Newsletter
AVIC Centre for Structural Design and Manufacture

Imperial College London
2018
...a very challenging and productive year...

Technical Objectives

The agreed collaboration between Imperial College London and the Aviation Industry Corporation of China (AVIC), in particular AVIC Manufacturing Technology Institute (MTI) and First Aircraft Institute in Xian (FAI), promotes world leading research with the aim of developing a thorough understanding of the physical properties of materials and their manufacturing routes. Our goal is to collaboratively research, discover and innovate. The aim of this collaboration is to further improve safety, light-weighting and efficiency for the next generation of aircraft.

Executive Summary

This has been a very productive year for us. Now five years after the establishment of the centre, fourteen PhDs and four RAs have undertaken research in the AVIC Centre for Structural Design and Manufacture, working closely with the twenty-four visitors from MTI and FAI on a wide variety of topics. This year two conference workshops were organised, one in Xi’an in June and the other in London in December, both events being attended by AVIC and Imperial researchers. These events have greatly helped forge a closer working partnership, together with strong collaboration. This has resulted in innovative and novel research, the findings of which can be found in the six-monthly reports, as well as in journal and conference publications.

This year, the AVIC Centre has started its journey for the next five years. We look forward to building on our achievements going forward.

Prof Jianguo Lin, FREng
Centre Director

Prof John Dear
Executive Co-Director
Held 2 conference workshops

Involved 16 academic staff

Hosted 8 visiting academics in current year

Received 30 visitors from AVIC, MTI and FAI

Recruited total 4 RAs and 14 PhDs

13 Journal Papers Published in current year

6 PhDs graduated

Produced two sets of six monthly reports

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The management and governance arrangements for the Centre are as follows.

### Directors of the Centre
Professor Jianguo Lin FReng – Director, Professor John Dear – Executive Co-Director
Dr Daniel Balint – Co-Director, Dr Catrin Davies – Co-Director

### Steering Committee

**Membership**
- Prof Xinguo Zhang, Executive Vice President of AVIC
- Prof Jeff Magee (FReng), Dean of the Faculty of Engineering
- Prof Jinzhong Wei, Vice President of Science and IT of AVIC
- Prof Tony Kinloch (FRS, FReng)
- Prof Zhiqiang Li, President of MTI
- Prof Peter Cawley (FRS, FReng), Head of Department of Mechanical Engineering
- Prof Xiaofeng Liu, President of FAI
- Prof Fionn Dunne (FReng), Professor of Micromechanics, Materials

**Representatives of the Management Committee shall carry out, including:**
(i) formulate and approve the development plan of the Centre;
(ii) monitor the quality, timely implementation and execution of approved Statements of Work
(iii) seek any amendments to Statements of Work proposed by the Parties
(iv) provide the Steering Committee with strategic management information
(v) develop plans for seeking additional funding sources.

### Management Committee

**Membership**
- Mr Gang Chen, Deputy Director of Technology and IT of AVIC
- Prof Jianguo Lin (FReng), Head of Mechanics of Materials Division
- Prof Jun Feng, Deputy President, FAI
- Prof John Dear, Professor of Mechanical Engineering
- Dr Wei Xie, Director, International Cooperation, MTI
- Dr Dimitris Sarantaridis, Senior Associate, Corporate Partnerships

### Other associated academic staff
Dr Bamber Blackman, Professor Trevor Dean, Prof Stephen Garwood FReng, Prof Kamran Nikbin, Dr Liliang Wang, Prof Gordon Williams FRS, FReng, Dr Zhusheng Shi, Dr Jun Jiang, Prof Peter Childs, Dr Nan Li, Dr Xiaoyu Xi

### Academic visitors in current year
Dr Yongguan Jing – MTI - Microstructure and mechanical properties of brazing joint for T664AV alloy – Dr Jun Jiang & Prof Jianguo Lin, February 2016 (12 months)
Mr Enguang He – MTI - Post-weld strength prediction for aluminium-lithium alloy – Dr Liliang Wang & Prof Jianguo Lin, February 2016 (12 months)
Mr Fenghong Liu – MTI - Stress relaxation ageing and constitutive modelling of 7804 aluminium alloy – Dr Zhusheng Shi & Prof Jianguo Lin, December 2016 (12 months)
Mr Zhipeng Zhang – FAI - Residual stress effects on the stability of Al structures – Prof Jianguo Lin, December 2016 (12 months)
Mr Mengxin Xing – FAI - Thermoplastic composites structure design and application – Prof John Dear & Dr Bamber Blackman, December 2016 (12 months)
Dr Yaqiong Liu – FAI - Process simulation of Al die forging – Dr Zhusheng Shi & Prof Jianguo Lin, December 2017 (12 months)
Dr Hui Chai – FAI - Failure mechanisms of thermoplastic composites – Prof John Dear & Dr Bamber Blackman, December 2017 (12 months)
Dr Haitao Qu – MTI - Al die forging – Dr Liliang Wang & Prof Jianguo Lin, December 2017 (12 months)
Development Plan of the Centre

