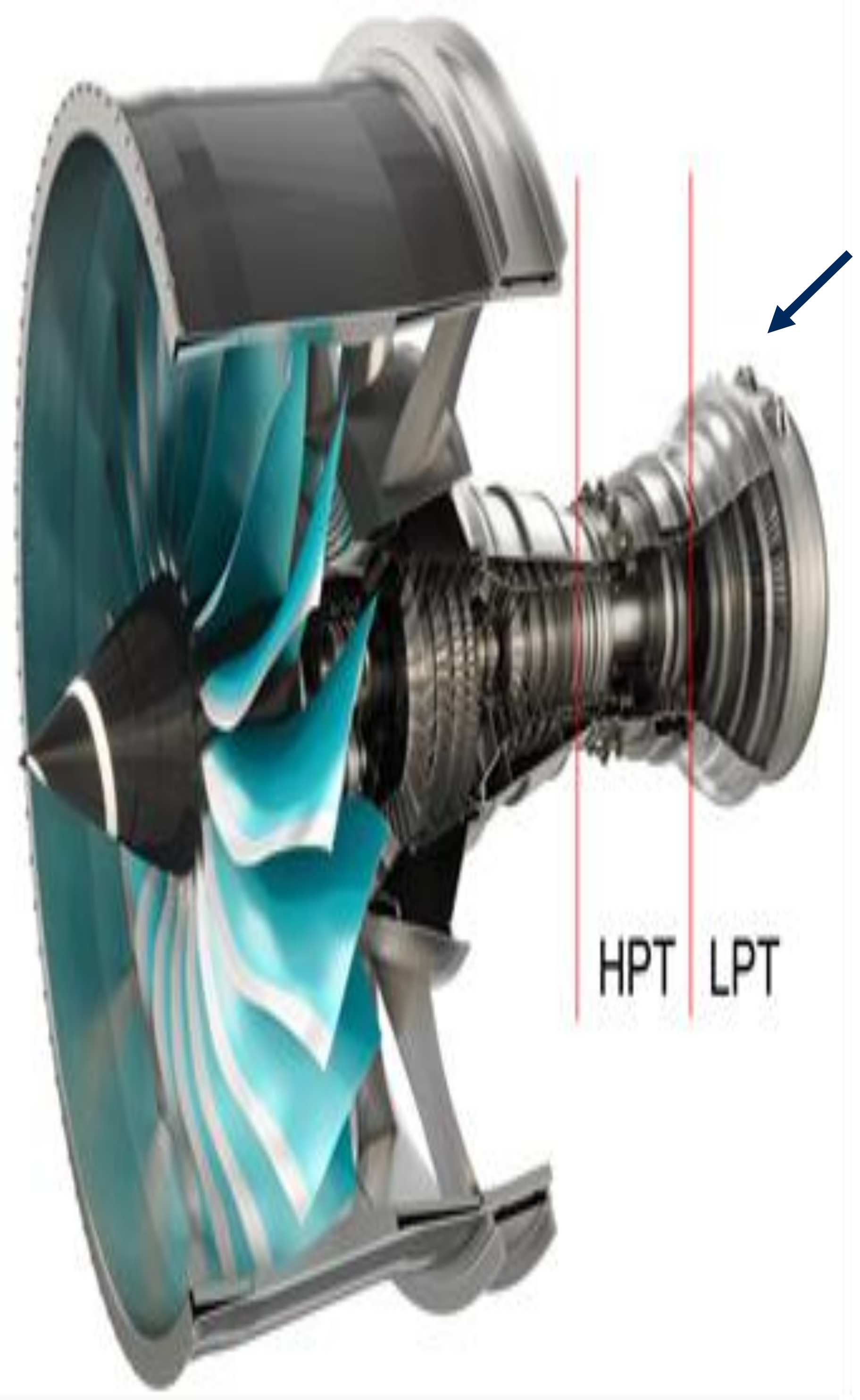
Development of Advanced Manufacturing Platform for High Integrity Forged Components

Sean Peters[1], Paul Blackwell[2], Marcos Perez[3], Yvon Millet[4]

1- DMEM, Advanced Forming Research Centre, , University of Strathclyde, Glasgow (sean.peters@strath.ac.uk)
2- DMEM, Advanced Forming Research Centre, , University of Strathclyde, Glasgow
3- DMEM, Advanced Forming Research Centre, , University of Strathclyde, Glasgow
4- Timet, Savoie

Background and the challenge from industry

There are ever increasing demands on aerospace engine manufacturers to develop systems with improved efficiency and reduced environmental footprint. **Advanced titanium aluminide** designs are required for higher service temperatures, lighter weight, and higher operation speeds.[1]



Rolls Royce, Pratt & Whitney and GE all apply different TiAl alloys to their low-pressure turbine (LPT) blades[1,2]

1/ Knowledge Gap

- Nearing limits of conventional metallic systems for use in aero engines.
- Industry accepted intermetallics such as cast titanium aluminide can now be developed to optimize properties and processing via hot working.[3]

2/ What makes titanium aluminide (TiAl) difficult to hot work?

