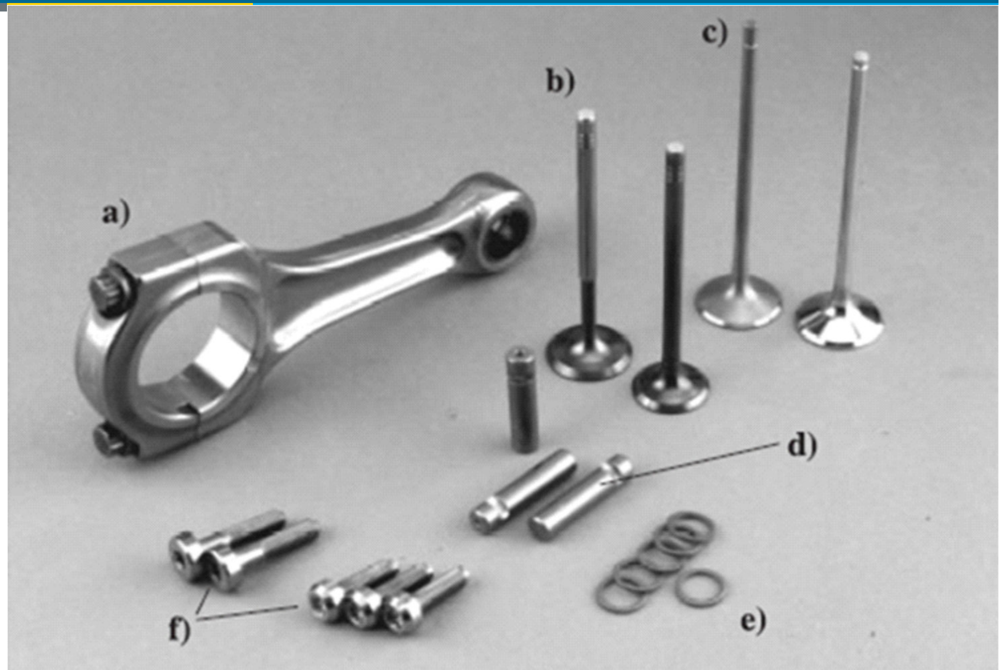
Low-Cost Titanium Alloy Production

Titanium for Energy Efficient Mechanical Systems.

Titanium (Ti) is highly valued for its strength-to-weight ratio and corrosion resistance. However, after conventional wrought processing and machining, it is typically in excess of 40 times more expensive than a corresponding steel part and nearly 20 times more expensive than an aluminum part. The high cost of Ti parts is a function of both high materials loss and multiple high temperature forging steps. This, in turn, has limited Ti to high-value-added parts, like those in the aerospace industry where a premium can be paid for its light weight.

The aerospace industry accounts for 60%–75% of Ti used currently. Having a manufacturing process with the ability to address one or both of these challenges would advance direct industrial use and open other Ti market applications. In addition, Ti's light weight would provide greater lifetime energy savings in transportation applications.

This project will replace existing melt and wrought-forming steps with a novel hydrogen (H_2) sintering near-net-shape Ti production process using low-cost powder metallurgy (PM) techniques. The hydrogen sintering and phase transformation (HSPT) process dramatically reduces energy costs, and reduces machining steps needed to fabricate a component. Processing at lower temperatures and at atmospheric pressure reduces the energy intensity of the manufacturing process.



Example Ti auto parts: a) connecting rod – Ducati, b) intake and outtake valves, c) coated/uncoated valves, d) brake pins – Mercedes-Benz, e) brake sealing rings – Volkswagen, f) rim screws – Ronal & BBS. *Photo credit Titanium and Titanium Alloys, Leyens & Peters.*

Benefits for Our Industry and Our Nation

The development of low-cost Ti-based parts could have a positive impact on U.S. manufacturing and the transportation fuel economy. Fuel consumption would be decreased by lightweighting both cars and other vehicles when heavier components are replaced by Ti. Increased fuel efficiency benefits the U.S. military by shortening supply chains and reducing the logistical burdens associated with delivering supplies to forward operating sites. Furthermore, using Ti-based components increases corrosion resistance and decreases the cost of ownership due to longer vehicle lifetimes.

Applications in Our Nation's Industry

The development of a powder-based process for manufacturing Ti parts at low cost would help all industries that can utilize the material property benefits that Ti provides, especially its high strength-to-weight ratio and corrosion resistance. In particular, the development of this process would benefit the aerospace, automotive, and defense communities that have large manufacturing footprints in the United States.

Project Description

The project objective is to demonstrate the viability of this technology by providing quantitative data that assesses the potential of the technology compared to commercial wrought materials. The research team seeks to achieve a 90% reduction in manufacturing costs by decreasing both the cost and energy intensity of producing Ti alloy parts.

Barriers

- A link between process variables and microstructure, which ultimately impacts the physical properties of the final material.
- Understanding of component specifications needed for utilization in commercial applications.
- Synthesis of parts without requiring additional energy intensive processing steps.

Pathways

This project involves optimizing processing parameters for manufacturing Ti components from powder via cold compaction and a novel process for sintering Ti in hydrogen. Verification of the microstructure and mechanical properties is providing insight regarding the effect of processing parameters that will help with prototyping. Commercially acquired Ti hydride is being used and during sintering, the green compacts are exposed to hydrogen atmosphere to produce near-net-shaped parts with 99% to 100% density and ultrafine grain sizes. Researchers are currently characterizing the mechanical properties of the processed materials. Simultaneous research is investigating components in both the automotive and defense supply chains that could be replaced by the Ti parts produced by this process.

Milestones

This project began in 2012. All properties below have met or exceeded project milestones, attempting to bring PM Ti into the same property ranges as wrought Ti materials at lower costs.

- Demonstrate >99 % relative density, ultrafine grain size (averages: <1.2 micrometers thick and <2 micrometers long), low oxygen content (<0.3 wt.%), and hydrogen, nitrogen, and carbon content easily surpassing the ASTM specifications using the new hydrogen sintering and controlled phase transformation technology (HSPT) (Completed).
- Demonstrate targeted mechanical properties, including static tensile (yield strength: 950MPa and elongation of 13.1%), fracture toughness of K_{Ic} at 47.8 MPa*m$^{0.5}$, and fatigue properties (endurance limit: ~500 MPa), using HSPT (Completed).
- Establish commercialization and licensing plans, identify end users and manufacturers, establish a path to market, provide slides describing the process, establish a conceptual production path and produce selected prototype parts for different industrial applications to demonstrate the utility of the integrated fabrication processes (2015).

Commercialization

Commercialization of this technology is predicated on producing lightweight, long-lasting Ti parts. Advancements are projected to occur through two different prototyping applications: (1) deploying Ti in Army platforms, thus improving fuel efficiency and reducing maintenance costs, and (2) deploying Ti parts in automobiles. Both applications are ideal because they are currently largely limited by the cost of Ti relative to other alternatives. Project success will demonstrate commercial utility, allowing a commercial partner to begin volume production of low-cost Ti components. Work with Ford will identify a small number of parts and detail specifications for manufacturing. Licensing discussions have been initiated with interested commercial partners.

Project Partners

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