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General aspects of foam injection molding using local precision mold opening technology

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ABSTRACT

By using a special mold technology, it is possible to produce injection molded components with locally graded foam structures and locally different densities. This paper describes general results of foaming polypropylene with chemical and physical blowing agents. Particularly, the characteristics of the density in the different foamed areas and the mechanical properties depend on the process-specific process parameters. Differences in terms of processing in comparison to typically precision mold opening geometries result from the limited foamed areas of the locally foamed component. Whereas the density reduction in the highly foamed areas is directly set by the process, the density in adjacent thin-walled areas results as a function of process control. The structure formation, and thus the specific mechanical properties can also be influenced by the process parameter settings.

1. Introduction

In conventional foam injection molding process, the cavity is first partially filled. The melt containing blowing agent, expands when entering the cavity due to the resulting drop in pressure and leads to a complete filling of the mold. In this instance, the foaming process can only be influenced insufficiently. The cavity pressure is mainly set by the pressure of the blowing agent and can lead to a non-homogenous density distribution due to pressure differences along the flow path. Generally, a 5%–15% reduction in density is achieved. At the transition from plasticizing unit to the mold a huge pressure drop initiates the foaming process. Thus, in the filling process the gas may escape from the melt. This leads to silver streaks, flow marks and an increased surface roughness. To achieve higher density reductions, a more homogenous density distribution along the flow path and an improved surface quality, special mold technologies can be used.

By using the precision mold opening (PMO) method, the cavity is first volumetrically filled with melt containing blowing agent. A high injection pressure or high injection speed is used to counteract foaming, which is induced by a decrease in pressure during the filling process. In the second step, a short delay time, optionally in combination with holding pressure, is used to develop a compact skin layer. In the third step, the entire cavity is opened to a predefined extent. The pressure drop caused by the sudden increase in volume initiates the foaming process within the entire component. As a result, a component with a compact skin layer and a closed-cell, foamed core area is created. A flow path independent homogeneous density distribution, an improvement of the surface quality and much higher density reduction (typically 35%–55%) can be achieved.

Using the standard PMO method, the entire component is foamed in the area of the mold parting line. If the cavity's enlargement is not done by an opening stroke of the clamping unit, but rather by core-pulling, components can get foamed locally, while adjacent areas remain nearly compact. The core geometry limits the foamed areas and the core-pulling distance defines the expansion ratio. Multiple cores are able to be implemented, allowing differently foamed sections in a single component. This allows to manufacture graded components with individual mechanical properties in one step. So, for example, thin-walled components, such as covers or housing parts can be compiled with locally foamed large volume sections with a high rigidity at a constant component weight. Furthermore big wall-thickness variations can be achieved, which is traditionally problematic for conventional injection molding. The production technology severely restricted design freedom of compact and conventional injected molded ribbed components can greatly be expanded.

Technically, the local PMO differentiates, as cores are moved inside the closed mold and not by means of opening the clamping unit like in standard PMO. Besides essential process parameters for

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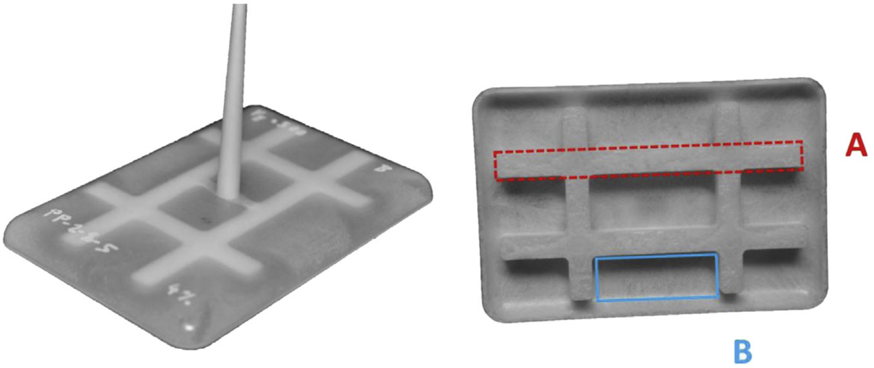

