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Metal Injection Moulding of HS12-1-5-5 high-speed using a PW-HDPE based binder

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In this communication, we present the Powder Injection Moulding (PIM) of HS12-1-5-5 high-speed steel parts using a wax-HDPE based binder. The injection molding process of the feedstock (68 % vol. of metal) has been optimized to obtain high quality green parts. The elimination of organic binder were carried out by thermal debinding under inert atmosphere. In order to keep carbon in the sample that could improve the sintering process, incomplete debinding were performed between 400 and 500 ºC. In this study, we have studied the effect of different atmosphres on the debinding process. Debinding was performed under nitrogen and argon. The specimens were sintered at temperatures between 1230 and 1260°C with steps of 10°C in folowing mixture N_2-10%H_2 atmosphere.The PIM parts present higher density than those obtained by conventional PM.

1. INTRODUCTION

Powder Injection Molding PIM has been well developed and is used industrially for materials such as Fe–Ni alloy, Fe–Co alloy, tungsten heavy alloy and stainless steel. However, PIM of HSS was just developed in recent years [1, 2] The injection moulding being the contemporary manufacturing method is used more and more widely, especially for manufacturing of the small elements with complicated forms and developed surfaces [2]. Its employment for manufacturing tools from the commonly known material like the high speed steel results in elimination of the plastic forming and machining operations, decreasing thus manufacturing costs of this type of tools. Moreover, the employed manufacturing technology, and especially the binder agent degradation and sintering processes carried out in the protective atmospheres, make it possible to use cheaper, continuous furnaces, compared to vacuum furnaces, which is important in the technological lines producing tools from the sintered high speed steel. Incomplete debinding of HSS parts produced by a modified MIM process was beneficial for sintering process. The sintering temperature was decreased about 60°C and the sintering windows was enlarged about 40°C these fact decreased the manufacturing cost and is permit a better control of the process [3, 4].

The aim of this work is to develop the Metal Injection Moulding of HS12-1-5-5 HSS parts using a binder that has been successfully used for HS6-5-2 HSS parts [5].

2. EXPERIMENTAL PROCEDURE

The metal powder used for the present study has been a prealloyed gas atomised steel of HS12-1-5-5 type. The chemical composition of powder is shown in table 1. The 80% of the particles are smaller than 21 μm and spherical in shape (fig. 1). The particle size distribution measured by a Laser Particle Sizer Fritch Analysette 22 model is shown in figure 3.

Table 1. Chemical composition of HS 12-1-5-5 high-speed steels powder.

Type of steel	Designation	Average composition, wt %							
		C	Mn	Si	Cr	W	Mo	V	Co
HS 12-1-5-5	T15	1,47	0,5	0,43	4,76	11,8	0,06	4,75	4,64

The used binder was based on a thermoplastic polymers, 50% of high density polyethylene and 50% of paraffin wax. The binder has a density of 0,93 g/cm^3. The optimized contents of metal powder was 68% in volume. Each component of the binder and also the metal powder were premixed in a Turbula Mixer at room temperature during 1h in order to homogenize the feeding of the twin screw extruder Rheomex CTW100p that was used to produce the feedstock. Every feedstock formation was granulated and extruded twice to guarantee a good homogeneity. The samples was injected with an Arburg 220-S injection moulding machine. The mould has three cavities, allowing produce tensile strength probes, 3-point bend bars and toroids. The injection was performed in two steps of 25 cc/s and 5 cc/s, and a holding pressure profile from 900 to 25 bar was applied during the 20 seconds of cooling time. The barrel temperature profile was from 160 to 170ºC and the nozzle temperature achieved 175ºC. The binder has been partially driven off by thermal debinding in a cylindrical chamber furnace Goceram AB GCDV-50 under argon or N_2-10%H_2 flowing gas between 400 and 500 ºC. These atmospheres prevent from the oxidation of metallic powders. The sintering process has been carried out at temperatures between 1230 and 1260^{o}C in N_2-10%H_2 in a tubular furnace.

