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EFFECTS OF GLASS FIBERS ON THE PROPERTIES OF MICRO MOLDED PLASTIC PARTS

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Abstract

Glass fibers are used to reinforce plastics and to improve their mechanical properties. But plastic filled with glass fibers is a concern for molding of micro scale plastic parts. The aim of this paper is to investigate the effects of glass fiber on the replication quality and mechanical properties of polymeric thin ribs. It investigates the effect of feature size and gate location on distribution of glass fibers inside the molded parts. The results from this work indicate that glass filled plastic materials have poor replication quality and non-homogeneous mechanical properties due to the non-uniform distribution and orientation of glass fibers.

Introduction

In the current state of injection molding technologies micro injection molding is an immensely important process for industries and the technology is growing at a rapid speed. The need for micro parts in the industries is on rise and the demand for tailor made materials with specific parameters becomes larger. One effective and economic way of mass production for micro parts is injection molding and the used materials for the process are mostly plastics because of their suitability for injection molding, good replication quality and cost. Nevertheless, plastic materials lack stiffness and mechanical strength. The most common way to improve the mechanical properties of a plastic material is to add glass fibers. Glass fibers improve the structural properties like strength, stiffness and reduce the shrinkage of the part [1]. Glass fibers used in plastic materials are distinguished as short glass fibers and long glass fibers. Typical lengths of short glass fibers is 0.2 to 0.5 mm and for long glass fibers, 10 to 15 mm. Short fiber reinforced thermoplastics are most commonly used for injection molding [2]. Although all thermoplastics can be reinforced with fibers, Polyamide, Polypropylene, Polystyrene, ABS and SAN are the most widely used fiber reinforced materials in the plastic industries [2]. Figure 1 shows the short glass fibers used with thermoplastic materials. The right picture of the figure 1 shows the cross sections of an individual glass fiber. The pictures were taken by Scanning Electron Microscope during the experiment of current investigation.

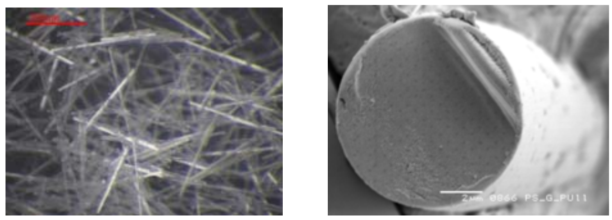

Figure 1: Picture of glass fibers (left picture), Magnified view of one single glass fiber (right picture).

Mechanical properties of glass fiber reinforced plastics can vary depending on the fiber distribution, fiber orientation, fiber size, fiber fraction, fiber-plastic adhesion etc [2]. Glass fibers are used as reinforcing materials in many sectors like automotive and naval industries, sport equipments, airplane industries and in many other plastic industries. Glass fibers improve the mechanical properties of plastic materials; on the other hand, they also impart some unwanted conditions and properties in the process and in the product, especially for micro molding and for micro products. For examples poor replication and surface finish, filling problems and so on. The investigation carried out in this paper revels the effect of glass fibers on the replication quality and surface properties of the micro moulded plastic parts.

Experiments

The aim of the current study is to investigate the effects of the glass fibers on the replication quality of thin polymeric ribs. The geometrical size effect on the amount of glass fiber in the molded plastic parts was also investigated in the experiments.

Test geometry

The test specimen used for this experiment (shown in figure 2) was 2.5 dimensional having long ribs with different aspect ratio. Different rib thickness of this geometry will simulate the different filling behavior of the glass-filled material. The section of the part shown with the red circle is termed as critical section of the part as it has sharp corners and the thinnest cross section with an aspect ratio of nine.

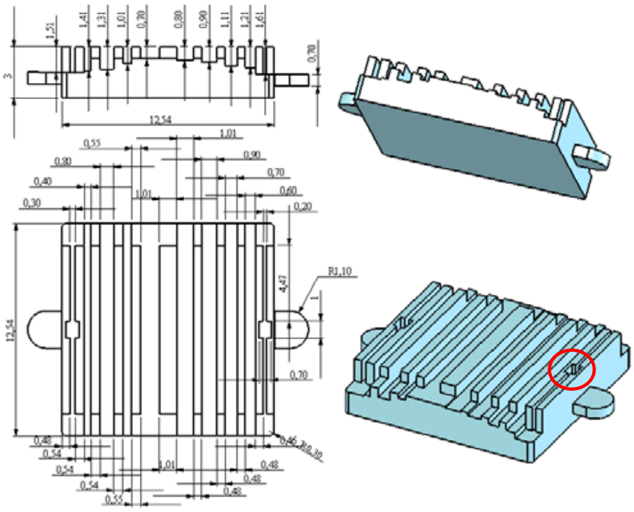

Figure 2: Part geometry used in the experiment (Critical section of the part is shown with the red circle).

