Near Net Shape Manufacturing of New Titanium Powders for Industry

Consolidating New Titanium Powders Into Near Net Shape Using Innovative Technologies

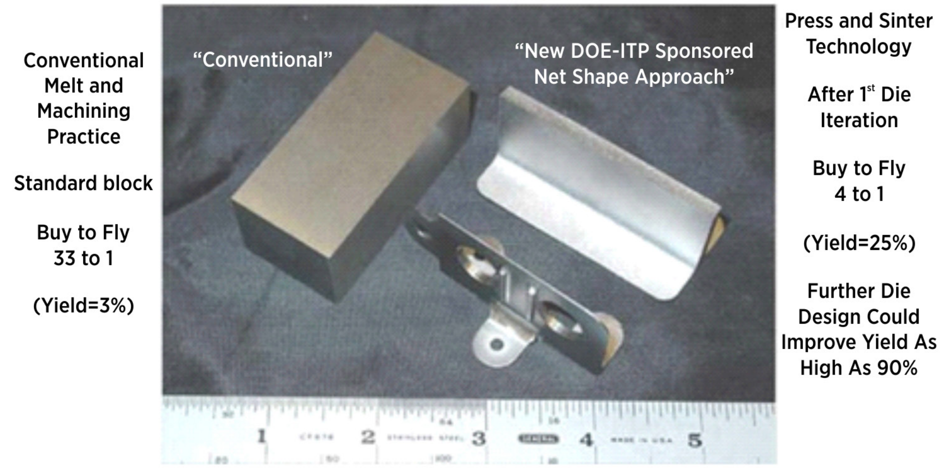
Introduction

Because of its high-strength, low density, excellent corrosion resistance, good elevated temperature performance, and allowance for damage tolerant design, titanium is a superior material for many applications. Broader and increased use of titanium in industrial applications would lead to significant energy savings and enhanced performance. However, the high cost and low availability of titanium has limited this opportunity. The elevated cost of titanium components is a result of the complex, multi-step production process and fabrication inefficiencies in the manufacture of titanium components.

The aerospace industry, which consumes over half of the U.S. titanium production, has very high scrap generation rates. On average, eight pounds of raw material must be machined to produce one pound of final product, with seven pounds of machinings discarded as waste. This low material efficiency results in high machining costs and significant energy consumption per pound of finished Ti product.

If the cost of titanium could be reduced by ~50%, its production and utilization in industrial applications would greatly increase. Recently, commercial titanium and titanium alloy powders produced by innovative lower-temperature processes, have become available. These new powders are powder metallurgy grade and could be used in solid state processing. To enable products from powder, researchers in this project investigated the full consolidation of these powders into low-cost, near-net-shape components using innovative technologies. This approach will improve yield by decreasing scrap generation. Also, the cost of titanium and energy consumption for processing can be significantly reduced, and provides the opportunity create a paradigm shift in the titanium market.

Die Pressed and Machined Ti-6Al-4V Lockheed Martin Component from Powder



A conventional titanium block (shown on the left) needs to be machined to achieve the desired final form (shown on the bottom) resulting in low yields. The pressed and sinter alternative (shown on the top right) can achieve much higher yields.
Photo courtesy of Oak Ridge National Laboratory

Benefits for Our Industry and Our Nation

Titanium components fabricated from powder metallurgy could have less than 5% to 10% scrap. When compared to conventional processes, the new titanium powders offer a 25% to 50% reduction in energy consumption.

Based on commercial estimates, the results of this project can help reduce the cost of titanium before machining by over 50% and the cost of aerospace titanium components by over 90%. Also, solid state consolidation of low cost titanium powders can reduce the energy used in the commercial aerospace industry.

Applications in Our Nation's Industry

The aerospace industry would greatly benefit from advances in titanium production. Other sectors that would benefit from low-cost titanium parts include: desalination, automotive, heat exchangers, chemical processing, nuclear industry, offshore petroleum, paper and pulp processing, defense applications, liquid natural gas processing, biomedical supplies, sporting equipment, and construction.

Project Description

The goal of this project was to develop a manufacturing technology to process new titanium powders into fully consolidated near net shape components for industrial applications. This was achieved through investigating various technologies including press and sinter, pneumatic isostatic forging (PIF), hot isostatic pressing (HIP), and adiabatic compaction.

Barriers

- Low tap densities of the new powders (6% to 8% of theoretical densities) present a challenge to volume reduc-tion and handling considerations.
- Designing an economic method of consolidating the powders while not picking-up interstitial impurities such as oxygen which limits performance.
- Obtaining fatigue properties for critical applications.
- Obtain part qualifications and market acceptance in sufficient quantity to sustain/grow demand.

Pathways

The project optimized the press and sinter parameters for processing the new, commercially pure (CP) titanium powders. In this step, low-tap densities of the powders were addressed by pressing and sintering to over 90% of theoretical density to eliminate interconnected porosity. Press and sintered net shape components were produced from the Ti and Ti-alloy powders.

Both HDH and Armstrong (CP Ti and Ti-6Al-4V) powders were fully consolidated. Direct hot isostatic pressing (HIP) and pneumatic isostatic forging (PIF) of Armstrong powder without canning achieved full consolidation with densities as low as 78% theoretical before isostatic pressing. A consolidation model was built for evaluation of press and sinter components. Mechanical properties including fatigue crack growth rate of HIP/PIFed titanium powder were comparable to the wrought materials. A first iteration of T-shape bracket made from powder reduced buy-to-fly ratio from 33:1 down to 4:1.

Electron beam deposition of titanium powder was also investigated to couple demonstration of additive manufacturing to the new Ti powders. The electron beam deposition of the same T-shape bracket further reduced the buy-to-fly ratio to between 2:1 and 1:1. Based on initial evaluations, an industrial partner is interested in pursuing further validation of electron beam deposited bracket.

A pump impeller was designed and built using electron beam deposition that decreased the component weight by 56% compared to conventional casting techniques currently used.

Milestones

This 3-year project started in September 2008 and was completed in 2012.

- Optimization of press and sinter consolidation to achieve above 90% of theoretical density for both new CP titanium and titanium alloy powders (completed).
- Fabrication of prototype near-net shape components and obtain OEM validation (completed).
- Fabrication of fully consolidated, low-cost, net shape components (an impeller for chemical pump manufacture and a bracket for aerospace applications) from titanium and titanium alloy powders (completed).

Commercialization

The project team was vertically integrated. To facilitate the commercialization of the technology, the project team included companies currently consolidating powder (e.g., AMETEK), and equipment manufacturers currently fabricating and utilizing titanium parts for the intended applications (e.g., Lockheed Martin). Equipment manufacturers, powder producers, and powder consolidators were provided more process and economic information to determine if an investment should be made to commercialize the technologies.

Project Partners

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DOE/EE-0464 • May 2013
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