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

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Objective

- 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

- Produced powder blends of Ti-6Al-4V material from Sodium Reduced Ti sponge fines with and without reinforcement (benchmark material).
- Received powder blend of Ti-6Al-4V material from International Titanium Powder (ITP) without reinforcement (low-cost alterative).
- Die-pressed powders in 0.500-in.-diameter carbide tooling to 0.500-in. thickness for metallographic examination.
- Compacted and processed powder blends into 3 inch x 5 inch blanks for tensile samples.
- Sintered in vacuum furnace, optimized heat treatment.
- Machined blanks into tensile samples.
- Completed metallographic examinations and tensile tests.
- Completed fracture analysis on composite material.

Introduction

The goal of this concept feasibility study is to develop a low-cost 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.

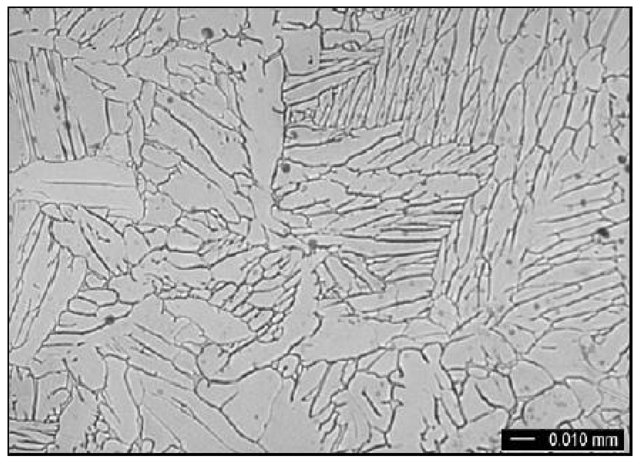

Figure 1. Ti-6Al-4V from Sodium Reduced Ti sponge fines (RMI "commercial" product).

Materials

Sample blanks (plates) have been manufactured using a baseline aerospace-quality Ti material (RMI) and a low-cost alterative material from International Titanium Powder (ITP). Small samples of the materials were mounted and polished followed by etching for eight seconds using Kroll's reagent. Photomicrographs were taken using a digital camera connected to a Leco metallograph.

Ti-6Al-4V from Sodium Reduced Ti sponge fines (RMI "commercial" product): The density of un-reinforced samples after compaction and sintering was greater than 99% of theoretical full density. Metallographic analysis revealed homogeneous microstructure with a basket weave morphology (Figure 1). Level of detected porosity is less than 1%. Samples reinforced with titanium carbide (TiC) had densities greater than 90% of theoretical full density. TiC was formed from elemental powder (Ti and graphite). Figures 2 and 3 show Ti-6Al-4V(RMI) with 10% and 20% TiC, respectively.

Ti-6Al-4V from International Titanium Powder: The ITP powder was compacted and sintered without TiC reinforcement. After an initial sintered density of 65% of theoretical full density, several compaction and sintering iterations were required to obtain a sintered density of 90+%. Figure 4 shows the microstructures of the compacted and sintered ITP material at 65%, 86%, and 90+% density.

Mechanical Properties

Tensile test results from Ti-6Al-4V Sodium Ti samples without TiC reinforcement and with10%

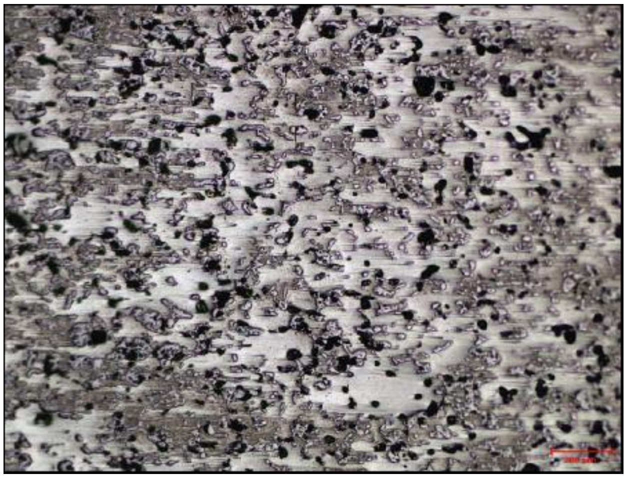

Figure 2. Ti-6AAl-4V + 10% TiC from Sodium Reduced Ti sponge fines (RMI "commercial" product).

