AEROSPACE TECHNOLOGY CONGRESS 2016

ANALYSIS OF SUPERPLASTIC FORMING PROCESS APPLIED TO AEROSPACE INDUSTRY: CASE STUDY OF Al 5083 ALLOY

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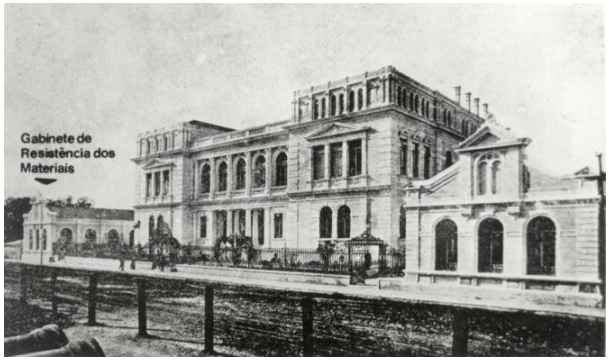
Summary

- Who we are
  - IPT
- Work objectives
- Introduction
- Materials and Methodology
- Results
- Conclusion

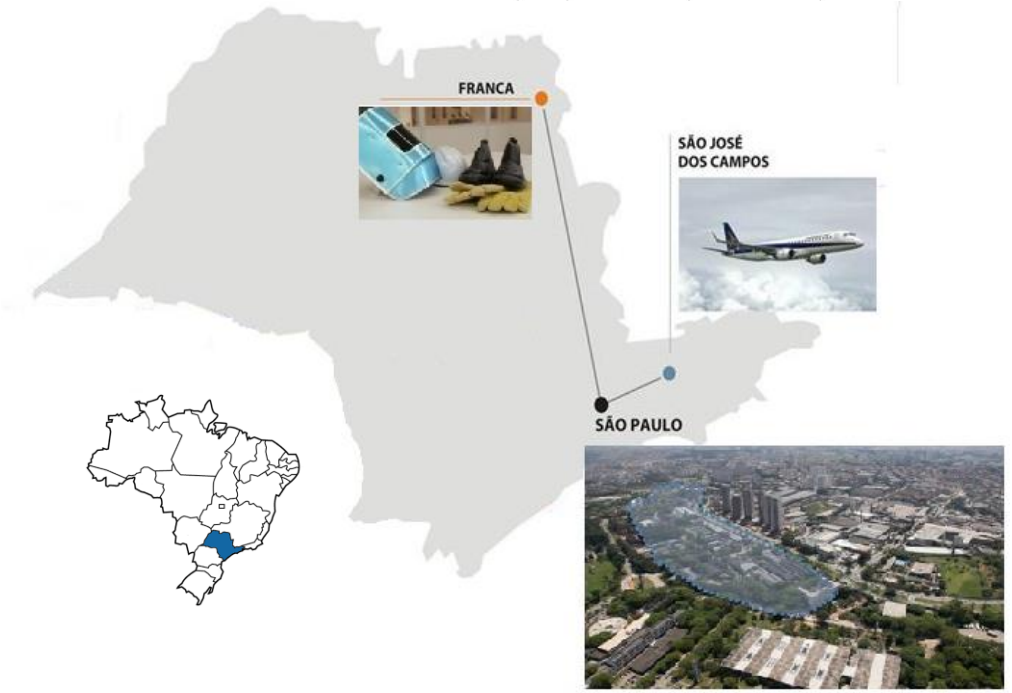
Who we are

- IPT: Institute for Technological Research of State of São Paulo
  - The first R&D institutions in Brazil (1899)
  - More than 900 employers
  - Of total revenue
    - 42% metrology,
    - 31% R&D
    - 27% Technological Services



