On the Use of Elemental Powders to Prepare Fe-50Co Alloys by Powder Injection Moulding

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Abstract

In order to obtain specific magnetic properties, it is of paramount importance to increase the alloy density of components fabricated by powder metallurgy. An alternative to increase the density of alloys such as Fe-49Co-2V would be the use of elemental Fe and Co instead of the pre-alloyed powder. Trying to give some insight on the industrial application of this strategy, this paper investigates the replacement of more conventional pre-alloyed Fe-49Co-2V powders with elemental Fe and Co. A previous analysis shows that it is possible to achieve higher densities and leads to a noticeable improvement in some important magnetic properties.

Keywords : Fe-Co alloys, powder injection moulding, magnetic induction, densification

1. Introduction

Iron-cobalt alloys near the equiatomic composition are technologically important because of their high saturation magnetization, low magnetocrystalline anisotropy and associated high permeability [1].

On the other hand, the Fe-50Co alloy tends to be brittle because of the ordering of the α-phase and the presence of trace amounts of C, H and O [1]. The difficulty to process by conventional ways due to the fragility, made the alloy Fe-50Co to be substituted by the Fe-49Co-2V alloy, which is more ductile, but has lower magnetic induction [2]

A material processed by MIM, however, will not necessarily suffer any mechanical deformation during processing; to avoid secondary operations is exactly the aim of this near net shape process. Moreover, the control of impurities in MIM components can be well managed and the fragility of the alloy should not be a problem

In the established literature it is reported that the magnetic induction of the Fe-50Co alloys is 4 % higher than that for conventional Fe-49Co-2V alloys [3]. Nevertheless it is also reported that the sintered Fe-Co alloys show a magnetic induction of only 1,7 T compared to a magnetic induction of 2,0 T for Fe-Co-V sintered alloys [4].

Taking into account the above mentioned factors was decided to analyze how the changes in chemical composition affect the processing and, more specifically, the sintering step and the final magnetic properties.

2. Experimental and Results

The two feedstocks used to perform the injection moulding of the specimens for evaluation of sintering behaviour and magnetic properties were prepared in a sigma-blade mixer. One feedstock with 13 wt% binder was prepared with elemental powders composed of 50% commercially available carbonyl iron powders and 50% cobalt powder, with an average particle size of 5 μm. The other feedstock with 8 wt% binder was prepared with a commercially available pre-alloyed Fe-49Co-2V powder, with an average particle size of 10 μm.

After preparation and proper granulation the feedstocks were injected in a mould with a toroidal shape. The specimens were submitted to the same debinding procedure. First they were chemically debound by vaporous and liquid hexane at 65ºC. After chemical debinding the samples were thermally debound and pre-sintered in a temperature of 980ºC for 40 hours in hydrogen atmosphere. The sintering was carried out at 1330ºC, in an atmosphere composed by 90% of argon and 10% of hydrogen at a pressure of 107 Pa.

In order to characterize the final properties of the sintered specimens the following properties were evaluated:

a) The density;

b) The carbon content;

c) The magnetic properties. The measurements were made in a closed magnetic circuit, with a frequency of 0,05Hz in alternated current and the highest magnetic field applied was 3000A/m.

After the debinding and sintering processes, the specimens presented no shape distortions or cracks, as well as very low carbon content. As it can be seen from Table 1 the samples prepared with elemental Fe and Co powders show the highest density after sintering. These numbers are an average of 5 samples and the calculated standard deviation was 0,01 and 0,02 for the samples made from elemental and pre-alloyed, respectively.

Table 1. Average and standard deviation (σ) of properties measured after sintering for Fe-50Co and Fe-49Co-2V alloys.

Properties	Fe-50Co	Fe-49Co-2V
Density [g/cm³]	8,03(0,01)	7,82(0,02)
Carbon [%]	0,005	0,015
Permeability [relative]	5603(591)	1610(343)
Magnetic induction [T]	1,69(0,18)	1,83(0,05)
Coercivity [A/m]	166(5)	245(16)
Hardness Rockwell B [transformed from HV0,2]	98(7)	96(10)

From the microstructural analysis it is possible to confirm hypothesis that the chemical gradient can greatly increase the sintering kinetics favouring therefore the densification of the alloys prepared from elemental powders[5] For the Fe-50Co alloy a very coarse microstructure could be found as shown in Fig-A. On the other hand the Fe49Co2V showed a much smaller grain size than the Fe-50Co-alloy Fig-B.

A B

Fig. 1. Microstructure of Fe-50Co (A) and Fe- 49Co-2V (B) after sintering (magnification of 100x).

A better view of this coarse microstructure can be seen in Fig. 2 where grains with the same size as the cross section of the toroid could be found.

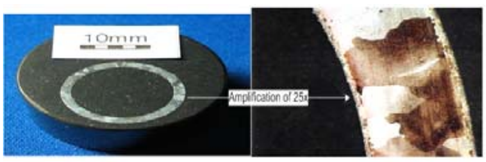

Fig. 2. Microstructure of Fe-50Co after sintering showing the grain size with the same diameter of the toroid cross section (magnification of 25x).

This coarser microstructure of the Fe-50Co alloys is in accordance to the previous results shown for the permeability.

3. Summary

The results for the magnetic induction confirmed the contradiction between the alloy produced by powder metallurgy and by conventional ways.

The larger particle size and the lack of chemical gradient of the pre-alloyed powders might affect the densification process and the overall final magnetic properties adversely, making a straight conclusion about the causes for a better densification of elemental powders compared to pre-alloyed powders difficult.

From the industrial point of view the result might be interesting, as iron and cobalt is available in quite small particle sizes. On the other hand pre-alloyed powders are difficult to be obtained with smaller particle sizes

For the industrial application, however, other aspects must be analysed in order to check if the processing route starting from elemental powders can be technically and economically attractive for some magnetic applications.

4. References

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