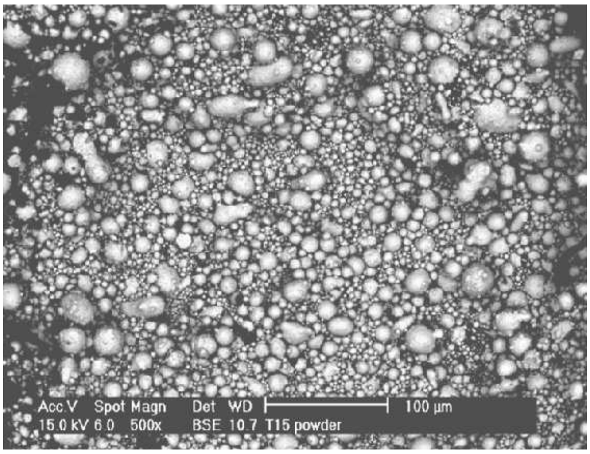

Fig. 1. The powder of high speed-steel HS12-1-5-5 atomized by argon

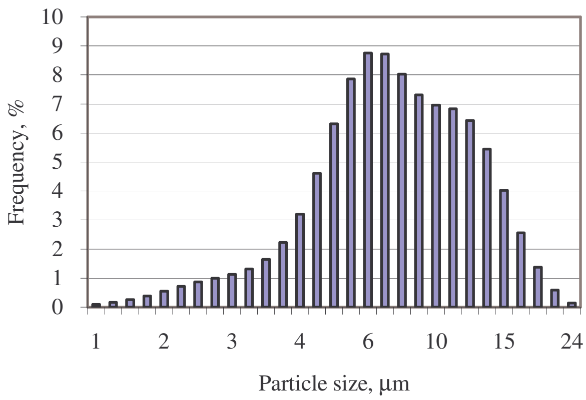

Fig. 2. Distributions of particle size of HS12-1-5-5 type high speed steel atomised by argon

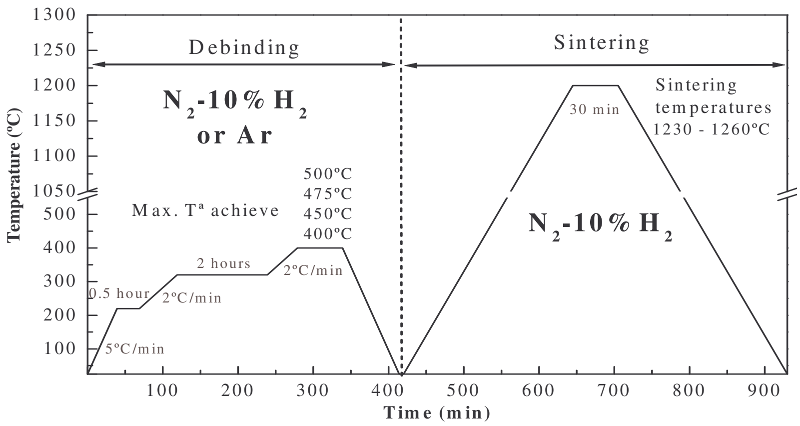

Fig. 3. Thermal cycle of debinding and sintering processes of HS12-1-5-5 high-speed steel.

The sintering time was 30 minutes in all the cases. The heating rate was not higher than 5°C/min in order to prevent crack formation. The debinding and sintering cycle is shown in the figure 3. Density of sintered specimens was estimated with Archimedean principle, by determining the product's mass and volume, and basing on the apparent loss of weight after immersing the specimen in water. Hardness of sintered specimens was measured using Vickers method. The carbon content of the debound and sintered samples was analyzed by the infrared absorption method using a LECO CS-200 carbon analyzer. Metallographic examinations were carried out in an PHILIPS XL30 scanning electron microscope equipped with a Backscattered Electron Detector (BSE) and an Energy Dispersive Analyser (EDAX 4i).

3. RESULT AND DISCUSSION

The green parts present very good homogeneity as deduced from the microstructural analysis and from green density values. Table 2 shows a the carbon content of different brown parts as determined by LECO. Independently of the debinding atmosphere the carbon content decreased as debinding temperature increased as a consequence of the polymer degradation. This degradation seems to be most effective using argon flux. At 500°C basically all the carbon content coming from the organic component disappear. Although the brown part present high amount of C, the sintering temperature was not reduced and the highest sintered density (about 8,2 g/cm^3) were obtained at 1250°C independently of the debindng temperature.

