THE INFLUENCE OF HOLDING PRESSURE ON POWDER DISTRIBUTION IN PIM TECHNOLOGY

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The powder injection molding technology (PIM) is very sensitive process where the resulting quality of the part is defined by quality reached in each step of the whole process. This quality of the part is then usually possible to see first at the end of the process while the fault could occur already at the beginning, often during injection-molding. Therefore is necessary to find the way how to evaluate the injection-molding process and discover the fault earlier. Very often cause of the defects is the "phase separation" (inhomogeneity in powder distribution), which occurs during injection-molding and can be also influenced by the holding pressure. This paper is then focused on evaluation of the powder distribution in the "green part" stage with the new method based on density measuring. Measurements were done with using different values of holding pressure.

Keywords
PIM, CIM, Holding pressure, Phase separation, Green part

1. Introduction

The powder injection molding technology (PIM) is very effective and precise technology for producing especially small metal and ceramic parts with complex shape in large-scale production. Technology itself consists of two subcategories CIM (ceramic injection molding) and MIM (metal injection molding). Clear difference is in using of different feedstock where the different powder is used (either metal or ceramic based). The overview of whole PIM process is possible to see on the Fig. 1.

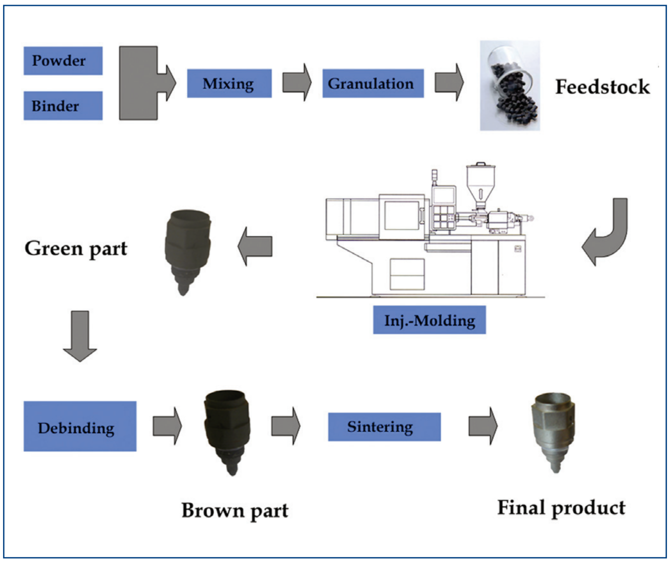

Figure 1. *Process overview of typical PIM (MIM) part*

The powder is in order to reach homogenous distribution in whole material properly mixed with polymeric binder and granulated. Processing of green part is very similar to standard injection – molding, but according to high abrasive properties of the powder is necessary to use proper machine with abrasion resistant parts (screw, cylinder, etc.). After injection-molding stage of the process is necessary to take out the binder. There are more ways how to remove the polymeric binder, among others catalytic debinding, water dissolving or thermal debinding [Laddha 2009]. The last stage of production is sintering, which produce a part with high density and is accompanied with a large shrinkage. Whole shrinkage is dependent on more factors like material (the ratio between powder and binder in feedstock, type of binder, material of powder, grain size etc.), processing conditions, mold, machine etc.

The resulting quality of the part is commonly influenced by many different factors in each step of the production, but the influence of holding pressure is still not well described. Several papers includes the rough description of the influence of holding pressure on PIM part's quality [Greene 2007] but not in relation to powder distribution. Unbalanced powder distribution is indicator of low quality product [Thornagel 2009] because the result after sintering is also unbalanced.

Solved project is aimed especially on the study of the influence of holding pressure on quality of molded part and this article describes the influence of holding pressure on powder distribution in different places of the specimen characterised by the new method – measuring of the density.

2. Materials and methods

2.1 Preparation of specimens

As a material for specimens was selected feedstock Inmafeed 1008 produced by Inmatec Germany. This material's exact composition is protected, but according to published data is based on Al2O3 and consists of powder (about 81-90%) and binder (about 10–19%). The powder composition is min 96 % of Al2O3 and up to 4% of inorganic flux additives. It is suitable for two step debinding (water and thermal). Sintering temperature is then 1620°C. The binder is based on polyolefin and wax mixture. For specimen, which density was evaluated in different places, was selected cavity with dimensions 120x10x4mm. These specimens were produced by powder injection-molding technology where the mold has a gate from the shorter side. The injection molding machine was used Arburg Allrounder 270S where the processing conditions were set according to material sheet with 2 different sizes of holding pressure (see Tab. 1).

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

Table 1. *Processing parameters of injection-molding of specimens*

2.2 Evaluation of the density in different places

The basic idea of evaluation the powder distribution in PIM part ("green" stage) is very simple: The difference between powder density (Al_2O_3 – approximately 4000kg/m^3) and binder (less than 1000kg/m^3 incl. all additives) is so significant, that according to resulting density it is possible to mark the places with higher or lower amount of powder and to evaluate powder distribution in different places. There was decided to measure the average density in 28 different places (4 rows on the shorter side and 7 rows on longer side of the sample, where especially close to the gate and at the end of the part were the measuring points placed with higher density because the higher influence of holding pressure was expected). More details are possible to see on Fig. 2. All specimens were conditioned according to EN ISO 291 before measuring of the density. Tested sample was in the places of measuring cut into the small peaces with dimensions 2x2mm where the thickness was still the same (4mm). This means that properties change across the thickness was not considered. For the testing was selected the Archimedean immersion method (according to EN ISO 1183). For weighing the samples was used balance A&D GF-300. Used immersion fluid was due to high density of the feedstock distilled water. Because of its high surface tension was necessary to use surfactant to reduce it (the tested sample then immersed much easier). Results were then evaluated by standard statistical methods (especially linear regression).

