Thrust Area Update:

Thermoplastic Processing

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Feature Project

Thin Wall Molding: Eliminating Degradation of PVC

By Jose Garcia (Koelling)

The technique of thin-wall injection molding (TW-IM) has been growing in popularity in recent years. The art of "thinwalling" is moving towards a market standard within the portable electronics industry. Moreover, material and process advancements directed at these markets are spreading to other industries because of lower cycle times, reduced material consumption, and potential for part cost savings.

The development of high flow PVC materials for injection molding applications is another recent advance. These materials contradict the traditional perception that PVC is difficult to work with because of its flow properties, HCl emissions, and the tendency to burn during processing. Some molders still believe that PVC can only be used in injection molding to produce small parts with thick walls, such as pipe fittings. However, the new high flow PVC resins have been successfully used in typical injection molding applications (e.g. computer monitors and computer casings), where the length/thickness ratios are approximately 100.

Even though this process may not fall within the “thin-wall” range for typical injection molding resins, it does push the limit for PVC molding. Furthermore, there are process conditions where the new high flow PVC resins may exhibit some degree of burning. Preliminary examination indicates that burn marks are caused mainly by thermal degradation of PVC due to viscous heating. Thus, current investigation is directed at evaluating possible sources for degradation and establishing guidelines for PVC injection molding.

In order to illustrate how PVC can degrade under extreme processing conditions, Figure 1 shows a small section of the cross-section in the radial direction of a plate molded using PVC M4200 (Geon). The plate had dimensions of 38 cm x 38 cm x 0.3 cm, and was center gated with a sprue approximately 8 cm long and 1 cm in diameter. The observed burn mark extended radially from the center with a radius of approximately 9.5 cm. Furthermore, a darker band formed a ring from 5.5 to 9 cm away from the center. Figure 1 shows the cross-section in the radial direction of a region 8 cm away from the center. This figure clearly indicates that the burn mark is not a surface defect and, in addition, it shows that degraded material is located near the gate side of the mold.

This result, then, indicates that the material near the gate side is hotter than the material near the cavity side. One explanation for this phenomenon is related to how the material flows from the sprue into the mold cavity. The proposed mechanism suggests that, as the material flows in the sprue, it undergoes viscous heating near the walls. Hence, as the material flows from the sprue to the cavity, the flow profile is such that the material that was near the wall in the sprue flows closer to gate side, while the material that was in the core in the sprue flows closer to cavity side. Therefore, it appears that degradation may be affected very early in the flow. Figure 2 shows the predicted temperature rise near the wall for the material in the sprue.

Continuing research in this area is directed at developing software code for simple geometries, such as radial flows and flow in tubes and rectangular channels. Examining simpler geometries supports a more detailed analysis of heat transfer during injection molding. In addition, these models also allow for implementation of thermal degradation data in numerical analysis. Also, since degradation may be influenced very early during injection, the simulation will take into account the history of the material being injected into the cavity. A tracer approach will be used for that purpose, where small volumes of material can be traced during injection and the material temperature and degradation history can be determined. These simulations will provide a means to determine the important parameters for PVC injection molding. Knowledge gained with these simple models can then be used to analyze results from commercial numerical packages, such as C-MOLD or Moldflow. The outcome will be a means to optimize processing conditions for PVC materials.

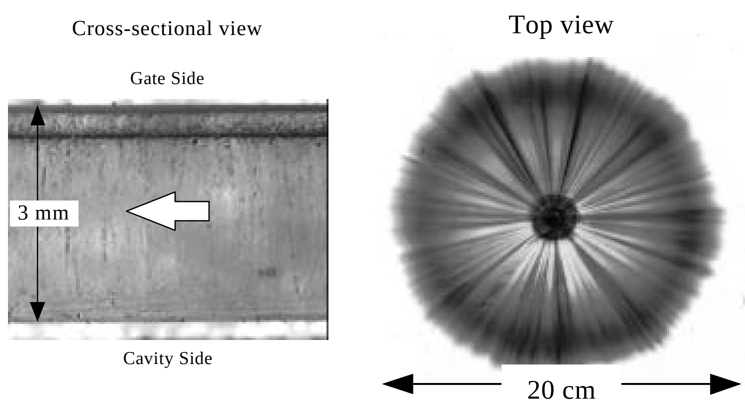

Figure 1. Cross-section of center-gated plate (arrow indicates direction of flow) and top view of plate (reduced).