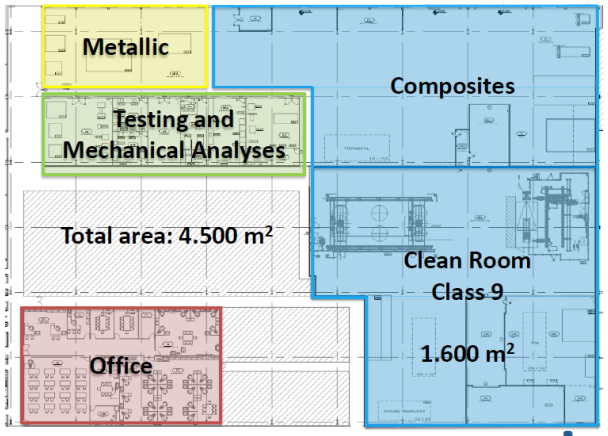
Who we are

- 37 laboratories:
  - Metallurgy
  - Chemistry
  - Electrical
  - Naval
  - Fluid Dynamics
  - Geoenvironmental
  - Bionanomanufacturing



Who we are

- Lightweight Structures Laboratory
  - Composite & Metallic
  - Inaugurated in 2014
  - Industrial capacity machines to give support to companies in theirs development and Research areas
  - Clean Room (Class 9, 1600 m²)



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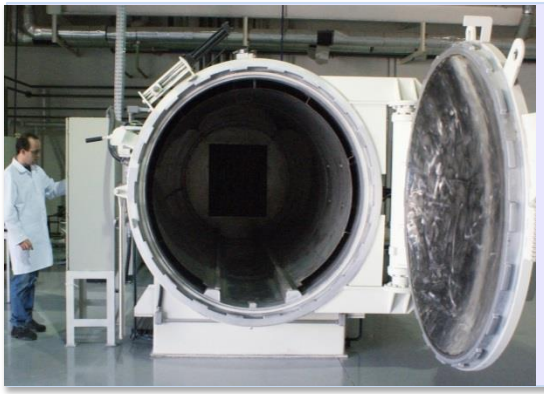
Who we are

- Composite: Laying and Infusion Process

Automated Tape Laying (ATL)

Resin Transfer Moulding (RTM)



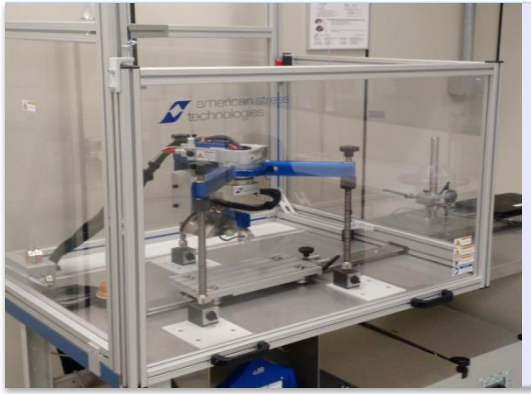
Autoclave

Automated Fiber Placement (AFP)

Who we are

- Destructive and non-destructive test

Automated Ultrasound Inspection



Residual Stress X-ray

Micrography

Mechanical tests

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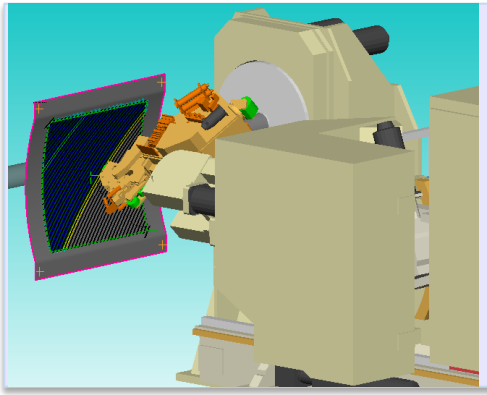
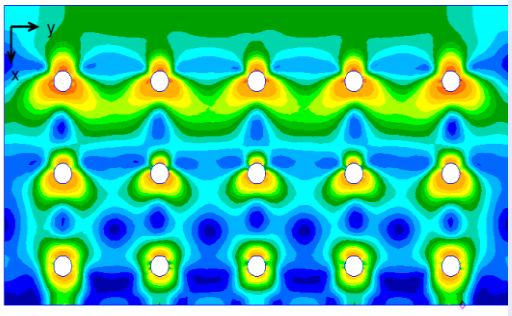
Who we are

