EuroSPF 2016

7-9 September 2016
Cité de l'Espace - Toulouse

EuroSPF 2016

11^{th} European Conference on Superplastic Forming

https://eurospf2016.sciencesconf.org/

Conference Program

Cité de l'Espace, France *September 7 to 9, 2016*

Conference Organisers

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Scope

The EUROSPF2016 conference is focused on all aspects related to SuperPlastic forming and SPF/DB (SuperPlastic Forming/Diffusion Bonding), i.e. material science, process simulation, press design, die optimisation, part manufacturing, innovative low cost processes. The purpose of the annual EUROSPF international conference is to allow an exchange between scientists and industrials working on all SPF aspects.

Committees

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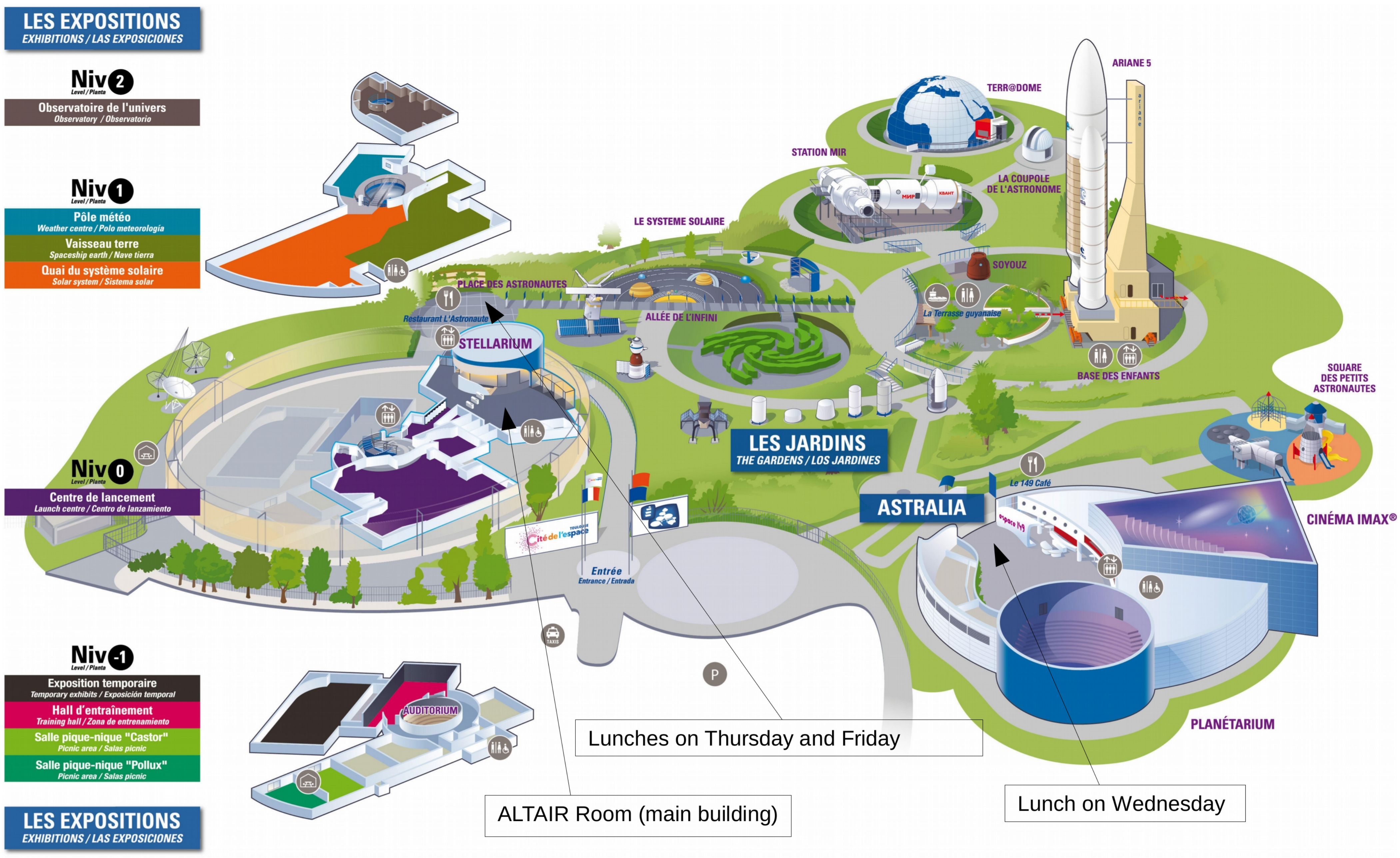
LES EXPOSITIONS
EXHIBITIONS / LAS EXPOSICIONES
Niv 2 Level / Planta
Observatoire de l'univers
Observatory / Observatorio
Niv 1 Level / Planta
Pôle météo
Weather centre / Polo meteorología
Vaisseau terre
Spaceship earth / Nave tierra
Quai du système solaire
Solar system / Sistema solar
Niv 0 Level / Planta
Centre de lancement
Launch centre / Centro de lanzamiento
Niv -1 Level / Planta
Exposition temporaire
Temporary exhibits / Exposición temporal
Hall d'entraînement
Training hall / Zona de entrenamiento
Salle pique-nique "Castor"
Picnic area / Salas picnic
Salle pique-nique "Pollux"
Picnic area / Salas picnic
LES EXPOSITIONS
EXHIBITIONS / LAS EXPOSICIONES
ARIANE 5
TERR@DOME
STATION MIR
LA COUPOLE DE L'ASTRONOME
LE SYSTEME SOLAIRE
SOYOUZ
PLACE DES ASTRONAUTES
Restaurant L'Astronaute
ALLÉE DE L'INFINI
La Terrasse guyanaise
STELLARIUM
BASE DES ENFANTS
SQUARE DES PETITS ASTRONAUTES
LES JARDINS
THE GARDENS / LOS JARDINES
Le 149 Café
ASTRALIA
CINÉMA IMAX®
AUDITORIUM
Entrée
Entrance / Entrada
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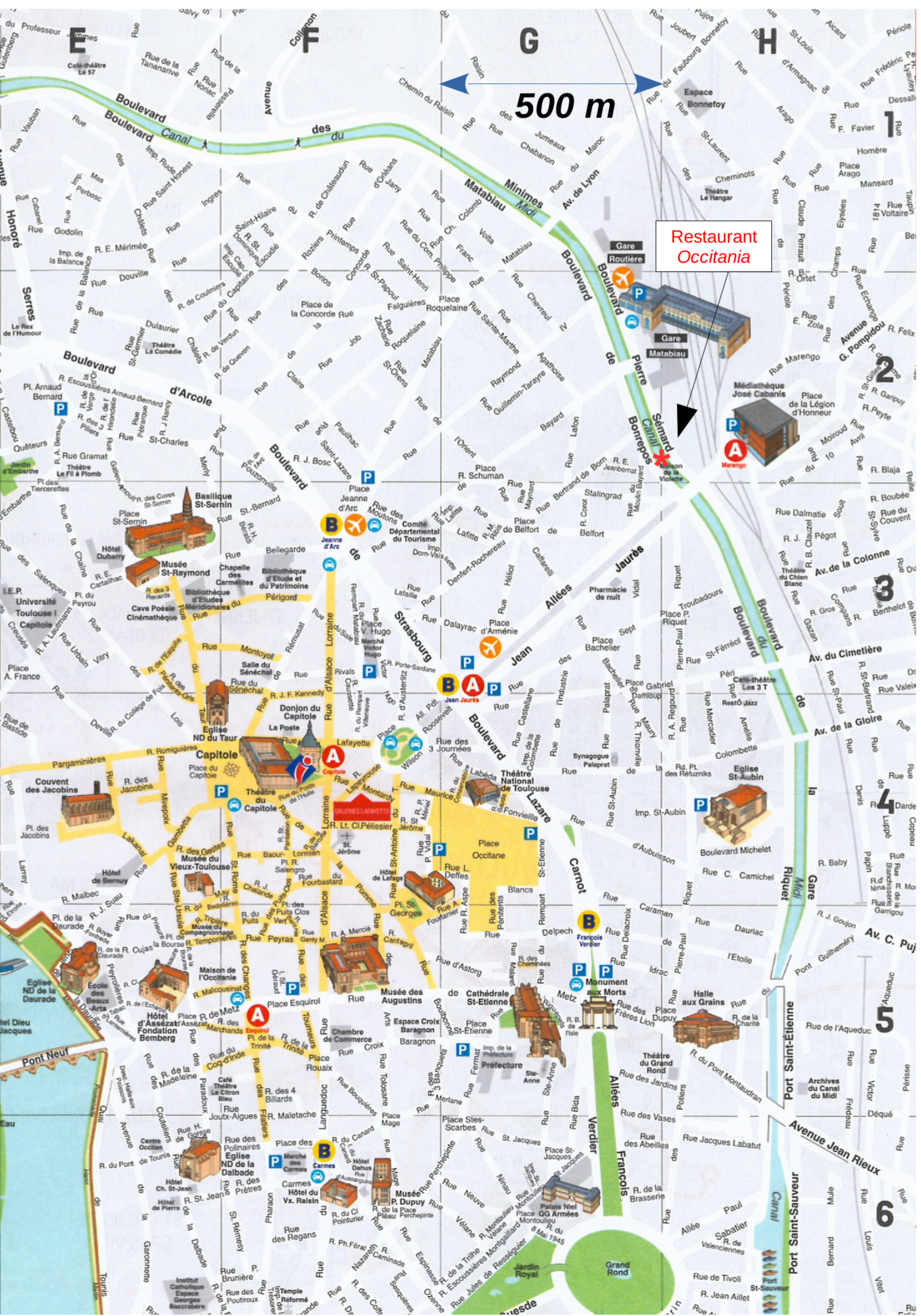
PLANÉTARIUM
Lunches on Thursday and Friday
Lunch on Wednesday
ALTAIR Room (main building)



