



CIRP2019

69th GENERAL ASSEMBLY

Birmingham, UK | 18 to 24 August 2019



PROGRAMME

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WELCOME

Dear CIRP Colleagues, Friends and Guests,

Welcome to the 69th CIRP General Assembly (GA) in the city of Birmingham, UK from 18 to 24 August 2019. The GA promises to be an intellectually stimulating and vibrant event with world-renowned scientists / academics and industrial experts presenting the latest advancements in production engineering. It will also provide an international platform to discuss novel ideas and form new partnerships for research. The CIRP family addresses new manufacturing engineering challenges and disseminates good practices across the world.

The UK CIRP delegation is proud to host the GA this year. The GA builds on the UK's strong manufacturing background and will showcase industry, the High Value Manufacturing (HVM) Catapult and leading Universities in the UK. This will be the sixth time the GA is held in the UK following London (1958), Nottingham (1968), Harrogate (1983), Edinburgh (1993) and Manchester (2008). Historically the hub for

the Industrial Revolution in the late 18th century, present day Birmingham is the UK's second most populous city, which boasts a diversified economy encompassing the manufacturing, service, education and technology sectors.

Situated in the 'heart' of England, Birmingham city and its immediate surrounding counties offer a unique cultural experience with exceptional contemporary and heritage attractions to explore and savour, which are reflected in the accompanying persons' programme. The Accompanying Persons' programme will present a mix of British heritage, nature, modern art and shopping experience. Additionally, the enthusiasm and energy of our CIRP UK volunteers will make the programme especially memorable.

We have no doubt that you will have a productive week and wish you a very pleasant and enjoyable stay in Birmingham!

Joint Chairs of the Organising Committee for the 69th CIRP General Assembly



Sein Leung Soo



Rajkumar Roy



ACKNOWLEDGEMENTS

The Organising Committee are grateful to the CIRP family for selecting the city of Birmingham as the venue for the 69th CIRP General Assembly. We are delighted that you could attend the GA!

We would like to thank the CIRP President and CIRP Office for their guidance and assistance throughout the preparation of the event.



CIRP President: Prof. Didier Dumur
(also Secretary General Treasurer)

CIRP Office: Mrs. Chantal Timar-Schubert
(Assistant Secretary General)

Ms. Agnes Chelet
(CIRP Accountant)

The advice and support provided by the entire UK CIRP delegation is gratefully acknowledged.

Our special thanks go to all the CIRP colleagues and authors of the technical papers and keynotes, which exemplify world-class research. We also appreciate the

efforts of our Research Affiliates and Corporate Members in attending as well as contributing to the GA.

The success of a GA is highly dependent on sponsorship and we would like to express our gratitude to all our official sponsors from industry, the HVM Catapult and the UK Research Council for their financial contributions and support. Similarly, to the exhibitors at the GA who are displaying exciting research, ideas and products, thank you.

We wish to take this opportunity to extend our utmost appreciation to everyone involved in the 88 Pianists organising team, especially the young artists / children and their parents as well as the Royal Birmingham Conservatoire, in preparing and delivering a unique display of British talent for the Opening Ceremony performance. Finally, we would also like to thank the GA Secretariat - Janet Adnams and her team for providing excellent support and coordination during preparation of the 69th CIRP General Assembly.

SPONSORS

DIAMOND

DMG MORI

DMG MORI CO. LTD.
www.dmgmori.co.jp/en

Digitization is changing our world both quickly and radically. The switch to digitization requires fundamental further development, which can only be achieved globally and jointly, in strong partnerships and on an equal footing. DMG MORI continues to develop positively – technologically, structurally and culturally. DMG MORI has kept supporting the entire manufacturing world as a leading machine tool company. This process has encompassed a long history of development and challenges. The company now aims to be the No. 1 machine tool company for the customers.



HIGH VALUE MANUFACTURING CATAPULT
hvm.catapult.org.uk

Established by Innovate UK, the High Value Manufacturing Catapult (HVMC) is here to bridge the gap between business and academia, helping to turn great ideas into reality by providing access to world-class research and development facilities and expertise that would otherwise be out of reach for many businesses in the UK. Catapults are a key tool in Innovate UK's range of innovation support for businesses. Each is focused on an area in which the UK has the potential to grow in strategically important global markets. Working through seven world-class centres of industrial innovation, HVMC helps to accelerate new concepts to commercial reality. Through the centres, HVMC has capabilities, which span basic raw materials through to high integrity product assembly processes.

SPONSORS

PLATINUM



**ENGINEERING AND PHYSICAL SCIENCES
RESEARCH COUNCIL (EPSRC)**
<https://epsrc.ukri.org>

The Engineering and Physical Sciences Research Council (EPSRC) is the main funding body for engineering and physical sciences research in the UK, this includes a significant investment in manufacturing research. By investing in research and postgraduate training, EPSRC is building the knowledge and skills base needed to address the scientific and technological challenges facing the nation. EPSRC is part of UK Research and Innovation (UKRI), a new body, which works in partnership with universities, research organisations, businesses, charities, and government to create the best possible environment for research and innovation to flourish. UKRI aims to maximise the contribution of each of their component parts, working individually and collectively. They work with many partners to benefit everyone through knowledge, talent and ideas.

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GOLD



MAKINO MILLING MACHINE CO. LTD.
www.makino.co.jp

Makino Milling Machine Co., Ltd. is recognised as one of the leading technology and service providers in the machine tool industry. The corporation is listed on the Tokyo Stock Exchange and employs more than 4,800 people throughout the Americas, Europe and Asia. Its revenues for the fiscal year ending 31st March 2019 totalled €1.6 billion. Makino's wide range of premium-quality production solutions include machining centres for the production of parts as well as for die and mould manufacturing in a great variety of applications in the aerospace, automotive, off-highway vehicles, industrial components and micro-technology industries.

SPONSORS

TITANIUM



ELEMENT SIX
www.e6.com

We harness the unique properties of synthetic diamond and tungsten carbide to deliver supermaterials that improve the efficiency, performance and reliability of industrial tools and technology. Part of the De Beers Group, we employ over 1,900 people. Our primary manufacturing sites are located in the UK, Ireland, Germany, South Africa, and the US. With over 60 years' experience, Element Six is a global leader in the design, development and production of supermaterials solutions. We work collaboratively with our customers to fully understand their challenges, enabling us to deliver customised solutions within given timescales.



ZYGO CORPORATION
www.zygo.com

ZYGO is a global leader in the design and manufacture of advanced optical metrology systems and ultra-precise optical components and assemblies. A valued partner by its customers for innovative technology, application expertise, and product reliability; ZYGO leverages its core competencies in metrology and optics to enable its customers' success. The Metrology business segment is comprised of three major groups: optical surface profilers, laser interferometers, and stage position metrology. The Optics business segment is comprised of two major groups: Electro-Optics and Optical Components. These groups leverage ZYGO's expertise in optical design and assembly, and high-volume manufacturing of precision optical components and systems.

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SPONSORS

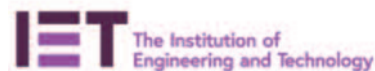
PEARL



RENISHAW PLC.
www.renishaw.com

Renishaw is one of the world's leading engineering and scientific technology companies, with expertise in precision measurement and healthcare. The company supplies products and services used in applications as diverse as jet engine and wind turbine manufacture, through to dentistry and brain surgery. It is also a world leader in the field of additive manufacturing (also referred to as metal 3D printing), where it is the only UK business that designs and makes industrial machines which 'print' parts from metal powder.

EXHIBITORS



CIRP COUNCIL 2019

| | | |
|------------------------------------|--------------------|---------------|
| President | Prof. D. Dumur | (France) |
| Vice President | Prof. M. Mitsuishi | (Japan) |
| Vice President Elect | Prof. H. Hansen | (Denmark) |
| Past President | Prof. D. Lucca | (USA) |
| Secretary General Treasurer | Prof. D. Dumur | (France) |
| Technical Secretary | Prof. B. Lauwers | (Belgium) |
| Council Members | Prof. T. Aoyama | (Japan) |
| | Prof. J. Aurich | (Germany) |
| | Prof. A. Balsamo | (Italy) |
| | Prof. C. Evans | (USA) |
| | Prof. S. Kara | (Australia) |
| | Prof. E. Lutters | (Netherlands) |

STC OFFICERS

| STC | Chairman | Vice Chairman | Secretary |
|--------|---------------|---------------|----------------|
| STC A | J. Sutherland | J. Krueger | Y. Umeda |
| STC C | D. Biermann | S. Melkote | P. Arrazola |
| STC Dn | R. Stark | T. Tomiyama | N. Anwer |
| STC E | P. Bartolo | M. Schmidt | F. Pfefferkorn |
| STC F | J. Cao | G. Hirt | J. Yanagimoto |
| STC G | K. Wegener | H. Yamaguchi | C. Heinzl |
| STC M | E. Budak | A. Matsubara | M. Zaeh |
| STC O | J. Vancza | G. Lanza | T. Tolio |
| STC P | A. Donmez | A. Archenti | Y. Takaya |
| STC S | E. Savio | B. Mullany | R. Leach |

EDITORIAL COMMITTEE

| | | |
|---------------|--------------------------|------------------------|
| D. Aspinwall, | X. Jiang, | R. Roy, |
| D. Brissaud, | S. Kara (Vice-Chairman), | E. Tekkaya (Chairman), |
| M. Davies, | R. M'Saoubi, | T. Tolio, |
| J. Duflou, | M. Nakao, | D-Y. Yang |
| K. Erkorkmaz, | K. Rajurkar, | |

ORGANISING COMMITTEE

Joint Chairs

Sein Leung Soo (University of Birmingham)
Rajkumar Roy (City, University of London)

Sub-committee coordinators

Accompanying persons:

Richard Hood and Carol Kong

Entertainment and 88 Pianists:

Julian Allwood, Philippa Horton, Kirsten Saward and Fran Sergent

Food and beverage:

Aydin Nassehi and Bernard Hon

Sponsorship:

Rajkumar Roy and Srichand Hinduja

Accompanying persons' programme group leaders

Mirela Axinte, Sandra Dankova, Sharmin Leach (lead), Mengyao Luan, John Webster

Members

David Aspinwall, Dragos Axinte, Debajyoti Bhaduri, Adam Clare, Christopher Cleaver, David Curtis, Anjali De Silva, Vimal Dhokia, Xin Dong, Mohamed El-Hofy, John Ahmet Erkoyuncu, Matthew Farnsworth, Joseph Flynn, Luiz Franca, Pasquale Franciosa, Hassan Ghadbeigi, Saurav Goel, Ali Abdelhafeez Hassan, Kevan Holloway, Xiangqian (Jane) Jiang, Gregor Kappmeyer, Blake Kendrick, Kevin Kerrigan, Christopher King, Peter Kinnell, Richard Leach, Wayne Leahy, Andrew Lewis, Lin Li, Zhirong Liao, Ying Liu, Evripides Loukaides, Andrew Mantle, Paul Maropoulos, Haydn Martin, Adelaide Marzano, Paul Mativenga, David McMurtry, Stephen Newman, Daniel O'Connor, Erdem Ozturk, Hannah Robbins, Tian Long See, Alborz Shokrani, Mark Stocker, Rong Su, Wahyudin Permana Syam, Nikolaos Tapoglu, Tetsuo Tomiyama, Sam Turner, Zhen Tong, David Whitehouse

Advisory Board

David Allen, Alan Bramley, Thomas Childs, John Corbett, Roger Crossley, Trevor Howes, Joseph McGeough, Pat McKeown, Graham Peggs, Brian Rowe, David Williams

GA Secretariat

Janet Adnams

PRACTICAL INFORMATION

Venue

The International Convention Centre (ICC)
8 Centenary Square
Birmingham
B1 2EA

Date

18 to 24 August 2019

CIRP Secretariat

The CIRP Office and President's Suite is located in the 'Media Suite' on Level 4 of the ICC

Mail and messages

Messages and announcements will be posted on the noticeboard in the Registration Area

Registration and Enquiries Desk

The Registration and Enquiries Desk is situated in the main foyer area (between Halls 1 and 3) on Level 4 of the ICC.

Note: There are 2 main entrances to the ICC, one at each end of the building; (i) Centenary Square Entrance (from city centre direction) on Level 3 and (ii) Brindleyplace Entrance (from canal and most hotel directions) on Level 2. When entering from either entrance, walk along the Central Mall towards the escalator / stairs in front of Starbucks (on Level 3) in the centre of the building. Go up the escalator or stairs to Level 4 for the Registration Desk.

Opening Hours:

| DATE | TIME |
|----------------------|---------------|
| Sunday, 18 August | 14.00 – 20.00 |
| Monday, 19 August | 08:00 – 19:00 |
| Tuesday, 20 August | 08:00 – 18:00 |
| Wednesday, 21 August | 08:00 – 18:00 |
| Thursday, 22 August | 08:00 – 17:00 |
| Friday, 23 August | 08:00 – 17:00 |
| Saturday, 24 August | 08:00 – 16:00 |

Public Transportation

The ICC is less than 10 minutes walk to New Street station, which is the main railway station in Birmingham for both intercity and local train lines. The other 2 major city stations are Snow Hill and Moor Street stations, which are both within 15 minutes walk from the ICC. Please note that the first trains and buses on Sundays start at 8.30 am.

Parking

Car parking is available at the nearby Arena Birmingham Car Park (King Edward's Road, B1 2AA) or the multi-storey Q-Park Brindleyplace (Brunswick Street, Birmingham B1 2JF). Details of car park charges and pre-booking options can be found at the following websites:

Arena Birmingham:

www.arenabham.co.uk/your-visit/parking

Q-Park Brindleyplace:

www.q-park.co.uk/en-gb/cities/birmingham/brindleyplace

PRACTICAL INFORMATION

On-site Registration Fees

Access to all General Assembly sessions and activities will only be permitted subject to registration. All prices and transactions are in British Pound Sterling (£).

| | | |
|-----------------------------|--------------|-------|
| Delegate | Part I & II | £1150 |
| | Part I only | £900 |
| | Part II only | £780 |
| Accompanying Person* | Part I & II | £700 |
| | Part I only | £520 |
| | Part II only | £450 |

**On-site registration for the Accompanying Persons' programme will be subject to availability and is not guaranteed. Please ask staff at the Enquiries Desk.*

Changes between Delegate and Accompanying Persons' programmes are not allowed. Day tickets for CIRP Members to the General Assembly as well as individual tickets to the Assembly Dinner will be available. Tickets to the Assembly Dinner must be booked at least a day before the event.

GA day ticket for CIRP Members £275

Individual ticket for Assembly Dinner £125

Payments for on-site registration can be made in cash (£) and credit card.

Accepted credit cards: VISA, Mastercard

ITEMS INCLUDED IN THE FEES

Delegate Part I & II

Attendance at all sessions from 19th to 24th August, programme booklet, conference bag, list of participants, lunches and coffee break refreshments during conference days, Welcome Reception on Sunday 18th August, Assembly Dinner on Wednesday 21st August, Farewell Dinner on Saturday 24th August and return transportation from the ICC to the Farewell Dinner venue.

Delegate Part I only

Attendance at all sessions from 19th to 21st August, programme booklet, conference bag, list of participants, refreshments, lunches and coffee break refreshments during conference days, Welcome Reception on Sunday August 18th and Assembly Dinner on Wednesday 21st August.

Delegate Part II only

Attendance at all sessions from 22nd to 24th August, programme booklet, conference bag, list of participants, lunches and coffee break refreshments during conference days, Farewell Dinner on Saturday 24th August and return transportation from the ICC to the Farewell Dinner venue.

PRACTICAL INFORMATION

Accompanying Person Part I & II

Attendance at the Opening Session on Monday 19th August, participation in the planned tours with lunches included from Monday to Friday, 19th to 23rd August, programme booklet, conference bag, list of participants, Welcome Reception on Sunday 18th August, Assembly Dinner on Wednesday 21st August, lunch and Farewell Dinner on Saturday 24th August and return transportation from the ICC to the Farewell Dinner venue.

Accompanying Person Part I only

Attendance at the Opening Session on Monday 19th August, participation in the planned tours with lunches included from Monday to Wednesday, 19th to 21st August, programme booklet, conference bag, list of participants, Welcome Reception on Sunday 18th August and Assembly Dinner on Wednesday 21st August.

Accompanying Person Part II only

Participation in the planned tours with lunches included from Thursday to Friday, 22nd to 23rd August, programme booklet, conference bag, list of participants, lunch and Farewell Dinner on Saturday 24th August and return transportation from the ICC to the Farewell Dinner venue.

The registration fees do not include flights, transfers from/to the airport, or accommodation.

Badges

The name badges are coloured to indicate the attendee / registration type, as follows:

| ATTENDEE TYPE | BADGE BORDER COLOUR |
|--------------------------------------|-------------------------|
| Delegate for Part I & II | Blue |
| Delegate for Part I only | Half Blue, Half White |
| Delegate for Part II only | Half White, Half Blue |
| Accompanying Person for Part I & II | Purple |
| Accompanying Person for Part I only | Half Purple, Half White |
| Accompanying Person for Part II only | Half White, Half Purple |
| Organising Committee and staff | Red |
| Exhibitor staff | Yellow |
| GA Day / Dinner tickets | Green |

Registration documents and badges are issued at the Registration Desk in the GA venue. For security purposes, badges must be worn at all times inside the Convention Centre and during all of the CIRP GA 2019 sessions, including the social events and Accompanying Persons' programme. Only persons wearing the official CIRP GA 2019 name badges will be admitted to the CIRP meetings, lunches, refreshments, social events and Accompanying Persons' programme.

PRACTICAL INFORMATION

Emergency Contact

Tel: +44 (0)7798870354.

Available 18 – 24 August during Registration Opening Hours only.

Lunches

Lunches for the CIRP GA delegates from Monday to Friday (19th to 23rd August) will be served in Hall 3 on Level 4 of the ICC. Lunch for the CMAG group on Tuesday 20th August will be served in Hall 8b on Level 5 of the ICC. Lunch on Saturday 24th August will be served in Hall 9 on Level 2 of the ICC.

Coffee break

Coffee / tea and light snacks for delegates will be served during breaks in the foyer areas outside Halls 1, 9, 10 and 11 on Levels 2, 3 and 4 of the venue.

Computer Room

Hall 8a is equipped with computers and a printer for delegates use from Monday 19th August to Friday 23rd August. There will also be space available for delegates to work in the room with laptops.

Speakers' Presentations

All speakers are invited to check their presentations in Hall 8a prior to the start of their respective sessions to ensure compatibility before uploading and transfer directly to the appropriate conference room.

All conference rooms are equipped with a data/video projector, screen, PC with internet access, laser pointer, microphones and sound system. Presentation slides should be prepared in widescreen 16:9 format.

If you wish to use your personal laptop, you should check in advance that it is compatible with the installed equipment (software, connectors and format).

IMPORTANT: The projector connector is HDMI. If you would like to use your own laptop with a different connector or if you use a Mac, please ensure that you bring along a suitable adapter.