- Computational Analysis:



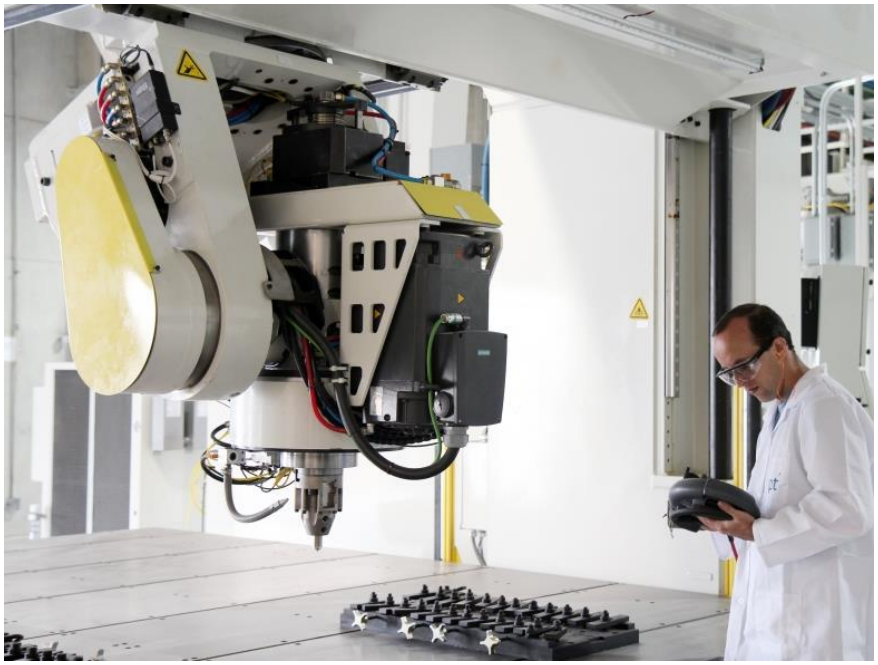
Manufacturing Optimization



Structure Optimization

Who we are

- Metallic Welding Process



- Max. Speed: 3000 rpm
- Area: 2 x 1,5 x 0,8 [m]
- 30 kW
- 5 Axis
- Z axis max. force = 80 kN
- Argon chamber;

Who we are

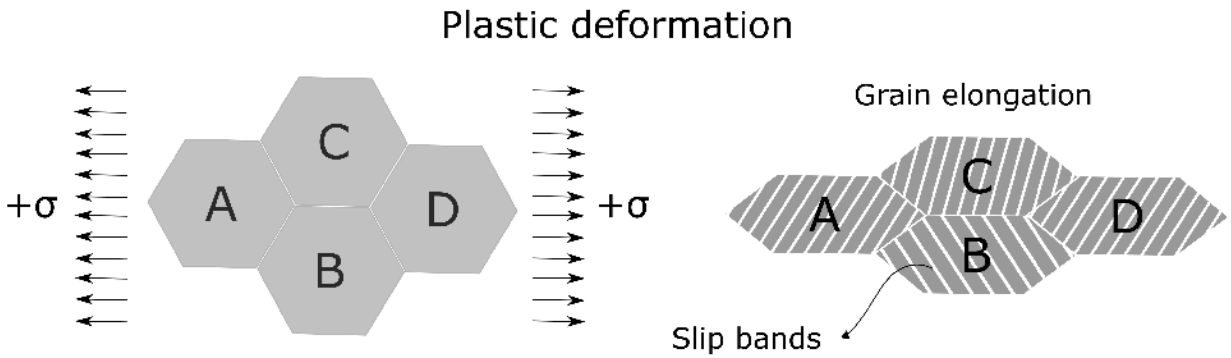
- Automatic Hot Press (SPF/HF/DB)