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500 m
Restaurant
Occitania
Gare Routière
Gare Matabiau
Médiathèque José Cabanis
Boulevard de Pierre Sémard
Canal du Midi
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Boulevard de Strasbourg
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Boulevard Lazare Carnot
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Hôtel d'Assézat Fondation Bemberg
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Program

Wednesday, September 7, 2016

TIME	EVENT
9:30 am - 1:00 pm	Visit of the Cité de l'Espace - We propose the visit of the "Cité de l'espace" before the opening of the conference.
1:00 pm - 2:00 pm	Opening cocktail
2:00 pm - 2:30 pm	Registration at the welcome desk (Room ALTAIR) (room ALTAIR)
2:30 pm - 3:00 pm	Welcome speeches (room ALTAIR) - Opening of the conference
3:00 pm - 4:00 pm	SPF Materials I (room ALTAIR)
15:00 - 15:30	› Comparison of Superplastic Forming Abilities of As-cast AZ91 Mg Alloy Prepared by Twin Roll Casting and WE43 Alloy - *Vit Janik, WMG - University of Warwick*
15:30 - 16:00	› Two-dimensional grain boundary sliding and strain rate effect on dislocation characteristics in ODS ferritic steel - *Hiroshi Masuda, Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, The University of Tokyo [Toyo]*
4:00 pm - 4:30 pm	Coffee break
4:30 pm - 6:00 pm	Tool / Surface Coating (room ALTAIR)
16:30 - 17:00	› A comparative study assessing the wear behaviour of different ceramic die materials during superplastic forming - *Ares A. Gomez-Gallegos, Advance Forming Research Centre, University of Strathclyde*
17:00 - 17:30	› A method for the systematic assessment of lubricant performance during superplastic sheet forming - *Marta Drabek, Advanced Forming Research Centre, University of Strathclyde*
17:30 - 18:00	› Protective coatings for superplastic forming ceramic dies: An initial study on protective coatings performance - *Andrea Staiano, University of Strathclyde*
6:00 pm - 11:55 pm	Free Evening