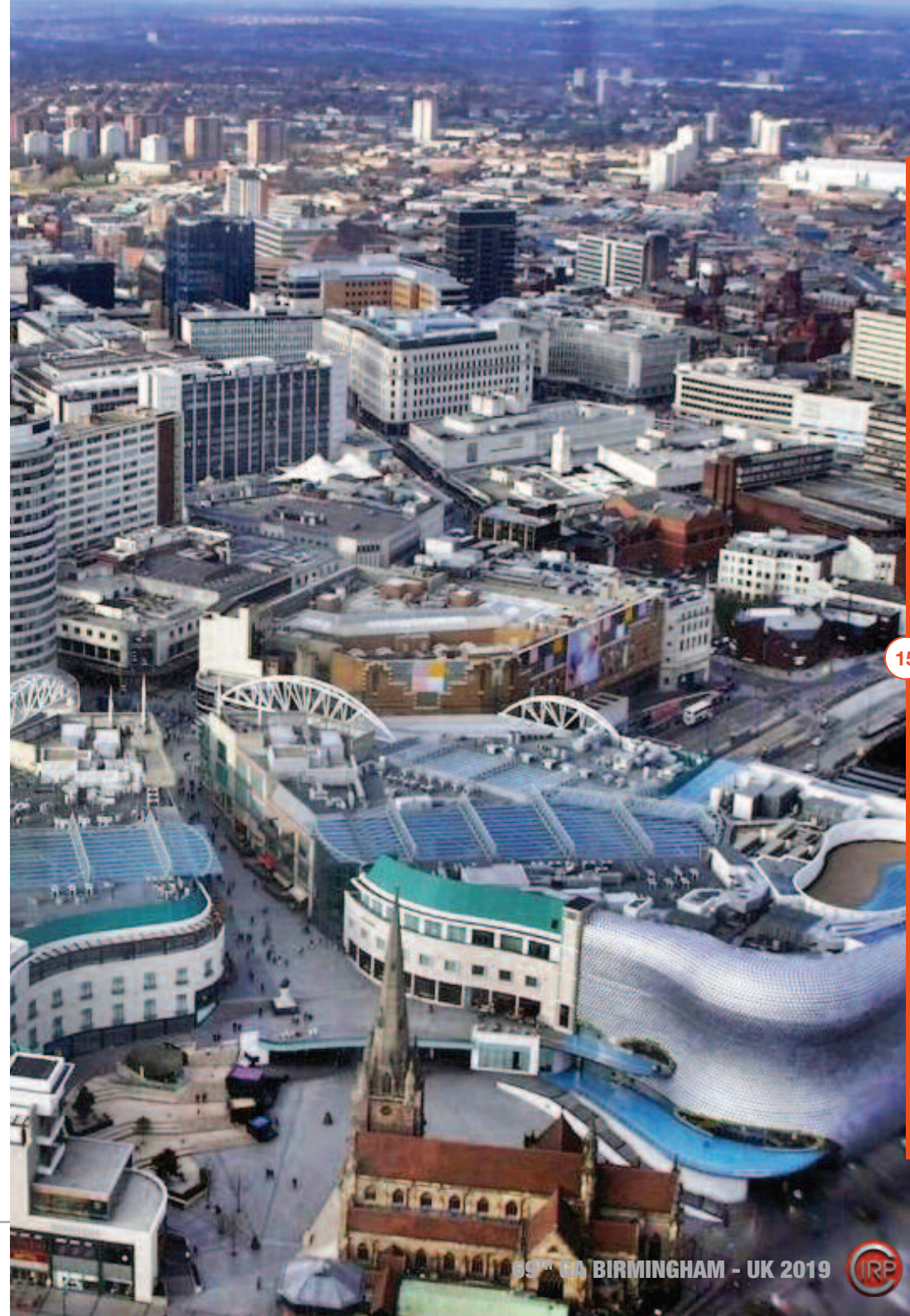
Technical assistance will be available in all of the conference rooms.

Internet Access

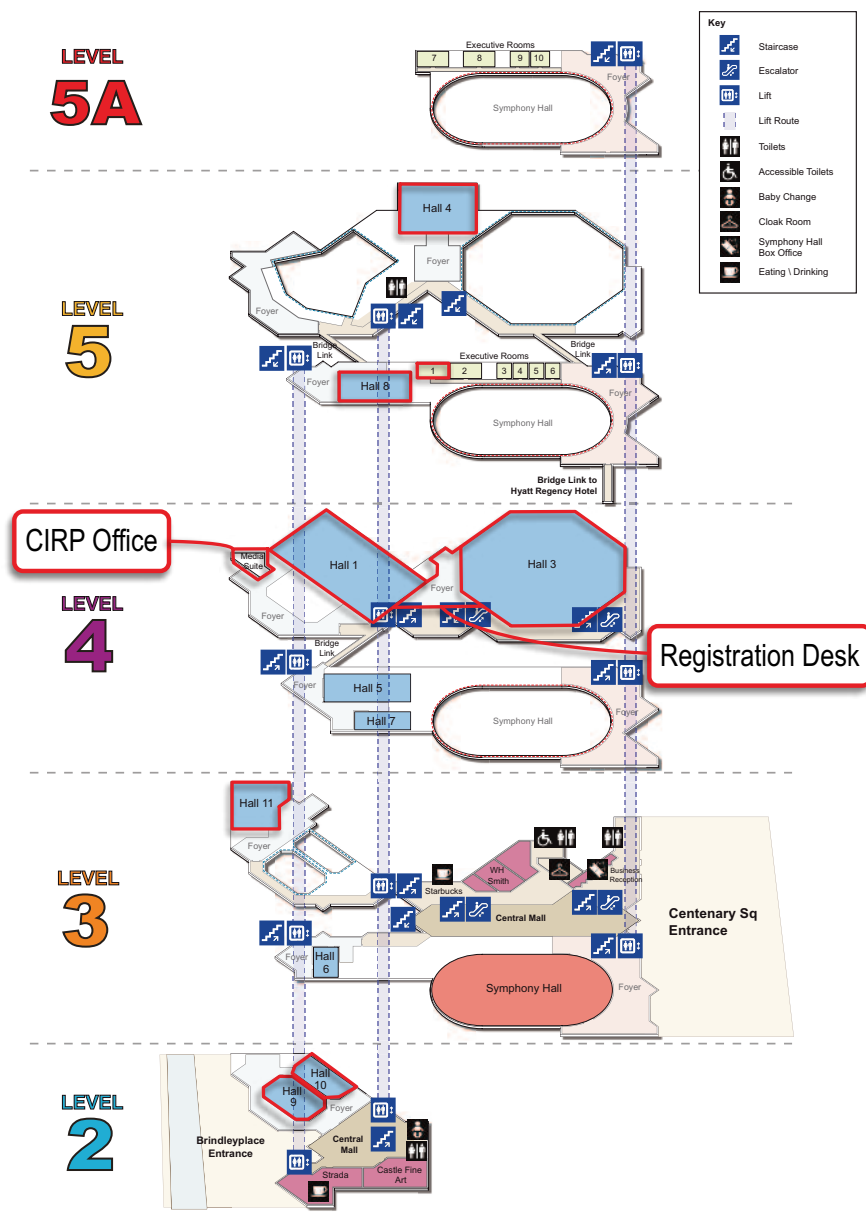
Wi-Fi is available throughout the venue.

Network name: CIRP2019

Password: birmingham2019



VENUE MAP / FLOOR PLAN



ROOM ALLOCATIONS

PART I

| Level | Room | Event |
|-------|------------------|------------------------------------------------------------------------------------------------------|
| 2 | Hall 9 | Session Room |
| | Hall 10* | Session Rooms (10a and 10b) |
| 3 | Hall 11* | Session Rooms (11a and 11b) |
| 4 | Hall 1 | Opening Session / Public Keynotes / Presentation of 70 th CIRP General Assembly in Munich |
| | Hall 3 | Lunch / Assembly Dinner |
| | Media Suite | CIRP Office and President's Suite |
| 5 | Hall 4 | Welcome Reception |
| | Hall 8* | Computer Room (8a) / Corporate Members (CMAG) Lunch (8b) |
| | Executive Room 1 | Board Meeting / Membership Committee / Council Meeting / Senate Meeting |

PART II

| Level | Room | Event |
|-------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2 | Halls 9 | Lunch on Saturday |
| | Hall 10* | STCs (10a and 10b) / Terminology Committee (10a) / Communications Committee (10a) / Biologicalisation CWG (10a) / Urban Factories Production in Cities CWG (10b) / Liaison Committee (10b) / Research Affiliates Meeting (10b) |
| 3 | Hall 11* | STCs (11a and 11b) / Additive Manufacturing CWG (11a) / Industrial Symbiosis CWG (11b) / Cross STC meeting (11a) / General Meeting |
| 4 | Media Suite | CIRP Office and President's Suite |
| | Hall 3 | Lunch |
| 5 | Hall 8* | Computer Room (8a) |
| | Executive Room 1 | Council Meeting |

*Halls 8, 10 and 11 will be divided into 2 separate rooms (designated a and b) for the majority of sessions held in these areas.

GENERAL INFORMATION

Emergency Calls

| FOR | NUMBER |
|---------------------------------------------------------------------------|--------|
| Main Emergency Number | 999 |
| Ambulance, Police, Fire Service (this will work from any mobile phone) | 112 |
| Non-Emergency Number for Police | 101 |
| Non-Emergency Medical Number | 111 |

Security

Street crime is often opportunistic, so making yourself less of a target, moving with purpose and being aware of your surroundings will go a long way to keeping you safe. Plan your route in advance. Carry a charged mobile phone and some cash, and tell someone where you are going. Keep your valuables including your mobile phone, other devices and jewellery hidden. Try to avoid walking alone at night in places such as parks and side streets or any unfamiliar environment.

Medical Assistance

Contact the reception desk at your hotel to ask for medical assistance or phone 111. If at the GA venue, please go to the Registration Desk and speak to staff on duty who will be able to source a first aider.

Drinking Water

Tap water is safe to drink anywhere in the UK unless mentioned otherwise. However, if you prefer, bottled mineral water is available for purchase at convenience stores, supermarkets, station kiosks, etc.

Currency Exchange

The official currency of the UK is the Pound Sterling (£) and it is the only currency accepted when paying by cash. Currency exchange is generally available at hotels, designated foreign exchange banks, large post offices as well as bureau de change outlets in the city centre (typically in major department stores and shopping centres).

Credit Cards, Debit Cards, Travellers' Cheques and ATMs

Major credit cards such as VISA and MasterCard are widely accepted in the UK, while cards such as Diners Club or American Express are only accepted by large retailers. Foreign issued debit cards may be accepted by UK payment terminals but you are advised to check with the retailer before paying. Travellers' cheques are generally not accepted in most shops, restaurants or hotels in the UK. They have to be cashed at major banks, post offices or bureau de change outlets, usually at unfavourable rates.

There are many ATM machines for you to use across the UK and almost every bank has a cash dispenser. Cash machines can also usually be found in supermarkets / shopping centres, post offices, petrol stations and train stations. Cards must have a chip and PIN in order to be accepted by ATMs in the UK. Most ATMs in the UK accept Cirrus, Maestro and VISA cards.

