Titanium and Ti6Al4V parts processed by metal injection moulding

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Introduction: Titanium and titanium alloys are excellent materials for biomedical applications because of their high specific strength, low density, good corrosion resistance and biocompatibility. A growing demand of the industry for low-cost processing of complex parts is the driving force for the development of new fabrication techniques. Recent advances in the production of high quality base-powders made of powder metallurgy a good alternative [1, 2]. In this work, net-shape manufacturing of Titanium and Ti6Al4V parts has been performed by powder injection moulding [3].

Materials and Methods: Titanium parts have been manufactured from titanium hydride TiH_2 powders (AG Materials Inc., Taiwan), which were mixed with a polymer binder to form a feedstock suitable for injection moulding. The binder consisted of 55 wt% paraffin wax, 35 wt% low density polyethylene and 10 wt% stearic acid. The binder volume fraction was of about 40 vol%. After shaping, the parts were subjected to successive steps of debinding, dehydrogenation and sintering. Binder removal was accomplished by solvent debinding in heptane at 50°C followed by thermal debinding in a MIM furnace at 500°C under argon atmosphere. After dehydrogenation, sintering was performed at 1200°C under argon atmosphere.

In addition, Ti6Al4V parts have been manufactured from prealloyed powders (AP&C Advanced Powder & Coatings Inc, Canada), which were mixed with the same binder used for titanium hydride-based feedstocks.

Polymer-powder feedstocks were prepared in a Coperion Werner & Pfleiderer double sigma mixer. Tensile test specimens and test parts were injection moulded in an Arburg 221K machine. Debinding & sintering was performed in a Nabertherm VHT16-MO MIM furnace. Quantitative analysis was performed by fusion and infrared detection with LECO systems to establish the content of interstitial elements O, N , C in sintered parts.

Results and Discussion: Figure 1 shows a green part (as injected), a brown part (after solvent debinding), and a net-shape part (after debinding and sintering). Good green strength is due to polyethylene, which is the backbone polymer of the multicomponent binder. The goal of the solvent debinding step is to remove paraffin wax and stearic acid, leaving an open porosity to allow proper thermal debinding of the backbone polymer. In this way, bubble gas formation during polymer burnout is avoided, reducing internal stresses and the risk of part damage or geometry distortion.

Figure 1: green, brown and sintered Ti6Al4V parts

The final linear shrinkage of sintered Ti6Al4V parts is of about 13%. For sintered Titanium parts, the linear shrinkage is higher (about 19%), because an additional contraction occurs during the dehydrogenation of the TiH_2 base powder.

MIM titanium parts have a density higher than 98% of the theoretical density and tensile strength of up to 700 MPa, but poor ductility. This is related with a too high oxygen content of about 0.6 wt% measured by fusion and infrared detection (for a nominal oxygen level of 0.2% for the base powder).

MIM Ti6Al4V parts have densities of about 92% of the theoretical density. Despite residual porosity, which can be observed in Figure 2, good mechanical properties were obtained. Tensile strength values of up to 780 MPa and ductile behaviour with up to 8.6 % strain were measured. This mechanical performance is possible due to the low content of interstitial elements, which is below the acceptable limits for the standard grade as revealed by quantitative analysis (Table 1)

Ti6Al4V	O [wt%]	N [wt%]	C [wt%]
powder	0.09	<0.01	0.02
MIM	**0.14**	**<0.02**	**<0.06**
standard grade	0.20	0.05	0.10

Table 1: interstitial content of Ti6Al4V powder (data sheet), MIM parts (measured) and standard grade

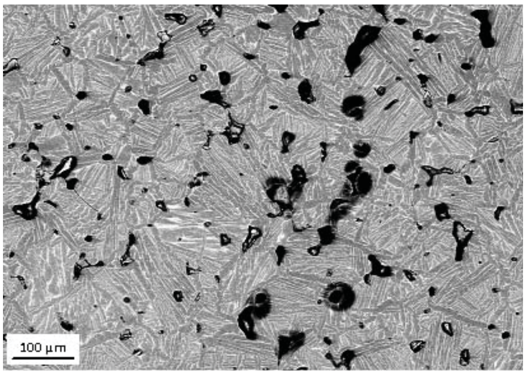

Figure 2: microstructure of MIM Ti6Al4V alloy

Concluding remarks: The final properties are strongly dependent on powder purity and processing steps. High levels of interstitials are detrimental for mechanical properties. Special care in powder selection and handling, feedstock preparation, debinding and sintering atmospheres, allowed to obtain low residual oxygen, nitrogen and carbon contents. Ti6Al4V injection moulded parts show good mechanical properties, good shape preservation and reproducibility.

References:

- F. H. Froes, Met. Powder Rep., **61**, 11, 2006, pp. 20-23
- T. Ebel, Powder Injection Molding International, **2**, 2, 2008, pp. 21-30
- R. M. German and A. Bose, Injection Molding of Metals and Ceramics, MPIF, Princeton, NJ, 1997