Thursday, September 8, 2016

TIME	EVENT
8:20 am - 9:00 am	Registration & Welcome coffee (room ALTAIR)
9:00 am - 10:30 am	Material modelling / Process modelling (room ALTAIR)
09:00 - 09:30	› Using the Particle Swarm Optimization Method for the Constitutive Modelling of AZ31B - *Firas Jarrar, The Petroleum Institute*
09:30 - 10:00	› Mechanical behavior of Ti-6Al-4V titanium alloy with microstructural evolution modeling under hot and superplastic conditions - *Marcio Santos, Institut Clément Ader, Polytechnic School of the University of São Paulo (Brazil)*

TIME	EVENT
10:00 - 10:30	› FE-based optimization of the preform geometry for the superplastic forming of a spherical tank - *Donato Sorgente, Università degli Studi della Basilicata [Potenza]*
10:30 am - 11:00 am	Coffee break
11:00 am - 12:30 pm	SPF Materials II (room ALTAIR)
11:00 - 11:30	› Aluminium alloys grain refinement and superplasticity - *Anton Kotov, National University of Science and Technology "MISIS"*
11:30 - 12:00	› In-Situ EBSD Analysis & Characterisation of Nickel Additions to a Medium Strength 7000 Series Alloy - *Scott Taylor, WMG - University of Warwick*
12:00 - 12:30	› On the Formability of AA6061/SiCp Composite Synthesized Using Friction Stir Processing - *Viswanathan D, Professor (Retd.), Department of Mechanical Engineering, Anna University - Padmanabhan K.A, Professor of Eminence, Department of Mechanical Engineering, Anna University*
12:30 pm - 2:00 pm	Lunch
2:00 pm - 3:30 pm	Process modelling / Simulation (room ALTAIR)
14:00 - 14:30	› Numerical and experimental integration in analysis of a superplastic forming - *GILMAR BATALHA, Polytechnic School of the University of São Paulo (Brazil)*
14:30 - 15:00	› Development of a strain dependent pressure law for superplastic forming of 2024 aluminium alloy - *Rou DU, Laboratoire Angevin de Mécanique, Procédés et innovAtion*
15:00 - 15:30	› Superplastic forming optimization technique based on average strain rate controlling – Numerical simulation and experimental validation - *Maxime ROLLIN, AIRBUS Operations Ltd., Ecole nationale supérieure des Mines d'Albi-Carmaux*
3:30 pm - 4:00 pm	Coffee break (room ALTAIR)
4:00 pm - 5:30 pm	SPF Processes (room ALTAIR)
16:00 - 16:30	› Low-temperature superplastic forming and diffusion bonding technology - *Rinat Safiullin, Institute for Metals Superplasticity Problems Russian Academy of Sciences*
16:30 - 17:00	› Press development for superplastic forming with in situ and real time pressure and temperature control system and module with digital image correlation for strain monitoring. - *Erick Marinho, Universidade de São Paulo*
17:00 - 17:30	› An industrialization case of superplastic forming by using Infra-Red heater - *Marion Le Fournier, Aurock*
6:00 pm - 6:30 pm	Bus to Toulouse city center: meeting point at the entrance of the "cité de l'Espace".
6:30 pm - 8:00 pm	Free downtown tour (around the restaurant place)
8:00 pm - 11:30 pm	Banquet - Dinner Cruise on board Occitania
11:30 pm - 11:55 pm	Bus to the "Cité de l'Espace"

Friday, September 9, 2016

TIME	EVENT
8:50 am - 9:30 am	Registration & Welcome coffee (room ALTAIR)
9:30 am - 10:30 am	Industrial Applications: advanced forming processes I (room ALTAIR)
09:30 - 10:00	› From SPF to Hotforming of Aluminium Sheets – Simulation & Modelling Challenges between Industry and Academia - *Rajab Said, ESI Group*
10:00 - 10:30	› Comparison of technical and commercial aspects regarding cold forming, SPF and hot stamping - *W. Beck, FormTech GmbH*
10:30 am - 11:00 am	Coffee break (room ALTAIR)
11:00 am - 12:00 pm	Industrial Applications: advanced forming processes II (room ALTAIR)
11:00 - 11:30	› Hot Forming 2.0: Hydraulic Press for Hot Deep Drawing of Titanium - *Hilko Siebels, Schuler Pressen GmbH*
11:30 - 12:00	› Hot & Cold Forming of industrial parts: A comparative study between aeronautical & automotive industries. How to improve collaboration with a die maker ? - *Michel Garson, Loire Etude*
12:00 pm - 1:00 pm	Concluding Remarks (room ALTAIR)
1:00 pm - 2:00 pm	Lunch
2:15 pm - 6:00 pm	Industrial visit - Aeroscopia Museum & AIRBUS Tour. At the end of the visit, please note that the bus will stop at the airport then at the railway station before coming back to the "Cité de l'espace" .

