EUROSPF 2024

PAYS BASQUE

BOOK OF ABSTRACT

15th EUROPEAN CONFERENCE ON
SUPERPLASTIC FORMING – **EUROSPF 2024**

Pays Basque (France)

(11-13 September 2024)

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GROUPE LAUAK

ESTIA INSTITUTE OF TECHNOLOGY

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EURO SPF 2024

The 15th European Conference on Superplastic Forming
September 11-13, 2024, Bask Country, FRANCE

https://eurospf2024.sciencesconf.org/

ESTIA
Technopole Izarbel 90 Allée Fauste d'Elhuyar
64 210 Bidart – France

Organized by

Scope

The EUROSPF is a conference focused on all aspects related to the super plasticity 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 super plasticity and the superplastic forming, giving the participants the opportunity to show their current works and promoting future collaborations.

Committees

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Basic Information

Date	11 – 13 September 2024
Venue	The EUROSPF 2024 will be held in the Basque Country, at the Institute of Technology ESTIA
Web	https://eurospf2024.sciencesconf.org/

Secretariat	**Manon HARRIET** eurospf2024@sciencesconf.org ESTIA Advanced Industrial Technology Institute Technopole Izarbel 90 Allée Fauste d’Elhuyar 64210 BIDART – FRANCE

Program

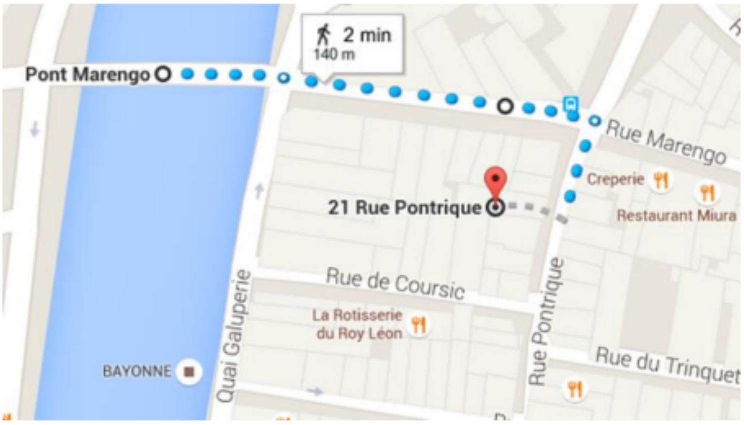
Each day, bus transport from hotel to conference and activities + return is planned.
Departure of the bus:

- FastHotel, Bidart
- Hotel Elissaldia, Bidart

Tuesday, September 10, 2024

TIME	*EVENT*
19 :00 (pm)	**Welcoming Cocktail – Bayonne – Peña LAUAK** First registration

21 rue Pontrique,
64100 Bayonne



Wednesday, September 11, 2024

TIME	***EVENT – ESTIA Bidart*** *(Technopole Izarbel, 90 Allée Fauste Elhuyar, 64210 Bidart)*
8 :15-9 :15	Registration
9 :15-9 :45	Opening
9 :45-10 :30	**Keynote** ➔ Dr. **Nikolai Kashaev** *Laser peening of thin-walled titanium structures: a combined experimental, data-driven and numerical approach to process optimization*
10 :30-10 :55	Coffee Break
10 :55-12 :30	**MICROSTRUCTURE - MATERIALS**
11:00-11:30	- **ISMPS** – **Evgeny Naydenkin (ONLINE)** *The effect of processing under-low temperature superplasticity on structural phase state and mechanical properties of ultrafine grained near beta titanium alloy.*
11:30-12:00	- **MISIS** – **Anastasia V. Mikhaylovskaya** *Superplasticity and Deformation mechanisms of Al-based alloys with enhanced strength properties.*
12:00-12:30	- **Amag Rolling – Daniela Vitzthum** *Superplastic Forming of AMAG CrossAlloy.57 - A systematic Study on the Impacts of Process Variables on Final Material Properties.*
12:30-14:00	**Lunch**
14:00-15:00	**MICROSTRUCTURE - MATERIALS**
14:00-14:30	- **Politecnico di Bari – Angela Cusanno** *Laser heat treatment prior to superplastic forming for tailoring the thickness distribution of a magnesium AZ31 component.*
14:30-15:00	- **MISIS** – **Anastasia V. Mikhaylovskaya** *Effect of minor alloying on the superplastic behaviour of Ti-Al-5-MO alloys.*
15:45-18:45	**SIMULATION**
15:45-16:15	- **ENIT Tarbes – Olivier Pantalé** *Comparative Analysis of Finite Element Formulations for Simulating Hot Forming of Ti-6Al-4V Aerospace Components.*
16:15-16:45	- **Strathclyde – Craig Knwoles** *Exploring the potential of SPF of TA6V tailored machined blanks for lightweight.*
16:45-17:15	**Coffee Break**
17:15-17:45	- **IRT Jules Verne – Olivier Valentin** *Manufacturing the future of superplastic and hot forming processes, an overview of some experimental and simulation methods.*
17:45-18:15	- **Autoform – Chovav Mordechai** *Optimizing Aerospace Hot forming: A Leap Forward with Simulation Technology*
18:15-18:45	- **IMT Mines ALBI – Lucas D'Archivio** *Investigation of the mechanical behaviour of Ti-6AL-4V in Hot Forming conditions: Experiment and Modelling.*
	Free Time

