Marlex® POLYETHYLENE

Premium Extrusion and Rigid Packaging Resins

CPChem™

PE PTC-3

MANAGE SHEET SAG FOR THERMOFORMED HDPE PARTS

INTRODUCTION

Sheet sag problems in thermoforming can often be avoided by choosing the right resin for the application. The melt index specifications for our sheet grade HDPE resins are based on performance feedback from our customers. Resins with higher molecular weight (lower melt index) values are used in those applications that require low sheet sag to prevent webbing. However, if the molecular weight target is too high, then problems with reduced sheet extrusion rates, rougher thermoformed part surfaces, increased part shrinkage, and greater part warpage may occur. As a result, non-resin parameters should also be considered when addressing most sheet sag issues. This Plastics Technical Center report will examine some of the options that are available to adjust high density polyethylene sheet sag to acceptable levels in the thermoforming process.

RESIN SELECTION

Resin selection is a simple process for most thermoformed HDPE sheet applications. A general type of resin is targeted, based on the performance requirements for the part. Critical properties like impact strength, stress-crack resistance, product stability, u.v. resistance, and durability are normally outlined in the end user's product specifications sheet. Consideration of the critical process parameters, such as sheet sag during thermoforming, helps determine the best overall resin for the application.

For example, a pickup truck bed liner needs very good environmental stress-crack resistance (ESCR) and toughness to perform well in its expected environment. ESCR performance is key for the liner because of the mechanical stresses that occur at its corners and fasteners. Toughness is also important when items are tossed inside the liner during the cold, winter months. Good melt strength is essential for large, HDPE parts so web problems can be avoided. An Extra High Molecular Weight (EHMW) HDPE resin, such as our Marlex® HXM 50100, meets all of those performance and process criteria.

HDPE thermoforming applications are usually divided into two general categories – those that require exceptional melt strength, ESCR and toughness, and those where conventional HDPE is acceptable. Examples of both groups are provided in Table 1.

TABLE 1
Typical HDPE Applications and Properties

	Primary Attributes	Typical Applications
Conventional HDPE	Good wall distribution Low part warpage Best surface appearance Fastest cycle time	Tote boxes Food containers Freezer trays Print stock
EHMW HDPE	Excellent melt strength Excellent ESCR Exceptional toughness Good Abrasion Resistance	Truck bed liners Dunnage Pallets Boats & canoes

CRITICAL SHEET SAG VARIABLES

Sheet sag is usually pretty easy to control, because several variables can be used to adjust it to an acceptable level. But some thermoformed parts have unusually critical melt strength requirements because of their size or draw characteristics. When difficult thermoforming situations are encountered, the following tools may prove useful.

Control Regrind Concentrations

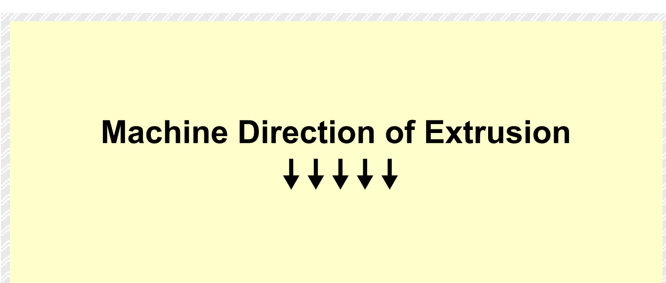
Our HDPE resins contain antioxidant packages that protect them from degradation during the sheet extrusion and thermoforming processes. In most situations, the regrind should be added back to the parts at the same rate it is generated in forming. If the regrind quality is good and contamination is avoided, sheet drawability and subsequent part wall distribution may be improved with regrind use.

A modest shift in the material's melt index value is expected during the sheet extrusion process. That shift occurs, in part, because the molecules become relaxed and less entangled as they are extruded. Additional MI shifts can occur because of factors like chain scission, and effects of the color concentrate. As a result, thermoformers of very large HDPE parts must sometimes limit the amount of regrind in order to prevent webbing. This problem is most evident in large, shallow-draw parts like portable toilet doors.

Specify Sheet Dimensions

HDPE sheet sag is minimized when the sheet blank is cut so the machine direction of extrusion is in the shortest dimension, as shown in Figure 1. However, thermoformed part shrinkage is always higher in the machine direction of extrusion, because the sheet orientation is greater in that direction. If the machine and transverse dimensions of a commercial part are switched, resampling is required in order to confirm that part shrinkage values are still viable. Some sheet extrusion equipment may not be wide enough to supply large blanks with the machine direction oriented as shown in Figure 1.