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Comparison of Superplastic Forming Abilities of As-cast AZ91 Mg Alloy Prepared by Twin Roll Casting and WE43 Alloy

Vit Janik * [1], Scott Taylor [2], Roger Grimes [3], Richard Dashwood [4]

[1] WMG - University of Warwick – United Kingdom
[2] WMG, University of Warwick – WMG, IDL University of Warwick, United Kingdom
[3] WMG, University of Warwick – WMG, IDL University of Warwick, United States
[4] Coventry University – United Kingdom

Magnesium alloys are emerging as an innovative solution to the problem of light weighting in low volume niche vehicles, a market in which advanced forming processes such as superplastic forming are well established. Magnesium alloys have the ability to undergo dynamic recrystallization during hot working and due to this they can offer superplastic like performance in the as-cast or as-twin-roll-cast condition without the need for further complex thermomechanical processing that is required when manufacturing superplastic forming aluminium alloys. The combination of superplastic forming whilst using alloys in the as-cast condition could lead to magnesium sheet becoming a more viable option for niche vehicle light weighting. This paper describes and compares the superplastic behaviour and microstructural evolution of AZ91 and WE43 alloys. Tests were carried out in uniaxial tension on both alloys and in the case of WE43 gas bulge testing was also employed which better simulates an actual superplastic forming process. Elongations of over 400% were observed within WE43 when tested under optimum conditions.

Keywords: Superplastic forming, EBSD, gas bulge testing, microstructure, AZ91, WE43.

*Speaker

Two-dimensional grain boundary sliding and strain rate effect on dislocation characteristics in ODS ferritic steel

Hiroshi Masuda * [1,2], Hirobumi Tobe [1], Eiichi Sato [1], Yoshito Sugino [3], Shigeharu Ukai [4]

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Grain boundary sliding (GBS) has been widely believed as the dominant mechanism of superplasticity. However, the microstructural behaviours accommodating GBS have yet to be known sufficiently. Two-dimensional deformation is helpful for easily understanding the physics in microstructures and restraining the appearance of floating grains which may mislead the mechanisms of superplasticity. Oxide dispersion strengthened (ODS) ferritic steel exhibits an anisotropic grain structure largely elongated in its rolling direction (RD), beneficially raising GBS in two dimensions except for the RD. High-temperature mechanical tests were performed perpendicularly to the RD at different strain rates in region II, II/III, and III, respectively. Both the macroscopic deformation and the microscopic GBS were confirmed to be in two-dimensions. Surface markers drawn by focused ion beam and electron back-scattered diffraction were applied for characterizing GBS and accommodating dislocation activities, respectively. The deformation behaviours and dislocation structures were strongly influenced by the strain rate. First, above region III, intragranular dislocation density significantly increased, suggesting that dislocation creep was dominantly operating. Next, in region II/III, GBS and dislocation density increasing around the sliding boundaries were confirmed. These dislocation activities were classified into the core–mantle type or the transgranular type, both of which finally led to continuous dynamic recrystallization. Last, in region II, siginificant GBS but small increase in dislocation density was confirmed, implying that other accommodating mechanisms, e.g. diffusional mass flow, should be operative rather than the above dislocation activities.

Keywords: grain boundary sliding, dislocation, continuous dynamic recrystallization

*Speaker

A comparative study assessing the wear behaviour of different ceramic die materials during superplastic forming

Ares A. Gomez-Gallegos * [1], Andrea Staiano [2], Mark Farrell [1], Nicola Zuelli [1]

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[2] University of Strathclyde – 16 Richmond Street, Glasgow G1 1XQ, Scotland, UK, United Kingdom

Superplastic forming (SPF) is an advanced manufacturing process where metallic sheets are heated to their superplastic region to be blow formed within a die set. The process allows for the forming of complex parts but it is typically restricted to low volume and high value products. Ceramic dies are a developing technology in the SPF domain as they offer lower production costs and shorter lead times than conventional metallic dies, thus reducing process costs. Ceramic dies, however, are limited for SPF applications due to their brittle nature. This paper presents a method to assess ceramic die wear which is based on a novel test rig developed at the Advanced Forming Research Centre (AFRC) where SPF die-blank interaction was replicated at laboratory scale. Controllable normal load and twist compression tests on different ceramic materials were carried out with a view to understanding their wear mechanisms and to ultimately identify methods to improve their wear resistance.

Keywords: superplastic forming, ceramic, wear, tribology, friction, ceramic die

*Speaker

A method for the systematic assessment of lubricant performance during superplastic sheet forming

Mark Farrell* [1], Marta Drabek † [1], Muhammad Qarni [1]

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Frictional forces at the die-sheet interface during superplastic forming (SPF) play an important role in controlling material flow. As such, lubricious coatings are routinely used to facilitate a low friction flow of sheet metal into the die cavity. They may also act as parting agents and/or oxidation barriers. The selection of coatings for the SPF of Ti-6Al-4V is limited by the requirement of thermomechanical stability at the high forming temperature, therefore, solid film coatings such as boron nitride are a common choice. However, little work has been published on coating performance during SPF, particularly under true process conditions. This paper presents a method for the systematic assessment of SPF coating performance by way of a multi-pocket die, which allows many coating types and combinations to be tested simultaneously during a single forming cycle. Sixteen coating combinations were evaluated in total and the resultant sheet thickness distributions compared, serving as an indicator of friction condition.

Keywords: Superplastic forming, Ti, 6Al, 4V, coatings, lubrication, friction, tribology

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†Speaker

Protective coatings for superplastic forming ceramic dies: An initial study on protective coatings performance

Andrea Staiano *† [1], William Ion [1], Lynne O'hare [2], Nicola Zuelli [2]

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[2] Advanced Forming Research Centre (AFRC) – 85 Inchinnan Drive, Renfrew PA4 9LJ, United Kingdom

Superplastic forming (SPF) is an advanced manufacturing process, typically restricted to low volume and high value products, where metallic sheets are heated at the superplastic temperature and blow formed into a metallic die. Refractory ceramics are a low cost option to substitute the high temperature resistant steels and other alloys conventionally used in SPF dies, but their brittle nature is a limiting factor for most SPF applications. Suitable surface coatings have shown a significant effect on wear resistance and can be employed to improve the ceramic performance in terms of tool life increase. This paper is focused on an initial study on protective coatings for SPF ceramic dies, in order to evaluate their effectiveness for SPF forming. The tests were conducted using a dedicated test rig built at the Advanced Forming Research Centre (AFRC) where the die-blank interaction under SPF conditions was replicated at laboratory scale.

