Establishment of Process of Manufacture of Ti-6Al-4V Alloy Sintering Body by MIM

A.Otsuka, K.Suzuki, and M.achikita

Sagami Plant, Electronics Division, Sumitomo Metal Mining, Shimotsuruma3860, Yamatoshi, Kanagawa 242-0001, Japan
Akihito_Ootsuka@ni.smm.co.jp, KunihikoK_Suzuki@ni.smm.co.jp, Masakazu_Achikita@ni.smm.co.jp

Abstract

Ti-6Al-4V has low specific gravity, high corrosion resistance and superior mechanical properties but it is very difficult to control oxygen content in MIM process. It is necessary to use powders with coarse particle size to decrease oxygen content of powders, so feedstocks with poor fluidity and sintered bodies with lower density are obtained in such cases.
Fine titanium hydride-dehydride powders were blended with atomized powders to accomplish higher fluidity and sintered density. Sintered bodies had higher sintered density and mechanical properties equivalent to those of wrought materials by controlling oxygen content less than 0.35mass%.

Keywords : powder injection molding, Ti-6Al-4V, oxygen content, mechanical properties

1. Introduction

Ti-6Al-4V has low specific gravity, high corrosion resistance, and superior mechanical properties with strength and durability, etc. But its durability decreases greatly by the reaction with oxygen at 773K or above temperature. It is necessary to use powders with low oxygen content to obtain sintered bodies with high durability. Generally gas atomized powders and water atomized powders are used for MIM process. However, it is difficult that they satisfy both low oxygen content and fine powder size requirements. In the case of using coarse powders with low oxygen content, it is difficult to obtain good green bodies because of its low fluidity, and the mechanical properties of sintered bodies become lower than those of the ones using fine powders. So, we evaluated the effects of fine titanium hydride-dehydride powders (H.D. powders) on the mechanical properties and attempted to decrease oxygen content of sintered bodies by optimizing the mixing ratio of gas atomized powders and fine H.D. powders, and applied the best optimized conditions to actual products with thin walls.

2. Experimental

Table 1 shows chemical composition and average diameter of powders used in this work. As shown in **Table 2**, feedstocks from F1 to F4 were obtained by mixing these powders and a wax-based binder.

Table 1. Chemical analysis and average diameter of used powders

Powder	Chemical composition (mass%)					A.D. (μm)
	Ti	Al	V	C	O	
G.Ti	Bal.	-	-	0.01	0.12	23
H.D.Ti	Bal.	-	-	0.01	0.24	18
Al-40V	-	Bal.	39.9	0.01	0.26	20

G.Ti :Gas atomized Ti powder, H.D.Ti :Hydride-dehydride Ti powder, Al-40V :Crushed powder, A.D. :Average diameter

Table 2. Mixing ratio and oxygen content of feedstocks

Feedstock No.	Mixing ratio of powders (mass%)			Total oxygen content (mass%)	Binder content (mass%)
	G.Ti	H.D.Ti	Al-40V		
F1	90	0	10	0.16	9.5
F2	70	20	10	0.18	12.0
F3	60	30	10	0.19	13.0
F4	50	40	10	0.20	14.0

The binder content was adjusted for all the feedstocks to obtain the same shrinkage ratio. These feedstocks were injected into the tensile test piece, then were debound thermally in nitrogen atmosphere and sintered according to the sintering profile shown in **Fig.1**. The fluidity and shape-keeping ability of the feedstocks were evaluated by appearance of the green bodies and the brown bodies. Tensile strength and elongation of the sintered bodies were measured by the tensile test. Density of the sintered bodies was measured by the Archimedes principle.