Climate

The daily weather forecast can be found on the UK Meteorological Office website: www.metoffice.gov.uk/public/weather/forecast/map

Electricity / Power Supply

The normal voltage and frequency of the electricity supply in the UK is 230 V and 50 Hz. It is not always safe to use electrical equipment that is rated at a voltage different from the UK supply. Check before you plug it in. Electrical sockets in the UK are 3 pin. Depending on your country, you may require a power socket adapter.

Value Added Tax (VAT)

The VAT rate (consumption tax) for the UK is currently 20% for the majority of purchased goods and services.

Taxis

Fares start at approximately £3 when flagged down with additional costs depending on distance covered and time elapsed. Payment is made when you reach your destination and the exact fare is shown clearly on the meter, for transparency and assurance. Tipping is not necessary at any time when taking a taxi. For those who prefer mobile app based ride hailing services, Uber is available in Birmingham.

Tipping

Tipping is entirely voluntary in the UK but it is customary to leave 10 - 15% of the bill when eating out. However, restaurants often

add on a discretionary service charge (usually 12.5%), especially if you are in a large group, so it is worth checking your bill so that you do not tip twice. It is not necessary to pay a tip for fast food, self-service or takeaway meals.

Smoking

Smoking is strictly banned in all indoor public places and at certain outdoor locations that are 'substantially enclosed', such as football grounds and covered walkways. It is also banned on all parts of a railway station, including open-air platforms. You are allowed to smoke outdoors, but always check surrounding areas for non-smoking signs.

Units of Measurement

The standard units of measurement in the UK is metric (kg, g, l, m, km, etc.), although some British imperial units are still quoted (e.g. pint) when buying drinks such as beer in pubs / bars.

Liability / Insurance

The Organising Committees and/or Conference Organisers cannot accept any responsibility for personal injuries or losses / damage to private property of registered delegates as a result of any cancellations, accidents, illness or other occurrences that may arise in connection to the General Assembly. Delegates are strongly advised to take out their own appropriate travel and medical health insurance prior to travelling.

MAP OF BIRMINGHAM CITY CENTRE



69TH GA BIRMINGHAM - UK 2019

69TH GA BIRMINGHAM - UK 2019

69TH GA BIRMINGHAM - UK 2019

OPENING SESSION PROGRAMME

Monday 19 August 2019, 09:00 – 10:30

Hall 1, Level 4

| | |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 09:00 | Opening Ceremony Performance – 88 Pianists |
| 09:20 | Welcome Address by the Joint Chairs of the Organising Committee Dr. Sein Leung Soo / Professor Rajkumar Roy |
| 09:25 | Opening Address by the CIRP President Professor Didier Dumur |
| 09:40 | Special Lecture: Risk, Responsibility and Innovation – The Challenging Role of Engineers in a Rapidly Changing World Dame Judith Hackitt, Chair of Make UK |
| 10:00 | Presentation of the Taylor Medal Award and General Nicolau Award CIRP President, Professor Didier Dumur |
| 10:20 | General Announcements |
| 10:30 | Coffee Break |



Special Lecture

**Risk, Responsibility and Innovation – The Challenging Role
of Engineers in a Rapidly Changing World**

Dame Judith Hackitt DBE, FREng, FICHEM
Chair, Make UK (formerly EEF)

Chair of Science, Engineering and Manufacturing Technologies
Alliance (SEMTA) Board

Senior Non-Executive Director of HVM Catapult

SYNOPSIS:

Referred to by the Sunday Times as the No-Nonsense Engineer in 2018, Dame Judith Hackitt will reflect on her own extensive experience as an engineer in the Chemical industry, her time as Chair of the Health and Safety Executive (HSE), the independent review of Building Regulations and Fire Safety which she conducted for the UK Government, and her roles with Make UK and the High Value Manufacturing Catapult.

PROFILE:

Dame Judith Hackitt is a chemical engineer and is currently Chair of Make UK, the manufacturers' organisation formerly known as EEF. She is also Chair of SEMTA the UK skills body for Engineering and Manufacturing and senior non-executive director of the High Value Manufacturing Catapult an organisation, which exists to support and encourage innovation in Advanced Manufacturing. She was appointed to the Board of HS2 in April 2019. Dame Judith worked in the chemicals manufacturing industry for 23 years. She joined the UK Chemical Industries Association (CIA) in 1998 and became their Director General in 2002. Following that appointment, she was a senior executive for the European Chemical Industry Association (CEFIC) based in Brussels. Dame Judith served as a member of the Health and Safety Commission between 2002 and 2005 and became Chair of the UK Health and Safety Executive (HSE) in October 2007, serving until March 2016.

The opportunities and the pace of change in manufacturing are exciting but also daunting. She will challenge the audience to see their role in manufacturing in the wider context of delivering solutions, which will truly benefit society – and that means being bold and innovative but also managing risk, taking responsibility and taking our knowledge, skills and ingenuity into other sectors beyond traditional manufacturing.

She was made a Dame in the 2015-16 New Year Honours for services to health and safety and engineering, in particular for being a role model for young women. She had previously been awarded a CBE in 2006 for services to the chemical industries. She was elected a Fellow of the Royal Academy of Engineering in 2010 and has recently been elected as a trustee of the Academy. She is also a Fellow of the Institution of Chemical Engineers and served as President of the Institution of Chemical Engineers (2013-14).

Following the tragic fire that occurred at Grenfell Tower in London in June 2017, Dame Judith was asked by the UK Government to conduct an independent review into Building Regulations and Fire Safety related to high-rise buildings. She began her review in July 2017 and her final report to Government was published in May 2018. In December 2018 the UK Government announced that it would implement the recommendations in the report in full.

Eighty eight pianists

Dear CIRP Delegates,

For a year, we've been looking forward to welcoming you to the UK. Engineers and musicians from across the country have come to our schools to ask us how 88 people could play the same piano at the same time and set an un-beatable world record.

They thought they were going to inspire us as the next generation of engineers. But really, we've inspired them. We've shown them how much more imagination they could bring to their work, how much more creative they could be.

Now we're ready. Come and join us at 9.00am on Monday 19th August in ICC Hall 1.

We want to show you what production engineering can really do – if only you have the imagination.

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PUBLIC SESSION KEYNOTE PAPERS

Monday 19 August 2019, 11:00 – 12:00

Hall 1, Level 4

| | |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11:00 | CROSS-STC KEYNOTE PAPER Manufacturing of Advanced Smart Tooling for Metal Forming Jian Cao (1), Ekkard Brinksmeier (1), Mingwang Fu, Robert X. Gao (1), Biao Liang, Marion Merklein (1), Michael Schmidt (2), Jun Yanagimoto (1) |
| 11:30 | KEYNOTE PAPER STC-C Machining of biocompatible materials - Recent advances Dragos Axinte (1), Yuebin Guo (2), Zhirong Liao, Albert J. Shih (2), Rachid M'Saoubi (1), Naohiko Sugita (2) |

Monday 19 August 2019, 14:00 – 15:30

Hall 1, Level 4

| | |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14:00 | KEYNOTE PAPER STC-G Abrasive Processes for Micro Parts and Structures Jan C. Aurich (1), Benjamin Kirsch, Dinesh Setti, Dragos Axinte (1), Anthony Beaucamp (2), Paul Butler-Smith, Hitomi Yamaguchi (2) |
| 14:30 | KEYNOTE PAPER STC-P Geometrical Metrology for Metal Additive Manufacturing Richard K. Leach (2), David Bourell, Simone Carmignato (2), Alkan Donmez (2), Nicola Senin, Wim Dewulf (2) |
| 15:00 | KEYNOTE PAPER STC-A Symbiotic Human-Robot Collaborative Assembly Lihui Wang (1), Robert Gao (1), Jozsef Vancza (1), Jörg Krüger (2), Xi Vincent Wang, Sotiris Makris (2), George Chryssolouris (1) |

Authors: (1) Fellows (2) Associate Members (3) Corporate Members

SESSION PROGRAMME

SESSION on Life-Cycle Engineering and Assembly (A)

Monday 19 August 2019, 16:00 – 18:00

Hall 11a, Level 3

| | |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16:00 | A1 - Designing assembly lines with humans and collaborative robots: a genetic approach Michela Dalle Mura, Gino Dini (1) |
| 16:30 | A2 - A human modelling and monitoring approach to support the execution of manufacturing operations Marcello Urgo, Marco Tarabini, Tullio Tolio (1) |
| 17:00 | A3 - Deep Learning for part identification based on inherent features Jörg Krüger (2), Jan Lehr, Marian Schlüter, Nils Bischoff |
| 17:30 | A4 - Allocation of Assembly Tolerances to Minimize Costs Yue Wang, Lei Li, Nathan W. Hartman, John W. Sutherland (1) |

SESSION on Life-Cycle Engineering and Assembly (A) *continued*

Tuesday 20 August 2019, 08:30 – 12:00

Hall 11a, Level 3

| | |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08:30 | A5 - System Interaction, System of Systems, and Environmental Impact of Products Shiva Abdoli, Sami Kara (1), Michael Hauschild (1) |
| 09:00 | A6 - Life cycle simulation system as an evaluation platform for multitiered circular manufacturing systems Shozo Takata (1), Keisuke Suemasu, Keito Asai |
| 09:30 | A7 - Integration of product entropy and LCA to screen the potential environmental impacts of complex product systems at the end-of-life stage Julian Rickert, Nicolas von Drachenfels, Felipe Cerdas, Christoph Herrmann (2) |
| 10:30 | A8 - Diversified recycling strategies for high-end plastics: technical feasibility and impact assessment Wim Dewulf (2), Florian Wagner, Ellen Bracquen , Jef R. Peeters , Joost R. Duflou (1) |
| 11:00 | A9 - A methodological approach for manufacturers to enhance value-in-use of service-based offerings considering three dimensions of sustainability Tomohiko Sakao (2), Raphael Wasserbaur, Fabrice Mathieux |
| 11:30 | A10 - A modelling framework for comparing the environmental and economic performance of WAAM-based integrated manufacturing and machining Paolo C. Priarone, Gianni Campatelli, Filippo Montevocchi, Giuseppe Venturini, Luca Settineri (1) |

