Low Cost Titanium – Propulsion Applications

Pacific Northwest National Laboratory

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lm_22_lavender

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Overview

Timeline

Project start date: October 2008
Project end date: October 2009
Percent complete: 10%

Barriers

- Material limits
- Lack of investment in improving the traditional reciprocator platform
- Cost of advanced materials and their processing

Budget

Total project funding:
- DOE – $180 K
- Cost Share – 75%

Funding FY09: $180 K

Partners

Industrial CRADA Participant:
Cummins Inc.
- Dr. Yong-Ching Chen

Supplier Development:
ADMA Products Inc.
- Dr. Vladimir Moxson

Support:
Engine System Analyst – TBD

Objectives of Project

Reduce the cost to manufacture titanium components for reciprocating and rotating applications

- Evaluate the capability of an emerging low-cost titanium powder metallurgy production technology for use in fatigue rated applications
  - Currently, high cost wrought processed titanium is used in low volume high performance propulsion systems
  - By reducing the cost of titanium and the associated processing the performance benefit can be applied to more engine platforms thereby impacting US fuel consumption
- Assess the efficiency gain possible with increased use of titanium in propulsion systems

Deliverables

- Strain-controlled fatigue data from press/sintered and press/sintered/forged Ti6Al4V fabricated from TiH_2 powder
- An initial assessment of the efficiency gains possible with titanium used in rotating and reciprocating components

Technical Approach

- **Technology Development**
  - **This is a highly leveraged activity applying technology developed by a Department of Energy Global Initiative for Proliferation Prevention (DOE/GIPP) project performed in the Ukraine**
    - Fabricate test bars from low cost TiH_2 powder using low cost high yield powder metallurgy methods
      - Press, sinter
      - Press, sinter and forge
    - Fatigue test samples machined from test bars using a strain controlled fatigue test that has been used to qualify titanium materials in propulsion systems
    - Develop cost model for process deployment

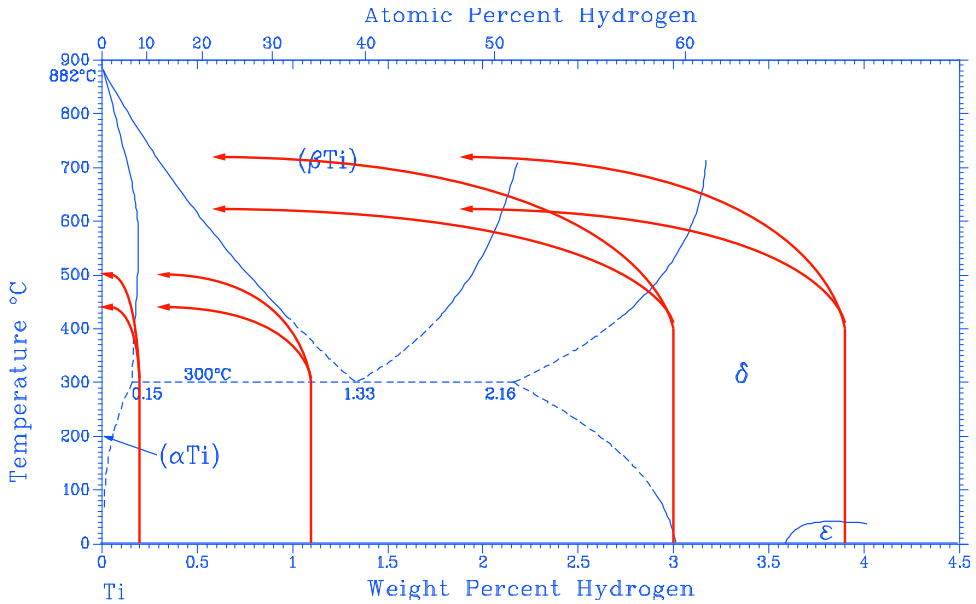
- **Technology Deployment**
  - The test methods are to be selected from procedures used by Cummins Inc. to qualify titanium materials and should be readily applicable to speed up the qualification
  - Test bars are to be fabricated at the commercialization partner of the DOE/GIPP project, ADMA Products Inc.
    - ADMA has been producing approximately 35,000 lbs of TiH_2 powder per year in the Ukraine
      - More vessels are readily available
      - US production under development

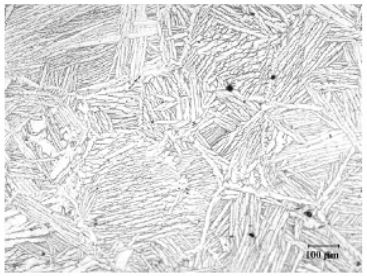
Technical Progress

- This is a new start project in October of 2008 and progress thus far:
  - A cursory cost analysis based on the DOE/GIPP project was made suggesting that a 50% cost reduction of forged Ti6Al4V through the use of TiH_2 may be possible
    - At this cost reduction it is probable that titanium will be used in more applications and engine systems
  - Cummins Inc. has identified components used in propulsion systems currently fabricated from titanium to use as a test article
  - Cummins Inc. has identified the most relevant mechanical properties test to evaluate the titanium material produced from TiH_2
    - Strain controlled axial fatigue at room temperature will be the initial test method