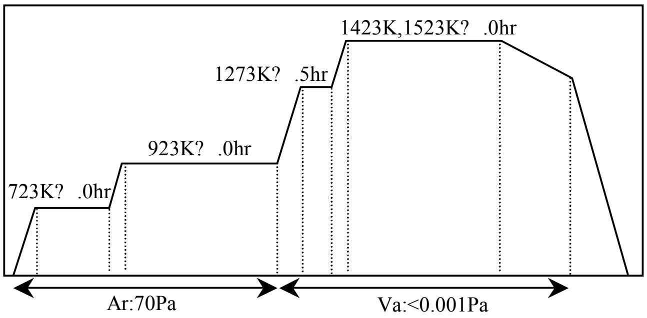

Fig. 1. Sintering profile

The actual samples with thin walls (0.5mm) for mass production were injected by using the best feedstock produced in F1 to F4. After the green bodies were debound, the sintered bodies with various oxygen content were obtained by controlling the sintering conditions. Fracture load of the actual samples was measured by pressing with a mechanical machine.

3. Results and Discussions

Table 3 shows the evaluation results by the appearance of the green bodies and the brown bodies using the feedstocks from F1 to F4. The fluidity and shape-keeping ability were not enough in the case of F1 without H.D. powder. On the other hand, in the case of H.D. powder by 30% or more added samples such as F3 and F4, they showed good results.

Table 3. Appearences of green and brown bodies (Tensile specimens)

Feedstock No.	Green bodies	Brown bodies
F1	Short shot	Deformation
F2	Short shot	Good
F3	Good	Good
F4	Good	Good

Table 4 shows relative density and oxgen content of the sintered bodies at 1423K and 1523K in the case of the feedstocks from F2 to F4. Higher density (above 95%) was attained at any temperature. But oxygen content at 1523K was higher than that of 1423K.

Table 4. Relative density and oxygen content of sintered bodies (Tensile specimens)

Sintered bodies No.	Feedstock No.	Sintering temperature (K)	Relative density (%)	Oxygen content (mass%)
F2-1	F2	1423	95.0	0.30
F2-2	F2	1523	97.1	0.42
F3-1	F3	1423	95.9	0.31
F3-2	F3	1523	98.0	0.45
F4-1	F4	1423	95.5	0.33
F4-2	F4	1523	97.7	0.46

Table 5 shows the mechanical properties of the sintered bodies and wrought materials. The sintered bodies at 1523K showed high tensile strength but low elongation. F3-1 showed the best mechanical properties equivalent to the wrought materials.

Table 5. Mechanical properties of sintered bodies and wrought materials (Tensile specimens)

Processing	Sintered bodies No.	Tensile strength (MPa)	Elongation (%)
MIM	F2-1	884	12.8
	F2-2	986	5.0
	F3-1	917	12.8
	F3-2	1007	4.7
	F4-1	899	11.7
	F4-2	1004	3.8
Wrought	-	980	14.0

Fig. 2 shows the relationship between oxygen content and fracture load of the actual samples at the condition of F3-1. These results suggest that the fracture load more than $1 kg/cm^2$ is attained by controlling oxygen content of the sintered bodies to be 0.35mass% or less, and is almost corresponding to the threshold of the tensile tests (**Table 3,4**). It is necessary to satisfy this oxygen content to obtain the sintered bodies with superior mechanical properties.

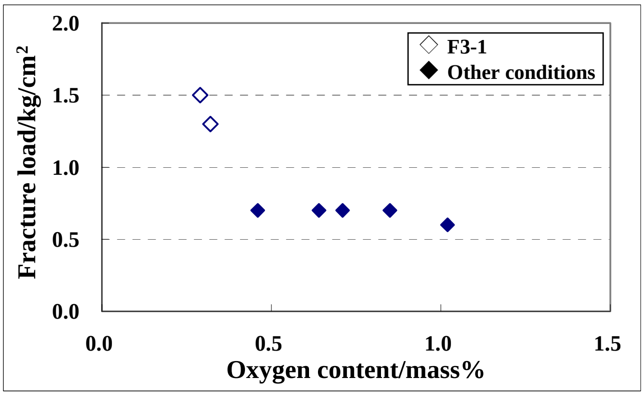

Fig. 2. Relationship between oxygen content and fracture load of sintered bodies (Actual samples)

4.Conclusions

1) Fluidity and shape-keeping ability were improved by optimizing the mixing ratio of gas atomized powders and fine H.D. powders.

2) Mechanical properties equivalent to wrought materials and superior fracture load were attained by controlling oxygen content of the sintered bodies to be less than 0.35mass%.