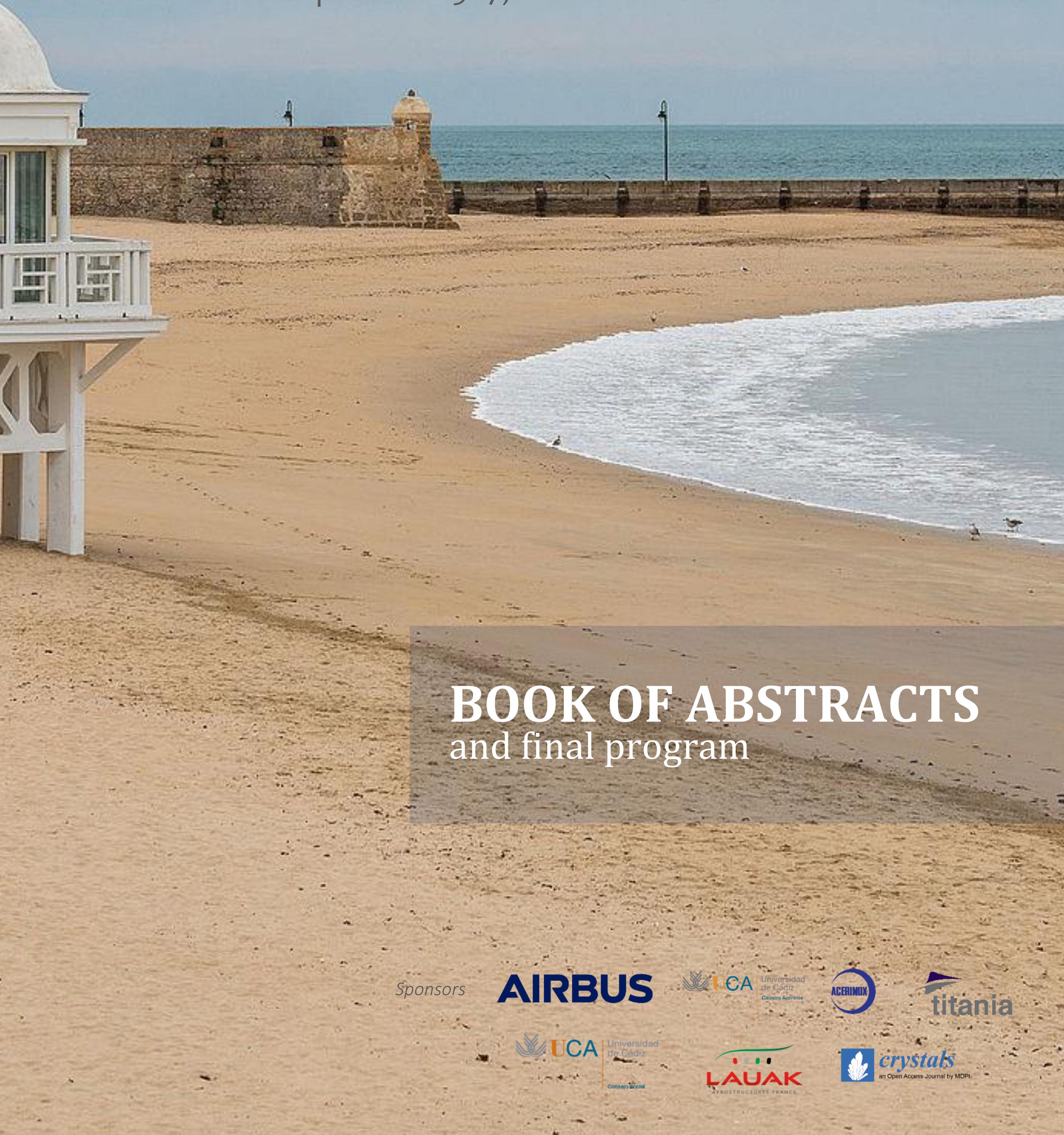
Universidad de Cádiz

EuroSPF 2021

The 14th European Conference on Superplastic Forming
September 15-17, 2021 Cádiz - SPAIN



BOOK OF ABSTRACTS
and final program

Sponsors

EuroSPF 2021

14th European Conference on Superplastic Forming

https://eurospf2021.sciencesconf.org

1812 Constitution Building - University of Cádiz
September 15-17, 2021
Cádiz - SPAIN

Organized by UCA Universidad de Cádiz

Sponsors AIRBUS — UCA Universidad de Cádiz, Cátedra Acerinox — ACERINOX — titania — UCA Universidad de Cádiz, Consejo Social — LAUAK Aerostructures France — crystals, an Open Access Journal by MDPI

Scope

The EUROSPF is a conference focused on all aspects related to the superplasticity of materials and the Superplastic Forming. Since 2001, it has been annually organised by different universities and institutions of France, United Kingdom, Germany, Spain, Liechtenstein and Italy. The Conference aims to serve as a referential and meeting point around the superplasticity and the superplastic forming, giving the participants the opportunity to show their current works and promoting future collaborations.