SESSION on Cutting (C)

Monday 19 August 2019, 16:00 – 18:00

Hall 9, Level 2

| | |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16:00 | C1 - Controlling segmentation in cutting of metals Mojib Saei, Anirudh Udupa, Koushik Vishwanathan, Tatsuya Sugihara, Rachid M'Saoubi (1), Srinivasan Chandrasekar |
| 16:30 | C2 - Dynamics of shear band instabilities in cutting of metals Shwetabh Yadav, Gan Feng, Dinakar Sagapuram / H. Chandrasekaran (1) |
| 17:00 | C3 - Microstructure Based Flow Stress Model to Predict Machinability in Ferrite-Pearlite Steels Mikel Saez-de-Buruaga, Patxi Aristimuno, Daniel Soler, Enrico D'Eramo (3), Amandine Roth, Pedro J. Arrazola (1) |
| 17:30 | C4 - Chip morphology and surface integrity in ultraprecision cutting of yttria-stabilized tetragonal zirconia polycrystal Takumi Okuuchi, Jiwang Yan (2) |

SESSION on Cutting (C) *continued*

Tuesday 20 August 2019, 08:00 – 12:00

Hall 9, Level 2

| | |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08:00 | C5 - Measurement and prediction of through-section residual stresses in the manufacturing sequence of bearing components Vikram Bedekar (2), Rohit Voothaluru, Jeffrey Bunn, Scott Hyde |
| 08:30 | C6 - A quick method for evaluating the thresholds of workpiece surface damage in machining Dongdong Xu, Zhirong Liao, Dragos Axinte (1), Mark Hardy, Rachid M'Saoubi (1) |
| 09:00 | C7 - Effect of the crystallinity of diamond coatings on cemented carbide inserts on their cutting performance in milling Georgios Skordaris, Konstantinos-Dionysios Bouzakis (1), Tilemachos Kotsanis, Apostolos Boumpakis, Fani Stergioudi, Dimitrios Christofilos, Oliver Lemmer, Werner Kölker, Michael Woda |
| 09:30 | C8 - Oxygen-shielded ultrasonic vibration cutting to suppress the chemical wear of diamond tools XinQuan Zhang, Hui Deng, Kui Liu / E. Brinksmeier (1) |
| 10:30 | C9 - Cooling capability of liquid nitrogen and carbon dioxide in cryogenic milling Franci Pusavec, Damir Grguras, Matthias Koch, Peter Krajnik (2) |
| 11:00 | C10 - Flow characteristics of optimized hybrid cryogenic-minimum quantity lubrication cooling in machining of aerospace materials Ahmed Damir, Bin Shi, Helmi Attia (1) |
| 11:30 | C11 - Fluid structure interaction (FSI) modelling of deep hole twist drilling with internal cutting fluid supply Ekrem Oezkaya, Ivan Iovkov, Dirk Biermann (1) |

SESSION on Cutting (C) *continued* ►

SESSION on Cutting (C) *continued*

Tuesday 20 August 2019, 13:30 – 18:00

Hall 9, Level 2

| | |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | C12 - Practical Implementation of Cutting Force Model for Step Drill using 3D CAD data Duong Mai, Byeong-Chan Kwon, Sunglim Ko (2) |
| 14:00 | C13 - Dedicated drill design for reduction in burr and delamination during the drilling of composite materials Naohiko Sugita (2), Liming Shu, Katusyo Kimura, Giichi Arai, Koichi Arai |
| 14:30 | C14 - Increase of chip removal rate in single-lip deep hole drilling at small diameters by low-frequency vibration support Friedrich Bleicher (2), Manuel Reiter, Jens Brier |
| 15:00 | C15 - Cutting of blood clots - experiment and smooth particle Galerkin modelling Yang Liu, Yihao Zheng, Annie Dian-Ru Li, Yao Liu, Luis E. Savastano, Albert Shih (2) |
| 16:00 | C16 - Optimization of subtractive-transformative hybrid processes supported by the technological heredity concept Wit Grzesik (2), Krzysztof Zak, Roman Chudy, Mariusz Prazmowski, Joanna Malecka |
| 16:30 | C17 - Distortion in milling of structural parts Abbas Hussain, Ismail Lazoglu (1) |
| 17:00 | C18 - Chip geometry and cutting forces in gear power skiving Pierce R. McCloskey, Andrew Katz, Luke Berglind, Kaan Erkorkmaz (1), Erdem Ozturk (2), Fathy Ismail |
| 17:30 | C19 - Effects of turn-milling conditions on chip formation and surface finish Kaveh R. Berenji, Umut Karagüzel, Emre Özlü, Erhan Budak (1) |

SESSION on Design (Dn)

Wednesday 21 August 2019, 08:30 – 12:00

Hall 10b, Level 2

| | |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08:30 | Dn1 - Optimised Lattice Structure Configuration for Additive Manufacturing Nadhir Lebaal, Yicha Zhang, Frederic Demoly, Sebastien Roth, Samuel Gomes, Alain Bernard (1) |
| 09:00 | Dn2 - Conceptual manufacturing system design based on early product information Chantal Sinnwell, Nicole Krenkel, Jan Christian Aurich (1) |
| 09:30 | Dn3 - Human factors integration in Manufacturing Systems Design using Function-Behaviour-Structure framework and behaviour simulations Jean-Yves Dantan (2), Ismail El Mouayni, Leyla Sadeghi, Ali Siadat, Alain Etienne |
| 10:30 | Dn4 - Development and operation of digital twins for technical systems and services Rainer Stark (2), Carina Freseemann, Kai Lindow |
| 11:00 | Dn5 - Creation of helicopter dynamic systems digital twin using multibody simulations Damien Guivarch, Emmanuel Mermoz (2), Yoan Marino, Marc Sartor |
| 11:30 | Dn6 - A novel paradigm for managing the product development process utilising blockchain technology principles Nikolaos Papakostas (2), Anthony Newell, Vincent Hargaden |

SESSION on Design (Dn) *continued*

SESSION PROGRAMME

SESSION on Design (Dn) *continued*

Wednesday 21 August 2019, 13:30 – 17:30

Hall 10b, Level 2

| | |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | Keynote Paper Dn - Development capabilities for Smart Products Tetsuo Tomiyama (1), Eric Lutters (1), Rainer Stark (2), Michael Abramovici (2) |
| 14:00 | Dn7 - AI for Design: Virtual Design Assistant Sang-Gook Kim (1), Sang-Min Yoon, Maria Yang, Jungwoo Choi, Haluk Akay, Edward Burnell |
| 14:30 | Dn8 - A Design Method of Data Analytics Process for Condition Based Maintenance Tomoaki Hiruta, Takayuki Uchida, Shinya Yuda, Yasushi Umeda (1) |
| 15:00 | Dn9 - Intelligent Kano classification of product features based on customer reviews Diandi Chen, Dawen Zhang, Ang Liu (2) |
| 16:00 | Dn10 - Maximum length scale requirement in a topology optimisation method based on NURBS hyper-surfaces Giulio Costa, Marco Montemurro, Jerome Pailhes, Nicolas Perry (2) |
| 16:30 | Dn11 - Categorical formulation of mathematical design theories applied to system design processes analysis Hitoshi Komoto (2) |
| 17:00 | Dn12 - An Agile Model for the Eco-design of Electric Vehicle Li-Ion Batteries Peggy Zwolinski, Serge Tichkiewitch (1) |

SESSION PROGRAMME

SESSION on Electro-Physical and Chemical Processes (E)

Tuesday 20 August 2019, 13:30 – 18:00

Hall 10b, Level 2

| | |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | Keynote Paper E - Visualization of Electro-physical and Chemical Processes Masanori Kunieda (1), Ludger Overmeyer (2), Andreas Klink (2) |
| 14:00 | E1 - Improving the accuracy of the blade leading/trailing edges by electrochemical machining with tangential feeding Hao Wang, Di Zhu (1), Jia Liu |
| 14:30 | E2 - Pulse electrochemical discharge machining of glass-fiber epoxy reinforced composite Murali Sundaram, Yu-Jen Chen, Kamlakar Rajurkar (1) |
| 15:00 | E3 - Study of Precision ECM in Stationary Electrolyte using Stamp Flushing Method Miyuki Nakamura, Masanori Kunieda (1) |
| 16:00 | E4 - Surface Enhanced Micro Features Using Electrochemical Jet Processing Adam Thomas Clare (2), Alistair Speidel, Jonathon Mitchell-Smith, Ivan Bisterov, James Murray |
| 16:30 | E5 - One-process Surface Texturing of a Large Area by Electrochemical Machining with Short Voltage Pulses Tomohiro Koyano, Akira Hosokawa, Taishi Takahashi, Takashi Ueda (1) |
| 17:00 | E6 - Sink electrical discharge machining of hydrophobic surfaces Chancheng Guo, Philip Koshy (1), Felipe Coelho, P. Ravi Selvaganapathy |
| 17:30 | E7 - Global integrity in 420 stainless steel by asynchronous laser processing Michael P. Sealy, Haitham Hadidi, Cody J. Kanger, Xueliang Yan, Bai Cui, Joe McGeough (1) |

SESSION on Electro-Physical and Chemical Processes (E) *continued* ►

SESSION on Electro-Physical and Chemical Processes (E) *continued*

Wednesday 21 August 2019, 08:30 – 12:00

Hall 11a, Level 3

| | |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08:30 | E8 - Tailored laser vector fields for high-precision micro-manufacturing Olivier Allegre, Zhaoqing Li, Lin Li (1) |
| 09:00 | E9 - High surface quality micro machining of monocrystalline diamond by picosecond pulsed laser Yasuhiro Okamoto, Akira Okada (1), Atsuya Kajitani, Togo Shinonaga |
| 09:30 | E10 - Functionalisation of titanium alloy surface through oxygen gas jet-assisted gliding arc discharge plasma Kazutoshi Katahira (2), Nobuhito Mifune, Jun Komotori |
| 10:30 | E11 - Photoelectrochemical mechanical polishing method for n-type gallium nitride Zhigang Dong, Liwei Ou, Renke Kang, Huiqin Hu, Bi Zhang (1), Dongming Guo, Kang Shi |
| 11:00 | E12 - Biomanufacturing of customized modular scaffolds for critical bone defects Bahattin Koc, Anil A. Acar, Andrew Weightman, Glen Cooper, Gordon Blunn, Paulo J. Bartolo (1) |
| 11:30 | E13 - Thermography based in-process monitoring of Fused Filament Fabrication of polymeric parts Eleonora Ferraris, Jie Zhang, Brecht Van Hooreweder / H. Haitjema (1) |