Keywords: Superplastic forming, wear, ceramic die, protective coating

*Speaker
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Using the Particle Swarm Optimization Method for the Constitutive Modelling of AZ31B

Zemin Li [1], Guangwen Dai [1], Firas Jarrar *† [1], Fahrettin Ozturk [1], Jamal Ahmad [1]

[1] The Petroleum Institute – United Arab Emirates

The magnesium alloy AZ31B has a great potential for lightweight applications that do not require high strength. The superplastic forming (SPF) method is already being used to form this alloy into complex lightweight components. However, in order to provide accurate predictions of the SPF of AZ31B, suitable constitutive models should be established. In this paper, the particle swarm optimization method is used to identify the parameters of an appropriate constitutive model. High temperature bulge experiments are used to validate the model.

Keywords: Material Modelling, Particle Swarm Optimization, Superplastic Forming, AZ31B

*Speaker

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Mechanical behavior of Ti-6Al-4V titanium alloy with microstructural evolution modeling under hot and superplastic conditions

Marcio Santos * [1,2], Vincent Velay [2], Vanessa Vidal [2], Gérard Bernhart [2], Gilmar Batalha [1], Hiroaki Matsumoto [3]

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[3] Kagawa University – Department of Advanced Materials Science, Faculty of Engineering, 2217-20 Hayashi-Cho, Takamatsu, Kagawa 761-0396, Japan, Japan

The present work aims at evaluating and understanding the mechanical behavior of Ti-6Al-4V alloy under hot and superplastic forming conditions. Tensile tests were thus performed at temperature range from 650◦C to 950◦C at strain rates between 10-2 s-1 and 10-4 s-1. Three equiaxed microstructures each characterized by a different starting grain size (4.88 μm, 3.0 μm and 0.5 μm) are compared and allow to obtain an understanding on microstructure evolution under hot and superplastic forming conditions. An accurate material model with microstructural considerations is proposed. The model capabilities take into account the grain size evolution that is influenced by the temperature and the deformation. The computed flow stresses strongly depend on the strain rate but also on the considered initial grain size. Temperature and strain rate conditions may lead to a strain hardening phenomenon in some cases. The comparison between the model response and experiment shows a good agreement for all the tests performed.

Keywords: superplastic, hot forming, microstructure evolution, Titanium, mecanichal bahavior

*Speaker

FE-based optimization of the preform geometry for the superplastic forming of a spherical tank

Donato Sorgente *† [1], Antonio Piccininni [2], Firas Jarrar [3], Gianfranco Palumbo [2]

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Superplastic forming (SPF), as the word speaks for itself, is based on superplastic alloys which are materials with a high strain rate sensitivity index. This peculiarity of the material leads to an extraordinary capability to diffuse the necking and uniformly distribute the thickness along the deformed sheet. In spite of this, the blow forming technique, the most widespread SPF technique, due to its process configuration tends to create a nonuniform thickness along the sheet. The material is constrained in the periphery of the blank and the thickness distribution strictly depends on the geometry of the die cavity. In some industrial applications, especially aerospace ones, the thickness variation cannot be tolerated. Different solutions have been explored in order to solve or, at least, to limit this issue. One of the most promising solutions is the two-stages forming. This solution is already applied in production but it has not be completely optimized. In this work, a simple 2D finite element (FE) model is interfaced with an optimizer to define the optimal geometry of the preform cavity. In particular, the SPF of a spherical tank for aerospace applications is considered and the optimization procedure is based on the minimization of the thickness variability along the deformed sheet. With this purpose, the geometry of the preform die has been parametrized and the variability of the thickness value has been quantified by an objective function to be minimized. Results of the optimization reveal that with the proposed optimization procedure an almost uniform thickness distribution can be achieved in a spherical tank by a preform die with an optimized geometry.

Keywords: Superplastic forming, Finite element analysis, Two_stage forming

*Speaker
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Aluminium alloys grain refinement and superplasticity

Anton Kotov * [1], Anastasia Mikhaylovskaya [1], Elena Avtokratova [2], Oleg Sitdikov [2], Andrey Pozdniakov [1], Mikhail Markushev [2], Vladimir Portnoy [1]

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The efficiency of several methods of Al-Mg, Al-Cu-Mg, Al-Mg-Si and Al-Zn-Mg-Cu type alloys grain refinement to enhance their superplasticity was analyzed. The alloys fine-grained structure has been processed via continuous and discontinuous recrystallization under thermomechanical processing (TMP), involving hot and cold rolling. The effects of additions of Mn, Cr, Zr, Sc, forming dispersoids with a size less than 100 nm for Zener pinning of the grain boundaries, and Ni, Fe, Co and Ce additions, forming coarse 1-2 mm in size eutectic particles, for particle stimulated nucleation of recrystallization, were studied and discussed. It was concluded that bimodal distribution of second phases by size, i.e., the presence of coarse and disperse particles of different origin, and supersaturated aluminum solid solution are the basing processing requirements for significant improvement the alloys superplastic parameters. For instance, with these requirements the high strength Al-Zn-Mg-Cu alloys could exhibit high strain rate superplasticity with elongations up to 1100% in the strain rate interval of 10-2-10-1 s-1, Al-Mg alloys - with elongations more than 450% at a constant strain rate range of 5 $\times$10-3 to 10-2 s-1 and Al-Mg-Si alloys - 400% at 5$\times$10-3 s-1.
The effect of cryorolling at a temperature of liquid nitrogen was demonstrated for Al-Cu-Mg-x alloys. It was found that heterogeneity control increase the alloys elongations up to 550% at 1$\times$10-3 s-1.

