O. Ti-6Al-4V Billet Feedstock Manufacture and Evaluation

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Objectives

- Develop a low-cost Ti-6Al-4V billet feedstock using a blend of titanium (Ti) and alloy powders and inexpensive Ti-6Al-4V machine turnings.
- Evaluate this low-cost Ti alloy feedstock as a starting billet material for casting, forging, and extrusion operations.

Approach

- Develop a procedure for producing low-cost Ti billet using a combination of inexpensive Ti alloy machine turnings and Ti and alloy powders. Evaluate the billet for density and microstructure.
- Produce a total of nine billets for use as a starting material in casting, forging, and extrusion operations. The three operations will yield Ti-6Al-4V test bars.
- Evaluate the quality of the test bars produced through chemistry and mechanical testing.

Accomplishments

- Selected a supplier of high-quality Ti-6Al-4V turnings.
- Produced a billet using a core of a turnings/powder blend, surrounded by a solid powder "can," with very low void content.
- Produced a billet using 100% turnings, achieving full density, using a cold + hot isostatic pressing technology with conventional canning in mild steel for the hot isostatic pressing (HIP) operation.
- Produced a high-density billet containing 60% turnings/40% Ti alloy powder that was produced using a core of 100% turnings, surrounded by a can made from Ti alloy powder. This billet will be used to cast test bars.

Future Direction

- Produce eight additional Ti-6Al-4V billets using the procedures being developed by Dynamet. These billets will incorporate three selected processing variations.

- Produce test bars from the feedstock using three different technologies that would benefit from low-cost feedstock: casting, forging, and extrusion.
- Evaluate the resulting test bars for chemistry and tensile properties.

Introduction

Dynamet proposed to develop Ti-6Al-4V alloy billet feedstock manufactured using a combination of Ti alloy powder blended with inexpensive Ti alloy fine turnings. The blended alloy powders plus turnings will be consolidated to high density billet by isostatic pressing, vacuum sintering, and HIP (Figure 1). The process will be optimized to produce billets with the highest-possible percentage of turnings, thereby minimizing billet cost, while maintaining acceptable chemistry and process capability. Nine alloy billets will be subsequently (a) cast, (b) forged and (c) extruded to test bars (three billets for each operation). The resulting test bars will be evaluated for chemistry and mechanical properties.

Results

The results to date include the selection of a source of fine Ti-6Al-4V turnings, initial trials involving the pressing of turnings/powder blends, and further process improvements that resulted in a Ti-6Al-4V billet with its center composed of 100% turnings surrounded by an integral Ti alloy can.

Four suppliers of Ti-6Al-4V turnings have been identified and contacted. These suppliers have all sent samples, which were evaluated for chemistry and compactibility. Based upon these evaluations, and the supplier's ability to provide large quantities of fine turnings, the turnings from one supplier have been selected for this program.

Initial trials involved mixing the turnings with powder, packing the turning/powder mixture into Ti-6Al-4V P/M cans, and cold isostatic pressing the filled cans to form billets. Using this method, Dynamet

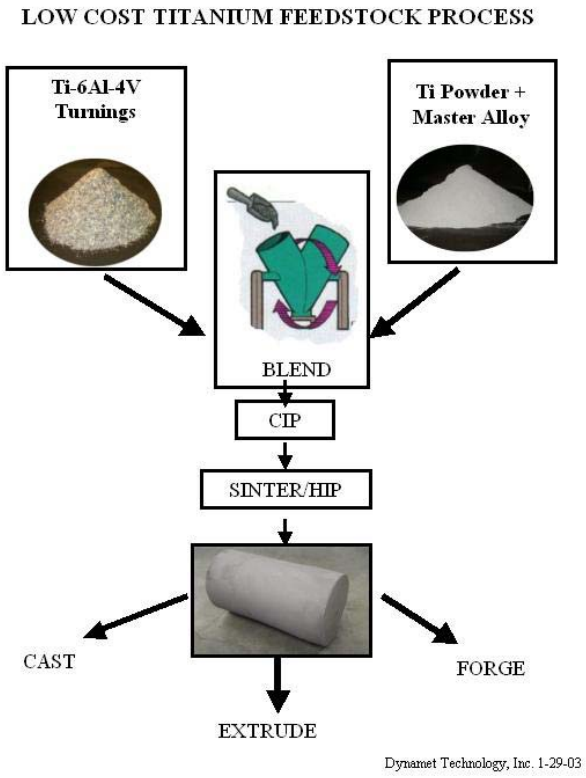

Figure 1. Dynamet's proposed approach to forming low-cost Ti alloy billet involves the blending of Ti powder with inexpensive Ti-6Al-4V machine turnings.

