INVISTA™
POLYPROPYLENE

Polypropylene Sheet Extrusion Guide

The information set forth herein is being provided for informational purposes only. The information is provided on a without prejudice basis and should not be viewed as giving technical advice, instruction, or otherwise. The information is furnished free of charge and is based on INVISTA Polypropylene's knowledge and understanding. INVISTA Polypropylene *makes no representation or warranty as to the completeness or accuracy of the information contained herein*. It is intended for use by persons having technical skill, at their own discretion and risk, who will make their own determination as to its suitability for their purposes prior to use. As with any material, evaluation of any compound under end-use conditions prior to specification is essential.

Why Should I Use INVISTA Polypropylene for My Sheet Extrusion?

Polypropylene is a strong, low density polymer which exhibits outstanding resistance to heat, good surface characteristics (hardness, gloss, rigidity, etc.) excellent mechanical properties and low taste and odor.

PROCESS TECHNOLOGY CAPABILITIES

INVISTA provides a wide range of sheet extrusion polypropylene products. With the diverse capabilities of our polymerization plant, we can obtain polypropylene products that exhibit properties "unique" to the industry. INVISTA can produce Polypropylene sheet grades for industrial applications that use thick to extremely thin gauge products for high clarity food containers. Our polymerization processes have the ability to produce products with high stiffness and excellent impact, to sheet that requires low stiffness and good impact. INVISTA can produce homopolymers, random copolymers, impact copolymers, and blends based on our customers' needs.

Extrusion Procedures and Conditions

TEMPERATURE SETTINGS

Because there are many types of extruder designs, the settings for each extruder may vary. In the absence of previous experience with FHR polypropylene, consider the following extrusion conditions:

Extruder Profile

Zone 1 (Feed Zone)	380-420°F	(193-216°C)
Zone 2	400–440°F	(204-227°C)
Zone 3	410-450°F	(210-232°C)
Zone 4	440-470°F	(227-243°C)
Zone 5	440-470°F	(227-243°C)
Adapter	440-470°F	(227-243°C)
Melt Temperature	450-480°F	(232-249°C)
Back Press, psi (MPa)	1500-2500	(10-17)

Die Profile (Coat Hanger & Fixed Land Dies)

Zone 1	380-450°F	(193-232°C)
Zone 2	380-450°F	(193-232°C)
Zone 3	400-470°F	(204-243°C)
Zone 4	380-450°F	(193-232°C)
Zone 5	380-450°F	(193-232°C)

The melt rheology, or melt flow, of the polymer is a principle factor used for selecting temperature settings. For low melt flow polypropylene resins, higher temperature settings are required. For high melt flow resins, lower settings are more appropriate.

BACK PRESSURE

Back pressure is also a function of melt rheology, with lower melt flow materials producing higher back pressure. The recommended back pressure is essential to insure that extrudate uniformity problems such as surging, voids and un-melted resin are avoided.

SCREW SPEED

Generally, the extruder speed is set as high as possible for increased efficiency. However, the screw speed setting versus extruder power consumption is dependent on the screw design and melt rheology. For coextrusion dies, consultation with FHR technical personnel is recommended.

ROLL STACKS

Roll stacks can be configured either up or down stack. INVISTA found that the following settings produced the best results when extruding INVISTA polypropylene.

Roll stack settings:

Top roll	80-150°F (27-66°C)
Middle roll	100-175°F (38-79°C)
Bottom roll	80-150°F (27-66°C)

Die gap settings: 10% over desired gauge

1st nip gap settings: 1-3% over desired gauge

2nd nip gap settings: "dead on" desired gauge

For increased gloss, clarity and lower haze after forming, lower roll stack temperatures are preferred. It is imperative that the web is partially molten (in the core) when it reaches the second nip. If the web is super cooled, stress induced crystallization occurs as a result of forces applied in the nip, and the resulting sheet can be difficult to form.

Improper extrusion or quenching of polypropylene can cause a high degree of orientation in the sheet. Orientation is the alignment of polymer chains in the machine-direction. When oriented polypropylene is reheated, it will attempt to return to an un-oriented state resulting in sheet deformation. Orientation can be minimized by using proper processing temperatures, die gap and quenching the sheet under minimum tension.