It was concluded that the right chose of the alloy composition and regimes of grain refinement TMP, involving control of size and distribution of second phase constituents, could provide enhance balance of the alloy (and the product) ambient temperature mechanical properties, corrosion resistance and superplasticity.
The work was supported by the RFBR grant N 15-38-20654a.

Keywords: aluminum alloys, superplasticity, fine, grained structure, high strain rate, thermomechanical treatment, cryogenic deformation

*Speaker

In-Situ EBSD Analysis & Characterisation of Nickel Additions to a Medium Strength 7000 Series Alloy

Scott Taylor * [1], Vit Janik [1], Roger Grimes [1], Richard Dashwood [2]

[1] WMG - University of Warwick – United Kingdom
[2] Coventry University – United Kingdom

7000 series aluminium alloys are gaining increased interest within superplastic forming processes due to their high post forming mechanical properties. Good age hardening response offers use within niche automotive light weighting applications to help meet emission reduction targets via down-gauging or material replacement. Alloys are used as cold rolled with a relatively coarse grain structure and recrystallize during the early preheating stages of the forming process. This work presents in situ observations of the recrystallization of two such coarse grained cold rolled aluminium alloys whose formability was seen to be well under what would be described as super plastic but are still of interest industrially. Observations of microstructural evolution and processes are typically carried out by means of "snap shots" where a sample is removed from a thermal cycle and then analysed using varying microscopy techniques. Advanced techniques such as hot stage Electron Back Scattered Diffraction (EBSD) allow for direct in-situ observation of these processes to give better and more accurate analysis. This work looks to advance and expand the knowledge of the recrystallization behaviour or a medium strength 7000 series alloy and compares it to a nickel containing variant, by means of an in-situ heated EBSD stage within a Zeiss Sigma Feg-Sem. The validity of this technique was verified by comparison of the recrystallization observations and final grain structures of bulk EBSD analysis.

Keywords: Hot, stage EBSD, FSD, Aluminium, Recrystallization, Recovery, Particle Stimulated Nucleation

*Speaker

On the Formability of AA6061/SiCp Composite Synthesized Using Friction Stir Processing

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Friction stir processing (FSP) is a potentially useful method for producing composites of enhanced surface properties. In this work, an AA6061/SiCp composite, synthesized using FSP, was tested in three-point bending, uni-axial hot tensile and bi-axial stressing to assess its formability. Bending test results display an increased bending strength and decreased ductility in the composites compared with AA 6061 alloy, just subjected to FSP. Based on the hot tensile tests, the biaxial stressing temperatures were fixed as 623 K and 673 K. The superplastic process variables such as formed height, forming time, strain rate and strain rate sensitivity index were determined. Bi-axial stressing reveals that a maximum dome height of 18 mm could be obtained by superplastic forming into a cavity of 59 mm diameter at a pressure of 0.2 MPa. Strain rate sensitivity index increases with increasing forming pressure from 0.2 to 0.25 MPa and reaches a maximum value of 0.40 at a forming pressure of 0.25 MPa within the present experimental range. Therefore, it is safe to assume that this alloy has a maximum value of atleast 0.4. Microstructures and forming limit diagram of the composite were obtained and analysed in detail. These findings can pave the way for the commercial exploitation of FSP-technology-based superior processing of the AA6061/SiCp composite.

Keywords: Friction stir processing, Formability, Three point bending test, Forming limit diagram.

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Numerical and experimental integration in analysis of a superplastic forming

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This work presents an experimental analysis of a superplastic forming process to forming metal parts, also exposes research capacity to integrate different levels of Technology Readiness Levels (TRL). The study shows a finite element analysis model to calculate the optimized pressure cycle to apply in an Accudyne© SPF machine present in the Lightweight Structures Laboratory. It works with a noble gas pressure of 1 to 40 bar and temperature range between 50 to 1000∘C.

Keywords: superplasticity, aluminum, titanium, lightweight, FEM

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Development of a strain dependent pressure law for superplastic forming of 2024 aluminium alloy

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Superplastic forming is widely used in aeronautic industry to produce complex parts due to the ability of the material to sustain very large deformation. However, it is quite difficult to control this process. Indeed, the main problems lie on the determination of the pressure law which must be applied during the process to control the maximum strain rate in the formed sheet. Many algorithm exist in numerical codes to predict the pressure law, but they generally use a constant value of maximum strain rate as reference to control the pressure evolution. These simulations give globally good results, but they lead to important forming times. In this work, pressure control rules have been modified in order to use a non-constant strain rate during the forming. The value of the optimum strain rate is indeed adapted to the level of strain developed within the part during the forming. This approach has been applied on a 2024 aluminium alloy. Uniaxial tensile tests have been performed over a wide range of temperatures and strain rates in order to determine the influence of strain level on the maximum allowable strain rate. Then, the new pressure control algorithm has been implemented in the ABAQUS code. Numerical simulations of generic parts have finally been performed and results show a significant reduction of the forming time without decreasing the quality of the parts.

