Polypropylene Cast Film Equipment and Operating Suggestions

One of the major uses for polypropylene is in the manufacture of extrusion-cast film. This bulletin covers equipment requirements and gives suggestions for operating ranges and conditions.

Equipment Design

Screw

Compression Ratio — Polypropylene can be extruded successfully into cast film with screw compression ratios of 4:1 to 3:1. Lower compression ratios favor greater output with the possible
disadvantage of nonhomogeneous melts. When a choice of screws is available, a compression ratio of 3.5:1 is a good starting point

Feed Zone Depth — For a 3½-in. (90-mm) extruder with a 3.5:1 compression ratio, feed zone depth should be in the 0.435 to 0.490-in. (11 to 12-mm) depth range. This figure varies as the metering zone depth changes. For extruders larger than 3½ in., the feed zone will have to be deeper.

Metering Zone Depth — For a 3½-in. extruder, a metering zone depth of 0.125 to 0.140 in. (3.2 to 3.5 mm) can work well, depending on the operating conditions and metering zone length. On new equipment it is better to start shallow so that refinement adjustment cuts will be possible later. An existing screw with a metering depth in the range mentioned can usually be made to work.

Screw Cooling — Internal screw cooling can correct minor screw design problems and increase operating flexibility. However, screw cooling is not required for most operations.

Extruder LID — The length:diameter ratio of the screw should be at least 24:1 to 28:1.

Other — Advances in screw design have been successfully applied to film extrusion. So-called barrier screw designs and a number of mixing devices have usually given good results. The use of static mixers can be successful in improving melt uniformity and pigment distribution. Gear pumps have been used to improve uniformity of pressure and output

Die

Because polypropylene is a polymer with highly non-Newtonian flow characteristics, good caliper uniformity across the web width requires compensation for die-manifold pressure drop. Center fed coat hanger manifold dies are therefore preferred. However, if the manifold cross-sectional area is large enough and die width is not excessive, keyhole manifold dies can be used.

The following die lip openings are good guides for polypropylene.

Product Thickness, mils	Die Lip Openings, mils

1-10	15-20
11-15	20-25
16-25	25-30
>25	<20% greater than product thickness

Air Gap — The distance from the bottom of the die lips to the line of fi[m contact on the chill roll (air gap) should be as short as possible, especially when an air knife is used. The recommended air gap is less than 1 in. (2.5 mm). Quality film and thin sheet are possible with gaps of up to 4 in. (102 mm), but operation becomes more difficult.

Several factors dictate this gap. It is desirable to rapidly quench the melt upon die exit to lower the haze, increase gloss, and improve impact- and tear-strength, at the sacrifice of some stiffness. A long air gap decreases the quench rate. A short air gap diminishes the possibility of melt flutter caused by stray air currents.

Air Knife — It is desirable to obtain rapid and uniform cooling of the melt on the chill roll. To achieve this, it is necessary that the film make intimate and equal roll contact across the cooling drum face. This is often accomplished with the use of an air knife. Other melt-to-roll contacting methods such as pressure rolls, electrostatic force devices, and vacuum knives also work, but offer no easier solution to the problem. It should be noted, however, that there are several patents in this field.

Proper utilization of the air knife, where one is used, is probably the most difficult part of the film-casting process. When correctly adjusted for lip opening, it will supply a continuous stream of air This stream should be directed slightly downward to avoid die lip cooling and melt flutter The airstream should contact the web above the point where the normal tangential contact to the roll would be. To best utilize airstream momentum, the lips of the knife should be as close to the roll as possible.

Basically, there are two ways of operating the air knife: with large openings (>25 mils) at low pressure, or with small openings (<5 mils) at high pressure. In either case, airstream momentum is approximately the same.

While experience indicates that either method works, small openings are usually more effective with polypropylene. Exact air knife lip openings and manifold pressures depend on operating conditions, especially film thickness and takeoff speed. Thicker films and faster rates require greater airstream momentum.

As a useful starting point, a 10-mil opening set uniformly across the lips is suggested. Adjustments to the knife can be made best after the film die has been set to give a uniform thickness profile. When uniform film is obtained, air knife pressure is increased until the film has the desired appearance. Air knife lip adjustments are then made to produce uniform snugging of the melt to the chill roll across the roll face. Final air pressure adjustment is then made.