Committees

Advisory board EUROSPF:

Dr. Donato Sorgente, University of Basilicata, Italy
Rajab Said, United Kingdom
Dr. Vincent Velay, Institut Clément Ader - Mines Albi, France
Dr. Vit Janik, Institute for Future Transport and Cities, Coventry University, United Kingdom
Werner Beck, FormTech GmbH, Weyhe-Dreye, Germany

Local Organizing Committee:

Adrián Ojeda, University of Cádiz, Spain
Ana Pilar Valerga, University of Cádiz, Spain
Antonio Juan Gámez, University of Cádiz, Spain
José Hermenegildo García, University of Cádiz, Spain
Lucía Rodríguez, University of Cádiz, Spain
Luis García, University of Cádiz, Spain
María Alonso, University of Cádiz, Spain
Severo Fernández, University of Cádiz, Spain

Table of contents

Program

Wednesday, September 15, 2021

TIME	EVENT
8.30-9.:30	Registration
9.30-10.00	Opening
10.00-10.45	Keynote
10.45-11.15	**Coffee break**
11.15-12.45	**SUPERPLASTICITY I - Lin Jinguao**
11.15-11.45	*› The grain rotation accommodated GBS mechanism on the superplasticity of Ti-6Al-4V alloy*
11.45-12.15	*› The influence of the microstructural parameters on the superplastic deformation mechanisms for Al-Mg-based alloys*
12.15-12.45	*› Influence of Fe and Ni additions on the microstructure evolution and superplasticity of Ti-Al-Mo-V alloys*
12.45-14.15	**Lunch**
14.15-15.45	**SUPERPLASTIC FORMING I – Yves Marcel**
14.15-14.45	*› A new approach for the tool-blank interaction modelling in superplastic forming*
14.45-15.15	*› Impact of the formulation of the behavior model in the prediction of hot forming operations*
15.15-15.45	*› Accurate determination of uniaxial deformation*
15.45-16.15	**Coffee break**
16.15-18.15	**SUPERPLASTICITY II - Anastasia Mikhaylovskaya**
16.15-16.45	*› Develop a data-driven viscoplastic materials flow model through machine learning method*
16.45-17.15	*› Superplasticity of Al-Mg-Si-based alloy doped with eutectic-forming and dispersoid-forming elements*
17.15-17.45	*› Natural correspondence between the quantum mechanics and relativistic frequency parameter and the deformation mechanisms associated with superplastic*
20.30	**Cadiz Tour**

Thursday, September 16, 2021

TIME	EVENT
10.00-10.45	Keynote
10.45-11.15	**Coffee break**
11.15-12.45	**SUPERPLASTIC FORMING II – Carlos Pérez**
11.15-11.45	*› Biaxial hot forming of AA2219 with SPF and other hot forming processes*
11.45-12.15	*› Integration of the SPF technology in an efficient industrial production flow for high rates aeronautical parts*
12.15-12.45	*› SPF- the way forward for an increased quantity of hi-strength Titanium alloys in aviation industry*
12.45-14.15	**Lunch**
14.15-15.45	**SUPERPLASTICITY III – Donato Sorgente**
14.15-14.45	*› On the uniaxial testing of aluminium alloys in superplastic condition using a joule heating system and DIC measurements*
14.45-15.15	*› Integrating in-situ thermal-mechanical testing and constitutive modelling for superplastic forming technique on Ti alloys*
15.15-15.45	*› Flow behaviour and evolution of the microstructure and the texture during superplastic deformation of Fine-Grained and UltraFine-Grained Ti-6Al-4V alloy*
15.45-16.15	**Coffee break**
16.15-18.15	**SUPERPLASTIC FORMING III – Vincent Velay**
16.15-16.45	*› An Investigation of Alpha Case reduction in Superplastic Forming of Ti-6Al-4V*
16.45-17.15	*› A thickness thinning study of superplastic samples using dimensional analysis*
17.15-17.45	*› Estimation of constitutive parameters for superplastic light alloys based on inverse analysis and bulge tests with pressure jumps*
20:30	**Gala Dinner. Hotel Parador de Cádiz**

Friday, September 17, 2021

TIME	EVENT
9.00-10.00 am	Panel Discussion
10.00-10.30 am	Closing
10.30-11.00 am	**Coffee break**
11.00-13.00 am	**Industrial Visit – Airbus CBC Plant**

Wednesday

September 15, 2021

The grain rotation accommodated GBS mechanism on the superplasticity of Ti-6Al-4V alloy

Junzhou Yang *†1, Jianjun Wu

[1] Northwestern Polytechnical University [Xián], China

An investigation of grain rotation (GR) for Ti-6Al-4V alloy during the superplastic forming (SPF) has been present in this paper. The constant strain rate tensile tests were performed at 890~950 ℃ and strain rates of 10^{-2}, 10^{-3}, and 10^{-4} s^{-1}. Then, surface observation by Optical Microscope (OM), Scanning Electron Microscopy (SEM), and Electron Back-scattered Diffraction (EBSD) were applied to obtain the microstructure mechanism. With the pole figure maps (IPF) for α-phase, obvious texture gradually changes in the main deformation direction. For the titanium alloy in SPF, the evolution of texture in deformed samples should be attributed to the GR. Besides, significant grain rearrangement occurs between grains after deformation. Finally, a complete grain rotation accommodated grain boundary sliding (GBS) deformation mechanism for SPF is proposed, which can explain the texture evolution without grain deformation.

Keywords: Superplastic Forming, Ti-6Al-4V, Grain Rotation, Texture

* Speaker

†Corresponding author: yangjunzhou52@qq.com

The influence of the microstructural parameters on the superplastic deformation mechanisms for Al-Mg-based alloys

Anastasia Mikhaylovskaya *†1, Olga Yakovtseva[1]

[1] National University of Science and Technology MISIS 119049, Moscow, Leninskiy prospekt 4, Russia

