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Download this Handbook and Programme at bssm.org/Programme15
Foreword

Welcome to Heriot-Watt University and the BSSM’s 10th International Conference on Advances in Experimental Mechanics.

The BSSM sits at the interface between industry, academia and the wider engineering community and promotes their interaction to ensure the wide dissemination of new ideas and best practice in the field of engineering measurement.

This conference focuses on research which advances experimental techniques across the very widest range of applications in mechanics, including stress, strain and vibration analysis. The conference is partnered by the Institute of Physics Applied Mechanics Group to incorporate Modern Practice in Stress and Vibration Analysis (MPSVA).

In addition to the main conference, this year’s event includes all the ‘traditional extras’, including the BSSM Measurements Lecture, the annual BSSM EMex exhibition of experimental mechanics, the BSSM Young Stress Analyst Competition and BSSM short courses.

We are looking forward to a technically excellent conference and we are very grateful to the authors for their efforts in producing their contributions to the programme.

We also thank the organising committee without whom the conference would not have been possible, in particular Mrs Amanda Boaler (conference secretariat), Mrs Biana Gale (EMex), Prof Margaret Lucas and Prof Simon Quinn (for providing continuity with previous BSSM conferences), Dr Rachael Tighe (YSA Competition) and Dr Cris Mares (IoP Applied Mechanics Group).

We hope you enjoy the conference and its many events, all of which are described in this handbook. If you require any assistance during the conference please do not hesitate to contact the Conference main desk for help.

Conference Venue

The conference sessions take place in James Watt Centre 2, James Watt Hall.

Wi-Fi is available throughout

Connecting to KeySurf Wi-Fi

To connect to the Wi-Fi service please follow the steps below when you arrive at the venue:

1. View wireless connections available
2. Select KeySurf
3. Open browser, login page for KeySurf will appear
4. Select “Create Account”
5. Enter the following details:
   a. Enter date of birth
   b. Read and agree to the terms & conditions of use
6. Select “Continue to package selection”
7. Select the “No Charge” package
8. Select “Continue Registration”
9. Enter the following details:
   a. Enter a user name of your choice (please write this down as you will need it later)
   b. Your name
   c. Your email address
   d. Your telephone number
   e. The address that should be used is Heriot Watt University, Edinburgh, EH14 4AS
10. Continue to Confirmation – this will display a screen which summarises the information you have given
11. Select “Create Account”
12. Your password will be displayed, again please note this down as you will need it each time to sign into your account
13. Select “Sign In”

Help

If you have any queries or have issues logging onto the system please contact the help desk on 0300 103 0000 or email support@keysurf.net

Registration and Help Desk

The registration desk is situated in the foyer of the James Watt Centre 2 and will open on Tuesday 1st September from 8.30am and throughout the conference. The registration desk is also the help desk if you have any queries.

Sessions will take place in:
Plenary Lecture Theatre
Gibson Rooms 1 and 2
Craig Rooms 1 and 2

During the coffee breaks refreshments will be served in the foyer of the James Watt Centre 2.

On Wednesday a finger buffet lunch will be served in the exhibition area (see information on the exhibition page 8).

On Thursday lunch will be served in the Foyer of the James Watt Centre 2. Lunch on both days will be a self-service buffet with a choice including vegetarian options.

If you have requested a special meal other than vegetarian then this will be set aside for you, please inform staff.

Throughout the conference there is an Event Support Team on duty to help you. Please look for the distinctive blue tee shirts.

If you wish to store your luggage at the venue on the last day of the conference there will be a special baggage store located by the reception desk. If you are not staying at the campus please bring your luggage to the reception desk where Amanda Boaler will arrange storage.

Look out for the BSSM flags at the entrance to James Watt Centre 2.
Maps & directions to Edinburgh Campus

Our Edinburgh Campus is about 6 miles from the city centre. It’s well served by frequent local bus services and is also easy to access by car.

The easiest way to plan your journey to the campus is to use the Traveline Scotland Journey Planner, which uses up-to-date public transport timetables.

**Car**

The Edinburgh Campus is easy to access by car from the centre of Edinburgh and from all major routes leading to the city. The University is half a mile from the Calder Junction of the A720 City of Edinburgh by-pass and the A71, and you’ll see signs for Heriot-Watt University on your approach.

**Visitor parking**

You can find the location of the visitor car parks on the map of Edinburgh Campus.

- Visitors to the University should use car park A or B. Car park C is not available for delegates.
- Disabled visitors can use the accessible car park at Gait 10 next to the Centre for Sport & Exercise. Additional accessible parking spaces are available throughout the campus; you can contact us to reserve one.

**Bus**

Lothian Buses offers local bus services 25, X25, 34, 45 and N25/ N34 (night bus) to the Edinburgh Campus. Service 25 is the most frequent, leaving the city centre every 10 minutes during the day, and every 15 minutes after 8.00pm. The journey takes about 30–40 minutes from the city centre, depending on what time of day you’re travelling. Fares from the city cost £1.50 single/£3.50 day ticket. Note that exact money is required for Lothian Buses (with the exception of Airlink) but you can pay for tickets using your mobile phone, if preferred. Regular travellers to the campus should consider getting a Ridacard.

All national coach services to Edinburgh arrive at St Andrew Square bus station at the east end of Princes Street. Timetables can be found on the Citylink and National Express websites.

**Taxi**

A number of taxi services, such as Central Taxis, are available at taxi ranks in the centre of Edinburgh, including Waverley and Haymarket rail stations and St Andrew Square bus station, as well as at Edinburgh airport. The journey to Heriot-Watt University takes about 20–30 minutes from the city centre, and about 10 minutes from Edinburgh airport. A return journey to the city centre costs about £30.

You can request an outbound taxi from the Edinburgh Campus at the main reception desk.

