Quo vadis titanium? The status of the titanium industry in South Africa

In our Materials Engineering in Practice column this month, Leslie Chown of the School of Chemical and Metallurgical Engineering at the University of the Witwatersrand talks about titanium and its alloys and the dti’s aim to create a local titanium beneficiation industry.

“...our bullets ricochet ... I’m bulletproof ... I am ti – ta – ni - um...”. The lyrics of this song pop into my head as I write this article. It seems to be my theme song at the moment, as a lot of my work revolves around this amazing metal.

Titanium and its alloys seem to be a panacea for use in aggressive environments. Properties such as a good strength-to-weight ratio, excellent corrosion resistance, higher strength and fracture toughness than steel, high temperature resistance of up to ~590 °C, higher fatigue strength than aluminium or magnesium alloys, low density – half that of steels and superalloys – tick all the right boxes for a wide range of applications.

Typical uses are in aircraft structures, aero-engines, biomedical devices and components in chemical processing equipment. In 2012, 55% of titanium metal in China was used in chemical processing, with about 8.0% for structural parts in the aerospace industries and just under 7.0% in power generation.

Globally, South Africa has the second largest reserves of titanium ore, and is the largest supplier of titania slag, used as pigments in paint, paper and plastics. Pigments account for about 94% of titanium use, leaving 6.0% for metal products. While an ingot of titanium metal can cost $20 to 80 per kg, and high-end products such as implants 10-1 000 times more, slag sells for a mere $1 to $2 per kg.

So how much titanium metal from ore does South Africa currently benefit from? The answer is staggering; zero tonnes per annum. We are not capitalising on local beneficiation of this resource, because of the Kroll process for manufacturing pure titanium is expensive and we cannot be competitive. However, a small but growing, local industry imports semi-finished mill products, converting them to value-added products such as biomedical equipment and large titanium aerospace parts.

The dti aims to create a local titanium beneficiation industry within the next decade. South African universities and institutes collaborate in the dti Titanium Centre of Competence (TiCoC), hosted by the CSIR. Apart from driving commercialisation of titanium casting, powder production and additive manufacturing processes, this programme also ensures that we develop human capacity around titanium manufacture.

The ‘workhorse’ of titanium alloys is Ti-6Al-4V. Titanium on its own is expensive, and the aluminium-vanadium master alloy used in the production of Ti-6Al-4V adds to the cost. Researchers are looking at all aspects of manufacture to reduce the cost of titanium alloys. In one of our research projects, the possibility of partially replacing the Al-V master alloy with low cost ferrovanadium is being explored. Of course, this alloy would not compete with Ti-6Al-4V, but may offer a cost-effective solution for an application with less stringent requirements.

There is growing concern around life extension, especially in power plants and chemically aggressive industrial environments where corrosion, high temperatures, creep and wear occur. In some cases it would be beneficial to replace steel components entirely with suitable titanium alloys, especially in new plants. The initial higher cost of titanium parts is more than offset by the savings from the metal’s 20 to 50 year life, with reduced equipment maintenance and down time. The US Navy chose titanium over copper-nickel for seawater piping systems on LDP-17 ships, expecting titanium to last the ship’s lifetime of 40 to 50 years, with half of the weight. Where full replacement of components by titanium is not viable, coating the relevant surface may provide a low-cost, but very effective solution.

As new technologies, such as additive manufacturing using titanium powders and joining titanium, are developed, the alloys become more accessible. In 2012, the US Office of Naval Research used friction stir welding to join plates of titanium for a ship hull – a technology breakthrough.

Coming back to the song – yes, titanium can be bulletproof! Military-grade products are supplied for armouring land-based vehicles.

References
1. David Guetta lyrics from the song “Titanium”.