The superplastic forming technique is used for production lightweight constructions with a complex shape and a small amount of joints. Non-heat treatable Al-Mg-Mn-based alloys of AA5083 type are widely used for superplastic forming owing to a combination of the good mechanical properties, corrosion resistance, insignificant post-forming residual cavitation. A grain boundary sliding (GBS) is a dominant deformation mechanism for many alloys, an intragranular dislocation slip/creep and a diffusional creep typically have an accommodation nature. GBS contributes above 50% for ultrafine-grained and nanostructured alloys of various compositions. A chemical composition of fine-grained alloys significantly influences on the contributions of the deformation mechanisms. For the Al-Zn-based alloys GBS has a typical of superplastic behavior values of 50-70%. On the contrary, for the Al-Mg-based alloys with a similar grain size, experimental investigations observed a weaker GBS despite a high strain rate sensitivity of the flow stress.
In the present study, the markers of surface FIB-grid lines were applied to compare the superplastic deformation mechanisms in the several Al-Mg alloys with different chemical compositions, grain sizes, and precipitates parameters. The superplastic deformation behavior, evolution of the grain and dislocation structures were analyzed. Based on the results, the contributions of the intergranular and intragranular deformation to a total strain, grain rotation component were compared for the alloys with different microstructures. The results confirmed that the grain boundary sliding in the Al-Mg alloys was less intensive than that of in the Al-Zn-Mg alloys. The Mg increasing insignificantly influenced on the deformation mechanisms contributions. Meanwhile, for the Al-Mg-based alloys, the GBS intensity can be increased owing to grain refinement.
The study was funded by Russian Science Foundation (Grant # 17-79-20426).

Keywords: Superplastic Deformation Mechanisms, Deformation Behavior, Aluminum Based Alloys, Microstructural Evolution

* Speaker
†Corresponding author: mihaylovskaya@misis.ru

Influence of Fe and Ni additions on the microstructure evolution and superplasticity of Ti-Al-Mo-V alloys

Anton Kotov *†[1], M. Postnikova[1], Ahmed Mosleh[1], Anastasia Mikhaylovskaya[1]

[1] National University of Science and Technology MISIS 119049, Moscow, Leninskiy prospekt 4, Russia

Titanium alloys are widely used in various industrial fields due to their unique combination of excellent properties. However, forming titanium alloys parts by traditional methods is difficult due to high strength, relative low elastic modulus, and high sensitivity to processing parameters. Superplastic forming of titanium alloys sheets is considered a successful approach for forming complex shape parts with low gas pressure in one technological operation. It is known that for optimal superplasticity of titanium alloys, high temperatures, 800-900 °C, are required. The high process temperatures lead to an increase in the energy consumption and wear of equipment and dies. In addition, it forms oxides and an alpha layer on the surface of manufactured parts easily. Incorporating titanium alloys with beta stabilizers (such as Ni, Co, Fe, Nb, Cr, Mo, and V) to achieve an optimal alpha/beta ratio at low temperatures is one method of lowering the superplastic forming temperature. At the same time, elements like Ni and Fe, which have a high diffusivity in titanium, are of particular interest. These elements have the ability to speed up diffusion-dependent deformation mechanisms, resulting in superplastic flow at low temperatures.

In this work, the effect of different percentage of Fe, Ni, and Mo on the microstructure evolution and superplastic behavior of Ti-Al-V-Mo alloys was investigated. The results revealed that incorporating the Ti-Al-V-Mo alloy with different percentage of Fe, Ni, and Mo reduces the superplasticity temperature to 625 °C. At this temperature, a high strain rate sensitivity index m >0.4 and an elongation to failure >800% were achieved at a constant rate of $1{\times}10^{-3}$ s^{-1}.

The study was funded by Russian Science Foundation (Grant # 21-79-10380).

Keywords: Titanium alloys, Superplasticity, Microstructure Evolution, Thermomechanical Treatment

* Speaker

†Corresponding author: kotov@misis.ru

A new approach for the tool-blank interaction modelling in superplastic forming

Donato Sorgente *†1, Andrea Lombardi[1], Donato Coviello[1], Leonardo Daniele Scintilla[2], M. Fontana[2]

[1] School of Engineering, Università degli Studi della Basilicata, Via Ateneo Lucano, 10, 85100, Potenza, Italy

[2] FONTANA PIETRO SpA, Viale Alcide De Gasperi 16, 23800 Calolziocorte (LC), Italy

In the modeling of the tool-blank interaction in superplastic forming, a constant coefficient of friction is usually assumed. The determination of the real values of that value is very challenging because of its dependence on several parameters (e.g. temperature, lubrication conditions, materials in contact) and the available test methods to properly assess this dependence are still very expensive and time-consuming. In this work, we proposed the evaluation of the coefficient of friction by a specific set of closed-die forming tests in a multi-cavity die. A strain-dependent formulation of coefficient of friction is proposed. Both experimental results, acquired from forming tests interrupted at different time instants, and numerical ones are employed for the calibration of a mathematical model through the evaluation and the comparison of the thickness distribution of the formed samples. A very good prediction capability of the numerical model in which the strain-dependent formulation was implemented was found highlighting the limits of a formulation involving a constant (and uniform) coefficient of friction.

Keywords: Hot Metal Gas Forming, Friction, Finite Element Modeling

* Speaker

†Corresponding author: donato.sorgente@unibas.it

Numerical and experimental analysis of a Ti-6Al-4V part under hot / hot forming operations: influence of the behavior model on the final shape prediction

Quentin Sirvin[1], Luc Penazzi[1], Rébecca Bonnaire[1], Fabien Nazaret[2], Maxence Garson[3], Velay Vincent[*†1]

[1] Institut Clément Ader (ICA) ; Université de Toulouse ; CNRS, IMT Mines Albi, INSA, ISAE-SUPAERO, UPS ; Campus Jarlard, F-81013 Albi, France

[2] Aurock – Aurock -21 Rue Pierre gilles de Gennes, 81000 Albi, France

[3] Loire-Etude – Loire-Etude - ZI de Stelytec, 4 Allée Léonard de Vinci, 42400 Saint-Chamond, France

