated according to the piezoelectric effect. The electrical signals outputted by the piezo sensors need to be processed to enable real-time monitoring of milling forces and milling vibrations. The finite element model of the intelligent tool was established, and the structural mechanics analysis and piezoelectric coupling analysis were carried out to determine the feasibility and usability of the design of the tool holder. Mechanical load conditions were analyzed using the simulation software. The simulation results demonstrate that the innovative tool holder design concept can effectively sensing the cutting forces and vibrations. Preliminary experiments have further proved the concept of the smart tool holder.

MPT-4: Experimental and analytical investigation into cutting force and temperature of novel drill tool having hybrid micro scale textures

Niketh, Samuel Gonumakulapalle Lodi

Indian Institute of Technology Madras, Chennai, India

Abstract：

Frictional heating occurring at the cutting regime is one of the critical factors that deteriorate the machinability of materials. This will result in the increase of tool temperature leading to its catastrophic failure. The above mentioned issue will be even more critical while drilling low thermal conductive materials like Ti-6Al-4V. Hence the present work focuses on establishing a novel approach to minimize sliding friction by creating hybrid micro scale textures at the contact regime, using laser micro machining technique. Preliminary experiments were carried out using pin on disc setup for justifying the tribology enhancement characteristics of hybrid micro textures. From the tribo test, it was found that the coefficient of friction reduced from 0.49 to 0.33 for hybrid textured surfaces compared to non-textured surface, showing a net reduction of 16.33 %. Hence for the first time an attempt has been made to create hybrid micro scale textures on flute and margin side of the drill tools with an objective to enhance the machining performance by controlling the sliding friction. Drilling experiments were carried out using non-textured tool (NT) and hybrid textured tool (HT) for validation. The effectiveness of the textured tool was evaluated based on the variation in cutting forces and temperature. In addition, an inverse heat transfer model was also developed for predicting the heat distribution at the cutting lips. The results from the present work can be a benchmark for further advancements in the area of surface engineered tools.

MPT-4: A smart boring bar for compensation of radial deformation during machining

Shuyao Liu, Zhibing Liu, Xibin Wang

Beijing Institute of Technology, Beijing, China

Abstract：

Holes with a length-to-diameter ratio larger than 10 are usually defined as deep holes. As an important structure, the shape error of the deep hole structure has a great influence on the performance of the parts. Boring is an important process of deep hole machining. However, in the process of deep hole boring, the high overhang and weak stiffness of the boring bar lead to the deformation and vibration of the boring bar in the process, which easily causes large shape errors and difficult to meet the accuracy requirements. Intelligent machining based on compensation technique is a good way to solve this problem. This paper designed a smart boring bar which can detect radial deformation and compensate it in real time during machining. The device included radial deformation detection module, information processing module and feedback execution module. The photoelectric position sensor was used to measure the radial deformation of boring bar and give signal to information processing module, the information processing module processed and calculated the information from the information detection module, and got feedback pulse signals to feedback execution module, feedback execution module of the stepper motor received the pulse signal to drive the cam rotation, so as to adjust the position of the blade, completed the boring bar radial deformation compensation. In this way reduce the shape error in the machining process, the machining precision is improved， thus improved the service performance and life of the parts.

MPT-4: Influence of Different Featured Tools on Machining Accuracy in Electrochemical Milling

Koushik Mishra, Biplab R. Sarkar, B. Bhattacharyya

Jadavpur University, Kolkata, India

Abstract：

Drawbacks of electrochemical machining (ECM) can be conquered to a large extent with the introduction of electrochemical milling (EC milling) technique. In this method, a simple shaped tool follows a predetermined tool path and material gets removed atom-by-atom from anode workpiece by electrochemical reactions via a layer-by-layer approach. Thus, keeping in mind the rising trend of EC milling technique, this research work focuses to investigate the impact of major process parameters of EC milling e.g. feed rate and milling layer depth on foremost responses like MRR and width overcut during EC milling of Nimonic-263 alloy. In this research work, three different types of featured tools have been utilized and for each tool, ANSYS simulation has been carried out for analyzing their impact on machining accuracy. Furthermore, these obtained simulated results have been confirmed by experimentation. In this study, a developed mathematical model has also been considered and validated experimentally during machining of Nimonic-263 alloy which can closely predict the volumetric material removal for a particular feed rate, milling layer depth, material and given length. Finally, an attempt has been made to produce more accurate 'L' shaped features on Nimonic-263 alloy with the aid of tool rotation and inner spraying featured tools. This study confirms that, mixed electrolyte i.e. NaCl(1M) + $NaNO_3$(1M), tool rotation with internal flushing, number of outlets and the structure of the end face of the tool generate excellent machining accuracy with super finished surface with Ra value in the order of 0.07-0.08mm during EC milling of Nimonic-263 alloy.

MPT-4: Direct observation of discharging phenomena in vibration-assisted micro electrical discharge machining

Tatsuya Shitara, Kenjiro Fujita, Jiwang Yan

Department of Mechanical Engineering, Keio University, Yokohama, Japan

Abstract：

In micro electrical discharge machining (EDM), debris are hardly removed from the gap between tool and workpiece. This causes short-circuiting and concentrated discharge which makes machining unstable. To solve this problem, vibration-assisted EDM has been proposed. It has been reported that tool vibration improves machining speed, surface quality and tool life. However, the machining mechanism of vibration-assisted EDM has not been clarified, which hinders further optimization of this process. In this study, we attempted direct observation of the changes in discharging phenomena due to the tool vibration. To observe the small discharge gap, a transparent electrode made of 4H-SiC and a high-speed video camera were used. Machining experiments were carried out in different amplitudes and frequencies of vibration. We observed the discharge spot and investigated the distribution of discharges. In addition, we measured electrical current waveform with an oscilloscope to investigate discharge timing. It was confirmed that tool vibration caused dispersion of discharges and also increased discharge frequency. At higher amplitudes and frequencies, the distribution of discharges was more uniform and the number of discharges increased. In addition, an increase of the amplitude caused periodic discharge phenomena corresponding to tool vibration. Based on these results, it was concluded that dispersing and increasing discharges resulted in the improvement of machining speed and surface roughness in vibration-assisted EDM. By confirming and improving the effect of tool vibration, this study contributes to understanding the mechanism of vibration-assisted EDM and effects of vibration parameters.

MPT-4: Magnetorheological methods for internal cylindrical surface finishing - A review

Talwinder Singh Bedi, Ravi Kant

Indian Institute of Technology Ropar, Rupnagar, India

Abstract：

The operative functionality of different internal cylindrical products such as cylinder liner, air bearing, die cavity, etc. entirely depends upon the surface roughness. Lower the surface roughness values, higher the surface quality will be. Such products require high quality surface finish, nearly equals to mirror like surface with closer dimensional accuracy. Presently, finishing processes like grinding and honing are being used to finish the internal cylindrical surfaces. These processes use rigid nature of tool structure which consists of bounded abrasives to the rotating wheel. These finishing processes lack the control over the finishing forces which results into surface defects. Hence, it reduces the overall surface integrity of the manufactured products. To resolve these limitations, magnetorheological methods have been evolved utilizing the MR polishing fluid to enhance surface finish. The MR polishing fluid behaves like semi-solid type fluid under the influence of magnetic field with controlled finishing forces. The existing magnetorheological methods for internal cylindrical surfaces are found suitable for finishing of non-ferromagnetic materials only. These are not suited for ferromagnetic materials because of their tool structure. Recently, the task to finish ferromagnetic components has been conquered by a newer magnetorheological honing (MRH) process. In the present work, the finishing capability of various magnetorheological methods for internal cylindrical surfaces along with their mechanism of material removal have been illustrated.

WJ-1: Initial Instability in the Welding Pool of Aluminum Alloy

Wenjian Zhang, Yinghe Ma, Yanming He and Jianguo Yang

Institute of Process Equipment and Control Engineering, Zhejiang University of Technology, Hangzhou, 310014, P.R. China.

Abstract：

The initial planar growth stage play a key role in the whole solidification of the welding pool. The interface structure and mass concentration formed in the initial planar growth stage are the microstructure foundation in the subsequent nonlinear growth. To predict onset of the initial instability with different crystallographic orientation of epitaxial solidification during the solidification of welding pool of an aluminum alloy, coupled equations were conducted to describe the transient conditions of crystal growth near the fusion line, and coupled with a quantitative phase field model and a dynamic analytical model base on the time dependent instability analysis to simulate the growth process of the epitaxial solidification with different tilting growth angles between the preferred crystallographic orientation and the temperature gradient direction. The linear growth result of initial average spacing obtained by the phase field simulation model and the analytical model are in good agreement with that in experiment result. It shows initial instability evolutions of the epitaxial solidification with different crystallographic orientation. It shows that the greater the tilting growth angles, the better the stability of the interface, and the larger the critical time of onset of initial planar instability. The initial average spacing generally increases with increasing the tilting growth angle, however due to the transient conditions in welding pool and the randomness of the amplification mechanism in linear instability, the initial average spacing is seemingly irrelevant to the tilting growth angle of the epitaxial solidification.

WJ-1: Increasing efficiency in laser micro welding of copper by using a 515 nm disc laser

Marc Hummel[1], André Häusler[2], Alexander Olowinsky[2], Arnold Gillner[1,2], Reinhart Poprawe[1,2]

[1]Chair for Lasertechnology LLT, RWTH Aachen University, 52074 Aachen, Germany

[2]Fraunhofer Institute for Laser Technology ILT, 52074 Aachen, Germany

Abstract：

Copper is classified as ideal material for electronic components due to its high electrical conductivity. With society's increasing interest in alternative energy storage options, the demand for copper increases and processes for contacting electronic components for battery cells and fuel cells are gaining in importance. Therefore laser micro welding is used, which is characterized as a high-precision joining process in the micron range. Fiber lasers with a wavelength in the near infrared range (IR) have established themselves for this purpose. In these joining processes, material properties of copper such as high thermal conductivity and low energy absorption of infrared radiation cause significant difficulties such as process instabilities and pore and spatter formation. Newly developed laser beam sources in the visible wavelength range (VIS) prove to be an alternative to conventional fiber lasers. An increase in absorption of the electromagnetic wave from 55% (515 nm) of cooper at ambient temperature leads to a higher energy coupling and a stabilized energy input into the material during the process.In this work, the influence of the green wavelength of 515 nm on absorption, energy coupling during the laser welding process and the process dynamics is investigated on Cu-ETP and CuSn6. Therefore blind welds with a frequency doubled 515 nm disc laser are conducted and compared to investigations with a fiber laser at 1070 nm. The reflected radiation from the material surface is observed by using photodiodes, melt pool dynamics are observed by high speed imaging.

WJ-1: Research on GH3128 spot welding by fiber laser focus point rotation process

Qiang Wu, Shusheng Peng, Xintong Li, Rongshi Xiao

High-power and Ultrafast Laser Manufacturing Laboratory, Institute of Laser Engineering,, Beijing, China

Abstract：

The non-penetrate spot-weld technology with the high strength and high quality is the new requirement for the thin-wall component with lap structure. Increasing the weld width of seam on bonding surface and restrain the pore defect are the effective methods for this requirement. In this paper, the 6 kW fiber laser and laser focus point rotation apparatus are used for laser focus point rotation spot welding processing for GH3128 overlap structure. The results show that the rotation frequency and radius are critical influence for spot welding mode with the constant laser output power. With the increase of rotation frequency and radius, the welding mode is transited from deep penetrate mode to heat conduction mode. In the laser deep penetrate mode, the focus point rotation can increase the width of seam on the bonding surface and decrease the depth of seam slightly, and the weld beam morphology is the nail-head morphology. In the heat conduction mode, with the increasing of heat accumulation, the morphology of weld can be changed from double “V” shape to “W” and “U” shape, and the width of seam on the bonding surface can increase greatly. Moreover, the depth of spot seam is smaller than that obtained in deep penetration mode, and the depth of seam is positive correlation with the number of rotation. In both welding modes, on account of the high speed rotation of the laser beam, the porosity defect is reduced effectively, the strength of spot welding seam is increased.

WJ-1: Effect of welding on mechanical performance of laser welded NiTinol samples

Susmita Datta, Mohammad Shahid Raza, Partha Saha, Dilip Kumar Pratihar

Indian Institute of Technology Kharagpur, Kharagpur, India

Abstract：

NiTinol, because of its several superior properties like shape memory effect, pseudo-elasticity, corrosion resistance and biocompatibility, has become a promising member for various application areas including biomedical, MEMS, aerospace. Poor machinability, lack of joining techniques and high cost of the material are presently restricts use of the material in practical applications to its full potential. Laser welding is the most widely used joining technique for this material. The effects of welding on the bead geometry, microstructure, new phase formation, phase transformation temperature for laser welding of two mm thick NiTinol sheet in bead-on-plate configuration using Yb-fiber laser in continuous mode of operation were investigated through this study. Moreover, the mechanical properties of the joint were evaluated by means of tensile tests performed for failure through cyclic loading. The functionality of the cyclic loading was tested by analysis of the mechanical hysteresis response up to 6 % strain levels. Furthermore, the fractured surface was analyzed by scanning electron microscopy. Results revealed that the microstructure varied across the different zones of welding depending on temperature gradient and solidification rate.The microhardness value of the weld-bead was reduced considerably from that of the parent material. Brittle intermetallic compounds of Ti and Ni were formed during welding. It was also found that the welding greatly influenced the phase transformation temperature, overall mechanical properties and the mode of failure in comparison with parent material.

WJ-1: A Nano-Indentation study on Intermetallic compound in Friction Stir Welding of AA6061-T6 and AISI304

Raju Mahto, Perwej Iqbal, Surjya Pal

Indian Institute of Technology Kharagpur, Kharagpur, India

Abstract：

Aluminum and steel welded structures have huge potential for the light weight applications. But owing to the poor solid solubility of the Al atoms in Fe substrate, a diffused layer of Al and Fe results in the formation of intermetallic compounds (IMCs). IMCs (i.e. Fe_xAl_y) are hard and are the main reason for the failure of a weld. The thickness of an IMC layer depends on the heat input and the applied pressure. Friction stir welding (FSW) has been used for Al-Steel joining because of its capability to weld materials in the solid state. However, the thermo-mechanical action of FSW leads to the formation of IMC at the weld interface. The present study aims to investigate the behavior of the IMC layer against the nano-indentation loading up to 8000 μN. Results indicate the occurrence of low deformation and high hardness in the range of 8.5 GPa to 12.3 GPa at the IMC layer. IMC layers have shown pop-in behavior against the applied load of Nano-indenter. In addition to that, the steel flashes accumulated in the aluminum substrate have also found to be harder than the base materials. Transmission electron microscope (TEM) and scanning electron microscopy (SEM) have been used to investigate the high hardness of the steel flash and IMC Layer. X-ray diffraction test on the weld cross-section revealed presence of different types of IMCs such as Fe_2Al_5, Fe_4Al_{13} and $FeCrAl_3$.

WJ-1: Experimental Investigation on Low Power Laser Transmission Welding of Transparent Polypropylene

Dhiraj Kumar, Nand Kishor Maity, Arunanshu Shekhar Kuar

JADAVPUR UNIVERSITY, KOLKATA, India

Abstract：

Laser transmission welding has become a widely accepted significant joining process for transparent material with their increasing application in chemical tanks, medical equipment, marine application and other industries. The basic principle of laser Transmission welding is to apply the energy in between the two transparent materials at their interface to create a weld. However, joining of two transparent material is very difficult because laser radiation directly pass the two piece of transparent material. In the present research work, two thermoplastic polypropylene transparent material of 4 mm thickness have been joined by using Nd: YVO_4 pulsed laser of maximum capacity 9.4 Watt with spot beam diameter of 50 μm, laser pulse width of 4.2 ns and wavelength of 1064 nm. The effect of process parameters such as laser power, frequency and scanning speed have been investigated by using a diode laser system. Experimental investigation based on central composite design (CCD) technique of response surface methodology (RSM) is employed to develop mathematical relationships between the welding process parameters and the output variables of the weld joint to determine the welding input parameters that lead to the desired weld quality. The adequacy of the developed models is tested using the sequential F-test, lack-of-fit test and the ANOVA technique. Analysis of variance is applied to detect the significant factors. The effects of selected welding parameters on the seam geometry, defects and material crystallinity have also been investigated. SEM has also been used for microstructure study.

WJ-2: Dissimilar MIG welding between 316L Austenitic stainless steel and 409 Ferritic stainless steel: Experiment, Analyses and optimization

Nabendu Ghosh, Pradip Kumar Pal, Goutam Nandi

Jadavpur University, Kolkata, India

Abstract：

Welding of dissimilar metals has attracted attention of the researchers worldwide, owing to its many advantages and challenges. There is no denial in the fact that dissimilar welded joints offer more flexibility in the design and production of the commercial and industrial components. Welding of Ferritic and Austenitic stainless steel in general and MIG of such steel in particular, can well be considered as one of the areas where more extensive research may contribute, in a significant way, to the precise control of the welding process for better and acceptable quality of weldment. The purpose is to study the influence of the selected parameters: welding current, Gas flow rate and Nozzle to plate distance on the quality of weld Dissimilar Welding of AISI 316L Austenitic Stainless Steel to AISI 409 Ferritic stainless steel Weldment In Metal Inert Gas Welding. The purpose is to study the influence of the selected parameters on the quality of weld. The parameters will be varied at several levels by planning the experiments on the basis of any one of the several technique available like conventional design of experiments, Taguchi's Orthogonal Array, Response Surface methodology (RSM). After welding, visual inspection and next, radiographic test have been carried out. Tensile tests have also been conducted. Microstructural studies have been done as well; hardness at different zones of the weldment has been measured.

WJ-2: Fabrication of large copper foam plate using friction sintering: Effect of tool traverse speed

Vyas Mani Sharma, Vikranth Racherla, Surjya Kanta Pal

Indian Institute of Technology Kharagpur, Kharagpur, India

Abstract：

A novel friction sintering process is used to obtain large plate copper foam using NaCl as spacers by sintering and dissolution process at different tool traverse speeds. This process provides for quick removal of sintered specimen after sintering. Downfeed movement of rotating tungsten tool against the top sheet provides heat and pressure required for sintering. Tool diameter determines the width, whereas tool travel distance determines the length of sintered specimen. Tool was traversed along the top sheet, as in case of friction stir processing. No external heat source is required to perform sintering, except the friction heat generated by rotating tool and top sheet. Cu-NaCl mixture was used as the starting material. Tool downfeed determines the final thickness of sintered specimen. Scanning electron microscopy (SEM) and X-ray CT scan of fabricated sample indicates that the pore morphology was approximately uniform throughout the length. With increase in tool traverse speed bonding strength of copper reduces, this may be due to less time for heating at a particular point hence, it was observed that with the increase in tool traverse speed sintering temperature decreases and the bonding strength reduces.

WJ-2: Aluminum Alloys(Al6061-T6) and Copper(Cu) Welded by Friction Stir Welding Detecting Surface using NDT Techniques

NEETESH SONI, AMBRISH SINGH

Southwest Petroleum University, Chendgu, China

Abstract：

Friction stir welding is a solid state welding process for joining materials like aluminum, zinc, magnesium, and copper alloys which are employed in rail, aerospace, automobile and marine industries. Generally, Al6061-T6 and Cu are welded using conventional welding technique in marine industries for electrifying purpose. The drawbacks in the conventional welding process in aluminum is the presence of an oxide layer, high thermal conductivity, high coefficient of thermal expansion, solidification shrinkage and above all the high solubility of hydrogen and other gases in molten state. Heat input during the welding is dependent on the many factors like welding parameter rotational speed and transverse speed, tool design pin geometry, pin diameter, shoulder diameter etc. But in FSW, the welding process is done by solid state welding of the material and below melting point of the materials. In this work, FSW joints have been made between AA6061-T6 and Cu of aluminum plates dimension (260 x 120 x 3) mm using different combinations of process parameters. The nondestructive analyses have been done to check the weld quality using ultrasonic A-scan and radiography. The defects that are mostly present in the friction stir welding process are debonding, tunnel defect and voids, are analyzed using ultrasonic A-scan technique. The results concluded to the NDT techniques and beneficial features that analyzed during this research work.

WJ-2: High Energy Deposition of TiN Coating with Pulse Enhanced Vacuum Arc Evaporation

Yinghe MA[1,2], Xiubo TIAN[1], Yanming HE[1], Wenjian Zheng[1] , Jianguo Yang[1]

[1]Institute of Process Equipment and Control Engineering, Zhejiang University of Technology, Hangzhou 310014, P.R. China.

