Investigation in Influence of Screw Design on the MIM Process

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Abstract

The results of investigations in screw design for metall injection molding (MIM) will be presented. The consistency of cavity pressure, metering time and MFQ (monitoring of feedstock quality; parameter measured during metering) was chosen to compare different screws. A simulation program was used to optimize the conveying and melting mechanisms in the plastification unit. The theoretical background of this simulation programm will be explained.

Keywords : powder injection moulding, plastification screw design, modelling

1. Introduction

The injection molding process can have a big impact on the quality of the final parts. In some cases the influence of the injection molding process is underestimated because at first sight it looks very simple. But it is not only the mold design and the process parameters, e.g. the injection speed profile, which influences the green part quality it is also the way how the melt preparation is done. The aim of this paper is to explain the basic mechanisms of melting and conveying inside the plastification unit and to show the influence of the screw design on the metering time and the MFQ-value.

The plastification unit should prepare a thermal and mechanical homogeneous melt. There should be no trapped air inside of the melt because this would lead to voids in the green part. The time needed for metering should necessarily not increase the cycle time. This means the metering should be over before the end of the cooling time. The screw design has not only an impact on the duration of the metering but also on the consistency of the metering time. The screw design should allow a large processing window. So the melt quality should be good at different settings of barrel temperatures, screw speeds and back pressures. There should be no excessive dissipation due to the created shear in the plastification unit because this can cause degradation of the polymeric binder components. A further important demand on the components of the plastification unit is a good wear resistance [1]

2. Experimental and Results

In the feeding zone there is only solid material. In the so called delay zone a thin melt film is created on the barrel surface due to the heat conduction from the heated barrel. The thickness of that melt film increases rapidly because of the dissipation created in this thin melt film. As soon as the thickness of the melt film is thicker than the clearance between the screw flights and the barrel the melt is scraped by the pushing flight of the screw (figure 1). In the melting zone the portion of the melt in the screw channel increases and the portion of the solid material decreases. The complete material should be melted before the end of the compression zone of the screw. In the melt zone the melt is mixed in a helical flow which leads to a homogeneous melt.

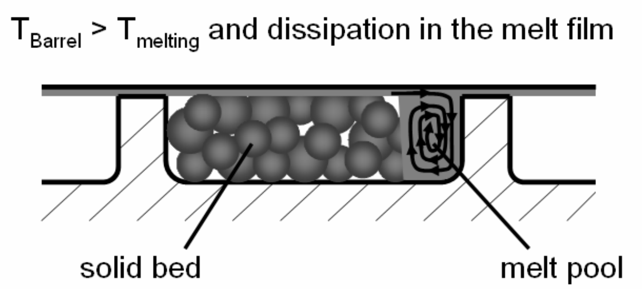

Fig. 1. Melting mechanism in the melting zone

The so called “cooling experiment” [2] has been performed when processing a MIM (Catamold® 316L, BASF) feedstock. After cooling down the barrel and pulling out the screw the solid granules fell out of the screw channel. The molten material is still on the screw. As figure 2 shows the melting is finished approximately in the middle of the screw length.

Fig. 2. Screw with molten feedstock fraction

Tadmor [3] introduced a theoretical model to calculate the width of the solid bed, X. The model assumes that the melt film thickness δ is constant. The melt created in the melt film flows into the melt pool. This leads to a continuous increase of the melt pool width and a corresponding decrease in the solid bed width. There is heat conduction from the barrel and dissipation which leads to a heat flux into the transition zone where the temperature is equivalent to the melting temperature of the binder. There is also a heat flux into the solid bed. Tadmor derived a formula for the relative solid bed width, X/b. X/b depends on the barrel temperature, the melting temperature of the material, the thermal conductivity of the feedstock, the viscosity of the melt film, the velocity of the solid bed and the specific heat capacity of both the melt and the solid material. The decrease of the relative solid bed width as a function of the axial position in the screw for a polypropylene (PP) and a MIM feedstock has been compared. PP has a very low thermal conductivity and it needs a lot of energy for melting. So it takes approximately a length of 20D (20 times the diameter of the screw) to melt the PP completely. In contrast to that the MIM feedstock has a much higher thermal conductivity and the energy needed for melting is usually lower than that needed for PP. So the melting is finished after only 5D.

As soon as there is only melt inside of the screw channel the conveying mechanism is based on the fact that the melt adheres to both the screw and the barrel surface. This leads to a velocity profile along the height of the screw channel. The velocity component v_z leads to the volume flow through the screw. But there is also a cross channel flow caused by the velocity component v_x. The volume flow depends not only on the screw rpm but also on the pressure conditions inside the plastification unit.

So during metering there is a certain velocity profile inside of the screw channel. This velocity profile leads to the corresponding shear stresses in the material and it is also responsible for the energy and the torque needed for metering. The MFQ (monitoring of feedstock quality value considers the energy needed to plasticize and convey the feedstock in the plastification unit [4] and it depends not only on the feedstock but also on the screw design as it will be demonstrated. A general purpose screw for plastics processing and a screw designed for MIM processing has been compared. For these experiments a Catamold® 316L feedstock from BASF was used. The screw diameter was 18 mm and the part “thick spoon” had a shot volume of approximately 7.9 cm³. The variation of the MFQ during 50 shots could be reduced by a factor of 2 by using the MIM screw geometry. The MFQ for the MIM screw was also less which means the shear energy introduced into the material was less. The effect on the process consistency can be seen in the cavity pressure. For 50 shots the maximum cavity pressure was recorded (figure 3). This leads to similar results as the MFQ value. The variation in cavity pressure is more than double in the case the plastics screw geometry is used. This leads to more variations in the green part quality. The mean value of 50 shots of the maximum cavity pressure is lower for the MIM screw design. So the stress in the material during the filling phase is lower which reduces the risk of separation of binder and powder.

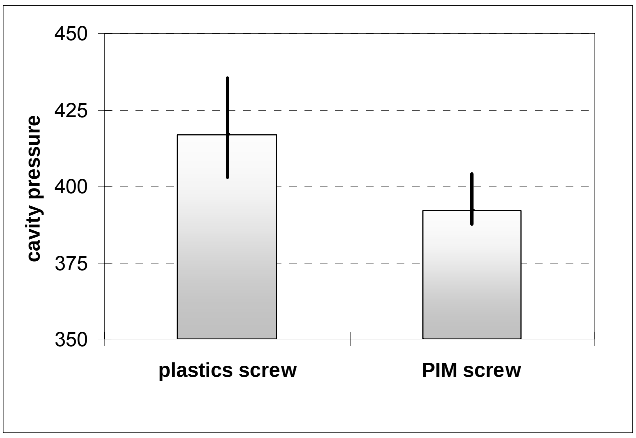

Fig. 3. Cavity pressure for a plastics screw and MIM screw design

3. Summary

Based on model calculations the proper screw design can be found on condition that the material data is available. The screw design influences the process consistency and the part quality. The proper screw design depends not only on the powder material but it depends on the feedstock composition. In most cases a screw for plastics processing is unsuitable for MIM and CIM processing. The proper screw design is just one piece of the puzzle for a good green part. The mold design and the settings of the injection molding machine are of course also very important for a successful production.

4. References

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