- Intermetallics such as TiAl show both metallic and ionic bonding character giving defined long-range ordered phases, for TiAl they are based on **γ(TiAl), β_0/B2 (Ti)** and **α_2 (Ti_3Al).**[4]
- Cast TiAl alloys, **4822** and **45XD,** follow a **peritectic** solidification pathway resulting in **elemental segregation** and large **grained microstructures**

This results in a material that shows:
- **Ease of fracture** during processing <1000°C
- **Plastic anisotropy** due to large grain sizes
- **Slow recrystallisation** due to elemental segregation

Making this material difficult to forge under normal industrial conditions

However, forging would increase possible TiAl use via;

- ✓ Improving damage resistance
- ✓ Near net shape processing
- ✓ Replace high density/volume materials with TiAl
- ✓ Refine microstructure for toughness

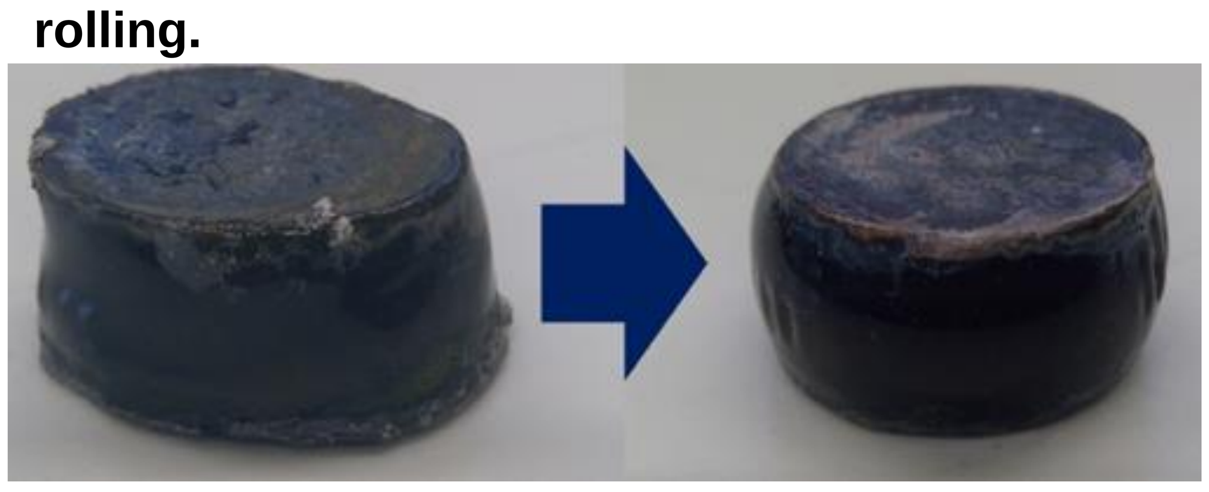
3/ Who is involved?

TIMET- with material expertise,

AFRC & TIER ONE MEMBERS- globally-recognised companies backing our Centre of excellence in innovative manufacturing technologies for metal forming and forging research

4/ Project aim- starting 01/07/2019

- Apply thermomechanical processing techniques to improve the forgeability and forging outcome of two **cast** alloys, **45XD** and **4822**
- Produce **high integrity forged titanium aluminide** material with equipment based at the AFRC ready for processing via high deformation secondary processes such as **closed die forging** or **hot rolling.**

