

## Formability of Titanium Ti-6Al-4V sheets at low temperature

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# Formability of Titanium Ti-6Al-4V sheets at low temperature

- Introduction
- Warm Forming of Titanium 6Al-4V
- Initial lab results
- Production process validation

**CAPABLE OF**

**EXPERTS IN**

**CERTIFIED BY**

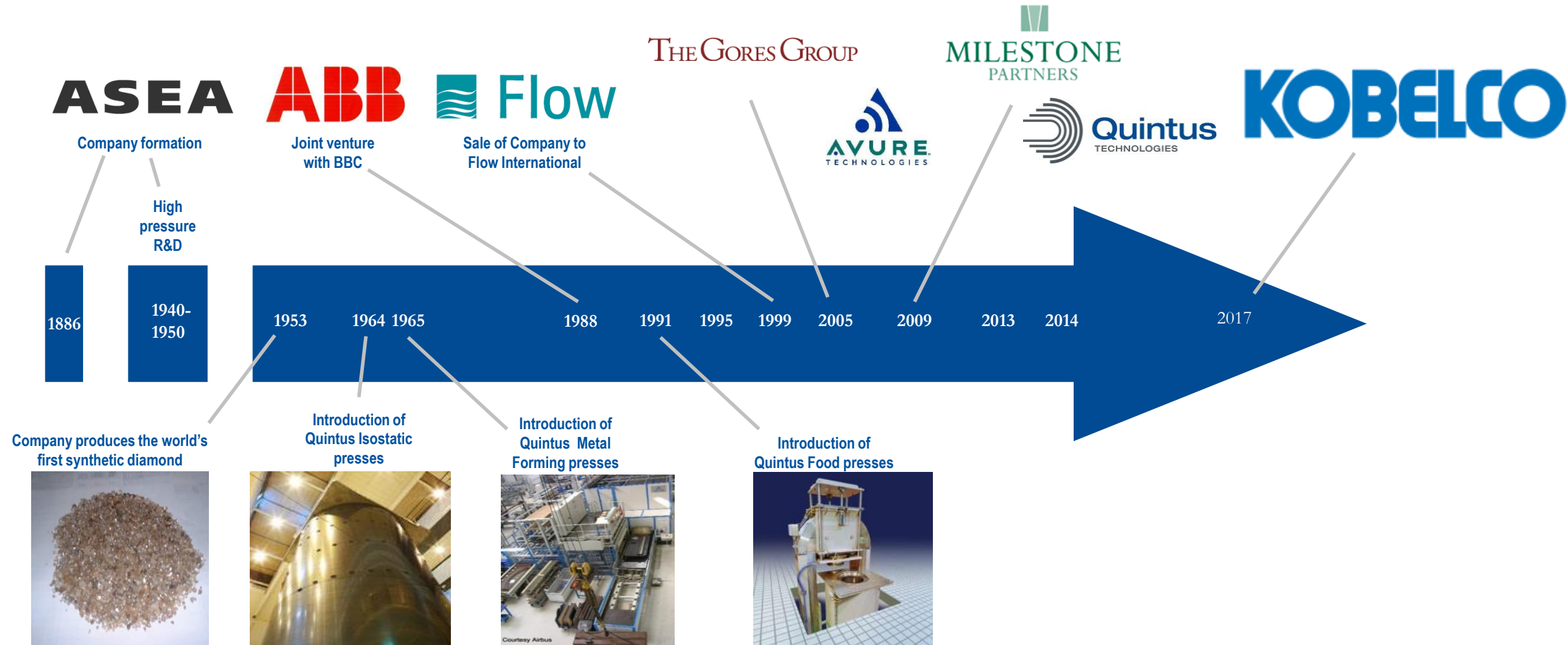
**2000**  
Bar

**150K**  
Ton

**HIGH PRESSURE**



# Foundation and history of excellence





## MATERIAL DENSIFICATION

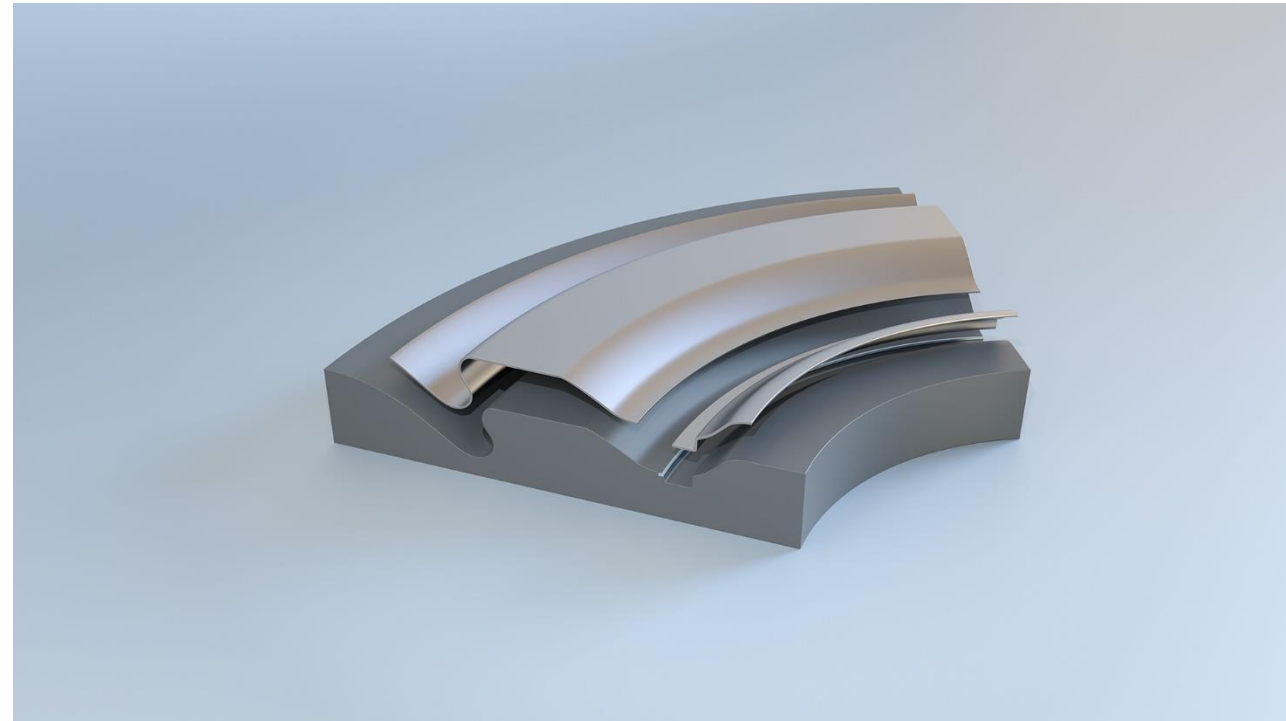


## SHEET METAL FORMING



# The Flexform Sheet Metal Forming Technology

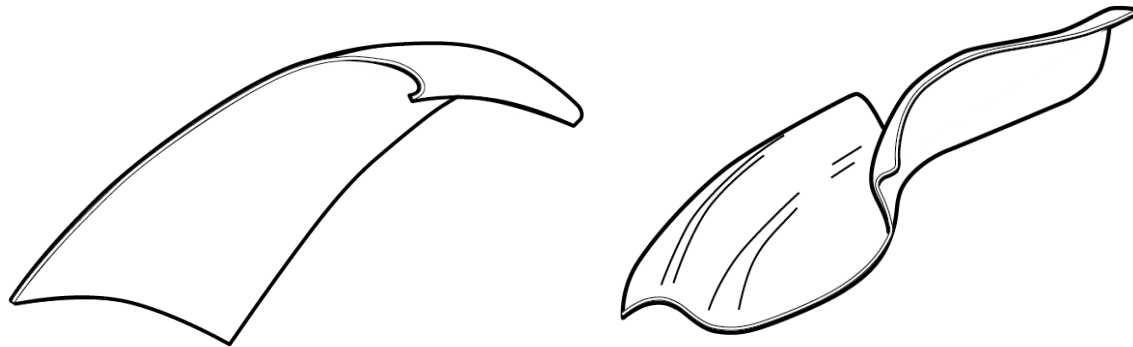
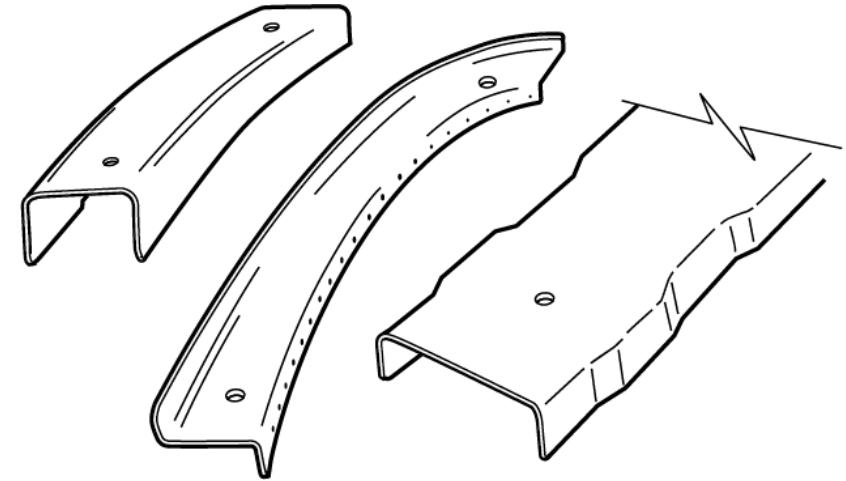
- Historically a cold forming process
- Using one shape defining tool half
- Second tool half being a flexible rubber diaphragm, backed up by hydraulic pressure
- Blank thickness from thin foil to some 15 mm stainless steel may be formed



