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PULL AND FOAM – INJECTION MOULDING METHOD: FOAMED RIBS FOR STIFFENING PLANE COMPONENTS

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Abstract

The *pull and foam* method is a foam injection moulding method which is currently being developed at the Institut für Werkstofftechnik (IfW) (Institute of Materials Engineering) at the University of Kassel. The processing principle represents an alternative to the existing foam injection moulding special procedures and introduces the possibility to partially foam a component. In so doing, thin-walled, hardly foamed components with foamed ribs can be made in one processing step, thus also components with graded properties.

Conventional foaming methods do not enable the manufacture of complex component geometries, wall thickness variations, and components with areas with varying degrees of foaming while maintaining a satisfactory surface quality. The *pull and foam* method offers possible solutions and makes it possible to attain locally targeted, customised mechanical properties. Therefore, it is possible to produce components with foamed areas that possess a high stiffness and compact areas with a high surface quality. In doing so, the method introduces the advantages of foam injection moulding procedure (lower clamping forces = smaller machines, material efficiency, lower melt viscosity, etc.) to new application fields, which were previously barred due to insufficient surface qualities or for constructive reasons.

Introduction

Plastic components are increasingly being produced using the foam injection moulding method due to numerous advantages. One typical application field is the manufacture of thick-walled components or thick ribs used to brace plane components. Here, compact injection moulding is limited, because mass pile-ups caused by poor or locally varying heat dissipation lead to surface defects caused by shrinkage and warpage on the component surface. The economic efficiency of foam injection moulding results from component and process-related advantages. Apart from weight and material savings, the freedom of design enabled by a minimising of shrinkage, a reduced warpage, the energy absorption ability, good acoustic properties, as well as an enhanced specific stiffness should be mentioned in regards of the component. When regarding processing, a reduction of the cycle time, a lowering of the viscosity and and smaller clamping forces are the advantages. [1] The cost savings induced by these advantages outweigh in many cases the higher investment costs for the necessary tools employed in the special method [2].

The methods conventionally used up till now are starkly restricted in their application. In particular, controlling the degree of foaming can be rated as one of the largest processing-technological challenges when employing thermoplastic foam injection moulding. For example, a high injection pressure is needed to fill the thin-walled areas of a thin-walled moulded part with partially thick parts. Often, only a small foaming degree can be accomplished in the whole component. Furthermore, foamed components often have a rough, porous surface. The insufficient surface quality of the components makes it impossible to employ them in many application fields, especially in visible components. The bubbles in the polymer, which occur during injection due to a pressure decrease, shear on the cavity surface while filling the form and the melt skin breaks open. As a result, flow marks and roughness occur on the surface. Leaked gas moves between the tool and moulding surface, thus giving the component surface its typical vortex pattern. In addition to the poor visible quality, the moulded parts also display brittle breaking behaviour because of notch effects on the rough surface. [1,3,4] So as to counteract the problem of lacking surface quality and the correlating consequences, various special methods have been established that also have processing-technological limitations themselves. For instance, in the gas counter-pressure process none too extensive flow paths and thin cross-sections can be realised (the melt freezes). In regards of the tool and the ejector system, complete gas impermeability is obligatory. This, in turn, is connected to significant additional costs concerning the tools [2]. The precision mould opening method (short PMO or „breathing tool“) includes the injection of a melt, which contains a blowing agent, into a cavity. Subsequently, after freezing the outer areas, the melt is enlarged by opening the tool [1,4,5]. In doing so, components with a compact outer skin and a closed cellular, foamed core can be achieved. The same are needed for most application cases [6]. However, the foam structure is formed over the complete component cross-section. Here is where the *pull and foam* method comes in. It introduces the possibility to clear sections of the cavity for the development of foam structures by means of core pulls and hereby, realising partial foaming.

Processing Method

As opposed to the precision mould opening method, the *pull and foam* method enables a partial foaming by means of a local enlargement of the cavity. First, the cavity is filled with melt containing blowing agent using high pressure. After freezing the thin-walled sections, thick-walled sections with defined foaming degrees are formed by means of core pulls. Pulling the core lowers the pressure in the cavity and the polymer-blowing-agent-mixture can expand. As a result, a component with hardly foamed thin-walled sections that have a high surface quality, but also specific foamed thick-walled sections is obtained. The controllable foaming degree makes it possible to influence the foam structure or density distribution. This method is suitable for both physical and chemical thermoplastic foam injection moulding. Figure 1 illustrates the procedure.