The plan is to provide for research as needed by AVIC (FAI and MTI). The research interests of FAI and MTI are centred on the manufacture and in-service maintenance of aircraft structures. The mode of operation for planning future research in the AVIC Centre is for FAI and MTI staff to provide a brief covering a specific research requirement. It is expected that visiting researchers from AVIC will be assigned to research in the AVIC Centre, and each AVIC visitor will be associated with a specific research topic. The AVIC centre will allocate funding for a PhD or postdoctoral researcher to initiate and perform the research, working in association with the visiting academics from AVIC. This mode of operation should work well as it means all AVIC visitors will have PhD or post-doctoral staff within the College to work alongside, and this connection will continue after the visiting academic returns to AVIC. The academic supervisor for the PhDs and post doctorates is also the academic supervisor for the visiting academic. Examples of research topics are given below:

- Residual stress of large aluminium components: methods to model, measure and remove detrimental stresses post-quenching; Imperial: Dr Michael Kaye, Ran Pan & Jinghua Zheng; AVIC: Chen Li & Wei Zhang; Supervisors: Prof Jianguo Lin & Dr Catrin Davies
- Structural integrity assessment of Additive manufactured products; Imperial: Youssef Ibrahim Supervisors: Prof John Dear, Dr Catrin Davies & Dr Paul Hooper
- Hot stamping of titanium alloys; Imperial: Mateusz Kopec; MTI: Haitao Qu; Supervisors: Dr Liliang Wang & Prof Jianguo Lin
- Thermoplastic composites structure design and application; Imperial: Jun Liu; FAI: Mengen Xing, Hui Chai; Supervisors: Prof John Dear & Dr Bamber Blackman
- Hybrid manufacturing: Additive manufacturing and subsequent forging; Imperial: Zinong Tan, Chris Hopper; Supervisors: Dr Jun Jiang & Prof Jianguo Lin
- Design optimisation methods for high stiffness and super-light structures; Imperial: Lei Zhu; Supervisors: Dr Nan Li, Prof Peter Childs, Prof Jianguo Lin

List of research projects

1. Residual stresses of large Al component
2. Surfi-sculpt and composites to metal joints
3. Hot stamping of complex shaped Al-Li alloy components
4. Structural integrity assessment of additive manufactured products
5. Stress relaxation ageing and constitutive modelling of 7804
6. Thermoplastic composites structure design and application
7. Recrystallisation of aluminium alloys
8. Hot stamping of titanium alloys
9. Residual stress effect on the stability of Al structures
10. Hybrid manufacturing: Additive manufacturing and subsequent forging
11. Design optimisation methods for high stiffness and super-light structures

"The agreed collaboration... relates to promoting world leading research on streamlining the construction and testing of... the next generation of aviation structures."
Testimonials

Personal statement from research staff and students currently involved within the Centre

Mr Fenggong Lyu, Academic visitor since December 2016 - Stress relaxation ageing and constitutive modelling of aluminium alloy 7B04 - Dr Zhusheng Shi & Prof Jianguo Lin

“I am a PhD student, sponsored by the AVIC centre, and have been studying the residual stress reduction technique for extra-large aircraft component for 3 years. Through years’ study, we have established a novel manufacturing process to produce high-quality low-residual stressed parts, overcoming the residual stress (RS) induced distortion that is concerned by the industry for years. Thanks to the centre, which enable me to be guided by supportive, kind and intelligent supervisors, to work with excellent colleagues, and more importantly, to theoretically and practically gain deep understandings of the generation and elimination of the RS that will benefit my further career. My work is divided into 2 aspects: experiments and simulations. For experiments, I’ve developed skills on operating residual stress detection facilities, such as neutron diffraction, X-ray diffraction techniques, that can accurately quantify the RS distributions. Meanwhile, I’ve learned the microstructural observation techniques, such as TEM and SEM, to characterise the precipitate evolution during residual stress relaxations. For simulations, an integrated RS reduction model has been established and validated, which can be used as valuable RS prediction tool for the established manufacturing process. Based on the above study, up till now, several high-quality research papers have been generated. I absolutely love the research life here, and am very happy to share my research experience with anyone, who is interested in this area.”