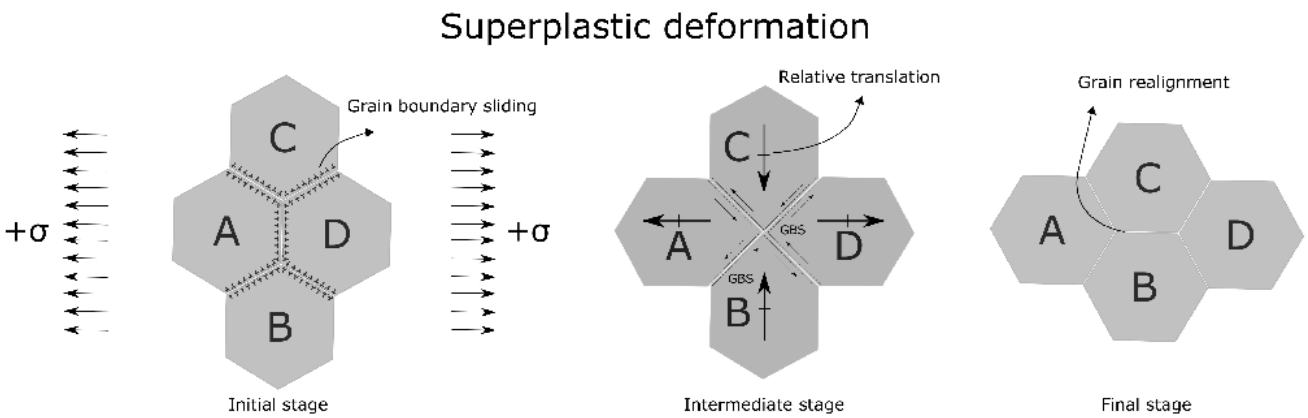
- Max. Temperature: 1000 ºC (100 ºC/h)
- Max gas pressure: 40 bar
- Max. clamp: 150 Ton
- 762 x 863 x 600 (mm)
- 2 gas channels
- Purge and vacuum system

Work objectives

- Analyses the Superplastic forming process;
- Show the capability of the process;
- Specimen manufacturing in Aluminum alloys ;
- Tests and analysis;

Introduction





***Rolls-Royce* engine part SPF Ti64.**

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Introduction

- Advantages
  - Forming complex geometries
  - Great surface finish
  - No “Springback”
  - Slight or no residual stress
  - Savings in costs and weight

Introduction

- Relevant questions
  - High temperature
  - Low productivity compared with conventional process (ex. hot forming)
  - Limited number of SPF alloys