In the aerospace industry, titanium alloys are used for their excellent mechanical behavior associated with low density. They are widely available in sheet form and the final shape can be obtained through three processes: at room temperature by stamping operation, at very high temperatures (T= 900°C) by superplastic forming (SPF) and at intermediate temperatures (T = 730°C, 880°C) by hot forming (HF). The project is based on the development of the warm stamping process of Ti-6Al-4V titanium alloy sheet under isothermal conditions at temperatures below than 700°C. Therefore, the determination of the process and material parameters constitutes an important stage for implementing the numerical simulation while contributing to the success of the stamping operation at the scale of an industrial part. The process parameters are related to the punch speed, the blank holder forces and the friction induced between the sheet and the tool. Their analysis allowed to determine two temperature levels (400°C et 500°C) leading to a drastic energetic decrease induced by this process, compared to HF or SPF processes, while ensuring the required level of elongation for the forming process. The material parameters influencing the behavior of the alloy are analyzed and quantified. They can be influenced by several mechanisms: elasticity, viscosity, anisotropy and nature of hardening (isotropic, kinematic). In this study, an anisotropic elasto-viscoplastic behavior model, able to consider the loading path undergone by sheet during forming, has been formulated. The implementation of the behavior model is achieved in Abaqus/Standard Finite Element code. It enables, on the one hand, stamping numerical simulations of a simple shape Omega profile for which experimental comparisons were done, on the other hand, calculations on an industrial part with a complex.

Keywords: Titanium Alloy, Warm Forming, Large Strains, Mechanical Behavior, Modelling, Numerical Simulation

[*] Speaker
[†]Corresponding author: vincent.velay@mines-albi.fr

Accurate determination of uniaxial deformation behavior of sheet material based on superplastic tensile test

Sergey Aksenov *†[1], Vadim Mikolaenko[1]

[1] National Research University Higher School of Economics – Moscow, Russia

Inaccuracies of the standard superplastic forming tests provided by nonuniform deformation of a specimen are reported multiply in the literature. Nevertheless, there is a lack of techniques aimed to correct these inaccuracies and obtain accurate information characterizing the material behavior in uniaxial tension conditions. Due to the viscoplastic character of material deformation, the material flow from the grip section to the gauge region is unavoidable in the standard superplastic tensile test. The result is an overestimation of the strain-hardening effect at the beginning of the test. At the later stages of deformation, the width and thickness of the gauge section become nonuniform, which results in the overestimation of the strain-softening effect. Thus, the stress-strain data obtained by the superplastic tensile test are affected by specimen geometry. In the framework of this study, the technique for the determination of accurate stress-strain data based on the results of the superplastic tensile test is proposed. The deformation behavior of a material is iteratively adjusted aiming to eliminate the effects provided by the nonuniform deformation of the specimen. Finite element simulation is utilized to address the inhomogeneous material flow in the specimen volume. The proposed technique is implemented t construct the model of deformation behavior of Al-Mg-Fe-Ni alloy in conditions of uniaxial superplastic deformation.

Keywords: Superplastic Tensile Test, Deformation Behavior Characterization, Deformation Inhomogeneity, Specimen Geometry, Finite Element Simulation, Constitutive Data

---

* Speaker

† Corresponding author: saksenov@hse.ru

Develop a data-driven viscoplastic materials flow model through machine learning method

Chi Zhang *†[1], Jun Jiang[1]

[1] Imperial College London, United Kingdom

In Finite Element (FE) Analysis, the material behaviours are usually described by implementing the constitutive equations in the FE software. These constitutive equations describe the material flow mechanism and the microstructure evolution during the forming process, and could significantly affect and the accuracy of the FE simulation results. As a result, finding the material constants (also known as parameters) is vital.

However, the material flow model itself could be very complex and finding the material constants could be very time-consuming using the controversial fitting methods. In addition, when there are multiple outputs (e.g., stress-strain curve, grain size evolution) in the flow models, it is difficult to balance the accuracy of them, and manually compromising some results for others could be time-consuming.

As powerful computing resources are available currently, and the rapid development of Machine Learning (ML) methods, this project aims to develop a data-driven model using ML methods to save the time and efforts in finding the constants in the constitutive equations. In addition, the 'Smart manufacturing simulator and characterization unit' in the testing centre is able to provide large sets of different experimental data, including stress, strain, GND, grain size, etc.

Keywords: Constitutive Equation, Maching Learning

* Speaker

†Corresponding author: chi.zhang18@imperial.ac.uk

Superplasticity of Al-Mg-Si-based alloy doped with eutectic-forming and dispersoid-forming elements

Andrey Mochugovskiy *†1, Esmaeili Majid[1]

[1] National University of Science and Technology MISIS 119049, Moscow, Leninskiy prospekt 4, Russia

The development of Al–Mg–Si-based alloys with advanced superplasticity and improved mechanical properties is an important task for further applications of superplastic blow-forming technology in the production of complex-shape parts. The current study focuses on the influence of eutectic forming Y, Er, Ni, Fe, Ce and dispersoid forming Sc and Zr alloying elements on the microstructural evolution, superplastic behavior, and tensile properties at room temperature for the Al-1.2%Mg-0.7%Si-1.0%Cu (AA6013-type) alloy. The X-Ray diffraction, scanning, and transmission electron microscopy were used for microstructural characterization. The bimodal particle size distribution was observed after the thermomechanical treatment of the alloy studied. The high density of the L12 coherent dispersoids with a mean size of 10 ± 1 nm providing a significant Zener pinning effect was formed during homogenization annealing. The near-equiaxed coarse particles with a size in a range of 0.5–5.0 μm belonged to the eutectic-originated phases led to an important particle-stimulated nucleation (PSN) effect. The alloys studied exhibited a superplastic behavior in temperature and strain rate limits of 440–520 ◦C and 0.001 - 0.01 1/s, respectively. The best superplastic behavior was observed in Fe and Ni bearing alloy that demonstrated elongation-to-failure range of 350–480%. The age-hardening heat treatment of the alloy provided a yield strength of 370 ± 4 MPa, an ultimate tensile strength of 415 ± 2 MPa, and elongation of 6 ± 1%.
This work is supported by the Russian Science Foundation under grant number 20-79-00269.