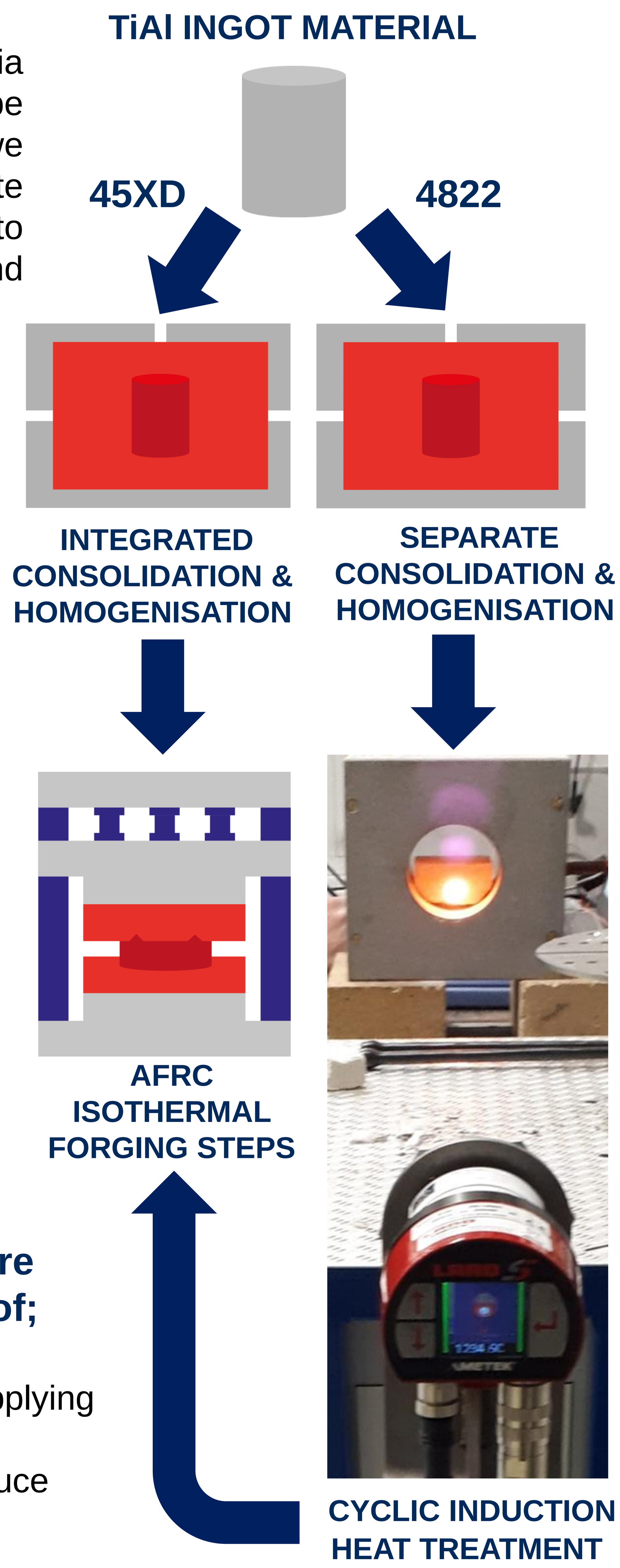


The aim of our work in an image, improving forgeability of these cast alloys

5/ Methodology

Both cast alloys require consolidation via hot isostatic pressing (HIP) to remove casting porosity. But on its own it is not enough to improve forgeability or forging outcomes.

Homogenisation (HMG) via vacuum furnace is found to be essential but from this point we have found the ideal process route for the two alloys to differ due to very different microstructures and response to processing



6/ Findings to date

45XD
- Integrated HIP & HMG reduces initial brittle β_0/B2 fraction and reduces the number of cooling stages where grain growth can occur

4822
- Cyclic induction heat treatment (CHT) uses the chemistry of the metal to refine the grain size without hot working, easing primary forging. Work is ongoing to investigate the microstructural outcome

Both alloys look to benefit from two stage forging to return material with acceptable workability

7/ Outcomes and impacts are aligned with SRPe themes of;

- ✓ **Advanced manufacturing**; applying advanced thermomechanical processing techniques to produce components from advanced materials
- ✓ **Infrastructure and environment**; end users driving towards sustainability and fuel efficiency rely on light weighting structures to reduce carbon emissions

References;
1. Williams, G. Lutjering, Titanium, 5, (2003), 360-366
2. https://www.flickr.com/photos/rolls-royceplc/48486636831/in/photostream/ [online]
3. Clemens, H., Mayer, S., Design, processing, microstructure, properties, and applications of advanced intermetallic TiAl alloys, *Advanced Engineering Materials,* 15, (2013), 191–215
4. Clemens, H., Kestler, H., Processing and applications of intermetallic γ-TiAl-based alloys, *Advanced Engineering Materials,* 2, (2000), 551-570

Scottish Research Partnership in Engineering
National Manufacturing Institute Scotland
University of Strathclyde Glasgow
TIMET
Scottish Funding Council
Promoting further and higher education