FIGURE 1
Rectangular Sheet Blank Sheared with the MD in the Shortest Dimension



Heat the Sheet Properly

As the sheet is heated for thermoforming, it sags as the weight of the blank overcomes the stresses that are trying to hold it up. If the blank is large and fairly thick, heat the sheet as rapidly as possible without burning it. Faster heating cycles reduce sheet sag, because the molten sheet is exposed to gravity for a shorter period of time.

With some plastics, localized heat is sometimes used to control webs, or to improve wall distribution in the deeper areas of draw. However, this approach may cause warpage in HDPE because of non-uniform cooling in the parts.

Choose the Right Mold Design Options

Male molds are often selected for the deepest draw applications in order to optimize wall distribution, or to put sheet texture on the outer side of the part. However, male molds are more likely than their female counterparts to generate webs. Many of the largest parts, like truck bed liners, are thermoformed on female molds for that reason.

Female molds are also selected for most multi-cavity projects, because the spacing between cavities can be much closer than with male tools. Additional mold design guidelines are available in TIB-82, our Technical Information Bulletin on "Designing Thermoforming Molds for HDPE".

Use Appropriate Forming Techniques

Review alternative thermoforming techniques to eliminate webs in the part. For instance, moving the mold to the other platen, or using web blocks, sag bars, or a ring assist, will resolve many sheet sag problems. Additional options for sheet sag control are reviewed in TIB-81, our Technical Information Bulletin on "Thermoforming HDPE Parts".

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Select the Right Additives

The effect of resin additives on sheet sag can be investigated by thermoforming fully formulated sheet against a natural HDPE control. In most cases, though, the phenomena discussed in this section, and their solutions, are common knowledge.

Hindered amine light stabilizers (HALS) are often used in outdoor applications to protect against ultraviolet degradation. However, some HALS may also increase melt index and sheet sag values, dramatically, when their concentrations exceed the additive supplier's recommendations.

The color of the sheet also affects sheet sag properties. For instance, black sheet absorbs more heat than white sheet, so its sag will be a bit higher. In most cases, though, the effect of sheet color on sheet sag is minor.

Color concentrates are usually comprised of organic or inorganic pigments, various additives, and a compatible polyethylene carrier resin. If the carrier resin's nominal melt index value is high, sheet sag may be excessive.

Control Sheet Orientation

Sheet orientation is a measure of the stresses generated during the sheet extrusion process. Since the sheet is flowing in the machine direction of extrusion, the molecules are always more aligned in that direction than in the transverse direction of flow. In general, as sheet orientation values are raised, the sheet's sag when heated is reduced.

Sheet orientation should be one of the last variables used to address sheet sag problems. When the molecules become too aligned in the machine direction of extrusion, wall distribution suffers and the parts are more prone to warpage. As a result, sheet orientation should be minimized for most projects, and should only be increased if all other options to improve melt strength have been exhausted.

SUMMARY

The size of the thermoformed part and required properties will help determine which HDPE grade to select. In most applications, the standard sheet grade resins have enough melt strength to prevent webs. In those situations where large, shallow-draw parts are formed, some of the other critical variables reviewed in this report can be adjusted to keep sheet sag at acceptable levels. If HDPE sheet sag is excessive, consider these changes:

- Evaluate a lower melt index resin
- Cut the blank with the MD of extrusion in the shortest dimension
- Heat the sheet as fast as possible, without burning it, in order to minimize "hang time" in the thermoformer.
- Use a female mold or review male forming options such as straight drape vs. inverted; and use web blocks, sag bars, plug and ring assists to control webs in critical areas.
- Ensure light stabilization additives are at appropriate levels.
- Reduce regrind concentrations, since virgin sheet sags less than sheet with regrind.
- Increase sheet orientation as a last resort.

We did not provide specific limits for the variables discussed, because the optimum targets are different for each project. The best solution should be obvious, though, after you review the details with your sheet, resin, and color concentrate suppliers.

If we may be of further assistance, please contact our Polyethylene Sales and Marketing team. Contact information is available at this web site http://www.cpchem.com/pe/index.asp, along with links to our polyethylene resins and MSDS sheets.

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