3. ADVANCED MATERIALS DEVELOPMENT

A. Low-Cost Powder Metallurgy Technology for Particle-Reinforced Titanium Automotive Components: Manufacturing Process Feasibility Study

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Objectives

- Demonstrate production-intent process scheme for fully densified titanium alloy powder metallurgy (PM) composite samples.
- Benchmark process capability using commercial-grade titanium powder feedstock, and follow with one of the proposed low-cost titanium powder materials. Blend additives to achieve final titanium alloy material with reinforcement.
- Perform microstructure characterization and interfacial studies.
- Confirm test specimens are crack-free by nondestructive evaluation method (Lawrence Livermore National Laboratory).
- Generate static mechanical properties and perform failure analysis.
- Perform a technical cost modeling study on the novel ADMA Products, Inc., process and establish sensitivity of each processing step for cost-effectiveness.

Approach

- Use titanium metal feedstock to produce blanks in simple shapes via the ADMA manufacturing process that will then be machined into coupons for mechanical property determination.

- Conduct microstructural and interfacial studies together with mechanical property testing.
- Perform a technical cost model on the ADMA manufacturing process.

Accomplishments

- Purchased and received raw materials required for the program.
- Produced powder blends of Ti-6Al-4V material from sodium-reduced titanium sponge fines without reinforcement (benchmark material) and Ti-6Al-4V without reinforcement from magnesium-reduced titanium sponge fines produced in Russia (lower cost alternative to benchmark material). Die-pressed powders in 0.500-in.-diameter carbide tooling to 0.500-in.-thickness for metallographic examination.
- Compacted and processed Ti-6Al-4V material from sodium-reduced titanium sponge fines into 3- by 5-in. blanks. Blanks were machined into tensile testing samples.
- Completed metallographic examinations on materials described above.
- Completed tensile tests on sodium-reduced material.

Introduction

The goal of this concept feasibility study is to develop a low-cost powder metallurgy (PM) manufacturing process to obtain fully dense parts based on current commercial-grade materials and a novel processing technology. The study will use particle-reinforced titanium metal feedstock in conjunction with PM press and sinter technology to manufacture simple parts for testing. A technical cost model will be performed to document the cost of the manufacturing process. The decision gate criteria are (1) a cost-competitive manufacturing process and (2) acceptable microstructure and mechanical properties that have been identified for connecting rods targeted for high-performance reciprocating engine applications.

Materials

Sample blanks (plates) have been manufactured using a baseline aerospace quality titanium material (RMI) and a low-cost Russian-grade material. Small samples of the materials were mounted and polished followed by etching for 8 s using Kroll’s reagent. Photomicrographs were taken using a digital camera connected to a Leco metallograph.

Ti-6Al-4V from sodium-reduced titanium sponge fines (RMI “commercial” product): As-compacted density of the samples is 87%, and density after sintering at optimized temperature is more than 99% of theoretical. Metallographic analysis revealed homogeneous microstructure with a basket weave morphology (Figure 1). Level of detected porosity is less than 1%.

Ti-6Al-4V from innovative magnesium reduced-titanium sponge fines produced in Russia: As-compacted density of the samples is 84%, and density after sintering at optimized temperature is more than 99% of theoretical. Metallographic analysis revealed homogeneous microstructure with a basket weave morphology (Figure 2). Level of detected porosity is less than 1%.

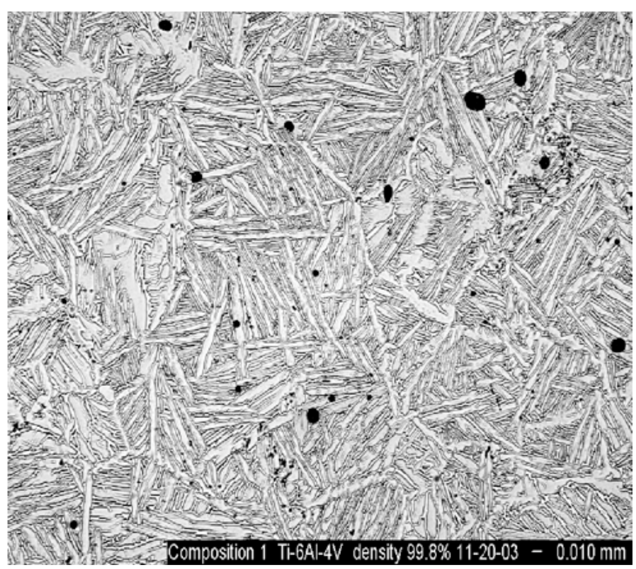

Figure 1. Ti-6Al-4V from sodium-reduced titanium sponge fines (RMI “commercial” product).

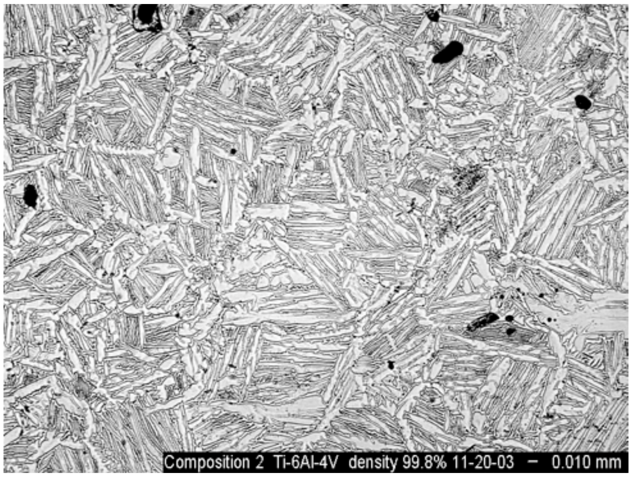

Figure 2. Ti-6Al-4V from innovative magnesium-reduced titanium sponge fines produced in Russia.

Mechanical Properties

Tensile test results shown in Table 1 are for Ti-6Al-4V sodium titanium powder without reinforcement. Both ultimate (UTS) and yield (0.2% YS) strength are higher than that specified by the American Society of Testing and Materials (ASTM) (UTS—130 ksi and 0.2% YS—120 ksi). Ductility is also higher than ASTM requirements (ASTM B348 for forged bars and billets specifies elongation—10%, RA—25% and ASTM B367 for castings specifies 6% elongation).

Ongoing—Future Work

- Manufacture blanks (plates) from Ti 6Al-4V sodium titanium powder with reinforcement. Heat treat to optimize mechanical properties.
- Manufacture blanks (plates) from International Titanium Powder, Inc. (ITP) ("low-cost" alternative) without reinforcement. Heat treat to optimize mechanical properties.
- Perform microstructural and interfacial characterization.
- Perform nondestructive evaluation to confirm tensile samples are crack free.
- Generate static mechanical properties.
- Perform failure analysis on tensile samples.
- Complete cost model on ADMA manufacturing process.
- Assess cost model and mechanical properties against decision gate criteria.

Table 1. Mechanical properties of Ti-6Al-4V without reinforcement

Composition	Sample No.	Tensile strength (ksi)	Yield strength (ksi)	Elongation (%)	Reduction of area (%)	Modulus of elasticity (msi)
Ti6A1-4V from sodium-reduced titanium sponge fines (RMI "commercial" product)	1	143.2	123.1	12.2	18.2	16.9
	2	143.6	123.7	13.8	19.6	18.3
	3	142.6	122.8	11.4	16.5	16.7
	4	142.7	123.1	11.8	23.3	16.8
Ti-6A1-4V from ASTM Standard B348-03 Grade F-5		130	120	10	25	