LyondellBasell Technical Tip

tech.topic

Mold Shrinkage

INTRODUCTION

Most mold makers and molders face the problem of mold shrinkage of polypropylene (PP) and polyethylene (PE). For many, it is difficult to understand why, with all the resources and technology available, one can't get more accuracy in mold shrinkage data than a "typical". This Technical Tip briefly explains what mold shrinkage is and why it's impossible to establish a constant value for PP and PE.

WHAT IS MOLD SHRINKAGE?

In some respects, mold shrinkage can be compared to linear thermal contraction or expansion. A mass of molten polymer cooling in a mold contracts as the temperature drops. Holding pressure is used to minimize shrinkage but is only effective as long as the gate(s) remains open. If the polymer is homogeneous, all parts should shrink essentially the same amount even after the pressure is removed or the gates freeze off. This is generally the case with amorphous polymers such as polystyrene, polycarbonate, ABS, etc. Published values for mold shrinkage of these materials are very low and do not exhibit a broad range, generally in the order of less than 0.010 in./in.

COMPARATIVE MOLD SHRINKAGE VALUES

Material	Type	Shrinkage/in/in
Polypropylene	Semi-Crystalline	0.010 – 0.025
Polyethylene	Semi-Crystalline	0.015 – 0.040
Nylon (6-6)	Semi-Crystalline	0.007 – 0.018
Acetal	Semi-Crystalline	0.018 – 0.025
ABS	Amorphous	0.004 – 0.009
Polycarbonate	Amorphous	0.005 – 0.007
Polystyrene	Amorphous	0.004 – 0.007
PPO	Amorphous	0.005 – 0.008

Why are PP and PE (and nylon and acetal) different? Unlike amorphous polymers, PP and PE are not homogeneous but semi-crystalline, with a structure containing both amorphous and crystalline components.

As they cool, crystals form which shrink much more than the amorphous regions and shrink at different rates. This imbalance results in a net increase in shrinkage and introduces a sensitivity to other molding parameters which have additional effects on the shrinkage.

Another factor influencing shrinkage is the visco-elastic characteristic of high-molecular-weight-polymer melts. The long, molecular weight chains are literally stretched and placed under stress as they fill the mold. As the stresses are relieved during cooling, the chains want to relax, analogous to stretching a rubber band and slowly letting it return to its original size. This relaxation also influences the shrinkage, especially in different flow directions. Both the average molecular weight and the molecular weight distribution are key material factors that control this facet of mold shrinkage.

WHAT PROCESS AND DESIGN PARAMETERS INFLUENCE MOLD SHRINKAGE?

The relative proportion of crystalline to amorphous component changes the shrinkage. This is a very critical variable with polyethylene but is not as significant with polypropylene, as evidenced by the much narrower range of specific gravity, another property affected by the degree of crystallinity.

Since it is related to the physical contraction due to cooling, mold shrinkage is greatly affected by the thermal history of the molding. The melt temperature, cooling rate, part thickness and gate dimensions can be critical variables which control the amount of shrinkage as shown in the following graph obtained from a laboratory study using a 6 in. x 6 in., variable-thickness-plaque mold and a polypropylene impact copolymer.

Shrinkage data obtained under controlled laboratory conditions and using relatively simple mold geometries should be used only for comparison purposes and should not be applied to actual tool design.

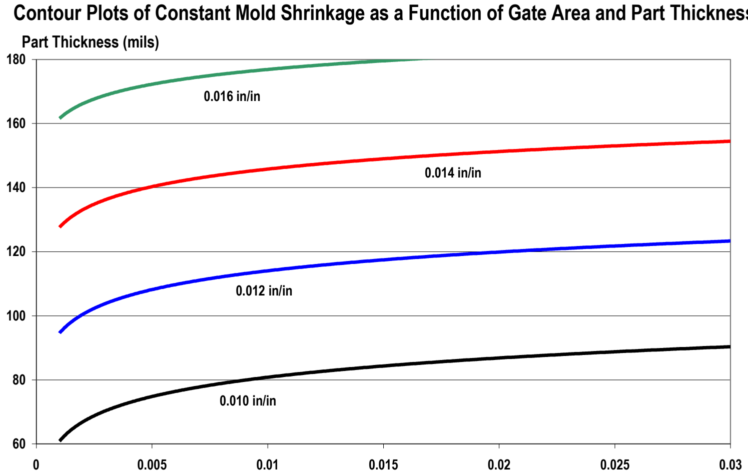
Mold Shrinkage *(Continued)*

One facet often overlooked in mold design is the need for uniform filling and cooling. In a part having a complex geometry, even with relatively uniform wall thickness, it is not unusual to observe different shrinkage rates in different sections of the part. This may be due to non-uniform cooling and/or non-uniform filling patterns. The use of modern computer analysis to study the filling and cooling patterns is an extremely useful tool to identify these problems and provide guidance for their minimization or elimination

SUMMARY

Mold shrinkage of semi-crystalline polymers such as polypropylene and polyethylene, is a very complex problem influenced by the inherent structure of the material and also by the heat transfer dynamics that occur during the injection molding process. Consideration of these factors, in conjunction with flow and cooling analysis, are important means of minimizing shrinkage and ensuring it is as uniform as possible throughout the part.

Contour Plots of Constant Mold Shrinkage as a Function of Gate Area and Part Thickness



Material: 12 MFR Polypropylene Impact Copolymer
Mold: 6 in x 6 in adjustable depth plaque

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