Ms Jinghua Zheng, PhD student since October 2014 - residual stress reduction technique for extra-large aircraft component – Dr Catrin Davies and Prof Jianguo Lin

“I am very honoured to be a member of AVIC Centre for Structural Design and Manufacture as an academic visitor in Imperial College London in the whole year of 2017. In this year I mainly worked on the failure mechanisms of thermoplastic composites. With the helpful advice and guidance of knowledgeable supervisor and the extraordinary cooperation with PhD partners here, I started this project from the research of impact properties of thermoplastic composite, mainly on how different materials, impact energy, ply sequences and ply angles affect the results of impact. I designed and completed many tests and simulations of the impact process for this research. Through the whole year’s work, I not only obtained the deep understanding of the manufacturing process and mechanical impact properties of thermoplastic composite, but also learned the simulation methods of thermoplastic composite impact. All of these will contribute much to my future work and the engineering applications of thermoplastic composite on the aircraft.”

Mr Mengen Xing, Academic visitor since December 2016 - Failure mechanisms of thermoplastic composites - Prof John Dear

“Working within the AVIC centre has been a very rewarding experience, both personally and professionally. I was given the opportunity to develop my research and critical thinking skills under the guidance and support of BAMTRI. This has given me a strong foothold in the new and exciting field of additive manufacturing and its applications in the aerospace and medical implant industries. Having worked alongside the extraordinary mentors and colleagues at the AVIC centre, I find myself well equipped for a prosperous career in engineering research and development”

Mr Youssef Ibrahim, PhD student since October 2014 – Structural integrity assessment of Additive Manufactured components – Prof John Dear, Dr Catrin Davies, Dr Paul Hooper

“I’m very honoured to have the opportunity to be an academic visitor at AVIC Centre in Imperial College London. My research project focuses on the stability of aluminium alloy structures with residual stress. During my visit, I have been in contact with many outstanding experts in the College. Everyone in AVIC Centre is friendly and knowledgeable, I got a lot of guidance and assistance from our research group. With their help, I found an effective way to simplify the representation of welding and shot-peening residual stress. Then, I used thermal load equivalent residual stress distribution and calculated the effect coefficient of residual stress on different aluminium structures. I also designed a test device to investigate the relationship between residual stress and yield stress. The research conclusions will be very useful in aircraft design process. Overall, I have had a pleasant and fulfilling time in Imperial College London which will be the most memorable memory in my life. I believe the future of AVIC Centre will be even brighter.”

Zipeng Zhang, Academic visitor since December 2016 - Effect of residual stress on the stability of aluminium structures - Prof Jianguo Lin

“I am an engineer and work in AVIC MTI. I am honoured to be a visiting researcher in the AVIC Centre for Structural Design and Manufacture at Imperial College London from December 2016. It is great to study here and provides a chance for me to communicate with many overseas experts face to face. My research area focuses on stress relaxation ageing and constitutive modelling of aluminium alloy 7B04 (AA7B04). In this year’s study under supervision and support of Dr Zhusheng Shi and Prof Jianguo Lin, I have completed all the designed experiments including creep test, stress relaxation test and tension test. I have got the first-hand data of stress relaxation curves and mechanical strength variation to analyse the creep and relaxation behaviour of AA7B04. In addition, I have done the numerical simulation of creep age forming for AA7B04 stiffened plates and obtained good results compared with the process experiments. So greatly appreciate the CAF group for giving me so many great information, directions and tips. Everything is going very fast this year but I am happy I’ve got the chance to experience and learn new things in AVIC Centre at Imperial College.”
Research Projects

Hybrid Manufacture – Additive Manufacturing and Subsequent Forging

Research Associate: Tan Zinong; PhD: Chris Hopper;
Start and expected end dates: February 2017 – Feb 2022

The manufacture of metallic components by the use of Additive Manufacture (AM) has great future potential, particularly in aerospace applications where conventional machining (Subtractive Manufacturing) often results in poor material utilisation and high cost. In some cases as much as 95% of the original billet is machine away in forming the final part. Progress in this area has, however been slow as a result of uncertainties in the mechanical properties of AM parts, particularly under dynamic loading.