Plastic material used in the experiment

Two commercial Polystyrene (PS) materials were used for the experiment. The reason to choose PS material was the availability on the same grade, with only difference in the content of glass fiber. PS is also one of the commonly used industrial thermoplastics. The specification of the materials and their important injection molding process parameters used in experiment are listed in table 1.

Table 1: List of plastic materials

Name	**Glass**	**Manufacturer**	**Molding condition**		
			T_{mo}	T_{me}	V_{in}
PS 158K	0%	BASF	60 °C	235 °C	102 mm/s
PS 158KGf30	30%	BASF	60 °C	235 °C	102 mm/s

Molding machine and process

The mold and machine used for the experiment are presented in the figure 3. The molding machine was an Engel ES 80/25 HL-Victory and the mold was produced by Wire Electro Discharge Machining.

Figure 3: Injection moulding machine used for molding of the plastic parts (left), and the moving side mould with cavity (right).

Result and analysis

Mechanical strength

As mentioned before glass fibers increase the mechanical strength of the molded plastic parts. Injection molding of ISO standard tensile bars with and without glass fibers confirms the effect of glass fibers on the mechanical strength of the materials. The results are plotted in figure 4 and it shows there is a significant increase of mechanical strength due to the addition of glass fibers.

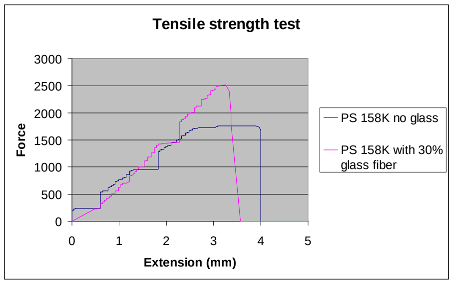

Figure 4: Tensile test performed on ISO standard tensile bars –samples are made with and without glass fibres.

The calculation shows that approximated increase in strength due to the addition of 30% fibers to the PS material is 24%. Figure 5 shows the broken surface of the molded part after tensile testing which shows that the broken surface is smooth in case of non-filled material. The broken surface with the glass filled material is very irregular. This indicates that glass fibers actually change the fracture plane or slip plane of the plastic materials and dislocated it to make a stronger failure surface [3].

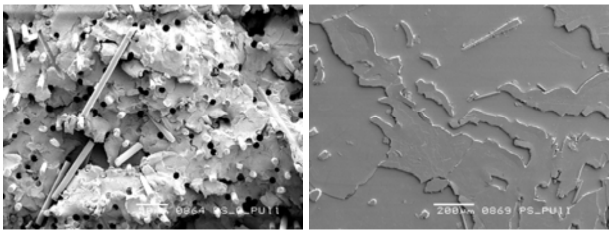

Figure 5: Broken surface of PS molded tensile bar after tensile testing (left hand side picture- taken on the sample with glass and right hand side picture -taken on the samples without glass).

Besides influencing the mechanical strength, glass fibers also decrease the elasticity of the material and make it stiffer. For this reason, it can result in cracks on the micro features of the part during de-moulding like the crack visible in figure 6. The pictures were taken on the critical sections of the molded parts.

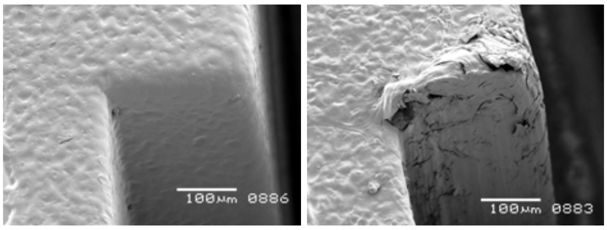

Figure 6: Effects of glass fibers on micro cracks of the injection molded plastic parts (Part without glass fiber-left picture, part with glass fiber-right picture).

Surface quality

Addition of glass fibers increases the roughness of the plastic parts. In the experiment, big difference on the surface roughness of the molded plastic parts was observed based on the glass fibers. The average surface roughness measured on the molded part with PS with glass fiber was about 7.84 μm and roughness of the part moulded without glass fiber was about 2.58 μm. The surface replication of PS without added glass fiber is close to the actual mould surface. The additional of the glass fiber not only increase the average roughness but also the span between the maximum and minimum height of the samples is increased [2].