Advantages

The advantages of products made using the *pull and foam* method include, apart from the good surface quality and the controllable foaming degree, a low weight while maintaining a high stiffness and short delay. The combination of thin- and thick-walled sections enables wall thickness variations without trouble and the mechanical properties can be customised to the require-ments for products. This way, functional components with partial foaming or targeted combinations of varying foam structures can be manufactured in one processing step. The cycle time is distinctly lower than that of compact components of the same volume. The manufacture can be carried out of injection moulding machines with a low plasticisation volume and relatively low clamping forces. Due to the attainable weight reduction, *pull and foam* mouldings display a significant light-weight construction potential. The energy and resource efficiency of production lead to a further improvement of the results due to smaller injection moulding machines, shorter cycle times and a lower material consumption.

So as to be able to realise components with a high surface quality or even graded components with foamed sections that possess a high stiffness while simultaneously also having compact sections with a high surface quality, several processing steps or combinations of various processing methods are necessary at present (i.e. joining foamed and non-foamed components, back injection moulding of inlays in tools, 2K-method, etc.). In terms of an economic conduction of processing, it is necessary to be able to manufacture injection moulded components in one processing step. Here, the *pull and foam* method provides solutions. Furthermore, the number and height of foamed ribs can be reduced due to the enhanced stiffness and thus, making it possible to modify the construction or the design of ribbed components. New construction options are available. Imaginable applications can be found in many sectors of the furniture industry, in the automobile industry, but also in white goods and packaging technology. Additionally, applications are also found wherever an increased stiffness is required in plane components.

Results

The essential feasibility of the method was shown using an experimental tool with a flat geometry that was stiffened with ribs. The components were plate-shaped with variously strong stiffening ribs that were achieved with the aid of an adjustable core pulling (Figure 2). Selected materials were foamed with according chemical blowing agents. Apart from the core pulling beginning and end positions (heights of the foamed bar) the machine settings such as pressure and temperature were varied. The analyses of the manufactured injection moulded pieces concentrated on the density of partial foaming, the morphology, the pore distribution, the mechanical properties and the surface quality in visible sections.

It became evident that, besides the selection of material, especially the ratio of the blowing agent proportion and the core pulling times or positions are decisive processing parameter. The component properties like the foam structure or the surface condition were determined by the employed material, the processing technique, the set processing parameter and the tool design. By means of bending tests conducted on the component, as well as on freed stiffening ribs, mechanical values were verified (Figure 3). The experimental components were compared to hardly ribbed compact components. In dependency of the heights of the bar and the blowing agent content, stiffness increases of up to 90% could be achieved at a constant component weight (Figure 4). In order to assess the morphology, microscopic images were evaluated using image editing software. Here, the focus of assessment was on the distribution of pores and the thickness of the marginalised layer (Figures 5 and 6). In accordance with the materials and the processing settings, pore ratios of up to 68% were measured in foamed sections. The thickness of the skin layer of the specimen equalled approximately 0,6mm. Furthermore, measurements were carried out using a confocal laser scanning microscope on the unribbed side of the component in the area of the ribs and in the thick-walled sections in order to assess the surface roughness. It became evident that an increased surface roughness can be found in the ribbed section. It was assumed that this effect can be worked against using an aimed, contour-close tempering [7]. Measurements of the gloss degree and the surface structure reveal advantages in comparison to standard injection moulding. However, it is still necessary to adjust the processing parameters precisely. [8]

Prospect

The experimental tool is constructed relatively simple in regards of the geometry, cooling and core mechanics. For this reason, the limitations are quickly reached concerning process optimisation. To carry out further investigations a project proposal was written. In this context a further tool should be designed, which will differ due to the possibility to locally temper it and in terms of its geometry. Heating should take place via ceramic heating elements. The focus of analyses when using this tool should be temperature control and the limitations of moulding part designs. Different rib-geometries should be used as well as varying surface textures, in order to be able to make recommendations concerning the component design and the employment of the method. In addition, the mechanics should be optimised so far that the core pulling speed is controllable, if possible in levels.

