Case Study – FAST-*forge* – From Powder to Component in Two Steps

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Background

Titanium alloys have excellent mechanical properties; they have strengths comparable to steel but with half the density, in addition to excellent corrosion resistance and biocompatibility. However, the major drawbacks for titanium alloys are the cost of production and a limited supply (~130000 tonnes pa), which confines their use largely to the aerospace industry where properties such as low density, high levels of strength and good fatigue resistance in safety critical components are essential. The use of titanium alloys will continue to be limited unless additional sources and low cost processing routes can be developed.

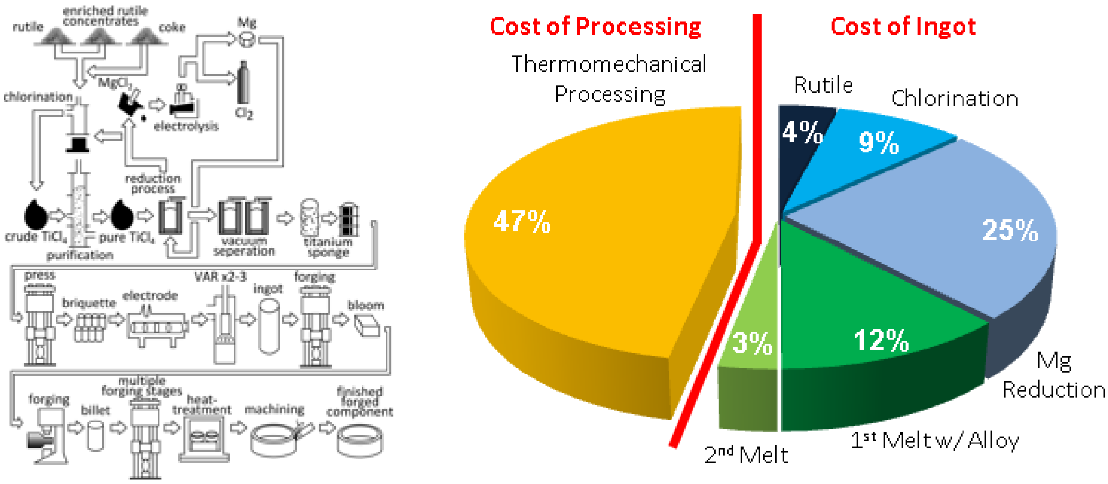

Fig. 1 The Kroll process for traditional titanium extraction and multi-stage processing steps to produce an aerospace grade component together with the cost breakdown of the process.

Description

CDT students have been working on both the titanium extraction and downstream processing aspects of this problem.

Step 1: Titanium Extraction - Novel titanium alloy powder production

In 2013, Metalysis supported a CDT PhD project on the chemistry of titanium powder produced using the FFC Cambridge process, developed in the early 2000s. This enables the production of titanium from natural sands, or synthetic rutile at much reduced economic and environmental cost compared with traditional Ti refinement through the Kroll process.

Step 2: Downstream Processing - FASTForge - powder to shaped component in two steps

Another CDT project in collaboration with DSTL and Kennametal looked at optimising the Field Assisted Sintering (FAST) process for titanium feedstocks. FAST has advantages over hot isostatic pressing as more rapid sintering can be achieved without the need for expensive and process-limiting steel canning and degassing steps. The combination of FAST with traditional precision hot forging produces components with refined microstructures and higher structural integrity than other powder techniques such as additive manufacturing. This process has the potential to create a near net shape component, in titanium alloys, having the same (or very similar) material properties to high strength titanium alloy forgings currently used in the aerospace industry.

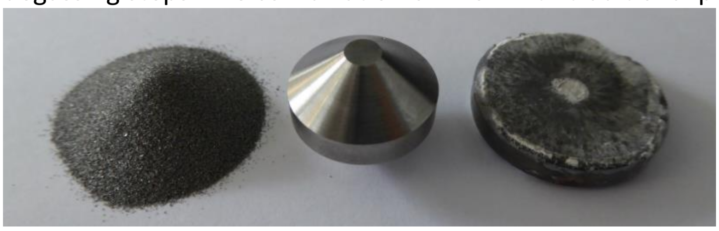

Fig. 2 Three stages of the process: Powder, FAST and Forged

Benefits

Significant cost savings are achievable through combining the Metalysis and FAST processes with a one-step forging operation in the FASTForge process through reducing both the raw material and processing costs (see fig. 1). On the raw material side, the chlorination step is eliminated and the first and second melts are replaced by a single oxide reduction step. The one step forge means almost all of the complex thermomechanical processing is eliminated. The combination of these exciting developments has the potential to lead to a step change in the titanium manufacturing. Lightweight, corrosion resistant, high strength titanium alloys could become an economically viable option, opening up markets in a range of sectors including aerospace, automotive, heavy transport and defence. This technology is being developed and exploited in the UK.

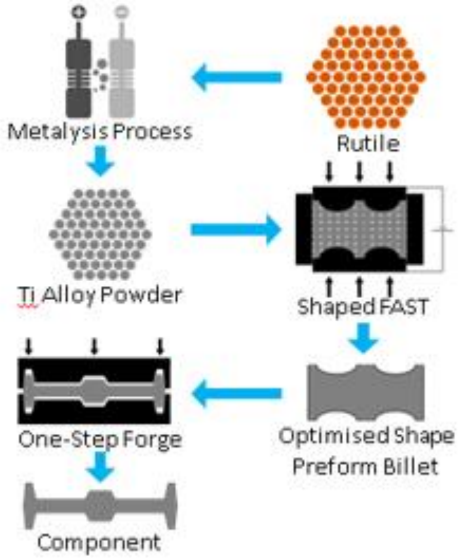

Fig. 3 The FASTForge process

Outcomes

Building on the success of EPSRC funded PhDs on a small scale, a UK-based consortium of industry, a Catapult Centre and academia is now looking at upscaling the combination of titanium powder production, FAST and one step forging, through a £1M Innovate UK project; FASTForge. Metalysis, Advanced Forming Research Centre and the University of Sheffield will work with Safran to take the project from proof of concept to a demonstrator aircraft landing gear component. The aim is to reduce their cost by 70% using the FASTForge process.

The exciting opportunities for a step-change in Ti production and manufacture afforded by this work have resulted in a range of media coverage.

Scienmag (http://scienmag.com/sheffield-fast-forge-process-set-to-change-uks-high-value-manufacturing-industry/)
Institute of Mechanical Engineers (https://www.imeche.org/news/news-article/production-process-promises-cheaper-titanium-alloy-components)
Phys Org (http://phys.org/news/2016-10-fast-forge-uk-high-industry.html)
The Manufacturer (http://www.themanufacturer.com/articles/fastforge-to-deliver-cheaper-aerospace-titanium/)

Contribution of the CDT

Fig. 4 CDT students Nick Weston and Lyndsey Benson undertaking FAST experiments

The regular intake of funded CDT students enabled the coordination of a multi-stranded project with different industrial partners collaborating on different elements. Moreover, the differing skillsets required by different strands of the project could be supported by the range of backgrounds of the students recruited to the CDT. For example Lyndsey Benson is a chemistry graduate, ideally suited to the study of the solid state extraction process, bringing new skills and knowledge to the research group. The additional CDT training has enabled her to combine her chemistry knowledge with materials in order to take on this challenging multidisciplinary research and integrate with the downstream processing aspects of the wider project and its industrial collaborators