This project investigates a method to achieve the desired mechanical properties in AM components by applying a combination of hot forging and heat treatment to a near net shape AM part. This process uses hot forging to control porosity, and heat treatment to control final microstructure.

Progress to date:

- Specimens of Stainless Steel 316 have been prepared by AM. They have subsequently been hot forged and heat treated. These treated blanks were then machined into standard tensile specimens and tested.
- The results to date show that it is possible to improve mechanical properties and affect microstructure by this process, as indicated in figure 2.

A numerical investigation of effect of residual stresses on stability of welded thin-walled aluminium alloy structures

Start and expected end dates: December 2016 – December 2017
Visiting Academic: Mr Zipeng Zhang

A numerical method to investigate the effect of welding induced residual stress on stability of aluminium alloy structures is developed and applied to buckling and post-buckling analysis for various thin-walled structures. The purpose is to find a practical method to introduce residual stress and obtain basic data of buckling/post-buckling character for aluminium alloy structures. The followings list the progress that has been made:

- A temperature field method integrating the self-equilibrium cosine function is developed and successfully implemented with the welding residual stresses into FE models of various thin-walled aluminium alloy structures, such as plates and panels, for buckling and post-buckling analysis.
- Residual stress of compression dominated distribution (TCT) decrease the buckling critical value of plate. As the plate length increase, the influence of residual stress in buckling critical value become smaller. Residual stress of stretching dominated distribution (CTC) increase the buckling critical value under a strict condition. When the residual stress level is high or the plate is wider, additional shear stress also decrease the structure stability. For most narrow plates, the influence of CTC residual stress distribution on buckling critical stress can be neglected.
- Residual stresses have minimal impact on the first order buckling properties of long columns, and the maximum impact on medium-columns, consistent with the post-buckling analysis. All of this can be regarded as the section yield stress decreased. Residual stress in the structure can reduce the bear capacity under compression load. The specific influence size depends on the proportion of the cross section occupied by the residual stress area.
Structural Integrity Assessment of Additive Manufactured Components

PhD: Mr Youssef Ibrahim

Start: October 2014

Expected end: September 2017

The project aims to develop and implement effective design optimisation procedures based on in-depth knowledge of the manufacturing process and its influence on the structural and mechanical properties of the processed material. This is investigated through a series of experimental tests on additive manufactured components along with computational modelling and analysis of the manufacturing process. Current progress in this field is mainly hindered by the inherent inconsistency exhibited by AM due to limited process control. The project investigates the possibility of characterising and incorporating these inconsistencies into the design process while allowing for upgrade-ability as the technology develops.

The project currently focuses on cellular lattice structures. This is an implementation of topology optimisation for high strength-to-weight ratio components. Various cell geometries are investigated and the correlation between cell geometry and the mechanical properties is established. This allows for tailoring of the mechanical properties for specific component service conditions. The AM process exhibits very efficient material consumption compared to conventional subtractive manufacturing. This, coupled with material savings achieved through the use of cellular lattice structure designs, generates substantial reductions in overall material usage.

Fig 1. Regular and stochastic cellular lattice structure samples of the same relative density

Fig 2. Appearance of lattice specimens with increasing strain

Fig 3. Stress-strain plot of the regular and stochastic lattice structures under uniaxial compression
Research Projects

**Micromechanical study of recrystallization in aluminium and its alloys**

**Start and expected end dates: November 2016 – October 2019**

**PhD: Qinmeng Luan**

The engineering required properties for aeroplane aluminium components such as high strength and high toughness can be achieved through recrystallization process to obtain a designed microstructure with small and homogeneous grains. Reliable computational models based on sound physical concepts are vital to optimize the process. Unlike the other models including Monte Carlo Potts model, cellular automata, vertex model and level set model, phase-field model is capable to consider many different microstructure processes based on thermodynamic formulations and can trace arbitrary grain interface geometries. Hence, a phase-field model coupled with a crystal plasticity finite element (CPFE) method was developed to study the microstructure evolution during recrystallization based on the theory of crystal plasticity and minimization of stored free energy.

