Metal Injection Moulding of Duplex Stainless Steels

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Abstract

In this communication the development of a new metal injection moulding (MIM) system for duplex stainless steels is presented. The metal powders were prepared by premixing 316L and 430L stainless steels gas atomised powders in a ratio of 50:50. The binder used to prepare the feedstock was composed by HDPE and paraffin wax. Torque measurements of the mixture indicated that the maximum amount of metal was 68 vol %. The polymeric part was driven off by thermal debinding and the sintering was performed in low vacuum. The final densities were close to the theoretical ones.

Keywords : metal injection moulding, duplex stainless steels

1. Introduction

MIM is a technique to manufacture complex shaped components from filled systems containing metal powders, and thermoplastics or thermosetting binders [1]. The major advantages of this technology include high product density, more intricate shape, higher mechanical properties, and better surface finish than for conventional powder metallurgy products.

Injection moulding of premixed 316L and 430L powders develops microstructures consisting of ferrite and austenite which produce a combination of good properties such as corrosion resistance, strength and toughness [2, 3].

2. Experimental and Results

The metal powders were gas atomised 316L and 430L with a spherical shape morphology. Table 1 summarizes some of the characteristics of powders used in this study. The optimized binder was a 50:50 mixture of HDPE and paraffin wax, which was developed for other systems in our laboratory [4, 5]. The powder mixture of 50 vol % 316L with 50 vol % 430L was pre-mixed in a turbular mixer for about 15 min. Powder-polymer mixtures were carried out in a Haake Rheocord machine. Three powder volume percentages were used: 50, 68 and 70. Mixing speed was 80 rpm and mixing temperature was 175 ºC. When the torque reached a steady state value it was assumed to obtain a uniform mixture. Figure 1 shows the mixing behaviour of the three tested mixtures. In the case of 70 vol % loading, the steady state torque was not achieved even after 30 min of mixing. However, a homogeneous mixture was attained for 68 vol % powder loading after 30 min.

Table 1. Characteristics and chemical composition of powders (%wt)

316L (80% less than 22 µm)								
Fe	C	Cr	Ni	Mo	Si	Mn	S	P
Balance	0.02	17.29	10.83	2.37	0.65	1.44	0.006	0.023
Pycnometric density: 7.94 gcm^{-3}								
430L (90% less than 16 µm)								
Fe	C	Cr	Si	Mn	S	P		
Balance	0.026	16.2	0.75	0.71	0.008	0.029		
Pycnometric density: 7.70 gcm^{-3}								

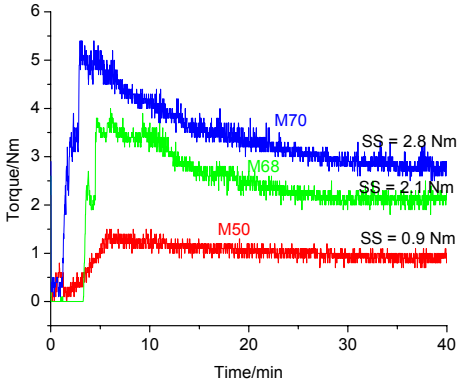

Fig. 1. Mixing behaviour at different volumetric powder loadings.

The feedstock was granulated and moulded on an injection moulding machine (Arburg 220S, 250-60). The injection temperature was 175 ºC, and mould temperature was 40 ºC. Moulded parts were three point bending test specimens. Thermal debinding cycle is shown in Figure 2.

Samples debounded at 450 ºC had an average residual carbon content of 0.02 wt % as determined by elemental analysis with a LECO instrument.

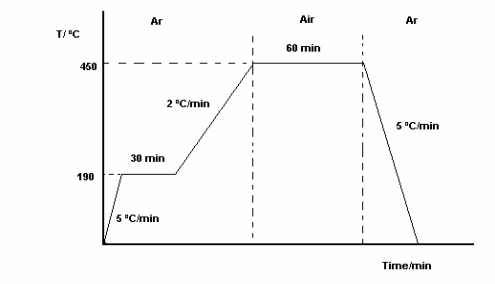

Fig. 2. Optimized debinding cycle.

Sintering of debound specimens was performed in vacuum at 1200 ºC for 1 hour. The specimens sintered achieved an average density of 7.49 gcm^{-3} (96% of theoretical density). Beraha etchant (1 g $K_2S_2O_5$ + 10 ml HCl in 100 ml solution) was selected to reveal duplex microstructure which is shown in Figure 3 by optical microscopy. Bright contrast corresponds to ferrite while the small amount of austenite corresponds to dark contrast. The very few amount of austenite was also confirmed by XRD experiments.

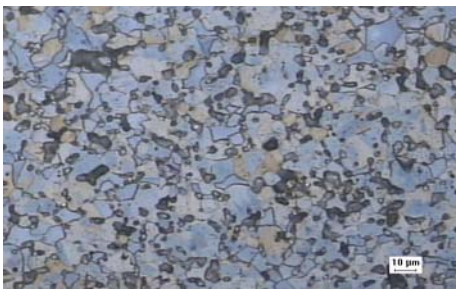

Fig. 3. Optical micrograph of the sintered duplex stainless steel produced by MIM process.

Figure 4 shows X-ray diffraction patterns of 1200 ºC sintered specimen, a mixture 50:50 of metal powders 316L and 430L, and a convencional 2205 duplex stainless steel bar. Considering that after sintering process the cristalinity of the different phases has not been reduced, the total amount of austenite after sintering is much lower than the original one in the starting powder mixture. This fact indicates that during sintering some transformations occur involving both ferrite and austenite, which promote the destabilization of the latter. This fact was studied in conventional PM parts where Ni seems to diffuse into ferrite during sintering [6].

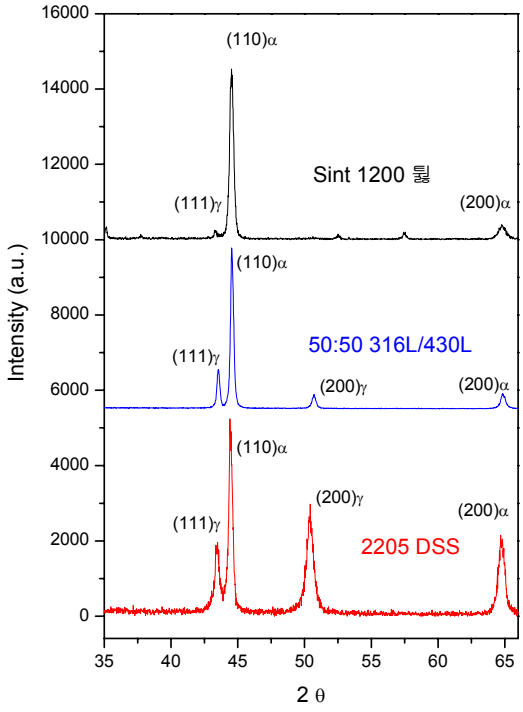

Fig. 4. X-ray diffraction patterns of 1200 ºC sintered specimen, a mixture 50:50 of metal powders and a conventional 2205 duplex stainless steel bar. Miller Indexes of different phases are indicated. α and γ subscripts correspond to ferrite and austenite.

3. Summary

Duplex stainless steels parts have been obtained by MIM using a binder system based on HDPE and PW. Every stage of the process to obtain duplex stainless steels by MIM was optimized. A 50:50 316L and 430L powder mixture was evaluated showing that after sintering austenite destabilization takes place. Different ratios of these powders to obtain feedstock and sintering conditions should be investigated in order to improve duplex microstructure.

4. References

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