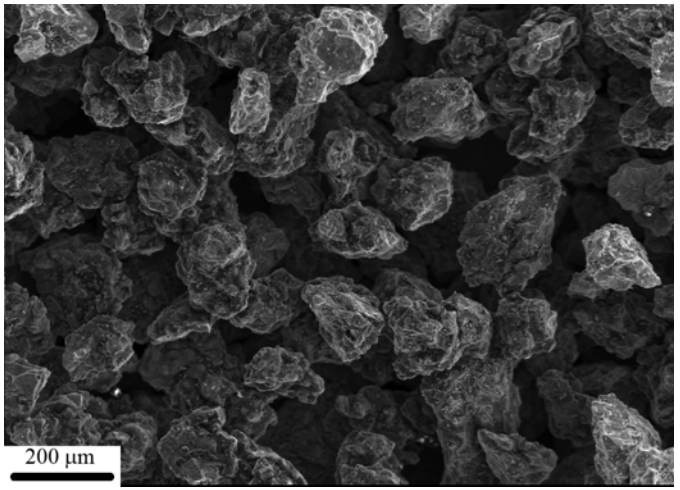
Low Cost Titanium Hydride Processing

- TiH_2 Powder – direct press and sinter to reduce machining loss
  - Greater than 96% dense
  - Fine grain sizes observed in TiH_2 pressings may meet the fatigue requirements
  - Will have application in other components i.e. valves etc…

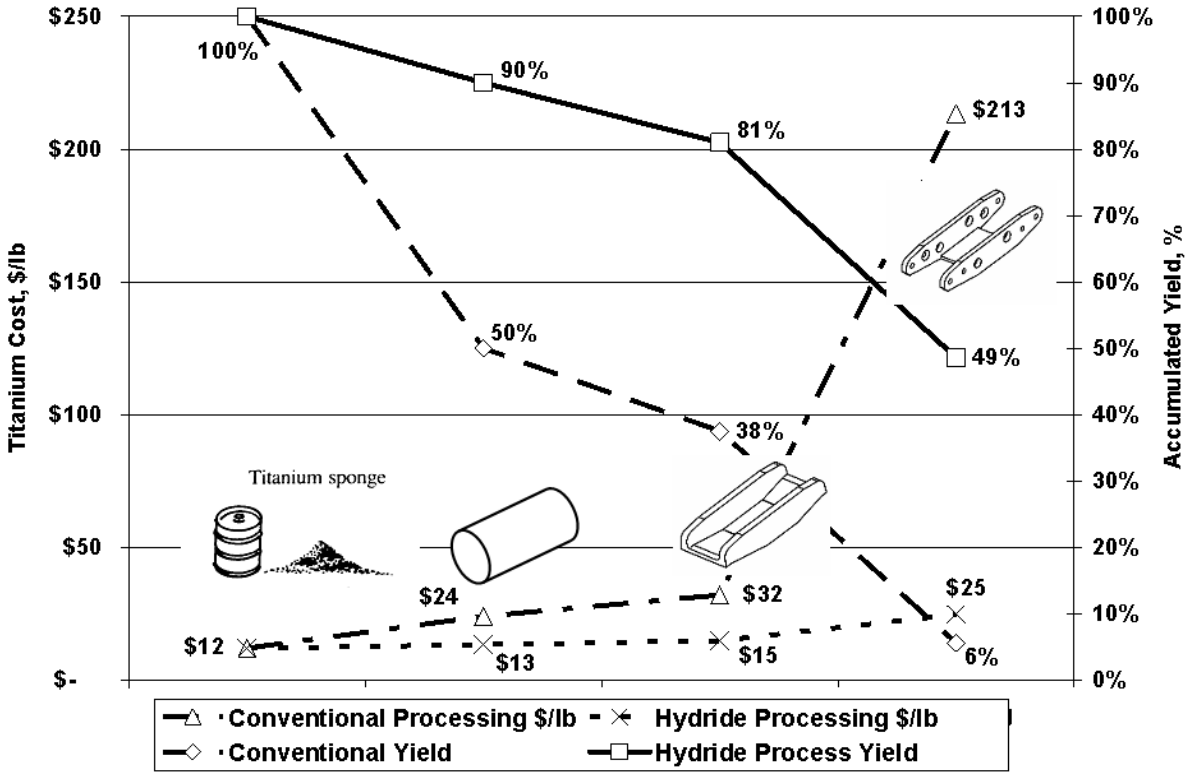




Fine as-sintered grain size



Low Cost Titanium Manufacture from TiH_2



- Elimination of large yield losses associated with ingot forging can reduce the cost of a forge blank or forging by 50%
  - Yield improvement associated with near-net shape powder metallurgy processing
- Machining requirement may be reduced by nearer-net shape processing
  - Currently 30% of part cost

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Product Forms – Ti Hydride

- Direct P/M

- Powder rolled sheet
- CIP/sinter for slab or billet

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Future Work

- Fabricate test bars and machine fatigue samples
  - ADMA will blend/press/sinter and PNNL will forge
- Perform strain controlled fatigue tests
  - PNNL
- Identify expert in engine efficiency analysis and perform analysis of efficiency improvement with titanium

Summary

- A titanium powder developed during a DOE/GIPP project appears to produce a product with mechanical properties sufficient for a propulsion application from a very low-cost press and sinter process
  - Could replace costly ingot processed forgings
    - Eliminates yield loss associated with ingot forging
    - Greater than 50% cost reduction predicted from yield savings alone
  - Unique properties are developed during sintering of TiH_2
    - High density – critical to fatigue initiation
    - Fine-grain size – import to reduce fatigue crack propagation
- Cummins Inc. has identified a relevant application using the Ti6Al4V alloy and provided the requirements to adequately assess the performance of the press/sinter/forged bars produced from TiH_2