[2] State Key Laboratory of Advanced Welding and Joining, Harbin Institute of Technology. Harbin 150001, P.R. China.

Abstract：

TiN films are deposited by pulse enhanced vacuum arc evaporation (PEVAE) and the substrate current, morphology, microstructure, adhesion, and high-temperature oxidation resistance are investigated. The films deposited by PEVAE are denser than those prepared by the conventional DC vacuum arc evaporation because there are more charged particles. The films with the preferential (111) orientation are also thicker due to the magnetic field created of the high current and higher pusled power in PEVAE. The resistance to high-temperature oxidation is also improved because of the denser structure. At different nitrogen pressure the microstructure and properties of the TiN thin films deposited by PEVAE change a little in contrary to those prepared with the vacuum arc evaporation. The film adhesion is also better using the PEVAE mode which is demonstrated to be a versatile tool with a wide processing window capable of producing thin films with a dense structure, good adhesion, and higher resistance to high-temperature oxidation.

WJ-2: Welding Distortion Straightening Technique by TIG Method

Sai WANG, Wenjian ZHENG, Yinghe Ma, Yanming HE and Jianguo YANG

Institute of Process Equipment and Control Engineering, Zhejiang University of Technology, Hangzhou, 310014, P.R. China.

Abstract:

It is well known that weld distortion often occurs unavoidably in the process of ship construction and repair. Reasonable correction of deformation have an important significance in shortening the shipbuilding cycle and improving the quality of ship construction. Since the shipyard generally uses manual operation for water fire correction, resulting in low production efficiency and low quality, the TIG arc correction device is developed. Using the device to carry out the actual experiment, it is concluded that the TIG arc correction technology can correct the welding deformation of the thin plate. The mechanical properties of TIG arc correction and water fire correction are tested and the microstructure is analyzed. The results show that TIG arc correction improves the mechanical properties relative to water fire correction. Combined with numerical simulation to analyze the deformation mechanism and optimize the process parameters.

FALM-5: Developing Status and Typical Application of Domestic Laser Equipment

Feixing Lu

Wuhan HG Laser Engineering Co., Ltd., China

Abstract：

With rapid development of economy and technology, demands for laser equipment from all walks of life increased year by year, which put forward higher requirements to domestic laser equipment. The report first describes the existing problems of domestic laser equipment, such as small in size, dispersed distribution, low level and shortcomings. Then the report analyses the technical bottlenecks of domestic laser industry and puts forward relevant development proposal, in the view of critical core components, intelligent equipment and apply technics research. Finally, the report introduces the latest research results of laser application, in order to pointing the direction for further improvement of laser equipment.

随着经济技术高速发展，各个行业对激光设备的需求逐年攀升，对国产激光装备的发展也提出了更高的要求。报告针对目前国内激光装备存在的小、散、低、缺等问题，从关键核心部件、装备智能化、应用工艺研究等角度分析了目前国内激光行业技术的瓶颈，并提出了相应的发展建议。报告最后介绍了目前最新的激光应用研究成果，为激光装备的发展指明了方向。

FALM-5: Effect of Narrow Pulse Width Laser Cleaning on Corrosion Performance of Aluminum Alloy

Wang.Fei. sen[1],Cheng.Yin.fen[1], Ai. Si.fei[1], Wang Qian[1],Chen. Hui[*1],Chen.Jin.wen[1,2], Xie. Di [1]

[1]Key Laboratory of Advanced Technologies of Materials (Ministry of Education), School of Materials Science and Engineering, Southwest Jiaotong University, Chengdu 610031, China;

[2]AVIC Chengdu Aircraft Industrial (Group) Co., Ltd.，Chengdu，610092，China

Abstract:

The use of laser cleaning with a pulse width greater than 10 ns to remove the oxide film on the surface of aluminum alloy has been practically applied in the automotive industry. During the laser cleaning process, the wide pulse width will increase the temperature, thus changing the microstructure and oxidation state of aluminum alloy surface, and affecting its corrosion behavior. In this work, A5083-111H aluminum alloy was cleaned by 2ns pulse width laser. The corrosion behavior of laser-cleaned aluminium alloy samples in mixed acid solution of copper oxide and sodium chloride was studied by analyzing 3D morphology, microscopic morphology and element distribution, and compared with the mechanical grinding samples. The results showed that the aluminum alloy after 2ns laser cleaning exhibited higher corrosion resistance, which can be explained by its uniform 3D morphology, element distribution and fine grains. These made the difference between the composition of the grain boundary and the intragranular extremely small, thereby reducing the corrosion current density and the corrosion rate, and improving the corrosion resistance of the surface after laser cleaning.

采用脉宽大于 10ns 的激光清洗去除铝合金表面氧化膜，已在汽车工业中得到实际应用。激光清洗过程中，宽脉宽使温度升高，改变了铝合金的显微组织和氧化状态，从而影响了铝合金的腐蚀行为。采用 2ns 脉宽激光清洗 A5083-111H 铝合金，通过测试分析 3D 形貌、微观形态和元素分布，研究了铝合金在氧化铜和氯化钠混合酸性溶液中的腐蚀行为，并与机械打磨进行了对比。结果表明，2ns 激光清洗后的表面具有更高的耐腐蚀能力，均匀的 3D 形貌、元素分布和细小的晶粒，使得晶界和晶内成分差异极小，降低了腐蚀电流密度，从而降低了腐蚀速率，提高了激光清洗后表面的抗腐蚀性。

FALM-5: High-performance Integrated Additive Manufacturing with Laser Shock Peening–induced Microstructural Evolution and Improvement in Mechanical Properties of Ti6Al4V Alloy Components

J.Z. Lu, H.F. Lu, J. Cai, K.Y. Luo*

School of Mechanical Engineering, Jiangsu University, Zhenjiang, Jiangsu 212013, China

Abstract：

Laser shock peening (LSP), an innovative surface treatment method, was specially combined with selective laser melting (SLM) to improve residual stress, enhance tensile properties and refine microstructure of metallic components. Phase, residual stress distribution, tensile properties and microstructural evolution of SLMed and SLM-LSPed specimens in horizontal and vertical directions were examined. In particular, typical microstructural features in the surface layer of all specimens were characterized by transmission electron microscopy (TEM) observations. Results indicated that tensile residual stress was transformed into compressive residual stress by LSP-induced plastic deformation, and both SLMed specimens in two directions exhibited a good combination of the ultimate tensile strength (UTS) and ductility. Meanwhile, high-density dislocation structures and a large number of mechanical twins were generated in the coarse α' martensites by laser shock wave, and gradually evolved into refined α' martensites. Furthermore, according to the included angle between LSW and the deposited plane, LSW-induced atomic diffusion processes were presented, and the influence mechanisms of the building direction on tensile properties of both SLM-LSPed specimens were revealed. The hybrid additive manufacturing technology combined SLM with LSP realized the high-efficiency and high-quality integrated manufacturing of the formed metallic components for practical applications.

激光冲击强化（LSP），一种新型的表面处理方法，创新地与选区激光熔化（SLM）相结合，以改善金属构件的残余应力，增强拉伸性能并细化微观结构。研究了水平和垂直方向 SLMed 和 SLM-LSPed 试样的物相，残余应力分布，拉伸性能和微观结构演变。特别地，通过透射电子显微镜（TEM）表征了所有试样的表面层中的典型微观结构特征。结果表明，通过 LSP 诱导的塑性变形，残余拉应力转变为残余压应力，并且两个方向的 SLMed 试样均表现出良好的极限抗拉强度（UTS）和延展性。同时，激光冲击波（LSW）在粗大的α'马氏体中诱导产生了高密度位错结构和大量机械孪晶，并逐渐演变为细化的α'马氏体。此外，依据 LSW 与沉积平面之间的夹角，给出了 LSW 诱导的原子扩散过程，揭示了增材方向对 SLM-LSPed 试样拉伸性能的影响机制。SLM 与 LSP 相结合的组合增材制造工艺实现了实际应用中成型金属构件的高效高质量整体制造。

FALM-5: Analysis on Inter-particle Bonding Behavior and Cohesive Strength of WCp-reinforced Stellite-6 Alloy Coating Prepared by Supersonic Laser

Lijuan Wu, Bo Li, Xuanjie Huang, Weilin Wang, Qijian Shi, Jianhua Yao

Institute of Laser Advanced Manufacture, Zhejiang University of Technology, Hangzhou, China

Abstract：

Supersonic Laser Deposition (SLD) is a newly developed materials deposition method which combines Cold Spray (CS) with synchronous laser irradiation. While SLD can deposit metals through intensive plastic deformation upon impact in a solid state at the temperatures well below their melting point, it still remains unclear for the bonding of inter-particle and coating-substrate. In this paper, WC particle reinforced Stellite 6 alloy coating was fabricated with SLD and the bonding strength was evaluated using three-point bending testing. The fracture surfaces and interfacial element diffusion were analyzed and compared to the counterparts prepared by laser cladding (LC), in order to elucidate the bonding mechanism in the SLD composite coating. The experimental results show that the maximum load of SLD coating in the three-point bending test is 38.9N, which is 77% of that of LC coating. The adhesion strength and tensile strength of SLD coating is comparable to that of LC coating, suggesting improved bonding strength in SLD coating as compared to that of CS coating. Benefiting from the solid-state deposition characteristics, the SLD coating still preserves the original properties of the feedstock materials, thus exhibiting better plasticity than the LC coating. The interfaces of WC particle and Stellite 6 particle are tightly bonded without cracks. Moreover, EDS test shows the interfaces of inter-particle and substrate-coating have micro-scale inter-penetration, which improves the adhesion of into-particles. With the assistance of laser irradiation, the bonding mechanism evolves from mechanical bonding in CS coating to co-existence of mechanical and metallurgical bonding in SLD coating.

FALM-5: Mechanical Properties and Electrochemical Corrosion Resistance of Laser Cladded Fe-based Composite Coatings on 4Cr5MoV1Si Steel

X. Xu, K.Y. Luo, H.F. Lu, J.Z. Lu*

School of Mechanical Engineering, Jiangsu University, Zhenjiang, Jiangsu 212013, China

Abstract：

Multilayer coatings with Fe-based powders that mixed different elements were prepared on the surface of 4Cr5MoV1Si steel by laser cladding, and the corresponding microstructure and phase transformation between both adjacent layers was carried out. Mechanical properties and electrochemical corrosion resistance were subsequently investigated. Results indicated that the microstructure at the interfaces between both adjacent layers of multi-layer cladding was composed of equiaxed dendrites and netlike eutectic structures, and the scale of these microstructures were more balanced on account of the addition of excess Ni element making the elements more diffused. Furthermore, with regard to two different Fe-based base powders, as the ratio of specific element contents in the cladding coating increased, surface microhardness decreased continuously after heat treatment. In addition, the introduction and increment of Ni element to the Fe-based alloy significantly improved the impact toughness, and exhibited higher corrosion resistance of the cladding coatings.

在 H13 钢表面多层激光熔覆混合不同元素的铁基粉末，研究了相关的相邻层间的微观结构和元素分布。然后研究了涂层的机械性能和电化学腐蚀性能。结果表明多层熔覆的相邻层之间的微观结构主要由等轴枝晶和晶间网状共晶结构组成，并且它们的分布由于过量的 Ni 元素引起的元素扩散而变得很均衡。并且，关于两种不同的铁基粉末由于特定元素比例的增加使表面微观硬度在热处理后出现下降。而且，添加一定的 Ni 元素到铁基合金能够显著提高材料的冲击性能，并且熔覆层表现出更好的抗腐蚀能力。

FALM-5: Microstructure Evolution Mechanism during Heat Treatment of IN939 Superalloy Prepared by Laser Cladding

Jiajin. Sheng [1], Rong. Liu [1,2] ,Liang. Wang [1], Jianhua. Yao [1,*]

[1] Institute of Laser Advanced Manufacturing, Zhejiang University of Technology，Hangzhou, Zhejiang 310014, China；

[2] Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, Zhejiang 310014, China

Abstract:

Nickel-based superalloys are widely used in industrial and marine gas turbine blades but they are vulnerable to cracking, corrosion and wear in severe working environments. As an advanced material processing technique, laser cladding is often employed to repair the defective blades, also known as laser remanufacturing. In this paper, nickel-based superalloy Inconel 939 is prepared via cladding layer, and the subsequent heat treatment was carried out by three different schemes: “solid solution”, “aging” and “aging after solid solution”, so as to investigate the microstructure evolution mechanisms due to heat treatment and the influence of microstructure changes on the mechanical properties of the alloy. Optical microscope (OM), scanning electron microscope (SEM) and X-ray diffraction (XRD) are used to analyze the microstructure morphology and phases present. It is shown that the laser cladded Inconel 939 alloy has a regular microstructure with consistent epitaxial growth direction. No obvious defects such as pores and cracks are observed in the microstructure. Heat treatment has the following effects on the microstructure evolution of the cladding layer: (1) eliminating harmful phases; (2) promote the precipitation of γ′ phase; (3) change the size and distribution of carbides. The experimental results of mechanical properties show that these microstructure changes are favorable for the cladding layer, and the hardness and friction/wear properties are improved by the heat treatments among which solid solution at 1160℃ for 4 hours (air cooling), then aging at 850℃ for 16 hours (air cooling) appears to result in the best performance of the cladding layer with the hardness as high as 475.6$HV_{0.2}$ and the wear resistance improved by 18%. In summary, laser cladded Inconel 939 superalloy has excellent comprehensive performance after the heat treatments, and laser cladding has potential to repair nickel-based superalloy gas turbine blades as a material remanufacturing approach.

镍基高温合金广泛应用于工业和船用燃气轮机叶片，这些镍基合金叶片在复杂的工作环境中叶片容易产生裂纹、腐蚀和磨损等缺陷，而激光熔覆作为一种先进的材料加工技术被用于修复缺陷叶片。本文采用激光熔覆技术制备 Inconel 939 镍基高温合金熔覆层，并采用“固溶”、“时效”、“固溶后时效”三种方式进行后续的热处理，进而研究热处理过程中显微组织演变机制以及这些组织变化对力学性能的影响。采用光学显微镜（OM），扫描电子显微镜（SEM），X 射线衍射（XRD）分析组织形貌与物象组成，并采用硬度和摩擦磨损性能来评价力学性能。结果表明，激光熔覆 Inconel 939 合金成型性能良好，熔覆层组织外延生长方向一致且没有出现气孔、裂纹等缺陷。热处理对熔覆层显微组织产生以下影响：（1）消除

有害相；（2）促进γ′相的析出；（3）改变碳化物的尺寸与分布。性能测试结果证明，这些显微组织的变化对熔覆层是有利的，热处理后硬度和摩擦磨损性能都有了一定的提高。其中，性能最优的热处理工艺为 1160℃保温 4 小时（空冷）后 850℃保温 16 小时（空冷），其硬度达到了 475.6$HV_{0.2}$，磨损量比热处理前降低了 18%。综上所述，激光增熔覆 Inconel 939 高温合金经热处理后综合性能优异，具有修复镍基高温合金燃气轮机叶片的潜力。

FALM-5: Effect of Electromagnetic Induction Coupling on Hardening Depth of Laser Deep Quenching on 42CrMo Bearing Steel

Zhang Qun-li,Gai Ming-Wen,Chen Zhi-jun,Tong Wen-hua,YAO Jian-hua

Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou 310014, China

Abstract：

42CrMo bearing steel on deep quenching mostly adopts medium frequency induction hardening process. There is inevitable soft band in the starting and ending position of bearing induction quenching. The soft zone hardness is much lower than the hardness requirement of 55-62HRC of the quenching layer. Bearing defects also produced here. Now, a new process of inductively coupled laser deep-layer quenching is used to couple the electromagnetic source with the laser source in two spatial forms. The uniform wide-spot laser beam is used to heat the material above the austenitizing temperature, and the synchronous coupled electromagnetic induction heating assists. Through controlling the temperature gradient of the quenching zone and changing the cooling rate of the hardened layer, the desired high carbon content of twinned martensite is obtained. Therefore, the surface hardness of the material and the depth of the hardened layer is greatly increased. The effects of different sensor forms, the spatial positional relationship between the inductor and the laser and the inductive power on the depth of the deep hardening of the 42CrMo bearing steel were studied. It is found that the hardening depth of laser quenching of 42CrMo bearing steel is about 2.1 mm. The quenching depth is obviously improved with the increase of induction power. When the planar inductor is located 5 mm on the front side of the laser spot, the depth of quenching hardening of electromagnetic induction coupling laser is 6 mm, and the hardness of the hardened layer is stable between 55-62 HRC. The results show that the electromagnetic induction coupled laser deep quenching technology greatly increases the depth and hardness of the hardened layer of 42CrMo bearing steel, which is an effective method to improve the bearing capacity of 42CrMo bearing steel.

42CrMo 轴承钢深层淬火多采用中频感应淬火工艺，在轴承感应淬火的起始位置与结束位置不可避免的存在软带，软带区硬度远低于淬火层的硬度要求的55-62HRC，轴承的缺陷也多在此处产生。现采用感应耦合激光深层淬火的新工艺，将电磁感应与激光两种空间形式的热源耦合，用均匀宽光斑激光束将材料加热至奥氏体化温度以上，同步耦合电磁感应加热辅助作用，通过控制淬火区域的温度梯度，改变淬硬层冷却速率，获得所需的高碳含量的孪晶马氏体，从而大幅提高材料的表面硬度和淬硬层深度。研究了不同的感应器形式、感应器与激光的空间位置关系及感应功率对 42CrMo 轴承钢激光深层淬火淬硬深度的影响。发现 42CrMo 轴承钢激光淬火的淬硬深度约为 2.1 mm，随着感应功率的增加淬火深度得到显著提高；平面型感应器位于激光光斑前侧 5 mm 时，电磁感应耦合激光深层淬火淬硬深度达 6 mm 以上，淬硬层的硬度稳定在 55-62 HRC 之间。结果表明，电磁感应耦合激光深层淬火技术大幅增加 42CrMo 轴承钢淬硬层深度和硬度，是一种能提升 42CrMo 轴承钢的承载能力的有效方法。

FALM-6: Investigation of Femtosecond Laser Micro-Welding of Glass

Miao Yu, Ting Huang, Rongshi Xiao

High-power and Ultrafast Laser Manufacturing Lab, Institute of Laser Engineering, Beijing University of Technology, Beijing,100124

Abstract：

Glass welding have many applications in optics, telecommunications, electronics, MEMS, biomedical, and so on. The femtosecond laser micro-welding with high precision and small thermal effects has realized the connection between the glasses in the optical contact area. However, it is difficult to achieve large area optical contact between the glasses even with highly polished surfaces and rigorous cleaning processes, which limits its practical use. In this paper, the femtosecond laser micro-welding of glass in the non-optical contact area was successfully achieved. The non-optical contact welding windows under different process parameters (pulse energy, scanning speed, focus position) were explored. The weld morphology, strength and defect were also studied.