SESSION on Electro-Physical and Chemical Processes (E) *continued*

Wednesday 21 August 2019, 13:30 – 18:00

Hall 11a, Level 3

| | |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | E14 - Multi-material laser direct writing of aerosol jet layered polymers Ludger Overmeyer (2), Arndt Hohnholz, Oliver Suttman (3), Stefan Kaierle (3) |
| 14:00 | E15 - Selective Laser Melting Process Optimization of Ti-Mo-TiC Metal Matrix Composites Bey Vrancken, Sasan Dadbakhsh, Raya Mertens, Kim Vanmeensel, Jef Vleugels, Shoufeng Yang, Jean-Pierre Kruth (1) |
| 14:30 | E16 - Temperature Determination in Laser Welding Based Upon a Hyperspectral Imaging Technique Tobias Staudt, Eric Eschner, Michael Schmidt (2) |
| 15:00 | E17 - High-Speed X-ray Investigation of Melt Dynamics during Continuous-Wave Laser Remelting of Selective Laser Melted Co-Cr Alloy Brodan Richter, Christian Werner, Nena Blanke, Niranjana D. Parab, Tao Sun, Frank Vollertsen (1), Frank E. Pfefferkorn (2) |
| 16:00 | E18 - Initial transient phase and stability of annular laser beam direct wire deposition Matjaz Kotar, Makoto Fujishima (3), Gideon Levy (1), Edvard Govekar (1) |
| 16:30 | E19 - Evaluation of surface / interface quality, microstructure and mechanical properties of hybrid additive-subtractive aluminium parts Debajyoti Bhaduri, Pavel Penchev, Khamis Essa, Stefan Dimov, Luke N. Carter, Catalin I. Pruncu, Daniele Pullini / T. Childs (1) |
| 17:00 | E20 - Investigation of novel trochoidal toolpath strategies for productive and efficient directed energy deposition processes Masakazu Soshi, Kyle Odum, Geng Li / B. Lauwers (1) |
| 17:30 | E21 - Investigation of novel metal additive manufacturing process using plasma electron beam based on powder bed fusion Dong-Gyu Ahn, Ho-Jin Lee / D.Y. Yang (1) |

SESSION on Forming (F)

Monday 19 August 2019, 16:00 – 18:00

Hall 11b, Level 3

| | |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16:00 | F1 - Extended Gurson-Tvergaard-Needleman model for damage modeling and control in hot forming Markus Bambach, Muhammad Imran / R. Kopp (1) |
| 16:30 | F2 - Manufacturing efficient electrical motors with a predictive maintenance approach Hannes Alois Weiss, Nora Leuning, Kay Hameyer, Hartmut Hoffmann (2), Wolfram Volk (2) |
| 17:00 | F3 - A new theoretical model of material inhomogeneity for prediction of surface roughening in micro metal forming Tsuyoshi Furushima, Tomoko Nakayama, Kanta Sasaki / M. Kiuchi (1) |
| 17:30 | F4 - Wave Formation in Impact Welding: Study of the Cu-Ti System Taeseon Lee, Shunyi Zhang, Anupam Vivek, Glenn Daehn, Brad Lee Kinsey (2) |

SESSION on Forming (F) *continued*

Tuesday 20 August 2019, 08:30 – 12:00

Hall 11b, Level 3

| | |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08:30 | F5 - Joining sheets to rods by boss forming Luis M. Alves, Rafael M. Afonso, Paulo A.F. Martins (2) |
| 09:00 | F6 - Simultaneous Deep Drawing and Cold Forging of Multi-Material Components: Draw-Forging Oliver Napierala, Christoph Dahnke, A. Erman Tekkaya (1) |
| 09:30 | F7 - Application of flow model in metal cutting to cold forging of tubular products Zhigang Wang (2), Tomoyuki Hakoyama, Yoshiki Endo, Kozo Osakada (1) |
| 10:30 | F8 - Approach for bidirectional laser bending of sheet metal with one-sided accessibility Peer Woizeschke / F. Vollertsen (1) |
| 11:00 | F9 - Design and fabrication of formable CFRTP core sandwich sheets Jingwei Zhang, Jun Yanagimoto (1) |
| 11:30 | F10 - Folding-shearing: shrinking and stretching sheet metal with no thickness change Julian Mark Allwood (1), Christopher J. Cleaver, Evripides G. Loukaides, Omer Music, Adam Nagy-Sochacki |

SESSION on Forming (F) *continued* ►

SESSION on Forming (F) *continued*

Tuesday 20 August 2019, 13:30 – 18:30

Hall 11b, Level 3

| | |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | F11 - Local enhancement of the material properties of aluminium sheets by a combination of additive manufacturing and friction stir processing Mounarik Mondal, Hrishikesh Das, Sung-Tae Hong (2), Byeong-Seok Jeong, Heung Nam Han |
| 14:00 | F12 - A new one-phase material model for the numerical prediction of critical material flow conditions in thixoforging processes Mathias Liewald (3), Kim R. Riedmüller / D. Banabic (1) |
| 14:30 | F13 - Delayed fracture in cold blanking of ultra-high strength steel sheets Ken-ichiro Mori (1), Yohei Abe, Kyohei Sedoguchi |
| 15:00 | F14 - Two-step shear bending of tube with small bending radius for satisfying both space conservation and inner gas/liquid fluidity Takashi Kuboki (2), Daisuke Kusuda, Shohei Kajikawa, Takahiro Noguchi, Kazuaki Adachi |
| 16:00 | Keynote Paper F - Models and modelling for process limits Wolfram Volk (2), Peter Groche (1), Alexander Brosius (2), Andrea Ghiotti (2), Brad L. Kinsey (2), Mathias Liewald (3), Lukasz Madej (2), Junying Min, Jun Yanagimoto (1) |
| 16:30 | F15 - Contact Resistance between Roll and Titanium Sheet during Cold Rolling Hiroshi Utsunomiya (2), Shugo Kameyama, Ryo Matsumoto |
| 17:00 | F16 - Modular system to measure and control the force distribution in deep drawing processes to ensure part quality and process reliability Welf-Guntram Drossel (2), Wolfgang Zorn, Lucas Hamm |
| 17:30 | F17 - Incremental sheet forming with active medium Noomane Ben Khalifa, Sebastian Thiery / M. Kleiner (1) |
| 18:00 | F18 - In-situ springback compensation in incremental sheet forming Huaqing Ren, Jiaxi Xie, Shuheng Liao, Dohyun Leem, Kornel Ehmann, Jian Cao (1) |

SESSION on Grinding (G)

Wednesday 21 August 2019, 08:30 – 12:00

Hall 11b, Level 3

| | |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08:30 | G1 - Model-based manufacturing and application of metal-bonded grinding wheels Berend Denkena (1), Thilo Grove, Fabian Kempf, Patrick Dzierzawa, Abdelhamid Bouabid, Yanwei Liu |
| 09:00 | G2 - Analysis of workpiece thermal behaviour in cut-off grinding of high-strength steel bars to control quality and efficiency Matthias Putz (2), Macario Cardone, Martin Dix, Rafael Wertheim (1) |
| 09:30 | G3 - Evaluation of superabrasive grinding points for the machining of hardened steel Richard Hood, Fernanda Medina Aguirre, Luis Soriano Gonzalez, Donka Novovic, Sein Leung Soo (1) |
| 10:30 | G4 - Discontinuous profile grinding of multi-phase, case-hardened gears with improved load-carrying capacity Tobias Hüsemann, Peter Saddei, Bernhard Karpuschewski (1) |
| 11:00 | G5 - The impact of fluid supply on energy efficiency and process performance in grinding Carsten Heinzel (2), Benjamin Kolkwitz |
| 11:30 | G6 - Fabrication of optical freeform molds using slow tool servo with wheel normal grinding Guangpeng Yan, Fengzhou Fang (1) |

SESSION on Grinding (G) *continued* ►

SESSION on Grinding (G) *continued***Wednesday 21 August 2019, 13:30 – 18:00****Hall 11b, Level 3**

| | |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | G7 - Ultra-precision grinding of optical glass lenses with La-doped CeO₂ slurry Yasuhiro Kakinuma (2), Yoshiki Konuma, Masahiko Fukuta, Katsutoshi Tanaka |
| 14:00 | G8 - Profiled Rotary Dresser with Controlled Size and Distribution of Abrasive Grits: Performance Assessment Alessio Spampinato, Dragos Axinte (1), Paul Butler-Smith |
| 14:30 | G9 - Analysis of the beating frequencies in dressing and its effect in surface waviness Ruben Merino, David Barrenetxea (2), Jokin Munoa (2), Zoltan Dombovari |
| 15:00 | G10 - Surface finishing of biodegradable stents Hitomi Yamaguchi (2), Mingshuo Li, Kotaro Hanada |
| 16:00 | G11 - Superfinishing of polycrystalline YAG ceramic by nanodiamond slurry Hirofumi Suzuki (1), Mutsumi Okada, Yoshiharu Namba, Tomohiro Goto |
| 16:30 | G12 - Model of material removal in vibratory finishing, based on Preston's law and discrete element method Yusuke Makiuchi, Fukuo Hashimoto (1), Anthony Tadeus Beaucamp (2) |
| 17:00 | G13 - Centrifugal and hydroplaning phenomena in high-speed polishing Wule Zhu, Soufian Ben Achour, Anthony Tadeus Beaucamp (2) |
| 17:30 | G14 - Optimization of the stream finishing process for mechanical surface treatment by numerical and experimental process analysis Frederik Zanger, Andreas Kacaras, Patrick Neuenfeldt, Volker Schulze (2) |

SESSION on Machines (M)