Chill Rolls — To aid a rapid quench, the chill rolls should be operated at as low a temperature as practical, consistent with the fact that operation below the ambient air dew point is undesirable because of water condensation on the roll surface. Inlet cooling water temperature should be held at or below 70°F (21 °C). Water flow rate should be high enough to keep the temperature increase across the chill roll to about 5°F or 3°C.

Plate-Out — Polyolefins, including polypropylene, extruded at the high filming temperatures, deposit a residue on the chill roll. This very thin film or condensate will increase in thickness with time and will eventually transfer back onto the film, appearing as random patches of white. Excessive plate-out may indicate that the melt temperature is too high.

Intimate contact between the film and chill roll produced by the air knife greatly reduces and can eliminate plate-out. Greater operating flexibility is possible, however, by removing the roll residue with some form of wiping device. This can be a felt or cloth pad or a roller that is force-loaded against the chill roll.

Dies and flow channels should be designed to give streamlined flow from the extruder discharge to the die lips. Dead spots will cause holdup of the polymer, with subsequent degradation.
For film and thin sheeting, die lands should be ½ to 1 ½ in. (13 to 38 mm) long. Within this rather wide range, satisfactory performance is possible. Short die land leads to poor caliper control and increased tendency for melt resonance to occur Excessively long land causes high back pressure and reduced output.

OPERATION

Extruder Operating Conditions

Melt Temperature — The recommended melt temperature range for the production of chill-roll cast film of Pro-fax polypropylene is 500 to 550°F (260 to 288°C). This temperature is measured by a thermocouple probe extending into the adapter a distance equal to ¼ to ½ the melt channel diameter. Melt temperature below 500°F (260°C) may lead to higher haze, lower gloss, poorer drawdown performance, internal film distortion, and surface roughness.
Temperatures above 550°F (288°C) can cause loss of strength, discoloration, and increased neck-in, and can aggravate plate-out problems.
Serious degradation will begin at about 575°F (302°C), although noticeable polymer changes will occur at lower, temperatures.
The precise melt temperature is a mailer of choice. The temperature is chosen by experiment beginning at the bottom of the range (500°F) and moving up in 10-degree increments until the product quality and processability are satisfactory. Other things being equal, the lower the temperature, the better.

Extruder Barrel Temperature Profile — The particular temperature profile used depends on many variables, including extruder size, throughput rate, screw design, back pressure. residence time, and feed pellet temperature. A good starting point is 350°F (177°C) on the first zone at the hopper, increasing linearly to the melt temperature (500 to 550°F) on the last zone. In machines that have an L/D ratio greater than 24:1, it may be possible (and is desirable) to operate the last two or three zones at the same temperature. If pressure surging is encountered, increase the feed zone temperature.

Adapter and Die Temperature — Since virtually no mixing occurs in the adapter and die, heat transfer through the polymer is greatly inhibited. Therefore, to prevent optical distortion or impairment of caliper control, the adapter and die temperature should be held as close to the

melt temperature as possible.

Extruder Back Pressure — Melt pressure at the discharge of the screw upstream of the valve and screen pack should be 1,000 to 2,500 psi (6.9 to 17 MPa). Pressures in this range normally indicate good mixing, provided other operating conditions are optimum. Proper melt mixing is required to achieve thermal homogeneity at the screw discharge. The desired back pressure is best achieved by extruder valving.

Screen Pack — A screen pack is required to prevent accidental fouling of the die slot opening. Screen combinations of mesh sizes from 60 through 200 are usually satisfactory. A coarse and a fine screen, used together, such as a 60 and a 120, with the fine size upstream, work well. Stainless steel screens are preferred.

Die, Air Knife, and Chill-Roll Geometry

Die Opening — The die lip opening depends on the film thickness being cast Drawdown ratio (die lip opening:film thickness) should not exceed 20:1 to avoid melt resonance problems. Thus, for a 1 -mil film, the lip opening should be about 20 mils or less. Lip openings below 12 mils lead to undesirably high operating pressures, rate reduction, and oversensitivity of die opening adjustments. Die lip opening as expressed here should be measured with shim stock at the operating die temperature, without polymer in the die slot unless otherwise instructed by the die manufacturer.

As the product thickness becomes greater, it is desirable to reduce the drawdown ratio. For thick film and thin sheet it is desirable to maintain a positive draw for good gauge control, chill-roll contact and web-handling ease.