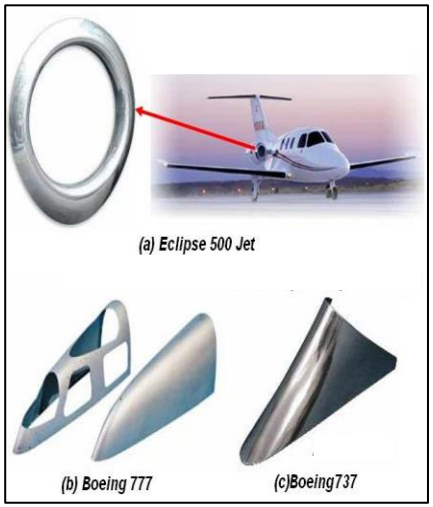
Introduction

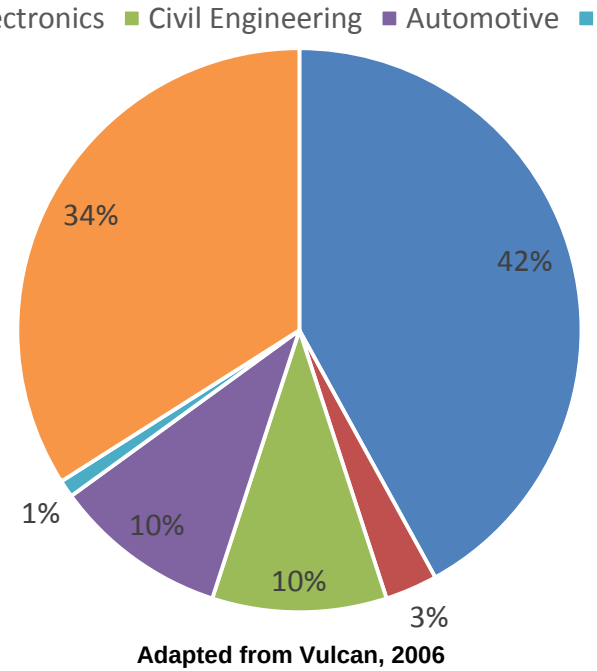
- Commercially available superplastic alloys

	Alloy	Composition, wt%	SPF temperature	Strain rate	Elongation
Titanium	Ti-6/4	Ti-6Al-4V	880-920ºC	$5 \times 10^{-4} s^{-1}$	~1000%
	SP700	Ti-4Al-3V-2Fe-2Mo	750-800ºC	$3 \times 10^{-4} s^{-1}$	$\geq 300\%$
	Ti-6242	Ti-6Al-2Sn-4Zr-2Mo	850-940ºC	$5 \times 10^{-4} s^{-1}$	$> 500\%$
	IMI550	Ti-4Al-4Mo-2Sn-0.5Si	880-900ºC	$5 \times 10^{-4} s^{-1}$	$> 500\%$
	IMI834	Ti-5.8Al-4Sn-3.5Zr-0.7Nb-0.5Mo-0.3Si-0.05C	950-990ºC	$\sim 10^{-4} s^{-1}$	~300%
Aluminum	2004	Al-6Cu-0.4Zr	460ºC	$\sim 10^{-3} s^{-1}$	$800 - 1200\%$
	5083	Al-4.5Mg-0.7Mn-0.1Zr	500-520ºC	$10^{-3} s^{-1}$	~300%
	7475	Al-5.7Zn-2.3Mg-1.5Cu-0.2Cr	515ºC	$2 \times 10^{-4} s^{-1}$	800%
	8090	Al-2.4Li-1.2Cu-0.7Mg-0.1Zr	530ºC	$5 \times 10^{-4} s^{-1}$	1000%
	2090	Al-2.5Cu-2.3Li-0.12Zr	530ºC	$\sim 10^{-3} s^{-1}$	~500%