Monday 19 August 2019, 16:00 – 18:00**Hall 10b, Level 2**

| | |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16:00 | Keynote Paper M - Robots in Machining Alexander Verl (2), Anna Valente (2), Shreyes Melkote (1), Christian Brecher (1), Erdem Ozturk (2), Taner Tunc |
| 16:30 | M1 - Virtual prediction and constraint of contour errors induced by cutting force disturbances on multi-axis CNC machine tools Yusuf Altintas (1), Jixiang Yang, Zekai M. Kilic |
| 17:00 | M2 - Estimation of the virtual workpiece quality by the use of a spindle-integrated process force measurement Christian Brecher (1), Hans-Martin Eckel, Tobias Motschke, Marcel Fey, Alexander Epple |
| 17:30 | M3 - Semi-active Joint for Ultra-precision Positioning using Sliding/Rolling Bearings Xin Dong, Chinedum Emmanuel Okwudire / M. Balazinski (1) |

SESSION on Machines (M) *continued* ►

SESSION on Machines (M) *continued*

Tuesday 20 August 2019, 13:30 – 18:30

Hall 10a, Level 2

| | |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | M4 - A machine tool motorized spindle with hybrid structure of steel and carbon fiber composite Daisuke Kono, Soichiro Mizuno, Toshiyuki Muraki , Masamitsu Nakaminami, / T. Moriwaki (1) |
| 14:00 | M5 - Predictive simulation of damping effects in machine tools Michael F. Zaeh (2), Christian Rebelein, Thomas Semm |
| 14:30 | M6 - Pre-compensation of servo tracking errors through data-based reference trajectory modification Alper Dumanli, Burak Sencer / L. Monostori (1) |
| 15:00 | M7 - Stability Optimal Selection of Stock Shape and Tool Axis in Finishing of Thin-Wall Parts Lutfi Taner Tunc, Mikel Zatarain (1) |
| 16:00 | M8 - On stability of emulated turning processes in HIL environment Gabor Stepan (2), Bence Beri, Akos Miklos, Richard Wohlfart, Daniel Bachrathy, Gabor Porempovics, Andras Toth, Denes Takacs |
| 16:30 | M9 - Regenerative chatter by teeth allocated in the cutting direction with position-dependent modal displacement ratios Takehiro Hayasaka, Yang Xu, Hongjin Jung, Eiji Shamoto (1), Liangji Xu |
| 17:00 | M10 - Monitoring of vibrations and cutting forces with spindle mounted vibration sensors Martin Postel, Deniz Aslan, Konrad Wegener (1), Yusuf Altintas (1) |
| 17:30 | M11 - Direct observation and analysis of heat generation at the grit-workpiece interaction zone in a continuous generating gear grinding Toru Kizaki, Toshifumi Katsuma, Masashi Ochi, Rui Fukui / T. Nagao (1) |
| 18:00 | M12 - Portable damping system for chatter suppression on flexible workpieces Xavier Beudaert (3), Kaan Erkorkmaz (1), Jokin Munoa (2) |

SESSION on Production Systems and Organizations (O)

Tuesday 20 August 2019, 13:30 – 18:00

Hall 11a, Level 3

| | |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | O1 - Planning for changeability and flexibility using a frequency perspective Fabio Echsler Minguillon, Jan Schömer, Nicole Stricker, Gisela Lanza (2), Neil Duffie (1) |
| 14:00 | O2 - Degradation-aware decision making in reconfigurable manufacturing systems Xingyu Li, Aydin Nassehi (2), Bogdan I. Epureanu |
| 14:30 | O3 - Integrated production and reconfiguration planning in modular plug-and-produce production systems Marcello Colledani (2), Alessio Angius |
| 15:00 | O4 - Transparency increase in global production networks based on multi-method simulation and metamodeling techniques Gisela Lanza (2), Stefan Treber |
| 16:00 | O5 - Optimal platform design and process plan for managing variety using hybrid manufacturing Hoda A. ElMaraghy (1), Mostafa A. Moussa |
| 16:30 | O6 - CAM Planning for Multi-Axis Laser Additive Manufacturing Considering Collisions Denys Plakhotnik, Lothar Glasmacher, Tom Vaneker (2), Yury Smetanin, Marc Stautner (3), Yavuz Murtezaoglu (3), Fred van Houten (1) |
| 17:00 | O7 - Machine learning-based image processing for on-line defect recognition in additive manufacturing Alessandra Caggiano, Jianjing Zhang, Vittorio Alfieri, Fabrizia Caiazzo, Robert X. Gao (1), Roberto Teti (1) |
| 17:30 | O8 - Heterogeneous data-driven hybrid machine learning for tool condition prognosis Peng Wang, Ziyue Liu, Robert X. Gao (1), Yuebin Guo (2) |

SESSION on Machines (M) *continued* ►

SESSION on Production Systems and Organizations (O) *continued*

Wednesday 21 August 2019, 08:30 – 12:00

Hall 9, Level 2

| | |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08:30 | Keynote Paper O - Global Production Networks: Design and Operation Gisela Lanza (2), Kasra Ferdows, Sami Kara (1), Dimitris Mourtzis (1), Günther Schuh (1), Jozsef Vancza (1), Lihui Wang (1), Hans-Peter Wiendahl (1) |
| 09:00 | O9 - Machine Learning and AI in long-term fault prognosis in complex manufacturing systems Satish T. Bukkapatnam, Kahkashan Afrin, Darpit Dave, Soundar Kumara (1) |
| 09:30 | O10 - Data Mining in Battery Production Chains towards multi-criterial Quality Prediction Sebastian Thiede, Artem Turetskyy, Arno Kwade, Sami Kara (1), Christoph Herrmann (2) |
| 10:30 | O11 - Databased prediction of order-specific transition times Günther Schuh (1), Jan-Philipp Prote, Frederick Sauermann, Bastian Franzkoch |
| 11:00 | O12 - Data analytics-based decision support workflow for high-mix low-volume production systems Istvan Gödri, Csaba Kardos, Andras Pfeiffer, Jozsef Vancza (1) |
| 11:30 | O13 - Knowledge-based multi-level aggregation for decision aid in the machining industry Mathieu Ritou, Farouk Belkadi, Zakaria Yahouni, Catherine Da Cunha, Florent Laroche (2), Benoit Furet |

SESSION on Production Systems and Organizations (O) *continued*

Wednesday 21 August 2019, 13:30 – 17:00

Hall 9, Level 2

| | |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | O14 - Robust Model-Based Control of Multistage Manufacturing Processes Dragan Djurdjanovic, Asad Ul Haq, Maria Chiara Magnianini, Vidosav Majstorovic (1) |
| 14:00 | O15 - Parameters identification of health indicator aggregation for decision-making in predictive maintenance: Application to machine tool Thomas Laloix (3), Benoit lung (1), Alexandre Voisin, Eric Romagne |
| 14:30 | O16 - A novel method for accurately monitoring and predicting tool wear under varying cutting conditions based on meta-learning Yingguang Li, Changqing Liu, Jiaqi Hua, James Gao, Paul Maropoulos (1) |
| 15:00 | O17 - Virtual sensing and virtual metrology for spatial error monitoring of roll-to-roll manufacturing systems Xiaoning Jin, Huanyi Shui, Moshe Shpitalni (1) |
| 16:00 | O18 - Energy efficient communication based on self-organisation of IoT devices for material flow tracking Gasper Skulj, Alojz Sluga, Drago Bracun, Peter Butala (1), Rok Vrabic (2) |
| 16:30 | O19 - Digital twin driven human-robot collaborative assembly Arne Bilberg, Ali Ahmad Malik / L. Alting (1) |

SESSION on Precision Engineering and Metrology (P)

Wednesday 21 August 2019, 08:00 – 12:00

Hall 10a, Level 2

| | |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08:00 | P1 - Artifact-free Coordinate Registration of Heterogeneous Large-Scale Metrology Systems Tilo Pfeifer (1) Benjamin Montavon, Martin Peterek, Ben Hughes |
| 08:30 | P2 - Practical conformance evaluation in the measurement of flexible parts Edward P. Morse (3), Corbin Grohol / C. Evans (1) |
| 09:00 | P3 - Improved Gear Metrology Based on the Calibration and Compensation of Rotary Table Error Motions Qichang Wang, Yue Peng, Ann-Kathrin Wiemann, Felix Balzer, Martin Stein, Norbert Steffens, Gert Goch (1) |
| 09:30 | P4 - Characterisation of additively manufactured metal surfaces by means of X-ray computed tomography and generalised surface texture parameters Filippo Zanini, Luca Pagani, Enrico Savio (1), Simone Carmignato (2) |
| 10:30 | P5 - Effect of form errors on the positioning precision of over-constrained systems Denis Teissandier, Yann Ledoux, Santiago Arroyave-Tobon, Vincent Delos, Jean-Marc Linares (1) |
| 11:00 | P6 - In-process roughness quality inspection for metal sheet rolling Andreas Fischer, Dirk Stöbener / B. Scholz-Reiter (1) |
| 11:30 | P7 - In-process measurement for cure depth control of nano stereolithography using evanescent light Satoru Takahashi (2), Deqing Kong, Masaki Michihata, Kiyoshi Takamasu |

SESSION on Precision Engineering and Metrology (P) *continued*

Wednesday 21 August 2019, 13:30 – 18:00

Hall 10a, Level 2

| | |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30 | P8 - Uncertainty of particle size measurements using Dynamic Image Analysis Justin G. Whiting, Vipin N. Tondare, John Henry J. Scott, Thien Q. Phan, M. Alkan Donmez (2) |
| 14:00 | P9 - Uncertainty evaluation in calibration of low-cost digital MEMS accelerometers for advanced manufacturing applications Maurizio Galetto (2), Alessandro Schiavi, Gianfranco Genta, Andrea Prato, Fabrizio Mazzoleni |
| 14:30 | P10 - Design, Data Analysis and Measurement Uncertainty Evaluation of an Eddy-Current Sensor Array for In-Process Metrology of Carbon Fiber Reinforced Plastics Benjamin Haefner, Dietrich Berger / J.H. Chun (1) |
| 15:00 | P11 - Observer-based compensation of thermal disturbances for linear displacement sensors Sebastian Böhl, Wolfgang Knapp (1) |
| 16:00 | P12 - Identification of machine tool squareness errors via inertial measurements Károly Szípká, Andreas Archenti (2), Gregory W. Vogl, Alkan Donmez (2) |
| 16:30 | P13 - A New Measurement Method for Machine Tool Thermal Deformation on a Two-dimensional Trajectory using a Tracking Interferometer Masahiko Mori (1), Naruhiro Irino (3), Masahiro Shimoike |
| 17:00 | P14 - Five-axis machine tool fault monitoring using volumetric errors fractal analysis Kanglin Xing, Xavier Rimpault, Rene Mayer (2), Jean-François Chatelain, Sofiane Achiche |
| 17:30 | P15 - Tuned diamond turning of micro-structured surfaces on brittle materials for the improvement of machining efficiency Zhiwei Zhu, Zhen Tong, Suet To (2), Xiangqian Jiang (1) |