Thursday, September 12, 2024

TIME	*EVENT*
08:00-08:45	**Board Meeting** *(Technopole Izarbel, 90 Allée Fauste Elhuyar, 64210 Bidart)*
08:45-10:15	**APPLICATIONS - PROCESS**
08 :45-09 :15	- **AIRBUS – Anne Lepied** *SPF Process in the aeronautic industry.*
09:15-09:45	- **TECNALIA – Amaia Arroyo** *Manufacturing routes for hot stamping of aluminium alloys applied to a wing rib.*
09:45-10:15	- **AUROCK – Elise Lamic** *Industry 4.0 for Superplastic and Hot Forming manufacturing processes: effective developments and deployments in the AUROCK factory*
10:15-10:30	Coffee Break
10:30-11:30	**TOOLS**
10:30-11:00	- **SEVA – David POYEN** *Steps and Key Choices for Designing and Building Efficient HF & SPF Titanium Forming Tools.*
11:00-11:30	- **CRONITE – Peter White** *Titanium Forming Tools – Press Platens.*
11:30-12:30	**GREEN**
11:30-12:00	- **Strathclyde – Jun Liu** *Green Manufacturing: Hybrid Superplastic Forming of Titanium*.
12:00-12:30	- **University of Basilicata – Emanuele Fulco** *Numerical Study of the Reshaping process of End-Of-Life components by gas forming at elevated Temperatures.*
12:30-13:30	**Lunch**
14:00	**CULTURAL VISITS “Basque Country”**
19:30	**Gala Dinner – Hotel Berria Hasparren** *(68 rue Francis Jammes, 64240 Hasparren)*

Friday, September 13, 2024

TIME	*EVENT* *(Technopole Izarbel, 90 Allée Fauste Elhuyar, 64210 Bidart)*
8 :30-9 :15	**Keynote: Werner Beck** Industrial development of SPF-production process for high quantities. Overview since the 1980-ties
9 :15-10 :45	**INDUSTRIAL**
9:15-9:45	- **Formtech - Werner Beck** *Benefit of isothermal hot-forming with double-action hot press.*
9:45-10:15	- **Macrodyne – Eugene Ryzer** *Gas Oscillation technology for superplastic forming of titanium and aluminium alloys.*
10:15-10:45	- **FONTANA – Andrea Lombardi //Amag - Florian Schmid** *Study on the Blow Forming of 5xxx/7xxx Aluminium alloy for automotive applications.*
10:45-11:00	**Coffee Break**
11:00-11:30	- **ACB – Thierry Favre – Valentine Legrand – Axel Beuzit** *From specific press design to manufacturing SPF aeronautical parts.*
11:30-12:00	- **ALU SPF – Christoph Pirchl** *Super Plastic Forming Process for Traditional Vintage Helmet for Austrian Firefighters.*
12:00-12:30	- **NMIS** Die friction
12:30-13:00	**Closing**
13:00-14:00	**Lunch**
	INDUSTRIAL VISITS

Visit A	Visit B
CompositAdour / AddimAdour *2 rue Pierre Georges* *64100 Bayonne*	**LAUAK Groupe** *2245 route de Minhotz* *64240 Hasparren*

ABSTRACTS

Wednesday
September 11, 2024

Laser peening of thin-walled titanium structures: a combined experimental, data-driven and numerical approach to process optimization

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The demand for complex shaped thin-walled structures in the aerospace industry is steadily increasing, requiring robust and reliable manufacturing techniques. Traditional sheet metal forming (SMF) processes often face challenges such as wrinkling, shearing and spring back, which affect the quality and precision of the formed parts. This work, carried out as part of the PEENCOR project [1], focused on optimizing the Laser Peen Forming (LPF) process, a modern and innovative SMF technique that uses high-intensity laser pulses in ns regime to deform materials with minimal surface damage. The targeted application of LPF is in the aerospace sector to form sheet metal into specific geometries and to correct unwanted deformations, particularly in the case of the titanium alloy Ti-6Al-4V. Experimental investigations have focused on identifying the optimal LPF process parameters to achieve the desired deformations [2]. Data-driven methods used artificial neural networks to predict deformations based on process parameters, increasing the potential for autonomous forming processes [3-4]. Numerical simulations using the finite element method complemented the experimental work, providing insights into the deformation mechanisms and the optimization of process parameters [4]. The results of the project extended the understanding and application of LPF to thin-walled Ti-6Al-4V structures.

Keywords: Laser peen forming (LPF), Ti-6Al-4V, artificial neural networks, machine learning, process planning.

The effect of processing under low-temperature superplasticity on structural-phase state and mechanical properties of ultrafine-grained near beta titanium alloy

Evgeny Naydenkin[1] , Il'ya Ratochka[1] , Olga Lykova[1] , Ivan Mishin[1]

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The study was conducted to investigate the impact of low-temperature superplastic deformation (forming) on the structural-phase state and room temperature mechanical properties of an ultrafine-grained titanium alloy Ti-5Al-5V-5Mo-1Cr-1Fe. The results showed that subjecting the alloy samples to tension at strain rates of $2\cdot10^{-3}$ and $6.9\cdot10^{-3}$ s^{-1} at a temperature of 823 K (~0.4 T_m) had minimal effects on its mechanical properties at room temperature. This was attributed to the retention of the ultrafine-grained alloy structure, originally formed through all-round pressing, during superplastic deformation (forming) under the above conditions. Alternatively, compressing the ultrafine-grained alloy workpieces at the same temperature (823 K) and strain rate (~10-2 s^{-1}) resulted in a slight decrease in ultimate strength values.

Keywords: near β titanium alloy, ultrafine-grained structure, low-temperature superplastic forming, mechanical properties

Superplasticity and deformation mechanisms of AL-Based alloys with enhanced strength properties

Anastasia V. Mikhaylovskaya[1], Olga A. Yakovtseva, Anna A. Kishchik,

Zarina S. Turaeva, Anton D. Kotov

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The development of new superplastic alloys with improved formability and/or service properties is an issue for scientists and industry. In order to achieve the desired properties, the composition of the modifying alloy and the processing parameters are required. In this study, the influence of small additions of solute alloying elements for aluminium-based alloys (type 5083) on the contributions of superplastic deformation mechanisms was investigated. It was shown that grain size, precipitation parameters and solute content should be controlled. to control the superplastic properties. It was shown that small additions of Zn and Si can stimulate grain boundary sliding, but Cu reduces its contribution to the total strain. Based on this effect, the alloy composition was optimized, and the alloy sheets were processed by a simple thermomechanical treatment.
The superplastic properties of commercially processed sheets of aluminium-based alloys (type 5083) with enhanced strength properties were studied. The sheets with a thickness of 1.2 to 2 mm and a grain size of about 8 µm exhibited a strain rate sensitivity coefficient, m, of more than 0.5 and an elongation to failure of 400% at a constant strain rate of 2×10^{-3} s^{-1}. Superplastic forming of the complex-shaped model parts was successfully processed at 520 °C and a strain rate of 2×10^{-3} s^{-1}. The alloy exhibited a yield strength of 190 MPa, an ultimate tensile strength of 370 MPa, and an elongation of 20-22% at room temperature. Dynamic grain growth occurred during superplastic deformation, which reduced the strength properties and ductility, but by less than 5-10%.