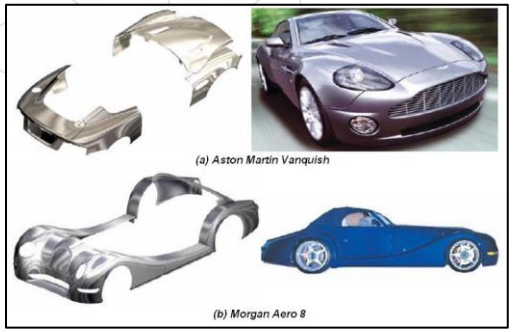
Introduction

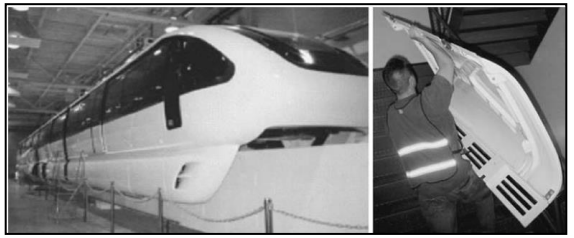
- Applications

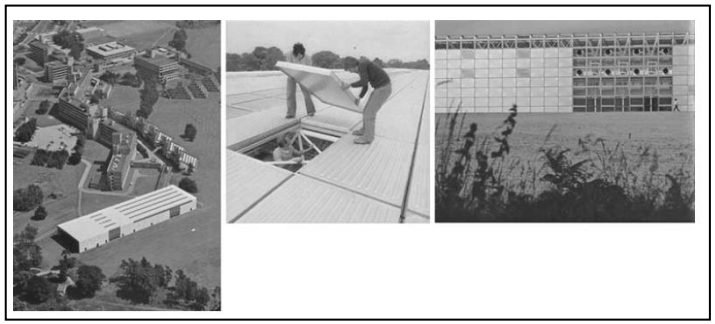




Adapted from Vulcan, 2006







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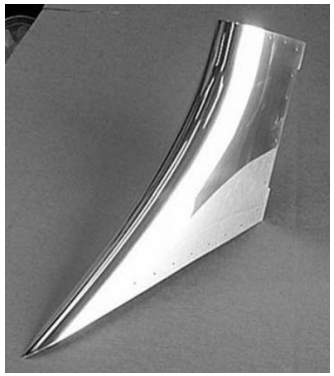
Introduction

- Al 5083 applications

Superplastically components formed in SP5083, 1. wing tip light housings 2. strakelets, 3. engine intake lipskins and 4. winglet (SUPERFORM ®)

Boeing 777 Wing Tip Light Housing



Boeing 737 Outboard Leading Edge Strakelet

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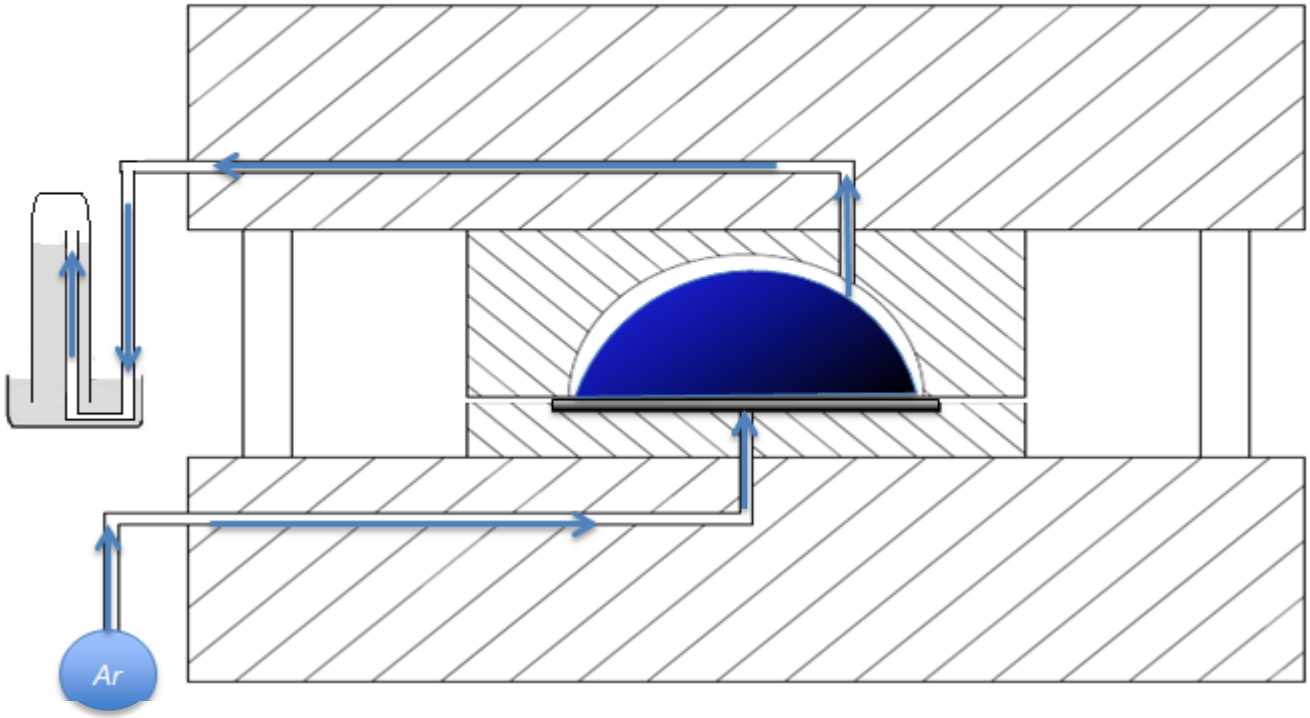
Materials and Methodology