How to find us

http://www.hw.ac.uk/student-life/campus-life/edinburgh/getting-around.htm

Some useful contacts

http://www.edinburghairport.com/
http://www.nationalrail.co.uk/
http://www.taxisedinburgh.co.uk/
http://lothianbuses.com/
http://www.citylink.co.uk/

**Rail**

The mainline rail network serves the centre of Edinburgh well. Edinburgh Waverley is at the end of the Princes Street and Haymarket Station is at the west end, Curriehill Station, one mile from the University, offers a frequent service to Edinburgh Waverley and a service to Glasgow Central Station.

We do not recommend alighting at either Edinburgh Park or Curriehill as there is no direct transport link to the campus from these stations. Proceed to Haymarket and catch a number 25 bus from Dalry Road (terminating at Riccarton). Rail timetables can be found on the National Rail website.

Edinburgh International Airport is served by scheduled national and international flights. The airport is on the west side of the city, just three miles from the Edinburgh Campus.

The bus journey from the airport takes about an hour.

The taxi journey from the airport to the campus takes about 10 minutes and costs about £25 return.

The bus journey from the airport takes about an hour.

Fares from the city cost £1.50 single/£3.50 day, and every 15 minutes after 8.00pm. The journey takes about 40 minutes during the day, and every 10 minutes during the night. The journey takes about 30 minutes during the day, and every 15 minutes after 8.00pm.

Note that exact money is required for Lothian Buses (with the exception of Airlink) but you can pay for tickets using your mobile phone, if preferred. Regular travellers to the campus should consider getting a Ridacard.

The University encourages staff, students and visitors to use alternative methods of travel to our campus. For more information visit www.hw.ac.uk/directions-edinburgh.

Car Parking Map

Our car parking map shows the location of our car parks as well as parking areas for disabled drivers, bus stops, academic and central service buildings and cycle facilities.

www.hw.ac.uk/directions
Exhibition

The exhibition will take place on Wednesday 2nd September 2015 and is open from 10:00 to 16:30.

Delegates are free to visit the exhibition at any time the exhibition is open. Refreshments and lunch will be served to conference delegates in the exhibition hall on the day of the exhibition.

Exhibitors will give a short 1 minute pitch style presentation.

Instructions for Presenters

All presenters please ensure that you bring your presentation (which can be in pdf or PowerPoint) to the conference on a memory stick or CD-Rom. James Watt Centre 2 will be operating Windows 7 and/or 10, have all standard MS Office programmes plus items such as Quicktime, Adobe & Prezi. If there is a specific programme that a speaker needs please let Amanda Boaler know at amandaboaler@bssm.org

There is no support for Macs. Should speakers wish to use their own Mac this is possible however they will need to supply all relevant adaptors.

On the day of your presentation, please report to the support staff in the lecture theatre at 08.00 prior to the first session of the day – or during the break, 15 minutes before your session starts. Please also report to the session chair before your session starts. If you intend to use animations, please ensure you bring the movie files with you as well. Alternatively you may wish to send your presentation prior to the conference. Please email to amandaboaler@bssm.org to arrive by Monday 24th August 2015.

You may wish to use your own laptop – if this is the case you are still required to attend in advance to check that the presentation will work. Please be in the room of your presentation about 5 minutes before the session starts to introduce yourself to the session chairman.

With the exception of the keynote and invited presentations, the time slot for each paper is a maximum of 20 minutes. You should therefore aim to speak for 15 minutes, leaving the remaining 5 minutes available for questions.
We have invited three internationally leading researchers to start proceedings on three of the days of the conference. Their work represents the diverse range of topics covered by experimental mechanics.

### Plenary Lectures

**Tuesday 1st September - Plenary lecture theatre**

**Prof Olof Lindahl**
Uméa University, Sweden

**“Tactile resonant sensors for the measurement of human soft tissue stiffness”**

Olof Lindahl got his PhD in biomedical engineering in 1993, Linkäping University, Sweden. He became associate professor 1996 and professor 1999 in biomedical engineering at Umeå University, Sweden. He is today managing the biomedical R&D department at the University hospital of Northern Sweden. He is a founder of several companies and abiological engineering research centre, CMIF, where he is director. Professor Lindahl was awarded the Erna Ebeling price 2008 and is a member of several professional societies like IFMBE and IEEE. His research focus on biomedical sensors for detection of prostate cancer. He has produced more than 150 scientific publications, patents and book chapters in the area of biomedical engineering and business development.

**Wednesday 2nd September - Plenary lecture theatre**

**Prof Peter Woodward**
Heriot-Watt University, UK

**“The effects of shear strain on the determination of the track critical velocity for high-speed trains”**

Professor Peter Woodward has a PhD in the field of numerical geotechnics from the University of Manchester. During his PhD he worked for WS Atkins in the field of earthquake engineering, analysis and design. He was appointed to the post of Lecturer in Geotechnical Engineering in 1994 at Heriot-Watt University and to the post of Reader in Railways and Geotechnical Engineering in 2007. In 2010 he was promoted to Professor of Railway Geotechnical Engineering. Since 2001 he has been seconded to industry for 1 day per week working on the application of polyurethane geocomposites to railway track stabilisation and reinforcement. This patented technology was spun-out from Heriot-Watt University and is now widely used across the UK railways and increasingly internationally. He has won multiple awards for his developed technologies, including the Highly Commended Award at the 2005 National Rail Awards, in the Innovation of the Year category. He has also been a previous winner of the ICE Webb Prize (2008) and the UK Young Engineers Award (2001) amongst others. He has acted as Principal Investigator on many research grants, most recently on EPSRC funded research on high-speed train track interactions at critical track velocities.

**Thursday 3rd September - Plenary lecture theatre**

**Prof John Mottershead**
University of Liverpool, UK

**“Image analysis of full-field vibration and strain data”**

John Mottershead has BSc and PhD degrees in Mechanical Engineering and was awarded the DEng degree by the University of Liverpool, where he is the Alexander Elder Professor in Applied Mechanics. His research interests include FE model updating, image processing of full-field vibration and strain data, active vibration control and servoelasticity. He has published over 300 papers in international journals and conference proceedings and his industrial collaborations include, from the motor industry BMW, Fiat, Ford and Peugeot-Citroen, and from the aerospace industries AgustaWestland Helicopters, Airbus UK and Rolls-Royce. He is presently Editor-in-Chief of Mechanical Systems and Signal Processing.