Click: <https://www.youtube.com/watch?v=m0HtZq9pokY>

# Typical Cold Formed Parts – Airframes

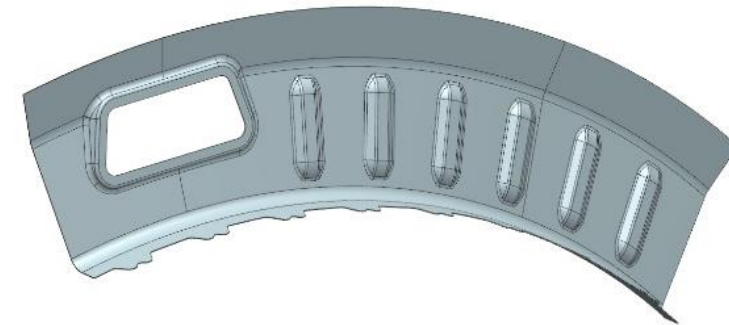
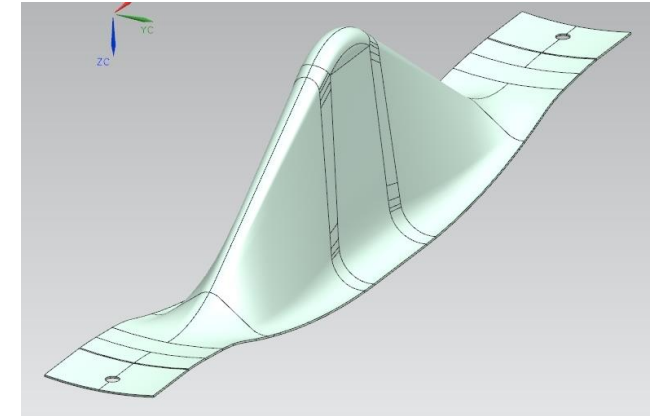
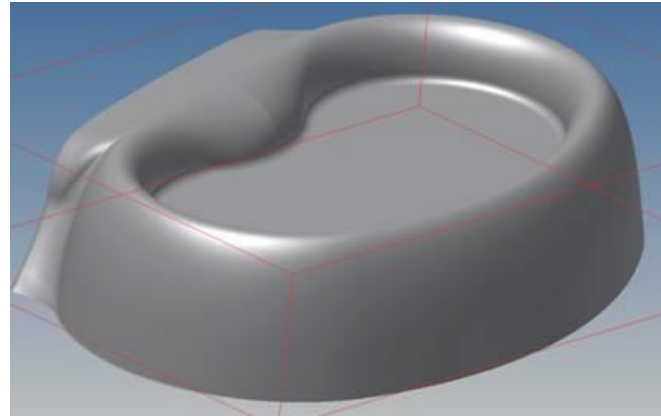
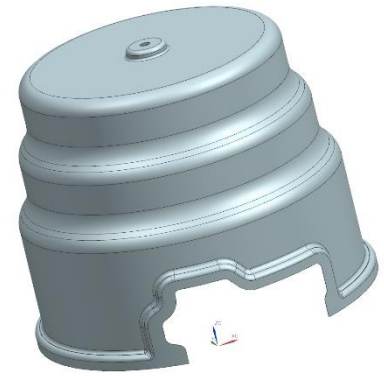
- Shrink and stretch flanges
- Double curved
- Recessed parts





# Typical Flexform Parts – Jet engines

- Deep parts
- Tough alloys, typically Inconel and Titanium
- Severe tolerance and quality demand





# Examples - Customers & Partners



**BOMBARDIER**



DE BEERS



CORNING



DAIMLER



Gulfstream



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# Why?

- Growing need for Ti 6Al-4V due to the composite growth
- Need for a competitive process vs. various hot forming processes
- Perceived hot forming challenges:
  - High energy cost
  - High tooling cost
  - Slow process, low productivity and low capacity
  - Poor process control
  - Labor dependent

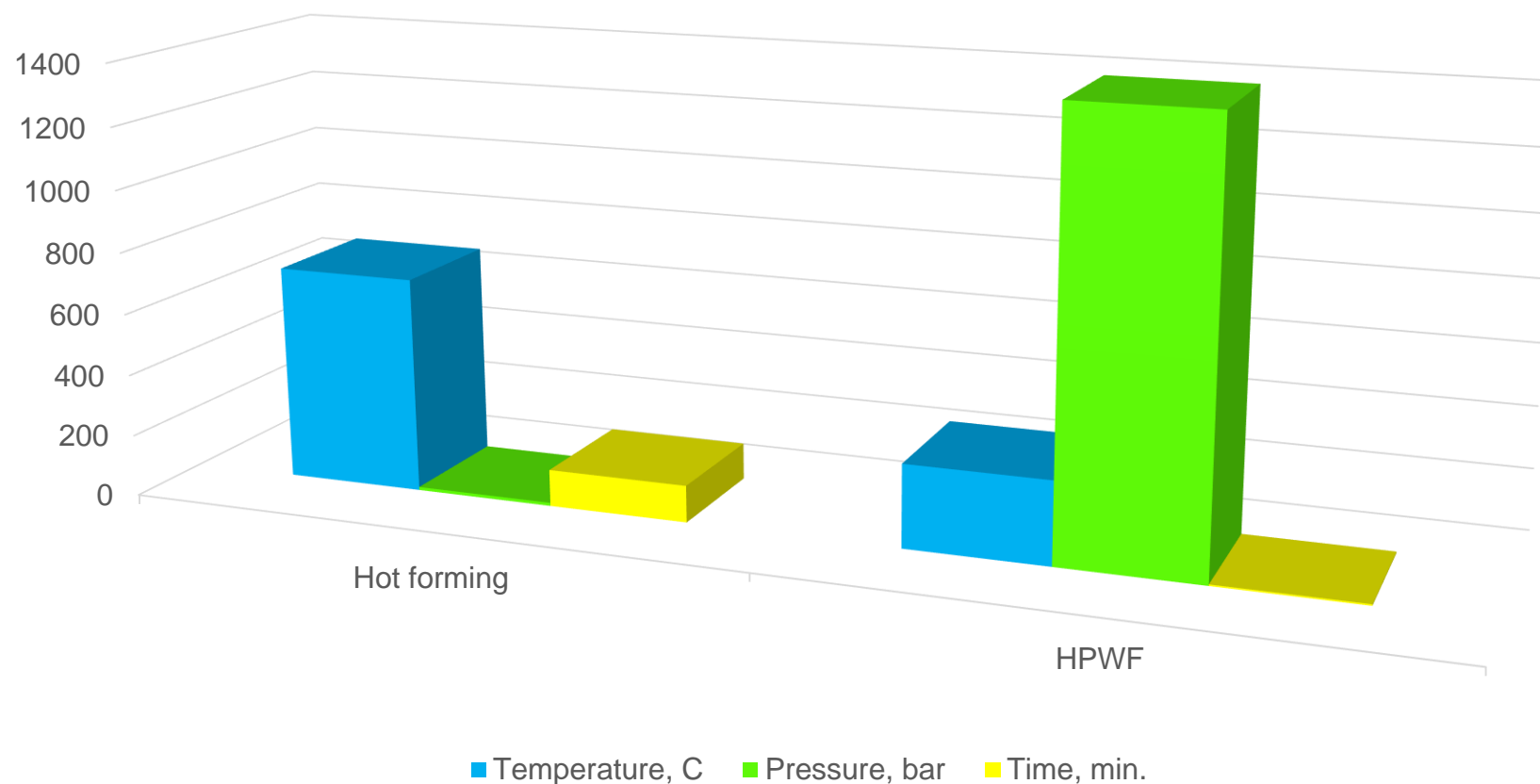
## Current hot forming processes



# Hot vs. Warm Forming

Hot Forming Processes	High Pressure Warm Forming
600-900°C	270°C
<10 bar	1400 bar / 140 MPa
-120 min	<5 min

Pressure, temperature & time



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# High Pressure Warm Forming



2014-04559

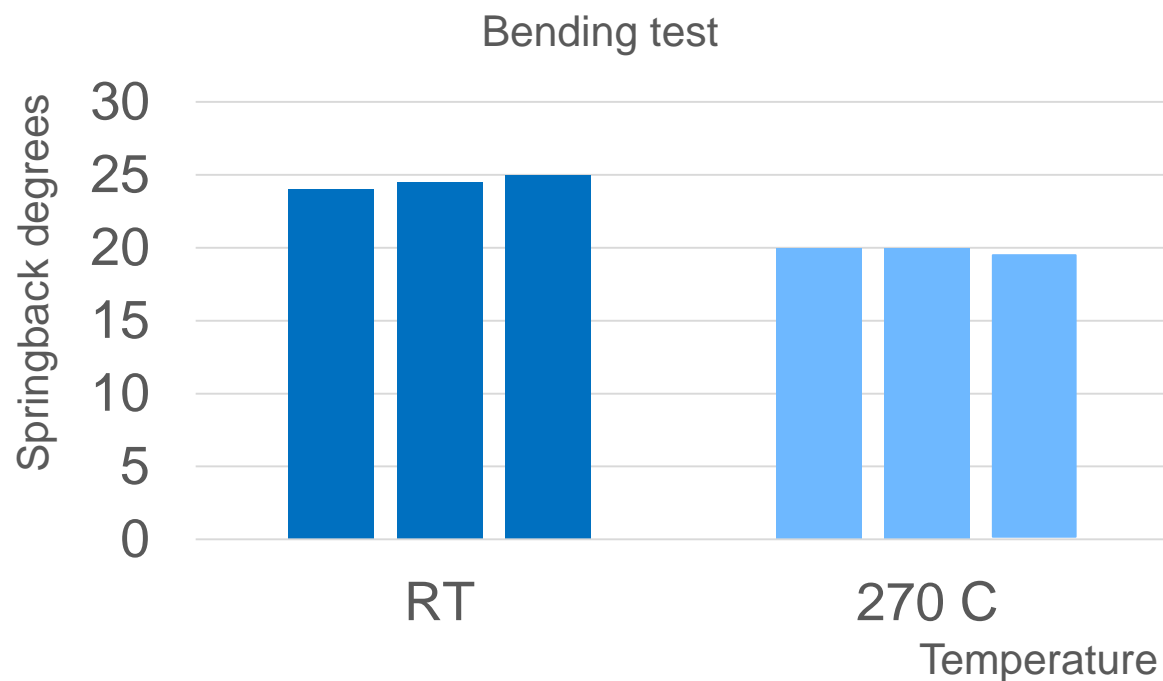
Pre-study funding

Warm forming of Titanium

# Initial lab test conclusions

## *Springback reduction*

- Springback reduced with 20% in bending tests
- Lab cases indicate bigger reduction

