**25th Annual Conf. of Polymer Processing, Goa, 1-5 mars 2009**

# Experimental study of water assisted injection molding

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**Abstract:** The objective of this work is to establish relations between water assisted molding parameters and product property. The molded part is a polypropylene handle, with a nearly circular outer cross section. Three different molding techniques were selected: overflow, short shot and co-injection. Regular wall thicknesses were obtained with the overflow process, whereas for the two other processes, the wall thickness varied from 3 to 4 mm. No significant wall thickness variations were observed when varying the molding parameters, except for the overflow process when varying the polymer filling flow rate and the polymer packing time. The water injection pressure level has been linked to the pressure drop in the polymer, but also to the size of the water entrance near the injector. The cristallinity ratio appeared to be quite homogeneous.

**Keywords:** Polymer – Water injection molding – Molding conditions – Dimensional characterization.

**Introduction:** Water assisted injection molding allows to mold hollow parts. Compared to the competing gas assisted technique, cooling is faster, and the internal surface aspect is improved. The objective of the work is to quantify the influence of the molding conditions mainly on the dimensions and volume of the part.

**Experimental:** A polypropylene Sabic 108MF97 has been used. The injection molding machine is a DK Codim, 110 t clamping force, equipped with a water injection system from DK. The water flow rate is imposed. The cavity itself looks like a handle, with a circular outer cross section 19 mm in diameter. A water injector is located in the feeding channel, and a valve upstream the overflow cavity (Fig. 1). The following parameters have been recorded: hydraulic pressure for the polymer injection, screw displacement, water pressure, injected water volume, and three pressures in the cavity.
Three different molding techniques were used:

- the overflow process: the cavity is fully filled with polymer, the polymer in excess is pushed in the overflow cavity.
- Short shot: the cavity is partially filled, then water is injected.
- Co-injection: at a given time during polymer injection, water is simultaneously injected, until completion of cavity filling.

For each process, each of the following parameters were varied around a standard value: melt and mold temperatures, polymer flow rate, polymer packing time and length (for the overflow process only), water flow rate, injected water volume, water packing pressure and length. The water was at room temperature.

**Results:**
*Overflow process:* cross sections (fig. 2) show that the polymer thickness is quite regular in the straight regions of the handle. In the curves, the thickness if the inside wall is much smaller than the outside one. The reproducibility of the measurements (polymer wall thickness, weight of the overflow, of the handle, volume of water inside the handle) is very good, with an error less than 1 %. Figure 3 shows that when the injected water volume is lower than 20 cm$^3$, the water flow front does not reach the tip of the handle. Above 20 cm$^3$, there is no change of the volume of water (or hollow cavity volume) in the handle.

The influence of the molding conditions on the weight and volume of the hollow core is negligible, except for the polymer packing time (the weight of the handle increases with the packing time) and the polymer injection flow rate (the weight of the handle decreases with the injection velocity). The variations are around 10 % in both cases.
When the water is injected, it has first to go through the layer of solidified polymer formed around the injector. Therefore, the measured water pressure is function of the local pressure drop at the injector, and of the pressure necessary to push the polymer. When the melt temperature is low, when the polymer packing pressure or time are high, the size of the channel is smaller. For instance, when the melt temperature increases from 210 to 240 °C, the size of the channel increases from 2 to 3.7 mm, and the maximum water pressure decreases from 17 to 14 MPa. When the packing time increases from 0 to 4 s, the size decreases from 3.5 to 1.5 mm, and the maximum pressure increases from 14 to 20 MPa.
The cristallinity ratio was around 42 %. No significant difference has been observed between the area in contact with the mold, and the area in contact with water.
*Comparison of the three processes:* The reproducibility of the measurements for the co-injection and short shot techniques is not very good, compared to the overflow technique. The wall thickness is less regular than for the overflow. The weight of the handle averaged over all the molding conditions, is smaller for the co-injection and short shot techniques (Table 1). The highest hollow core volume, and the largest diameter of hollow core is obtained for the short shot technique. This is due to the shortest time between polymer mold filling and water injection for the short shot process.

**Acknowledgements:** The authors thank Cetim for financial support, and DK, Transvalor and Cetim, partners of this research project, for technical help and helpful discussions.

Table 1: Global dimensional measurements, averaged over all the molding conditions, for the three processes.

| | Overflow | Co-injection | Short shot |
|---|---|---|---|
| Handle weight (g) | 30,3 | 29,7 | 28 |
| Volume of hollow core ($cm^3$) | 16,0 | 16,1 | 17,8 |
| Diameter of the hollow core (mm) | 11,3 | 12,6 | 13.6 |
| Polymer wall thickness in the straight region of the handle (cm) | 3,4 | 3,2 | 3 |

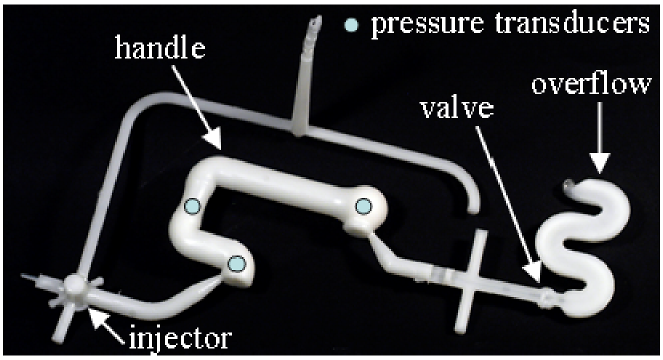


Figure 1: Picture of the molded part

Figure 2: Cross section of the handle

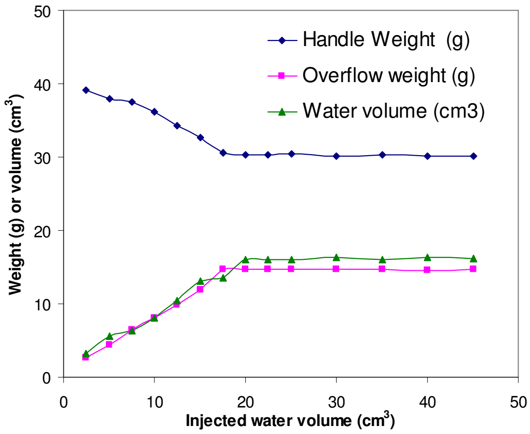


Figure 3: Handle and overflow weights, hollow volume vs injected water volume