Marlex® POLYETHYLENE

Premium Extrusion and Rigid Packaging Resins

CPChem™

PE TSM-2

THERMOFORMED HDPE PART SHRINKAGE

INTRODUCTION

Some processors consider it impossible to predict or control size for thermoformed HDPE parts. Others are able to make accurately sized parts on a consistent basis. Why is there such a difference in results between custom shops?

The successful HDPE thermoformers are able to do two things well. They design their molds with suitable shrinkage allowances. They also understand the variables that affect part shrinkage in production and make appropriate adjustments to control them.

Is managing part size always important? No. Some parts, such as tote boxes and food trays, often have generous dimensional specifications. For other applications, the guidelines below will help you achieve the accuracy you need.

KEY VARIABLES

Let's look at some typical shrinkage values. As seen in Table 1, many molds are built with the same shrinkage values (in/in of part length or width) for both the machine direction (MD) and transverse direction (TD) of sheet extrusion. Some applications, however, require more specific MD and TD shrinkage values for adequate performance.

There can be large differences in the size of your parts, depending on how the sheet was extruded and thermoformed. Here are some key variables to consider.

Resin Type - High molecular weight (HMW) HDPE resins shrink 0.003 - 0.005 in/in more than medium molecular weight (MMW) resins when formed under the same conditions.

TABLE 1

Typical Design Values for HDPE Part Shrinkage

THICK PARTS	SHRINKAGE, MD/TD
non-critical MMW part	0.020/0.020 in/in
non-critical HMW part	0.025/0.025 in/in
average MMW female part	0.024/0.021 in/in
average HMW female part	0.027/0.022 in/in
average HMW male part	0.020/0.016 in/in

THIN PARTS	SHRINKAGE, MD/TD
vacuum forming, 170°F mold	0.035/0.015 in/in
pressure forming, 100°F mold	0.020/0.014 in/in

Mold Temperature - On average, an increase in mold temperature of 6 -10°F raises part shrinkage by 0.001 in/in in the direction the sheet was extruded.

Mold Type - As shown in Table 1, female parts can shrink as much as 0.007 in/in more than male parts because they are unrestrained during cooling.

Sheet Orientation - Higher drawdown between the die and polish roll nip increases MD sheet orientation. That, in turn, will increase MD part shrinkage, but will also reduce TD shrinkage.

Effect of Regrind - Parts thermoformed from virgin resin always shrink more than those formed from that resin's regrind. As a result, regrind content should be consistent between runs for critical parts.

PRACTICAL EXAMPLE

If there are so many things that affect part shrinkage, how do you choose the right design values for your mold? Sources of information can include the resin supplier, the mold builder, and data from prototype runs. However, the best resource is your own production records.

The chart in Figure 1 shows how much information can be obtained by running your molds at two temperature settings and then plotting part shrinkage. The straight line between points approximates the expected results of running your mold at any intermediate temperature in the range tested. If it is more convenient for your quality personnel, the y-axis can show part lengths and widths in inches.

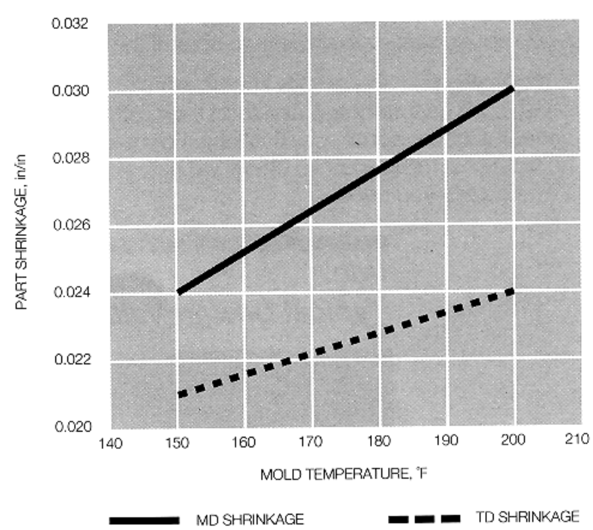
This trial normally would be conducted just once for each new mold. The charted data help determine whether it is possible with the existing sheet and mold to make parts as specified by your customer. In the example pictured in Figure 1, if the MD design shrinkage is 0.022 in/in, the chart shows that it cannot be achieved without lowering the mold temperature below 150°F. The slope of the lines can also be computed to predict the amount of change in mold temperature needed to achieve a specific part size. In the pictured example, MD shrinkage changes 0.001 in/in for each 8.3°F change in mold temperature. That type of information makes it much easier to control part size during production runs.