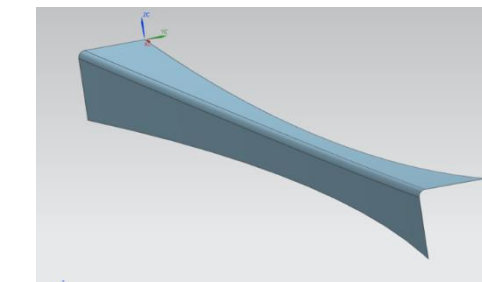
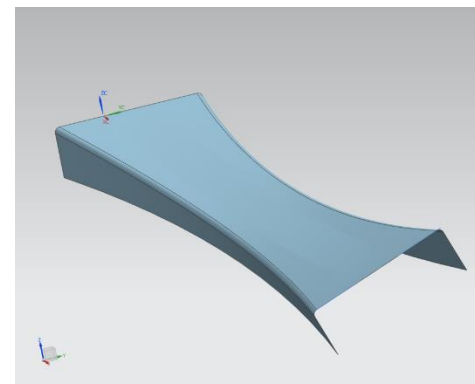
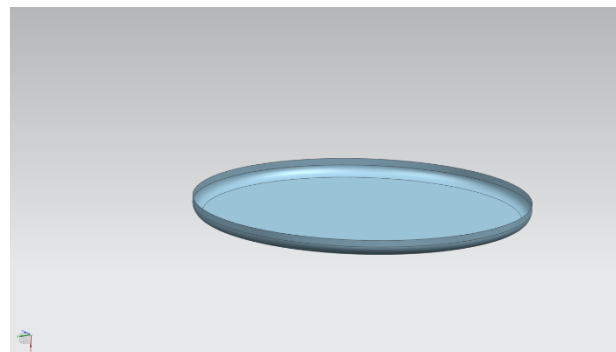
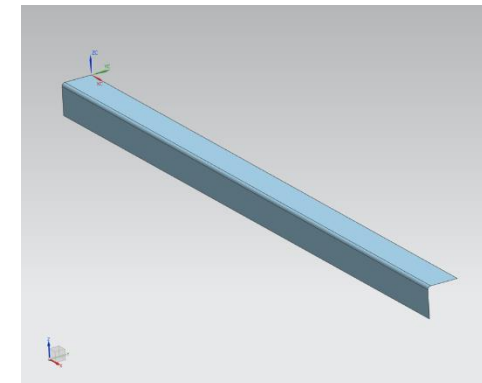
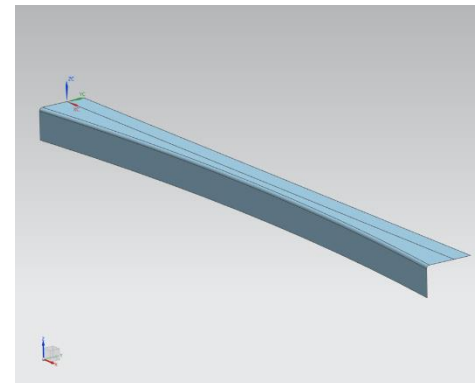
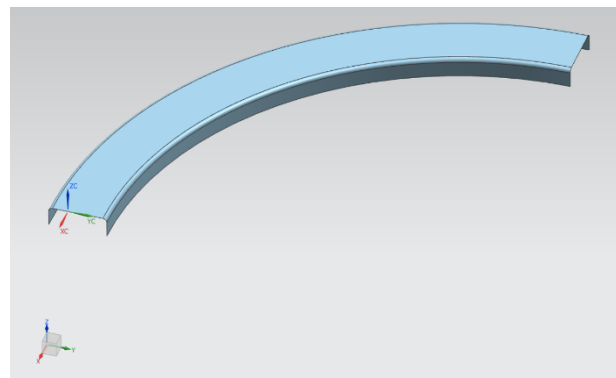


RT = Room temperature



# HPWF - Part forming suitability

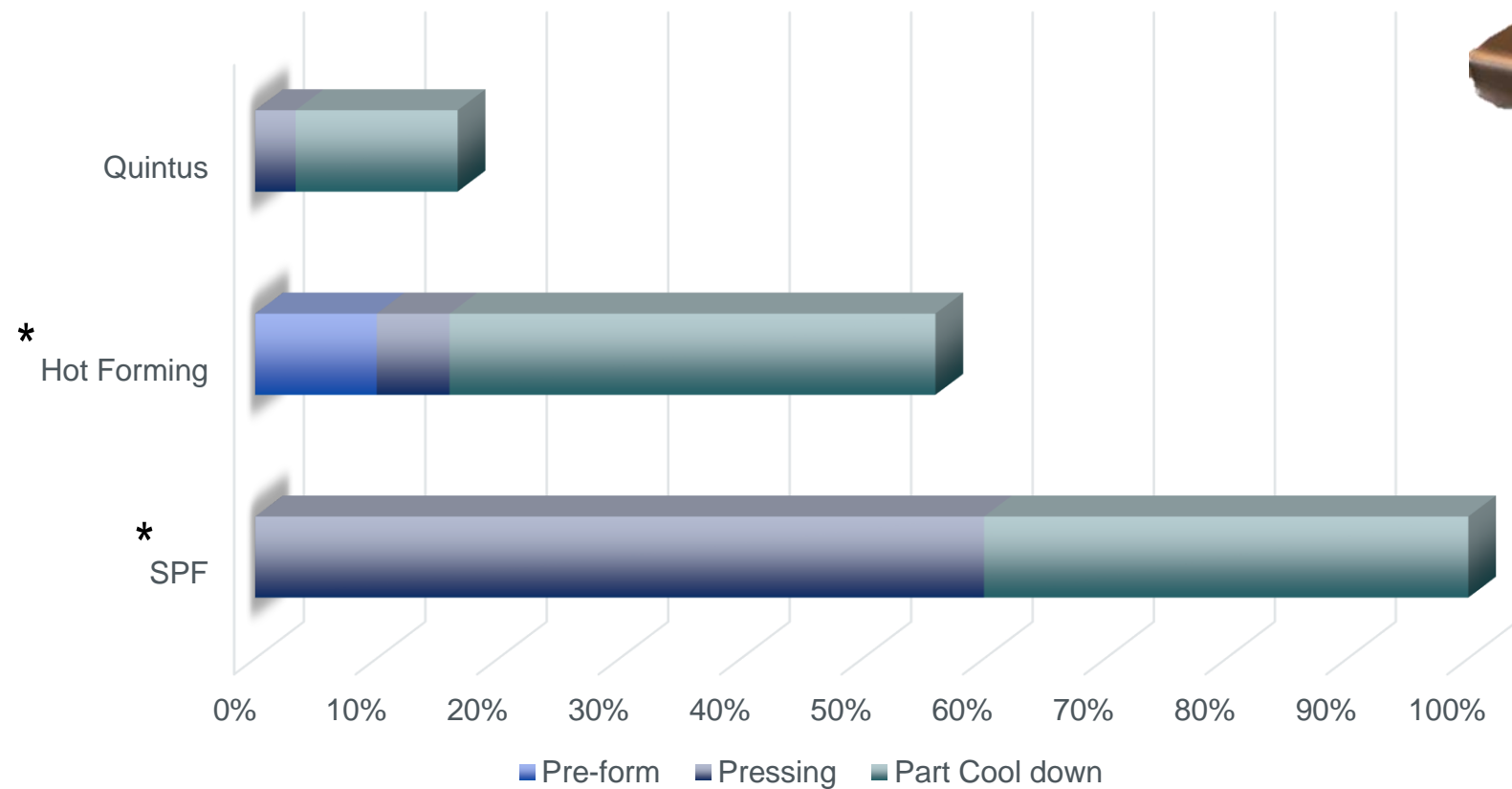
Part configuration  
deemed suitable for  
the HPWF process