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At each of its annual conferences BSSM invites a leading UK-based researcher to give the ‘Measurements Lecture’.

### The BSSM Measurements Lecture

**Wednesday 2nd September - Plenary lecture theatre**

**Prof Fabrice Pierron**
University of Southampton, UK

**“New opportunities in high strain rate testing based on full-field measurement”**

Abtract:

The fast development and diffusion of full-field deformation measurement techniques such as digital image correlation has opened new prospects in the identification of the mechanical behaviour of materials. The very rich experimental information enables to perform complex tests activating more of the material parameters to be identified. Professor Fabrice Pierron has been active in this research area for nearly 20 years. In particular, an original identification method dedicated to full-field measurements has been at the centre of the developments in his group. This technique is called the Virtual Fields Method (VFM, http://www.springer.com/gp/book/9781461418238).

Most of the work to date has however been targeted at quasi-static situations where standard CCD cameras could be used. This is now being transferred to the community through a dedicated software platform (www.matchidmbc.com).

The availability of high performance ultra-high speed cameras makes it possible now to record images at frame rates up to 5 MHz while keeping significant spatial resolution. This opens the way for new test methodologies at high rates where the acceleration field can be measured together with the strain field. The presentation will provide a brief description of the VFM as applied to dynamic material identification. In particular, the idea of using acceleration information as an image-embedded load cell will be developed and illustrated through several examples in vibration and impact loading. The presentation will be concluded by a short review of near future opportunities in this area of research.
The BSSM Young Stress Analyst (YSA) competition is an annual competition that is intended to encourage and reward young practitioners in the field of experimental mechanics.

The competition is generously sponsored by Airbus

YSA Finalists

* Determination of micro-residual stress distribution in multi phase ceramic composites using Raman spectroscopy
  - Matthew DeVries, University of Florida (USA)

* A new white light imaging approach for intralaminar fatigue characterisation of GFRP
  - Jens Glud, Aalborg University (Denmark)

* Three dimensional in situ quantification of localised non-linear deformations within heterogeneous materials
  - Matthew S. L. Jordan, University of Oxford (UK)

* Measurement of highly non-uniform residual stress fields with reduced plastic error
  - Ho Kyeom Kim, University of Bristol (UK)
Tuesday 1st September 2015

Welcome Reception
James Watt Centre 2, Foyer
Starts 18.00
Ends 19.30

Wednesday 2nd September

Gala Conference Banquet
The Playfair Library, Old College, South Bridge, EH8 9YL, Edinburgh.

Coaches depart outside main reception 19.00 (see page 7)
Conference reception 19.30
Conference dinner 20.30
Coaches depart 23.30

Scientific Committee

Dr Taiji Adachi, Kyoto University, Japan
Dr Antonio Baldi, University of Cagliari, Italy
Prof Janice Barton, University of Southampton, UK
Prof David Bucknall, Georgia Tech, USA
Dr Richard Burguete, Airbus, UK
Prof Gary Couples, Heriot-Watt University, UK
Prof Joris Dirckx, University of Antwerp, Belgium
Prof Bruce Drinkwater, University of Bristol, UK
Prof Josef Eberhardtsteiner, Vienna University of Technology, Austria
Prof Stephen Eichhorn, University of Exeter, UK
Prof Spilios Fassois, Patras University, Greece
Dr Carol Featherston, Cardiff University, UK
Prof Antolino Gallego, University of Granada, Spain
Prof James Gimzewski, UCLA, USA
Dr Inna Gitman, University of Sheffield, UK
Prof Michel Grédiac, Clermont-Ferrand University, France
Dr Salih Gunor, Open University, UK
Dr Jack Hale, University of Newcastle, UK
Dr Stephen Hall, Lund University, Sweden
Prof Joachim Hammer, FH Regensburg, Germany
Dr Johan Hoefnagels, TU Eindhoven, The Netherlands
Prof Karen Holford, Cardiff University, UK
Dr Dave Hollis, LaVision, UK
Prof Jon Huntley, Loughborough University, UK
Prof Steve James, Cranfield University, UK
Dr Arthur Jones, University of Nottingham, UK
Prof Patrick Keogh, University of Bath, UK
Dr Vasileios Koutsos, University of Edinburgh, UK
Dr Leslie Lamberson, Drexel University, USA
Dr Pascal Lava, University of Leuven, Belgium
Prof Jean-Benoit Le Cam, University of Rennes, France
Dr Jerry Lord, NPL, UK
Dr Bill Macpherson, Heriot-Watt University, UK
Prof James Marrow, University of Oxford, UK
Dr Bob Mines, University of Liverpool, UK
Prof Wolfgang Müller, Berlin Technical University, Germany
Prof Wolfgang, Osten, University of Stuttgart, Germany
Prof Huajiang Ouyang, University of Liverpool, UK
Prof Eann Patterson, University of Liverpool, UK
Dr Dominique Pioletti, ETH, Switzerland
Dr Bill Proud, Imperial College, UK
Dr Rhys Pullin, Cardiff University, UK
Prof Pramod Rastogi, EPFL, Switzerland
Prof Daniel Rittel, Technion, Israël
Dr Marco Rossi, University Polytechnic from the Marche, Italy
Dr Anish Roy, University of Loughborough, UK
Dr Pablo Ruiz, Loughborough University, UK
Dr Hazel Screen, Queen Mary University of London, UK
Prof Chris Smith, University of Exeter, UK
Dr David Stifter, Johannes Kepler University, Austria
Prof Andy Tan, Queensland University of Technology, Australia
Dr Rachel Tomlinson, University of Sheffield, UK
Dr Irina Trendafilova, University of Strathclyde, UK
Prof Chris Truman, University of Bristol, UK
Prof Gioacchino Viggiani, Laboratoire 3SR, France
Prof Keith Worden, University of Sheffield, UK
Dr José Xavier, University of Porto, Portugal
Prof Ramón Zaera, Carlos III University of Madrid, Spain

Social Programme
Accommodation

For delegates who have booked campus accommodation check in is from Monday 31st August. Guests must check in at Main Reception. Accommodation will be available from 15.00 onwards. If any residents plan to arrive outside normal opening hours of 07.30 hrs to 22.00 hrs please contact amandaboalear@bssm.org so arrangements can be made for you to access your room. Check-out time is by 10.00. There will be a £20.00 charge for any bedroom key not returned to reception after 10.00 and by 11.00 on the morning of departure. Where the situation arises that a guest has not checked out by noon, a full accommodation charge will apply.