successfully produced a billet containing a low percentage of voids (Figure 2). The turnings/powder blend core was surrounded by a ring of Ti alloy powder. The outer powder layer forms a solid layer of Ti alloy during sintering, with no surface-connected porosity. This solid skin of Ti allows HIP of the billet without canning. While this method was successful in producing a billet, further trials will concentrate on increasing

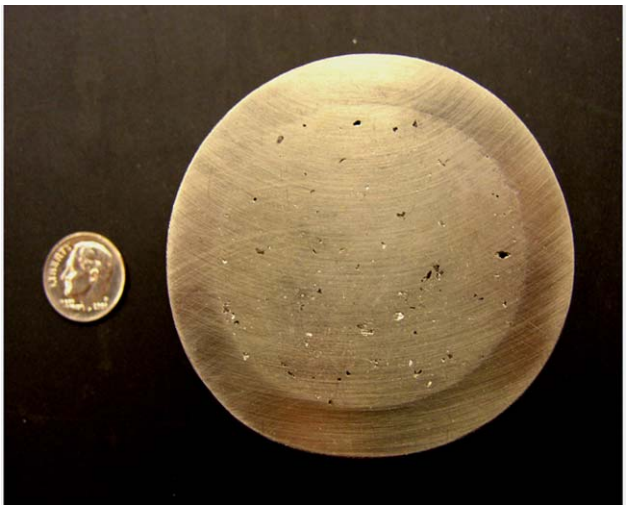

Figure 2. Cross-section of a billet produced by Dynamet from a core of turnings/ powder blend and "can" of Ti alloy powder.

the percentage of turnings to maximize the economic advantage.

Further trials used discs die-pressed from 100% turnings (Figure 3). These discs were pressed to 80% density. The discs were

Figure 3. Discs die-pressed to 80% density from high-quality machine turnings.

stacked and sintered to form a solid cylinder of 100% turnings, achieving approximately 85% density (Figure 4). Dynamet has demonstrated that these cylinders can be consolidated to full (100%) density using HIP. However, because of the cylinder's

Figure 4. The stacked discs are sintered to form cylinders of 100% turnings.

residual interconnected porosity, the cylinder had to be canned in a custom-made mild steel container, welded and evacuated prior to HIP (Figure 5).

Figure 5. The custom-made evacuated steel "can" used to hot isostatically press the cylinder made from 100% turnings.

The next trial was aimed at eliminating the need for steel canning. A cylinder made from sintered discs of turnings was inserted in a thin-wall as-pressed Ti-6Al-4V can made with Dynamet's powder metallurgy/cold isostatic pressing technology (Figure 6). This can becomes an integral part of the billet during the sintering and HIP. The can and discs were successfully processed by HIP to form an integral billet (Figure 7) without the

Figure 6. By enclosing the cylinder of turnings in a "can" made from the Ti alloy powder, Dynamet eliminated the need for steel canning. The can becomes an integral part of the billet.

Figure 7. The solid billet produced using a core of 100% turnings, and a "can" of Ti powder blend.

expensive and material- and labor-consuming steps of canning (and decanning) in steel. This billet contained approximately 60% turnings and 40% powder. Future efforts will be aimed at processing refinements to decrease the thickness of the outer Ti wall, thereby increasing the percentage of low-cost turnings used in each billet.

The initial billet produced using the Ti alloy can will be supplied to Howmet for casting trials and evaluation.

Conclusions

Dynamet is developing a viable method for commercially producing low-cost Ti-6Al-4V billet feedstock by combining inexpensive machine turnings with Ti and alloy powders. In the ongoing program, the applicability of these low cost Ti-6Al-4V alloy billets as feedstock for casting, forging, and extrusion operations will be assessed. Additionally, the resulting properties of the finished Ti-6Al-4V alloy material will be determined.