# Expected process benefits

# Reduce production cost

Production time/part

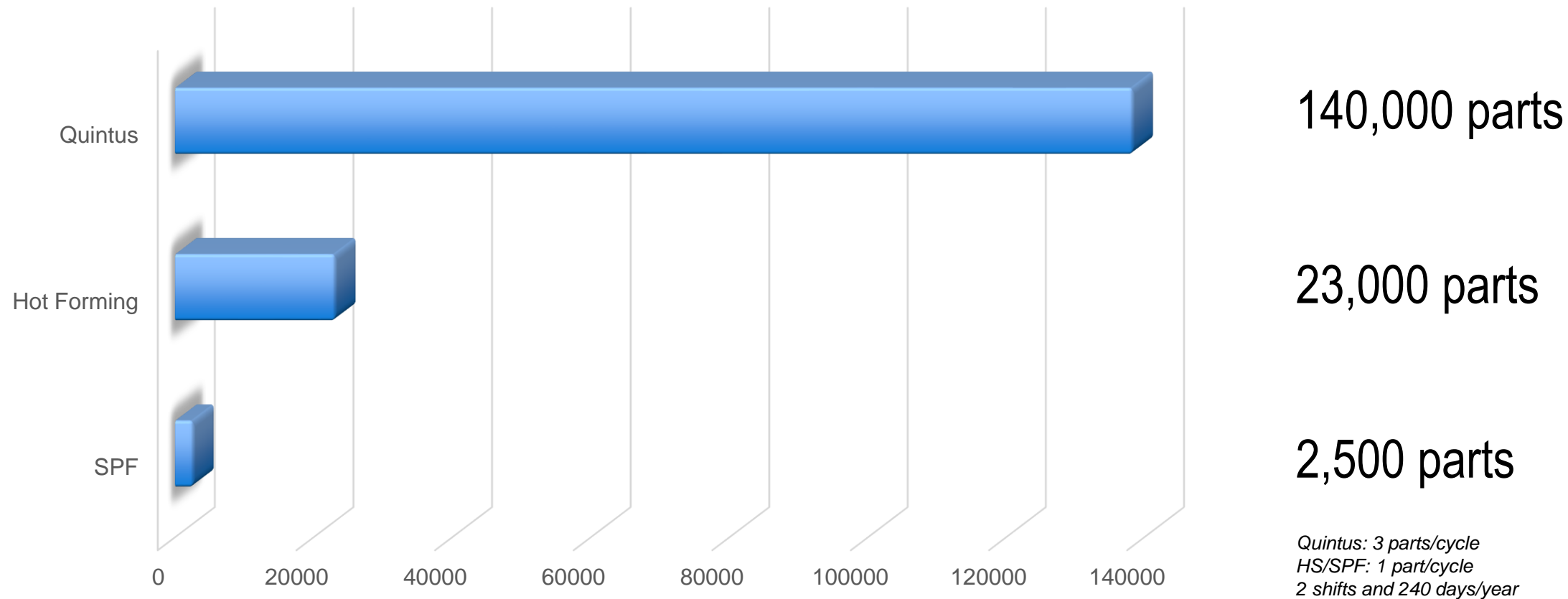


SPF = Super Plastic Forming

\* Data from: Advanced Forming Research Centre (AFRC), University of Strathclyde

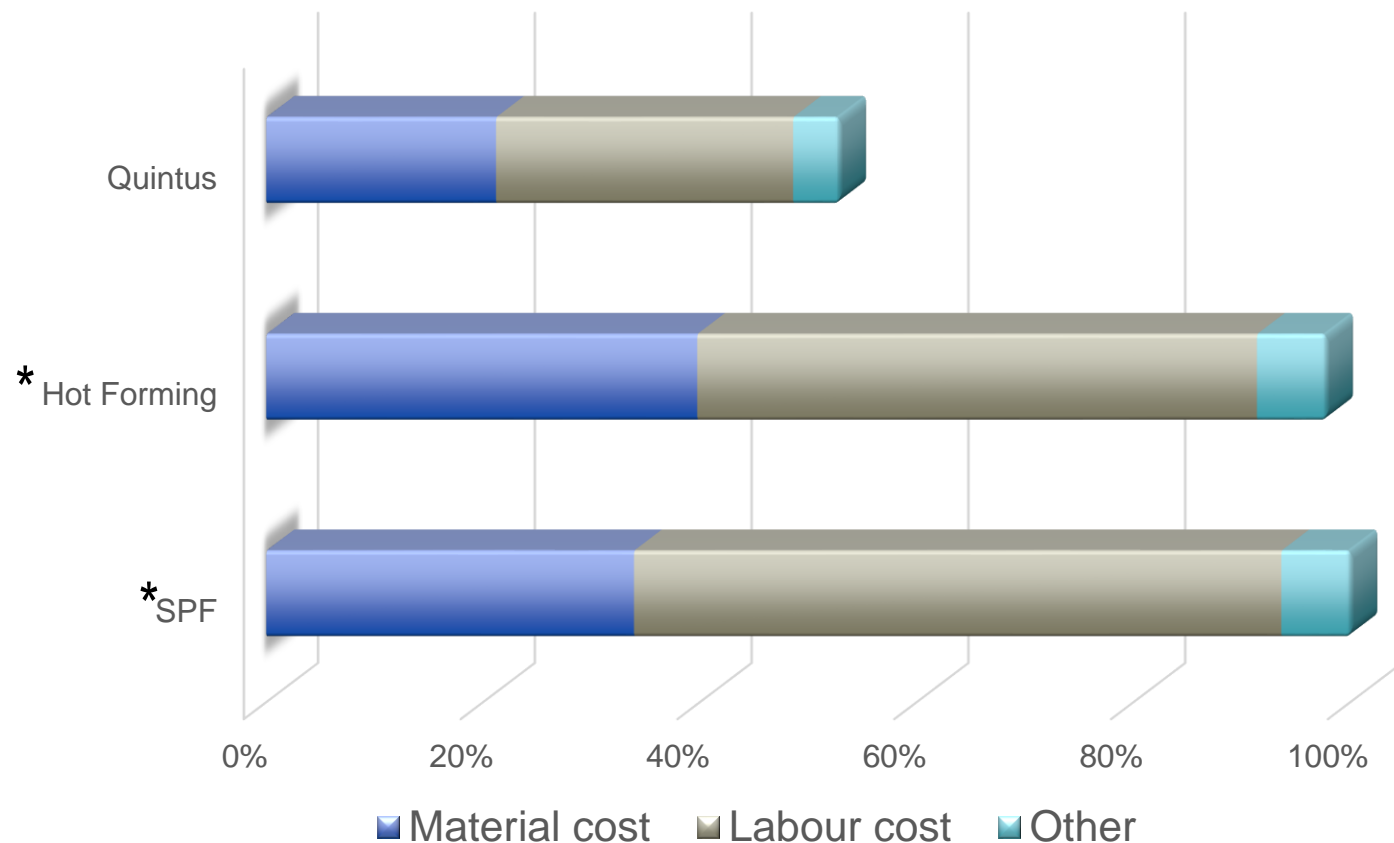
# Increase productivity

Production output, parts/year



# Reduce production cost

Production cost



*\* Data from: Advanced Forming Research Centre (AFRC), University of Strathclyde*

# High Pressure Warm Forming



2015-05196

Process demo project funding  
High-pressure process for Titanium

# Lab scale warm forming system

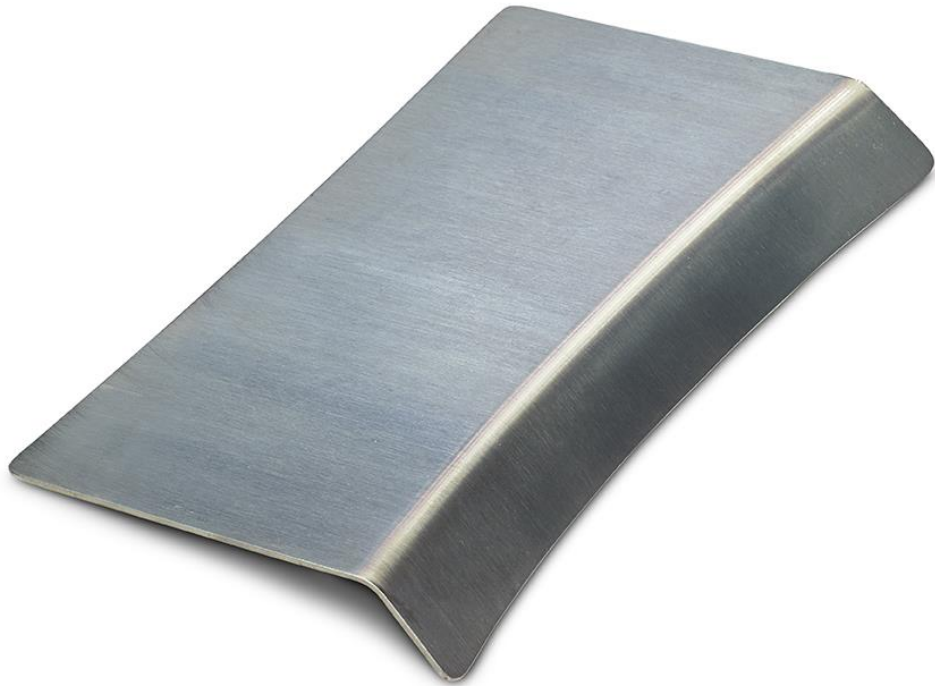
- Scalable
- Automation
- Process control