Keywords: Aluminum Alloys, Superplasticity, Grains and Interfaces, Recrystallization, Dispersoid

* Speaker
†Corresponding author: mochugovskiy@mail.ru

Natural correspondence between the quantum mechanics and relativistic frequency parameter and the deformation mechanisms associated with superplastic flow in advanced materials

Juan Muñoz-Andrade *†[1]

[1] Universidad Autónoma Metropolitana, Mexico

The main purpose of this work is to highlight the natural correspondence that exists between the quantum mechanics and relativistic frequency (QM-RF) parameter proposed by Muñoz-Andrade and the deformation mechanisms during superplastic flow (SPF) in advanced materials. Therefore, by applying the quantum mechanics and relativistic model (QM-RM) formulated by Muñoz-Andrade, under different thermo-mechanical conditions, the activation energy and the QM-RF parameter for the super plastic flow in advanced materials with fine grain size were determined. The main findings denote that the nature wavelength associated with the QM-RF parameter fully corresponds to the grain boundary sliding (GBS) and the cooperative grain boundary sliding (CGBS). Considering, as a case study, the superplastic behavior in fine-grained Ti–6Al–4V sheet, which was studied previously by others researchers, through performing at temperature of 873 K the uniaxial tensile test, with grain size of 0.51 µm, strain rate of $3x10^{-4}$ s^{-1} and strain rate sensitivity of 0.72. For such conditions, the activation energy for SPF calculated by conventional method and also by the QM-RM was 220 KJ/mol and the QM-RF value was $F=5.51x10^{14}$ s^{-1}. Consequently, the nature wavelength was 0.544 µm. Such value is related with GBS. While, the same analysis performed with the conventional Zener-Hollomon parameter, allows obtained the value of $Z=4.3x10^{9}$ s^{-1}, which is associated with a wavelength of 69767.4 µm. Consequently, it is possible to observe that the Zener-Hollomon conventional frequency parameter, does not coincide with the nature wavelength related to the main superplastic flow mechanisms.

Keywords: Superplastic Flow Mechanisms, Activation Energy, Quantum Mechanics and Relativistic Frequency Parameter, Zener, Hollomon Frequency Parameter

* Speaker

† Corresponding author: jdma@azc.uam.mx

Thursday

September 16, 2021

Biaxial hot forming of AA2219 with SPF and other hot forming processes

Werner Beck *†1, Sabine Wagner[1], Andrew Norman[2], Graham Harris[2]

[1] FormTech GmbH, Germany

[2] ESTEC/ESA, Netherlands

In the framework of an ESA project FT was working on an advanced forming method for dome forming of tank structures for space applications. Three different hot forming procedures as" Gas pressure forming SPF"," Hot deep drawing HDD" and" Hot stretch forming HSF" were applied on test samples from AA2219 sheet metal in thickness t=2,0mm. Parameters and limits of formability were investigated with Cone-cup and Swift tests. Formed parts underwent metallographic inspection. The three forming principles were compared and the forming results evaluated regarding their performance for dome forming.

Keywords: SPF, Hot Forming, AA2219

---

* Speaker
†Corresponding author: werner.beck@formtech.de

Integration of the SPF technology in an efficient industrial production flow for high rates aeronautical parts

Yves Marcel *†1, Jeremy Pion[1], Benjamin Boniface[2]

[1] LAUAK AEROSTRUCTURES – Groupe LAUAK, France

[2] Lauak Innovative Solutions – Groupe LAUAK, France

The presentation will illustrate the creation and production ramp up of the Titanium Hot forming and Superplastic Forming Technology in a French Aeronautical supplier from Industrialization to Full A320 rate production of titanium parts.
With deformation and elongations well beyond classical" cold" sheet metal forming capabilities (specially with high strength titanium alloys such as Ti64 and Ti6242), Superplastic Forming was chosen to be complementary to other manufacturing methods already used in the factories of the LAUAK group.
Several aspects of the project will be presented, including the installation of two HF/SPF Presses, the industrialization steps of Airbus A320NEO pylon parts from tooling design to the qualification, and then integration of the SPF in the full logistics flow of the factory production lines (from material, blanks, SPF, 5 axis laser trimming and machining, control and finally assembly).
Some of the industrial challenges faced and overcame will be highlighted and illustrated.

Keywords: Superplastic Forming, Titanium, Hot Forming, Industrial, SPF

* Speaker
†Corresponding author: yves.marcel@groupe-lauak.com

On the uniaxial testing of aluminium alloys in superplastic condition using a joule heating system and DIC measurements

Nagore Otegi Martinez *†1, Unai Ibarretxe[1], David Abedul[1], Javier Trinidad[1], Lander Galdos[1], Xabier Agirretxe[2]

[1] Mondragon Unibertsitatea, Spain

[2] Ekide S.L., Spain

The relation of materials testing and finite element model can be a key to optimize Super Plastic Foming (SPF) processes. Numerical models provide solutions for obtaining pressure time curves maintaining the optimum SPF behaviour throughout the forming. However, a very important aspect of such models is the development of constitutive equations that represent accurately the variation of flow stress for a large range of strains and strain rates. Inaccurate prediction of the pressure history may result in premature fracture of the sheet or suboptimal exploitation of the superplastic capabilities of the material.

One of the key aspects of a good simulation relays on the obtaining of precise superplastic constitutive curves. In most cases, uniaxial test is the most commonly used experiment for capturing the constitutive behaviour, but this type experiment presents some challenges. On one hand, big furnaces are used for getting a homogenous high temperature, preventing the access of displacement measurements by DIC or other non-contact extensometric techniques.