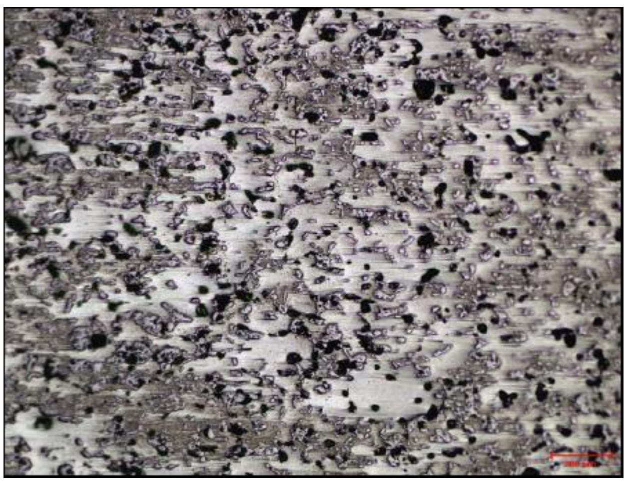

Figure 3. Ti-6AAl-4V + 20% TiC from Sodium Reduced Ti sponge fines (RMI "commercial" product).

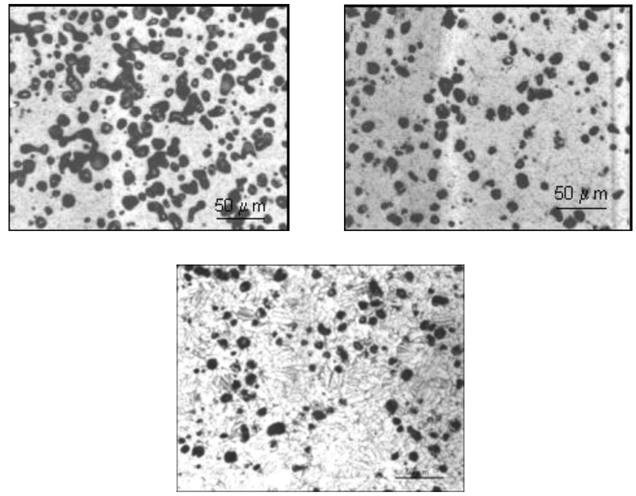

Figure 4. Ti-6AAl-4V ITP material at 1) 65%, 2) 86%, and 3) 90+% density.

and 20% TiC reinforcement and are shown in Table I. The Ultimate (UTS) and Yield (0.2%YS) strength are higher than that specified by ASTM (UTS -130 ksi and 0.2%YS – 120 ksi) for both the un-reinforced material and the material with 10% TiC reinforcement. Tensile testing on the ITP material is in progress.

On-Going / Future Work

- Complete cost model on ADMA manufacturing process.
- Assess cost model and mechanical properties against decision gate criteria.
- Complete USAMP final report.
- Begin process for phase II (manufacture component – connecting rod).

Table 1. Mechanical Properties of Ti-6Al-4V

Composition	Sample No.	Tensile Strength (ksi)	Yield Strength (ksi)	Elongation, %	Modulus of Elasticity, MSI
Ti-6Al-4V from sodium reduced Ti sponge fines (RMI "commercial" product)	1	143.2	123.1	12.2	16.9
	2	143.6	123.7	13.8	18.3
	3	142.6	122.8	11.4	16.7
	4	142.7	123.1	11.8	16.8
Ti 6Al-4V + 10% TiC	1	150.3	143.5	3.0	17.7
	2	151.4	137.9	3.0	17.7
	3	150.4	142.4	3.0	17.9
	4	150.1	143	2.0	18.1
	5	148.5	141.1	2.0	17.5
Ti 6Al-4V + 20% TiC	1	115	115	2.0	18.3
	2	119.2	119.2	1.0	19
	3	124.5	124.5	2.0	20.1
	4	122.3	122.3	2.0	19.5
	5	121.5	121.5	2.0	19.6
Ti-6Al-4V from ASTM Standard B348-03 Grade F-5		130	120	10.0	