STUDY OF THE INJECTION FLOW OF GLASS FIBER REINFORCED PBT AND ITS INFLUENCE ON THE SURFACE ROUGHNESS OF THE INJECTED PARTS AND THE STEEL MOLD WALLS

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Abstract

Polybutylene Terephthalate (PBT) reinforced with two different fractions of glass fibre (20%, G4 and 50% G10) have been processed by injection moulding using mould steel 1.2344 (X40Cr MoV51; SAE H13) for the moulding chamber. 3D surface topography images and surface roughness values after 1,000 injections have been obtained both for the mould steel and for the composite materials. SEM micrographs and elemental maps have been obtained in order to study the fibre orientation according to mould geometry and injection flow, and to discuss their relationship with surface finish.

1 Introduction

In the injection molding manufacturing of glass fiber-reinforced polymers, the service life of the mould and the surface finish of the injected parts are a function of the surface damage and wear due to the very large number of injection operations and the repeated incidence of the fibres on the steel surface [1-6]. Surface attack by corrosion of the mould steel can also be found under the high injection temperatures used, due to the polymer itself or to some additive present in the blend. This surface degradation increases the cost of maintenance and reconditioning operations and increases the number of rejected parts, thus decreasing productivity.

In our previous study [7], we determined the surface roughness variations for the injected parts and the mould steel walls as a function of the number of injection operations. In the present study, we have determined the influence of the density of the fibres and its orientation with respect to injection flow on the surface roughness.

Polybutylene terephthalate (PBT), obtained from 1,4-butanediol and dimethyltereftalate (DMT), is one of the most frequently used engineering thermoplastic polymers. PBT reinforced with short glass fibre is now broadly used in electronic, communication and automobile applications. Therefore, the investigation on fibre-reinforced PBT is becoming increasingly relevant. Reinforced plastics are often manufactured by injection moulding due to excellent surface finish and the possibility of manufacturing complicated geometries. The selection and control of the injection process parameters that affect the fibre condition is a major concern in the plastics industry. The mechanical properties of the final composite materials have been explained in terms of fibre orientation [3].

2 Materials and testing methods

Two composite materials have been studied. PBT reinforced with a 20% glass fibre (Ultradur B4300 G4; BASF, Germany) and PBT reinforced with a 50% glass fibre (Ultradur B4300 G10; BASF, Germany). The injection machine was a 250H55 miniVP (Industrias DEU; Spain). The mould steel used was 1.2344 (X40Cr MoV51; SAE H13) quenched and tempered to a hardness 52-54 HRC. Surface roughness values (table 1) and 3D surface topography profiles were obtained using a Talysurf CLI optical profilometer, according to ISO 4287 standard. SEM micrographs and element maps were obtained using a Hitachi S3500N. Composite samples were previously gold-coated.

3 Results and discussion

Table 1 shows that the surface roughness of the mould steel increases alter 1,000 injection operations of Ultradur G10 both on sections I, where the glass fibres orient preferentially parallel to the steel wall (figure 1) and on section IV, with the fibres preferentially perpendicular to the steel wall (figure 2). On section I (figure 1), the steel roughness slightly increases from 0,073 μm to 0,084 μm, after the injection of 1,000 Ultradur G10 parts. When section IV is considered, a more severe roughness increase is observed, a 24% increase from 0,092 μm a 0,121 μm.

The incidence of the fibres tips (figure 3) on the steel surface has an abrasive effect. This result is in agreement with the 10.7%increase of surface roughness on section IV (0.310 μm; table 1) with respect to section I (0.280 μm; table 1) for the Ultradur part #1,000.

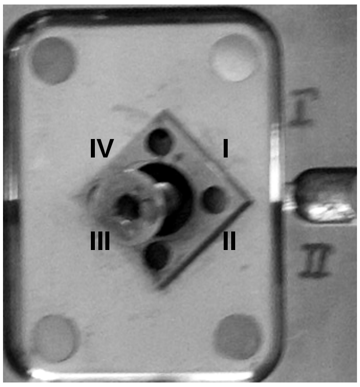

Figure 1. 1.2344 steel mould wall indicating the edges (I-IV) where roughness have been measured.