TROUBLE SHOOTING GUIDE TO SHEET EXTRUSION

Problem	*Possible Cause*	*Suggested Remedy*
Line in Sheet – Extrusion Direction Continuous	Material build-up on die lips, or scratched die.	Clean die or residue.
	Die lip setting too close to or below desired sheet thickness.	Increase die lip setting.
	Excessive or uneven bank causes lines where melt loses contact with roll surface.	Adjust die for even gauge.
	Damaged roll surface.	Resurface roll.
	One-sided shrinkage due to cold center roll. (Sheet appears corrugated).	Increase center roll temperature.
Lines in Sheet – Extrusion Direction Discontinuous	Extruder surge causes bank to increase and decrease. (Appears as bank or bead roll ripple marks)	Eliminate extruder output variation (metering screw or melt pump fluctuations). See "Surging".
	Polish rolls are not concentric.	Replace rolls.
	Worn lead bearings on rolls.	Replace bearings.
	Insufficient hold down pressure on top roll allowing roll to float. (Appears as ripple marks.)	Increase hold down. {Note: exercise care not to exceed roll stack capabilities. Typical hold down force is 70-350 lbs. (32- 159 kg.) per inch of sheet width.}
	Excessive winder tension – pulling sheet through pull rolls.	Slow down winder.
	Moisture in compound.	Dry compound before extruding – use vented extruder.
Line in Sheet – Transverse Direction	Extruder output varies (surging).	See "Surging".
	Chill roll "chatter" from overloading. (Appears as fine parallel lines running perpendicular to chill rolls)	Minimize bank and run roll stack at within specified torque range. For very thin sheet, independent roll drives may be required.
	Pull roll chatter or slippage.	Decrease speed (tension) of pull rolls, and clean to ensure positive gripping action.
	Winder pulling sheet through pull rolls.	Slow down winder.
	Web sticking to cool rolls.	Polish rolls, reduce roll temperatures, and reduce melt temperature.

Line in Sheet – Parabolic Marks	Bank is too large rising and falling, or "walking".	Adjust line speed, adjust die gap to minimize differences in transverse web thickness, and eliminate extruder surging.
	Improper die temperature settings cause uneven flow across die.	Adjust die temperature – lower hot zone and/or raise cold zone temperatures.
	Viscosity mismatch in co-extrusion.	Select polymer grades with matched rheology, adjust melt temperatures to match rheology, or modify feedblock configuration.
	Material contamination in extruder or die.	Purge extruder and die. If problem persists, break down line and scour components.
Surface Imperfections – Low Gloss	Poorly polished rolls.	Clean and polish rolls.
	Temperature differential between center, and top or bottom rolls is too low or too great.	Adjust roll temperature to recommended settings.
	Insufficient bank in first nip (starved nip gap).	Decrease chill roll speed, increase output by increasing screw speed, or adjusting restrictor bar.
	Improperly gauged chill roll nip gaps.	Adjust gaps to recommended gauge settings.
	Web is not contacting second nip to polish surface.	Increase first nip gap to allow more material through to second nip.
Surface Imperfections – Spot on surface	Cold spot on roll surfaces.	Purge fouling or air bubbles from chill rolls. Maintain uniform temperature control across chill rolls. (inlet/outlet temperature difference should be less than 10°F or 5.5^0C)
	Uneven bank.	Adjust die lips to ensure uniform flow across die.
	Air bubbles trapped between center roll and sheet before first or second nip.	Reduce roll stack speed, increase first nip gap, and increase center roll temperature. After these adjustments, open the roll gaps to allow trapped air to pass through, then re-close and resume operation.