Keywords: Superplastic deformation, commercial aluminum alloy, grain boundary sliding, strength properties

Superplastic Forming of AMAG CrossAlloy®.57 – A Systematic Study on the Impacts of Process Variables on Final Material Properties

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Aluminum alloys are traditionally classified based on their primary alloying element, dictating their properties and applications. This standardization restricts advancements and the use of secondary raw materials. The AMAG CrossAlloy® family aims to overcome these limitations with an innovative alloy design strategy.
AMAG CrossAlloy®.57, the first in this series, has been industrially produced, thoroughly characterized, and tested in various applications. Initial prototype trials indicate that AMAG CrossAlloy®.57 performs exceptionally good in and after superplastic forming (SPF) and thereby helps to overcome certain limitations attributed to 6xxx, 7xxx, and 5xxx series alloys.
Our systematic study investigates the effects of varying material and process parameters on the final properties of AMAG CrossAlloy®.57. Two material variants were superplastically formed and subjected to different cooling strategies and heat treatments. The results reveal the respective impacts on final material properties including strength, corrosion resistance and microstructure.
This study highlights the potential of AMAG CrossAlloy®.57 to revolutionize aluminum alloys, providing enhanced properties for diverse applications.

Laser Heat treatment prior to superplastic forming for tailoring the thickness distribution of a magnesium AZ31 component

Angela CUSANNO[1], Pasquale GUGLIELMI[1], Antonio PICCININNI[1], Donato SORGENTE[1], Gianfranco PALUMBO[1]

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Magnesium (Mg) alloys are widely used in sectors where weight reduction is crucial, such as the automotive, aerospace and biomedical field. Superplastic Forming (SPF) is an effective method for creating complex shapes with Mg alloys, particularly AZ31, which exhibits excellent superplastic behaviour at high temperatures. However, SPF often results in significant thickness variations, impacting component performance. Achieving uniform thickness throughout a superplastically formed component is still challenging.

In the present work, a numerical/experimental approach for improving the thickness uniformity of components produced by superplastic forming has been proposed. Through heat treatments using a CO_2 laser the grain size was locally changed, thus modifying the superplastic behaviour in a predefined area of the blank. Both the grain coarsening produced by the laser heat treatment and the superplastic forming of the heat treated blank were simulated using Abaqus software, which allowed to set the related process parameters for the manufacturing of the investigated case study. The thermal finite element model of the laser heat treatment, calibrated using the experimental temperature evolutions acquired in specific areas during the heat treatment, was used to evaluate the influence of the laser heating process parameters on the grain size evolution. The resulting grain size distributions were implemented in the mechanical finite element model of the superplastic forming process. The proposed approach revealed to be effective, since it allowed to design the laser heating parameters able to improve the thickness uniformity of the formed AZ31 component.

Keywords: Laser Heat Treatment, Grain size, Finite Element, magnesium alloys, thickness uniformity.

Effect of minor alloying on the superplastic behavior of Ti-Al-Mo-V alloys

Anton D. Kotov[1], Maria N. Postnikova, Alena Y. Trishina, Anastasia V. Mikhaylovskaya

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Titanium-based alloys are widely used in various industrial fields due to their unique properties such as low density and high strength-to-weight ratio, excellent corrosion resistance and heat resistance. However, high stress levels, a relatively low modulus of elasticity and increased sensitivity to processing parameters make it difficult to produce complex shaped parts from titanium alloys by hot stamping and forging. Superplastic forming (SPF) overcomes these difficulties and allows forming at low gas pressure in a single operation. The duplex-structured Ti-6Al-4V and Ti-4Al-3Mo-1V alloys exhibit good superplasticity at high temperatures of 800-900°C due to their stable duplex structure. High SPF temperatures increase energy consumption, tool and die wear and lead to the formation of oxide and alpha layers on the part surface. In this context, the design of titanium alloys that exhibit superplasticity at low temperatures is a current issue.

The effects of minor alloying elements Fe (0.5 wt%), B (0.01-0.1 wt%), and Y (0.05-0.2 wt%) on the superplastic behavior, microstructural evolution and mechanical properties of Ti-Al-V-Mo alloys were investigated. It is shown that even small additions of these elements provide stable flow and reduce the flow stress values at the initial deformation stage. An increase in the high-angle grain boundary fraction was observed at the initial deformation stage, which facilitates the grain boundary sliding contribution and flow stability at a steady state of superplastic flow. The effect was pronounced at low temperatures and was thus explained by the acceleration of recrystallization and globularization of the microstructure. As a result, minor additions of the studied elements provided good superplasticity at the comparatively low temperatures of 625-775 °C (m ~0.50 and strain to failure ~500-900%) and improved the postforming room temperature strength (830 MPa YS and 990 MPa UTS). *The study was done in framework of RSF project (code 23-79-01155).*

Keywords: Titanium alloys; superplastic behavior; microstructural evolution; grain boundary sliding; dynamic grain growth; mechanical properties

Comparative Analysis of Finite Element Formulations for Simulating Hot Forming of Ti-6Al-4V Aerospace Components

