Profile Extrusion of Geon® Rigid PVC Cubes and Pellets

INTRODUCTION

PVC is often the material of choice for profiles for a variety of reasons, including good chemical resistance, weatherability, ease of extrusion and good dimensional control.

Extrusion of PVC cubes and pellets into profiles is accomplished by shearing and heating the cubes or pellets until they are soft and deformable, mixing them and then forcing them through a die of appropriate size and shape.

EXTRUSION EQUIPMENT

A typical extrusion line consists of some method of storing the material (silo, hopper, gaylord) to feed the extruder, an extruder, tooling (die), sizing and cooling, take-off (puller) and a method of cutting the profile to the desired length. Requirements for each element of the extrusion line are reviewed in more detail.

STORAGE & FEED SYSTEM

PolyOne delivers rigid PVC cubes and pellets in bulk or in gaylords. Silos and all transfer lines should be made from stainless steel since Aluminum tends to gray the compounds. Recommendations on designing silos or transfer systems are available from your PolyOne Technical Service representative.

Drying cubes or pellets is normally not required for profiles. However, some specialty compounds require drying for at least 1 hour at 200°F. Please consult PolyOne compound Technical Data Sheets for specific requirements.

EXTRUDER REQUIREMENTS

The extruder should be a 24/1 L/D. Longer barrels should be avoided as they tend to over-heat the compounds through excessive shear heating.

Barrel materials should offer superior chemical and wear resistance. Although Technical Service Bulletin # 57 ***"Processing Guide for Fiberloc Extrusion"*** describes some materials of superior wear resistance, most barrel manufacturers use correct materials when they know rigid PVC is to be extruded.

A breaking-in period on new barrels is often required. PVC degradation at the metal surface, sometimes called PINKING even though it is black or gray, can often occur for up to a few days on a new barrel. This degradation reaction is usually reduced or eliminated by using low barrel temperatures and compensating by using a higher screw RPM. Occasionally, high barrel temperatures, which change the flux or melting point on the screw, can help eliminate this degradation at the metal surface. Refer to Technical Bulletin # 39 ***"Pinking in Rigid PVC Profiles"*** for more information on PINKING.

Drive motors should have adequate horsepower and be geared for high torques at relatively low RPM's, ie 35 max.

Extruder size	Recommended Horsepower
2 1/2" or 50 mm	40
3 1/2" or 90 mm	75
4 1/2" or 110mm	100

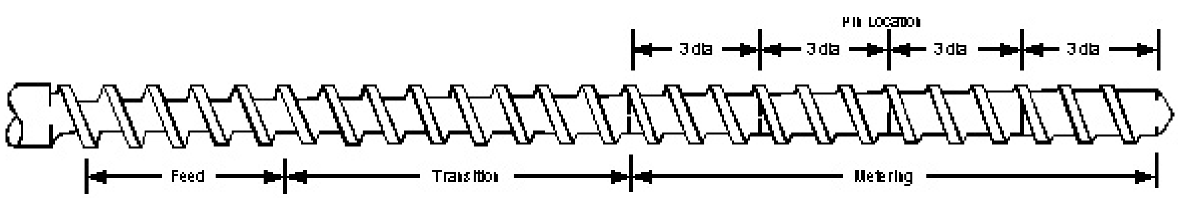
Oil cooling or high capacity air blowers with finned heaters are preferred on barrels with a deep thermocouple control system. A pressure gauge should be located at the end of the barrel.

SCREW DESIGN

A good general-purpose screw design is one with a single flight, constant pitch with the pitch equal to the diameter, and length equal to 24 diameters. It should be bored for potential screw cooling. Screw flights should be flame hardened or capped with Colmonoy 56 or other suitable treatments for rigid PVC. The screw should be chrome plated. The following designs will produce good results under a variety of conditions. It should be noted that other screw designs work as well.