Surface imperfections – Bubbles or Fish Eyes, Dimples, Pits and Lakes	Moisture in the feed.	Dry pellet/additives before extruding and use extruder venting.
	Air entrapment in melt.	Increase back pressure and lower rear extruder zone temperatures. Reduce screw speed to ensure uniform feed compression and plastication. Vent the extruder. Use screw design with increased feed zone and transition length. Increase overall compression ratio or screw.
	Poor roll contact caused by dirt on rolls.	Clean rolls and polish.
	Melt is too hot resulting in polymer decomposition.	Lower melt temperature by lowering extruder zone temperatures.
	Second gap is starved causing "lakes".	Increase first nip gap to allow more material through to second nip.
Surface Imperfections – Rough Surface (Sharkskin, alligator or tread marks)	Improper roll temperature settings.	Readjust roll temperatures to recommended settings.
	Poor roll contract in second nip.	Increase take-off speed, increase pull roll tension, increase first nip gap, or reduce line speed.
	Melt temperature is too low, or viscosity is too high.	Increase the melt temperature or decrease output rate. Increase die land gauge to length ratio. Increase first nip hold down pressure.
	Die land gauge to length ratio is too low. (Melt break or excessive die swell at high output.	Increase melt temperature or decrease output rate. Increase first nip hold down pressure.
	Material is solidifying too quickly on center roll.	Increase roll temperatures, increase line speed, or increase melt temperature.
	Moisture in feed.	Dry material before extruding – use vented extruder.
	Improper screw design.	Change out screws. Increase back pressure. Decrease output rate.
Sheet Curl – Edge Curl	Temperature differential across rolls or between rolls is too great.	Adjust roll temperatures to recommended settings.
	Insufficient cooling.	Reduce line speed and reduce roll temperatures.

Streaks and discolorations – Additive Dispersion	Poor color dispersion.	Use color concentrate vs. dry blend. Ensure that the concentrate carrier (liquid or solid) is rheologically compatible with polypropylene.
	Melt inhomogeneity and insufficient mixing in extruder.	Change screw. Increase back pressure by valving. Use static or dynamic mixers.
Streaks and Discolorations – Contamination	Improper cleaning or extruder and die.	Purge extruder and die. If problem persists, break down line and scour. Static mixers and screw may require decompositional cleaning.
	Residual contaminants in feed hopper or transfer tubes of extruder throat.	Lower extruder zone temperatures.
Streaks and Discolorations – Plate Out	Excessive roll temperatures.	Reduce roll temperatures and increase line speed.
	Excessive extruder temperatures.	Reduce extruder temperatures to recommended settings.
	Excessive additives in the polymer.	Reduce additive levels and consult a FHR representative.
Surging – Improper Equipment or Setup	Improper screw design.	Change screw or alter to meet recommended design specification. Add valving or screen packs to increase back pressure. Lower screw speed.
	Insufficient back pressure valving.	Increase back pressure valving.
	Incorrect extruder temperature profile.	Adjust temperatures to recommended settings or invert temperature profile (adapter zone should be the same temperature as the die).
	Bridging in feed zone.	Cool hopper zone. Cool feed zone of screw.
	Insufficient melt homogeneity (mixing).	Control screw temperature. Change screw design. Increase back pressure. Use hopper crammer if there is a large particle size difference in feed material (excessively large or small particles in regrind).

Surging – Equipment Malfunctions	Malfunctioning thermocouples or heaters.	Checking for overheating or under-heating. Verify correct controller functions (temperature reading, control setting response). Replace malfunctioning equipment.
	Drive malfunction.	Consult with extruder manufacturer.
	Variation in line power.	Check drives and utility connections.
Poor Melt Thermoforming or SPPF Processability – Excessive Machine Direction Orientation	Too much tension on pull rolls.	Decrease speed of pull or increase chill roll and line speeds.
	Winder pulling sheet through pull rolls.	Decrease winder tension.
	Excessive calendering in first or second nip.	Adjust the die gauge closer to finished sheet gauge. Increase melt temperature. Decrease hold down pressure in second nip.
	Excessive drawdown between die and roll stack.	Increase output or decrease line speed.
	Sheer induced crystallization at first or second nip.	Increase melt temperature or output and line speed.
	Cold working in first or second nip.	Increase melt temperature or output and line speed to ensure that sheet is not completely solidified before entering the nip. Decrease hold down pressure. Use die lip adjustment and line speed to achieve gauge instead of calendaring to gauge in roll stack.