- A 2D grain structure model having random grain orientations was developed for simulating the recrystallization process. The dislocation density distribution on the 2D grain structure model of pure aluminium after uniaxial compression was calculated by CPFE method and then imported into the KWC phase-field model after code parallelization (i.e. data mapping).
- The deformed pure Al was EBSD mapped to calculate the dislocation density from the misorientation information as a comparison of CPFE calculated dislocation density.
- The in-situ EBSD mapping equipped with a heating stage was done for the rolled sample to obtain the nucleation of new grains and grain growth during recrystallization.
- The in-situ EBSD results will be used to calibrate the phase-field model for the recrystallization in the future.

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**Fig 1. Methodology of using the EBSD results to calibrate the recrystallization model (i.e. phase-field model coupled with CPFE model)**

**Fig 2. Phase-field modelling results based on the experimental EBSD data**

**Fig 3. Phase-field modelling results based on the CPFE simulation data**
Residual Stress Generation Measurement and Elimination large section aluminium components

Start and expected end dates: October 2012 – May 2018
Research Associate: Dr Michael Kaye; Visiting Academics: Ms Chen Li, Mr Wei Zhang; PhD: Mr Ran Pan, Ms Jinghua Zheng

Residual stresses are known to reduce fatigue life and cause unacceptable distortion and these effects increase with increasing thickness of components. Residual stress removal is normally achieved with annealing or deformation. However, annealing would annihilate the desired microstructure. Due to the size and complexity of new aeronautical components, it is not possible to use destructive methods to measure residual stress. An accurate numerical model is required to predict the residual stress. Since it is impractical to apply traditional cold working techniques e.g. cold stretching and cold compression to reduce residual stresses in extra-large T-section components, the effect of cold rolling on reducing residual stresses of a quenched AA 7050 block has been studied. In addition, the influence of ageing, which is the final step of the heat treatment process after cold rolling to improve the strength of the aluminium components, on the residual stress reduction by exploiting the creep-relaxation mechanism was also investigated, as cold rolling leads to large tensile residual stresses on the surfaces of quenched AA 7050 samples.

- An updated material model for predicting residual stresses in quenched components has been validated against a multiple temperatures of quenching medium.
- The ultrasonic method was applied to measure residual stress (using the acoustoelastic effect).
- The temperature dependent convective heat transfer coefficient between AA7050 aluminium alloy and water has been determined.
- Contour, Neutron and X-ray diffraction measurement have been carried out on quenched and cold rolled AA 7050 block. The results had good consistence with model prediction.
- Updated physically-based constitutive equations for predicting the residual stress reduction due to the relaxation mechanism during ageing has been validated using multi-step stress relaxation ageing data. Good agreement was achieved.
- Contour and X-ray measurement on as quenched, cold rolled, artificial aged T-shaped 7050 component is proposed.

![Fig 1. The experimental (symbols) and predicted (solid line) residual stresses (i.e. $\sigma_x$, $\sigma_y$, $\sigma_z$) along (a), (c), (e) the middle line (ML) of the T-section panels at water quenched (WQ), cold rolled (WQ+CR) and constrained aged (WQ+CR+CA) stages; (g) schematic illustrations of the ML. (b), (d), (f) The FE predicted distributions at each stage](image)
Research Projects

Stress relaxation ageing and constitutive modelling of aluminium alloy 7B04

Visiting Academic: Mr Fenggong Lyu
Start: December 2016, End: December 2017

Creep age forming (CAF) is an efficient processing method for fabricating integral panels of aluminium alloys. The springback control and material strength prediction are the two key problems in the development of CAF process. This project focuses on investigating the deformation behaviour and microstructural evolution of AA7B04 during creep ageing so as to predict the springback and material strength of stiffened plate after CAF. In addition, stress relaxation ageing behaviour of AA7B04 under high stress levels or plastic deformation conditions have been investigated.

- The creep strain is mainly distributed on the stiffener of the plate. The higher the equivalent stress is, the more creep strain is accumulated, such as at point A.
- Yield strength on the skin is evenly distributed when compared with those on the stiffener. The yield strength of stiffener (Point A) is the lowest.
- In elastic stage, the higher the initial stress, the higher the residual stress. When the pre-loading enters the plastic state, residual stress becomes stable after 16h relaxation.
- As the stress relaxation ageing proceeds, the yield strength decreases gradually for extended time due to over-ageing. The higher the initial stress, the lower the yield strength after ageing.