玻璃连接在光学，电信，电子， MEMS，生物医学等方面具有很多应用。飞秒激光在 玻璃之间的光学接触区域实现了两者的连接，具有加工精度高、热损伤小等优势。但是，即 使在高度抛光和严格清洗的工艺条件下，也难以实现玻璃之间的大面积光学接触，不利于实 际应用。非光学接触焊接和实现高焊接强度是目前仍需解决的难题。本文采用具有振镜扫描 系统的绿光飞秒激光器进行玻璃焊接，实现了毫米级别大离焦量非光学接触区域的玻璃焊 接。探究了不同工艺参数（单脉冲能量、扫描速度、焦点位置）下的非光学接触焊接窗口。 通过焊缝形貌表征、焊接强度测试、焊接缺陷分析进行了参数优化。

FALM-6: Study on Formation of Key Hold of High Power Fiber Laser

Le Zhao

Beijing University of Technology, China

摘要：

在高功率光纤激光焊接中，焊接缺陷与深熔小孔的特性行为密切相关，而激光功率与焊接特征时间(作用光斑半径与焊接速度之比)均对小孔动态行为特性具有显著影响。本文结合实验及模拟对激光焊接中小孔形成过程及其特征行为进行了研究，主要采用了以下三种研究手段：在不同焊接工艺参数下，使用 IPG YLS-6000 激光器焊接“三明治”模型，运用高速摄像机进行原位观察小孔形成过程；控制激光器使其超短出光时间（控制出光时间分别从 1 ms 到 20 ms），扫描焊接低碳钢，观测熔深熔宽变化；借助 marc 模拟软件实现连续激光焊接中小孔形成过程。研究结果表明，在“三明治”模型以及超短出光时间（毫秒量级）两种实验方案中，当焊接速度为 2 m/min，焊接功率从 2 kW 到 6 kW 变化，形成稳定熔深的时间基本相当，熔深逐渐增大；固定激光功率，焊接速度从 1 m/min 提高到 4 m/min，熔深逐渐变浅，并且形成稳定熔深的时间也在变小。根据不同参数下的激光焊接有限元模拟结果显示，深熔小孔形成过程变化规律与实验结果基本一致。基于以上三种研究手段所得结果，分析如下：高功率激光焊接过程中，深熔小孔的形成主要由急速加深过程，缓慢加深过程以及孔深基本稳定不变三个过程组成，并且小孔加深的整个过程的时间与焊接特征作用时间基本相当。

FALM-6: Study on Process and Properties of Laser Cladded Fe-based Wear Resistant Coatings on Inner Wall of Barrel

Zhongyao Cai[1,2], Zhijun Chen[1,2], Jianhua Yao[1,2*], Volodymyr Kovalenko[1,2,3]

[1] Institute of Advanced Laser Manufacturing, Zhejiang University of Technology, Hangzhou 310014, China

[2] Zhejiang Provincial Collaborative Innovation Center of High-End Laser Manufacturing Equipment, Hangzhou 310014, China

[3] laser technology reach institute, National Technical University of Ukraine, Kiev 03056, Ukraine

Abstract：

During running of the injection molding machine barrel, the long-term work will cause the barrel to fail. Abrasion is one of the main failure modes of the barrel. It is different from the traditional laser cladding in process environment and scanning method. There were few researches on laser inner wall cladding. Therefore, the preparation of Fe-based wear-resistant coating by laser cladding on the inner wall of 40Cr cylinder was studied in this paper. Firstly, the optimum processing parameters were found. On this basis, The effects of the scanning method and the deflection angle of the laser cladding layer were studied in depth. Since the properties of the cladding layer are significantly affected by the microstructure, the mechanism of the influence of scanning mode on the size of the top wave crest layer of the cladding layer is explained by simulating the transient temperature field of the cladding layer under different scanning modes. The morphological changes of the cladding layer, the change of the delamination area and the distribution of the elements in the bonding area under different bonding strategies were analyzed by OM and EDS, and the phase composition of the cladding layer was analyzed by XRD. Finally, the wear resistance of the substrate, the flat cladding layer and the inner cladding layer are compared at room temperature and high temperature, and the wear mechanism was analyzed. The results show that the cross-sectional area of the cladding layer in the radial spiral scanning mode is larger than that in the axial scanning mode under different scanning modes. The difference in temperature field results in a radial helical scanning mode. The proportion of the cladding layer to the dendrite area is smaller than that of the axial scanning mode. The change of the skew angle has no obvious influence on the radial spiral scanning mode, but the larger the skew angle in the axial scanning mode, the worse the forming quality of the cladding layer and the more uneven the microhardness distribution. The microstructure of the cladding layer at the bonding position is coarsened, the direction of dendrite growth changes, the elements of the overlapping region are evenly distributed, and element diffusion occurs at the bonding position. At high temperature and room temperature, the wear resistance of the inner wall cladding layer is slightly worse than that of the flat cladding layer. In this study, the laser inner wall cladding process has been systematically studied on the Fe-based wear-resistant coating with no defects, good shape, high hardness and high wear resistance, which provides technology and foundation for laser cladding in the inner wall environment.

在注塑机机筒运行期间，长期工作导致机筒发生故障。磨损是机筒的主要失效形式之一。它与传统的激光熔覆工艺环境和扫描方式不同。因此，本文研究了40Cr 圆筒内壁上激光熔覆制备 Fe 基耐磨涂层。首先，找到了最佳的加工参数。并对扫描方式和激光熔覆层偏转角的影响进行了深入研究。由于熔覆层的性质受微观组织的影响，通过模拟不同扫描方式下熔覆层的瞬态温度场来解释扫描方式对熔覆层顶部转向枝晶区域大小的影响机制。通过 OM 和 EDS 分析了不同结合方式下熔覆层形貌变化、搭接区域组织变化以及结合区域元素分布，并通过 XRD 对熔覆层物相组成进行分析。对常温和高温情况下基体、平板熔覆层、内壁熔覆层三者进行耐磨性对比，并对磨损机制进行分析。结果表明，不同扫描方式下，径向螺旋扫描方式熔覆层横截面面积大于轴向扫描方式。同时，温度场的差异导致径向螺旋扫描方式熔覆层转向枝晶区域占比小于轴向扫描方式。偏斜角度的变化对径向螺旋扫描方式无明显影响，但是在轴向扫描方式下偏斜角度越大，熔覆层成形质量越差，显微硬度分布越不均匀。多道搭接情况下，熔覆层搭接结合位置的组织粗大化，枝晶生长方向出现变化，搭接区域元素分布均匀，结合位置出现明显元素扩散现象。在常温和高温条件下，内壁覆层的耐磨性略差于平板熔覆层的耐磨性。本研究进行了系统的激光内壁熔覆工艺探索，制备了无缺陷，形状好，硬度高，耐磨性好的熔覆层，为内壁环境激光熔覆提供技术和基础。

FALM-6: Prediction of Geometrical Shape of Coaxial Wire Feeding Cladding in Three Beam

蒋伟伟 ,傅戈雁*,张吉平,吉绍山,石世宏，刘凡

苏州大学机电工程学院，江苏 苏州 215021

摘 要：

目的 研究“三分光束”光内同轴送丝激光熔覆各工艺参数的工艺区间及工艺参数与熔覆层几何形貌映射关系。方法 采用单因素实验方法研究激光功率、扫描速度、送丝速度、离焦量四个工艺参数的工艺区间；以熔覆层的高度、宽度、横截面积作为熔覆层几何形貌的量化指标；分别建立神经网络模型和二次回归模型实现熔覆工艺参数和熔覆层形貌量化指标之间映射关系的预测；结果 基于单道单因素实验，当激光功率介于 1300W-1700W，扫描速度介于 3mm/s-7mm/s，送丝速度介于 9mm/s-15mm/s，离焦量介于-2.5-（-1.5）时都能获得液桥过渡形成熔覆质量较好的单道；在对测试样本数据的预测中，在置信度 85%情况下，BP 神经网络模型对熔覆层高度、宽度、横截面积的预测精度分别为 100%,100%,93.33%，均方根误差分别为 0.21,0.07,0.24；二次回归模型的精度分别为 100%,66.67%,73.33%，均方根误差分别为 0.21,0.13,0.28。

FALM-6: Influence of Argon Flow on the Oxidation Sensitivity of TC4 Titanium Alloy Processed by Laser Cladding in Air

Jinchao Zhang

Soochow University, China

Abstract：

Titanium alloy has the characteristics of high specific strength, good heat resistance and strong corrosion resistance, widely used in aerospace, chemical, petroleum and medical. To reduce oxidation, the process of forming of titanium alloys is usually carried out in a vacuum or inert atmosphere chamber. However, for the parts with larger size or need to be repaired in the field, it needs to be carried out in the atmospheric environment, and the key problem is reducing oxidation. TC4 alloy cladding coatings are prepared with the laser inside powder feeding technology, and the effect of argon gas flow on sensitivity of TC4 cladding coatings is investigated. The results show that with decrease of argon gas flow, the color of the cladding coating surface gradually darkens, which is attributed to the mixing of colored titanium oxides in the oxidation layer. The oxidation layer changes from thin and dense to thick and loose. When the color of the coating is blue, the hardness of the cladding coating becomes higher, which indicates that the oxygen diffusion depth is high and the oxygen element content is large. The blue should be regarded as critical color between the acceptable and unacceptable oxidation degree of the oxidized titanium alloy.

基于热-弹-塑性有限元与以能量准则为判定的薄板稳定理论，采用 ABAQUS 有限元分析软件，对 0.07mm 厚的 316L 超薄板平板堆焊的应力场进行分析，得出了固有应变的分布区域与大小。采用线性特征值分析法，将固有应变等效为为焊缝区的热载荷对薄板的焊后屈曲变形进行数值模拟，获得超薄板的焊接变形规律。研究并分析了约束类型、焊缝长度、板宽变化和热输入大小等对薄板的临界失稳载荷和对应屈曲模态的影响。结果表明，通过缩短焊缝长度，减少板宽可以提高薄板焊接结构的临界失稳载荷，降低结构发生失稳的概率。随着热输入的增加，固有应变区的宽度有所增大，由此造成的固有应变在焊缝方向上的分布不均匀，会导致薄板屈曲模态与相应特征值的变化，进而影响薄板焊接变形的最终形态。

FALM-6: Fabrication of Dye-sensitized Solar Cell TiO2 Photocathode by Femtosecond Laser Etching Combined Hydrothermal Method

CHENG Ming-yu, QING Xiao-yang, HUANG Ting, XIAO Rong-shi
Beijing University of Technology,Institute of Laser Engineering, Beijing100124

Abstract:

Dye-sensitized solar cells have many advantages, such as high photoelectric conversion efficiency, low production cost and low toxicity.TiO_2 is the most widely used photoanode material in dye-sensitized solar cells. In this paper, TiO_2 photocathode was fabricated by femtosecond laser etching combined hydrothermal method. Firstly, the microstructures of Ti wafers were fabricated by femtosecond laser etching. Secondly, nanowires of TiO_2 were prepared on the surface of microstructures by hydrothermal method. By changing the femtosecond laser etching parameters and hydrothermal reaction parameters, the structure of titanium dioxide photocathode can be controlled at micron and nanometer scales, respectively. The surface microstructures of Ti substrate increase the specific surface area of TiO_2 nanowires and enhance the dye adsorption and light capture ability. At the same time, because TiO_2 is directly formed by the growth of Ti substrate, its contact resistance is small and the electron transfer speed is fast.

染料敏化太阳能电池有较高的光电转换效率、较低的生产成本以及低毒性等诸多优点。TiO_2 是染料敏化太阳能电池中应用最为广泛的光阳极材料。本文通过飞秒激光刻蚀复合水热法制造 TiO_2 光阳极。首先，采用飞秒激光对 Ti 片进行刻蚀制造微结构。其次，通过水热法在微结构表面制备 TiO_2 纳米线。通过改变飞秒激光刻蚀参数和水热反应参数，可以分别在微米和纳米尺度对 TiO_2 光阳极结构进行调控。Ti 基底表面微结构增大了 TiO_2 纳米线的比表面积，提升了染料的吸附量和对光的捕获能力。同时，由于 TiO_2 直接由 Ti 基底生长形成，因此其接触电阻小，电子转移速度快。

LPAM-5: Fluid film bearing slideways for ultra precision machine tools

Paul Shore[1], Keith Carlisle[1], Frank Wardle[2]

[1]Loxham Precision Limited, Cranfield, United Kingdom

[2]Ultra Precision Motions, Swindon, United Kingdom

Abstract：

Fluid film bearings offer high precision smooth motion and enable nanometre precision positioning accuracy. This paper will detail the manufacturing technology developments undertaken to establish a new range of ultra precision machine tool slideways. The paper will give details of a micro electrochemical processing technology that has been especially developed to enable sub micrometre accuracy processing of the critical, highly intricate and fine features of air bearing slideways. As a means of validation of this microECM processing technology the performance of an ultra precision slideway is presented.

LPAM-5: A Characterization Method for Mechanical Properties of Metal Powder Bed Fusion Parts

Nandhini Raju, Samyeon Kim, David William Rosen

Singapore University of Technology and Design, Singapore, Singapore

Abstract：

The main objective of this research is to characterize parts fabricated in metal powder bed fusion (PBF) processes, a type of Additive Manufacturing (AM) process. The specific focus was on material and mechanical property characterization of the EOS maraging steel grade 300 material processed in an EOS M280 system. However, to achieve the objective, a characterization method is needed. To characterize conventionally manufactured parts, many methods and standards are available, while no comprehensive standards or methods are available for AM parts. In this paper, a mechanical property characterization method is proposed that involves the selection of existing test standards and the adoption of modifications that accommodate the unique characteristics of the AM process. Sample sizes need to be considered to attain high precision results from tests. Key decisions are presented in the development of the method.The decided sample lots were manufactured at the Singapore University of Technology and Design. Sub-size specimens were utilized when possible to minimize material and energy consumption. Printed parts were post-processed using several methods. Parts were removed from the build plate and support structures by wire cutting. Some were heat treated according to the maraging steel protocol, some were finish machined, and some were heat treated & machined to test various final part conditions. The paper reports on the statistical analysis to select sample sizes, test coupon design considerations for metal printing, printing parameters and applicability of existing testing standards for metal PBF, in addition to several mechanical properties.

LPAM-5: Digital design and manufacturing of personalized lingual brackets based on SLM and LW

Dong Cai Wang[1], Yun Feng Liu[1], Bo Xiu Li[2], Xian Feng Jiang[1], Xing Tao Dong[1]

[1.]Key Laboratory of E&M (Zhejiang University of Technology), Ministry of Education & Zhejiang Province, Hangzhou, China

[2.]Department of Orthodontics, the Second Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, China

Abstract：

The purpose of this paper is to explore the feasibility of digital design and manufacturing of personalized lingual brackets based on selective laser melting (SLM) and laser welding (LW).A personalized lingual bracket consists of two parts: a personalized base plate is based on lingual surface of tooth, and a standard socket is fabricated with general injection molding. A 3D laser scanner was used to acquire dental model data and then reconstruct a 3D dental model. Based on the digital model, personalized lingual brackets were designed with software platforms.Firstly, using platforms of Magics and Geomagics, a orthodontic scheme and ideal digital tooth arrangement based on the digital model were designed. With the ideal dentition after the tooth arrangement, the superstructures of the personalized lingual bracket were designed using CAD platform of UG. With Geomagics, the individualized base plates were designed based on the shape of the lingual side of the tooth surface. Positioning of the personalized plate and socket is interspersed.The personalized lingual plate is printed by SLM, and the standard part of socket is mass-produced by MIM. Then, the socket and the personalized plate were welded together by laser welding.Finally,personalized lingual bracket should remove redundant positioning parts.The dental model data obtained by the 3D laser scanner can meet the requirements of personalized lingual bracket design. The personalized lingual plate made with SLM can be closely attached to the tooth surface. The positioning error of the bracket socket and the personalized plate is within 0.04mm, and the welding strength is 35N.Based on the combination of SLM and LW, the digital design and manufacturing of personalized lingual brackets is feasible, which can meet the clinical requirements and provide a new process for the manufacture of personalized lingual brackets.

LPAM-5: The numerical studies of residual states in laser deposited additive manufacturing and the scaling effects

Zhao Zhang, Peng Ge

Dalian University of Technology, Dalian, China

Abstract：

Sequentially coupled thermo-mechanical model is used to simulate the residual stress and residual distortions in laser deposited additive manufacturing. The residual stress distribution is validated by comparison with experimental data. Different sizes of components are used to study the scaling effects. Results indicate that the residual stress can be controlled by the components sizes. This phenomenon can be explained by the bending deformation and the temperature fluctuations, especially the cooling rate, in the laser deposited additive manufacturing process. Both the bending deformation and the temperature fluctuations can be controlled by the ambient temperature and the designed process parameters. Further work is performed to show how the components sizes affect the final residual states in combination with different ambient temperatures and the designed process parameters.

LPAM-5: Study on the performance of 3D printing in oral cavity

Lu Yao[1], Zhendi He[1], Wu Li[2], Peixin Hu[1], Q.T. Lue[1,2]

[1.]Shenzhen technology university, shenzhen, China

[2.]Shenzhen Han's laser technology co. LTD shenzhen, China

Abstract：

As a new technology that subverts traditional manufacturing, 3D printing has attracted wide attention since its invention. In recent years, with the rapid development of digital dental technology and electronic information technology, the application of 3D printing technology in the medical field gradually deepens. In order to compare the traditional processing of the difference between inlay and 3 d print inlay, in this paper, by using the same resin material, respectively, using the traditional machining method and the use of 3 d printing technology made of inlay contrast, this paper expounds the 3 d printing technology in embedded system is better than the limitation of traditional methods, higher precision, save material, and the characteristics of the there was no significant difference of mechanical properties.

LPAM-5: Tensile properties in adaptive sliced additive manufacturing of silicone elastomer

Xiaoqing Tian, Shengyi Wang, Dingyifei Ma

Hefei University of Technology, Hefei, Anhui 230009, China, Hefei, China

Abstract：

Silicone additive manufacturing is a layer-by-layer process in which defects such as surface contour errors occur due to changes in the curvature of the workpiece during the fabrication process. The adaptive slicing method can reduce defects generated during printing such as surface contour errors and can improve processing efficiency. In order to investigate whether the adaptive slice can reduce the strength between layers, we designed horizontally placed, longitudinally filled silicone dumbbell specimens for tensile testing. Four silicone dumbbell specimens fabricated by extrusion-based additive manufacturing with different adjacent line spacings for tensile testing, and then compared the test results. The first silicone dumbbell specimen was filled with three sections of different adjacent line spacings. The remaining three silicone dumbbell specimens are uniformly filled with three different adjacent line spacings. Results show that the tensile strength of silicone dumbbell specimens with four different adjacent filling methods is different. Within a certain range, as the adjacent line spacing increases, the tensile strength of the silicone dumbbell specimens will decrease, and the first silicone dumbbell specimen has the highest tensile strength. We show that the adaptive slicing method plays an important role in reducing defects in the silicone extrusion-based additive manufacturing process and improving workpiece processing efficiency. These results can be applied to workpieces with complex surface shapes fabricated by silicone extrusion-based additive manufacturing, such as silicone orthoses and silicone prosthetic hand, etc.

LPAM-5: Processing of Submicron Spiral Grooves on Spherical Surface by Picosecond Laser

Wenhao Wang[1,2], Lingfei Ji[1,2]

[1].Institute of Laser Engineering, Beijing University of Technology, Beijing, China

[2].Key laboratory of trans-scale laser manufacturing technology, Ministry of education, Beijing, China

Abstract：

The advantages and potentials of picosecond laser have been well known and their applications continue to develop because of known excellent processing characteristics like little thermal effect. Picosecond laser equipped with three-dimensional (3D) galvanometer can be used to process curved surface parts. However, the processing accuracy often fails to meet the requirements, especial in the sub-micron range. In this paper we report a focus compensation method for ultrafast laser processing of spherical parts, by which precision spiral grooves with sub-micron size were machined on a hemispherical TiC cermet by a picosecond laser with 2D galvanometer. 12 spiral grooves with gradient helix angle on the hemispherical surface were machined by a continuous laser processing. The spiral grooves with depth of 3-5 μm and gradient width with the helix angle from 300 to 500 μm are evenly distributed on the hemisphere surface. More notably, the surface roughness can be only 70 nm. Such hemispherical TiC cermets are generally machined by ion-beam etching. The technique reported in our work shows the significant advantages of picosecond laser precision processing of superhard hardworking materials in terms of both time and cost.

LPAM-6: Effects of Ultrasonic Vibration on Laser Metal Forming

Zhehe Yao[1], Xiaowen Yu[1], Jianhua Yao[1*], Xijiang Lu[1]

[1] Institute of Laser Advanced Manufacturing, Zhejiang University of Technology,

Hangzhou 310023, China

Abstract：

Laser metal forming is the basis of metal additive manufacturing and remanufacturing. However, traditional laser metal forming is prone to cause defects easily. In this paper, ultrasonic vibration was introduced into the process of laser metal forming, and the mechanism of ultrasonic vibration on laser metal forming was explored. The numerical model of ultrasonic vibration-assisted laser forming was established by COMSOL MULTIPHYSICS to analyze the influence of ultrasonic vibration on the temperature field and the flow field. Meanwhile, in the high-frequency vibration assisted laser cladding 316L experiments, the effects of high-frequency vibration on the microstructure and tensile properties of the forming was investigated. With the influence of vibration, the internal convection of the molten pool is accelerated, the cooling rate is increased, and the temperature gradient is reduced, therefore, the crystal grains of the cladding layer are refined, the width of the orientation changed dendrite increases. The three-dimensional high-frequency vibration increases the tensile strength of the cladding layer by 27.2% and the elongation after fracture by 14.3% simultaneously.