# Demo parts – Lab scale

- With and without springback compensation



# Demo parts – Lab scale

- Shrink & stretch flanges
- Joggles
- Gentle curvatures



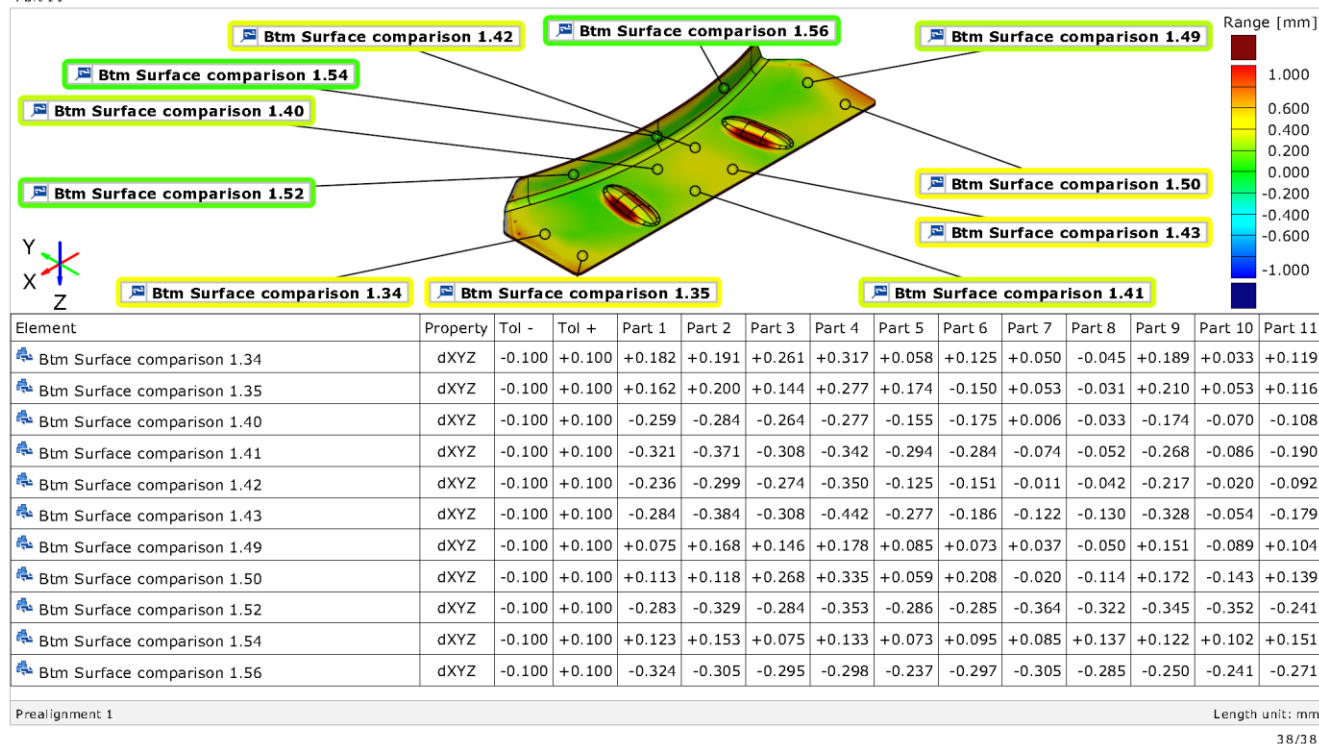
# Lab test conclusions – Excellent forming repeatability

Generated with ATOS Professional V8 SR1

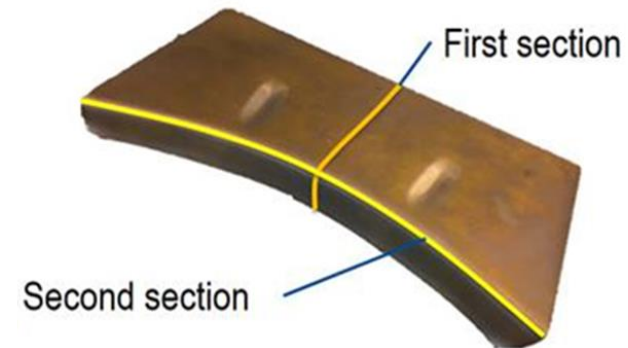


Deviation values for selected points across all 11 parts - scans best fit to CAD

Part 11



# Test sample



## AFRC\_DIRF\_1047\_SoW\_V2

Materials Characterisation of as-received and warm hydroformed parts.

### Overview:

Following on from the metrology work carried out under DIRF\_713, the AFRC will carry out materials characterisation (Optical and electron microscopy) on one off as-received sample, and one off warm hydroformed sample.

### Aims:

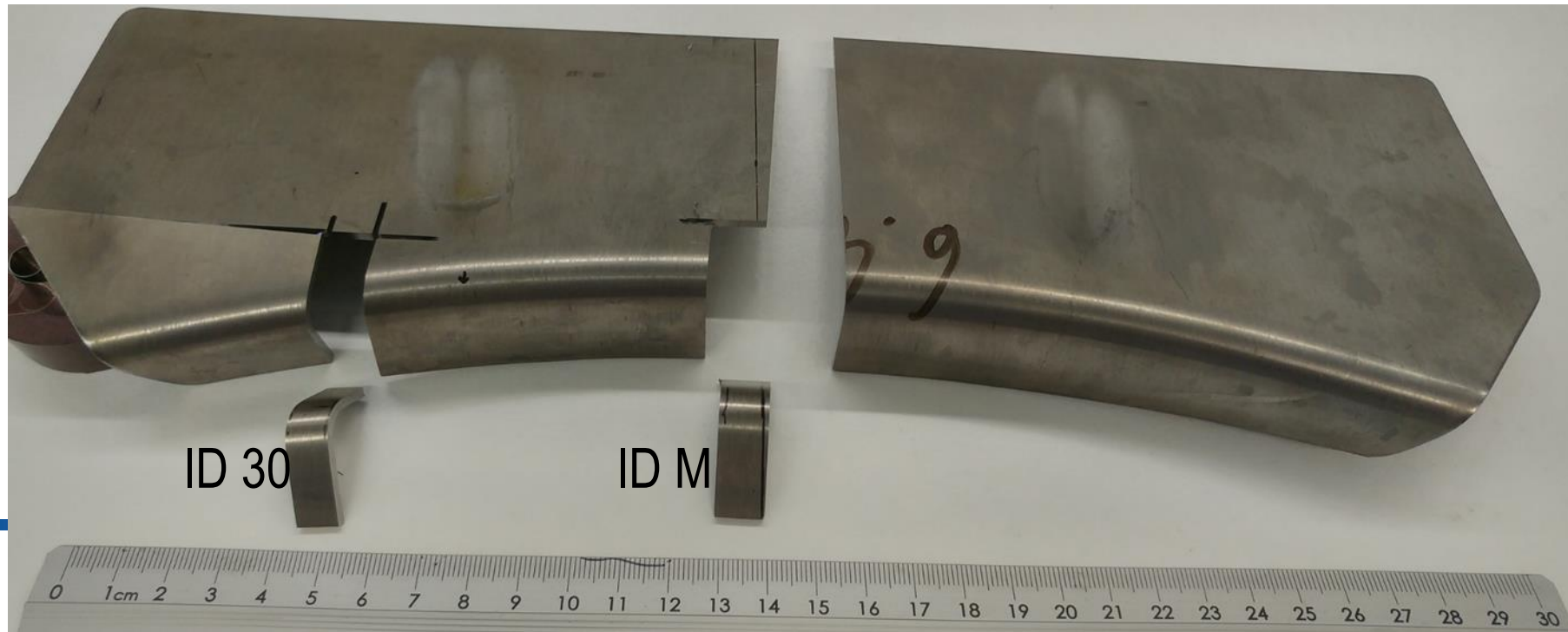
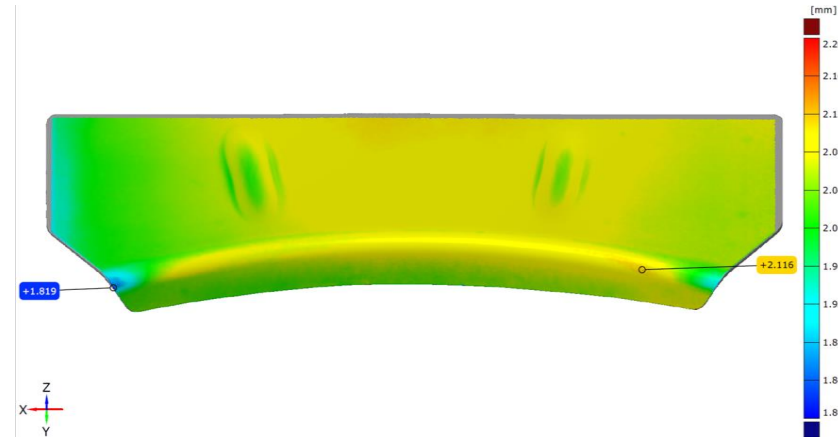
- Carry out metallographic examination of one off warm hydroformed component to assess for the presence of cracks within the microstructure.

### Key tasks:

- Using optical and electron microscopy, examine the microstructure for subsurface cracks taking samples from 3 locations on the formed part (flat, lozenge-shaped feature, and bend radius).

# Extracted Samples for Section 2

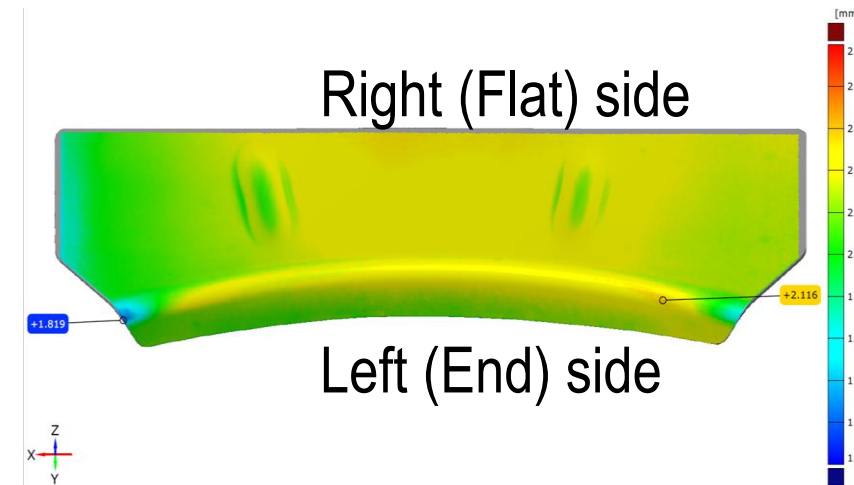
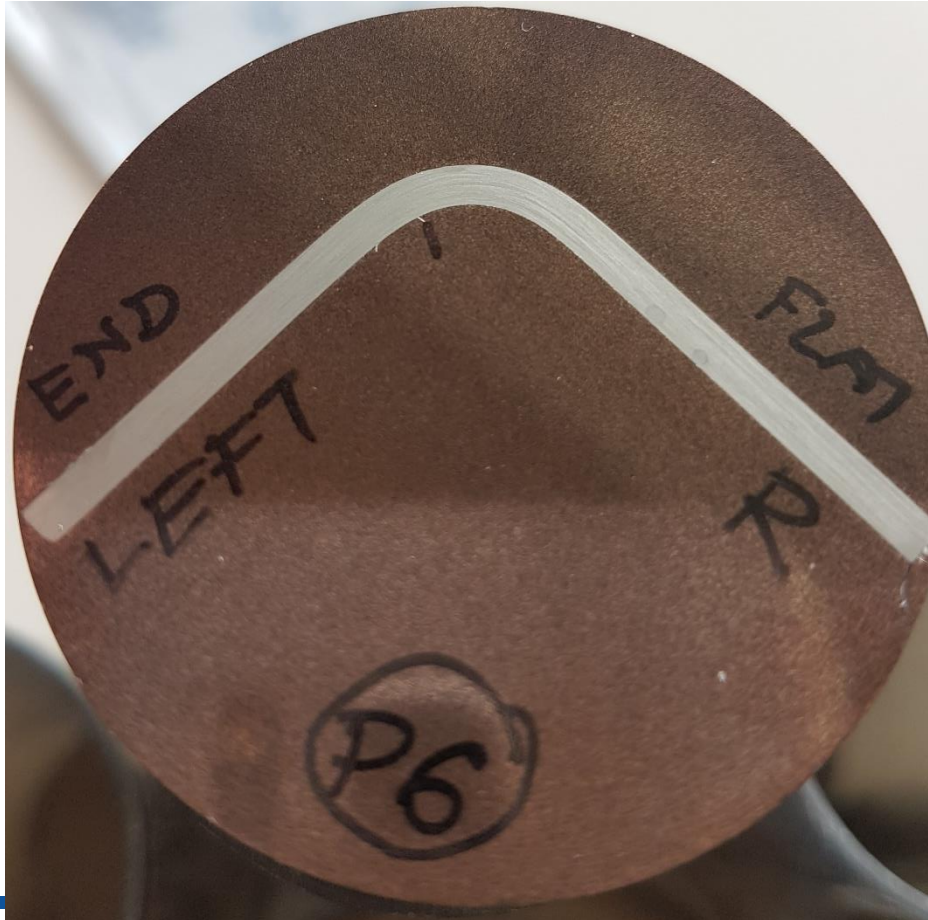
ADVANCED FORMING RESEARCH CENTRE





