Influence of the Morphology and the Particle Size on the Processing of Bronze 90/10 Powders by Metal Injection Moulding (MIM)

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Abstract

The MIM technology is an alternative process for fabricating near net shape components that usually uses gas atomised powders with small size (< 20 μm) and spherical shape. In this work, the possibility of changing partially or totally spherical powder by an irregular and/or coarse one that is cheaper than the former was investigated. In this way, different bronze 90/10 components were fabricated by mixing three different types of powder, gas and water atomised with different particle sizes, in order to evaluate how the particle shape and size affect the MIM process.

Keywords : MIM, bronze, irregular powder, coarse powder

1. Introduction

In this work, bronze 90/10 parts were fabricated with the same binder by MIM using two irregular water atomised powders with different particle size and a conventional MIM powder (gas atomised) and also mixtures of these powders in order to try to find a good compromise between production costs and final properties. This study is aimed at investigating and comparing the processing and the properties of MIM compacts made from powders with different particle shapes and sizes, and also evaluating the effect of the powder shape/size on the processing by MIM.

2. Experimental and Results

The study was carried out taking three different 90/10 bronze powders, one spherical gas atomised with particle size under 22 μm and two irregular water atomised powders (W50 and W100 smaller than 35 μm and 140 μm respectively). Next, nine blends were prepared by mixing different amounts of powder. Only two types of powder were used in each mixture as shown in Table 1. The apparent density of all mixtures was evaluated with a Hall apparatus. Each blend was mixed with a wax-polyethylene binder (50/50 %vol.) in a 252P ThermoHAAKE internal mixer at 170 ºC for 30 minutes. The solid loading for each blend was determined by measuring the torque during the mixing and it is shown along the apparent density in Table 1. In these proportions, nine feedstocks were fabricated in a ThermoHAAKE twin screw extruder at 170 ºC and then injection moulded to fabricate green parts. Debinding of the parts was carried out in two steeps: first the different parts were solvent debounded in hexane at room temperature for 24 hours and then thermal debinding was driven in a Hydrogen atmosphere to 600 ºC at heating rate of 1 ºC/. A sintering study was done in Hydrogen atmosphere between 800-870 ºC for 60 minutes at heating rate of 10 ºC/min.

For the sintered material characterization, the dimensional change of the material during the sintering cycle was measured. The densities were determined by Archimedes water immersion method while porosity was evaluated using an image analyzer device. The Brinell hardness was also measured to see the progression of the mechanical properties following the change in the particle shape and size of the powder and the sintered temperature.

Table 1. Proportion of each powder (% wt), apparent density and solids loading (% vol.) for the different powder blends

Blend	A	B	C	D	E	F	G	H	I
OSP	100	67	33	0	67	33	0	0	0
W50	0	33	67	100	0	0	0	67	33
W100	0	0	0	0	33	67	100	33	67
Apparent density (g/cm3)	4,55	4,25	4,08	3,91	4,81	4,57	3,54	4,23	4,18
Solid Loading (%)	68	65	63	60	68	63	58	60	58

2.1. Mixing

As it is shown in Table 1 the apparent density changes when the shape of the powder becomes irregular, making lower when the amount of irregular powder increases. Althogh the same behaviour was expected with the irregular coarse powder, but instead we observed an improvement of the packing capacity in spherical with irregular coarse powder mixtures. The same trend was found from the torque measurements obtained during powder and binder mixing. Solids loading used to fabricate each feedstock increased when coarse and fine powders were mixed since is necessary less binder for moulding the feedstock when the packing of powder is higher. It is well known that the use of irregular powders in MIM causes an increase in the feedstock viscosity during moulding, leading to reduction of the solid loading. For this reason, feedstock made from irregular powders must be fabricated increasing the amount of binder that involves higher shrinkage during sintering and, therefore, worse dimensional accuracy in the final component [1]. However, as it is shown in Table 1, powder packing can be improved by mixing powders with different particle sizes in spite of the fact that coarse powder has an irregular geometry. This improvement of the packing when powders with different particle sizes are mixed had been observed by German [2]. This fact allows improve the moulding capacity using irregular powders that are cheaper, diminishing production costs in this technology.

2.2. Sintering and mechanical properties

Fig. 1 shows the densification of the different feedstocks during sintering. Feedstock A achieved the highest densification (96%) at 810ºC while feedstock I reached the maximum (92%) at 860ºC. The rest of materials had densification of 92% to 95% between 830ºC and 860ºC. Mixtures B and E with 67% of spherical powder and 33% of irregular and coarse powder respectively reached 95% both of them at 830ºC. Depending on the type of powder used to fabricate the feedstock the maximum densification appears at different temperatures due to the optimal sintering temperature changes with the medium particle size of the powder. Feedstocks with spherical fine powder present a faster sintering and last less time for arriving the maximum densification than those ones made with coarse powders. Shrinkage and Brinell hardness showed the same trend that densification while porosity of all sintered compacts followed the opposite one.

One problem of using coarse powders could be the difficulties that this powder presents during sintering since a particle surface reduction, produced when the particles of powder are bigger, usually comes with a penalty of lower sintered density and mechanical properties. The study about the sintering process performed gave the behaviour of the different blends of powder during the sintering steep. Feedstock fabricated mixing coarse and irregular powder with the gas atomised one showed densification, porosity and mechanical properties very close to those ones attained in the material prepared with only fine spherical powders. The initial solids loading do not appear to have a high influence on the final densification of the parts as it had previously been reported by Suri et al. [3], although it had a great influence in the shrinkage undergone in the compacts during sintering. This is due to each feedstock presents a different solids loading and, therefore, injection moulded compacts have a different green density increasing the shrinkage as the green density is lower. The temperature required for the optimal sintering in each material was higher as the amount of coarse powder was increased in the mixture. This is due to the fact that a bigger particle size implies a particle surface reduction causing an increase of sintering activation energy.

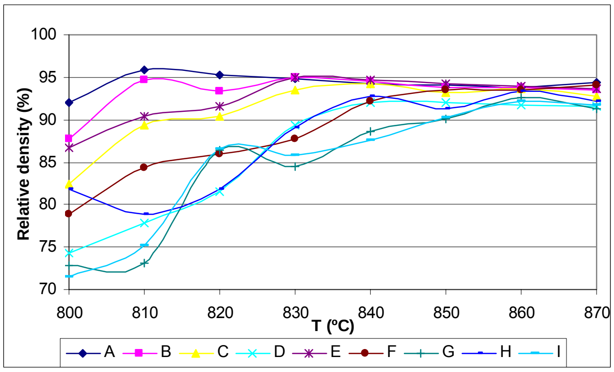

Fig. 1. Densification of the parts sintered at several temperatures.

3. Summary

The processing of nine blends from three different bronze powders, one gas tomized and two water tomized with different particle size, was carried out by MIM to determine the influence of the powder shape/size on the process. High packing mixtures of powders were formed by mixing fine gas tomized powders with coarse water tomized ones, which are five times cheaper, reaching higher apparent density and similar moulding capacity than feedstocks made only with gas tomized powders Besides that, a good densification could be attained in components fabricated by MIM from spherical fine powder and blends prepared mixing spherical with irregular and coarse powders achieving 96% in feedstock A and 95% in feedstocks B and D. The faster densification in gas tomized powders is due to the smaller average particle size since it provides a major surface area, that is, the driving force in the sintering step. When the amount of water tomized powder increases in the mixture, the sintering temperature should be increased.

4. References

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