LPAM-6: The Comparative Effects of the SMD Process on Type 316L Stainless Steel Powder Feedstock

Udisien Woy[1], Stephen Preston[1], Vishal Patel[2], Rosemary Gault[1], Steven Jones[1]

[1]University of Sheffield, Sheffield, United Kingdom

[2]University of Birmingham, Birmingham, United Kingdom

Abstract：

The purpose of this investigation is to assess the feasibility of processing type 316L stainless steel powder feedstock via shaped metal deposition (SMD). Typically, arc based DED processes such as SMD are exclusively used for processing wire feedstock. In the current AM landscape, multi-material processes refer to combinations of different metals and alloys, and may potentially include feedstock types. Samples of powder and wire material were deposited to determine the comparative effects of SMD and post-processing factors on the resulting microstructure. These samples were homogenised at 1150 C for 30 minutes, water quenched and then annealed at 1050 C for another 30 minutes before extracting uniaxial tensile specimens for testing. Test specimens were extracted horizontally (i.e. across the build) and tested in accordance with ASTM E8-11. The heat treatment of the wire and powder SMD materials resulted in more homogenised microstructures. On average, the wire specimens exhibited higher ductility that the powder specimens, with reductions in cross-sectional area of 75.5% and 14% respectively. The average 0.2% proof stress was higher for wire specimens at 229MPa, than for powder specimens at 190.5MPa. However, distinct values obtained from both samples were within the range of 220 - 240 MPa, as specified in BS EN 10028-7. The main differences in the microstructures and material properties appear to be due to the effects of SMD on the different feedstock types. Nevertheless, further work is necessary to increase understanding of variability issues in AM due to the distinct system configurations, processing mechanisms and feedstock materials utilised.

LPAM-6: Engineering the PCL/grapheme Scaffold with Additive Manufacturing for Bone Regeneration

Weiguang Wang, Paulo Bartolo

The University of Manchester, Manchester, United Kingdom

Abstract：

Bone defects assume importance in growing prevalence of chronic health conditions since fractures and critical defects should increase as the population ages. This problem is worse if we consider also significant bone damage due to accidents and diseases. To solve large scale bone damage, bone grafting is required. However, natural bone grafts (allografts, autografts and xenografts) present several problems related to site morbidity, disease transmission, accessibility and costs. To solve these limitations, synthetic grafts (scaffolds) represent a promising approach for tissue engineering. These scaffolds are made with biocompatible and biodegradable polymers, ceramics and composites and they must provide the adequate environment for cell attachment, proliferation and differentiation. As cells proliferation and differentiation is a regulated process, which depends on scaffold topology, materials and also specific stimulation mechanisms (mechanical or electrical), our group is exploring the use of electro-active scaffolds for bone regeneration. To produce these scaffolds, conductive nanofillers (graphene) mixed with non-conductive polymers had been explored. This research discusses the use of 3D-printed poly (ε-caprolactone) (PCL)/graphene scaffolds for bone applications. An extrusion-based additive biomanufacturing system was used to fabricate the scaffolds, while PCL/graphene blends were prepared through melt blend process. Scaffolds with same architecture but different concentrations of graphene were evaluated from morphological, surface properties (graphene dispersion and hydrophilicity) and in vitro/in vivo biological (cytotoxicity, cell proliferation/differentiation) points of view. All results suggest that the addition of graphene improves the performance of scaffolds and have great potential for support and speed up the bone regeneration.

LPAM-6: Thermo–mechanical monitoring and analysis of multipass laser forming of stainless steel

Mohammad Shahid Raza, Susmita Datta, Partha Saha

Indian Institute of Technology Kharagpur, Kharagpur, India

Abstract：

Monitoring of laser forming process is necessary in order to obtain precise deformation as well as to understand the forming mechanism for the multipass scanning process. The laser forming of stainless steel was carried out using a 2 kW Yb-fibre laser in continuous mode. The bending angle and temperature were monitored using a displacement sensor and infrared pyrometer respectively for five consecutive scans on the same path. Laser power, scan speed and spot diameter were varied and the effect of varying parameters was studied in terms of bending angle, microhardness and microstructural variations. A maximum bending angle of around 8o was observed for 500 W power, 1500 mm/min scan speed and 2 mm spot size with 5 scans. When scan speed was increased, the bending angle decreased while counter bending effect got increased. The change in spot size also affected the bending and counter bending of the sheet. The recorded surface temperature revealed that the melting depth along the cross-section could affect the plastic deformation mechanism. The bending angle with subsequent scans were analysed as well and it was established that the decrease in bending angle is a cumulative effect of a change in surface temperature and strain hardening process. At last Scanning Electron Microscopy and microhardness measurements were performed to observe the change in microstructure and microhardness value. Variation of microstructure was restricted to the top thin layer while microhardness did not show much difference except in a few cases.

LPAM-6: Evaluation of engineering high performance thermoplastics for robot-based 3D printing of moulds: a critical perspective to support Automated fibre placement process

Rajkumar Velu, Nahaad Mohammed Vaheed, Felix Raspall

Singapore University of Technology and Design, Singapore, Singapore

Abstract：

High-performance polymers are plastics with better thermal and mechanical properties than other engineering plastics. In general, polymers are relatively lighter than metals. In the current research era, challenges are focused towards developing parts with high performance plastics such as PEEK (Polyetheretherketone), PEI (Polyetherimide) and PPSU (Polyphenylsulfone) with applications in formula one, drones and rockets. These polymer materials are significantly lighter and as durable as metals, with the ability to withstand operating temperatures of above 150oC. Although, these materials are well established and can be fabricated using conventional methods, these processes have limitations that restrict the freedom of achieving highly complex structures, which in-turn adversely affect their functional properties. In contrast, additive manufacturing techniques can produce complex shapes, with a degree of control over their process parameters. Although, 3D printing with these polymers have been attempted, more promising approaches such as robot-based polymer extrusion, attained very little attention. Particularly, 3D printing of high-performance moulds for prepreg layup using Automated fibre placement (AFP) process needs more attention. Experimental investigations with PEEK, PEI and PPSU using the robotic extrusion method, including the effects of significant process parameters on critical responses, mechanism of material consolidation, thermal and mechanical properties, that are critical to the AFP process will be determined.

LPAM-6: Comparative study on quality characteristic of laser beam cutting of Inconel superalloy at Different Environment by Sensitivity Analysis

Nilanjan Roy, Arunanshu Shekhar Kuar, Souren Mitra

DEPARTMENT OF PRODUCTION ENGINEERING, JADAVPUR UNIVERSITY, KOLKATA, India

Abstract：

A comparative study on depth of cut during laser blind cut on Inconel 625 superalloy at different environment has been presented here. To identify the criticality of environment along with other controllable process parameters, the present study focuses on sensitivity analysis inspite of concentrating on the response surface based parametric study. Second order polynomial model has been developed to perform sensitivity analysis of process variables, i.e. lamp current (amp), pulse frequency (kHz), Pulse width (%), cutting speed (mm/sec) and environment in terms of assist compressed air pressure (kg/cm^2) and height of water column (mm). Depth of cut is selected as quality characteristic. Assist gas is flown on the machining zone co-axially through the same delivery nozzle of laser beam whereas water at static condition is used during laser blind cut of the said material with aid of low power nanosecond pulsed Nd: YAG laser machine. It is observed from the sensitivity analysis that depth is more positively sensitive with higher value of air pressure whereas negatively sensitive with height of water column. From the study it is also found that laser power in terms of lamp current is the most sensitive controllable variable to depth of cut. It is also observed from sensitivity analysis that the process variables are sensitive to depth of cut when laser cutting operation in micro domain is performed in underwater condition.

LPAM-6: Experimental Analysis of the effect of laying speed of IR assisted Automated fibre placement with PA-6/carbon prepreg over 3D printed PEI mould

Chadurvedi Venkatesan[1], Naahad Vaheed[1], Felix Raspall[1], Tay Tong Earn[2], Arlindo Silva[1]

[1]Singapore University of Technology and Design, Singapore, Singapore

[2]National University of Singapore, Singapore, Singapore

Abstract：

Automated fibre placement is a productive method for fabricating composite material parts with reduced material scrap and increased repeatability. The use of thermoplastic prepreg with AFP is advantageous over thermoset due to recyclability, no cooling need during storage and printing and no secondary processing requirement. Laying up thermoplastic prepreg over flat and complex surfaces is challenging as the process is prone to defects such as voids, overlaps and wrinkles and there are more parameters to control the overall process. The AFP parameters such as temperature, pressure and laying speed have a significant influence over the layup, so optimizing these parameters is essential for high performance of the material and fabricated structure. The prepreg material used in the process is polyamide-6 carbon 45 and the mould material selected is 3D printed flat and curved high-performance Polyetherimide to withstand the heating. A temperature difference of laying tow and laid tow leads to shrinkage which creates distortion at the microstructural level and decreases the mechanical performance. During the placement, an IR lamp with power of 250 W is used to heat the prepreg with a desired temperature which can be controlled. A basic fibre alignment of [0/45/-45/90] is fabricated through proper planning of tool-path with a custom developed software. The microstructure of the samples will be analyzed for voids, and other defects by Field emission electron microscopy (SEM, Joel JSM-7600F) and the mechanical performance is analysed through Universal Tensile Tester. From this paper, the optimum laying- speed with minimum defects can be comprehended.

MPT-5: Study on the ultrasonic vibration assisted abrasive slurry jet micro-machining process

Huan Qi, Zhichao Cheng, Shikang Qin

College of Mechanical Engineering, Zhejiang University of Technology, Hangzhou, 310014, P.R. China

Abstract：

The ultrasonic-vibration assisted micro-channelling process on glasses by an abrasive slurry jet (ASJ) is presented and discussed both numerically and experimentally. A numerical investigation using the dynamic meshing technique in Computational Fluid Dynamics (CFD) is carried out first to model the ASJ flow and explore the effect of ultrasonic vibration on the stagnation zone, particle impact velocity and impact angle, and viscous flow induced erosion process. It has been found that the static pressure in the stagnation zone, particle impact velocity and impact angle are varied periodically with an assistance of the ultrasonic vibration on the workpiece which in turn could affect the material removal process in ASJ micro-channelling of glasses. It is also found from simulation that the ultrasonic vibration is beneficial to the viscous flow induced erosion during the low pressure ASJ micro-machining process. Then, a set of ultrasonic vibration-assisted micro-channelling experiments are conducted on glasses using an ASJ to evaluate its effect on the major micro-channelling performance. It is found that ultrasonic vibration assisted ASJ micro-channelling increases the material removal rate, channel depth and top channel width, while decreases the channel wall inclination angle, as compared to the traditional ASJ micro-channelling process at the same experimental condition. However, the surface quality on the bottom of the channel seems to be not significantly affected by the ultrasonic vibration. These findings from the experiment are in a reasonably good agreement with the corresponding simulated results.

MPT-5: Evolution of Final Shape of Micro-Tools Fabricated by Various Fabrication Methods in Micro-EDM

Biswesh Ranjan Acharya, Abhijeet Sethi, Partha Saha, Dilip Kumar Pratihar

IIT Kharagpur, KHARAGPUR, India

Abstract：

In both micro-EDM and micro-ECM, micro-tools are essential for generating various micro-features on any electrically conductive material by moving them along a predefined path. Tungsten carbide (WC-Co) is widely used as a material for micro-tools due to its superior properties such as higher electrical and thermal conductivity, mechanical rigidity, melting point and chemical resistance. In micro-ECM, a suitable mixed-electrolyte (preferably with an acidic component) with a precise mixing ratio is used for anodic dissolution of WC-Co, which results in a conical shaped micro-tool. Hence, micro-ECM should be avoided when maintaining shape accuracy of the micro-tool is the prime intention. There are several routes by which a micro-tool may be fabricated by the micro electrical discharge grinding (μ-EDG) process. However, there is variation in the final shape of the micro-tool obtained by different routes.In the current study, for each of moving block EDG, wire EDG and disk EDG processes, three micro-tools were fabricated with three levels of parameters such as voltage, duty ratio and spindle RPM. Shape accuracy aspects of the fabricated micro-tools (such as tool taper, standard deviation in diameter and surface roughness) were compared based upon the fabricating methods as well as different levels of process parameters. Finally, this paper discusses the various difficulties faced in each of these individual tool fabrication processes, and also compares their advantages and disadvantages, which will eventually give a guideline for selecting an appropriate process for micro-tool fabrication.

MPT-5: Application of machine learning techniques to predict the surface roughness in electrical discharge machining of hardened EN31 steel with cermet tool tip

Arminder Singh Walia, Vineet Srivastava, Vivek Jain

Thapar Institute of Engineering & Technology, Patiala, India

Abstract：

In this study, electrical discharge machining was utilized for the machining of EN31 steel (hardened up to 56 HRC). Sintered cermet tool tip with 75% copper-25% titanium carbide was fabricated and used as a tool electrode. 262 experimental trials were performed to analyze the effect of machining variables (Discharge current, Gap voltage, Pulse on time, Pulse off time, Flushing pressure) on surface roughness of the machined cavity. The output from the trials was used as the input to develop regression models. Four machine learning techniques viz. Decision tree, Random forest, Linear model and Neural network were applied to the experimental outputs. The random forest technique was found to be the most effective to predict the surface roughness and predicted the response accurately (97.5 %) and obtained correlation value (0.98), coefficient of determination (0.97) with mean absolute error (0.09 μm).

MPT-5: Acceleration of CO2Absorption Rate of Temperature-responsive Hydrogels by Precision Machining and Spray Coating Process

Syuhei Kurokawa

Kyushu University, Japan

Abstract：

The CO_2 capture process used in the thermal power plants now has a problem of its running cost because it must heat the adsorbent at high temperature to desorb the carbon dioxide. Since a new hydrogels-based absorbent developed at Kyushu University absorbs and desorbs CO_2 in response to small temperature change, it may be the best way to reduce CO_2 emissions from the thermal power stations. Furthermore, since this absorbent can be fabricated as coating films, it can be applied not only to a flat surface but also to a complicated shape. However, the way to use it with high efficiency has not been developed yet. We fabricated an aluminum reactor which has many fine grooves by precision machining and formed tens of an absorbent gel film on it by spray coating. This method accelerates the absorption and/or desorption rate of the carbon dioxide, reducing size of the CO2 capture reactor. In this paper, the influence of the film thickness and the carrier surface area on the absorption rate was investigated. CO2 gas was guided into the reactor and the concentration of the carbon dioxide contained in the gas after contact with the absorbent was measured. Comparison was made between reactors with fine grooves and without grooves. Desorption process and absorption process were performed once. As a result, it has been found that the absorption-desorption cycle improves as the film thickness decreases and the carrier surface area increases.

LPRC: Laser Additive Manufacturing and Remanufacturing Ferrous Metal Components

Shiyun Dong, Shixing Yan, Xueliang Kang

National Key Laboratory for Remanufacturing, Academy for Armored Forces, Beijing, China

Abstract：

Additive manufacturing gained great progress in the past decade. And laser additive manufacturing technology has been successfully applied to various sectors for its technological superiority in manufacturing the complicate-structured, innovative-designed, and high-priced single-piece or small patches of metal components. And also, laser additive manufacturing has been employed to remanufacture the local damaged metal parts, which can be called as laser additive remanufacturing. However, the laser additive manufacturing metals on which the researchers concerns were mainly titanium, nickel, and aluminum alloys. It is still insufficient for application to research on laser additive manufacturing ferrous alloys. It is still a hard work to gain a high-qualified ferrous alloy part with high precision and high performance by laser additive manufacturing because of the complex chemical composition and complicated phase transformation for the ferrous alloys. This paper introduces the microstructure characteristics and phase transformation of several steel samples prepared by laser selective melting and laser melting deposition methods. The phase transformation kinetics and residual stress evolution rules of the ferrous alloys during laser additive forming will be revealed. The measures to control defects and residual stress in the laser additive formed ferrous alloy samples will be discussed. And then, with technical comparison analysis on laser additive manufacturing and remanufacturing methods, it puts forward a view that the remanufacturing creates a valuable field for laser additive manufacturing. At last, some cases are introduced to show advantages and prosperous future of laser additive remanufacturing ferrous alloys.

LPRC: Influence of Laser Pulse Width on Laser Drilling of Carbon Fiber Reinforced Plastic (CFRP)and the Strategy for Enhancing Drilling Quality

Yunxia Ye[1,2], Tingting Du[1,2], Xudong Ren [1], Naifei Ren[1]

[1]School of Mechanical Engineering,Jiangsu University, Zhenjiang,Jiangsu, China

[2]Institute of Micro-nano Optoelectronics and Terahertz Technology,Jiangsu University, Zhenjiang,Jiangsu, China

Abstract：

Carbon fiber reinforced plastic(CFRP) is increasingly being used in aerospace, automotive manufacturing and other important industries, so the machining technology of CFRP with high efficiency and high quality has also become an significant issue of common concern in academia and industry. In this work, millisecond laser and picosecond laser were used to drill holes on T300 CFRP through trepanning method,and then the drilling quality was observed by the overall morphology observation and scanning electron microscope. The results indicate that millisecond laser drilling efficiency of CFRP is more than 10 times faster than that of picosecond laser. But the millisecond laser has caused a large heat affected zone, and the larger the pulse width, the larger the heat affected zone. Water immersion processing can reduce the heat affected zone and suppress the combustion phenomenon during processing, which can effectively improve the drilling quality. Theresults in this paper can provide a good reference for the development of CFRP laser processing methods in the engineering applications.

LPRC: Droplet transfer behavior during laser welding of 6082 Al alloy with filler wire

Fuquan Li, Shi Feng, Mingwei Li

Harbin Institute of Technology, Harbin, China

Abstract：

In this paper, laser welding of 6082 Al alloy with filler wire was conducted. By optimizing and adjusting the process parameters, the “keyhole penetration type” forming mode of the weld is converted into the “keyhole non-penetrating type” welding mode, which solves the problem of weld seam collapse and obtains a well-formed weld seam. For the typical molten pool morphology and welding wire droplet transfer using high-speed video observation, found that in the case of negative defocus, the molten pool transition form is an unstable large-drop transition mode, this time the tendency of the pore is very large, the porosity rate reaches 4.8 %.A stable liquid bridge transition mode can be obtained with zero defocus. In the liquid bridge mode, the heat input of the welding has a great influence on the stability of the transition. X-ray inspection found that in the liquid bridge transition mode, the porosity rate shows a "V" distribution with the increase of welding heat input, and the heat input is P=4250W, vs=0.04m/s (Q=106.25J/ mm), the lowest porosity was 0.12%.

LPRC: Microstructure and mechanical properties of selective laser melting of HR-2 hydrogen embrittlement resistance stainless steels

Xianfeng Shen, Guowei Wang, Shengwang Zhang, Qin Yang, Zhiyao Cheng

Institute of Machinery Manufacturing Technology, China Academy of Engineering Physics, Mianyang, China

Abstract：

HR-2 is a single-phase austenitic stainless steel with excellent hydrogen embrittlement resistance which has a wide range of applications in hydrogen storage pressure vessels. In the process of powder preparation and additive manufacturing, nitrogen burning will cause martensite transformation of HR-2, which deteriorates its hydrogen embrittlement resistance ability and mechanical properties. In this paper, HR-2 stainless steel powder was prepared by vacuum induction melting atomization (VIGA), and the HR-2 powders with acceptable nitrogen content were obtained by using a nitrogen atmosphere. The effects of process parameters in selective laser melting including laser energy density on the part density, microstructure and mechanical properties of the formed specimens were also investigated. The results showthe density of the formed components increases first and then decreases with the density increases. With optimization of process parameters, the density of the testpieces can reach more than 99%, the tensile strength can reach 735±5MPa, and the elongation is 43±1.5%.

LPRC: Numerical simulation of laser shock on residual stress of cladding layer in laser additive manufacturing

Gong Chen[1], Gangxian Zhu[1], Lifang Wang[2], Tianlin Song[1]

[1.]School of Mechanical and Electric Engineering, Soochow University, Suzhou, China

[2.]Engineering training center, Soochow University, Suzhou, China

Abstract：

In order to control the residual stress of cladding layer in laser additive manufacturing and reduce the influence of residual stress on the performance of parts, ANSYS software was adopted to analyze the the residual stress distribution of cladding layer. Firstly, a single-track cladding layer model was established and the residual stress field was calcalated in laser additive manufacturing. Next, the laser shock peening was applied to cladding layer after the calculation of laser additive manufacturing. Finally, the influence of laser shock on residual stress of cladding layer was studied by changing the laser shock energy and cladding layer temperature. The calculated results show that the residual stress along the direction of scanning speed(Y direction) on the depth of cladding layer section is from tensile stress to compressive stress after introducing laser shock peening with the increase of laser shock energy, and the residual stress of Y direction is that tensile stress first decreases and then compressive stress increases, whereafter the compressive stress decreases with the growth of cladding layer temperature. There are maximum compressive stress at 600 degree. The simulation results are consistent with the existing experimental results, which verify the correctness and reliability of the model. It provides a method for the control the residual stress of cladding layer in laser additive manufacturing.