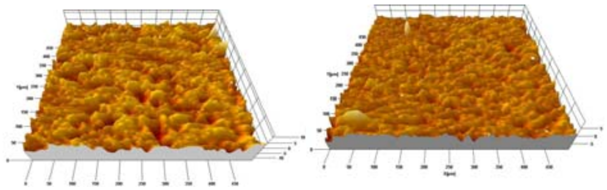

Figure 7: 3D picture of the molded surface (part surface with glass fiber-left side picture and part surface without glass fiber-right side picture).

A clear difference in the surface of the part is visible based on the glass fiber in the material. The part with the glass fiber material is rougher compared to the other part surface. There is also difference in the edge sharpness and weld line formation based on the amount of glass fiber in the plastic materials. When a smooth surface and minimally visible weld line are desired, materials without glass fibers are recommended. Figure 8 shows the difference in replication quality of the critical section of the part with and without glass-filled materials.

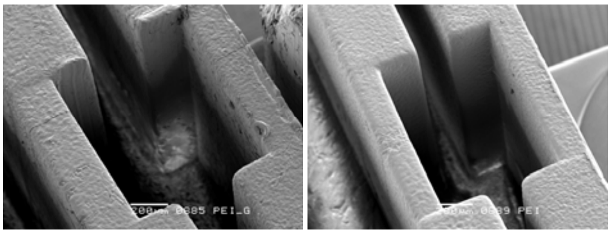

Figure 8: Surface of critical section of moulded part –PS without glass fiber (left picture) and PS with glass fiber (right picture).

Fiber distribution and orientation

To investigate the amount of glass fibers and their directional orientation at different sections of moulded part, the part moulded with glass filled PS material, was cut in three different sections (shown in figure 9): one was close to the gate; another one was far from the gate and one in the middle where the critical sections are placed.

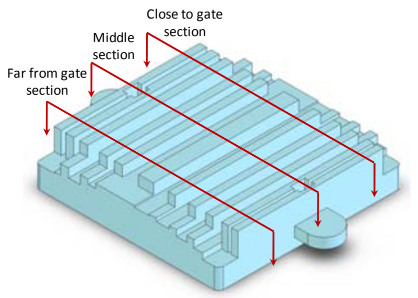

Figure 9: Picture showing different cross sections of the part for the investigation of glass fiber distribution and orientation.

Each section was then grinded, and investigated under light optical microscope. Approximate location of the investigation is shown in the following figure; the spot size was 325 µm × 250 µm. Pictures taken by light optical microscope at three different sections are shown below.

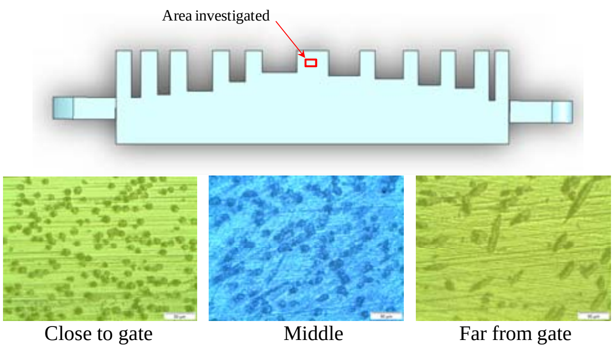

Figure 10: Cross section of the part moulded with glass filled PS (Picture taken under the thick rib and at three different sections based on the distance from the gate location).

From the above picture, it is clear that there is difference in the distribution and amount of glass fibers, since all pictures have the same size and resolution. Approximate count of glass fibers are 166, 88 and 41. In the section close to the gate, the fibers are orientated along the longitudinal direction of the initial flow. Far from the gate, fibers are more unorganized. To calculate the exact area covered by glass at different sections of the moulded part, the software package Scanning Probe Image Processor (SPIP) was used. SPIP located and mapped the glass covered area as show in figure 11 and automatically calculated the total area and the area covered by glass fibers. The results are presented in table 2. It shows that there is a difference in the percentage amount of glass fibers at various cross sections based on their distance from the gate.

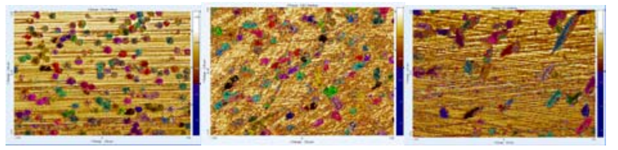

Figure 11: Pictures from glass covered area calculation by SPIP on the three sections under the thick rib.

Table 2: Area calculation by SPIP on three different sections under thick rib.