Each bedroom is equipped with single bed, bed linen, towels, tea/coffee and free access to internet. No hairdryers, toiletries, TV or alarm clocks are provided.

Should delegates require assistance please contact reception on 0131 451 3501 between the hours of 0730-2200 hrs and Security Control on 0131 451 3500 out of these hours.

There are no disabled accessible rooms available during the dates of the conference, however, there are lifts in the accommodation buildings.

There is no room service or concierge service. There is a launderette available and guests can purchase a card for £2.00 inside the launderette then go on-line to http://www.circuit.co.uk/card-top-up-unauth/ to add money to it.

For anyone who does not wish to stay on campus there is a list of hotels close to campus which can be found at www.bssm.org/conf2015

Catering outlets open on campus

Central – offer a variety of hot meals
08.00-19.00 hrs
Breakfast available between 08.00-10.00 hrs

Café Brio – offers tea/coffee/soft drinks/limited alcoholic drinks; sandwiches, pastries, cake, soup, baked potatoes
09.00 hrs to 19.00 hrs

The Piece – offers Starbucks coffee, soft drinks, pizza, hot sandwiches
08.00 hrs to 19.00 hrs

College Lounge Dinner & Bar

Tuesday 1st September
Dinner: 19.30-20.30 hrs. Bar open until 22.00
A cash sale dinner option will be available for delegates after the drinks reception. The price is £6.50 per person for a main course (meat or vegetarian option) with dessert available at an additional cost.
A bottle only bar is also available in the College Lounge until 22.00 hrs.

Pre-conference Short Courses

Tuesday 1st September 9.00 am to 1.00 pm
Registration will take place from Tuesday 1st September for all delegates attending the short courses in the James Watt Centre 2 in the Foyer
Refreshments will be available in Foyer of the James Watt Centre 2 from 10.30 to 11.30 and a packed lunch from 1pm for short course delegates only.

The Conference starts at 1.30 pm

Short Course Details

An introduction to Acoustic Emission (AE) monitoring

INSTRUCTOR:
Tim Bradshaw – Mistras Group Ltd

COURSE DESCRIPTION

Acoustic Emission is a passive monitoring technique used in industry and academia to monitor, in real time, the degradation of materials. The application of AE has developed over the last 40 years from monitoring lab based applications to industrial field testing. Successful application of the technique is through a knowledge of the mechanism being monitored, the environment the technology is to be applied and the data processing.
The goal of this workshop is as follows:
• Discuss the nature of Acoustic Emission and how it is generated.
• Evaluation of AE acquisition hardware and data acquisition methodology.
• Data analysis approaches.
• A review of real life Applications for Acoustic Emission.

Who should attend

Any members of academia and industry who are interested in a background in the technology and its successful application. No specific pre-knowledge is required and the monitoring technique is introduced step by step.

COURSE SCHEDULE

09.00 Slot 1:
• What is Acoustic Emission
• AE sources and sensitivity
• The measurement chain
• Data acquisition and processing
• Location of sources.

Digital Image Correlation Practical considerations & guidelines towards consistent analysis and reporting

INSTRUCTOR:
Prof. Pascal Lava, University of Leuven, Belgium

COURSE DESCRIPTION

Digital Image Correlation (DIC) is gradually becoming a standard tool in experimental mechanics, for both industry and academia. Despite the fact that the measurement system is often sold with the argument of being easy in use and setup, a poor understanding of issues arising in the whole measurement chain (imaging, noise, correlation algorithm, smoothing, …) can result in poor or misinterpreted results.

The principal goal of this workshop is not to provide a detailed theoretical study on these. However, practical guidelines towards a consistent analysis of results and reporting in DIC will be delivered to the participants, helping them to understand more clearly the benefits and limitations of the measurement technique. All aspects will be live demonstrated and introduced step by step to guarantee an interactive course.

Who should attend

Practitioners of DIC at post graduate level working in both academia and industry. No specific preknowledge is required and the measurement technique is introduced step by step.

Accordingly, also people that have no experience with DIC
measurements can learn about what this technique can mean for their application.

DIC
09.00 Slot 1: DIC
• Basic principles of DIC: Image matching. Why is a speckle pattern needed? What is subset size and step size (what are their limitations)? Shape functions and correlation criteria
• From displacements to strains
• Resolution/spatial resolution: what is the meaning and relationship of these concepts and what is their role in an actual experiment

Coffee Break
11.15 Slot 2: Practical guidelines
• Field of view, depth of field, aperture, exposure time: how to setup a DIC experiment
• Practical considerations for speckling and lighting
• Artificial strain fields due to out-of-plane motion
• Integrated DIC/VFM demo: seamless identification of mechanical properties

13.00 End of Session

Course Instructor
The workshop is led by Dr Pascal Lava from the University of Leuven, Belgium. He brings a wealth of experience in the practical application/data analysis of DIC for both local and global methodologies, and their interpretation in terms of resolution and spatial resolution.

In June 2002 Pascal Lava obtained a master degree in mathematics at Ghent University. In 2006, he acquired a PhD in sciences - nuclear physics at Ghent University. Since January 2008, he works as an associate professor at the department Metallurgy and Materials engineering (MTM) at Leuven University. His research topics include Digital Image Correlation (DIC) and material identification via virtual fields and finite element updating. Pascal Lava is author of more than 30 peer-reviewed journal papers and the founder and main developer of the DIC platform MatchID (http://www.matchidmbc.com)

Infra-red thermography in experimental mechanics: using temperature measurement to evaluate stresses, strains and damage evolutions

Instructors: Professor Janice Dulieu-Barton, Dr Rachael Tighe, University of Southampton, UK.

