Holding Pressure and Its Influence on Quality in PIM Technology

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Abstract

The PIM (powder injection molding) process consists of several steps in which faults can occur. The quality of the part that is produced usually cannot be seen until the end of the process. It is therefore necessary to find a way to discover the fault earlier in the process. The cause of defects is very often "phase separation" (inhomogeneity in powder distribution), which can also be influenced by the holding pressure. This paper evaluates the powder distribution with a new method based on density measurement. Measurements were made using various holding pressure values.

Keywords: PIM, holding pressure, phase separation.

1 Introduction

Powder injection molding technology (PIM) is a very effective and precise technology, especially for producing small metal and ceramic parts with complex shapes in large-scale production. The technology itself consists of two subcategories, CIM (ceramic injection molding) and MIM (metal injection molding). A clear difference between CIM and MIM is in the use of different feedstocks, where a different powder is used (either metal-based or ceramic-based). The powder is mixed with a polymeric binder and is granulated. The processing is very similar to standard injection molding, but due to the highly abrasive properties of the powder it is necessary to use a suitable machine with abrasion-resistant parts (screw, cylinder etc.) After the injection-molding stage of the process, it is necessary to take out the binder. There are various ways to remove the polymeric binder, including catalytic debinding, water dissolving or thermal debinding. The last stage of production is sintering, which produces a part with high density and is accompanied by considerable shrinkage. The shrinkage is dependent on several factors, e.g. the material (the ratio between powder and binder in the feedstock, the type of binder, the material of the powder, grain size, etc.), processing conditions, mold, machine, etc. The quality is often influenced by a range of factors, but the influence of holding pressure remains not well described. The aim of our project is to study the influence of holding pressure on the quality of the molded part. This paper describes the influence of holding pressure on powder distribution in various places in the specimen characterised by a new method — density measurement.

2 Materials and methods

2.1 Preparation of the specimens

Inmafeed 1008 feedstock, produced by Inmatec (Germany), was selected as a material for the specimens. The exact composition of this material is protected, but it is based on Al_2O_3 and consists of powder (about 81–90 %) and a binder (about 10–19 %). The powder composition is min 96 % of Al_2O_3 and up to 4 % of inorganic flux additives. It uses two-step debinding (water and thermal). The Sintering temperature is 1 620 °C. The binder is based on a polyolefin and wax mixture. A cavity with dimensions $120 \times 10 \times 4$ mm was selected for the specimens, of which was the density evaluated in various places. These specimens were produced by powder injection-molding technology, where the mold has a gate from the shorter side. An Arburg Allrounder 270S injection molding machine was used. The processing conditions were set according to the material sheet with two different holding pressure values (see Table 1).

Table 1: Processing parameters for injection molding of the specimens

Processing temperature	From feeding zone 159 °C to nozzle tip 162 °C
Mold temperature	60 °C
Injection speed	80 ccm/s
Dose volume	30 ccm
Holding pressure	300/150 bar
Switching to holding pressure	11 ccm
Cooling time	10 s

2.2 Evaluation of the density in different places

The decision was taken to measure the average density in 28 different places (4 rows on the shorter side of the sample and 7 rows on longer side, where especially close to the gate and at the end of the part the measuring points were placed more densely because higher influence of the holding pressure was expected). More details are shown in Figure 1. All specimens were conditioned according to EN ISO 291 before measuring the density. In places where the measurements were to be made, the tested sample was cut into small pieces 2×2 mm in dimensions, while the thickness remained constant (4 mm). This means that the variations in properties across the thickness were not considered. The Archimedean immersion method was selected as the testing method (according to EN ISO 1183). An A&D GF-300 balance was used for weighing the samples. Due to the high density of the feedstock that was used, the immersion fluid was distilled water. It was necessary to use a surfactant to reduce the high surface tension. The sample then immersed much more easily.

The results were calculated according to the Archimedes principle, and the results are shown in the graphs in Figures 2 and 3.

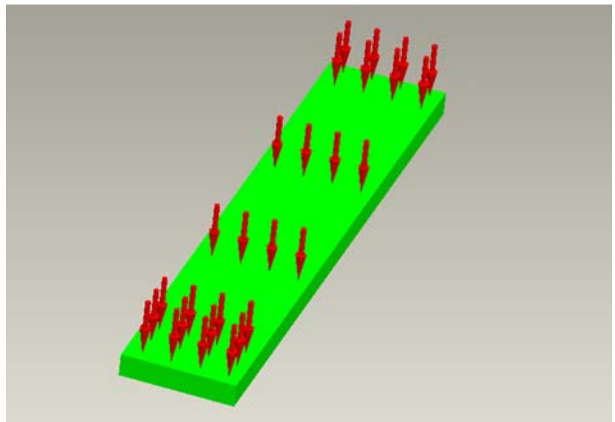

Figure 1: Specimen with 28 measuring points: On the shorter side, all distances are 2 mm and on the longer side the points are placed 2/4/8/40/80/114/118 mm from the gate