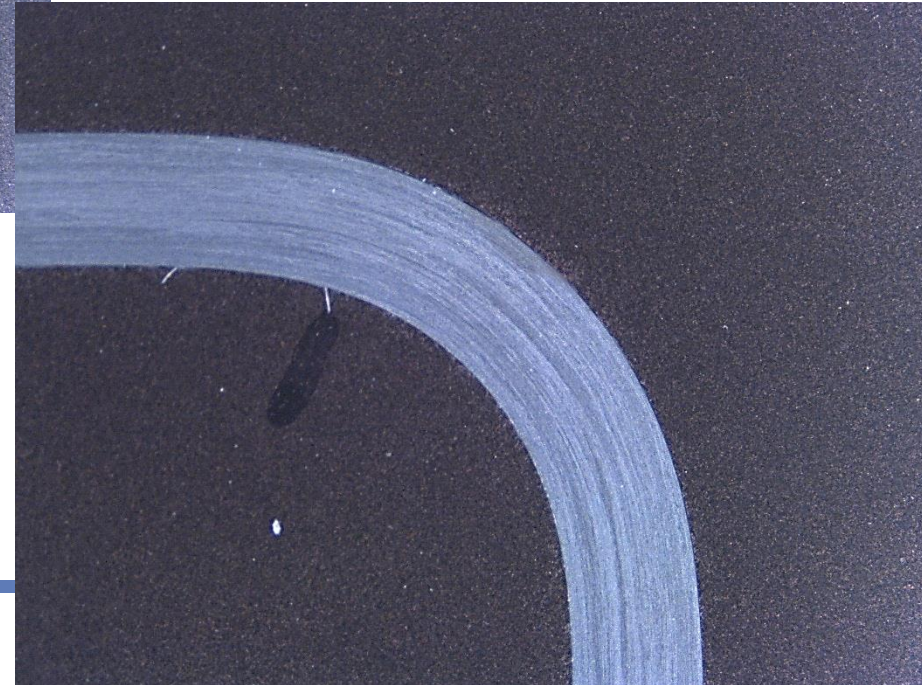
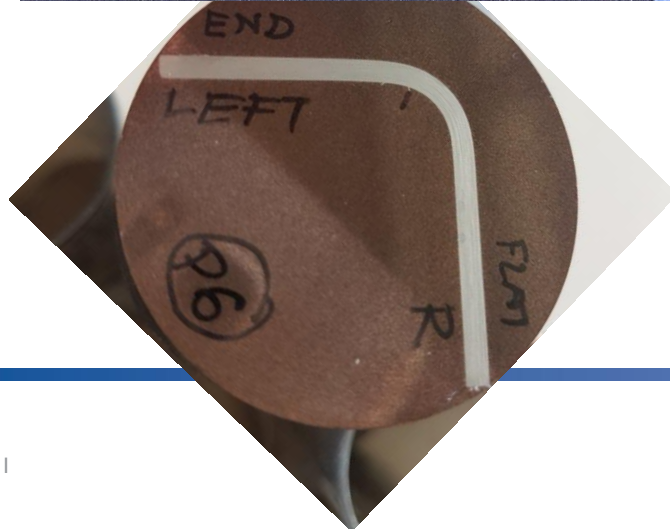
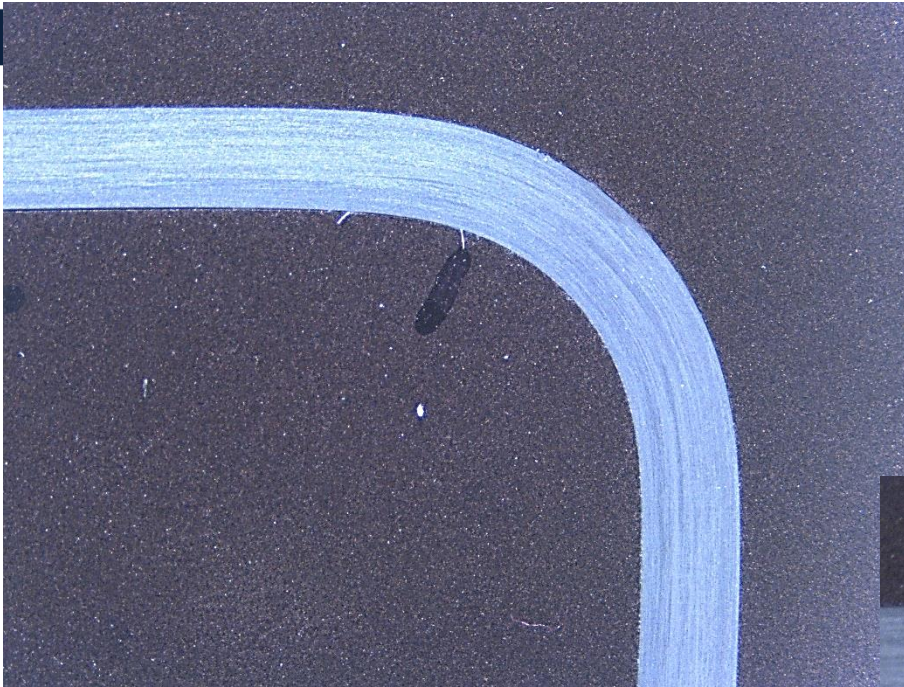
# Section sample mounted