Keywords: 2024 Aluminium, pressure law, strain dependence

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Superplastic forming optimization technique based on average strain rate controlling – Numerical simulation and experimental validation

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In AIRBUS, most of the complex shaped titanium fairing parts of pylon and air inlets are produced by superplastic forming (SPF). These parts are cooled down after forming to ease their extraction and increase the production rate, but AIRBUS spend a lot of time to go back over the geometric defects generated by the cooling step. This paper investigates the optimization of forming cycles in order to propose rapid forming sequence that suits industrial strategy, and which enable to control microstructure evolutions, and therefore ease material modeling issue for simulation of cooling phase. An optimization algorithm using ABAQUS coupled with MATLAB has been developed in order to improve forming cycles while warrantying superplastic parameters. The optimization technique is based on an algorithm controlling the average strain rate of the non-formed mesh of part instead of the maximum strain rate on the whole mesh for "classical" ABAQUS algorithm. This paper details firstly the optimization algorithm and then presents numerical and experimental results of different forming conditions obtained from industrial, "classical", and optimized pressure cycle.

Keywords: Superplastic Forming, Optimization, Average Strain rate

*Speaker

Low-temperature superplastic forming and diffusion bonding technology

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Reducing the temperature of the sheet materials processing technology superplastic forming and diffusion bonding (SPF and DB) is one of the most important tasks for further improvement of this advanced technology. PSC "VSMPO-AVISMA" Specialists of the Russian company developed a new sheet titanium alloys Ti64 (VT6) and VST2k specifically for SPF process at low temperatures. The paper studied the superplastic and technological properties of new alloys. As a result of comprehensive studies found that both alloys exhibit good superplastic properties over a wide temperature range. It was found that the best superplastic properties of the blanks exhibit at temperatures 750-850°C. Studies formability and solid state weldability of blanks showed that these sheets can be successfully used in SPF/DB technology in conditions of low temperature superplasticity. With the use of investigated blanks were made hollow three-layer structures. The results of the research have been developed technological recommendations on the production of hollow sandwich structures in the conditions of low temperature superplasticity.

Keywords: superplasticity, titanium alloy, formability, diffusion bonding

*Speaker

Press development for superplastic forming with in situ and real time pressure and temperature control system and module with digital image correlation for strain monitoring.

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This works presents the full development of a superplastic bulge forming Press which contains an in situ and real time pressure and temperature control systems, as well as a deformation monitoring module that applies digital image correlation technique. The Press can achieve optimum superplastic forming conditions supported by dedicated instrumentation and control of the parameters that characterize the superplastic forming process; these parameters are pressure, temperature and strain rate. The following topics discussed are design and construction of the press that meets the project requirements; Press instrumentation and control system implementation. The application and development of the control system in biaxial forming process involves the selection of forming conditions, pressure cycle determination, implementation of dedicated controls that meet the forming requirements, besides methods for calculating important coefficients (m, n K). With the referred instrumentation, it is possible to determine these coefficients from biaxial tests, rather than simply using the uniaxial tensile tests coefficients. A Ti6Al4V alloy fluid static superplastic biaxial test was conducted, controlled around its optimum condition. Summarizing the control system, the thermal control system minimizes the stabilization temperature time, avoiding temperature overshooting. The pressure control system applies a pressurization cycle, responsible for conducting the forming process, to achieve a specific strain rate.

Keywords: Superplasticity. Superplastic Forming. Instrumentation.Control. DIC (digital image correlation). In situ Control.

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An industrialization case of superplastic forming by using Infra-Red heater

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The superplastic forming is used in aeronautics in order to manufacture titanium parts with complex shapes. Regarding to others forming processes, it is important to save costs of superplastic forming. Using Infra-Red lamps to heat directly the blank is an economic way to raise the temperature as the heating time is cut to a few minutes instead of 24 hours. TA6V sheets with a size of 500X500mm2 were successfully formed by using this technology. Numerical simulations have been used as a predicting tool of the infra-red lamps power to ensure a homogeneous temperature of the blank during the superplastic forming. Thermo-mechanical simulations are needed. The microstructure is not affected by the quick heating phase. An industrialization is presented from a simulation point of view which demonstrates the efficiency of the IR heating for the superplastic forming. The chosen case is an aircraft part with a size of 1m2.

Keywords: SPF, Titanium, Aeronautical part, Simulation

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From SPF to Hotforming of Aluminium Sheets – Simulation & Modelling Challenges between Industry and Academia

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Superplastic Forming (SPF) has been successfully used to produce complex shaped parts out of aluminium sheets for decades. Several alloys with excellent specifications are available in the market, and SPF applications are well spread across the industry - particularly in ground transportations and aeronautics. There is already a wealth of knowledge and experience in how to manipulate process parameters on the shop floor, as well as in how to utilise available simulation and modelling tools to design parts, dies, and optimise the forming cycle.
The paper will first reflect on the above, showing the complete optimisation cycle for a complex industrial case using the simulation package PAM-STAMP [1]. It will then highlight the challenges imposed by industries with interest in large volume production of aluminium panels – recalling the increasing pressure on the automotive sector to utilise lightweight alloys in manufacturing mainstream family-cars. A novel process for a 'quick forming' of aluminium sheets, developed by researchers at Imperial College London (ICL) - called "solution Heat treatment, cold die Forming and Quenching (HFQ)", will be presented.
The HFQ Process integrates heat treatment and forming of the sheet in one operation. In order to simulate such a process, a multidisciplinary approach that addresses the various physics involved is inevitable. Aspects related to the complex material behaviour in the heated/cooled sheet, and the need to design dies that can maintain the same thermal conditions to ensure consistency in the outcome of quenching-step, need to be fully coupled. The paper will present an overview of the comprehensive solution developed by ESI Group to address all these issues within one framework based on its own portfolio of SMF and CFD solutions; see Figure 1 for an illustration of the adopted strategy which highlights all physics involved in the Process beside the associated software packages.