On the other hand, as large strains are achieved on the specimen, and all the specimen is deformed (including heads), the calculation of the strain evolution can be challenging. In the current work, a joule heating device is used for heating superplastic aluminium alloys, and a DIC camera system is used for in-situ recording of the local deformation of the materials. With the information gathered, the constitutive behaviour is calculated for each alloy, and compared to results obtained by using a traditional furnace system and reverse engineering simulation.

Keywords: DIC, Material Characterization, Uniaxial Tests, Superplastic Aluminium Alloys

* Speaker
†Corresponding author: notegi@mondragon.edu

Integrating in-situ thermal-mechanical testing and constitutive modelling for superplastic forming technique on Ti alloys

Tabassam Yasmeen[1], Chi Zhang[2], Jun Jiang [*†2]

[1] Advanced Forming Research Centre, University of Strathclyde – 85 Inchinnan Drive, Inchinnan, Renfrew, Scotland, PA4 9LJ, United Kingdom

[2] Imperial College London, United Kingdom

Developing accurate physically-based constitutive equations to reliably modelling the superplastic behaviour at the macro and micro scale is vital. This will ensure the forming quality and in-service performance (such as fatigue resistance) of superplastically formed (SPF) parts. However, such development is often uneasy due to the lack of available information on the microstructure distribution and evolution during the SPF. Building on micromechanical testing and modelling expertise, we developed and harnessed the in-situ micromechanical testing and characterization capabilities, which were applied to reveal the microstructure changes such as grain size and dislocation density (GNDs), texture and phases during the SPF. These results were combined with observed macroscopic superplastic stress-strain behaviours. As a result, the physically-based constitutive equations were developed and validated. This mode provides more insights into the microstructure evolution and also improves the accuracy of materials flow during the SPF production.

Keywords: Micro Mechanical Testing, Characterization, Constitutive Equations, Titanium Alloys

[*] Speaker
[†]Corresponding author: jun.jiang@imperial.ac.uk

Flow behaviour and evolution of the microstructure and the texture during superplastic deformation of Fine-Grained and UltraFine-Grained Ti-6Al-4V alloy

Laurie Despax[1], Vanessa Vidal [*†1], Moukrane Dehmas[2], Denis Delagnes[1], Hiroaki Matsumoto[3], Vincent Velay[1]

[1] Institut Clément Ader (Université de Toulouse: CNRS, IMT Mines Albi, INSA, UPS, ISAE-SUPAERO) – IMT Mines Albi, France

[2] Centre Interuniversitaire de Recherche et d'Ingenierie des Matériaux (CIRIMAT) – Université de Toulouse, CNRS, 4, allée Emile Monso, BP 44362, 31030 Toulouse Cedex 4, France

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

Two phase titanium alloys (as Ti-6Al-4V) with an initial equiaxed microstructure are known to exhibit interesting superplastic properties under specifics conditions of temperature (T ≥ 900°C), strain rates ($\dot{\varepsilon} \leq 10{-}3$ s−1) and microstructure (fine and stable grain size). One of the main challenges of superplastic forming, which enables the production of complex part geometries, is to decrease its costs by reducing the forming temperature and/or its forming time, in particular, using optimized microstructure (as grain refinement).
Superplasticity is mainly explained by grain boundary sliding (GBS) associated with different accommodation mechanisms that may depend on the temperature, the strain rate but also on the initial alloy microstructure (preferred orientation, size and shape of the grains, phases fraction and spatial distribution, etc.). So there is a strong interaction between the microstructure evolution and the hot deformation behaviour during hot deformation processes. In this context, this study focuses on the hot deformation and superplastic behaviour as well as the microstructural evolution of Ti-6Al-4V alloy sheets with different initial microstructure (Fine Grain microstructure FG with dα=0.5 µm and Ultra-Fine Grain UFG microstructure with dα=2 µm).
The mechanical behaviour was obtained by tensile tests performed in a wide temperature range (650°C -920°C) and strain rate (10^{-2} s^{-1} to 10^{-4} s^{-1}). The evolution of the microstructure and crystallographic texture was studied by using SEM observations, EBSD and synchrotron diffraction experiments on samples after interrupted tensile tests as well as by in-situ synchrotron radiation diffraction measurement during thermo-mechanical loading. Specifics flow behaviour and different microstructural and texture evolution in both phases (α+β), depending on the test conditions and the initial microstructure are evidenced. These results will be presented and discussed in terms of dominant mechanisms of deformation (movement/slip of dislocation and/or grain boundary sliding) and role of the two phases and their interfaces depending on the tensile test conditions and the initial microstructure.

Keywords: Superplasticity, Titanium Alloy, Crystallographic Texture, Microtructure, SEM, Synchrotron Diffraction

* Speaker
†Corresponding author: vanessa.vidal@mines-albi.fr

An Investigation of Alpha Case reduction in Superplastic Forming of Ti-6Al-4V

Hosam Elrakayby *†1, Paranjayee Mandal[1], Diego Gonzalez[1]

[1] Advanced Forming Research Centre, University of Strathclyde – 85 Inchinnan Drive, Inchinnan, Renfrew, Scotland, PA4 9LJ, United Kingdom

Commercial titanium alloy Ti-6Al-4V (Ti64) is a well-known alloy for superplastic forming (SPF) applications within the aerospace sector. Ti64 components are usually formed at temperatures close to 900 ◦C, and their exposure to oxygen at this high temperature results in surface oxidation. This superficial hardened oxide layer is referred to as alpha case, which is brittle and very abrasive in nature. The alpha case can be removed by machining or chemical etching, which increases the costs and the times of manufacturing, besides environmental and health and safety concerns in the case of etching. Reducing the forming temperature significantly affects the alpha case development on formed components along with other benefits such as life extension of tooling and heating elements, less energy consumption, use of cheaper platen and die materials. This paper investigates the possibility to form Ti64 alloy at lower temperature (800 ◦C) in order to reduce the alpha case formation and studies the mechanical and microstructural behaviour of the Ti-6Al-4V material at those temperatures.