Table 2. Influence of thermal debinding temperature on carbon content at HS12-1-5-5 type HSS

Temperature of debinding	400°C		450°C		475°C		500°C	
Atmosphere of debinding	Ar	N_2-10%H_2	Ar	N_2-10%H_2	Ar	N_2-10%H_2	Ar	N_2-10%H_2
Carbon content of debounded steel (wt.%)	3,7	3,93	2,9	3,44	2,41	2,87	1,59	1,66
Carbon content of sintered steel (wt.%)	1,37	1,47	1,34	1,44	1,34	1,41	1,33	1,32

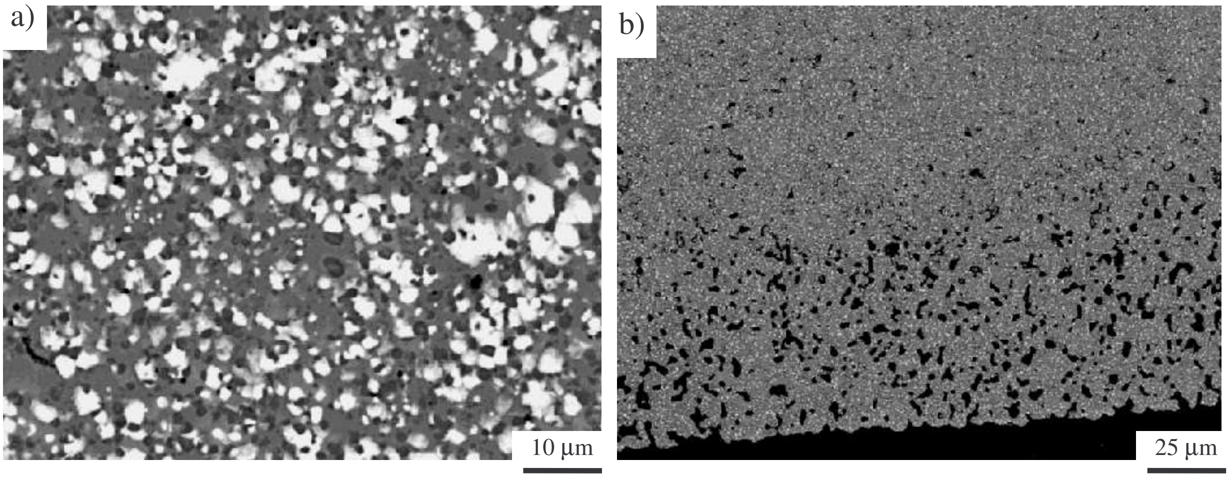

Fig. 4. Microstructure of the HS12-1-5-5 type steel debound at the temperature of 500^{o}C under N_2-10%H_2 and sintered at 1240^{o}C in the N_2-10%H_2 atmosphere a), debound at the temperature of 500^{o}C under argon and sintered at 1230^{o}C in the N_2-10%H_2 atmosphere b).

This fact seems to be indicated that the carbon content coming from the binder degradation is not incorporated to the metal matrix. This fact was confirmed by elemental analysis. As shown in figure 4a the microstructure is quite homogeneous with the fine carbides distributed along the matrix. The porous surface of debound under argon and sintered samples is shown in figure 4b.

4. CONCLUSIONS

On the basis of the experimental work the following conclusions are deduced:

- the Metal Injection Moulding process using a HDPE based binder has been successfully developed for manufacturing of HS12-1-5-5,
- the debinding under N_2-10%H_2 atmosphere produced samples with higher quality than using argon atmosphere,
- sintering at 1250^{o}C produced high density parts (about 8,2 g/cm^3) with homogeneous microstructure with rounded carbides distributed along the matrix,
- independently of the debinding atmosphere and temperature the carbon content after sintering decreased to the indicated carbon content of the powder.

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