LPRC: Laser cleaning and surface modification of CFRP

Yanqun Tong

Zhenjiang University, China

Abstract：

Carbon fiber reinforced polymer (CFRP) has many excellent properties, such as high specific strength, high specific modulus, lightweight and fatigue resistance, which is widely used in aerospace, automotive, petrochemical and other industrial fields. However, surface defects are produced in the process of manufacture and leading to deterioration of surface properties. In order to remove the surface defects and improve the properties of CFRP, the compound processing were proposed. The surface morphology, contact angle, free energy, chemical activity and bonding performance were measured. The results showed that laser cleaning removed the surface resin and surface free energy, chemical activity and adhesive properties were improved. The bonding strength after processing with laser power of 16W and scanning speed of 1500mm/s was 1.6 times higher than that of the untreated surface.

WJ-3: Tailoring Microstructure and Mechanical Performance of the Graphite-Ni based Superalloy Brazed Combination Used for Molten Salt Reactors through Thermal Exposure

Yanming MA[1,2], Wenjian ZHENG[1], Yinghe MA[1], Jianguo YANG[1,2] and Zengliang GAO[1,2]

[1]Institute of Process Equipment and Control Engineering, Zhejiang University of Technology, Hangzhou 310014, P.R. China.

[2]Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, 310014, P.R. China.

Abstract：

The research investigated the effect of high- and medium-temperature thermal exposure on the microstructure and mechanical performance of the graphite/Au/Hastelloy N alloy brazed joint. The microstructure in the joint was analyzed through scanning electron microscope and transmission electron microscope. The joint bond strength was evaluated through a shear test. Results indicate that: two zones (zone 1 and 2) were observed in the joint with the zone 1 close to graphite while the zone 2 adjacent to Hastelloy N alloy. The precipitates in each zone were characterized and their formation mechanism was proposed. High-temperature thermal exposure was performed at 980C-1100C for 1-90 min. Among the investigated brazing process parameters, the highest joint strength obtained was 34.1 MPa. Medium-temperature thermal exposure was performed at 873-1073 K for 240 h. A high-quality joint was maintained when aged below 973 K. The work performed will provide basic design principles for the graphite/Hastelloy N alloy brazed combinations used in molten salt reactors.

WJ-3: A study on welding force, torque and temperature evolution during friction stir welding of aluminum pipes

Md Perwej Iqbal[1], Ranjan Kumar Vishwakarma[1], Surjya Kanta Pal[1], Parthasarathi Mandal[2]

[1]Friction Stir Welding Laboratory, Department of Mechanical Engineering, Indian Institute of Technology, Kharagpur, India

[2]School of Mechanical Aerospace and Civil Engineering, The University of Manchester, Manchester, United Kingdom

Abstract：

The use of circular conduits to transport fluids is ubiquitous in the modern industrialized world. As such, the applications of circular conduits demand proper installation methodology and working of the pipes. Traditionally, joining of the pipes is mostly performed through fusion welding techniques. However, during fusion welding techniques, various types of weld defects such as lack of fusion, over penetration, slag inclusions, root crack, undercut root gap, thermal distortion etc. are observed in the weld region. These shortfalls need to be overcome by the use of advanced welding techniques, and friction stir welding (FSW) is one such method. FSW is economic and environment-friendly and is being used for welding of pipes. The present work attempts to investigate the weldability of aluminum pipes by using FSW. Experiments have been performed by varying the process parameters such as plunge depth and rotational speed. Successful welds have been achieved which have been examined visually. Physical parameters such as force, torque, and temperature have been acquired during the process of welding. The effect of process parameters on the acquired data during the welding has also been studied. It was observed that with the increase in plunge depth, proper contact between tool shoulder and workpiece occurred which resulted in the weld with good surface finish. With increasing the rotational speed of the tool, while force and torque have been found to be decreasing, peak temperature increases.

WJ-3: Characteristics of welding mode transition induced during 1-μm and 10-μm laser welding

Shihui Guo, Jianglin Zou, Rongshi Xiao

Beijing University of Technology, Beijing, China

Abstract：

Welding pattern is divided into heat conduction welding mode and deep penetration mode according to the formation or not of the keyhole. In this study, the transition characteristics of welding modes were studied by the comparison of deep penetration welding threshold (DPWT) in different lasers. Nd: YAG laser and CO_2 laser were adopted to weld aluminum alloy.Heat conduction mode hardly exists during CO_2 laser welding. The welding bead was consisted of non-fusion and then micro-fusion, followed by the formation of deep penetration and plasma. Materials properties and surface roughness had little effect on the DPWT during CO_2 laser welding. The opposite behavior was discovered in Nd: YAG laser welding. The DPWT of Nd: YAG laser welding and CO_2 laser welding were 3.4 kW/mm~3.8 kW/mm and 4.2 kW/mm, respectively, which indicated that the difference of DPWT with two wavelengths of laser was less than that of laser absorption of aluminum alloy. Finite element simulation software was used to simulate the transformation of laser welding mode. The results showed that the theoretical DPWT value of Nd: YAG laser had consistencies with the experimental value. While the theoretical value of CO_2 laser welding threshold was much higher than the experimental value. The analysis showed that the plasma which was formed by CO_2 laser igniting the surface defect vapor of the plate significantly enhanced the energy coupling between the laser and the plate (increased the absorption). Accordingly, the DPWT was greatly reduced.

WJ-3: Weld Formation Mechanism of Laser Pressure Welding

Jingquan Zhang, Ting Huang, Rongshi Xiao

Beijing University of Technology, Beijing, China

Abstract：

Laser pressure welding is a unique welding technique combining a laser with a pair of rollers. The bonding of work pieces is realized by both fusion welding and pressure welding effects, which are produced by laser and rollers, respectively. The laser beam is used to scan the welding interface, which is rapidly heated by multiple reflections of the laser beam due to the open angle between the two work pieces. The work pieces are pressed simultaneously by the rollers to form the weld. This study was conducted to obtain a basic understanding of the weld formation of laser pressure welding. Microstructure, misorientation angle distribution and texture of the weld were characterized by electron backscattered diffraction (EBSD) to determine the formation mechanism. For the lap joint of commercial pure aluminum, equiaxed grains with low fraction of low angle grain boundaries (LAGBs) and random texture were observed in the center of the weld, suggesting that the melted aluminum solidified after rolling; the deformed columnar grains with increased fraction of LAGBs observed between the center and heat affected zone indicated that the melted aluminum solidified first and then was rolled. For the lap joint of T2 copper, deformed equiaxed grains with typical fcc texture in the weld center suggested that the copper was solidified firstly and then was affected by pressure.

WJ-3: Wear Behavior of 7075-Aluminum After Ultrasonic-assisted Surface Burnishing

Zhongyu Piao[1,2], Guanglei Yu[1,2], Zhenyu Zhou[1,2], Qiuyang Zheng[1,2]

[1]College of Mechanical Engineering, Zhejiang University of Technology, Hangzhou 310012, Zhejiang, China, Hangzhou, China

[2]Key Laboratory of Special Purpose Equipment and Advanced Processing Technology (Zhejiang University of Technology), Ministry of Education, Hangzhou 310012, China, Hangzhou, China

Abstract：

The numerical simulation and experimental study on the gradient nanostructure which fabricated by ultrasonic rolling process(USRP) on the surface of 7075-aluminum alloy flat plate are carried out. Based on Deform-3D software, it simulates three kinds of depressions (0.01, 0.05, 0.1 mm), three ultrasonic vibration frequencies (20 KHz, 60 KHz, 100 KHz), and five kinds of rotation speeds (150, 300, 450, 600, 750 mm/min) in USRP under room temperature and oil lubrication conditions. The intrinsic properties of the grain size distribution, elastoplastic strain and residual stress of the treated samples were simulated by Deform-3D which the Avrami phenomenological model is embed into. The simulation results show that ultrasonic vibration amplitude and depressions have obvious influence on the processing strengthening effect, and other parameters have less influence. As the number of USRP processing passes increases, the surface grain is gradually refined to the nanometer scale, and the thickness of the grain refinement layer also increases, both eventually reaching the extreme value. USRP enhances the degree of elastoplastic deformation due to the stress superposition effect and ultrasonic softening effect of ultrasonic vibration, thence furtherly promotes the refinement of surface grains. By studying the intrinsic relationship between the parameter group and the strengthened surface, the optimal parameter group is obtained. The simulation results have great consistency with the USRP test results.

WJ-3: Temperature Field Evolution and Analysis of Laser Deep Quenching of 42CrMo Steel

Wenhua Tong[1,2], Qunli Zhang[1,2], Huipeng Liao[1,2], Jiyu Du[1,2], Jianhua Yao[1,2]

[1]Collaborative Innovation Center of High-end Laser Manufacturing Equipment Zhejiang Province, Hangzhou, China

[2]Institute of Advanced Laser Manufacturing，Zhejiang University of Technology, Hangzhou, China

Abstract：

In order to explore the laser deep quenching mechanism of low carbon steel and obtain the deep hardened layer to meet the actual demand, the transient temperature field model of laser transformation hardening of 42CrMo steel was established by using COMSOL Multiphysics software. Considering the thermophysical parameters of the material, the hardened layer morphology was obtained by non-equilibrium austenite transformation temperature and martensite critical cooling rate with different processing parameters, such as preheating, water cooling, laser power and scanning speed, surface coating which could increase the absorbance of the material and slow down the heat transfer rate. The heating and cooling process were analyzed from temperature history and cooling gradient. The influence of the laser processing parameters on the depth of the hardened layer was explored. And under the guidance of the model, the laser quenching experiment of 42CrMo steel was carried out by fiber-coupled diode laser. At the same laser power and scanning speed, the depth of 3.7 mm of the hardened layer with water cooling can be obtained and the average hardness is above 750$HV_{0.3}$, both are deeper and higher than the depth and hardness without water cooling. The results show that the depth of the hardened layer obtained by the experiment is consistent with the simulation results and the model can be used to predict the corresponding hardened layer size and the limit depth of the hardened layer of the specimen under external coating and cooling conditions.

Poster: Characterization and experimental analysis of silicon carbide and rare earth compounds reinforced al-6063 aluminum alloy hybrid composites

Vipin Sharma[1,2], Vinod Kumar[3], Ravinder Joshi[3], Deepak Sharma[3]

[1]Thapar Institute of Engineering and Technology, Meerut, India

[2]Meerut Institute of Engineering & Technology, Meerut, India

[3]Thapar Institute of Engineering and Technology, Patiala, India

Abstract：

This paper investigates the mechanical behavior of Al-6063-SiC-Rare Earth (RE) hybrid composites. Hybrid composites containing wt% of SiC from 3,6 and 9 wt% and (CeO_2+La_2O_3) mixtureas RE from 1,2 and 3 wt% were fabricated using Stir Casting technique. The Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), Electron Backscattered Diffraction (EBSD) and Energy Dispersive Spectroscopy (EDS) analysis were used to characterize the prepared samples of Al-6063 hybrid composites. The mechanical behaviours including Rockwell hardness, Vicker's microhardness, impact strength and tensile strength are tested using their ASM standards. The fractured samples of different hybrid composites are studied using SEM. The data obtained from various test are quantitative. The hardness is higher for Al-6063-6SiC-2RE. The highest hardness is 69 HRB at 6wt% of SiC and 2wt% of RE mixture (CeO_2+ La_2O_3). The highest Vicker's microhardness is 114.24HV at 6wt% of SiC and 2wt% of RE mixture (CeO_2+ La_2O_3). The highest tensile strength is 91MPa at 6wt% of SiC and 2wt% of RE mixture (CeO_2+ La_2O_3). The highest impact strength is 56J at 6wt% of SiC and 2wt% of RE mixture (CeO_2+ La_2O_3) in hybrid composites. The obtained data are analyzed on Design Expert software Version 6.0.8 using two level factorial design. The regression equations obtained from the software is validated using diagnosis plots and the optimized values of reinforcements are obtained using desirability analysis.

Poster: The static performance of the high-speed aerostatic spindles with modified discharge coefficients

Laiyun Song[1], Kai Cheng[2], Hui Ding[1], Shijin Chen[1]

[1.]School of Mechatronics Engineering, Harbin Institute of Technology, Harbin, China

[2.]College of Engineering, Design and Physical Sciences, Brunel University, London, United Kingdom

Abstract：

The typical high-speed aerostatic spindles consist of thrust bearings and journal bearings, which provide the axial stiffness and the radial stiffness of the spindle, respectively. However, with the demand of the larger cutting forces and the more precise prediction of the performance of the spindle, the angular stiffness of the high-speed spindle should not be ignored. In this paper, three-freedom model of the aerostatic spindle is established by considering the one set of the thrust bearing and journal bearing together. In high speed condition, the discharge coefficients should be modified with the function of the rotating speeds and eccentricity ratios. As a result, static characteristics of the high-speed aerostatic spindle is obtained by the modified discharge coefficients with the FEM method and analyzed in different operations.

Poster: Digital design and fabrication of personalized compression hemostasis device for cardiac pacemaker implantation based on 3D printing

Hong-Tao Fu[1], Yun-Feng Liu[1], Dong-Cai Wang[1], Xiao-Hong Pan[2], Xian-Feng Jiang[1], Xian-Tao Dong[1]

[1.]Key Laboratory of E&M (Zhejiang University of Technology), Ministry of Education & Zhejiang Province, Hangzhou 310014, China

[2.]Department of Cardiology, The Second Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou 310009, China

Abstract：

The compression hemostasis device is used to achieve hemostasis at the implant site after cardiac pacemaker implantation, and reduce the postoperative complications, as well as improve the rehabilitation efficiency and quality of the patient. The traditional hemostasis method using a flexible bandage and sandbag for hemostasis, is poor on stability and easy to cause comlications including subcutaneous congestion, capsular hematoma, capsular bag rupture, capsular bag infection. To improve the hemostasis effect for cardiac pacemaker implantation, a personalized compression hemostasis device with individualized components and irregular parts are designed with patient's data and faricated using 3D printing, and then evaluated by finite element anslysis and experimented with physical device for checking the supplied pressure and device safety. The new device can supply optimal pressure and has the characteristics of simple operation, precise hemostasis, high comfort and small quality. This article also discusses the possibility of using 3D printing on more medical devices in the future.

Poster: Nondestructive Rape Blackleg Early Detection Method with Low-frequency Ultrasonic Technology

XIN QIAO[1], Hongli Chen[2], Guilin Tu[2]

[1]Zhejiang University of Technology, HangZhou, China

[2]Zhejiang Sci-Tech University, HangZhou, China

Abstract：

Breeding for resistance to stem disease currently requires a hands-on field phenotyping screen that involves severing each plant and performing a visual assessment of the stem. This is labor intensive, poses many EHS risks and is not analytically robust given the subjective human scoring in adverse field conditions.Ultrasound testing is a non-destructive technology used for detecting the presence of inhomogeneities of density or elasticity in materials. Using this technology to determine inhomogeneity caused by a stem disease in an infected plant could provide a valuable tool to quantify disease presence. Bringing ultrasound technology into the field for the evaluation of disease presence would eliminate some of the labor involved in the early rough selection of lines and potentially provide more precise phenotyping on advanced staged lines. Eliminating the need for severing the plants would reduce safety & ergonomic hazards.The objective of this research is to evaluate the use of ultrasound technology as a way to reduce labor and risks associated with stem disease field phenotyping, while also improving the quality of the phenotypic data and providing a science foundation for early prevention and online monitoring of canola blackleg.

Poster: Mechanical and biological properties of 3D printed mandibular graft with PEKK

Chen Xu[1], Kang Jie Cheng[2], Yun Feng Liu[1], Fu Dong Zhu[1], Xian Feng Jiang[1], Xing Tao Dong[1]

[1.]Key Laboratory of E&M (Zhejiang University of Technology), Ministry of Education & ZhejiangProvince, Hangzhou 310014, China

[2.]Key Laboratory of E&M (Zhejiang University of Technology), Ministry of Education & Zhejiang Province, Hangzhou 310014, China

Abstract：

Background:Poly-ether-ketone-ketone(PEKK) is a semi-crystalline, high performance thermoplastic that possessing superior mechanical properties and other functional properties applicable for biomedical applications. Coupled with its capability to withstand sterilization treatment, PEKK polymer has got close attention especially in the biomedical field. Purpose:The object of this study is to evaluate the mechanical properties of three-dimensional printed mandibular graft with PEKK polymer by using mechanical tests and estimate the biological properties by cell culture experiments in vitro. Methods:Mechanical test specimens, including tensile, compressive and flexural, were printed by three-dimensional printer for mechanical testing. A three-dimensional mandibular graft was created and fabricated for cell culture experiments. Results:The mechanical and biological testing results showed that PEKK polymer owns exceptional mechanical properties and low cytotoxicity. Conclusions:PEKK polymer exhibits bone-like stiffness and great biocompatibility, which showed the potential of PEKK polymer as a bone graft substitutes used for mandibular reconstruction.

Poster: Motion planning and precise control of robotic surgical System for dental implanting

Wei Bin Wang[1], Yun Feng Liu[1], Xian Feng Jiang[1], Fu Dong Zhu[2], Xing Tao Dong[1], JiaYou[3]

1Key Laboratory of E&M (Zhejiang University of Technology), Ministry of Education & Zhejiang Province, Hangzhou , China

[2]The Affiliated Stomatology Hospital, College of Medicine, Zhejiang University, Hangzhou , China

[3]6D-Dental Ltd. Company, Hangzhou , China

Abstract：

Purpose: For a robotic surgery in narrow oral cavity with complex environment and variable surgical operation, the current robotic arm motion-planning algorithm cannot meet the requirements for planning efficiency and constraints for surgical environment. Aiming at this problem, an improved motion planning algorithm for robotic dental implanting will be proposed in this paper, which is a great significance for improving surgical efficiency and safety. Methods: (1) Before surgical operation, Two group CT images of a patient's two states (occlusion and opening mouth) with loosed teeth were obtained, and so two related 3D model of the internal structure size with the oral opening and occlusion could be available too. (2)Design a dental implanting plan under the guidance of doctor. Combined with the specific dental implanting environment, the collision model was established. (3) Analyzed the dental implanting robotic system which was constructed by the cooperative robot (UR5) and the drilling action in the established surgical plan. Based on current robot arm trajectory planning algorithms, a new algorithm for motion planning was proposed, with which the environmental constraints within oral cavity and the searching path efficiency to meet the requirements of surgical operation were considered. In the end, an experiment was conducted to verify the feasibility and efficiency of the algorithm with ROS platform simulation. Results: experiments showed that efficiency of motion planning based on robotic implant surgery was improved. Conclusion: The new algorithm of dental implanting robotic system effectively improves the efficiency of the surgery .

Poster: Effective CAD/CAM Systems for Injection Molding and Manufacturing

Ansar Sk, Pradeep Kumar, Vipin Sharma

Meerut Institute of Engineering and Technology, Meerut, India

Abstract：

In modern plastic injection molding and manufacturing industry, optimization of design and drafting techniques, time, demand of product variety is a great challenge. This paper covers effective and efficient CAD/CAM systems available in plastic and other related manufacturing industry. It also focuses on advantages and disadvantages of different design and analysis software like AutoCAD, Catia, Pro/e, solid edge and Ansys. A comparison is built among those software so that modern molding and manufacturing industries identify their need to optimize different parameters.

Poster: The optimization of wind turbine blade laying equipment structure by modal superposition method

Jinghua Wang, Leian Zhang, Xuemei Huang

Shandong University of Technology, Shandong Zibo, China

Abstract：

An optimization is carried out for the bearing structure of the wind turbine blade laying equipment by using modal superposition theory. Firstly, the finite element method is used to calculate the bearing structure, then established a mathematical model of optimization whose target is to minimize weight and complete the multi-parameter optimal match by iterative optimization. Finally, the field test shows that the weight loss of the bearing structure is 2311kg, the first-order frequency is increased to above 10 Hz, the amplitude is reduced by 5.44mm and the deformation is increased by 0.3mm. But the total deformation of the bearing structure is less than 3mm. It proves that using modal superposition theory to optimize some structures is feasible and it provides theoretical support for engineering application of laying equipment.