SESSION on Surfaces (S)

Monday 19 August 2019, 16:00 – 18:00

Hall 10a, Level 2

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|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16:00 | S1 - Model-driven photometric stereo for in-process inspection of non-diffuse curved surfaces Mingjun Ren, Gaobo Xiao, Limin Zhu, Wenham Zeng, David John Whitehouse (1) |
| 16:30 | S2 - Inline observations of tool wear in deep drawing with thermoelectric and optical measurements Peter Groche (1), Yutian Wu |
| 17:00 | S3 - Effect of cutting-edge micro geometry on surface generation in ball end milling Francesco G. Biondani, Giuliano Bissacco (2) |
| 17:30 | S4 - A novel realization of diffractive optically variable devices using ultrasonic modulation cutting Ping Guo, Yang Yang / S. Kalpakjian (1) |

SESSION on Surfaces (S) *continued*

Tuesday 20 August 2019, 08:00 – 12:00

Hall 10b, Level 2

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|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08:00 | Keynote Paper S - On-machine and in-process surface metrology for precision manufacturing Wei Gao (1), Han Haitjema (1), Fengzhou Fang (1), Richard K. Leach (2), Chi Fai Cheung (2), Enrico Savio (1), Jean-Marc Linares (1) |
| 08:30 | S5 - Internal Reinforced Domains by Intermediate Deep Rolling in Additive Manufacturing Daniel Meyer (2), Nicole Wielki |
| 09:00 | S6 - Defined surface adjustment for medical magnesium implants by electrical discharge machining (EDM) and plasma electrolytic oxidation (PEO) Alexander Kopp, Ralf Smeets, Ole Jung, Nadja Kroeger, Andreas Klink (2) |
| 09:30 | S7 - Droplet Sliding Behaviour on Textured and Fluorinated Surface Keisuke Nagato, Nana Takahashi, Tomohito Shimura, Masayuki Nakao (1) |
| 10:30 | S8 - Process chains for the mass production of transparent crowns for posterior teeth Aminul Islam, Hans N. Hansen (1), Lisa Rabenow, Keld Nielsen |
| 11:00 | S9 - Colour-tunable 50% strain sensor using surface-nanopatterning of soft materials via nanoimprinting with focused ion beam milling process Ying-Jun Quan, Min-Soo Kim, Younggyun Kim, Sung-Hoon Ahn (2) |
| 11:30 | S10 - Assessment of nano-scale tribological and mechanical properties of flexible transparent polymers based on atomic force microscopy Dong-Gap Shin, Tae-Hyung Kim, Dae-Eun Kim (2) |

CORPORATE MEMBERS ADVISORY GROUP (CMAG) MEETING

Tuesday 20 August 2019, 08:30 – 12:00

Hall 10a, Level 2

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|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. | WELCOME AND OPENING REMARKS Dr. Ö.S. Ganiyusufoglu | | 4. | TECHNICAL PRESENTATIONS (a) Science Meets Industry - International Center for Networked Adaptive Production Prof. T. Bergs – WZL Aachen, Germany (b) Incremental Forming and Generative Manufacturing – A New Approach for Individualized Multifunctional Components Prof. S. Ihlenfeld – Institute for Machine Tool Design and Adaptive Control – TU Dresden, Germany |
| 2. | PRESENTATION OF CIRP INDUSTRIAL TECHNICAL PAPERS (ITP) (a) Adaptive thermal displacement compensation method based on deep learning Dr. M. Fujishima, N. Irino a.o. – DMGMORI Co., Ltd. Japan (b) Development of a laser ablation process model and a disposable 3D-printed tool head for weakening thick steel sheets for the deflagration of hazardous substances Dr. S. Kaierle a.o. – Laser Zentrum e.V. Hannover, Germany (c) A digital factory platform for the design of roll shop plants W. Terkaj, Prof. T. Tolio – STIIMA CNR Milano, Italy | | 5. | RESILIENT PRODUCTION SYSTEMS Dr. Ö.S. Ganiyusufoglu, Prof. H. ElMaraghy, Prof. S. Ihlenfeld |
| 10:00 – 10:30 Coffee Break | | | 6. | CMAG OFFICERS MOVEMENTS – INTRODUCTION OF CANDIDATES AND ELECTION OF NEW OFFICERS Prof. Bert Lauwers, Dr. Ö.S. Ganiyusufoglu |
| 3. | COMPANY PRESENTATIONS (a) Zygo Corporation (New Corporate Member) Dr. Vivek Badami (b) Index-Werke GmbH & Co. KG (New Corporate Member) Dr. Dirk Prust | | 7. | CLOSING REMARKS Dr. Ö.S. Ganiyusufoglu |

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SOCIAL PROGRAMME

WELCOME RECEPTION

Date: Sunday, 18 August 2019

Venue: International Convention Centre (ICC), Hall 4

Time: 19:30 – 21:00

Dress code: Business casual



Meet up and socialise with colleagues and friends in an informal and relaxed setting while establishing new contacts / networks. A light buffet comprising a selection of canapés and bowl food will be served together with a range of drinks including beers, prosecco, juices and sparkling / still water.

ASSEMBLY DINNER

Date: Wednesday, 21 August 2019

Venue: International Convention Centre (ICC), Hall 3

Time: 19:30 – 00:30

Dress code: Semi-formal



Following pre-meal drinks starting from 19:00, delegates and guests will be treated to a sumptuous banquet style meal paired with suitably selected wines. An entertainment programme has been prepared, including a live soul band that will play after dinner with a dance floor in the venue. Groups who wish to sit together can book specific tables at the Registration Desk. A cash bar will also be operating throughout the evening.

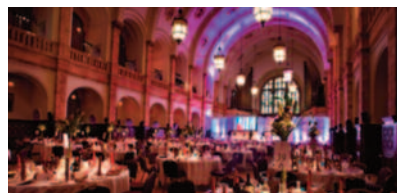
FAREWELL DINNER

Date: Saturday, 24 August 2019

Venue: Great Hall, University of Birmingham

Time: 19:30 – 23:30

Dress code: Semi-formal



The closing event of the General Assembly where you will enjoy a three-course dinner. Coaches will take you from the ICC to the University where you will be dropped off to enjoy a stroll through the recently completed Green Heart parkland to the Great Hall. Booking of tables can be done at the Registration Desk.

Coach pick up will be between 18.30 and 19:00 from outside the ICC.

Return coaches to the ICC will be available from 22.30 to 23.30.

ACCOMPANYING PERSONS' PROGRAMME

MONDAY, 19 AUGUST 2019

Morning

Following the conclusion of the Opening Session, enjoy a serene boat ride along the canals from the ICC to the University of Birmingham. Experience the main mode of transportation for goods / supplies during the Industrial Revolution in the 18th century.

A seated lunch will be served in the Astor Restaurant at the University's Staff House.

Afternoon

Guided tours of the Barber Institute of Fine Arts and Winterbourne House & Garden. The Barber Institute houses one of the finest art collections in Europe including 19th century Impressionist masterpieces from Manet and Degas together with notable late medieval and Renaissance paintings. Winterbourne House & Garden is an Edwardian style home with a 7-acre botanical garden having over 6000 plant species.



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ACCOMPANYING PERSONS' PROGRAMME *continued*

ACCOMPANYING PERSONS' PROGRAMME

TUESDAY, 20 AUGUST 2019

Morning

A trip to the historic city of Oxford will begin with a visit to Christ Church College where guests can explore the Great Hall, Quadrangle, Cathedral and Cloister within the college grounds.

A short trip to St. Anne's College where a plated lunch will be served.

Afternoon

Venture to Blenheim Palace and Gardens, designated a World Heritage Site, it is the Duke of Marlborough's 18th century country home and birthplace of Sir Winston Churchill. Explore the stately rooms of the palace with the aid of an audio guide and enjoy one of the walking paths around the extensive grounds and estate.



THURSDAY, 22 AUGUST 2019

Morning

Arrive at the medieval market town of Stratford-upon-Avon to tour the birthplace of William Shakespeare, arguably the most famous author in English literature, and Anne Hathaway's Cottage, the family home of his wife. Experience the atmosphere and living conditions of a typical house in the 16th century.

Afternoon

A private guided tour of Ragley Hall and Gardens, which is the 17th century stately home and ancestral seat of the Marquess of Hertford. Marvel at the ornate and grand décor of the various rooms while also enjoying the beauty of the surrounding gardens.



FRIDAY, 23 AUGUST 2019

An excursion to explore Blists Hill Victorian Town in Telford, which is a recreation of a Victorian era town. Watch demonstrations by foundry workers, blacksmiths and printers while possibly picking up some of

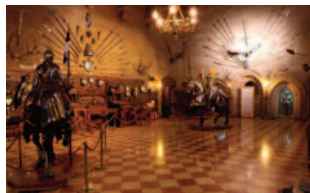
the interesting items offered at the various shops. Returning to the ICC following lunch with ample time for leisure shopping in Birmingham city at your own pace.



WEDNESDAY, 21 AUGUST 2019

Enjoy a day trip to the medieval Warwick Castle built in 1068 where you will have the opportunity to explore the Castle's battlements, towers, turrets and interior of the Great Hall. You can also stroll around the grounds and catch some of the daily shows

including the bird of prey, jousting and display of the Trebuchet (siege machine). You will also have exclusive use of the Riverside Marquee with a hogs roast served for lunch.





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