A Study on Constitutive Relations and Failure Criteria for Thermoplastic Composites

Start and expected end dates: December 2016 - February 2020
PhD: Jun Liu; Visiting Academic: Mr Mengen Xing.

Nowadays carbon fibre reinforced plastic composites (CFRP) have been widely used in primary structures of aircrafts such as wings and fuselages. The main aim of the project is to seek characterization methods to evaluate mechanical performances of thermoplastic composites, study the constitutive relationship, establish the failure criterion and verify models developed by studying AS4/PEEK thermoplastics and comparing with equivalent thermosetting composites. This understanding helps us to design a lightweight impact resistant CFRP for primary structures of aircrafts. The followings list the progress that has been made:

- Woven fabric CFRP with PEEK and epoxy matrices have been manufactured. CFRP with PEEK matrices with different configurations have been designed in Imperial and manufactured in University of Liverpool.
- A series of DIC and perforation tests has been performed with various types of projectiles in order to investigate the effect of material of projectile, and CFRP with PEEK and epoxy matrices on the impact performance.
- A gas gun has been set up for performing high velocity impact with rigid, semi-rigid and soft projectiles on CFRPs in order to simulate small scale ballistic test in the lab. High velocity 3D digital image correlation (DIC) has been set up to monitor the deformation and strain of the sample under impact.
Research Projects

Optimisation of Aircraft Wing Stiffness with Super High Aspect Ratio

Aircraft wings with super high aspect ratio can cause insufficient wing stiffness. It is crucial to optimise material and structures of the wing box to maximise the wing stiffness under the weight limitation. The aim of this project is to improve the structural efficiency of the primary wing structure through structural optimisation of components layout and parameters, as well as tailoring composite scheme. The progress has been achieved involve:

- Literature study on enablers of light-weighting design, which has been presented in the 2nd LIMAS conference and a proceeding was published afterwards.
- The work was divided into conceptual designs, embodiment and detailed designs. A cantilever beam was used as a representative unit during the conceptual design stage. The results indicate that 3D truss structures provide optimal structural efficiency in this case.
- A hierarchical optimisation strategy was adopted during the concept design stage. In global domain, the material is assumed to be isotropic and topology optimisation is operated. Then the truss element in local domain is optimised again through performing shape and sizing optimisations, as well as tailoring composite schemes.
- A composite material lamination elastic model has been established.

Hot Stamping of titanium alloys

This project aims to develop a novel hot stamping process for titanium alloys using cold forming tools and a hot blank to reduce the cost of producing titanium alloys components. The followings list the progress that has been made:

- The formability of Ti6Al4V alloy was investigated through uniaxial tensile tests at temperatures ranging from 600 to 900 degrees and strain rates ranging from 0.1 to 5 s⁻¹.
- Hot stamping tests were performed in a wide temperature range to verify the feasibility of the novel process for the Ti6Al4V alloy.
- Three microstructure evolution mechanisms were revealed at different conditions: recovery, recrystallization and phase transformation. The formability and post-form properties varied greatly with the deformation conditions due to the different deformation mechanisms.
- The microstructure and post-form mechanical properties were mainly determined by heating temperature and soaking time, hence formability and post-form properties of the material could be tailored through the adjustment of the forming process.

Fig 1. A hierarchical strategy of structural optimisation: Topology optimisation of isotropic material distribution on global domain, followed with shape and sizing optimisation with tailored anisotropic material properties in local domain.

Fig 1. View of parts formed at (a) 600°C, (b) 750°C, (c) 850°C, (d) 900°C.
Equipment

An extensive range of equipment is available to the researchers within the Centre

Heavy Testing Machines
A 250 Tonne hydraulic forming press and 100 Tonne high-speed (up to 1.6 m/s) hydraulic forming press are available. These machines can act in tension and compression and can be used for three-point bending tests and forging tests. The 100 Tonne high-speed press can also be used for large scale fatigue tests.

High-rate Testing Machines
There are 25 Tonne (up to 5 m/s) and 2 Tonne (up to 25 m/s) testing machines available for high strain rate tests. These machines are important for studying strain-rate dependent effects such as work hardening and can be used for impact research.