Olivier Pantalé[1] , Sharan Raj Rangasamy Mahendren[1] , Yves Marcel[2] , Olivier Dalverny[1]
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Mostly driven by cost and performance, titanium alloys are among the most widely used metallic materials for aeronautical applications and can make up to 15% of the total weight of an aircraft. Increasing environmental awareness and soaring energy prices have bolstered the need for lighter yet high-performing materials, especially to accommodate the high temperatures of engines and exhausts. The availability of titanium alloys in sheet metal form makes them ideal for forming processes such as Hot Forming (HF) and Superplastic Forming (SPF) [1,2]. With deformation and elongation requirements exceeding the capabilities of cold forming (particularly in high-strength alloys such as TA6V), HF and SPF remain essential for aerospace manufacturing. In this context, numerical simulation methods such as finite element analysis (FEA) are of primary interest in the development and feasibility assessment phase of manufacturing complex geometries by forming. We are interested in developing numerical models of processes and methods from the HF family, to provide efficient models that allow relevant simulation, at a limited numerical cost, capable of evaluating the feasibility of such processes for new parts with complex geometries. More precisely, this study presents a comprehensive finite element analysis to compare the performance of different element formulations (classic shell elements, solid elements, and continuum shell elements) in simulating the hot-forming process at 725 °C of a complex Ti-6Al-4V aerospace component. The simulation accounts for temperature and strain rate effects on the material properties, incorporating phenomena such as friction and anisotropy. Three different element types are studied and compared: classic shells, solid elements (full and reduced integrated), and continuum shells with reduced integration. The model is validated by comparing the predicted final part geometry, especially the thickness distribution, against the experimental measurements. The model can also predict the spring-back effect on the final geometry. The continuum shell element provides the smoothest representation of thickness variations along critical regions of the final part. The study highlights the importance of selecting the appropriate element type for the accurate simulation of hot-forming processes involving large deformations and complex contact conditions. The ability of continuum shell elements to accurately capture the thickness variations makes them an ideal candidate for such applications.

1. Odenberger, Eva-Lis. Concepts for hot sheet metal forming of titanium alloys. PhD Thesis. Luleå University of Technology, 2009.
2. Chartrel, B. Analyse et optimisation des procédés de formage de pièces en alliage de Titane. PSL Research University, 2016

Exploring the potential of superplastic forming of TI-6AL-4V Tailored machined blanks for lightweight designs

Marco Bucconi [1] , Elangovan Parameswaran [2] , and Diego Gonzalez [3, 4, 5]

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Tailored machined blanks are sheets that feature heterogeneous thicknesses, allowing different areas of the final part to withstand distinct structural loads effectively. Conventional methods of tailoring the thickness of the final part, like chemical machining, are labour intensive processes that requires pre-masking and post cleaning of complex industrial component. The proposed method provides a cost-effective solution to manufacture light-weight components by simplifying the material removal compared to shaping intricate 3D parts. In fact, machining a flat blank is simpler than removing the material from complex 3D geometries. In this study, the feasibility of superplastically formed Ti-6Al-4V tailored machined blanks was analysed. Three industrial relevant design examples were developed for components forming with initial dissimilar thickness distributions. The results were examined through Finite Element (FE) simulation and experimentation. The FE simulations guided the design of these blanks. Two examples aimed to address the excessive thinning issue typically encountered with standard homogeneous thickness approaches, where specific regions in the part undergo maximum deformation. The blank designs preserved higher thicknesses in regions where maximum deformation was expected. The third example explored forming a structured pattern thickness distribution, incorporating thicker stiffeners covering the sheet in two perpendicular directions. Although the approaches differed, the ultimate goal of all three designs was to reduce the total weight of the part. The tailored blanks were manufactured via CNC machining from a 2.6 mm thick Ti-6Al-4V sheet, introducing variable thickness profiles. Subsequently, the blanks were superplastically formed in an SPF press (Figure 1). The successful forming of the parts demonstrated the feasibility of the tailored thickness blank approach that can ultimately enable the reduction in component weight. Also, this approach can help the industry to move away from chemical milling for the purpose of light-weighting and removing of excess material from post formed component. Importantly, the experimental trials showed good correlation with the FE simulations, emphasizing the crucial role of the FE tool in designing such components.

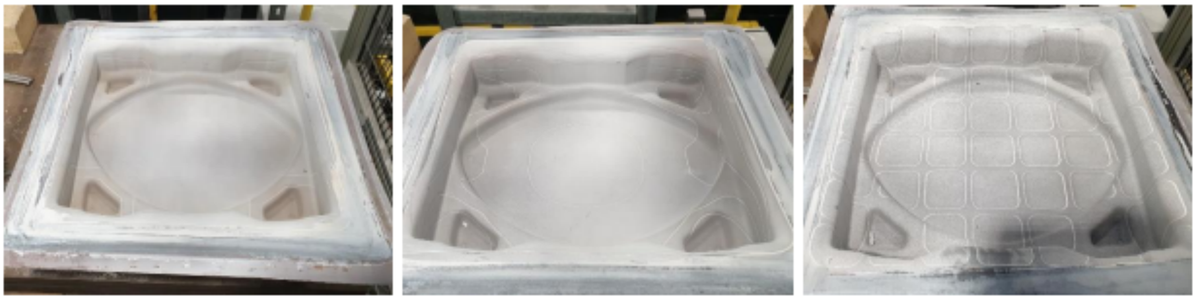

Figure 1 - Three tailored blanks that were designed and formed at the Advanced Forming Research Centre

Keywords: Superplastic forming; Ti-6Al-4V; Tailored blanks; light-weighting; finite element modelling

Manufacturing the future of superplastic and hot forming processes, an overview of some experimental and simulation methods