The aim of the research activities at the IfW concerning this topic is to determine possibilities and limitations of this processing method. Examinations are meant to verify to what extent complex component geometries, wall thickness variations and components with varying degrees of foaming can be satisfactorily produced. Graded components with specifically locally adjusted mechanical properties will be manufactured. Special attention will be paid to the surface qualities and mechanical properties of the mouldings. Besides processing-technical limitations, the processing window must be determined and the achievable density reduction for different polymer types must be assessed. Last but not least, the correlations between the morphology, the mechanical properties and the density reduction will be profoundly clarified.

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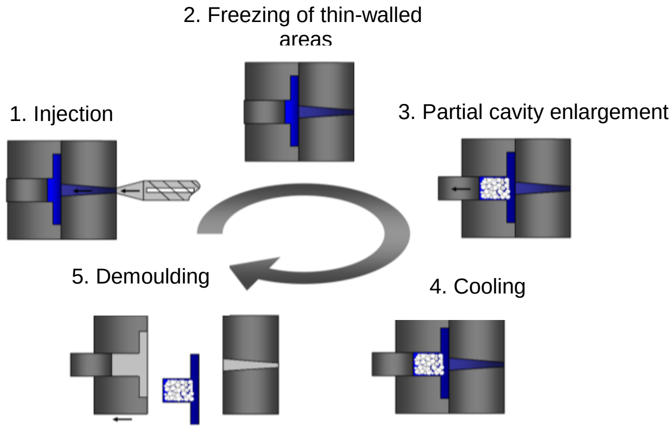

Figure 1: Processing Outline of pu*ll and foam*-Method

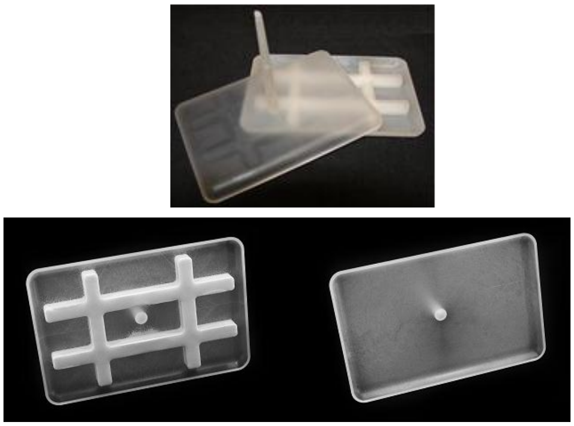

Figure 2: Experimental components of prototype-tool with variable base height of ribs from 0mm to 8mm

Figure 3: 3-point-bending test on component (left) and extracted plank (right)

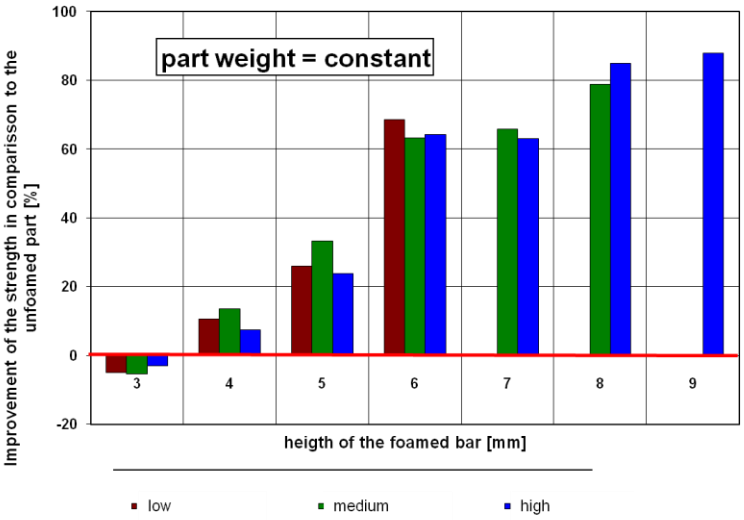

Figure 4: Increase of component stiffness in percentage in regards of compact components with low ribbing, a constant component weight and differing blowing agent contents applied to various heights of the foamed bar

Figure 5: Cross-section of a specimen manufactured using the *pull and foam* – method, core movement of 2mm to 8mm (personal preliminary investigations), right: specimen with fine pore distribution

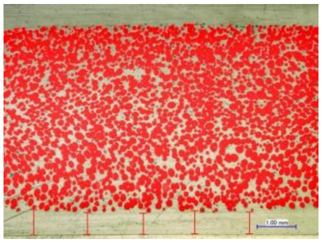

Figure 6: Morphology of thick-walled section with pore ratio of up to 68% and a marginalised layer thickness of approx. 0,6mm