500 ºC



Heating → Purge → Blank → Homogenization → Forming

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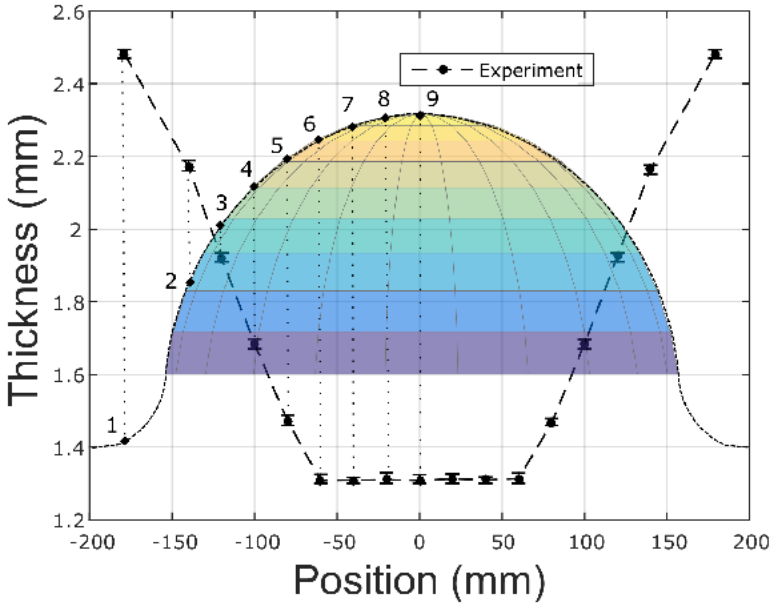
Materials and Methodology

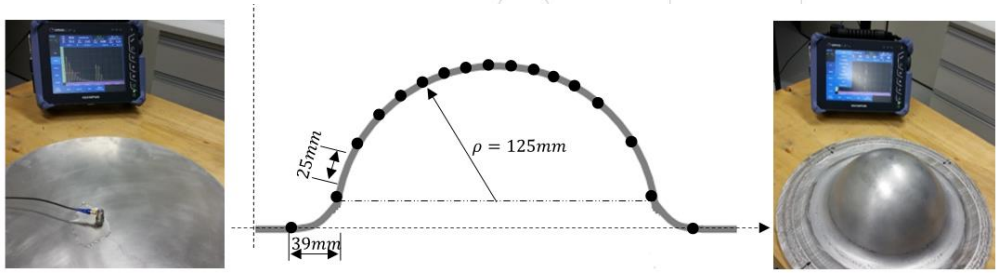
- Forming

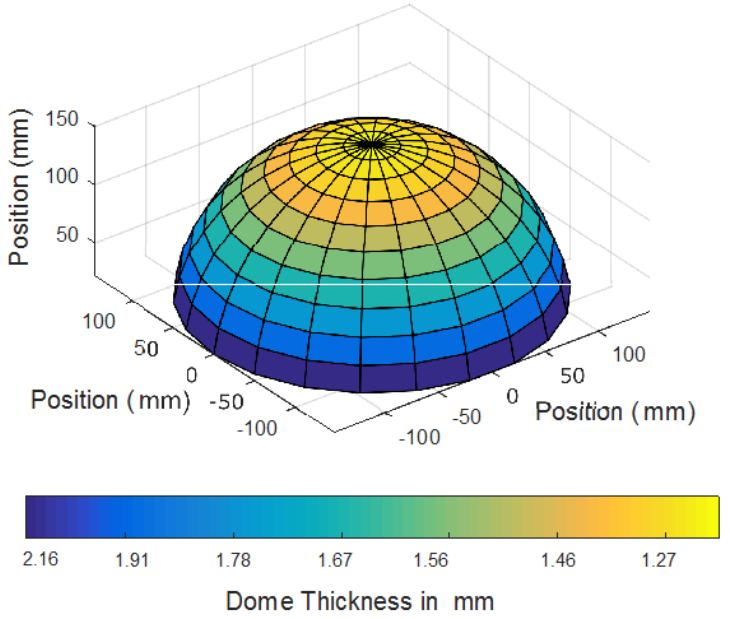
- Gas: Argon
- Total time: ≈ 51min
- Release agent: boron nitride
- Temp.: 500 ºC
- Conventional Al 5083