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Super Plastic Forming (SPF) allows the production of complex-shaped metallic parts with near net shape and limited risk of tearing. However, this process has a low production rate and significant maintenance costs and requires high electrical power. Hot Forming (HF) has a higher production rate and is cheaper and easier to operate but stays limited to specific designs. For ten years, IRT Jules Verne and its industrial partners in the Aircraft and Naval industries have been leading a series of strategic projects on SPF and HF forming processes. It involves innovative development forming methods, high temperature instrumentation, process simulations, mechanical and metallurgical characterization, industrial tests, and transfer of technologies. These developments target time and cost reduction, energy savings, tool life extension, and systematically ensuring the tolerance of forming parts. The presented work is an overview of workflow and results of past, current, and future projects on HF and SPF processes. We will share a look at a hybrid HF/SPF process and its consequences on the microstructure and mechanical properties of shaped Titanium part s. Next, we will address the identification of constitutive laws for numerical simulations of HF process on aluminium parts. Then, we will highlight through simulation the impact of cycle temperature on HF tools damages for Titanium parts obtained in another past project. One of our ongoing projects focuses on the understanding of high-temperature phenomena impacting the lifespan of SPF tools, we will share a state-of-the-art from a surface aging and distortion tools point of view. Finally, we will introduce some main lines of our next project under construction to integrate energy-efficient practices and technologies to reduce the environmental footprint of SPF.

Keywords: SPF, HF, Titanium and Aluminum alloys, Simulation, Thermomechanical Behavior, Coatings, Mold Surface Treatment, Thermal performance

Optimizing Aerospace Hotforming: A Leap forward with Simulation Technology

Darren GODFREY (STATE), Chovav MORDECHAI (AutoForm)

Senior Aerospace Thermal Engineering has been a leader in producing hot-formed parts for the aerospace industry for years.

To remain competitive in this demanding market, we prioritize meeting deadlines, managing material and tryout costs, and providing agile and rapid quotations and process development.

Since 2021, we have invested in hot-forming simulation technology to sustain our edge and uphold our standards of excellence.

We needed to find a fast and reliable solution capable of delivering practical results within hours.

This presentation highlights our achievements in accelerating and securing our quotation and process development timelines, while significantly reducing the number of tryout iterations.

Investigation of the mechanical behavior of TI-6AL-4V alloy in hot forming conditions: Experiment and Modelling

Lucas D'ARCHIVIO[1], Luc PENAZZI[1], Vincent VELAY[1], Vanessa VIDAL[1]

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Superplastic Forming is a forming process using the superplastic properties of titanium alloys allowing them to reach high level of deformations and drawings. These properties require high temperature ($T \geq 900\ °C$) and low strain-rates ($\dot{\varepsilon} \approx 10^{-4}\ s^{-1}$) to be activated [1]. However, these forming conditions induce a high energy consumption and long cycle time. In order to reduce them, titanium alloys could be formed at lower temperatures and higher strain-rates, in which conditions its superplastic properties decrease, but can still reach high level of elongation [2]. Our research focuses on Ti-6Al-4V alloy, one of the most common and widely used titanium alloy in the aerospace industry, which still needs to be characterized and modelled at lower temperature and higher strain-rates. The grain size is one of the main microstructural parameters impacting the behaviour of Ti-6Al-4V. Refining it can lower the temperature at which the material exhibits superplastic properties [3]. Two initial microstructures were studied, with respective alpha grain size of 6 µm (fully equiaxed) and 2 µm (equiaxed but slightly elongated along the rolling direction). The temperature range selected in this study is between 400 °C and 700 °C and for strainrates from $10^{-4}\ s^{-1}$ up to $10^{-2}\ s^{-1}$. Two experimental campaigns were carried out to characterize the isothermal behaviour. The first one is a series of traction-relaxation tests in small deformation using a mechanical extensometer to identify the elastic and viscoplastic parameters. The second one is a series of tensile tests up to rupture using digital image correlation to acquire the plastic hardening and the viscoplastic behaviour in large deformation conditions. Results show that high strains can be obtained for temperature below the superplastic temperature, especially for the fine microstructure. For example, an elongation to rupture of 300 % at 600 °C and $10^{-2}\ s^{-1}$ for the 2 µm microstructure whereas it reaches 170 % in the case of the 6 µm microstructure. An elasto-viscoplastic model has been identified for both microstructures showing good results both in small and large deformations. Its purpose is to be applied for anisothermal conditions and several initial microstructures.

Keywords: Ti-6Al-4V alloy; Mechanical characterization; Behavior modelling; Hot Forming; Digital Image Correlation

ABSTRACTS

Thursday

September 12, 2024

Super Plastic Forming Process in the aeronautic industry

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In the aeronautic industry, Super Plastic Forming is widely used to produce complex and deep components enabling fabrication of elementary parts constitutive of the pylon. The first ambition is to maintain SPF know-how for these specific deep parts typologies.
The ideal situation is to have the best formability of the material during the SPF stage and the highest mechanical properties of the final product under service conditions. However, both advantages are mutually exclusive on a short thermo mechanical manufacturing route. Indeed, the SPF is a technology with a long lead time at very high temperatures which induces high recurring costs, energy consumption and associated maintenance.
In the context of necessary carbon emissions reduction, the challenge is now to improve our current industrial system by deploying relevant qualified industrial processes such as Hot forming or even cold forming & corresponding co design activities in order to deal with the different requirements such as tolerances & mechanical properties without forgetting cost at completion. The objectives are recurring cost, cycle time, Buy to Fly ratio & environmental footprint reduction.
In such a context, the numerical simulation of these processes is also of key importance. Mechanical characterisation, Multi Proofs of Concept are investigated with the goal to gather appropriate input data for the numerical models of the End-to-End manufacturing routes under implementation.
Airbus relies also on diffusion bonding for slim flight control elements. Such elements lead to cost savings in integration and weight optimisation. With diffusion bonding we are able to produce parts with complex surfaces, fully reinforced and relatively small thicknesses.
The use of these elements is also realized in hot zones due to the thermal properties of titanium.

Keywords: SPF, Titanium

Manufacturing routes for hot stamping of aluminium alloys applied to a wing rib.