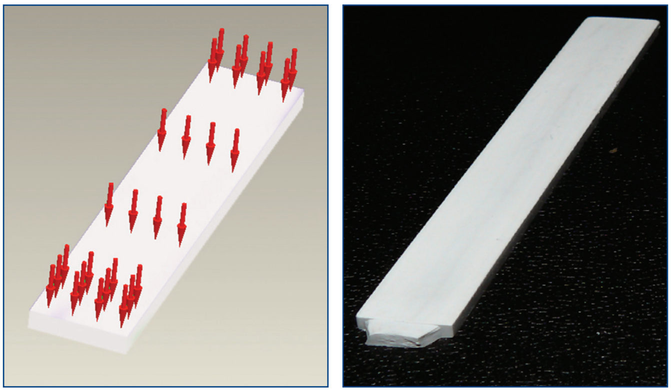

Figure 2. *Specimen with 28 measuring points where on the shorter side are all distances 2 mm and on the longer side are points placed 2/4/8/40/80/114/118mm from the gate*

3. Results and discussion

The powder content influences the rheology in the dominant way [Thornagel 2012] so the flow properties are in the case of PIM significantly different than in the case of conventional injection-molding. This is caused by lower amount of polymeric material and combination with inorganic grains. These inorganic grains have much worse fluidity than standard polymeric material and have also abrasive effect on machine and mold. The effect of the holding pressure is then quite different. It causes different coordination of both components of the melt in different places and as a result also different properties, shrinkage etc. Setting up the machine, especially the holding pressure is in order to get good results much more difficult. Measured data were fitted by plane with linear regression method and the homogeneity of the density distribution in different measuring points was evaluated by coefficient of determination. The value of coefficient of determination showed, that in the case of using higher holding pressure 300bar was the density distribution more homogenous (coefficient of determination was 0,41) against the values in the case of 150bar (coefficient of determination was 0,25). This was supported by graphic relations (Figure 3 and Figure 4), which also shows that the distribution of the average density in measuring points across the sample (not scaled), was in the case of higher holding pressure more homogenous. According to basic assumption, that the density values reflects the distribution of ceramic powder in material should be this powder distribution also more homogenous.

On the base of the experience with sintering is presumable, that the sample with constant powder distribution would show the quality surface after sintering. By comparing the mean values of samples injected with different holding pressures showed the sample produced with holding pressure 300bar higher values of density in 25 from 28 measuring points so it is possible to say, that higher holding pressure causes higher density of the part. This can signify higher content of ceramic particles which have higher density than polymeric binder.

4. Conclusions

The PIM technology is quite sensitive in question of changing the holding pressure but the influence of its changing on properties of PIM parts is still not properly described. Mentioned approach of evaluation the influence of holding pressure on quality represented by powder distribution which was quantified by density measuring is a new way, how to predict the distribution of ceramic (eventually metal) powder and binder in the injection molded part ("green part" stage).

This method could be useful for discovering the defect in PIM process earlier than after sintering and therefore allow us to avoid wasting of time, material, energy etc. in next steps (in the "green part" step is still possible to do recycling). For this purpose is then necessary to set up the border which distribution of powder in material is still acceptable.

From the experimental measuring was possible to see that samples produced with higher holding pressure showed more homogenous distribution of the density and generally also higher values of density, what could refer that the content of ceramic powder, which has a higher density than polymeric binder, was higher.

Mentioned new method is quite simple and provides visible results, but even in the case of very precise work is its accuracy limited. Therefore it is necessary to continue in research of this topic where new approaches, methods and measurement are required.

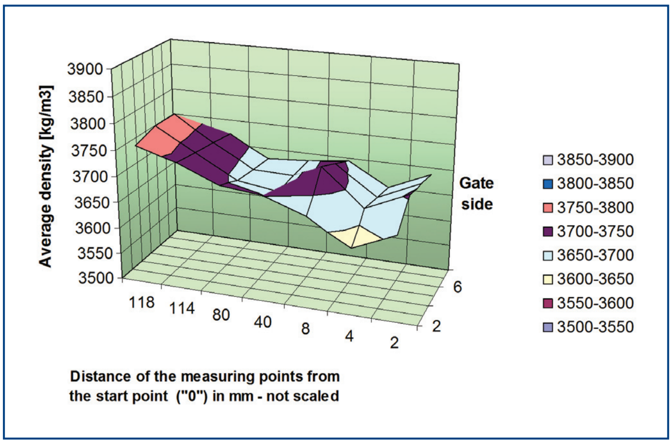

Figure 3. *Average density in each of 28 points of the specimen, where the holding pressure was 300Bar*

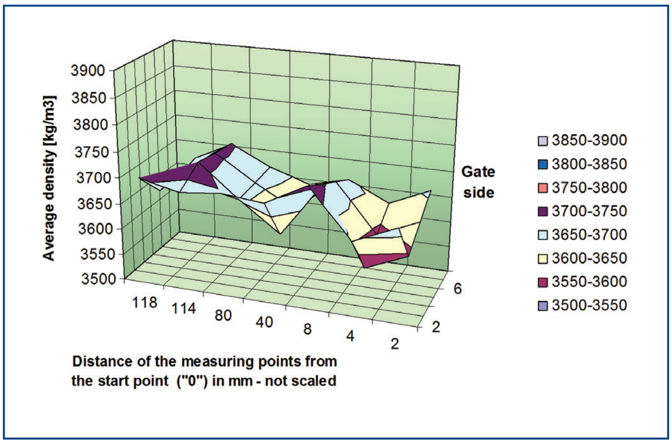

Figure 4. *Average density in each of 28 points of the specimen, where the holding pressure was 150Bar*

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