Low Cost Titanium – Propulsion Applications

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## Overview

### Timeline

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<td>Project start date:</td>
<td>October 2008</td>
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<td>Project end date:</td>
<td>October 2009</td>
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<td>Percent complete:</td>
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### Barriers

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

### Budget

- Total project funding: $180 K
  - 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 TiH₂ 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 TiH₂ 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 TiH₂ 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 TiH₂ 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 TiH₂
  - 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…

![Graph showing atomic percent hydrogen vs. temperature for TiH$_2$](image)

- Fine as-sintered grain size
Low Cost Titanium Manufacture from \( \text{TiH}_2 \)

- 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
Product Forms – Ti Hydride

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

Direct P/M
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 TiH₂:
    - 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 TiH₂.