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This study suggests the application of the hot stamping process, which delivers ready-to-use parts for the production of aircraft components, as an alternative manufacturing method to, for instance, machined parts. The research has been focused on examining the formability of aluminium alloys at high temperatures. The possibility of hot forming different aluminium alloys into intricate component shapes has been explored. An extensive experimental campaign has been conducted to establish the optimal hot stamping process parameters. Moreover, forming trials with various geometries have been executed, and after the corresponding heat treatment, material properties have been restored. Simulations of the hot stamping process have been performed using Pamstamp® 2G software, and these results have been correlated with those obtained in the experimental campaign. As a final stage of the development, a demonstrator corresponding to a wing rib with AA2198 aluminium-lithium alloy has been successfully produced. The characterization carried out on the prototype indicates that specifications are met.

Keywords: Aluminium alloys, Hot stamping, Hot forming, Aeronautics, FE process modelling, manufacturing route

Industry 4.0 for Superplastic and Hot Forming manufacturing processes: effective developments and deployments in the AUROCK factory.

Elise LAMIC, Lenny JACQUINOT, Fabien NAZARET Aurock – Albi – France

Reach good industrial performances with superplastic forming process requests a fine mastering and optimization of process and press environment parameters. These parameters have a strong influence on the part quality, the cycle time, the forming tools costs, the press maintenance charges and the energy consumption. Thanks to its longtime experience in Finite Elements (FE) models for digital forming processes and its good knowledge of forming press architecture and control, Aurock chooses to extend digital technology into its production workshop for factory's upgrade to smart manufacturing standards. To reach this objective, Aurock develops and started to deploy in its workshop its own Industry 4.0 tool dedicated to HF/SPF parts production. This tool enables to optimize the most influent process and press environment parameters to reach a high level of productivity while contributing to a strong team involvement through skills development and pleasant working environment. This Aurock's digital tool includes:

- a live Dashboard available on big screens at different workshop corners and on the company network for production supervision and live forming press monitoring,
- a Data Mining application offered to visualize and to analyse for optimization all the collected data from previous forming campaigns,
- a Digital twin of the presses giving the live thermal behaviour and enabling to optimize the energy consumption and avoid quality problems
- a Predictive maintenance application enabling the supervision and data analysis of a dedicated sensors network to maximize the press availability rate.

This 4.0 transverse tool combined with already existing FE process modelling empowers Aurock to succeed in numerous new complex parts productions with mastering of industrialization, quality, maintenance and production costs.

Steps and Key Choices for Designing and Building Efficient HF & SPF Titanium Forming Tools

Saint-Gobain SEVA – Florian BERNARD / David POYEN

Titanium superplastic forming is a sensitive process that requires specialized tooling. From customer specifications to the final forming of Titanium parts, each step in designing and building efficient HF & SPF Titanium forming tools demands a rigorous approach and meticulous follow-up. Technical decisions, based on extensive experience, are crucial to enhancing the efficiency and longevity of these tools. This presentation will provide a general overview of the main parameters to be carefully considered throughout the course of such projects, detailing the following phases: customer specifications, design & engineering, methods & industrialization (for both foundry and machining phases), casting (including the choice of tooling alloy grade), realization (machining, polishing, assembly), final inspection, and customer acceptance.

Titanium Forming Tools – Press Platens

Peter White - CRONITE

Presentation of the Cronite group and its global presence. Manufacturer of HF/SPF tools recognised in various field.
Supplier of platens.
Simulation for design.

Green Manufacturing: Hybrid Superplastic forming of Titanium Components

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Superplastic forming (SPF) has been an attractive process in the aerospace industries, especially for forming of excellent precision, large and complex-shaped components. However, the SPF process is normally conducted at a low forming rate (10^{-3} s^{-1} or slower) and very high temperature (typically 900°C or higher for titanium alloys), which has hindered its wider applications due to the low production rate, high energy consumption, expensive tooling materials, high manufacturing cost, etc. A hybrid forming approach has been exploited the usage of superplastic forming for faster production, by designing a process that combines hot drawing and gas blowing in one operation, to establish an energy-efficient and environment-friendly technology. Reduced temperature and reduced process time can minimise the alpha case formation in SPF part which can be potentially removed with less hazardous chemicals or alternative methods.

In the first stage of the process, the single-sheet material is deformed into the cavity die by mechanically drawing the material with the upper tool acting as a punch. In the second stage, an argon gas is introduced to superplastically form the local geometrical features of the component. Enhanced material formability and improved forming rate can be achieved by adopting the hot drawing operation before SPF. The SPF cycle time is reduced significantly from 73 min to 22.5 min, with an estimated manufacturing cost saving of 25% for an aircraft representative component. The final thickness distribution of the component can be more homogenous than in conventional SPF processes, as a large amount of material is drawn into the forming area by the punch during hot drawing. Furthermore, as a green manufacturing process, it is expected to reduce the forming temperature (e.g. for Ti64 from 900°C to 800°C), which is more compatible with existing manufacturing processes, with faster forming rate, less energy consumption and process cost.

Keywords: Superplastic forming, Hot drawing, Gas blow forming, Finite element simulation, Titanium

Numerical study of the reshaping process of End-of-Life components by gas forming at elevated temperatures

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The paradigm of reuse applied to End-of-Life (EoL) components is gaining momentum because of its inherent ability to reduce waste and, more generally, to reduce the environmental impact of manufacturing processes. In sheet metal forming processes, one of the most significant impacts is due to the production of the wrought alloy (the blank), which is the result of a long and energy-intensive process, especially when the entire chain from the ore extraction to the rolling mill is considered. At the same time, recycling metals is undoubtedly a feasible way to reduce the environmental impact, but it usually involves relatively high energy requirements. A viable alternative is to reuse EoL components by reshaping them for a similar or a completely different purpose. In this work, a numerical study of the reshaping process of an aluminium alloy component is presented: a deep drawn component, representing the EoL part, is reshaped by gas forming at elevated temperatures to give the blank a new shape. A numerical finite element model was built reproducing both the primary process (the deep drawing) and the reshaping process by gas forming. The numerical results allowed to verify the potential of the approach and to understand critical aspects of the process chain. Particular attention was paid to the effect of process parameters on the "feature residual marks" of the primary forming operation on the final component.