Poster: Five-axis machine tool error indirect measurement method based on sample test method

Shengkai Mei

Shandong University of Technology, Zibo, China

Abstract：

In order to improve the predictive ability of the five-axis machine tool error model, this paper proposes a five-axis machine tool error indirect measurement method based on the prototype test method, and completes the optimization design of the step shaft sample. After the machine space error model is reversed, the function analysis relationship between the sample machining error and the machine tool error is established, and the dynamic error of different machining states of the machine tool is obtained. The reliability of the method is verified by experiments. The results show that the method is in good agreement with the laser measurement results. This method can improve the prediction ability of the five-axis machine tool error model, thus improving the machining accuracy of the machine tool.

Poster: Surface Properties and Online Monitoring of Laser Cleaning of Carbon Fiber Reinforced Polymer

Yanqun Tong

Jiangsu University, ZhenJiang, China

Abstract：

In recent years, carbon fiber reinforced polymer (CFRP) has received extensive attention in the industrial field, due to its excellent performance. Surface contaminants and epoxy resin has a serious effect on the bonding strength of carbon fiber reinforced polymer. Laser cleaning technology for pretreatment of carbon fiber reinforced polymeris beneficial to improve the surface properties and the bonding strength of the interface. In this paper, we used the nanosecond pulse laser to pretreat carbon fiber reinforced polymer. The surface morphology with different processing parameters was observed by scanning electron microscopy. The surface contact angle was measured by contact angle measurement, and the wettability of the surface was analyzed. The timeliness of surface wettability at room temperature and pressure was studied. Meanwhile, the laser induced breakdown spectroscopy (LIBS) technology was used to control the laser cleaning process. The results showed that the 393.3nm S (II) and 589.5nm S(II) lines can effectively characterize the surface cleaning quality of carbon fiber reinforced polymer in the plasma spectrogram.

Poster: Experimental research on foil forming through nanosecond laser-induced breakdown in water

Zeng Nie[1,2], Yunxia Ye[1,2], Xudong Ren[1,2], Yonghong Fu[1,2], Yinqun Hua[1,2]

[1]School of Mechanical Engineering,Jiangsu University, zhenjiang,jiangsu, China

[2]Institute of Micro-nano Optoelectronics and Terahertz Technology,Jiangsu University, zhenjiang,jiangsu, China

Abstract：

Laser shock forming (LSF) is an effective method to induce plastic deformation of metal foil, but the need for an energy absorbent layer during LSF limits its engineering application. Strong wave can be launched through laser-induced breakdown in water. This shockwave can also be used to form mechanical parts. Through this method, LSF without absorbent layer can be achieved. In this paper, the process of nanosecond laser-induced breakdown in water is studied experimentally. On this basis, the feasibility of inducing foil plastic deformation through LSF was carried out. The laser-induced shock wave and the process of forming a bubble were recorded by a high speed camera, and the surface morphology of the obtained micro pit on the metal foil was observed and measured by a topography measuring instrument and a scanning electron microscope. It has been observed that the shockwave caused by laser-induced breakdown in water can successfully induce plastic deformation of the metal foil. There are two possible mechanisms: water-breakdown-induced shock wave and bubble-collapse-induced micro jet. The foil forming mechanism and the forming effect can be controlled by changing the distance between the laser focus point and the wall.

Poster: Dynamic Error Model of Five-Axis Machine Tool Based on AFSA-ACO-BPN Algorithm

Li Song, Mei Shengkai, Yuan Wei, Guo Qianjian

Shandong University of Technology, Zibo, China

Abstract：

In order to improve the machining accuracy of the five-axis machine tool, this paper proposes a dynamic error model of five-axis machine tool based on AFSA-ACO-BPN algorithm. The optimization of modeling variables was completed by establishing a grey relational analysis model, and the dynamic fusion of AFSA and ACO-BPN was carried out. The experimental results show that the proposed method is in good agreement with the measured results. The method comprehensively reflects the influence of different cutting conditions, improves the robustness of the error model, and provides a theoretical basis for improving the machining accuracy of the machine tool.

Poster: Systemetic Analysis and Curvature Control of BistableAnti-Symmetric Composite Cylindrical Shells in Hygrothermal Environment

Zheng Zhang, Hao Zhang, Weili Ma, Huaping Wu, Shaofei Jiang, Guozhong Chai

Department of Mechanical Engineering, Zhejiang University of Technology, Hangzhou, China

Abstract：

This paper systematically studies the effect of temperature and moisture on bistable anti-symmetric composite cylindrical shells in the hygrothermal environment. Based on the classical laminate theory, together with the principal of minimum potential energy, an analytical model is developed to predict the bistable behavior of those bistable anti-symmetric composite cylindrical shells in the hygrothermal environment. Finite element simulates the change of curvature of bistable anti-symmetric composite cylindrical shells. An experiment of temperature and moisture was presented to measure the principal curvatures and twisting curvatures in the hygrothermal environment. The numerical and experimental methods are employed for predicting and verifying the theoretical results. The temperature, moisture have prominent effects on the bistable anti-symmetric composite cylindrical shells. In order to optimize shell's shape for being used in some particular situations, a novel approach that may control the bistable shell's curvatures by adjusting the temperature or moisture are presented. For the moisture variation take a long time to affect the structure curvature, the twisting curvature are eliminated by adjusting the temperature to the given value

Poster: Adaptive Process Control Implementation of Wire Arc Additive Manufacturing for Thin Wall Components with Overhanging Features

Teng Foong Lam, Xiong Yi, Audelia Gumarus Dharmawan, Shaohui Foong, Gim Song Soh

Singapore University of Technology and Design, Singapore, Singapore

Abstract：

The ability to fabricate overhanging structures in WAAM (Wire Arc Additive Manufacturing) is vital in ensuring that a wide variety of designs can be realised. Unlike other additive manufacturing techniques that leverage on the addition of support structures, WAAM utilises a support-free approach for overhang fabrication to ensure components achieve a minimal buy-to-fly ratio. Currently, turntables are employed to achieve features with overhangs, but this does not scale well for large parts, in which the substrate's position is fixed. This paper presents an alternative approach to overcome this limitation by implementing adaptive process control for the printing of thin wall overhanging features under flat position deposition conditions. An overhang slicer algorithm was used to generate the travel path based on the sliced CAD model and tag it with overhang angle information. A data-driven regression model then determined the torch speed for each path segment based its overhang angle that would result in uniform layer height. A thin walled part with a complex overhang feature that varies from 0°-40° was fabricated using the proposed approach. The result is a near net shape part, as verified using an industrial optical 3D digitiser.

Poster: Design and Optimization of Regional Split Header Structure in Plate-Fin Heat Exchanger

Xiang Peng, Denghong Li, Shaofei Jiang, Jiquan Li

Zhejiang University of Technology, Hangzhou, China

Abstract：

Aiming at the problem that the flow distribution of the header of the existing plate-fin heat exchanger is not uniform, which leads to the decrease of heat transfer efficiency between the fins, a new type of regional split header structure is designed. The fluid is split into six sections by five baffles when entering the inside of the header and flows to the corresponding outlet area. Numerical calculation and analysis of the flow field inside and outside the header before and after improvement by CFD method. It is determined that the new header can effectively reduce the inhomogeneity of the flow into each layer of fins, thus improving the heat transfer performance. The influence of baffle height, baffle tilt angle and shell tilt angle on the outlet fluid unevenness of the header is analyzed, the optimal structural parameters are determined as the height of the baffle is 30cm, the tilt angle of the baffle is 55° and the tilt angle of the shell is 110°. The accuracy and effectiveness of present study are verified through comparing the inhomogeneity of outlet velocities of header with the literature results.

Poster: Conceptual Scheme Optimization of Mechanical Product Based on Functional Reliability Analysis

Shaofei Jiang, Tao Sun, Xiang Peng, Jiquan Li

Zhejiang University of Technology, Hangzhou, China

Abstract：

Reliability is one of the key factors in the design of mechanical products. During the conceptual design process of the product, analyse the reliability of the conceptual scheme to reduce the probability of failure of the final manufactured product. Due to the ambiguity of information and the uncertainty of components, the reliability of conceptual scheme is difficult to measure. To solve this problem, this paper proposed optimized method of mechanical product conceptual scheme based on functional reliability analysis. First, the functional structure diagram is analyzed the physical conversion relationship of each functional parameter, and determine the functional stress according to the weight of each parameter. Second, the fault information of each component is analyzed by use fuzzy set theory to get the reliability of the component. Third, the weight of each component feature is quantitatively evaluated by the AHP method to obtain the reliability of the function. Finally, by using TOPSIS (technique for order preference by similarity to an ideal solution) to analyze the functional reliability of each conceptual scheme and evaluate the reliability of the scheme, the most reliable scheme is obtained from all the conceptual schemes. The efficiency of the proposed methodology is verified using the examples of height adjustment mechanism of shearer.

Poster: Investigation of Mechanical Behavior of Pure Aluminum under Vibration-assisted Burnishing by Molecular Dynamics Simulation

Zhong Yu Piao[1,2], Qiu Yang Zheng[1,2], Zhen Yu Zhou[1,2], Guang Lei Yu[1,2], Sen Bin Ye[1,2]

[1]College of Mechanical Engineering, Zhejiang University of Technology, Hangzhou 310012, Zhejiang, China, Hangzhou, China

[2]Key Laboratory of Special Purpose Equipment and Advanced Processing Technology (Zhejiang University of Technology), Ministry of Education, Hangzhou 310012, China, Hangzhou, China

Abstract：

As ultrasonic vibration has been often adopted into metal rolling process to improve rolling efficiency, it is significant to understand the mechanism of rolling enhancement due to ultrasonic vibration excitation in metal's rolling process. In this paper, the pure Aluminum rolling process with ultrasonic vibration excitation was simulated by Molecular Dynamics (MD) method, to study the influence of ultrasonic vibration excitation to pure Aluminum rolling process in atom scale. In MD simulation, the frequency and amplitude of ultrasonic vibration in rolling process are considered to affect metal rolling quality and efficiency. The ultrasonic vibration excitation with different frequency and amplitude are employed in to rolling process, and the rolling results are compared to demonstrate the mechanism of rolling enhancement by ultrasonic vibration. The MD results shows, ultrasonic vibration excitation lead to obviously improvement of rolling processing, and lead to partial amorphous variation in pure Aluminum. In the MD simulation under our given parameters, increasing the amplitude of ultrasonic vibration can significantly increase the enhancement of rolling process, while increasing the frequency of that can only increase the enhancement in a certain range.

Poster: Effect of direction of rotations on process performance of a rectangular-rotating core magnetorheological finishing process

Manpreet Singh, Anant Kumar Singh

Thapar Institute of Engineering and Technology, Patiala, India

Abstract：

The fine finishing of the cylindrical parts is a key factor to achieve the better performance of the industrial machines. The 70% of the components which are used in the industrial machine are cylindrical in shape. The fine finishing in cylindrical components is required to achieve better functional performance. To accomplish this necessity, the magnetorheological rectangular-rotating core finishing process has been used. The surface finishing on the workpiece is obtained with the help of bidirectional motions of the tool. The process performance with the clockwise and anticlockwise rotation of the external cylindrical workpiece is analyzed. The clockwise rotation of the cylindrical workpiece with respect to the anticlockwise rotation of the tool core comparatively results in the higher magnitude of the cutting shear force which further enhances the finishing process performance for the same finishing time. The average surface roughness value was reduced from 450 nm to 50 nm when the cylindrical workpiece rotates in an anticlockwise direction and from 450 nm to 30 nm when the cylindrical workpiece rotates in the clockwise direction in the same finishing time of 60 minutes. Scanning electron microscope and mirror images were confirmed that the better process performance was achieved when the cylindrical workpiece was rotated clockwise with respect to the anticlockwise rotation of the tool core. The overall results indicate that the rotation of tool core in anticlockwise and the cylindrical workpiece in the clockwise direction is helpful in the significant finishing of the external surface of the cylindrical workpiece.

Poster: Design and Calibration of the Hybrid Long-Stroke Multi-Axis Nano-Positioning System

Po Yu Chen[1,2], Wen Yuh Jywe[2], Tung Hsien Hsieh[2], Hsueh Liang Huang[2], Tung Hsing Hsieh[2] , Ming Shi Wang[1]

[1]Department of Engineering Science, National Cheng Kung University, Tainan, Taiwan

[2]Smart Machine and Intelligent Manufacturing Research Center, National Formosa University, Yunlin, Taiwan

Abstract：

This paper presents the design and calibration of a hybrid long stroke multi-axis nano-positioning system, include the purpose of system design, assemble, calibration, this system consists by two major parts: (1) hybrid long stroke nano-positioning stage, (2) multi degree-of-freedom(DOF) laser interferometer positioning feedback measurement system, which composed with two plane mirrors. The hybrid long stroke nano-positioning stage composed by a H-type long stroke flotation linear motor stage and a nano-precision piezoelectric compensation stage, the H-type long stroke flotation linear motor stage installed on a granite stage, provide X-Y dual axes long stroke displacement, X axis: 100 mm Y axis: 150 mm, the nano-precision piezoelectric compensation stage installed on H-type long stroke flotation linear motor stage to compensation the movement error of the Y axis displacement error, X axis straightness error and θ_z angular error. This hybrid long stroke nano-positioning stage used multi-DOF laser interferometer positioning measurement system as feedback in control system, it has following advantages: high resolution, fast response, long range positioning measurement. The multi-DOF laser interferometer positioning feedback measurement system in proposed system can improve the accuracy of hybrid long stroke multi-axis nano-positioning system up to nanoscale. Experiment results shown The accuracy of X, Y- axis and dual-axis are ± 15 nm, ± 15 nm and ± 40 nm, respectively.

Poster: Compression Properties in Extrusion-based Additive Manufacturing of Moisture-cured Silicone Open-cell Foam

Xiaoqing Tian, Dingyifei Ma, Shengyi Wang

Hefei University of Technology, 193 tunxi road , Hefei, Anhui, China

Abstract：

Silicone open-cell foam is a kind of cellular foam fabricated by Additive Manufacturing (AM) based on “fluid mechanical sewing machine" (FMSM) theory. The compression properties in silicone open-cell foam specimens fabricated by extrusion-based additive manufacturing are investigated.Forces in compression test were measured to investigate effects of five key process parameters (volumetric flow rate Q, nozzle tip inner diameter d=2a0 , falls distance H, velocity of nozzle movement v and the parallel distance of the line of motion L) on compression strength. Different stress-strain curves were obtained by compression experiments on samples with different parameters. Results show that the stress-strain curve can be divided into three regions: the first linear region, the nonlinear region, and the second linear region. The reason for the formation of the nonlinear region has been discussed and is believed to be caused by the co-existence of contact state and non-contact state between the silicone foam. The nonlinear region can be used to produce foam with variable modulus of elasticity, which has potential applications in medical treatment and clothing. A silicone foam insole with variable elastic modulus was designed and fabricated to improve the comfort and air permeability.

Poster: Investigation on material remove of aero-engine blades based on abrasive belt grinding

Ge Man, Ji Shiming, Tan Dapeng, Qiu Lei

Zhejiang University of Technology, HangZhou, China

Abstract：

Titanium alloys offer high strength-to-weight ratio, high toughness, superb corrosion and creep resistance are used as the main material for aero-space blades. However, titanium alloys have the characteristics of active chemical properties and high strength and toughness, which easily causes grain wear and larger grinding heat, so blades surface quality will inevitably impacted. In order to improve the surface quality and profile precision of the aero-engine blade, the efficient material removal method of belt grinding for aero-engine industrial applications is indispensable. This paper aims to investigate the work piece surface integrity of titanium alloys under various parameters based on abrasive belt grinding, and the material removal mechanism and parametric model for titanium alloy is presented. Our approach consisted of single factor experiment that analyze the influence of grinding parameters on the materials removal rule of titanium alloy. Then according to the results of experiment, the method of orthogonal experiment with the parameters is used, the different grinding parameters is significant to the material removal model. This experimental results show that the surface quality and accuracy of blade profile are improved effectively by optimizing grinding process parameters.

Poster: Errors in the processing of aero-engine blades and their effects on blade performance

Qiu Lei[1,2,] Ji Shiming[3], Zeng Xi[3], Tan Dapeng[3], Ge Man[3]

[1] Zhejiang University of Technology, hangzhou, China

[2]Key Laboratory of E&M, Ministry of Education & Zhejiang Province, hangzhou, China

[3]Zhejiang University of Technology, hangzhou, China

Abstract：

In view of the structural characteristics and material properties of the small aspect ratio blades commonly used in current advanced aero-engines, combined with the commonly used processing methods, the paper analyzes the surface surface topography error and proposes a calculation method for this error. Moreover, the effects of blade torsion error, blade profile uniformity error, inlet and exhaust edge machining error and chord length error on blade performance were analyzed by numerical simulation. On this basis, the error analysis of the design section difference to the production section difference and the error analysis of the design and production fitting of the intake and exhaust sides were carried out. The machining experiment was carried out using the robot machining system, and based on the above simulations and experiments, the reliability of the blade design and processing data transmission accuracy was studied.

Two-phase flows simulation in pipeline leakage with coupled volume-of-fluid and level set method

Weng Xiaoxing, Li Chen, Xiao Fengqing

[1]zhejiang Academy of Agricultural machinery, jinhua, China

[2]China Jiliang University, hangzhou, China

[3]zhejiang institution of standardization, hangzhou, China

Abstract：

There are many hidden dangers in the safe transportation of pipelines. Thus, it is of great practical significance to study the rule of pipeline leakage for prediction and positioning of leakage points and making emergency plans. A coupled level set method (LSM) and moment of fluid method (CLSMOF) is described for computing solutions to incompressible two-phase flows. CLSOMF combines the advantages and overcomes the disadvantages of the fluid volume model (VOF) and LSM. In this method, VOF was used to capture interfaces, which can completely keep the mass-conservation. A geometrical operation was used to calculate the Level Set function near interfaces, which could be used to compute the accurate curvature and smooth the discontinuous physical quantities near interfaces. Through numerical simulation of pipeline leakage diffusion process, the interface between two phase flows was captured using CLSOMF. Using high-order TVD Runge-Kutta, and the upwind scheme combined with essentially nonoscillatory (ENO) method, the spatial and time equations in level set are discretized, respectively. And using the Navier-Stokes equation and pressure coupling equation of semi implicit compatible (SIMPLEC) algorithm, to pressure, velocity, and other parameters of the flow field can be solved. This paper provides a theoretical basis for establishing an effective forecast range of leakage accident and emergency disposal.

Poster: Adhesion enhancement of wear-resistant diamond coating deposited on titanium by seeding after carbonization pre-treatment

Jiye Gao, Feng Xu, Lili Shi, Chenhui Xu, Xue Wang, Dunwen Zuo

College of Mechanical and Electrical Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing, China

Abstract：

The adhesion of wear-resistant diamond coating deposited on titanium was weakened by the porous TiC interlayer, which was formed before film growth. In order to avoid the impact of this problem, a new pre-treatment method was presented: Ti substrates were carbolized by hot filament chemical vapor deposition (HFCVD) system, then the diamond micro-powder was embedded into the porous TiC by ultrasonic vibration. The effect of carbolizing parameters and grain size of diamond micro-powder on adhesion property were investigated. The carbolized substrates and the interface between diamond coatings and substrates were characterized. The friction and wear properties of as-deposited diamond coatings were tested. The results showed that seeding after carbonization pre-treatment can significantly enhance the adhesion of Ti-based diamond coatings, and the adhesion enhanced diamond coating has good wear resistance. High CH4 concentration, low gas pressure and appropriate boron concentration are beneficial to shorten the incubation period and thus thinning the TiC layer. The diamond micro-powder littered in the hole of TiC layer serves as nuclei for subsequent growth of diamond coating and increases the substrate-coating contact area. Moreover, the adhesion was enhanced by the anchoring effect between porous TiC layer and diamond micro-powder.

