EXPERIMENTAL AND SIMULATION ANALYSIS ON SHRINKAGE PROPERTIES OF FIBER REINFORCED POLYMER PARTS

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ABSTRACT

CAE in injection molding technology is widely used in the world today, so that is why we focused on injection molding simulations. This paper focuses on the effects of holding pressure and mold temperature to predict shrinkage of an injection molded part. We used a tensile test sample to compare the predicted and measured shrinkages. It was concluded that the holding pressure decreases the shrinkage, both in simulations and in practice, and quite good correlation was found between the simulated and the measured shrinkage. We also studied the effect of mold temperature on shrinkage and the importance of the mold thermal expansion was determined.

KEYWORDS

Moldflow, simulations, injection molding, shrinkage, warpage

1 INTRODUCTION

The use of injection molded parts has increased dramatically and constantly in recent years. A lot of applications require both high tolerances and high quality surface. Today many people including part or mold designers, mold makers and molders are involved in the technology of Computer-Aided Engineering (CAE) in injection molding. Since more and more people rely on solutions of CAE technology, it is important to have an accurate CAE result for the requirements [1-5].

Many new injection molded parts and injection mold designs rely on computer simulation results. The task is for the researchers and for the engineers to get more accurate simulation results. Besides the simulation program itself, the mesh density used in it has an important role in producing accurate simulations [1-5].

The injection molding simulation program can be used for designing a new part or optimizing an existing mold design. It is also useful for verifying molding problems and finding out the reasons of part warpage. Using simulation results, a better mold design can be achieved. It also improves part quality, and saves time and money. To get accurate simulation results, proper material data, processing conditions are needed. Mesh density of the part and the runner system has an important role in the simulation process. A coarse mesh causes approximate simulation result, while a very fine mesh needs excessively long computing time. Therefore optimized mesh density is needed to get accurate results within reasonable computing time [1-5].

Theoretical models cannot account for all the effects of processing conditions on material behavior. Moldflow performs several different mold trials to quantify and model the effects of processing conditions on the material's shrinkage behavior. Molding experiments are conducted over a range of part thicknesses, melt temperatures, mold temperatures, filling profiles and packing profiles. Actual part shrinkage is measured and the Corrected Residual In-Mold Stress (CRIMS) and strain models are fit to the data providing superior shrinkage prediction [2, 6].

Solidification of the polymeric melt in the cavity is a very complex process. It usually goes at elevated pressure. As cooling means volumetric change of the material, in some cases an air gap may form between the moldsurface and the plastic part (Fig.1-3.) [6].

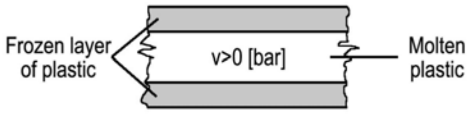

Fig.1. Early stage of packing: injected plastic has frozen layers near the boundaries, while the core remains molten

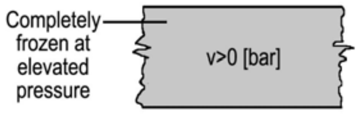

Fig.2. Later stage of packing: polymer completely solidifies at an elevated pressure

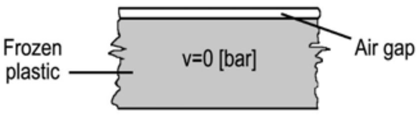

Fig.3. After cooling, an air gap may form between the frozen plastic and the mold

If the packing pressure is very low or the gate is too thin for the cavity, the melt pressure decreases to zero and the air gap between the plastic and the mold surface is formed before the plastic completely freezes (Fig.4.).

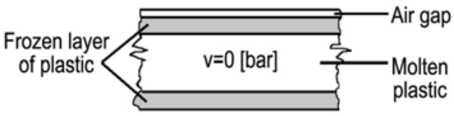

Fig.4. Sometimes, the air gap forms before the plastic completely freezes, while some molten core remains

For these latter cases, the mold constrains the in-plane deformation but does not constrain the deformations in the thickness direction because of the air gap. Thus, all the volumetric changes in the molten core modify the thickness of the plastic part and it has a small effect on the in-plane residual stresses. Moldflow Plastics Insight (MPI) 6.0 improves the shrinkage predictions for these cases when Midplane or Fusion simulations were used, since it correctly accounts for the thickness deformations in the molten core if the air gap is formed. This effect is already correctly handled in 3D Flow and 3D Warp simulations [6].

3 EXPERIMENTAL

Test specimens (Fig.5.) were prepared from nylon 6 reinforced with 30% of glass fiber (Schulamid 6 GF30 from Schulman GmbH). The packing pressure was varied between 20 MPa and 60 MPa. All the other parameters were constant.