The paper will introduce a novel plane-stress continuum damage mechanics (CDM) model developed by the group at ICL [2, 3]. Using this CDM model the Forming Limit Curves (FLC) of aluminium sheets can be predicted at different temperatures and strain rate forming conditions. Integration of the model into PAM-STAMP has been an essential part of a three-year EU collaborative R&D project - LoCoLite (Low Cost forming of Lightweight structures for transportation industries). Applying the combined solution (i.e. PAM-STAMP with CDM model)

*Speaker

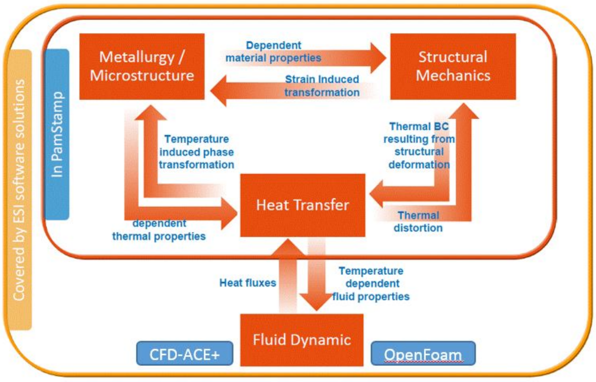
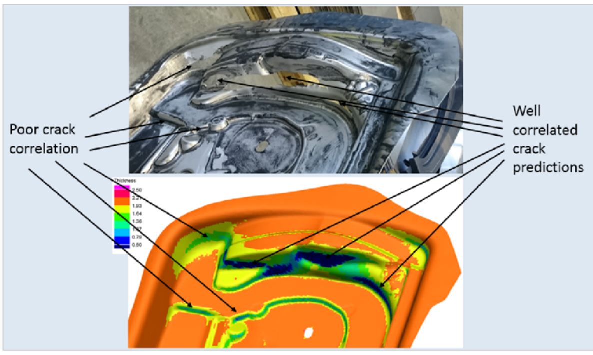
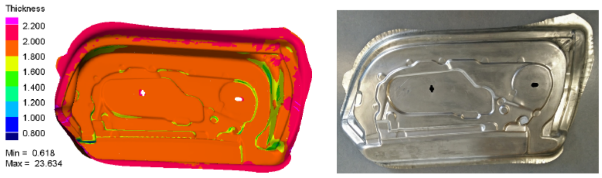


Figure 1: Sketch of the strategy adopted by ESI to address all physics involved in a typical HFQ problem, and to provide engineers with a comprehensive environment to design and optimise parts and dies.



(A)



(B)

Figure 2: Illustration of a door-inner case formed using the HFQ process during LoCoLite Project: (A) first design of the blank with predicted split using PAM-STAMP and (B) successful forming with an optimised shape of the blank-outline – final thickness distribution as predicted on the left.

on real life industrial cases has been carried out in two formats during the project: linked as external subroutine as a "User Defined Material" and fully integrated model inside the main Solver of PAM-STAMP. Extended comparison of the results between the two formats, as well as against traditional look-up-table approach and a full set of experimental trails & measurements will be presented. Figure 2 shows a snapshot of one of the Automotive Demonstrators considered in the project (i.e. a door-inner case provided by Lotus Cars).

The LoCoLite Project will conclude by the end of November 2016, and a follow up project (LoCoMaTech) is already scheduled to start shortly before that. The paper will discuss in detail all challenges and the achievements to date in the Simulation and Modelling activities in LoCoLite. It will also highlight some of the further developments planned in the new project. Both projects have an impressive collection of partners from Industry and Academia, and the paper will also elaborate on how such consortiums provide an ideal venue for a software vendor like ESI to carry out new developments in partnership rather than independently.

Acknowledgement:
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Keywords: Hotforming, simulation and modelling, automotive

Comparison of technical and commercial aspects regarding cold forming, SPF and hot stamping

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Titanium parts can be very expensive or can be a good compromise between cost and efficiency. Parts can be very satisfactory regarding the benefit for the customer especially if expected cost and weight reduction is reached or exceeded. Titanium properties are always well desired. The high level of material cost and the cost of manufacturing are of course not well accepted. But there are rather big differences concerning material waste, cycle time, process cost, intelligent tool design, overweight from minimum wall thickness requirements not well possible by the individual process restrictions. The paper describes decision guidelines to find the right process for a given inquiry asked by the client concerning alloy, service loads, number of load cycles, temperature, quantity, optical appearance, etc. etc. The total picture has to include the following assembly processes. Some representative solutions are described.

Keywords: SPF, HF, Cold Forming

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Hot Forming 2.0: Hydraulic Press for Hot Deep Drawing of Titanium

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The ever increasing demand for titanium parts is calling for new production methods that are fast, cost efficient and offer an improved part quality. These challenges can be met with the hot deep drawing process which requires a second axis in the press. The "2.0" in the title of this presentation not only means the next generation of titanium hot forming, but also stands for the double action press that is used for this process. Schuler has transferred the experience gained by building thousands of conventional cold double action presses and has introduced this technology into hot presses up to 950∘C. It is shown in the presentation how the precise control of blank holding pressure, forming speed, the precise slide guiding and the revolutionary furnace concept make it possible to have superior results in the forming process. Further it will be explained how the "2.0" also stands for the dual mode use of this press, which can be used as a standard cold deep drawing press when the furnace is removed.

Keywords: Hot Forming, Industrial Applications, Titanium

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Hot & Cold Forming of industrial parts: A comparative study between aeronautical & automotive industries. How to improve collaboration with a die maker ?

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Challenges of the Automotive & Aviation industries
- Fit to the market
- CO2 reduction
- Cost reduction
- Industrialization
- Etc.

How to get the best performance from a die maker
- Co-engineering
- Design
- Tryout

Examples
- Hot & cold forming processes in the Automotive & Aviation
- Commun point & differences between both industries.

Keywords: Hot Forming

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