Fig. 1. Demonstrator components – left: face side, right: core side.

injection molding like injection speed, mold and melt temperature, especially process-specific parameters are significant for the process used here. These parameters are:

- *Blowing agent content* (*BAC*): The content was varied within the processing window recommended for the material. Here, the gas content was varied to a minimum and maximum recommended value.
- *Expansion ratio* (*ER*): This parameter indicates the volume expansion. It is defined as volume after pulling the core in relation to the basic volume of the core area. The expansion ratio is directly set by the adjustable core of the demonstrator mold.
- *Delay time* (t_D): This parameter is defined as the time between end of filling phase (EOF) and the point in time of pulling the core to initiate the pressure drop. No holding pressure was applied.

In regards to the process, differences to PMO result according to the core geometry. The core defines the ratio of foamed core area to its surrounding skin layer, which is permanently in contact to the cooled mold. The process window, especially the expansion ratio and the delay time are hereby significantly predetermined. The amount of surface which is in contact to the cooled mold wall is thus significantly higher compared with conventional PMO. A more rapid cooling of the melt and, consequently a more restricted process window is the consequence. High delay times in combination with high expansion ratios can lead to insufficient molding or sink marks. The process-specific parameters directly affect the morphology, especially the formation of the compact skin layer and subsequently the mechanical properties. Structural differences result during the simultaneous development of adjacent areas with strongly varying degrees of foaming. Experimental investigations concerning the influence of process control on the structure and the correlating mechanical properties can be found in several technical papers: extensive investigations on foaming with PMO technology [1–5], results focused on polypropylene [3–9]. Due to the differences in geometry and process these results cannot directly be transferred to the local precision mold opening technology.

Foaming provides the possibility to optimize the component's stiffness by increasing the wall thickness without increasing the component's weight. Correlating with an increasing wall thickness, the moment of inertia increases with the third power of its thickness. Hence, the decrease of the modulus of elasticity caused by foaming is overcompensated and the flexural rigidity – a product of flexural modulus of elasticity and moment of inertia – consequently increases [3,4,10,11].

2. Experimental details

The geometry of the demonstrator component is in basic a thin-walled plate with the dimensions 120 mm × 80 mm with a wall

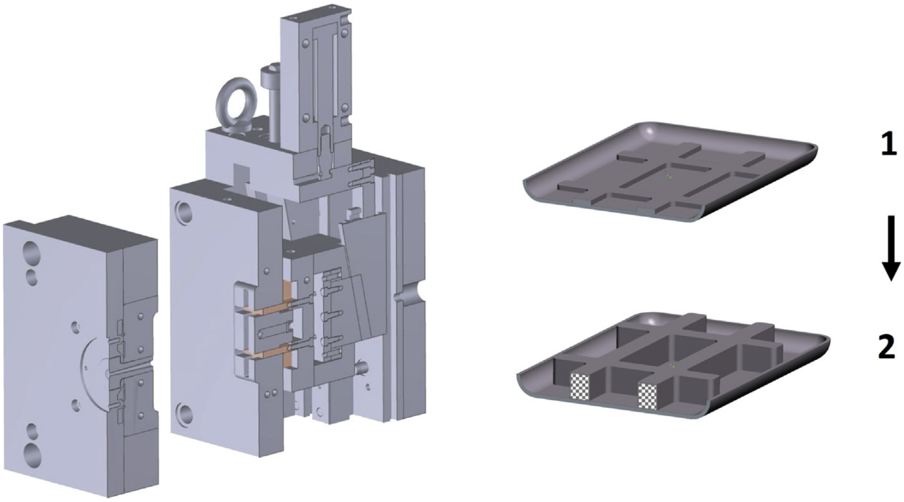

Fig. 2. Cross-section of the demonstrator mold and schematic depiction of the procedure.