Poster: A Rotational Magnetorheological Honing (R-MRH) Process for Improving Operational Function of Cylindrical Mold

Sunil Kumar Paswan, Anant Kumar Singh

Thapar Institute of Engineering and Technology, Patiala, India

Abstract：

In this paper, a rotational magnetorheological honing (R-MRH) process is used for finishing the internal surface of the cylindrical mold. The process uses the rotational motion of the magnetorheological honing (MRH) tool and cylindrical molds in the opposite direction to one another and the reciprocation motion of the MRH tool. The tool is made of four permanent (NdFeB) magnets. The magnetorheological (MR) polishing fluid is applied as the finishing medium. The magnetic field induced by the four magnets acts as an external mean to change the rheological properties of the MR polishing fluid. The cylindrical mold is one of the essential equipment used in the foundry shop of the industries. The finishing quality of the casted cylindrical products entirely relies on the internal surface finish of the cylindrical mold. In this process, the abrasive particles stiffly surrounded by the magnetic carbonyl iron particles, perform the motion over the surface of the work part, under the influence of motions taking place in the process. Therefore, the relative motions of the active abrasive particles cause the material abrasion from the finishing surface of the workpiece. The initial and final surface roughness of the workpiece are measured with Mitutoyo Surftest, and the change in surface roughness was found as 83.40% at the optimum process parameters of the finishing process. Also, for visually surface quality analysis the scanning electron microscopy is performed on the pre and post finished internal surface of the cylindrical mold.

Poster: Design of an eddy current displacement sensor for strong magnetic field interference environment

Fei Yang[1], Chengliang Pan[1], Heng Zuo[2]

[1]School of Instrument Science and Opto-electronics Engineering, Hefei University of Technology, Hefei, China

[2]National Astronomical Observatories / Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, Nanjing, China

Abstract：

Since eddy current displacement sensors are based on the phenomenon of electromagnetic induction, their measurement results would be seriously disturbed by strong external magnetic fields when these sensors are installed in harsh environments with power cables and electrical motors. The traditional solution is to add a shield integrated in the probe, isolating the sensing coil from magnetic field interference. However, it will increase the cost of production and the shield also influences the magnetic field distribution of sensing coil. In this paper, an alternative solution is proposed, focusing on the high-frequency signal conditioning circuit with deliberate filtering segments. A well-matched AC bridge is adopted to extract the inductance variation of sensing coil. The signal with displacement information is demodulated by phase sensitive detection and amplified by multistage amplifiers to the desired magnitude. In the process, the interference signal coupled in the sensing coil is attenuated by band-pass and low-pass filters to the acceptable faint value. A testing system is set to excite and measure the vibration of a steel beam by a coaxial voice coil motor and the eddy current displacement sensor, respectively. The testing results show that the prototype sensor provides a resolution of 10 nm with measuring range of 50 μm and bandwidth of 3 kHz, appearing a good suppression of strong magnetic field interference from the voice coil motor.

Poster: Applying Wireless Data Acquisition and Transmission System Design on the Precise Machine Tool Measurement

WenYuh Jywe[1], CaoSang Tran[2], YungHoh Sheu[3], PoChieh Hong[4], JingChung Shen[4], HsiuChing Chang[4]

[1]Automation Engineering, National Formosa University, Yunlin, Taiwan

[2]Power Mechanical Engineering, National Formosa University, Yunlin, Taiwan

[3]Computer Science and Information Engineering, National Formosa University, Yunlin, Taiwan

[4]National Formosa University, Yunlin, Taiwan

Abstract：

To do research studies on analyzing and exploring error of machine during operation caused by bad vibration which is the motion of mechanical objects that oscillate and affect precision of cutting. In this paper, the investigating multiple points on a machine is required and taking advantage from wireless technology is executed by using Wi-Fi signal to transmit and receive data from other sides, each device is integrated vibration instrument, temperature measurement and many supported external sensors. User interface is developed on mobile as an application that runs on Android Operating System that allows user set levels of thresholds for each sensor. The vibration is described through Fast Fourier Transform algorithm (FFT) that represents in frequency domain. With small size and using wireless technology, the setting device is easier. The research achievements developed in this study can also be used in other systems in order to take the investigation.

Poster: Deformation Mechanism and Experiment Study of Gel Wheel

Shi Meng, Zeng Xi, Ji Shiming, Qiu Wenbing, Xi Fengfei, Zheng Qianqian

Zhejiang University of Technology, Hangzhou, China

Abstract：

As a precision component of the aircraft, the aero-engine blade has an irregular three-dimensional curved twist surface, and its surface quality has a significant impact on engine performance. In order to solve the problem of force control on such complex curved surface finishing technology, a new method for processing the Gel Wheel to realize main power control is proposed. Based on the Flory gel swelling theory, a mechanical model of multi-dimensional equilibrium force established on a gel network; The deformation mechanism of the gel driver unit under the energized state was studied, and the macroscopic model of the gel driver unit was established to determine the topology of the gel driver unit in the gel wheel. The mechanical test platform of the Gel Wheel was built, and the correctness of the gel drive unit model was verified by experiments. A polishing test platform was set up, and a set of Gel Wheel production process plans and parameters were established through the finishing test. The relevant empirical formulas for guiding the complex surface machining of space were summarized.

Poster: A Novel Trajectory Tracking Control of Collaborative Robot Based on Udwadia-Kalaba Theory

Fanzhi Wang[1], Jiang Han[1], Fangfang Dong[1], Lian Xia[1], Wenfeng Si[2]

[1]School of Mechanical Engineering, Hefei University of Technology, Hefei, China

[2]Anhui Jiangji Heavy CNC Machine Tool Co., Ltd., Lu'an, China

Abstract：

Collaborative robot should track given trajectories to work with human in most cases. The given trajectories are regards constraints applied on the motion of collaborative robot. Thus, obtaining the constraint force becomes the core problem. Several approaches, which requires determining the Lagrangian multipliers, have been used to achieve such purpose based on the d'Alembert principle in past decades. The lack of traditional method is that if the constraint is nonholonomic, the dynamic model is complicate and only numerical solution could be obtained. Unlike those, a novel approach of trajectory tracking control is presented, which is based on Udwadia-Kalaba approach. This approach presents a novel, concise and explicit equation of motion for constrained collaborative robot systems with holonomic and/or nonholonomic constraints as well as constraints that may be ideal or non-ideal. The Udwadia-Kalaba equation is uncoupled and free from the Lagrangian multipliers, no Quasi Variables or additional generalized coordinates are required. Adopting this method, the given trajectories are regards as the performance constraints. The constraint force, obtained by analyzing Udwadia-Kalaba equation, is in closed-form so that it can be used in the control conveniently. Since the constraint force is determined by the given trajectory, the motion of collaborative robot meets the requirements exactly. A numerical example is given to demonstrate the details of implementation procedure. The results show that the proposed approach has better performance and less computation when compared to the former methods.

Poster: Effects of Ultrasonic Cavitation on Laser Cladding Forming

Xiaowen Yu, Zhehe Yao, Jianhua Yao

Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, China

Abstract：

In this study, a numerical model of ultrasonic assisted laser cladding was developed using COMSOL, and the effects of the ultrasonic cavitation on the laser cladding forming were analyzed by numerical simulations and experiments. The numerical simulation results show that the cavitation bubble undergoes a process of compression expansion under the action of positive and negative alternating sound pressure, and finally collapses. The cavitation bubble would generate micro-jet and shock wave when it collapses, both of which could make the dendrite subjected to an impulse pressure. It is calculated that the impact pressure of the jet on the dendrites is greater than the yield strength of the primary dendrites, therefore it would break the dendrite. Under the action of acoustic stream, these small crystals are uniformly dispersed throughout the melt as new nucleation, thereby increasing the nucleation rate of the melt and inhibiting grain growth. Besides, the ratio of the bubble radius to the distance from the dendrites is related to the magnitude of jet and collapse time of the bubble. With the decrease of the ratio, the impedance deformation of cavitation bubbles becomes more obvious and the deformation rate of bubbles is slowed down, the time from jet formation to final collapse increases. In addition, the ultrasonic acoustic pressure would also affect the collapse time. The experimental results show that the crystal grains in the cladding layer were refined by ultrasonic vibration. In addition, the microhardness of coating is significantly improved by the ultrasonic vibration.

Poster: Fatigue life of 32CrNi3MoVE alloy subjected to laser shock peening under rotary bending fatigue test

Yong Wang, Zhibing Liu, Xibin Wang

Beijing Institute of Technology, Beijing, China

Abstract：

32CrNi3MoVE alloy was widely applied in deep-bore parts of engineering because of its high strength and toughness. Surface integrity was an important factor for the fatigue life and reliability of 32CrNi3MoVE alloy, and surface integrity of 32CrNi3MoVE alloy was improved by laser shock peening (LSP). The effects of LSP on the surface integrity and fatigue property of 32CrNi3MoVE alloy were studied in this paper. The surface integrities before and after LSP were characterized by roughmeter, hardmeter and X-ray diffraction instrument. Microstructure before and after LSP and after mechanical testing was characterized by using scanning electron microscopy (SEM), electron backscatter diffraction (EBSD), transmission electron microscopy (TEM). The fatigue limits under 10^7 cycles of 32CrNi3MoVE alloy after LSP were tested by rotary bending tester. and the mechanism of LSP was also discussed. The rotary-bending fatigue results perform the scattered S-N data, flat S-N fitting curve and an excellent fatigue limit reached at 623 MPa. SEM results exhibit an obvious transition between stable crack growth and fast fracture surface. The fatigue limit of specimens after LSP is increased by 41% compared to that of the untreated ones. It is because LSP can decrease the roughness and improve the surface integrity, then leads to deep residual compressive stress field and surface hardening field. TEM analysis indicates that dislocation glide and mechanical twinning are the mainly deformation mechanism. The interlamellar and translamellar fracture result from dislocation pile-up and the inclined slip band or mechanical twinning, respectively.

Poster: Laser Deposition of Thin Al-Si Photo-Voltaic Coatings

Ruslan Zhuk[1], Qunli Zhang[2,3], Mykola Anyakin[1,2], Ruslan Zhuk[1,2], Jianhua Yao[2,3]

[1]National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Imstitute", Kyiv, Ukraine

[2]Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, China

[3]Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, China

Abstract：

Application of laser beam may increase the efficiency, productivity and versatility of metal deposition and metal coating techniques. This work is dedicated to the investigation of technological processes of pulsed laser deposition of silicon containing materials on a thin (average thickness - 10 microns) aluminum substrate. Waste material of silicon manufacturing (powder, fragments and splinters of silicon poly- and mono-crystals) and silicon dioxide (quartz sand) are used as a target material for laser beam to create a plasma plume with consequent deposition of silicon particles on aluminum substrate. The efficiency of developed deposition technique was proved with the analysis of deposited layers on a glass substrate in direct and reflected light. It was established that that it is possible to receive deposited silicon layers with thickness from 5 to 100 microns. Moreover, preheating of a subsrate material leads to the formation of uniform Al-Si structures and to the appearance of photo EMF.

Poster: Simulation and Experimental Study of Laser Quenching Characteristics based on Galvanomeer Scanning

K.Y. Chen[1,2], G.L. Wu[1,2], Y. Wang[1,2], J.H. Yao[1,2*]

[1]Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, 310014, China;

[2] Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, 310014, China

Abstract：

The galvanometer-based laser scanning method moves the laser beam at high speed by high-speed deflection of two plane mirrors. Then the laser beam is processed on the surface of the workpiece after focusing by the telecentric lens. Therefore, compared with the conventional laser quenching based on manipulator moveing, the galvanometer-based laser quenching scans faster and more flexible, and can achieve quenching of complex graphics that can be drawn by computer drawing software. In addition, scanning method of the galvanometer-based laser quenching is different from the conventional laser quenching, which also produces different temperature field and phase transition process. This paper compares the difference between samples of laser quenching based on manipulator moveing and galvanometer scanning, and focus on the comparison of the temperature distribution regular of the two laser quenching method through simulation.The results show that the cross-section morphology of samples after quenched in two ways is very different. The hardness of the sample of galvanometer-based laser quenching is slightly higher and the thickness is thinner. It is found that the temperature field of the galvanometer-based laser quenching process is different from the conventional laser quenching by simulation, which is characterized by more intense temperature change rate, multiple cycles of temperature rise and fall process, and larger temperature gradient.

振镜式激光扫描是通过两个平面镜的高速偏转从使激光束高速移动，通过远心透镜聚焦在工件表面上。因此，与传统基于机械手移动的激光淬火相比，振镜式激光淬火扫描更快，更灵活，并且可以通过计算机绘图软件实现复杂图形的淬火。另外，其异于传统激光淬火的扫描方式会产生不同的温度场和相变过程。本文比较了基于机械手移动与振镜扫描的激光淬火样品的区别，并通过仿真重点研究了两种激光淬火方法的温度分布规律。结果表明在两种方式淬火后样品的横截面形貌差异很大，振镜式激光淬火后样品的硬度略高，厚度更薄。通过仿真发现，相比传统的激光淬火，振镜式激光淬火过程温度场具有独特的特点，即更剧烈的温度变化速度，多次循环升降温过程以及更大的温度梯度。

Poster: Development of Tool Monitoring System for Smart Machine Engine

WenYuh Jywe, Chunjen Chen, Chuling Huang, ShinJyun Lin, Minglun Hu, Jiaxing You

National Formosa University, Yunlin, Taiwan

Abstract：

Tool life is the key factor in the machining. It's playing a major role in manufacturing cost. When it comes to the tool life, people always explore the wear and breakage. Tool wear and breakage which are the critical issue for the mechanical field. If the wear and breakage happened, they'll cause the cutting error then influence the surface quality and accuracy. However, to increase the tool life, we must be attention to the parameter before cutting or milling. It will be beneficial to not only decrease the probability of the wear and breakage but save the manufacturing cost. Establishing the system of the monitoring tool state is the main topic for this research. Through the current and vibration signals from the spindle, we'll collect the data to use the mathematic to modeling. Like the method of least squares and artificial neural network. Owing to establish this system, we can monitoring the tool then analyze the state. The system has an advantage in its accuracy and stability. By using the OPC Unified Architecture, we can connect the tool management system and machine tool in time. User could obtain the relative information for the cutting process in advance then prevent the bump damage, undercutting, wear and breakage in the machine tool.

Poster: Fiber Reinforced Composite Manufacturing for Passive Actuators

Dhileep Kumar Jayashankar, Sachin Gupta Sean, Naresh D Sanandiya, Javier G. Fernandez, Kenneth Tracy

Singapore University of Technology and Design, Singapore, Singapore

Abstract：

Structures with capacity for transformation require specially rationalized parts that are designed to mediate or translate this dynamic potential into desirable, specific physical changes. 3D-printing presents an opportunity to materialize such bespoke components, offering freedom of geometry that can be leveraged for making customized assemblies. Considering these advantages, we present a system of 3D-printing fabrication tests results documenting the creation of rotational joints that were instrumental to the dynamic performance of a water-responsive, shape-changing truss assembly. Experimentation of different 3D-printing technologies on a variety of commercial printers (Fortus 450mc, Stratysys J-750, and Mark Two) was conducted in order to compare each of their benefits and disadvantages. In particular, we present the results in printing fibre-reinforced joints on the Mark Two Mark Forged printer, which, although posing several fabrication challenges, resulted in strong and lightweight parts that were crucial for our application. Through a combination of design software, the composite rotational joints were designed and modeled with internal fiber arrangements, and then printed and tested in full-scale, kinematic load-bearing scenarios. The programmed motion of the 2-m -long truss assembly was successfully realized by the performance of thirteen unique joints.

Poster: Effects of DOD Piezoelectric 3D Bioprinting on the Cell Viability in Hydrogels

Ryan Meza, Bingbing Li

California State University Northridge, Los Angeles, USA

Abstract：

The growing number of people in need of organ transplants has increased steadily over the past few decades; however, the number of organ donors has not seen a large increase in about ten years. This shortage of biocompatible, viable organs has lead to an increasingly large number of organ-failure related deaths. As organ donor waitlists continue to increase to an all-time high, 3D bioprinting has emerged as a promising technological advancement to possibly solve this problem. Tissue engineering through freeform fabrication has provided an opportunity to have an unlimited supply of biocompatible tissues and organs using one's own cells. This opportunity has led to the development of various 3D bioprinters, each requiring specific bioinks capable of securely encapsulating cells. Of all the different biofabrication methods, inkjet printing has emerged as a promising bioprinting technique because it can be easily scaled up to dispense biological fluids as needed, eliminate waste, and allow a good spatial printing resolution. As one of the most widely adopted techniques for cell printing, inkjet printing could achieve a satisfactory post printing cell viability. The specific objective is to investigate the printability and droplet formation process (in terms of droplet size, velocity, and satellite formation using a time-resolved imaging approach) during the DOD inkjetting of biomaterials. Biomaterials used in the study consist of a widely used material known as Sodium Alginate. Multiple concentrations were studied to determine the effect on the material's printability when altering the piezoelectric printing parameters.

Poster: An Optical Geometric Errors Measurement System for Linear Guideway Assembly and Alignment

WenYuh Jywe[1,2], BorJeng Lin[1,2], HsuehLiang Huang[1,2], ChiaMing Hsu[1,2], YuWei Chang[1,2], ChingYing Chiu[1,2], JiaHong Chen[1,2]

[1]Department of Automation Engineering, National Formosa University, Yunlin, Taiwan

[2]Smart Machine and Intelligent Manufacturing Research Center, National Formosa University, Yunlin, Taiwan

Abstract：

The traditional measurement tools used for geometric error inspection of a linear guideway are granite reference blocks (square, tri-square, straight edge, parallels, etc.) plus a dial indicator, which are heavy, easily scratched, single-purpose, and low-accuracy compared to laser instruments, especially for the case of long-travelling measurements. A laser interferometer is the most reliable instrument for error measurement of displacement, straightness, yaw and pitch; however, it can only measure one error at one time with a time-consuming setup process. In view of literature, the repeatability of geometric error measurements using a pentaprism could be further improved by introducing a calibration mechanism to detect the altitude angle between the incident beam and the pentaprism. Therefore, two methods are proposed in this study for calibrating the above altitude angle: the first method is designed for ease of use based on Michelson principle using a laser interferometer as the light receiver, and the second one is aimed for high calibration repeatability based on autocollimator principle using QD to replace the light receiver.

Poster: Design of Production scheduling system for Flexible Manufacturing System

WenYuh Jywe, ChunJen Chen, ChuLing Huang, ShinJyun Lin, MingLun Hu, JiaXing You

National Formosa University, Yunlin, Taiwan

Abstract：

With the development of Industrial 4.0 technology and Flexible Manufacturing System, more and more enterprises were transformed their production system into automated production, the production requires a variety of different processing conditions and machine intelligence, a good production scheduling and management are the key point of a factory for dealing with emergent orders or orders fulfillment. This research is to develop a production scheduling system of the Smart Machine Client (SMC) in Smart Machine Engine system which was developed by our laboratory. This scheduling system can decide the status of the machine and the robot arm, automating dispatch list, satisfying with delivery on schedule, reducing overall processing time and rating of capacity utilization. Visual Studio C# and based on Genetic algorithm (GA) was used for scheduling problems with minimizing makespan, total tardiness, total flow time and multiple objectives. This system obtains order data, machine data and Bom data, creating schedules for manufacture, inserting and drawing orders and detecting machine status. It can display various processing information to users, providing enterprises with more efficient production, manufacturing and iii management operations.

Poster: An Analytical Model for Prediction of Bend Angle in Laser Forming based on Strain Energy Principle

Sujit Mulay, Vineet Paliwal, N. Ramesh Babu

IIT Madras, Chennai, India

Abstract：

Laser forming is a modern technique used to manufacture sheet metal parts of advanced materials by localized laser heating. The process offers high flexibility and accuracy over conventional forming by eliminating the need for tooling and enhancing the formability without any springback effect. Due to these advantages, laser forming is receiving applications in aerospace, automotive, micro-electronics and shipbuilding industries for manufacturing of micro and macro sheet metal parts. For efficient and effective use of laser forming for industrial applications, a simple analytical model is required, that can explain the deformation mechanism and effect of various process parameters on the bend angle. In the present work, a novel analytical model is proposed to predict the bend angle of a sheet during a single laser scan. The proposed model is based on the principle of strain energy stored in the sheet during localized laser heating. Bend angle is computed by using the fundamental bending equation and process parameters. In order to validate the model, the predicted bend angle is compared with the experimentally measured bend angle and also with the published literature results. The results show, the proposed model is computationally efficient and provides accurate results with a maximum error of 10%. The proposed model can be extended for multi-pass laser forming and for selecting various process parameters efficiently.