Keywords: Reshaping, Gas Forming, Finite Element, Environmental impact.

ABSTRACTS

Friday
September 13, 2024

Industrial development of SPF-production process for high quantities. Overview since the 1980-ties

Sabine Wagner, Werner Beck, both FormTech GmbH, Germany

The material phenomenon of metals´ superplasticity is known since ~100 years, but industrial production only started in the 1960th. Scientists were proud to obtain laboratory results those certain materials, e.g. ZnAl22, can show extensive strain of several hundred up to more than 2000 percent in uniaxial testing. Within a narrow range of temperature and strain superplastic properties were observed. Scientific interest focused on explanation of the phenomenon. Materials with a very limited industrial interest were examined. There is still an ongoing scientific discussion how to explain the superplastic mechanism in materials´ microstructure.
Industrial interest rose when it got obvious that other fine grain materials like Ti6-4 are very likely to exhibit superplastic properties and at the same time some programs badly needed parts made from alpha/beta alloys like Ti6-4 for structural applications due to service temperature and loads.
Project interest grew sharply for sheet metal parts with 3D-shapes and for heavy sections from hi-strength materials with military projects like “F15” and “B1” and as well with Gallo-Anglo supersonic project “Concorde”, but on a quantity-wise small scale.
Real industrial set-up of SPF process chains for titanium alloy Ti6Al4V got possible with the slowly but steadily increasing production rate in civil aircraft production in Europe. In the ~mid 1980´/early 1990-ties SPF-parts in wide-bodies A300/310 and single-aisle A320, e.g. “end-cap” and in space applications for launchers and satellites, mainly with tankage components like “hemispheres etc.” occurred.
SPF of aluminum alloys in numerous quantities started with the increasing interest of automotive industry in lightweight bodies and complex shapes in combination with “low” (relatively in automotive scale) production rate and gave a chance to suppliers since ~2000.
This paper accumulates key elements of successful set-up of SPF production flow of Ti6-4 parts since the “pioneering” times ~1979 until nowadays regarding the relevant post-SPF material properties and considerable process optimization for important cost savings.

Benefit of isothermal hot-forming with double-action hot press

Sabine Wagner, Werner Beck, both FormTech GmbH, Germany

Sheet metal forming of titanium alloys and of Commercially pure Titanium (CpTi) has its drawbacks. Cold forming properties mainly show two limiting factors: High forming stress and low forming strain, especially with multi axis forming paths. CpTi shows large anisotropy and comparable low strain, Ti6-4 and other Ti-alloys have useless strain. Additionally, the parts show extensive spring back and must be calibrated under temperature after forming. Alternatively, parts from Ti6-4 can be formed with SPF. CpTi doesn´t show SPF properties and must be formed at room temperature with conventional techniques in several steps with intermediate heat treatment and following hot calibration and solution heat treatment.
Higher forming temperature reduces the forming stresses considerably both for CpTi and Ti-alloys. 3-D hot-forming is possible if a drawing process with suppression of folds from material compression during material flow can be applied. The spring back can totally be eliminated with suitable temperature and exposition time. Process parameters for temperature and time for a suitable hot-forming process and the reduction of residual stress have been investigated. The existing hot press has been fitted with a new platen to achieve double action. It incorporates an integrated heated-platen and a fully controlled blank holder. Based on this isothermal Hot Deep Drawing (HDD) machine a novel hot forming process has been established which can replace both the both SPF process and as well conventional cold forming and associated heat treatment. Complex 3D-parts can be formed and calibrated in one shot. From the design point of view parts with complex shape and even with rectangular walls can be produced. Handling and/or distortion problems like with SPF are absent. The resulting oxidized surface layer is thin and need not to be chem-milled. Process-set-up time is low.
Commercial benefit is achieved from various factors. Very short press cycle times can be obtained.
In total the hot deep drawing process results in considerable part cost reduction.

GAS OSCILLATION TECHNOLOGY FOR SUPERPLASTIC FORMING OF TITANIUM AND ALUMINIUM ALLOYS

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AEM Power Systems, in collaboration with Macrodyne Technologies, is pioneering the cutting-edge gas oscillation technology to enable Gas Oscillation Superplastic Forming (GOSPF) process. This revolutionary technology dramatically improves the forming capability of Aluminum and Titanium alloy sheets into complex shapes. At the heart of GO-SPF is a unique, patented gas oscillation forming system designed to generate and channel specific gas oscillations into a superplastic blow forming tool. This innovative gas oscillation technology enhances forming material grain boundary sliding mechanism, enabling material to dynamically undergo partial stress relief during each oscillation cycle during the GO-SPF, thus significantly improving formability. Ongoing research and development efforts reveal that adding an oscillating load to a constant tensile load markedly enhances the formability of Titanium Ti-6Al-4V and Aluminum A5083 alloys. This breakthrough results in significant improvements in material elongation, thickness uniformity, and forming speed improvement up to 500% compared to conventional SPF. These advancements have been validated across various strain rates and will be highlighted in an upcoming presentation. Additionally, the presentation will feature a Finite Element Analysis (FEA) comparison between traditional SPF and the GO-SPF for Titanium Ti-6Al-4V and Aluminium A5083 sheets, focusing on specific component geometries to demonstrate the superior capabilities of GO-SPF. This comparison underscores significant advancements in metal forming technology, positioning GO-SPF as a transformative process for industries reliant on highprecision and complex metal components.

Keywords: GO-SPF Superplastic forming Gas Oscillation Ti-6Al-4V alloy A5083 alloy

Study on the blow forming of 5xxx/7xxx aluminium alloy for automotive applications

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The automotive industry is witnessing a surge in the global demand for aluminum alloys, driven by the imperative to enhance vehicle performance, ensure passenger safety, and meet the ever-growing need for CO2 emission reduction. This escalating demand underscores the importance of developing advanced materials and processes that cater to these multifaceted requirements.