Total area (μm^2)-Calculated by software	Area covered by glass (μm^2)	% Surface area covered by glass
80682	12440	15%
80682	10022	12%
80682	9365.34	11%

To investigate the influence of micro geometry on the distribution of glass fibers, the cross section of the thinnest rib (shown in figure 12) was investigated again at three different sections based on the distance from the gate. The glass fiber distribution can be seen in figure 12. Here also there is difference in the amount of glass fibers based on the location of the cross section (approximately 77, 61, and 50). The amount of glass fibers in this thin rib is much less, than the amount of glass found in the thick section of the part when the observation was made on the same size of cross sectional area.

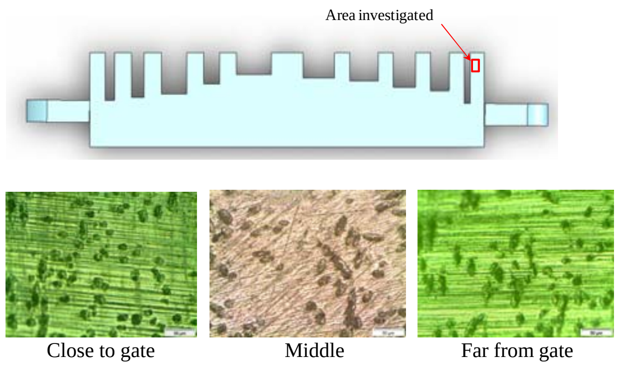

Figure 12: Cross section of glass fiber samples (Picture taken under the thin rib and at three different sections based on the distance from the gate location.

Same calculation was done with SPIP to determine the exact area covered by glass. The mapped picture by SPIP is presented in figure 13 and results are presented in table 3. These also agree with the previous result found in case of thick rib. That means the fiber distribution is different at different sections of the moulded part and depends on the distance from the gate of the moulded specimen.

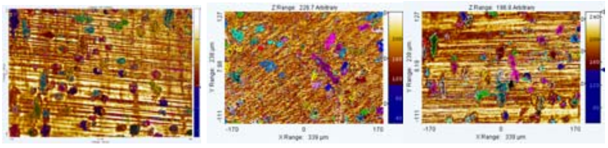

Figure 13: Pictures from glass covered area calculation by SPIP on the three sections under the thin rib.

Table 3: Area calculation by SPIP on three different sections under thin rib.

Total area (μm^2)-Calculated by software	**Area covered by glass (μm^2)**	**% Surface area covered by glass**
80682	9953	12%
80682	8698	11%
80682	7845	10%

A separate investigation was made to find the effect of injection molding process on the length of glass fibers. Injection molded PS parts were dissolved in solvents (in this case a combination of Acetone and Tetrahydroflouside was used) and afterwards the liquid was filtrated to separate the glass fibers from the liquid. Then the length of the glass fiber was measured and the average length was about 400 µm and the average diameter was about 10 µm. The same measurements were performed for the glass fibers collected from the plastic granulate and almost no difference was observed. This suggests that there was no significant change in the length of glass fibers due to the injection moulding operation. Figure 14 shows the glass fibers collected from the plastic granulate and from the moulded plastic part respectively.

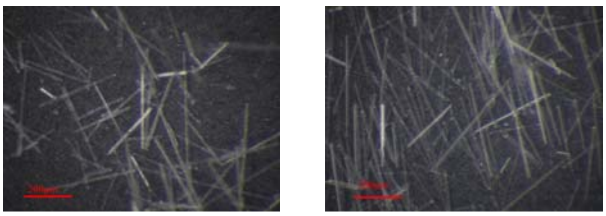

Figure 14: Glass fibers collected from the moulded plastic part-left picture and glass fiber collected from the plastic granulate- right picture.

Summary and conclusion

From the investigations, it is visible that the density of glass fibers in different sections of the plastic part depends on the location of the gate. It is also visible that part geometry has influence on the fiber distribution. Thinner a part or part section is, the lesser amount of fibers are distributed in the part or in the part section. This non-homogeneous fiber distribution imparts non-symmetric mechanical properties in molded parts. The addition of glass fibers in the plastic increases the material stiffness and the added stiffness affects the material's ability to be ejected from the mould without creating permanent defects on the specimen.

The results clearly show that if the same process condition is used to mold plastic parts with plastic with and without glass fibre, the result will be different. The plastic without glass fibre achieves better surface quality, boarder sharpness and filling. Unfilled material has a more homogeneous flow characteristic and better replication quality than glass filled material. Based on the investigations of the critical areas of the moulded specimens, it is concluded that for micro structure replication, material without glass fibers is preferable especially when a smooth surface finish and good replication quality is required.

Acknowledgement

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Key words: Glass fibers, Injection moulding, Micro replication.