Keywords: Superplastic Forming, Titanium, Ti-6Al-4V, Alpha Case

* Speaker
†Corresponding author: hosam.elrakayby@strath.ac.uk

A performing study of superplastic bulge-test samples using dimensional analysis

Luis García-Barrachina *†1, Antonio Gámez[1]

[1] School of Engineering, University of Cadiz. Av. Universidad de Cadiz, 10, E-11519 Puerto Real (Cadiz), Spain

Superplastic forming is undoubtedly a complex process at theoretical and applied levels. Considering a technological perspective, the large number of variables involving the process makes necessary the use of assistant tools in order to obtain a deeper understanding of the influence of the parameters involved. Recently, Dimensional Analysis has proven to be a useful technique to obtain phenomenological laws by combining experimental tests and a mathematical development. Here we present an application of the Dimensional Analysis to study the forming time of superplastic samples at free bulging tests. The procedure allows us to get an analytical expression of the target variable as a function of the dimensionless variables describing the process. This law is then compared to analytical expressions from other authors and to numerical results.

Keywords: Superplastic Forming, Dimensional Analysis, Free Bulge, Thickness

[*] Speaker
[†] Corresponding author: luis.barrachina@uca.es

Estimation of constitutive parameters for superplastic light alloys based on inverse analysis and bulge tests with pressure jumps

Antonio Piccininni *†1, Pasquale Guglielmi[1], Angela Cusanno[1], Donato Sorgente[2], Gianfranco Palumbo[1]

[1] Department of Mechanics, Mathematics and Management, Politecnico di Bari, Italy

[1] School of Engineering, Università degli Studi della Basilicata, Via Ateneo Lucano, 10, 85100, Potenza, Italy

The design of the superplastic forming process starts from a proper characterization of the material superplastic behaviour, often carried out via testing routes based on a strain condition close to the real one. Data from such tests are generally used to calibrate well-known constitutive models. In the present work, experimental free inflation tests with pressure jumps were carried out on three different alloys: the titanium alloy Ti-6Al-4V ELI, a 5XXX aluminium alloy (ALNOVI-U) and the magnesium alloy AZ31B. Height evolution of the dome was recorded continuously during each test and the resulting curve used as the target data for the inverse analysis, managed by a multi objective genetic algorithm. The minimization of the discrepancy between the numerical results and the experimental data led to the determination, for each investigated material, of the two constants belonging to the Backofen's constitutive equation. Results from the inverse analysis demonstrated that data from tests with pressure jumps were a good experimental reference for the algorithm convergence. Furthermore, despite its simple formulation, the model was able to accurately predict the superplastic behaviour of the Ti and Al alloys. On the other contrary, being the Mg alloy characterized by a non-constant evolution of the strain rate sensitivity index as well as a not stable grain size, the Backofen formulation revealed to be less accurate.

Keywords: Light Alloys, FEM, Inverse Analysis, Genetic Algorithm

* Speaker

†Corresponding author: antonio.piccininni@poliba.it

CADIZ

The city of Cadiz is geographically located at the south-western tip of the Iberian Peninsula, on the coast of the Atlantic Ocean. Thanks to its location, Cadiz has been an important economic enclave throughout history, being the oldest city on the Iberian Peninsula and one of the oldest in Europe.

The origins of the city date back to around 1100 BC with the arrival of Phoenician navigators from the East. Thanks to its geographical location, the Phoenicians founded the city of Gadir for strategic purposes and established trade routes between the Mediterranean and the Atlantic, developing a powerful trade based, among other things, on the extraction of silver.

Over the centuries, the city has been inhabited by different civilisations, including the Carthaginians, Romans, Goths, Muslims and Christians. In the 16th century Cadiz entered a period of great splendour with the arrival of the Renaissance, becoming the gateway for commercial traffic between the Old Continent and the New World. This led to an economic flourishing of the city during the Modern Age, which had a positive influence on the city's urban planning. During this period of prosperity, an incipient commercial and enlightened bourgeoisie grew up.

In the 19th century, Cadiz was the only city to escape Napoleonic rule during the reign of José I, serving as a refuge for liberalist politicians. In this context, the Cortes Generales were convened and, later, in 1812, the first Spanish Constitution, popularly known as "La Pepa", was drawn up.

Coming to the present day, the historical development of the city was marked by a thriving shipbuilding industry during the 1960s and 1970s, which was cut short after the oil crisis and the new direction of the construction of large ships.

Today, the city stands out, on the one hand, for the economic activity generated by its commercial port. On the other hand, its excellent location and favourable climate serve as a tourist attraction along with its beaches, local festivals and historical heritage.

Airbus Defence and Space

Centro Bahía de Cádiz

The beginnings of the aeronautical sector in the province of Cadiz date back to 1928 with the creation of the Construcciones Aeronáuticas S.A. (CASA) factory in the *Puntales* district of Cadiz. Initially, this factory was chosen as a platform for the manufacture of Dornier Do J seaplanes. However, the activity in this plant was gradually expanded with the assembly of aircraft under licence and self-developed aircraft, such as CASA III, C-201 Alcotán, C-202 Halcon and C-207 Azor, as well as other more recent models, such as C-212 Aviocar, C-101 Aviojet, CN-235 or C-295.