Gleeble Thermo-Mechanical Simulator
The Gleeble 3800 is a fully integrated digital closed loop thermal and mechanical testing system. Specimens can be heated at rates up to a maximum 10,000 °C/s by resistance heating, or can be held at constant temperature. It is capable of exerting up to 20 tonnes of static force in compression or 10 tonnes in tension, with applied displacement rates up to 2 m/s. Feedback consists of linear variable differential transformers, load cells or non-contact laser extensometry.

Optical Strain Mapping
The optical techniques available within the Centre include Digital Image Correlation (including Speckle and Grid Patterning), Electronic Speckle Pattern Interferometry and Moiré Interferometry. Digital Image Correlation provides 3D deformation mapping.

X-ray Diffraction
A wide range of X-ray diffraction techniques are available within Imperial College for the investigation of polycrystalline materials, single crystal and thin films. Samples may be examined in either bulk or powdered form. There are currently 2 PANalytical MRDs, 2 PANalytical MPDs and a Bruker D2 desk-top instrument for rapid data collection. There is also a high temperature X-ray diffraction facility. X-ray diffraction measurements can be performed at elevated temperatures up to 1000 °C using a combination of direct and indirect heating. This allows the investigation of the thermal behaviour of lattice parameters, crystallisation studies, and the detection and characterisation of high temperature phases. The high temperature chamber is fitted with a system to allow measurements to be made in controlled atmospheres (including oxidative) so that structural changes related to sample-gas interactions can be studied.

Neutron Diffraction
Imperial have been greatly successful in being awarded beam time at a number of research institutes including ISIS, UK; Helmholtz-Zentrum, Berlin; Institut Laue-Langevin, France; Heinz Maier-Leibnitz, Munich and The Paul Scherrer Institute, Switzerland. The highly penetrative neutron diffraction technique is well established for measuring 3D residual stresses deep within a volume of material, non-destructively. Imperial have widely employed the technique to measure macro scale residual stresses and strains, typically in welded on non-uniformly plastic deformed components. These measurements have been valuable for the verification of finite element models to simulate the welding or deformation process and predict the residual stress fields. The method has also been employed to measure intergranular strains in alloys and used to develop and verify crystal plasticity models.

Gas Gun
A new gas gun has been installed in the lab. The gas gun has a fast launching mechanism allowing firing ice balls as well as rubber and gelatine projectiles. The gas gun can be connected to both compressed air and helium to the pressure up to 10 bar. The target area is designed with polycarbonate windows allowing the strain mapping of the sample under impact. The gun has 3 m long barrels in three different diameters including 10, 25 and 40 mm.

Multi-Point Forming Tooling
A modular flexible tool for the creep-age forming of extra-large panel components has been designed, built and patented. An integrated optimisation process for tool offsetting is demonstrated in published results. The method can be used to make flexible CAF tools with less than 1 mm error in the forming surface. In addition, this error can eventually be compensated and thus eliminated from the CA-formed parts, by using the developed optimisation technique.

Materials Characterisation
The Harvey Flower Microstructural Characterisation Centre in the Department of Materials for electron microscopy provides modern facilities for advanced materials imaging and characterisation. The facilities include three scanning electron microscopes (SEMs) and three transmission electron microscopes (TEMs). This includes the state-of-the-art monochromated FEI TITAN 80/300 and FEI Helios NanoLab 600 DualBeam TEM.

Metal Additive Manufacturing Suite
The AM25 has a build rate of 5 cm³ - 20 cm³ per hour over an area of 250 x 250 up to 360mm high, the addition of 70 μm diameter powders can create complex shapes in stainless steel, inconel, titanium and aluminium.
A number of events have taken place to facilitate research interaction and deep dialogue regarding the Centre’s work and direction.

**AVIC Centre Workshop at FAI**

5 June 2017

**AVIC:** Ms Na Zhu

**FAI:** Prof Jun Feng, Prof Bintuan Wang, Prof Zhaodian Guo, Prof Weiping Yang, Prof Wutao Lei, Prof Quanli Chen, Prof Wei Yuan, Prof Xinquan Zhang, Mr Weiguo Zhou, and other researchers

**MTI:** Prof Yaping Zhang, Dr Wei Xie, Mr Yudai Wang, Mr Xingyun Ma, Mr Qiang Liu, Mr Yu Sun

**Imperial:** Prof Jianguo Lin, Prof John Dear, Prof Kamran Nikbin, Dr Bamber Blackman, Dr Jun Jiang, Dr Zhusheng Shi, Dr Xiaoyu Xi, Dr Dimitrios Sarantaridis, Dr Nan Li