Course description
The purpose of the short course is to introduce the range of applications of infra-red thermography in experimental mechanics.

Thermography is a full field, non-contact non-destructive measurement technique. It has been used for many years a qualitative tool for non-destructive evaluations of structures where ‘hot-spots’ are used to infer damage sites. The short course shows how thermography can be used to obtain quantitative information about the extent of damage, its effect on the temperature field and how to obtain accurate measurements. A detailed introduction to thermography is provided as well as introductions to techniques such as pulse phase thermography and thermoelastic stress analysis.

Who should attend
Engineers and researchers who have an interest in the use of full-field strain measurements to extract information regarding the fatigue and damage mechanisms in materials. The basics will be taught from the beginning so no prior knowledge of infrared thermography is required. The focus is on practical application and industrial relevance. The course will not require any specific mathematical background, although an understanding of basic solid mechanics is required.

Course schedule
09.00 Welcome and brief introductions
09.15 Physics of thermography
09.45 Thermography in NDE applications
10.30 Refreshments
12.15 Thermoelastic stress analysis – theory, assumptions and applications
12.15 High speed thermography
12.45 Closing remarks

Physics of thermography
This course will start with the derivation of Planck’s law and demonstrates how infra-red imaging systems work. It covers the mode of operation of both Bolometers and photodetectors. The aim is to highlight the key important points for consideration when using infra-red detectors in experimental mechanics applications.

Infrared thermography in experimental mechanics: using temperature measurement to evaluate stresses, strains and damage evolutions

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The Virtual Fields Method An introduction

Instructor: Professor Fabrice Pierron, University of Southampton, UK.

Course description

Full-field measurement techniques are gradually becoming routine procedures in industrial and academic mechanical testing labs thanks to the wide range of commercially available systems. Having access to the spatial distribution of strains at the surface of the material (or sometimes in the bulk, as in Digital Volume Correlation from X-ray tomography or OCT reconstructed volumes) enables the use of more complex test configurations to identify the mechanical behavior of materials, with the potential of tackling difficult problems like heterogeneous materials (welds, locally damaged composites, multi-materials, functionally graded materials etc...) or complex constitutive equations (viscoplasticity at high strain rate, hyperelasticity, phase changes as in SMAs etc...). However, in this case, the data processing is not straightforward and inverse problem resolution is usually required.

The present course will introduce the participants to a tool specifically developed to solve the above problem, the so-called Virtual Fields Method (VFM). This method is an alternative to Finite Element Model Updating over which it has a number of specific advantages, among which much shorter computation times. The idea of the course is to start from scratch on the subject and gradually lead the participants to an understanding of the basic concept of the method through simple examples in linear elasticity. The VFM will then be explored in more depth to demonstrate the basic principle of the VFM as well as some of its important features (virtual fields' selection, virtual boundary conditions etc.).

Complements on the VFM

After having acquired a basic understanding of how the VFM works, this session will be dedicated to exploring the method in more depth. It will first be shown how the VFM can be adapted to non-linear constitutive models and how it can deal with heterogeneous materials. The important issue of the selection of virtual fields will also be addressed. Finally, it will be shown how the VFM can be applied in dynamics (vibration, high strain rate testing...).

Practical examples of application of the VFM

The course will be concluded by an overview of experimental application of the VFM to composites (elasticity, damage), metals (including welds), wood and novel high strain rate testing applications.

Course handouts

The participants will be given a CD containing the slides used for the presentations, a set of scientific papers relevant to the subject as well as the CAMFIT software. There will also be an option for the participants to buy the VFM book at a reduced rate.


Who should attend

Engineers and researchers who have an interest in the use of full-field strain measurements to extract mechanical properties of materials. Although inverse problems are usually considered to be mathematically demanding, this course will focus on rather simple concepts that will not require any specific mathematical background. Basic solid mechanics training (graduate level) is enough to benefit from the course.

Participants can submit their own application/problem to the instructor for advice or even their own measurements for processing with the VFM.

Course schedule

09.00 Introduction
09.15 The Principle of Virtual Work
09.45 The Virtual Fields Method in elasticity
10.30 Coffee break
11.00 Complements on the VFM (non-linear VFM, dynamics etc.)
12.00 Examples of application
13.00 End of the course

Introduction

The determination of parameters driving the constitutive mechanical behavior of materials from experimental tests is an inverse problem. This section presents a brief overview of the problem to be solved and a number of different approaches used to solve it, with their advantages and shortcomings. The benefits of having access to full-field measurements to address this problem will be underlined.

The Principle of Virtual Work

One of the difficulties in understanding the VFM is the so-called Principle of Virtual Work on which the technique relies. This part of the course will recall the basics of this principle and detail how it can be used to derive integral equilibrium equations. The simple case of a cantilever beam will serve as an example.

The Virtual Fields Method in elasticity

The Virtual Fields Method (VFM) will be described in detail in the case of linear elasticity. This simple situation is chosen for its didactical value. Simple examples in linear elasticity will demonstrate the basic principle of the VFM as well as some of its important features (virtual fields' selection, virtual boundary conditions etc.).

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Complements on the VFM

After having acquired a basic understanding of how the VFM works, this session will be dedicated to exploring the method in more depth. It will first be shown how the VFM can be adapted to non-linear constitutive laws, heterogeneous materials etc. The important issue of virtual fields selection will also be briefly addressed. Finally, the course will be concluded by examples of application of the VFM to many different materials and situations.

Who should attend

Engineers and researchers who have an interest in the use of full-field strain measurements to extract mechanical properties of materials. Although inverse problems are usually considered to be mathematically demanding, this course will focus on rather simple concepts that will not require any specific mathematical background. Basic solid mechanics training (graduate level) is enough to benefit from the course.