In 2000, European Aeronautic Defence and Space (EADS), the largest aerospace company in Europe, was created through the merger of the companies Aerospatiale Matra S.A., Daimler Chrysler Aerospace AG and Construcciones Aeronáuticas S.A. Thus, the former CASA was renamed EADS-CASA. Years later, this division would acquire the name Airbus Defence and Space (Airbus DS) as a result of a restructuring of the company. In the same year, the need to build new facilities to provide continuity to the activities carried out at the *Puntales* plant was identified. With this objective in mind, a project was launched to conceive a new centre with sufficient industrial and technological capabilities to become a world reference. As a result of this project, in 2003 the old *Puntales* plant was moved to El Puerto de Santa María, creating Centro Bahía de Cádiz (CBC).

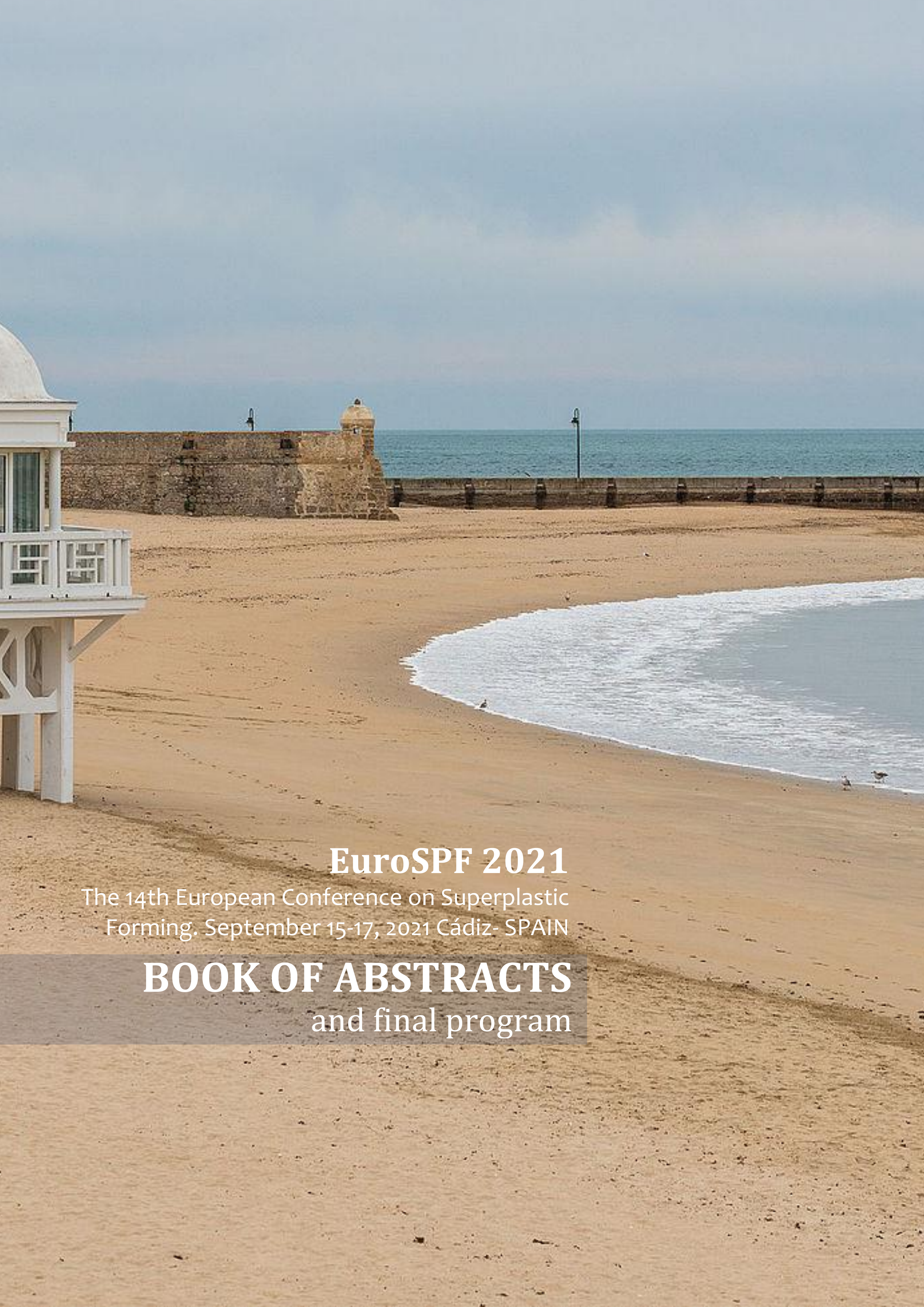
Since the transfer of the factory to the new CBC facilities, work has continued with the three main technologies present in the old factory: sheet metal work, superplastic forming/diffusion bonding and the manufacture of structures in composite materials. Thanks to the experience acquired over the years in these technologies and the strong R&D&I activity developed in its facilities, CBC has been able to access important work packages. Among them, it is possible to highlight the manufacture of the Fan Cowls of A340/500-600, A380, A320neo and Boeing B-737 Max aircraft models, the assembly of section 18 of A320 and the manufacture of the horizontal stabiliser (HTP) of Falcon 7X and A400M in composite material by means of horizontal taping (ATL).

However, the most prominent of the technologies being developed at the CBC facilities is known as superplastic forming/diffusion bonding (SPF/DB).

SPF technology was introduced at the *Puntales* plant in 1990 as a result of the technology transfer from Dornier to CASA between 1984 and 1989. Currently, the CBC plant has three presses capable of Hot Forming, SPF of titanium and aluminium alloys and SPF/DB of titanium alloys. This is the only plant with the capacity and know-how necessary to carry out the SPF/DB process, which makes the CBC a reference centre within the Airbus group. As an example we can cite its most emblematic part, the Slats of the Eurofigther Typhoon manufactured by SPF-DB with the Vanned Structure technique.

List of partners and sponsors

Author index



EuroSPF 2021

The 14th European Conference on Superplastic Forming. September 15-17, 2021 Cádiz- SPAIN

BOOK OF ABSTRACTS

and final program