This study focuses on the integration of the blow forming process with the novel 5xxx/7xxx alloy, CrossAlloy.57, as a pioneering solution to address the challenges posed by the automotive industry's evolving landscape. Through a series of carefully conducted industrial trials on real components, our research presents compelling experimental evidence highlighting the exceptional formability and high mechanical strength of CrossAlloy.57.

The findings not only affirm the compatibility of CrossAlloy.57 with blow forming technology but also underscore its outstanding mechanical properties. This alloy emerges as a formidable candidate for structural components within automotive bodies. Moreover, its remarkable mechanical characteristics open avenues for substantial reductions in required thickness, particularly for structural parts contributing significantly to the overarching goal of lightweighting.

In this study, a complex shaped door inner was successfully formed and the effects of subsequent operations at elevated temperature on mechanical performances were investigated. Post-formed material subjected to these heat treatments showed enhanced mechanical strength and potential for further improvement.

In summary, this study sheds light on the promising prospects of CrossAlloy.57 as a game-changing material in the automotive sector. By offering a compelling combination of formability, mechanical strength, and reduced thickness requirements, this alloy not only meets but exceeds the stringent demands of modern automotive design and manufacturing, positioning itself as a key player in the pursuit of sustainable and high-performance vehicles.

Keywords: Aluminum alloys, Gas Forming, Automotive, CrossAlloy.

From specific press design to manufacturing SPF aeronautical parts

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Complex titanium parts for aeronautical applications are possible to manufacture thanks to forming at high temperature. The press can be adapted and specifically dimensioned to combine both HF (Hot Forming) and SPF (Super plastic Forming) saving manufacturing time and production costs. This presentation will show a case study of a titanium SPF part from CAD file to the manufactured part with the description of the different process steps. Buy to fly ratio can be optimized with the process selection and the initial blank design. Multiple parts can be obtained from the same tool. Manufacturing time can be reduced, and consequent energy saving could be obtained. Modeling is used to validate the tool design and to define the key process parameters for both HF and SPF process.

Keywords: Super plastic forming**;** Dual press**;** Numerical modeling**;** Titanium Alloy

Supler Plastic Forming Process for traditional vintage helmet for Austrian firefighters

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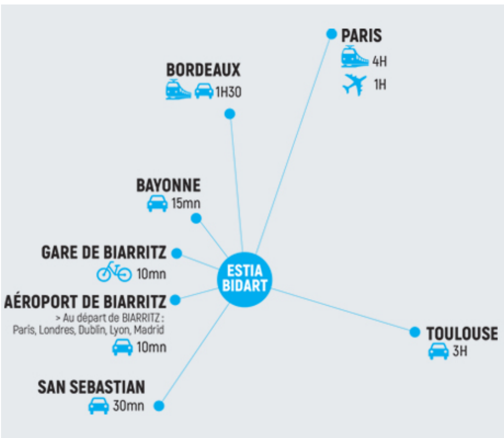
In industrial applications, feasibility studies are only half of success. Often, simulation does not correspond to reality. Female forming the base shape of vintage helmet for Austrian fire fighters was on limit at simulations, but similar part just short time before realization did not work with female forming. Once you have the order, there is no way back. Changing to male forming simulation showed better thickness distribution and no problems. After first try-outs, reality gave a different result with lot of wrinkles or cracks. Presentation describes heuristic approach to finally get a successful part at the end with bubble forming.

Keywords: Superplastic Forming, industrial approach.

Basque Country

The conference will take place in the Basque Country, at the ESTIA engineering school located in Bidart, on the Atlantic coast.

The Basque Country is a major industrial territory for the Nouvelle Aquitaine region. It boasts two ports, including the one in Bayonne, which is engaged in a development initiative with significant ambition supported by local authorities. Basque Country is renowned for its expertise in the textile, agri-food, aeronautics, health and medical sectors.



ESTIA which hosts this conference was created in 1985 and is based on a national and international university partnership. Its campus brings together:

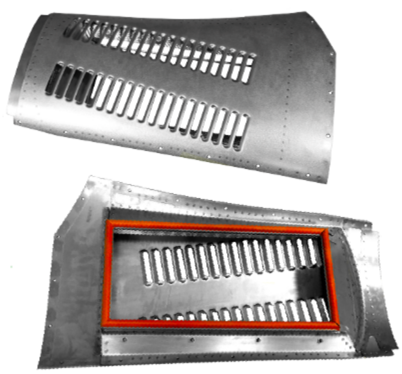
- An engineering program, with specialized diploma
- A research center (professor-researchers and doctoral candidates)
- Technical platforms (including AddimAdour and CompositAdour proposed for industrial visit)
- An incubator hosting a nursery with several companies

LAUAK GROUPE

In the 1930s the first aerospace companies established in the Basque Country. A hub began to develop, and in 1975, LAUAK GROUP was founded, initially under the name ESKULANAK, with the aim of providing sheet metal parts to Dassault Aviation, located in Biarritz.

Today, LAUAK GROUP has 10 international locations, in France, Portugal, Canada, Mexico and India. It is a family-owned company that has grown around strong values (agility, integrity, commitment, and humility) to become a European leader in the field of aerostructures and aeroengines.

Since 2018, the group has had a Hot Forming and Super Plastic Forming workshop equipped with 3 HF and SPF forming presses. Over the past 6 years since its establishment, the HF workshop has demonstrated increased skills and productivity, becoming a benchmark for our main client, AIRBUS, with iconic components such as the Wastewater Service Unit for the A350 and the Heat Exchanger cowling for the A320.

	
Waste Water Service Panel A350	**Heat Exchanger Cover A320**

EUROSPF 2024
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BOOK OF ABSTRACT

15th EUROPEAN CONFERENCE ON
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