Participants can submit their own application/problem to the instructor for advice or even their own measurements for processing with the VFM.
### Local Information

**Doctors** - [http://www.riccartongeneralpractice.co.uk/studenthealth/](http://www.riccartongeneralpractice.co.uk/studenthealth/)

**Chemist** – Lloyds Pharmacy, 162 Lanark Rd, West Currie, Lothian EH14 5NY Tel: 0131 449 3417 or Boots Edinburgh. The Gyle Centre, Gyle Avenue, Edinburgh, Mid Lothian, EH12 9JR Tel: 01313171288.

**Taxi** – there is a phone on the Main Reception desk which connects direct to Central Taxis – 0131 229 2468.

**Cash machine** – RBS Bank and cash machine located on the lower floor of Hugh Nisbet Building. The bank is open Monday, Tuesday, Thursday and Friday from 1200-1600 hrs.

### Fire Instructions

The James Watt Centre is equipped with Fire Protection Equipment to a high standard that is maintained and inspected in line with current legislation and Health and Safety requirements, this includes an extensive automatic Smoke Detection system.

In keeping with recent changes in the legislation the James Watt Centre is a designated No Smoking venue and anyone found in contravention of this may be requested to leave the premises, your cooperation and assistance in this matter is appreciated.

In the event of a fire: **ANY PERSON DISCOVERING A FIRE SHOULD RAISE THE ALARM BY OPERATING THE NEAREST FIRE ALARM CALL POINT / BREAK GLASS.** The fire alarm sounds as a two-tone electronic siren (similar to a yodel), there is no first stage.

In the event of the alarm sounding, Conference and Event Organisers should direct their delegates / guests to evacuate the premises by the NEAREST fire exit and assemble either in the Piazza to the west (front) of the building, or in the car park to the east (rear) of the building. Fire exits are clearly marked throughout the centre and there are doors all round the main hall and in the lounge area. Delegates / Guests should be discouraged from stopping to collect personal belonging and they MUST NOT re-enter the building until authorised by the Fire Authorities or a member of the University Security Staff. The Duty Security Supervisor and the Control Desk (extn 3500) must be advised in advance if any individuals might require extra assistance in the event of an evacuation.

### Conference Programme

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>09:00</td>
<td>Registration – James Watt Centre 2 Foyer (Open all day)</td>
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<tr>
<td>09:00</td>
<td>Short Courses – Gibson and Craig Rooms</td>
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<tr>
<td>10:30</td>
<td>Refreshment (short course only)</td>
</tr>
<tr>
<td>11:30</td>
<td>Packed lunch (short course only)</td>
</tr>
<tr>
<td>13:00</td>
<td>Introduction &amp; Welcome – Plenary Lecture Theatre</td>
</tr>
<tr>
<td>13:45</td>
<td>Plenary Lecture 1 – Plenary Lecture Theatre</td>
</tr>
<tr>
<td>14:30</td>
<td>Prolongation of fatigue life of TiNi shape memory alloy by ultrasonic shot peening</td>
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<tr>
<td>14:30</td>
<td>Study of the mechanical properties of the human soft tissue stiffness by optical interferometry and finite element modelling</td>
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</tbody>
</table>