ADVANCED FORMING RESEARCH CENTRE



# Macro optical image showing material flow

ADVANCED FO

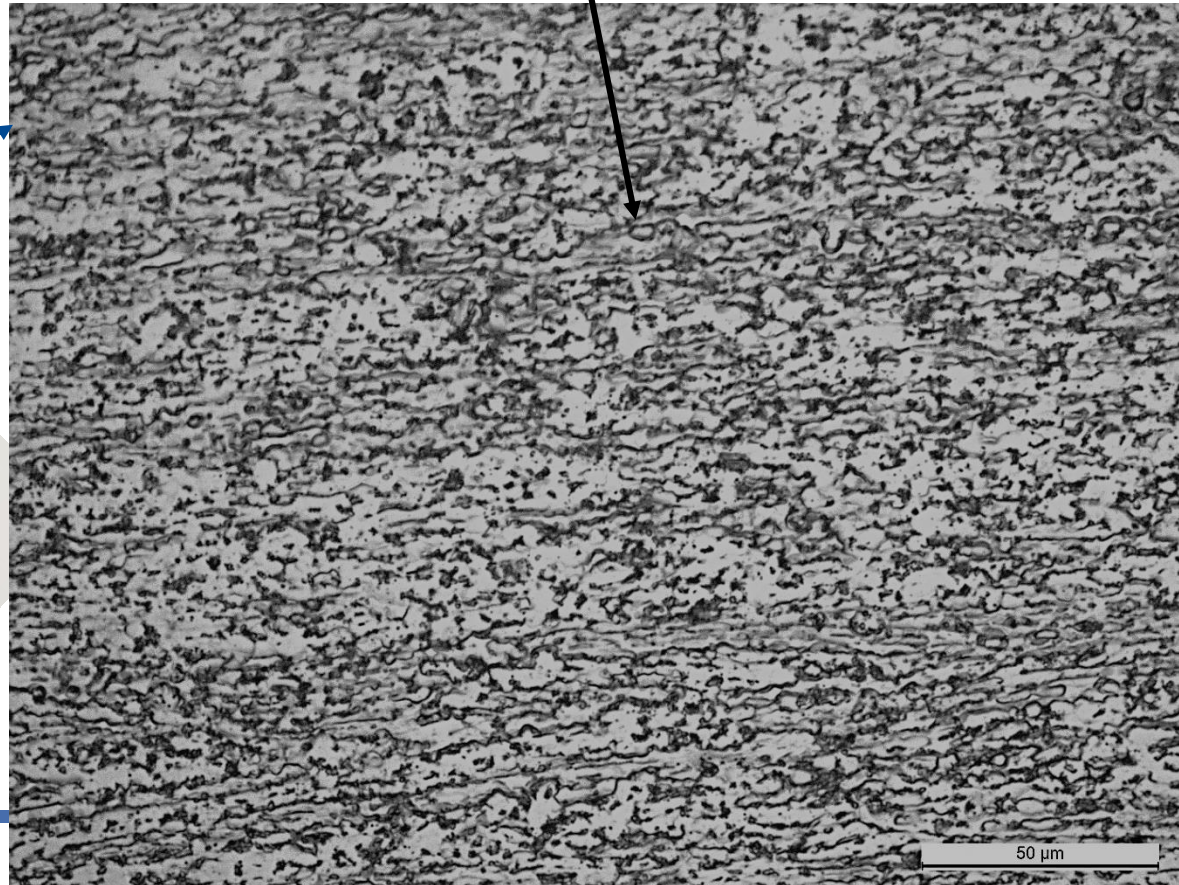
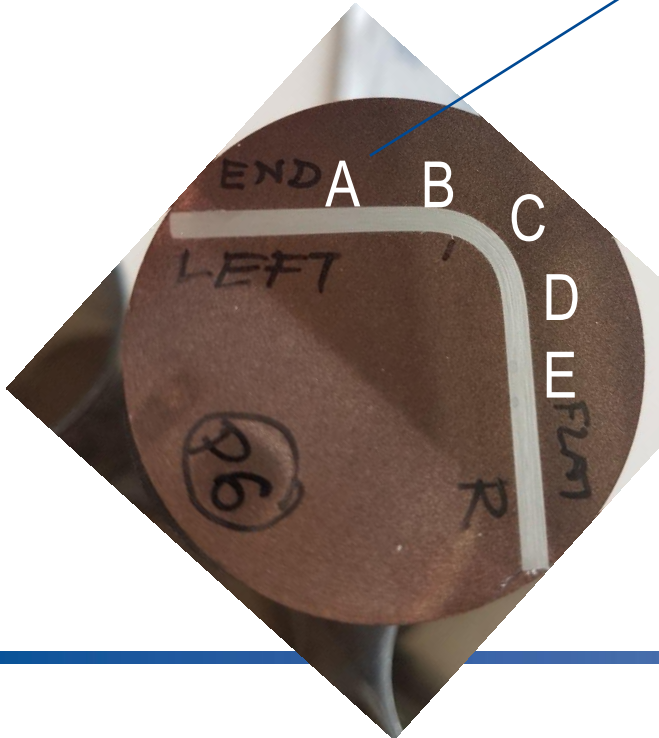




# Optical Micrographs of section1

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Optical image location A  
Fine and extended grains

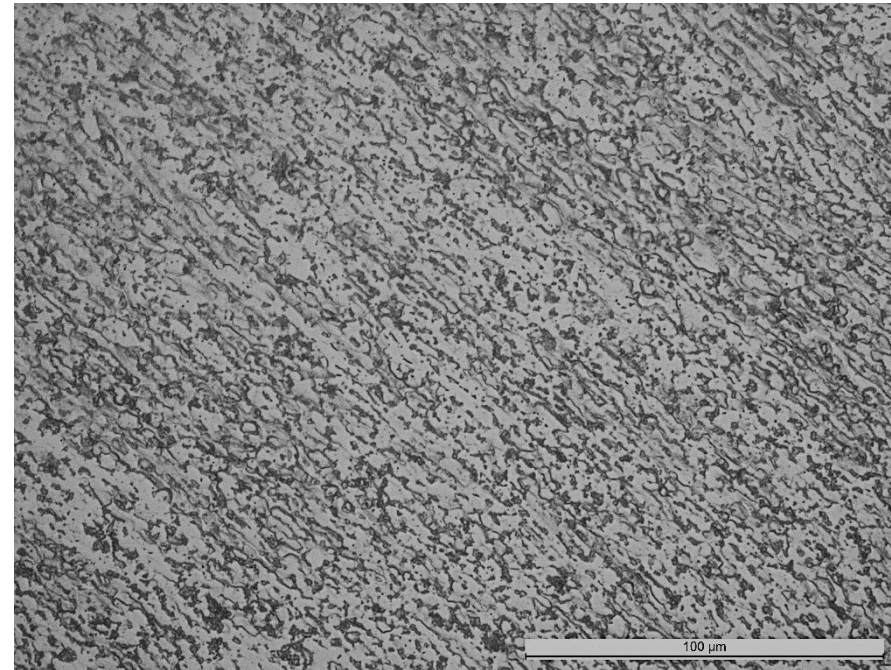
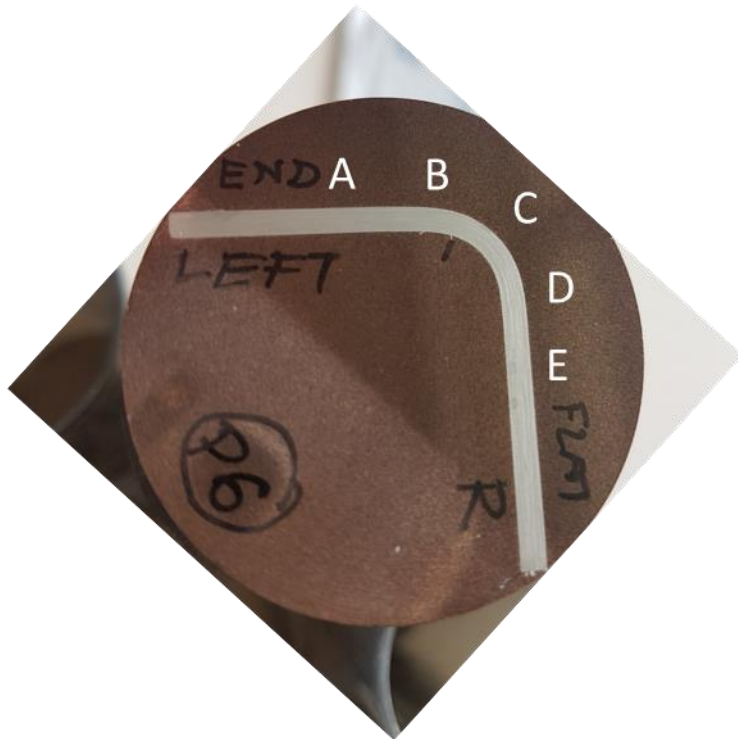


# Optical Micrographs of section1

ADVANCED FORMING RESEARCH CENTRE

Optical Image location C

Direction of grain flow has oriented along bending direction (horizontal axis on this page) around 15-20°



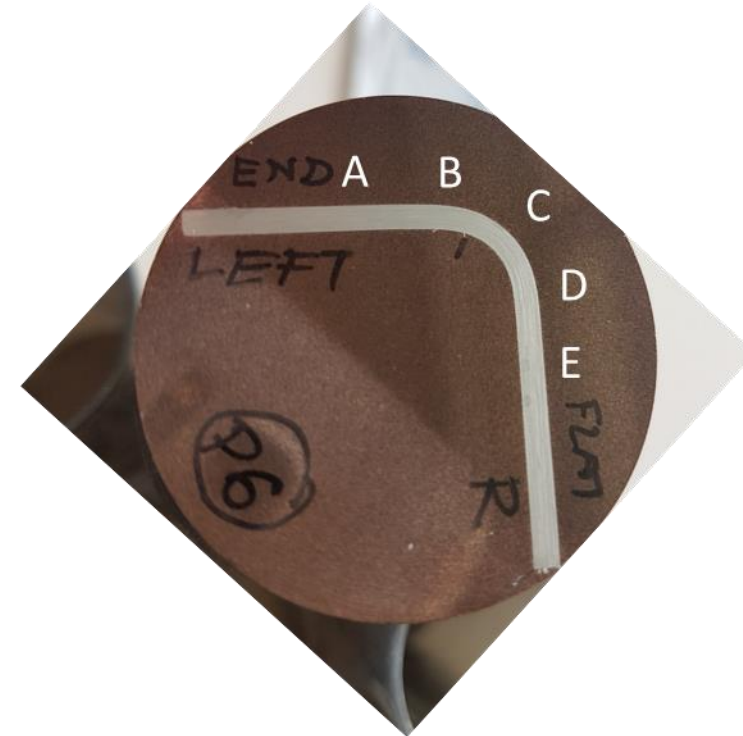
No evidence of any cracks within the macrostructure or along the edges of the section



# No Alpha case formation

## ADVANCED FORMING RESEARCH CENTRE

- Alpha case formation has been investigated at three points, A, C and E, of the 'L' shape section.
- Both optical microscope and SEM have been used for alpha case evaluation.

