FAST-roll: developing a new route to create novel composite titanium products from recycled powder

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Background

Powder metallurgy (PM) is a manufacturing process whereby parts are shaped through the consolidation of powders. It has been used for many years now to produce components of complex geometries from various alloys and with low material wastage. However, it is also characterised by the following issues:

- Long waiting periods
- Energy intensive procedures
- Powders used need to have stringent properties, hence produced through expensive routes

Figure 1 Titanium powder and gears [1]

Aims of the study

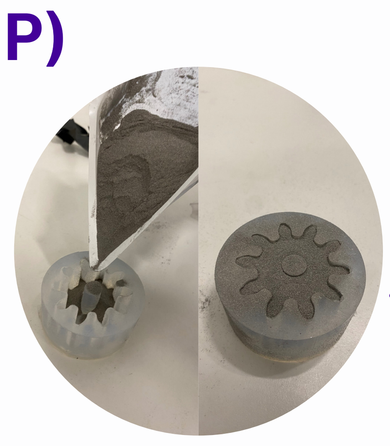
Development of a novel, more efficient route to produce titanium components from titanium powders whereby the following can be achieved:

- Decrease in manufacturing times, hence less energy consumption
- Repurposing of used materials (offering sustainable consumption and production)
- Minimisation of CO_2 emissions and fostering of sustainable industrialisation

Methods

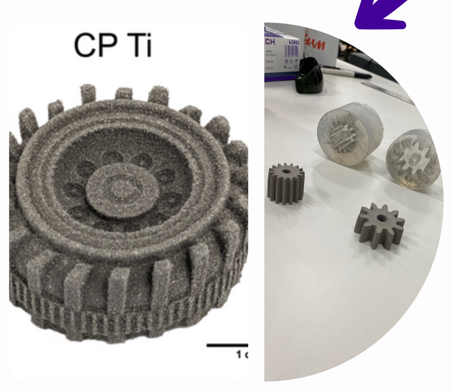
Cold Isostatic Pressing (CIP)

Step 1
Commercially Pure Ti powder was poured into custom made silicon moulds of various designs



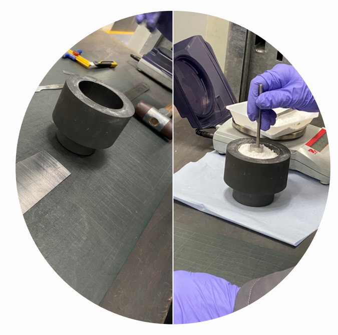
Step 2
Then vacuum sealed and placed into the chamber of the CIP machine where it was held at 350 MPa for 2 minutes

Step 3
The final consolidated parts were removed from the moulds



Field Assisted Sintering Technology (FAST)

Step 1
Compacts were inserted into a 60 mm diameter graphite mould fully covered by 170 g of calcined Z_rO_2 powder (pressing medium)



Step 2
The mould was then placed in the FAST vessel where it was heated at up to 980°C and pressured at 35 MPa

Step 3
Finally, the Ti pieces were extracted from the partially sintered Z_rO_2 using a hammer and any residual Z_rO_2 on the surfaces was removed by abrasive grit blasting

Results

Density

Through the Archimedes method, the density of the final sample was calculated in order to be compared with the theoretical density of the element. Figure 1 shows a relative density of 99.3% showcasing the succesful FAST procedure

	Processing	Archimedes density (gcm^{-3})	Relative density (%)
CP (theoretical density = 4.5 gcm^{-3})	CIP	3.71	82.4
	CIP-FAST 10 min	4.48	99.3

Figure 2 Density measurements of the samples [2]

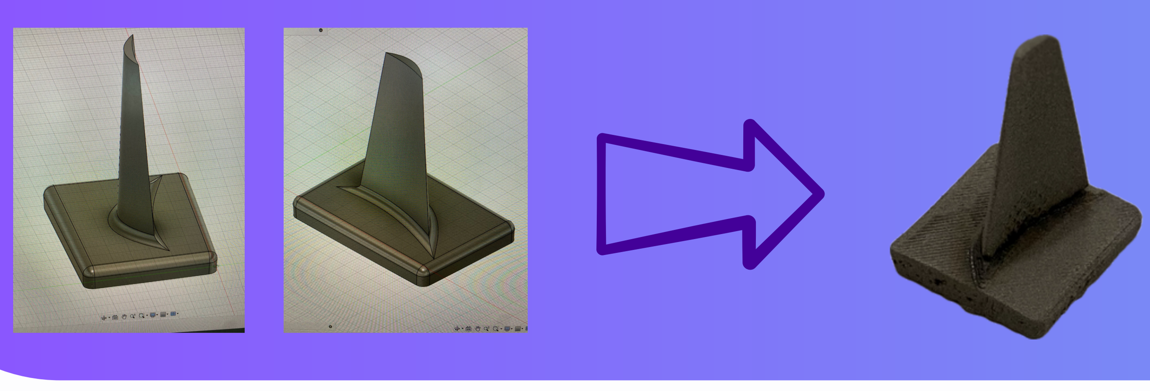


Figure 3 CIPed and FASTed part [3]