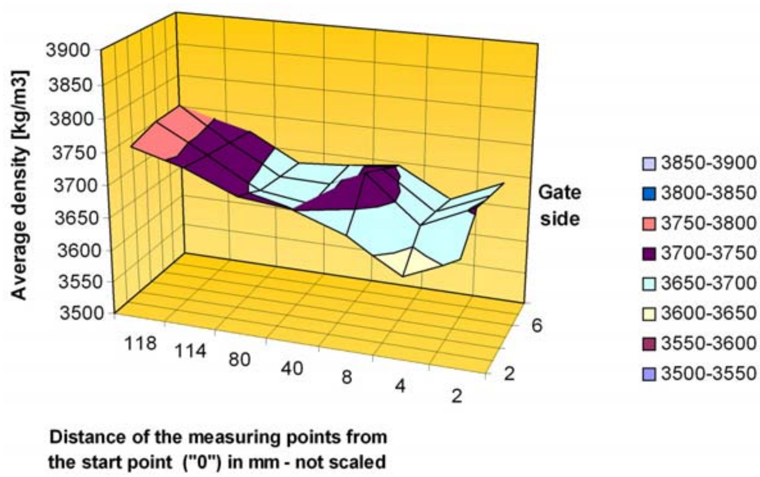

Figure 2: Average density in each of 28 points on the specimen, where the holding pressure was 300 Bar

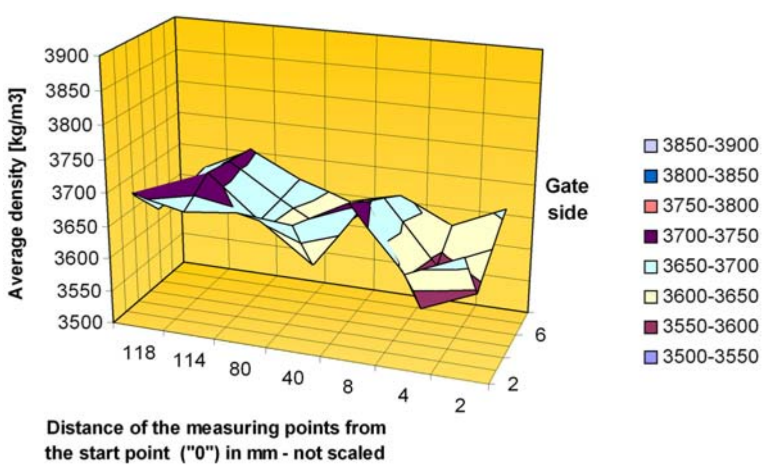

Figure 3: Average density in each of 28 points on the specimen, where the holding pressure was 150 Bar

3 Results and discussion

In the case of PIM, the flow properties are significantly different from the case of conventional injection-molding, because of the smaller amount of polymeric material and the combination with inorganic grains. These inorganic grains have much worse fluidity than standard polymeric material, and also have an abrasive effect on the machine and on the mold. The effect of the holding pressure is also different. It causes different coordination of the two components of the melt in different places and, as a result, also different properties, shrinkage etc. It is then quite difficult to set up the machine, especially the holding pressure.

It can be seen from these graphic relations, which show the density across the sample, that where there was higher holding pressure the distribution of the density values was more homogeneous. This means that the distribution of the ceramic powder should also be more homogeneous. If we focus on specific places, the density values were also more constant in the middle of the specimens (longitudinal direction) than in the area close to the gate or at the end of the sample. In these places with more constant values, it is likely that a quality surface can be obtained after sintering. It can also be seen that with higher holding pressure the average density is also higher. This indicates a higher content of ceramic particles, which are of higher density than the polymeric binder.

4 Conclusion

PIM technology is quite sensitive as far as changing the holding pressure is concerned, but the influence on the properties of PIM parts has not yet been described properly. The approach of evaluating the influence of the holding pressure on quality, represented by powder distribution, which was quantified by density measurements, is a new way to predict the distribution of ceramic (or metal) powder and binder in injection molded part by using a different holding pressure. This could be useful for discovering any defects before sintering has been performed, and therefore avoiding wasting time, material, energy, etc., in the subsequent steps (recycling can still be done in the "green part" step). The experimental measurements showed that samples produced with higher holding pressure showed more homogeneous density distribution, and generally also higher density values, this could indicate that there was a greater content of ceramic powder, which has a higher density than the polymeric binder. Also, as anticipated, the densities were slightly more homogeneous in the middle of the specimen than in the area of the gate or at the end of the specimen. The method is quite simple and provides visual results, but its accuracy is limited even when the work is carried out with great precision. It is therefore necessary to continue investigating this topic, to seek new approaches and methods, and to make further measurements.

Acknowledgement

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