Effect of Residual Carbon on the Microstructure Evolution during the Sintering of M2 HSS Parts Shaping by Metal Injection Moulding Process

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Abstract

In this present investigation, Metal Injection Moulding (MIM) of M2 High Speed Steel (HSS) parts using a wax-High Density Polyethylene (HDPE) binder is shown. The elimination of organic binder was carried out by thermal debinding under inert atmosphere. In order to keep carbon in the sample that could improve the sintering process, incomplete debinding was performed between 450 and 600 ºC. The specimens were sintered at temperatures between 1210 and 1280°C in high vacuum atmosphere, obtaining the 98% of the theoretical density. In the samples with higher residual carbon content, the sintering window was extended up to 20 degrees and the optimum temperature was lower.

Keywords : Metal Injection Moulding (MIM), High Speed Steel (HSS), debinding, sintering

1. Introduction

Powder injection molding (PIM) is becoming a cost-effective production route for relatively small, complex and high performance components that brings together the diversity of conventional PM and the geometric freedom of component design associated with thermoplastic injection molding [1].

The application of Metal Injection Moulding (MIM) process to High Speed Steel (HSS) has been developed in the recent years, and nowadays it is a production technology used as an alternative to obtaining parts of steel with a homogenous distribution of carbides on the matrix to enhance the final mechanical properties. The principal difficulty that exists when using these steels is the complex densification process by Supersolidus Liquid Phase Sintering (SLPS). This process occurs only in a small temperature range [2, 3].

The composition of HSS, specially the carbon content has a pronounced influence on the microstructure evolution and sintering temperature [4]. Since the microstructure and densification of HSS is very sensitive to carbon content, the effect of adding carbon or partial debinding if the part is produced by metal injection molding is being studied [5,6].

In our previous work where the samples were obtained by a modified MIM process using a thermosetting resin [7], the sintering temperature of MIM M2 HSS was reduced 100ºC, from 1350ºC to 1250ºC, by means of incomplete debinding, and the sintering window was substantially widened. This behavior is a consequence of the residual carbon coming from the binder degradation. In this communication, the effect of incomplete debinding on the sintering was studied for samples processed with a thermoplastic binder based on HDPE. The thermal debinding process has been designed on the basis on thermogravimetrical analysis that allows leaving different amounts of carbon in the brown parts.

2. Experimental and Results

The feedstock was prepared mixing a prealloyed gas atomized M2 High Speed Steel spherical in shape and particles lower than 21 μm, with a binder described elsewhere [8] based on a thermoplastic polymer (50% of high density polyethylene (HDPE) and 50% of paraffin wax). The mixing was carried on a twin screw extruder Rheomex CTW 100p of ThermoHaake and the feedstock was injected in an Arburg 220-S injection machine to obtain the green samples.

Thermal debinding under argon atmosphere was adopted in this work to prevent the oxidation of the metal parts. Heating cycle to get the brown parts showed in Figure 1 was used. This cycle was previously designed on the basis of a thermogravimetric study of the binder [9, 10]. Based on previous work [7, 11], we performed incomplete debinding processes, modifying the maximum debinding temperature within 450 and 600 ºC in order to retain residual carbon in the sample. The carbon, in this case, which forms as a result of the binder degradation, could be the cause for the improvement of the sintering of these steels [5, 6, 7 and 12].

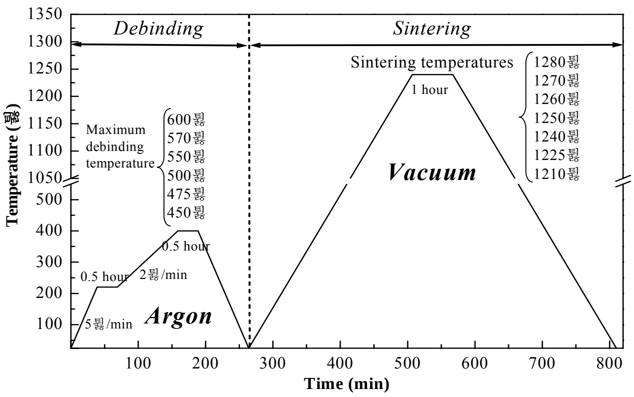

Fig. 1. Thermal debinding and sintering cycles applied

As expected, the carbon content increases as the debinding temperature decreases indicating that residual carbon or some non-degraded polymer still remained in the body. The samples used in the sintering process were debound at 475, 500 and 550ºC, with approximately carbon content of 3, 2 and 1% respectively. The samples with 1% [wt] of carbon could consider fully debound because the carbon content of the initial powder was 0.86% [wt] as result of LECO measurements.

The sintering process was carried out at different temperatures from 1210ºC to 1280ºC under high vacuum conditions. The evolution of the density with the sintering temperature in the samples with different degrees of debinding is shown in Fig. 2. In fully debound samples (1%C), the sintering process achieved a maximum densification at 1270ºC. In the case of partially debound samples (those with 2 and 3%C), the results were very similar and the quasi-full density was achieved at 1240ºC, reducing the optimum densification temperature in more than 30ºC.

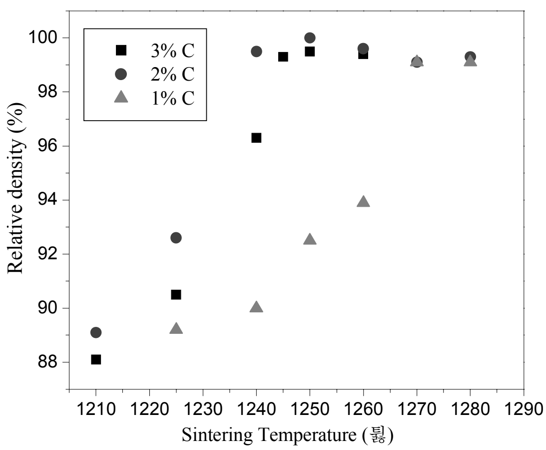

Fig. 2. Sintering curves for samples debound at different temperatures.

The sintering window in the fully debound samples was extended less than 10ºC, because the samples sintered at 1280ºC showed an oversintered microstructure. Coalescence of the grains and isolated carbides could be detected. However, the samples partially debound showed a sintering window extended over more than 20ºC, much wider than the usual results described for these kind of steel [13, 14]. The parts sintered from 1240ºC to 1260ºC show a homogeneous distribution of bright rounded carbides identified like M_6C (rich in W and Mo) and additionally V-rich carbides (MX) have been detected. The microhardness of the sintered parts has been measured and the results are in agreement with the density measurements. The maximum value was 700HV at 1240ºC.

3. Summary

The incomplete debinding process applied in the parts of M2 processed by Metal Injection Molding allowed residual carbon resulting from the binder degradation to remain in the specimens. This residual carbon was found to improve the sintering process, hence reducing the sintering temperature in 30ºC and expanding the sintering window at 20ºC.

4. References

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