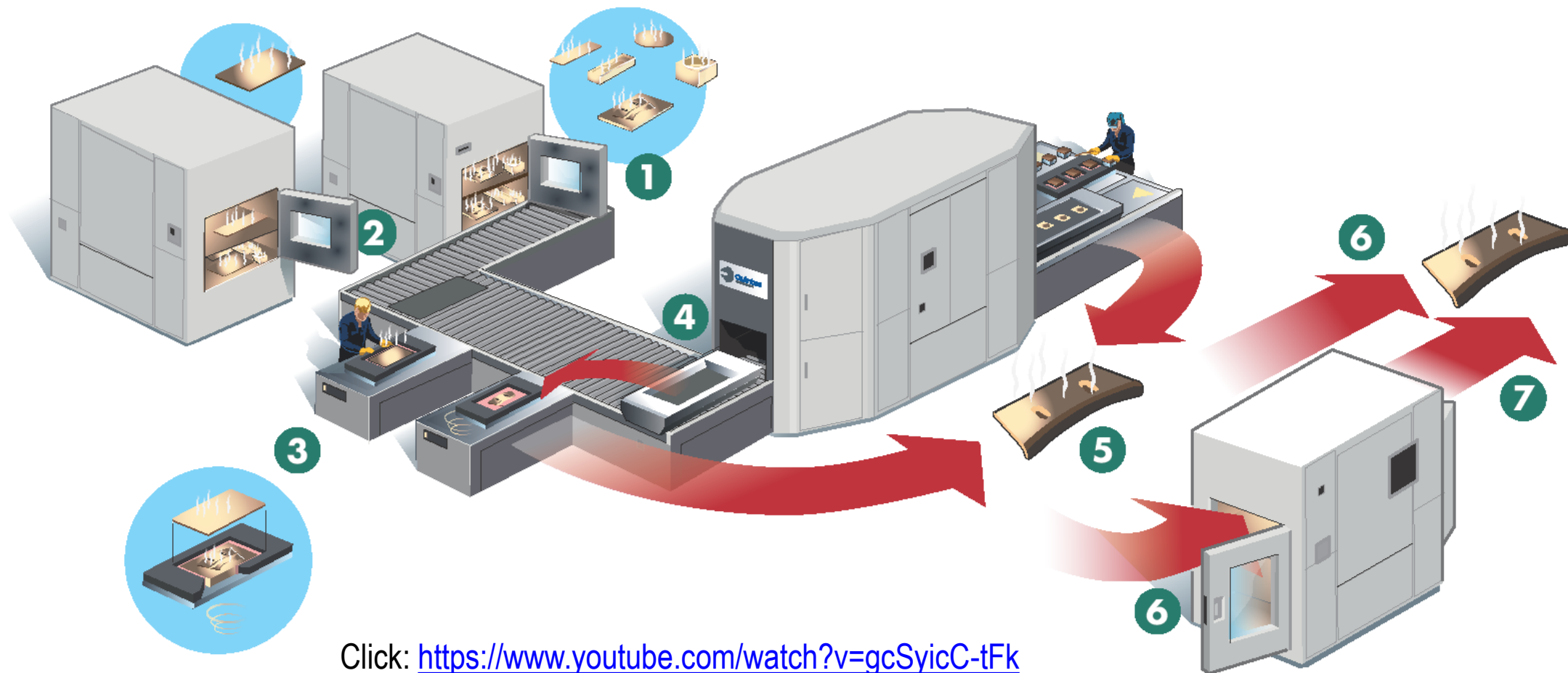


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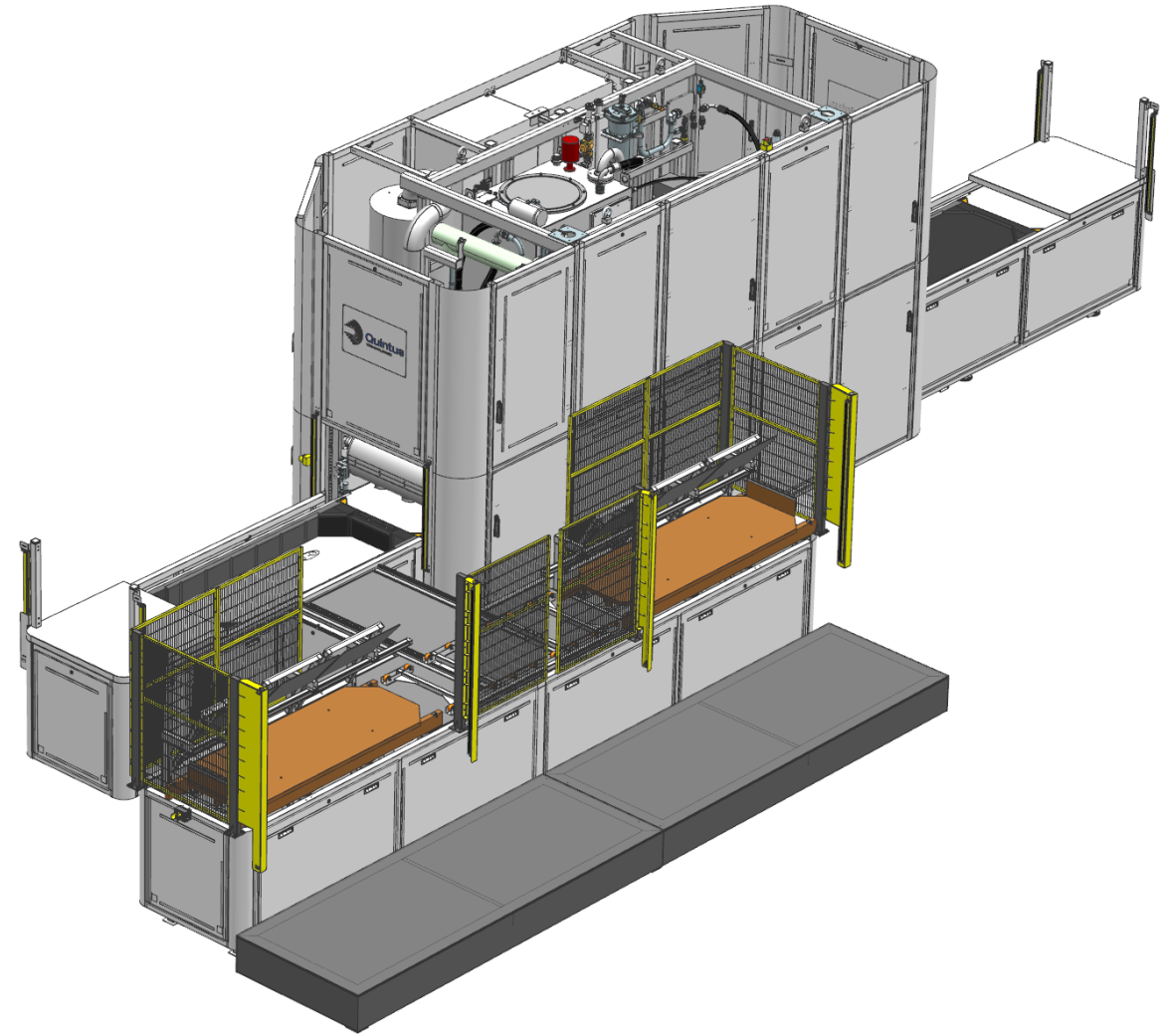
# How does it work?

# Quintus High Pressure Warm Forming – Step by step



# Next step

- **Equipment / system validation**
- Robustness
  - Handling
  - Productivity
  - Process cost
  - Isolation





# HPWF system under installation

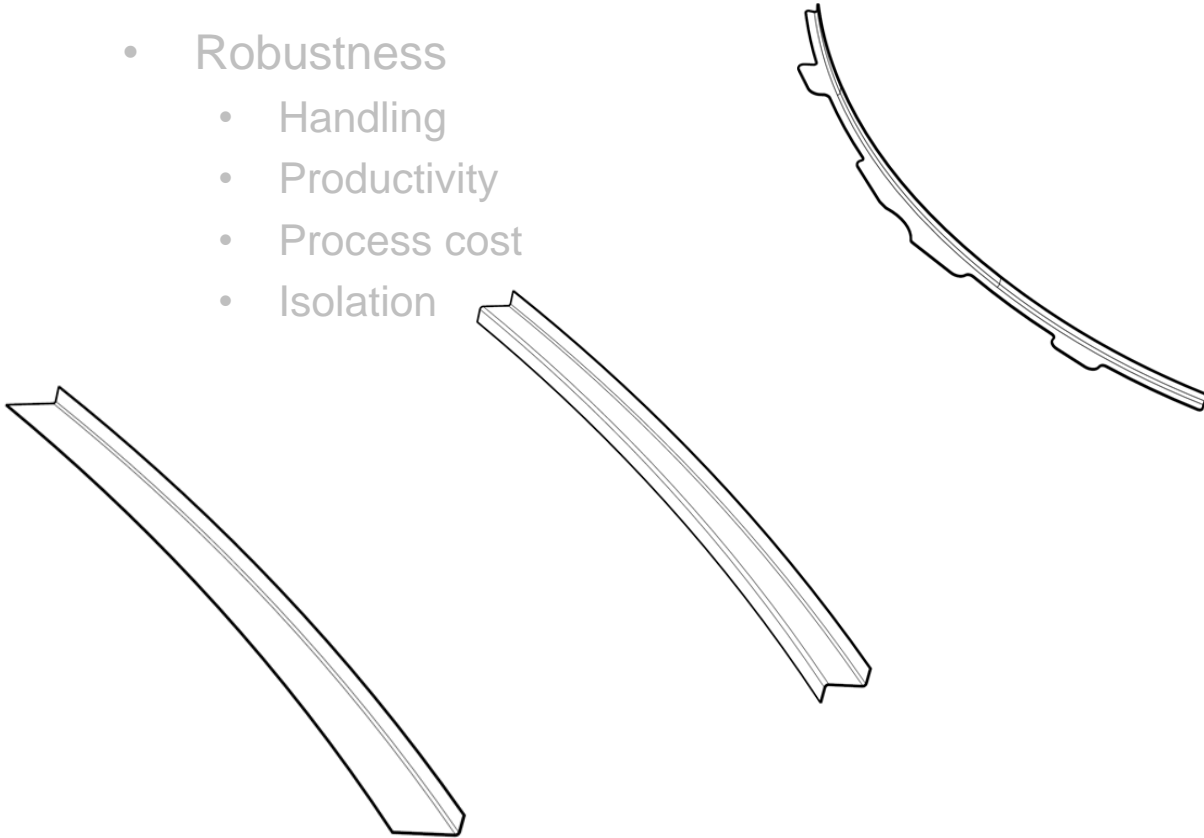


# Next step - Partners welcome!

- **Equipment / system validation**

- Robustness

- Handling
- Productivity
- Process cost
- Isolation



- **Process validation**

- Tooling

- Demonstrators, full size
- Spring back compensation
- Simulation correlation

- Final stress relief requirements
- Process envelope / part suitability
- Market acceptance

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Thank you for your attention!

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