### Plenary Lecture Theatre

- Mechanics of fatigue
- Proportion of fatigue life of TiNi shape memory alloy by ultrasonic shot peening
- Study of the mechanical properties of the human soft tissue stiffness by optical interferometry and finite element modelling
<table>
<thead>
<tr>
<th>Time</th>
<th>Session 1.2</th>
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<tbody>
<tr>
<td>14:50</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Thermal mechanical fatigue of nickel base superalloys – modelling versus experiment</td>
<td>Design, instrumentation and control of a force/displacement controlled rotating bending fatigue test rig</td>
<td>Experimental and numerical studies of bolted joints subjected to axial excitation</td>
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<tr>
<td>15:10</td>
<td>4</td>
<td>5</td>
<td>6</td>
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<tr>
<td>Multiplexing of long-gauge length fibre optic dynamic strain sensors using range-resolved interferometry</td>
<td>In-situ strain measurements with fibre Bragg gratings embedded into stainless steel by selective laser melting</td>
<td>Comparing the eFinger and the finger to measure the stiffness of the ex vivo prostate gland</td>
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<tr>
<td>15:30</td>
<td>7</td>
<td>8</td>
<td>9</td>
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<tr>
<td>Viscoelastic modelling of rectum tissue during short-term relaxation</td>
<td>Design, instrumentation and control of a force/displacement controlled rotating bending fatigue test rig</td>
<td>Experimental and numerical studies of bolted joints subjected to axial excitation</td>
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<tr>
<td>15:50</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Refreshments - Lounge</td>
<td>Image registration for quantifying deformation in penetrating ultrasound waves using speckle interferometry</td>
<td>Photoelastic measurement of sub-surface stresses using GHz radiation</td>
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<tr>
<td>Session 1.2</td>
<td>E. Cramphorn, M. J. Carre, Z. A. Taylor, , University of Sheffield, UK</td>
<td>P. Schemmel, G. Diedrich, A. M. Moore, Heriot-Watt University, UK</td>
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<tr>
<td>16:10</td>
<td>13</td>
<td>14</td>
<td>15</td>
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<tr>
<td>Novel inertial heterogeneous high strain rate test for non-linear constitutive model identification with the virtual fields method</td>
<td>Damage response of stationary and moving targets to ballistic impact</td>
<td>Critical force thresholds for laparoscopic grasping as an indicator of tissue damage</td>
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<tr>
<td>16:50</td>
<td>16</td>
<td>17</td>
<td>18</td>
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<tr>
<td>Mechanical force due to lightning strikes to metallic structures</td>
<td>Cost-effective vibration and displacement measurement using range-resolved interferometry</td>
<td>Exploiting elastic modulus of human cells for inspiration purposes</td>
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<tr>
<td>17:10</td>
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<tr>
<td>Damage response of stationary and moving targets to ballistic impact</td>
<td>Dynamic strain measurement in ball bearing</td>
<td>Explosive plastic modulus of human cells for inspiration purposes</td>
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<tr>
<td>S. A. Westcott, P. D. McCarthy, R. A. Greenwood, D. G. T. MacKie, University of Sheffield, UK</td>
<td>E. Cramphorn, M. J. Carre, Z. A. Taylor, , University of Sheffield, UK</td>
<td>M. J. Zadeh, N. Willoughby, H. B. Heo, Heriot-Watt University, UK</td>
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<tr>
<td>17:30</td>
<td>22</td>
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<td>24</td>
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<tr>
<td>Dynamic strain measurement in ball bearing</td>
<td>In-situ strain measurements with fibre Bragg gratings embedded into stainless steel by selective laser melting</td>
<td>Design, instrumentation and control of a force/displacement controlled rotating bending fatigue test rig</td>
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<tr>
<td>Time</td>
<td>Session 2.1a: DIC techniques and applications 1</td>
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<tr>
<td>09:30</td>
<td>Fraction of non-metallic inclusions in Zr-Cu</td>
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<td></td>
<td>L. S. Massé, H. Tamgou, L. Wang, Manchester, UK</td>
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<td></td>
<td>3D structural characterization of graphite at high strain: a pilot study</td>
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<td></td>
<td>V. V. Silberschmidt, Loughborough University, UK</td>
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<tr>
<td>10:30</td>
<td>Digital image correlation microscopy: a new tool for studying ultrastructural damage in metals and metal ceramics</td>
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<td></td>
<td>M. Barsoum, Drexel University, Philadelphia, PA</td>
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<td></td>
<td>J. A. Shah, J. B. McCann, Technical University of Darmstadt, Germany</td>
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<tr>
<td>11:00</td>
<td>Structural strain measurement of Zr-Cu-based metallic glasses: New technological applications</td>
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<td></td>
<td>D. G. Leary, D. M. Weatherly, University of Sheffield, UK</td>
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<td>L. Wang, Manchester Metropolitan University, UK</td>
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<thead>
<tr>
<th>Time</th>
<th>Session 2.2a: DIC techniques and applications 2</th>
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<tbody>
<tr>
<td>11:00</td>
<td>Shear band in Co-based metallic glasses: New insight</td>
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<tr>
<td></td>
<td>V. V. Silberschmidt, Loughborough University, UK</td>
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<tr>
<td>11:30</td>
<td>Plastic strain measurement of steel specimens: New insights</td>
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<td>J. R. Farthing, H. Tamgou, Manchester, UK</td>
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<tr>
<td>12:00</td>
<td>Surface and structural deformation bands in metallic glasses: A new tool for studying ultrastructural damage in metals and metal ceramics</td>
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<td>M. Barsoum, Drexel University, Philadelphia, PA</td>
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<td>L. Wang, Manchester Metropolitan University, UK</td>
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<th>Session 2.2b: Geomechanics</th>
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<td>M. Barsoum, Drexel University, Philadelphia, PA</td>
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<td>L. Wang, Manchester Metropolitan University, UK</td>
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<tr>
<th>Time</th>
<th>Session 2.2c: Geomechanics</th>
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<tbody>
<tr>
<td>12:00</td>
<td>Surface and structural deformation bands in metallic glasses: A new tool for studying ultrastructural damage in metals and metal ceramics</td>
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<tr>
<td></td>
<td>M. Barsoum, Drexel University, Philadelphia, PA</td>
</tr>
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<td></td>
<td>L. Wang, Manchester Metropolitan University, UK</td>
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</tbody>
</table>
14:00  Best Paper in Strain - Plenary Lecture Theatre  
Full-field measurements on low-strained geomaterials using environmental scanning electron microscopy and digital image correlation: improved imaging conditions  
L. L. Wang, M. Bornert, E. Héripré, S. Chancholle, A. Tanguy

14:30  BSSM Young Stress Analyst Competition  
Determination of micro-residual stress distribution in multi phase ceramic composites using Raman spectroscopy  
M DeVries, University of Florida, USA  
A new white light imaging approach for intralaminar fatigue characterisation of GFRP  
J Glud, Aalborg University, Denmark  
Three dimensional in situ quantification of localised non-linear deformations within heterogeneous materials  
M S L Jordan, University of Oxford, UK  
Measurement of highly non-uniform residual stress fields with reduced plastic error  
H K Kim, University of Bristol, UK

15:30  Refreshments and Exhibition - Lounge

16:00  BSSM Measurements Lecture - Plenary Lecture Theatre  
New opportunities in high strain rate testing based on full-field measurements  
Prof Fabrice Pierron, University of Southampton, UK

17:00  BSSM AGM – Room 1

19:00  Conference Dinner – Playfair Library  
Coaches depart main reception

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**Thursday 3rd September**

**Plenary Lecture Theatre**  
**Session 3.1a**  
**Residual strain measurement**  
Analysis of total residual strains around cold expanded holes  
K Amjad, E A Patterson, University of Liverpool, UK, W-C Wang, National Tsing Hua University, Taiwan

**Session 3.1b**  
**Material damage assessment**  
Quantitative measurement of the J-integral of loaded cracks using 2D and 3D digital image correlation  
S M Barhli, T J Marrow, University of Oxford, UK, J Réthoré, J Lachambre, J-Y Buffière, INSA Lyon, France

**Session 3.2a**  
**Vibration measurement**  
Active vibration reduction: Genetic algorithm optimisation using the physical structure  
J M Hale, Newcastle University, UK

**Session 3.2b**  
**Mechanical and material testing**  
The matrix method; a better alternative to the sin2ψ and other methods  
B Ortner, University of Leoben, Austria

**Session 3.2c**  
**Stress-strain measurement**  
Quantitative measurement of the J-integral of loaded cracks using 2D and 3D digital image correlation  
S M Barhli, T J Marrow, University of Oxford, UK, J Réthoré, J Lachambre, J-Y Buffière, INSA Lyon, France

**Session 3.3a**  
**Residual strain measurement**  
Study of total residual strains around cold expanded holes  
K Amjad, E A Patterson, University of Liverpool, UK, W-C Wang, National Tsing Hua University, Taiwan