The measured shrinkages are shown in Figure 6-7. The prediction plots show the results corrected by the CRIMS (Corrected Residual In-Mold Stress) model.

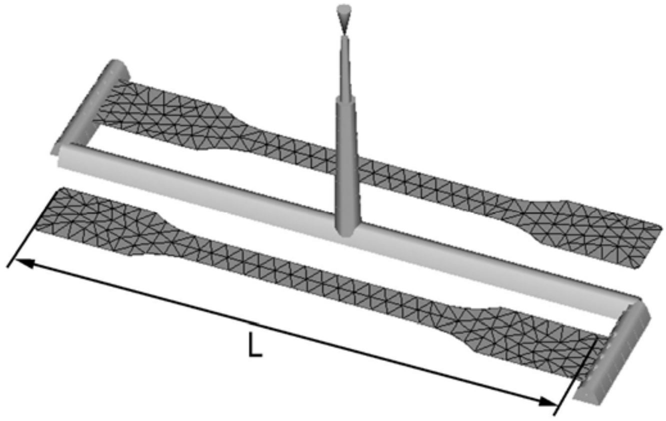

Fig.5. Model for tensile test specimen in MPI, used for shrinkage measurement (where L was the measured dimension)

4 RESULTS AND DISCUSSION

One can see that MPI predicts a strong increase in the shrinkage values for lower packing pressure (Fig.6.). The measured shrinkages show a gradual increase as the packing pressure decreases. The MPI results for the higher holding pressure are close to the measured data.

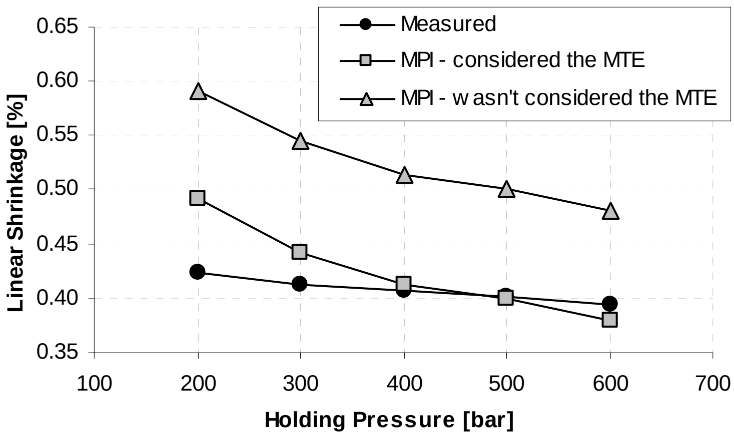

Fig.6. Shrinkage results where the packing pressure was varied between 20 MPa and 60 MPa (MTE is the Mold Thermal Expansion)

It can be also seen that the mold thermal expansion should be considered in the calculation (Fig. 6).

The effect of the mold temperature is shown in Fig. 7. It can be seen that the linear shrinkage increases with the mold temperature. An important fact was found: if the thermal expansion of the mold is taken into consideration, the shrinkage increases with the mold temperature. If a constant mold dimension is used, the shrinkage decreases with the mold temperature (Fig.7).

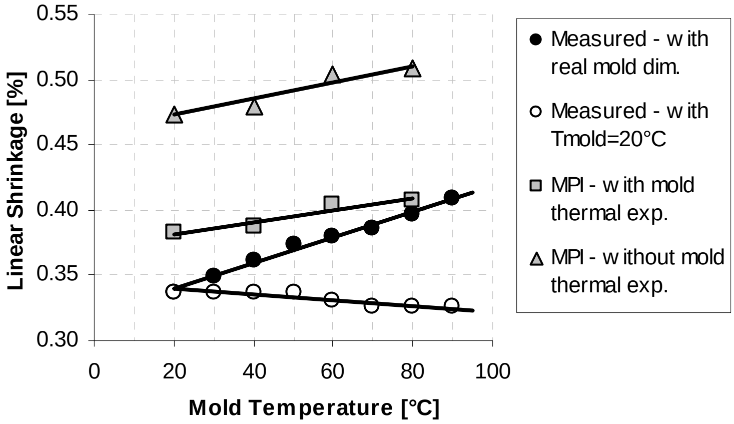

Fig.7. Shrinkage results

It can be seen that the simulated shrinkage data have a relatively good correlation with the measured ones, if the mold thermal expansion is taken into consideration.

5 CONCLUSIONS

We focused on the shrinkage variance caused by holding pressure and mold temperature. It was concluded that the holding pressure decreases the shrinkage, both in simulations and in practice. The correlation was quite good between the simulated and measured shrinkage if the thermal expansion of the mold was considered. We also highlighted that the effect of the thermal expansion was high at higher mold temperature.

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