Poster: Surface Patterning of Tungsten Carbide using Powder-mixed EDM

Sai Dutta Gattu, Jiwang Yan

Keio University, Yokohama, Japan

Abstract：

Electric discharge machining is an efficient method for transferring complex patterns on to a surface regardless of its hardness as long as it is electrically conductive. Tungsten carbide (WC-Co) possesses excellent mechanical properties, such as high hardness and melting point, and finds various applications in industries. Surface patterning of tungsten carbide using EDM is difficult due to high electrode wear rate (EWR). Previous studies have indicated that by making the discharge effects in a single pulse more uniform, powder-mixed EDM (PMEDM) can largely improve material removal rate (MRR) and reduce electrode wear rate. In this study, we have attempted to study the optimum parameters of PMEDM: powder material, powder size, concentration as well as of discharge parameters: discharge current, pulse on and off times, WC-Co grain size and Co concentration, for the accurate transfer of three-dimensional patterns onto the WC-Co mold surface. Study has been conducted on transferring various shapes of patterns such as sinusoidal, spherical and array, and optimum conditions has been listed

Poster: Experimental Analysis of Compressive Failure Load in Single-Lap Hybrid Joint (Bonded /Bolted) of Green Composites

Mridusmita Roy Choudhury, Kishore Debnath

NIT Meghalaya, Shillong, India

Abstract：

In this study, the strength of a single-lap hybrid joint (bonded/bolted) of green composites (bamboo fiber/PLA) has been studied by analysing the compressive failure load of the joint specimen. The mechanical fastening and adhesive bonding are mostly applied for joining of polymer composites. However, the hybrid joints are emerging for joining of polymer composites as it prevents the premature failure of the joint. In this work, the green composites have been fabricated by film stacking method in a compression moulding set-up. The important factors affecting the strength of the hybrid joint such as overlapping length of the specimen (2, 4, and 6 cm) and width of the specimen (2, 2.6, and 3.2 cm) have been studied for epoxy, polyurethane and parent polymer used for joining of developed green composites. The hole in the specimen required for the bolted joint has been obtained by conventional drilling using 8-facet drill bit (solid carbide) at a spindle speed of 2000 RPM and feed of 45 mm/min. The steel bolt (BSW 5/16²) has been used for mechanical fastening at the center of the overlap region of the composite specimens at bolt fastening torque of 20 N-m. From the experimental work, it was found that the failure load increases with an increase in the overlapping length and width of the specimen. The failure load of the joint specimen in compression loading was also found to be more for epoxy as compared to the PLA and polyurethane used for the purpose of joining.

Poster: Influence of Process Parameters on Weld Quality and Evolution of Microstructure, Microhardness in Laser Welding of NiTinol-SS304 Dissimilar Combination

Susmita Datta, Mohammad Shahid Raza, Chirikuri Kishore, Partha Saha

Indian Institute of Technology Kharagpur, Kharagpur, India

Abstract：

Both NiTinol and SS304 are extensively used in biomedical industries. Dissimilar welding of NiTinol with SS304 is not widely reported. In this experimental work dissimilar combination of NiTinol and SS304 for joining with the help of fiber laser was studied. The aim of this study was to understand the effect of laser welding process parameters on the quality of dissimilar joint of SS304 and NiTinol. Laser power and scan speed were selected as input variables, and top bead width, bottom bead width, microhardness of the bead were considered as output variables. Statistical regression analysis was carried out to determine the input-output relationship. The obtained equation was found to be adequate for predicting the output variables within the working range of the input variables.

Poster: Thermal and morphological analysis of the effect of different shrouding environment during laser cutting of gas-filled closed cell aluminium foam

Mohammad Shahid Raza, Susmita Datta, Jogender Singh, Partha Saha

Indian Institute of Technology Kharagpur, Kharagpur, India

Abstract：

Closed cell aluminium foam, a porous structure, is effectively used for insulation, structural applications, packaging and filtering. Cutting of Al foam with the help of fiber laser is an efficient method of cutting metallic foam due to inherent advantages of fiber laser. Laser cutting of Aluminium foam was carried out using a 2 kW fiber laser system for varying process parameters and different assist gas environment. Foam generation processes use different foaming agents that result in generation of gas filled closed cell metal foams. During laser cutting process, these gases interact with assist gas which results in in-situ reactions, generating different kerf quality (kerf width and taper percentage). The present research analyses the interaction of the assist gases (Ar, N_2 and O_2) on the kerf quality. The cut-quality was analyzed using optical microscopic image, SEM, EDS and XRD techniques. Thermal cycles were recorded to understand the occurrences of different in-situ reactions, due to interaction of different cutting gas and the foam entrapped gas. Though nitrogen environment gives better result for Al sheet cutting, for cutting of Al foam argon environment produced much better cut quality in comparison with oxygen and nitrogen environment. From temperature signal it was clear that highest temperature was obtained for oxygen environment due to exothermic reactions. XRD analysis showed the formation of different phases and compounds in the cut section for different gas environment. From the study it could be concluded that inert gas atmosphere was capable of producing much better cut-quality of Al foam.

Poster: Study on Laser Beam Butt Welding of NiTinol Sheets and Optimization of Process Parameters Using Desirability Function Analysis and Metaheuristic Techniques

Susmita Datta, Mohammad Shahid Raza, Amit Kumar Das, Partha Saha, Dilip Kumar Pratihar

Indian Institute of Technology Kharagpur, Kharagpur, India

Abstract：

Proper joining techniques of NiTinol, a widely used functional advanced material in many fields, would provide increased design flexibility among design engineers in terms of smart design for multifunctional systems. Most of the researches in this field focus on the welding techniques of NiTinol which can retain the superior properties, such as shape memory effect, pseudoelasticity, of the material after welding. Laser welding is most widely used joining technique for this material. The effects of process parameters on the bead geometry, microstructure, new phase formation and mechanical properties in laser welding of two mm thick NiTinol sheet in butt-joint configuration were established through this study. Laser power, scan speed and focal position were considered as input parameters, whereas bead area and microhardness value of the bead were taken as output parameters. Statistical regression analysis was performed in order to establish the input-output relationships. Optimization technique was applied in order to get the minimum weld area satisfying the condition of minimum deviation of microhardness of the weld area from that of the parent material. This was formulated as a constrained optimization problem and solved using four metaheuristic techniques, such as Genetic algorithm (GA), Particle swarm optimization (PSO), Jaya algorithm, Bonobo Optimizer (BO). The results obtained from these methods were compared with one traditional method of optimization named desirability function analysis. A good agreement was found between the results predicted by optimization tools and the experimental results.

Poster: Structure and Corrosion Behavior of TiAlN/CrNNanoscale Multilayer Coatings

Lijun Wang[1,2], Mengchao Wang[1], Hui Chen[1 *]

[1] Key Laboratory of Advanced Technologies of Materials（Ministry of Education）, School of Materials Science and Engineering, Southwest Jiaotong University, Chengdu 610031, China

[2] Equipment Manufacturing Institute, Chengdu Vocational & Technical College of Industry, Chengdu 610218, China

Abstract:

This study focuses on improving the corrosion resistance of the coatings using a layered design method. The different corrosion behaviors could be extracted for nanoscale multilayer coating (TiAlN/CrN) and single coatings (TiAlN and CrN), comparing with these microstructure and electrochemical properties. Based on the characteristics of microstructure, electrochemical response and corrosion morphology, it may provide a reference for the development of new anti-corrosive films. TiAlN/CrN multilayer coating and single coatings TiAlN, CrN were deposited on 316L stainless steel by multi-arc ion plating. For TiAlN/CrN multilayer coating, the almost 50nm Cr film was first deposited as a transition layer, and then CrN and TiAlN films were alternately deposited with a single layer thickness of 10nm. The effects of the layered design on the electrochemical behavior of the TiAlN/CrN multilayer coatings were investigated in a neutral saline (3.5% NaCl) solution, for which potentiodynamic polarization and electrochemical impedance spectroscopy were employed. The single TiAlN and CrN coatings and 316 stainless steel were regarded as comparative group. The surface morphology and structure of the coatings were analyzed by scanning electron microcopies (SEM), X-ray diffraction (XRD) and transmission electron microscopy (TEM). After the corrosion test, the surface morphology and composition of the coatings were examined by the scanning electron microscopy with an energy dispersive spectroscopy. The results showed that the TiAlN/CrN multilayer coating exhibit superior corrosion resistance compared with 316L stainless steel and single coatings. The TiAlN/CrN multilayer coating exhibited a face centered cubic structure and (200) preferred orientation. Compared with the substrate and monolayer films, the corrosion potential of multilayer film shifted positively and the corrosion current density decreased. The roles of the layered design in enhancing the corrosion resistance can be summarized as: (a) inhibiting the growth of the columnar crystal and (b) forming passive films with compactness.

Poster: Numerical Simulation and Experimental Research of Laser Cladding 316L Stainless Steel

H.H. Ge[1,2], C. Ye[1,2], F. Luo[1,2], H.Z. Xu[1,2], J.H. Yao[1,2*]

[1]Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, Zhejiang 310014, China;

[2]Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, Zhejiang 310014,China;

Abstract：

A three-dimensional transient model was adopted to simulate the dynamic growth of the cladding layer and the evolution process of the molten pool.Consider the energy loss of convection and radiation,various source terms were compiled by the Flunet user-defined function. The CLSVOF method was used to caputre the gas-liquid interface. The feature paramenters of the cladding layer were obtained by orthogonal experiments.The simulation results showed an inward flow in the molten pool driven by Marangoni force.The height and depth of the cladding layer were taken as the comparison objects. The numerical simulation results were consistent with experimental results under different combinations of process parameters.

采用三维瞬态模型模拟了单道单层激光熔覆过程熔覆层的动态生长以及熔池的演化过程。通过 Fluent 用户自定义函数编写了相应的移动热源模型，熔池流动的驱动源项以及对流传辐射的能量损失。模拟过程采用 LEVEL SET-VOF(CLSVOF)动态追踪熔覆层与空气相界面。通过正交实验获得熔覆层的特征几何参数，用于验证数值模型的正确性。模拟结果表明，激光熔覆熔池在 Marangoni 力的驱动下引起由外向内的环流。以熔覆层的熔高，熔深为两个形貌参数作为比较对象，在不同工艺参数组合下数值模拟结果与实验结果较为相符。

Poster: Effect of C Element on Microstructure and Properties of Fe-Cr-Ni-Si-C Laser Cladding Layer

Guofang Zhu[1,2]，Gang Dong[1,2]，Lei Shen[1,2]，Zhiwei Wu[1,2]，Jianhua Yao[1,2]

[1] Institute of Laser Advanced Manufacturing, Zhejiang University of Technology，Hangzhou, Zhejiang 310014, China；

[2] Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, Zhejiang 310014, China

Abstract：

In recent years, with the continuous development of the manufacturing industry, it has become a new topic of concern to control the microstructure and mechanical properties of steel by controlling the composition and content of elements. Moreover, the carbon content has a great influence on the microstructure and properties of the iron-based alloy. The microstructure and properties of iron-based alloy cladding layers with different carbon contents were studied. The effects of carbon on the microstructure and properties of iron-based cladding layers were compared and analyzed, and data were accumulated for industrial applications. The effects of carbon on the phase, macroscopic morphology and microscopic microstructure of the laser cladding layer were investigated by X-ray diffraction (XRD), optical microscopy (OM) and scanning electron microscopy (SEM). According to the service conditions of the components in different working conditions, the Vickers hardness tester and the friction and wear tester are used to test the hardness and wear resistance of the laser cladding layer.

近年来，随着制造业的不断发展，通过控制微量元素成分及含量使钢材获得良好的组织和力学性能成为令人关注的一项新课题，而且碳元素含量对铁基合金的组织及性能影响较大。为此研究了不同碳含量铁基合金激光熔覆层的组织及性能，对比分析了碳元素对铁基熔覆层的组织及性能的影响，为其工业应用积累数据。采用 X 射线衍射仪（XRD）、光学显微镜（OM）以及扫描电子显微镜（SEM）等方法，研究了碳元素对激光熔覆层的物相、宏观形貌以及微观显微组织的影响。根据零部件在不同工况中的服役情况，通过维氏硬度仪、摩擦磨损测试机，重点对激光熔覆层的硬度以及耐磨性能进行测试。

Poster: Study of Coating Technology of Laser Cladding Single Layer of 42CrMo Bearing Steel with Large Thickness and Low Dilution Rate

Jiyu Du

Zhejiang University of Technology, China

Abstract：

Laser cladding technology was used to fabricate single layer of large thickness and low dilution rate cladding layer on 42CrMo bearing steel surface by semiconductor fiber coupled laser. By this method, single layer of large thickness, high hardness, low dilution rate, high wear resistance and high corrosion resistance were obtained. In the process of preparing cladding layer, the optimum technology of single channel laser cladding with large thickness and low dilution rate is explored through the changes of spot dispersion, the comparison of coaxial powder feeding and pre-laid powder laser cladding, and the method of laser cladding at different substrate temperatures. The temperature field is simulated by ANSYS simulation software, and the temperature gradient changes of different process parameters during cladding process are explored. Impact. The effects of laser cladding power, scanning speed and powder feeding amount on the morphology of single cladding layer were studied by orthogonal experiments. High power, medium and low speed laser cladding experiments were carried out by Z-axis lifting positive defocusing method, and the difference of the dilution rate of cladding layer obtained by preset powder was compared. The effect of matrix temperature on dilution rate and heat affected zone (HAZ) of 42CrMo bearing steel was studied by liquid nitrogen cooling matrix. The mechanism of the effect of substrate temperature on heat conduction of 42CrMo bearing steel was revealed, and the dilution rate and HAZ of laser cladding were controlled. The microstructure of the coating was studied by means of OM, XRD and SEM. The mechanical properties of the coatings were studied by Vickers hardness tester and wear tester. The results showed that the coatings were dense, without cracks and pore defects. The thickness of the coatings was over 3 mm, the dilution rate was about 5% and the heat affected zone was reduced. The coatings had good metallurgical bonding with the matrix. The average hardness of the cladding layer is about 810HV, which is about 2.3 times higher than that of the matrix. The wear resistance of the cladding layer is obviously improved compared with that of the matrix.

Poster: Effects of Ultrasonic Vibration on Laser Remanufactured Microstructure of Inconel 939 Superalloy

Zhehe Yao[1,2], Xijiang Lu[1,2], Xiaowen Yu[1,2], Caoqi Zhang[1,2], Jianhua Yao[1,2]

[1] Institute of Laser Advanced Manufacturing, Zhejiang University of Technology，Hangzhou, Zhejiang 310014, China；

[2] Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, Zhejiang 310014, China

Abstract:

Inconel 939 nickel-based superalloys is provided with excellent high temperature properties and hot corrosion resistance which is used in a wide range of applications for hot section components of gas turbines. Due to the harsh service environment of the hot section components and the high manufacturing cost, different degrees of damage and even scrapping occur during the service. How to achieve high quality repair of hot section components is a difficult problem to be solved on gas turbines. Laser cladding is an advanced surface modification technology that can be used to metallize new materials on the surface of the substrate to enhance the properties of the substrate. However, defects such as pores and HAZ liquefaction cracks often exist in the cladding layer. Therefore, ultrasonic vibration is introduced in the process of laser cladding Inconel 939 superalloy to regulate the microstructure and defects of the cladding layer. The research shows that the introduction of ultrasonic will refine the microstructure of Inconel 939 superalloy, improve microhardness and accelerate the pores escape and significantly inhibit the precipitation of MC carbides.

Inconel 939 镍基高温合金具有优异的高温性能和耐热蚀性能，在燃气轮机的热端部件上具有广泛的应用。由于热端部件的使用环境恶劣且制造成本高，造成其服役过程中出现不同程度的损伤甚至报废。如何实现对热端部件高质量修复是燃气轮机上亟需解决的难题。激光熔覆是一种先进的表面改性技术，可在基体表面以冶金结合的方式熔覆新材料，增强基体材料的性能，但在熔覆层中常存在着诸如气孔、HAZ 液化裂纹等缺陷并伴随有害相的析出，导致力学性能下降。因此，本文在激光熔覆 Inconel 939 高温合金过程中引入超声振动，对熔覆层微观组织以及缺陷进行调控，研究表明：超声的引入会细化 Inconel 939 高温合金微观组织，提升显微硬度，加速气孔排逸，显著抑制 MC 型碳化物的析出。

Poster: Effect of coating materials on the depth of laser quenching hardened layer

Tang Zhou[1,2], Qunli Zhang[1,2,*], Zhijun Chen[1,2], Wenhua Tong[1,2], Weiwei Jin[1,2], Jian Lin[1,2]

[1]Institute of Laser Advanced Manufacturing, Zhejiang University of Technology

No.18 Chaowang Road, Hangzhou, China 310014

[2] Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, China 310014

Abstract:

In this paper, the thermal properties of the coating materials for laser quenching are studied to control the depth of the hardened layer. The effects of different aggregates and aggregate ratio on the depth of the hardened layer are analyzed. The effect of thermal conductivity of coating materials on the depth of laser hardened layer was studied. The effects of three kinds of aggregates and their different ratios on the depth of laser hardened layer were investigated. On this basis, the effects of different preset thicknesses on the depth of the hardened layer are compared. A quench hardened layer was prepared by laser quenching pre-coating techniques and sampled perpendicular to the laser scanning speed. The overall morphology of the hardened layer was observed by a metallographic microscope, and the effective hardened layer depth Hs was measured by a microhardness tester. By comparing the laser quenching experiment of the external coating and the laser quenching temperature field model of the external coating by COMSOL, the influence of the thermal conductivity of the coating material on the depth of the hardened layer was investigated, and the optimal formulation of the coating material was obtained. The experimental results show that when the absorbance of the coating material is constant, the depth of the hardened layer decreases with the increase of the thermal conductivity; the preset thickness of the coating increases, and the depth of the hardened layer gradually decreases. When the preset thickness is controlled to about 0.02 mm, the depth of the hardened layer is the maximum, and the quenching effect is the best.

本文研究了激光淬火用涂层材料的热物理性能对硬化层深度的调控作用，分析了不同骨料及骨料配比对硬化层深度的影响作用。本文重点研究了涂层材料的导热系数对激光淬火硬化层深度的影响研究，考察了 3 种骨料及其不同的配比对激光淬火硬化层深度的影响研究。在此基础上，比较研究了不同预置厚度对硬化层深度的影响。通过激光淬火预置涂层技术制备了淬火硬化层，从垂直于激光扫描速度方向取样。采用金相显微镜观察硬化层的整体形貌，采用显微硬度计测定有效硬化层深度 Hs。通过将外加涂层激光淬火实验以及采用 COMSOL 建立外加涂层激光淬火温度场模型进行对比，探究了涂层材料的导热系数对硬化层深度的影响规律，得到了涂层材料的最佳配方。涂层材料吸光率恒定时，硬化层深度随着导热系数的增加而减小；涂层预置厚度增加，硬化层深度逐渐减小，当预置厚度为控制在 0.02mm 左右时硬化层深度最大，淬火效果最佳。

Poster: Characterization of Stellite 6 Coating on 17-4PH Substrate by Supersonic Laser Deposition for Cavitation Resistance

Qijian Shi[1,2], Bo Li[1,2], Weilin Wang[1,2], Xuanjie Huang[1,2], Lijuan Wu[1,2], Jianhua Yao[1,2*]

[1] Institute of Laser Advanced Manufacturing, Zhejiang University of Technology, Hangzhou, Zhejiang 310014, China;

[2]Zhejiang Provincial Collaborative Innovation Center of High-end Laser Manufacturing Equipment, Hangzhou, Zhejiang 310014, China;

Abstract：

Due to the excellent comprehensive performance, Stellite 6 is the most widely used cobalt-based alloy. At present， Stellite 6 and WC/Stellite 6 composite coating are usually produced by thermal spraying and laser cladding. During the high-temperature processes, the raw materials are heated up to a molten or partially molten state, which makes it difficult to avoid oxidation, phase change, thermal induced residual stress, cracking, high dilution rate and other drawbacks of high-temperature processes.

In supersonic laser deposition (SLD), laser irradiation was introduced into cold spray process to heat and soften spraying materials and substrate, realizing the expansion of materials range that cold spray can deposit without changing the original structure and composition of spraying materials. In this paper, Stellite 6 coating was prepared on 17-4PH stainless steel by SLD. Microstructure, microhardness and compactness of the coating were examined by scanning electron microscopy, metallographic microscope and Vickers hardness tester. The results show that the coating has advisable density and deposition thickness when laser power is 1200W. The hardening phenomenon occurs during the impact process of the deposited particles. The microhardness is higher with the coating close to the interface.