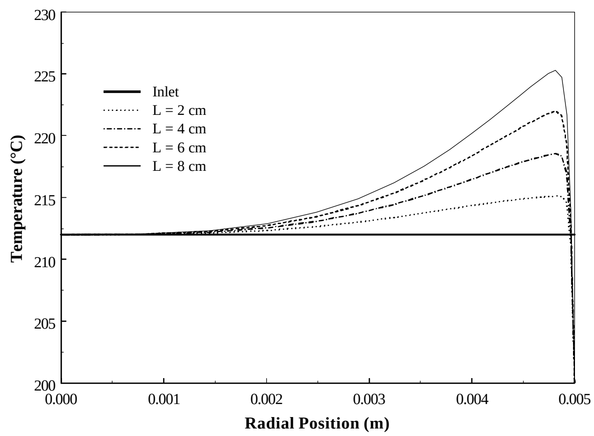

Figure 2. Estimated viscous heating in the sprue.

Understanding the Controlling Mechanisms of Gas-Assisted Injection Molding

By Vishal Gauri (Koelling)

Gas-assisted injection molding (GIM), a special process of injection molding, is one of the most innovative developments in the injection molding field in recent years. In this process, gas is injected into a partially filled mold in order to produce a hollow part. In order to obtain desired physical properties for a finished part, it is important to accurately predict the hydrodynamic coating thickness during the gas injection stage. The rheology of the fluid strongly influences the residual hydrodynamic coating thickness in this process. However, the interaction between the fluid response in the mixed flow geometry and the bubble shape is not well understood.

This study was undertaken with the goal of understanding the controlling mechanisms of the mold filling stage in GIM. The focus has been twofold: 1) To isolate important polymer rheological properties that influence the mold filling process and quantify their influence 2) To examine the validity of neglecting viscoelastic polymer properties by conducting rigorous Finite Element simulations. Test fluids have been designed with tailored properties to isolate important properties and understand how they affect the process. Coating thickness and Particle Tracking Velocimetry results show that viscoelasticity and extensional viscosity play an important role in GIM.

Extensional and Shear Rheology of Bimodal Polymer Solutions

By Alic Scott (Koelling)

Bimodal polymer solutions consisting of two monodisperse polymers of different molecular weights, dissolved in a Newtonian solvent were examined. The rheological behavior of these solutions was studied in dynamic oscillatory shear, steady shear, and uniaxial extensional flows. These solutions were used to determine the effect of varying individual polymer concentrations on transient extensional and shear rheology in bimodal solutions. Varying trace quantities of the higher molecular weight polymer were added to dilute polymer solutions containing the lower molecular weight polymer. This was done to isolate the effects of adding trace quantities of high molecular weight polymer to dilute solutions containing a lower molecular weight polymer.

Experimental results were compared to model predictions of the Oldroyd-B and Giesekus constitutive models. This was done to assess the validity of model predictions for bimodal solutions.

Analysis of De-Airing Process in Automobile Windshield Manufacturing

By Roger Juang and Denitra Bruer (Lee and Koelling)

The goal of this project is to establish the relationship between material properties, processing conditions, and pre-press quality. An apparatus has been constructed wherein the transparency of a glass/PVB/glass assembly undergoing vacuum de-airing can be monitored continuously. Experiments can be conducted with different combinations of de-airing conditions such as vacuum level, cold (ambient) de-airing time, and oven temperature. The behavior of PVB sheeting with different rheology and surface roughness can be studied using various de-airing conditions. Initial results show that the clarity of the assembly is a monotonically increasing function of time in the oven at a given vacuum level. More fundamental research has been undertaken by making a model material with known surface pattern and roughness. Compression of the model material under constant force has been carried out and the results are compared to the simulation using DEFORM, a commercial finite element code.

Supercritical Fluid Assisted Polymer Blending

By Mark Elkovitch (Tomasko and Lee)

Immiscible polymers can be blended to create materials with a wide range of properties. These properties include improved processing and end use capabilities. The great majority of polymer melts are immiscible, and as a result form multiphase domain structures. The structural details play an important role in the end-use properties of the blend.

One parameter that strongly influences polymer blending is the viscosity ratio of polymer melts. In polymer blending, the domain size of the minor (.e.g., dispersed) phase is at a minimum when the viscosity ratio of the individual polymers is close to one. The domain size increases as the viscosity ratio increases. Improved mechanical properties are achieved by closely matching the component melt viscosities.

A method for blending polystyrene and polymethyl methacrylate, (PMMA) using supercritical carbon dioxide was investigated. A high-pressure mixing vessel was used to prepare the blends under pressure with carbon dioxide for batch blending. This vessel was also used to estimate solubilities of carbon dioxide in the molten polymers. A single screw extruder was used to study the effects of injecting high-pressure carbon dioxide on the viscosity of polymer melts. The melt viscosity of PMMA was reduced by up to 70% with a CO2 amount of 0.35-0.40 wt.%. The melt viscosity of polystyrene was reduced by up to 56% with a CO2 content of 0.30 wt.%. A twin screw extruder was used to study the effects of injecting carbon dioxide in a continuous compounding operation.