**Session 3.3b**  
**Material damage assessment**  
Quantitative measurement of the J-integral of loaded cracks using 2D and 3D digital image correlation  
S M Barhli, T J Marrow, University of Oxford, UK, J Réthoré, J Lachambre, J-Y Buffière, INSA Lyon, France

**Session 3.4a**  
**Vibration measurement**  
Development of the European ultrasonic planetary core drill  
A Bolhovitskiy, X Li, R Timoney, P Harkness, M Lucas, University of Glasgow, UK

**Session 3.4b**  
**Mechanical and material testing**  
The matrix method; a better alternative to the sin2ψ and other methods  
B Ortner, University of Leoben, Austria

**Session 3.5a**  
**Residual strain measurement**  
Study of total residual strains around cold expanded holes  
K Amjad, E A Patterson, University of Liverpool, UK, W-C Wang, National Tsing Hua University, Taiwan

**Session 3.5b**  
**Material damage assessment**  
Quantitative measurement of the J-integral of loaded cracks using 2D and 3D digital image correlation  
S M Barhli, T J Marrow, University of Oxford, UK, J Réthoré, J Lachambre, J-Y Buffière, INSA Lyon, France

**Session 3.6a**  
**Vibration measurement**  
Development of the European ultrasonic planetary core drill  
A Bolhovitskiy, X Li, R Timoney, P Harkness, M Lucas, University of Glasgow, UK

**Session 3.6b**  
**Mechanical and material testing**  
The matrix method; a better alternative to the sin2ψ and other methods  
B Ortner, University of Leoben, Austria
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Paper Title</th>
<th>Authors</th>
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</thead>
<tbody>
<tr>
<td>11:40</td>
<td>1</td>
<td>Friction induced vibration of a moving slider on an elastic disc with separation and reattachment</td>
<td>Z Li, H Ouyang, University of Liverpool, UK</td>
</tr>
<tr>
<td>12:00</td>
<td>2</td>
<td>Squeeze-film levitation characteristics of plates excited by piezoelectric actuators</td>
<td>A Almursheid, M Atherton, C Mares, T Stolanski, Brunel University, UK, B Wei, Beihang University, China</td>
</tr>
<tr>
<td>12:20</td>
<td>3</td>
<td>Backbone curves and Nonlinear normal modes: a new identification tool</td>
<td>A Cammarano, University of Glasgow, T L Hill, S A Neild, University of Bristol, P L Green, University of Liverpool, UK</td>
</tr>
<tr>
<td>12:40</td>
<td>4</td>
<td>Damping performance of novel viscoelastic double shear lap joint dampers in lightweight honeycomb</td>
<td>P Aumjaud, D Lefranc, K E Evans, C W Smith, University of Exeter, UK</td>
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<tr>
<td></td>
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<td>sandwich panels - simulation and experimental measurement</td>
<td>An innovative method for measuring Young's modulus of a flexible circular ring (own-weight circular ring method)</td>
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<td>A Ohtsuki, Meijo University, Japan</td>
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<td></td>
<td>Squeeze-film levitation characteristics of plates excited by piezoelectric actuators</td>
<td>G Benoit, S Boyer, S Castagnet, G Henaff, E Laine, F Maugel, Pprime Institute, University of Pottiers, France</td>
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<td>Use of piezoelectric thick film sensors to measure stress distribution within a lap joint</td>
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<td>A Deligianni, G Kotsikos, J M Hale, University of Newcastle, UK</td>
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<tr>
<td>13:00</td>
<td>5</td>
<td>Lunch - Lounge</td>
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<tr>
<td>14:00</td>
<td>6</td>
<td>Differential scanning calorimetry of superelastic nitinol for tuneable devices</td>
<td>A Feeney, M Lucas, University of Glasgow, UK</td>
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<tr>
<td></td>
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<td>Preliminary evaluation of validation metrics for computational mechanics models</td>
<td>K Dvurecenska, E A Patterson, E Patelli, University of Liverpool, S Graham, National Nuclear Laboratory, UK</td>
</tr>
<tr>
<td>14:20</td>
<td>7</td>
<td>Motion compensation for complex deformations in thermoelastic stress analysis</td>
<td>J M Dulieu-Barton, W Wang, R Frühmann, University of Southampton, UK</td>
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<tr>
<td></td>
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<td>Characterisation of anisotropic plastic behaviour using an inverse method</td>
<td>J Seo, J-H Kim, F Barlat, Pohang University of Science and Technology, M Lee, Korea University, Republic of Korea, F Pierron, University of Southampton, UK</td>
</tr>
<tr>
<td>14:40</td>
<td>8</td>
<td>Relationship between temperature and stress of ultraviolet-curable resin during curing</td>
<td>E Umezaki, H Kpyama, Nippon Institute of Technology, Japan</td>
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<tr>
<td></td>
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<td>Inverse method to determine the plastic stress strain curve from non-conventional tests</td>
<td>F J Gómez, Advanced Material Simulation S.L., MA Martín-Rengel, J Ruiz-Hervías, Universidad Politécnica de Madrid, Spain</td>
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<tr>
<td>15:00</td>
<td>9</td>
<td>Towards combining thermoelastic stress analysis and digital image correlation for strain-based</td>
<td>S C Teige, J M Dulieu-Barton, S Quinn, University of Southampton, UK</td>
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<td>NDE</td>
<td>Topology optimisation and model validation of selective laser melted components using digital image correlation</td>
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<td>M Faes, Y Wang, P Lava, D Moens, KU Leuven, Belgium</td>
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<tr>
<td>15:20</td>
<td>10</td>
<td>Movement of uncured ultraviolet-curable resin during curing</td>
<td>H Koyama, E Umezaki, Nippon Institute of Technology, Japan</td>
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<tr>
<td></td>
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<td>Identification of advanced frictional laws in severe contact conditions</td>
<td>M Watremez, K Le Mercier, D Meresse, L Dubar, University of Valenciennes, France</td>
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<tr>
<td>15:40</td>
<td>11</td>
<td>Closing remarks</td>
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<tr>
<td>15:45</td>
<td>12</td>
<td>Refreshments - Lounge</td>
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<td>16:15</td>
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