Retention of complex geometry

Although there was clear deformation perpendicular to the sample's height after FAST, the minute features from the design were retained

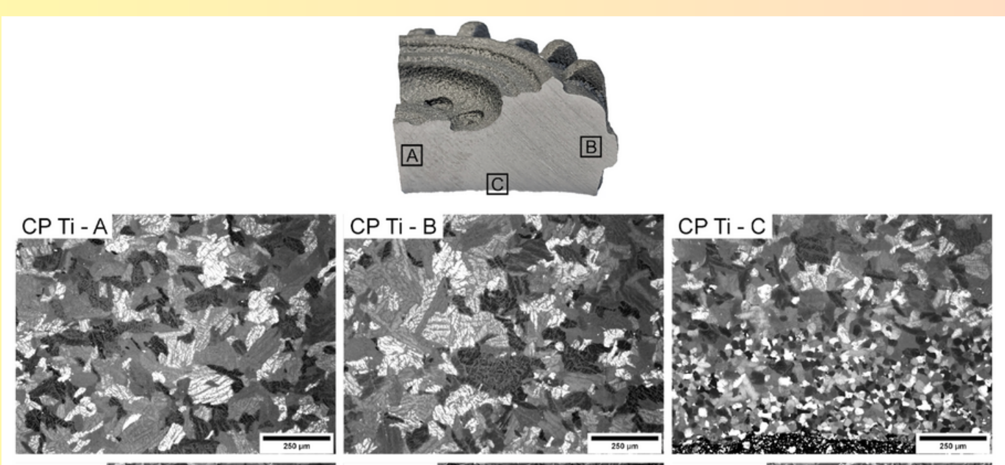


Figure 4 Microstrctural composition at different locations of the sample [4]

Fine Microstructure

During Vickers Hardness Test, the indents were smaller at the edges than at the centre, indicating higher hardness and concentration of oxygen there. One implication is that this region is more brittle and could lead to reduced fatigue performance.

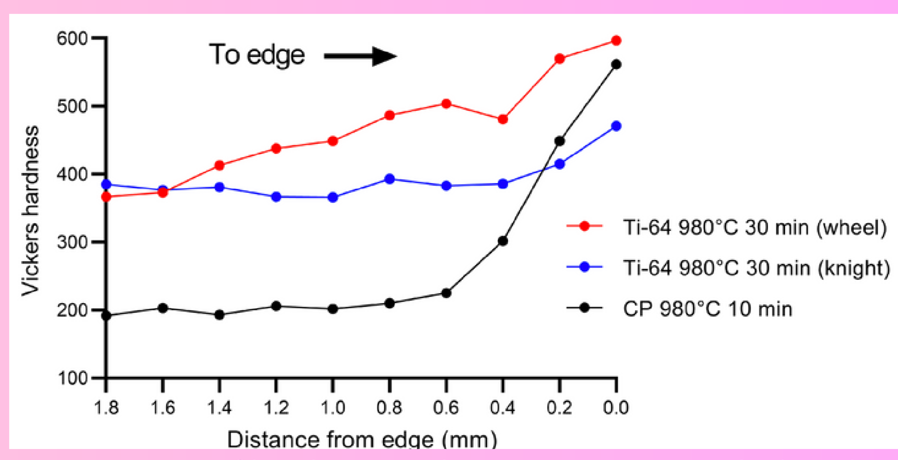


Figure 5 Increase of hardness as the test moves towards the edges [5]

Conclusions

- Combination of CIP & FAST, promising route with benefits over other methods such as high relative density, short processing times, use of cheaper angular HDH powder, no material wastage, reusability of the CIP moulds and FAST equipment
- Materials for CIP moulds should be reconsidered, e.g. higher hardness silicone in order to mitigate contamination into the Ti structure
- Use of a different pressing medium with a lower ΔGf° (Gibbs free energy of formation value) such as Y2O3 to reduce the oxygen pick up from Ti after FAST
- Development of larger CIP & FAST tooling could make the route more appealing for industrial component mass production

References

[1] "Design Resource Center", [Digital Image]. Value-Added Engineering for Component Designers and Engineer. https://www.pickpm.com (Accessed: Nov. 14, 2023)
[2], [3], [4], [5] S. J. Graham, Y. Alkali, J. Withey and M. Jackson, (2023) "CIP-FAST: Assessing the production of complex geometry titanium components from powders by combining Cold Isostatic Pressing (CIP) and Field Assisted Sintering Technology (FAST)," Powder Metallurgy, 66:5, 482-492, DOI: 10.1080/00325899.2023.2236907