**Visit of Vice President of AVIC**

15 September 2017

**AVIC:** Prof Xinguo Zhang, Prof Jinzhong Wei, Ms Na Zhu, Ms Xue Tian

**MTI:** Prof Zhiqiang Li, Prof Yuegang Zhang, Prof Mingxi Zhang, Prof Zhenghua Cao, Dr Wei Xie

**Imperial:** Prof Jianguo Lin, Prof John Dear, Prof Kamran Nikbin, Dr Dimitris Sarantaridis, Dr Catrin Davies, Dr Jun Jiang, Dr Nan Li, Dr Xiaoyu Xi, Dr Zhusheng Shi and other researchers

**Visit of MTI Vice President**

10 October 2017

**MTI:** Prof Yaping Zhang, Mr Junchao Liu, Dr Wei Xie, Mr Yan Gao, Ms Huanyi Liu

**Imperial:** Prof Jianguo Lin, Dr Xiaoyi Xi, Dr Zhusheng Shi, Mr Fenggong Lyu

**AVIC Centre workshop at Imperial**

4 December 2017

**FAI:** Prof Jun Feng, Prof Wutao Lei, Prof Weiping Yang, Prof Ruixiang Lou, Prof Lei Zhang, Dr Qiang Fu, Dr Bin Gu, Dr Lu Xie

**MTI:** Prof Feng Liao, Dr Wei Xie, Dr Huaixue Li, Dr Yinlong Han

**Imperial:** Prof Jianguo Lin, Prof John Dear, Prof Ricardo Martinez-Botas, Prof Peter Childs, Prof Kamran Nikbin, Dr Dimitris Sarantaridis, Dr Bamber Blackman, Dr Catrin Davies, Dr Liliang Wang, Dr Nan Li, Dr Zhusheng Shi, Dr Xiaoyu Xi, Dr Jun Jiang and other researchers
At the 2017 World Economic Forum in Dalian, experts in antibiotic resistance, tissue regeneration and brain implants presented an IdeasLab session to an audience of global business, political and scientific leaders.

Following the World Economic Forum presentations, Professor David Gann, Vice President (Innovation) addressed over a hundred alumni and special guests at a reception organized by Imperial College Alumni Association of South China.

In January 2018, at the Davos WEF, Imperial’s work to engage non-traditional communities in start-ups and enterprise grabbed the Davos spotlight.

President Alice Gast explained how initiatives like The Invention Rooms are strengthening confidence and opportunities for young people in communities that have previously had little interaction with higher education.

Imperial College London helps found new national battery research centre

Imperial is part of a new consortium creating a world class research institution dedicated to energy storage and batteries.

Greg Clark, the Secretary of State for Business, Energy and Industrial Strategy, announced in October 2017 the foundation of a new independent, national, battery technology research institute. The Faraday Institution will be based at the Harwell Campus, close to both the Rutherford Appleton Laboratory and major automotive industry players.

The seven-member consortium, which includes Imperial, will have initial funding of £65 million and a core aim to ensure that the UK remains a world leader in novel battery technologies and energy storage for electric vehicles.

BOOM IN STARTUPS MARKS “UNIQUE ENTREPRENEURIAL ECOSYSTEM” AT IMPERIAL

The number of startup companies founded by Imperial students and researchers has more than doubled in the past five years.

The College’s first Review of Enterprising Activity shows that there were 25 new Imperial founded startups in 2016/17, up from 11 in 2012/13. These companies support more than 1,300 jobs, and have collectively generated close to £900m of investment since 2012. Professor James Stirling, Provost, said: “Imperial has a deserved reputation for education, research, and translation of discoveries into benefits for society. Our support for enterprise pervades all three sectors.

Imperial sets out vision for White City

Imperial’s ambitions for its White City Campus have reached a new milestone with the submission of the masterplan for the south of the site.

The White City masterplan, submitted to the London Borough of Hammersmith and Fulham (LBHF), is the result of a year-long consultation with key stakeholders, including local residents and businesses. The masterplan puts the community at the heart of the development – prioritising flexible public spaces, new pedestrian routes to connect neighbouring areas, and vibrant facilities which will bring together local people, businesses and Imperial’s community of students and researchers.
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