Results

- Ultrasound Analysis

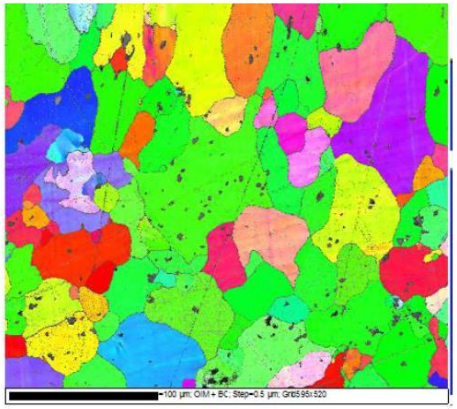


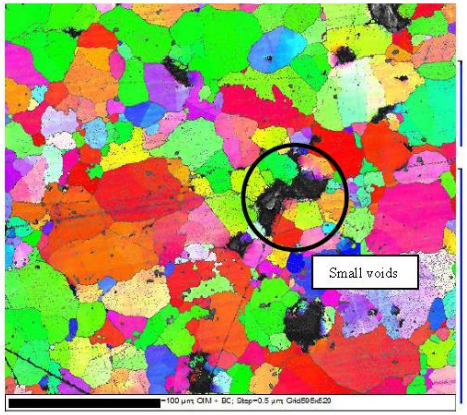




Results

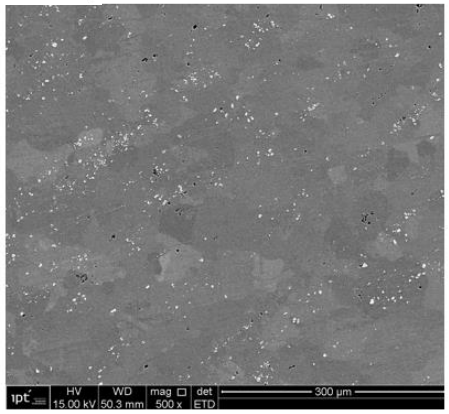
- Cavitation

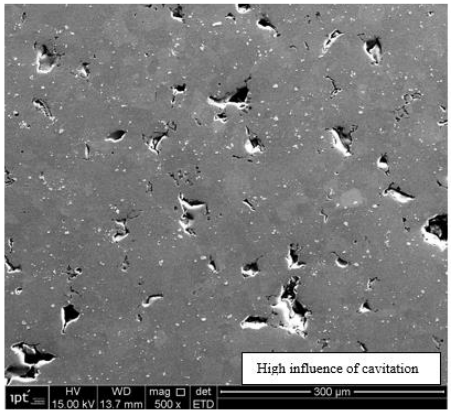




Electron backscatter diffraction (EBSD)
Before and after forming

scanning electron microscope (SEM)
Before and after forming





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Conclusions

- Dome did not reach the desired geometry;
- Cavitation problem;
- Ultrasound showed uniform thickness around the dome;

Conclusions

- Next steps:
  - Geometrical inspection;
  - Measure residual stress by X-ray diffraction;
  - Finite element analysis can improved the process;
  - Material characterization

Conclusions

- Next works:
  - Establish own experimental strain rate sensibility curves;
  - Forming new materials;
  - Using counter pressure during forming;
  - Studies in metallic honeycomb manufacturing by DB;
  - Search for new materials for the tooling;
  - FSW + SPF

Thank you!

Obrigado!

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