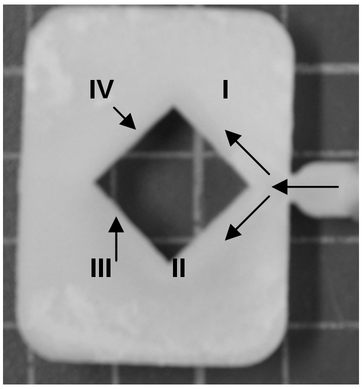

Figure 2. Ultradur injected part
(the arrows show the preferential orientation of the glass fibres with respect to the mould edge walls).

Figure 2 shows the injected part #1,000 of Ultradur G10. The arrows indicate the preferential orientation of the glass fibres with respect to the mould steel wall. Table 1 shows surface roughness values on steel and Ultradur G10 and G4.

R_a (μm)	
1.2344 mould steel (initial state, before the injection process)	
Section I	Section IV
0,073	0,092
1.2344 mould steel (after the injection of 1000 Ultradur G10 parts)	
Section I	Section IV
0,084	0,121
Ultradur G10 part #1,000 (50% glass fibre)	
Parallel orientation (Section I)	Perpendicular orientation (Section IV)
0,280	0,310
1.2344 mould steel (after the injection of 1000 Ultradur G4 parts)	
Section I	Section IV
0,139	0,116
Ultradur G4 part #1,000 (20% glass fibre)	
Parallel orientation (Section I)	Perpendicular orientation (Section IV)
1,160	0,254

Tabla 1. Surface roughness (R_a) of mould steel and Ultradur G4 and G10.

The orientation of the glass fibres inside the polymer matrix has been determined by electron microscopy. The micrographs on figures 3 and 4 show upper and edge views, respectively, of section IV of the Ultradur G10 part #1,000. The upper view shown in figure 3, shows that at the interface with the steel mould the fibres are oriented perpendicularly to it (see arrow in figure 3). Thus, in section IV, the fibre tips (figure 4) are in contact with the steel wall and cause the abrasive effect.

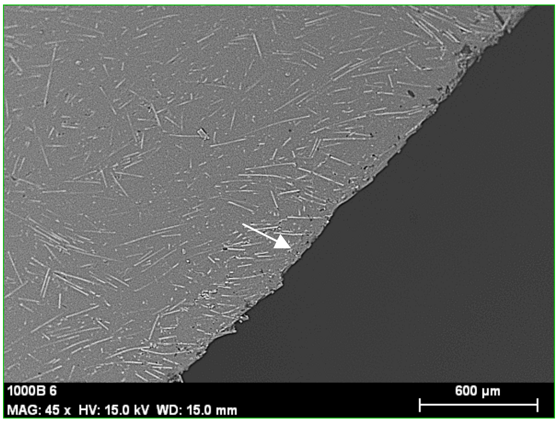

Figure 3. SEM micrograph of injected part #1000 of Ultradur G10 (section IV; upper view). The arrow indicates the fibre orientation at the interface with the steel edge wall.

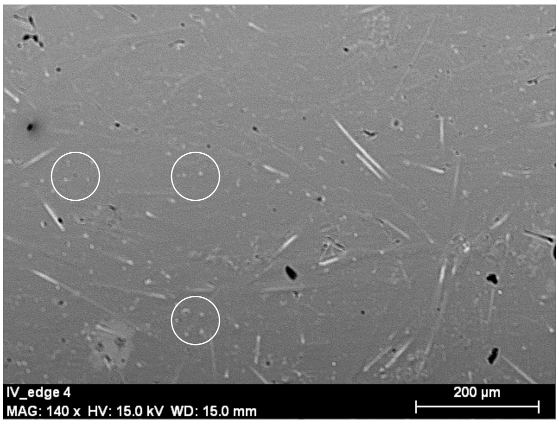

Figure 4. SEM micrograph of injected part #1000 of Ultradur G10 (section IV; edge view). White circles show fibre tips.