Unfortunately, it's fairly common to find molds that are designed with too little shrinkage. To achieve part size, mold temperature is then reduced so low that sink marks, shrinkage lines in the female radii, and part warpage occur. These problems can be avoided by using the right design value for new molds.

Once several molds have been charted as shown below, it is easy to find data on a part similar to the new one proposed. Those data can be used to supply well-grounded MD and TD shrinkage predictions to the mold builder.

The guidelines just presented will help you produce good quality parts. However, there's one more problem to consider. Medium and thick gauge HDPE parts (those formed from sheet thicker than 100 mils) will have shrunk only about 80% of the final amount when they are removed from the mold. Their shrinkage is roughly 95% complete after 4 hours and not totally finished for 24 - 48 hours. This delay in achieving final part dimensions makes it difficult to adjust size during a production run.

FIGURE 1
Plant Example



QUENCH COOLING

For thin and medium gauge HDPE parts, quench cooling provides immediate feedback on proper mold temperature settings while forming is being performed. Table 2 shows results of a study that compared sizes of parts quenched in a 60°F water bath with parts that were cooled in air for 24 hours. For the first test, sheet was cut with the MD in the long direction. Tote boxes were then thermoformed at the conditions shown in the Table. As reported in the first data column, the totes continued to shrink a substantial amount for the next 24 hours.

The next series of parts (bottom of first data column) were quenched in cold water for about 5 minutes just after forming. Those parts were then measured and found to be equal in size to the parts cooled slowly. They remained stable over the next 24-hour period.

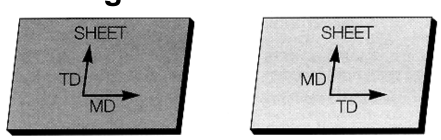
The second data column repeats the test, but with the sheet cut with its MD in the short dimension. Although shrinkage values were different because of the change in sheet orientation, the trends were the same. A couple of observations can be made from this data:

- Once the part temperature approached the mold temperature, cooling rate no longer mattered. All of the totes came to the same final dimensions, regardless of cooling rate, as long as the sheet was cut the same way.

- By comparing the two data columns, it's apparent that the direction the sheet blank is cut has a significant effect on part shrinkage. Therefore, the MD dimension should be the same for all subsequent sheet runs.

This quench study was conducted on medium gauge HDPE sheet. It should also be valid for thin gauges. Unfortunately, quenching may not be feasible for very large, thick HDPE parts for a couple of reasons. The first is a size problem - it's difficult to quench a truck bed liner or canoe. Also, thick parts are still so hot in their center that effective quenching may be hard to achieve. With such parts, standard measurement practices should be used.

TABLE 2
Effect of Quench Cooling



	SHRINKAGE, IN./IN. (MD long)	SHRINKAGE, IN./IN. (MD short)
TEST 1		
A. HOT FROM MOLD	MD/TD = 0.022/0.020	MD/TD = 0.025/0.016
B. AFTER 24 HOURS	MD/TD = 0.027/0.024	MD/TD = 0.033/0.021
TEST 2		
A. WATER QUENCHED	MD/TD = 0.027/0.024	MD/TD = 0.034/0.022
B. AFTER 24 HOURS	MD/TD = 0.027/0.024	MD/TD = 0.033/0.022

- Tote Box Thermoformed from 150 mil HMW HDPE Sheet
- Mold Temperature = 180°F
- Quench Water Temperature = 60°F

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