Ultradur G4 contains a 20% glass fibre, lower than the 50% present in Ultradur G10. This lower fibre density prevents a preferential orientation of the fibres with the injection flow (figure 5). This is in contrast with the observations made for Ultradur G10 (figures 3 and 4).

The lower fibre content in Ultradur G10, produces a less effective reinforcement, and more severe surface damage by material removal is observed at the more critical locations, such as the angle between sections III and IV, as shown in figure 6. In fact, the injected part #1,000 of Ultradur G4 show and the steel edges in contact with it, show very high surface roughness (table 1).

The severe damage and the change of dimensions produced in Ultradur G4 after 1,000 injection operations can be appreciated in the 3D topographic profile shown in figure 7.

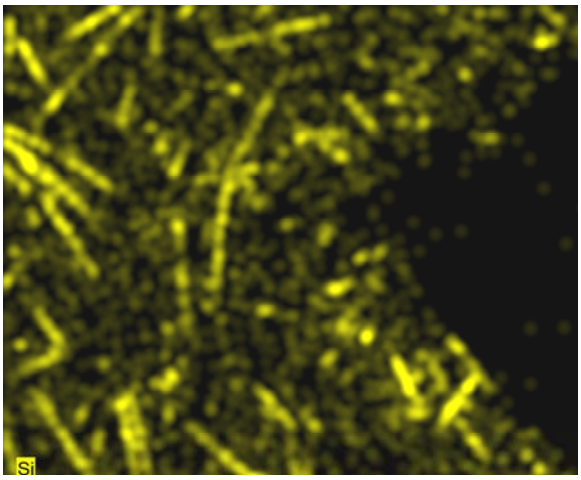

Figure 5. Silicon element map, showing glass fibres within the Ultradur G4 matrix.

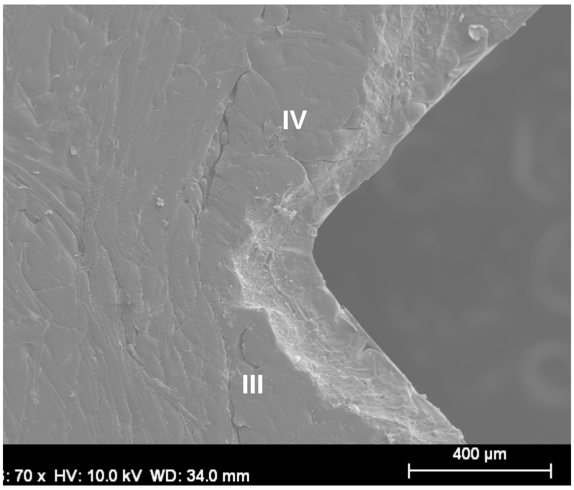

Figure 6. SEM micrograph of the upper view of III-IV angle on injected part #1,000 of Ultradur G4.

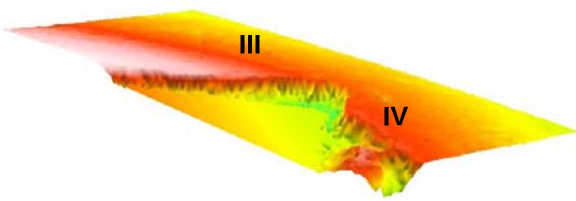

Figure 7. Topografic profile of III-IV angle on injected part #1,000 of Ultradur G4.

4 Conclusion

Fibre orientation with respect to mould steel walls has been determined for two glass reinforced PBT composites as a function of fibre content and mould geometry.

Surface roughness on mould steel and on the composite materials have been determined after 1,000 moulding operations.

For the composite containing 50% glass fibre, the surface roughness is a function of fibre orientation. A perpendicular orientation of the fibres causes a slight abrasive effect and an increase in surface roughness. This is attributed to the impact to fibre tips against the steel wall.

For a fibre content of 20%, the effect of fibre orientation decreases and the final damage on the injected parts increases. This is attributed to the less effective reinforcement of the steel matrix.

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