	Flights			
Diameter in/mm	Feed	Transition	Metering	Pounds/hr
2 1/2 - 60	5 @ 0.500"	7	12 @ 0.210"; 4 rows of pins*	50-80
3 1/2 - 90	5 @ 0.625"	7	12 @ 0.260"; 4 rows of pins*	80-300
4 1/2 - 110	5 @ 0.770"	7	12 @ 0.320"; 4 rows of pins*	150-500

- Typical pin placement: on a 3 1/2" screw for each row, use 27 pins made of 304/SS, 5/32" diameter on a 36 hole index. Press fit into 1/4" deep holes and grind to screw diameter. DO NOT interrupt the screw flight. Place the four rows of pins at 3, 6, 9 and 12 flights from the screw tip. Use 1/8" diameter pins on a 30 hole index on a 2 1/2" extruder and 5/32" diameter pins on a 43 hole index for a 4 1/2" extruder. Again, DO NOT interrupt the screw flight.



Regardless of the screw size, a 2.4:1 compression ratio is recommended for rigid PVC. This is the ratio of the channel depth in the feed zone to the exit depth in the metering zone. Higher compression screws, such as those designed for flexible PVC, can cause over-heating of the material. In extreme cases, the use of a high compression screw can lead to burning of the rigid PVC compound.

Constant taper screws, where the flight depth decreases at a constant rate from the first flight to the last flight, are also to be avoided. There is usually inadequate mixing within a given flight to maximize melt temperature uniformity. This can lead to variations in melt temperature at the approach to the die, which in turn can affect melt flow stability.

Badly worn screws, where the total clearance exceeds about 0.030", can result in over-heating of the PVC compound. This is because the pressure along the screw is sufficient to drive material backwards over the wider than normal gap between screw flight and barrel. The residence time increases within the barrel and the extra shearing causes the melt temperature to rise. The most common indicator of a worn barrel is a significant reduction in output at a given screw speed.

TWIN SCREWS

Special low shear screws are available for cube or pellet extrusion on twin screw extruders. Care should be exercised to avoid over-amping the extruder. Usually, this can be accomplished by starve feeding the cubes or pellets into the feed throat.

BREAKER PLATES AND SCREEN PACKS

Breaker plates are required to prevent the melt from twisting in the die and thus avoiding swirls in the profile. They also support the screen packs, which are recommended.

Use breaker plates made from Armco 17-4PH, 15-5PH, Carpenter Cartech Custom 450, or other suitable chemically resistant materials. They should be hardened and polished. Holes should be between 1/8" to 3/16" in diameter. Smaller holes can cause over-heating; larger holes can allow the screens to collapse in them. The entrance and exit of each hole should be chamfered to avoid stagnation. Avoid using carbon steel, simple because of its poor chemical resistance. Also avoid using Aluminum or brass, which can lead to degradation of the PVC. Crossover breaker plates have been known to help if PINKING is a problem.

Screens should be stainless steel. If multiple screens are used, always place the coarser screen downstream to back up the finer ones. A 20/40-mesh combination is usually sufficient.

DIES

Flat plate dies are usually adequate for short runs of about 6 hours or less at low melt temperatures. However, for longer run lengths, all sections of the die and adaptor should be streamlined to prevent stagnation and degradation.

Without going into the specifics of die design, the following are some guidelines:

- Transitions in the adaptor should be smooth with approach angles of 30° or less.
- The melt inventory behind the lips should be kept low by making the adaptor as short as possible. However, if swirling is observed in the melt, due to non-homogeneity off the screw, then the adaptor might need to be slightly larger.
- The critical element in die design is to get all sections of the melt moving out of the die at the same velocity. This is accomplished by adjusting the land length behind the die lips to balance pressure flow.
- Land length should be about 10-15:1 or as low as 8:1 for very thin profiles.
- Dies should be balanced for one compound at one temperature on one size of extruder, and ideally with one screw design.

Die materials must be chosen for corrosion resistance and durability. It is common to use softer metals that can be easily machined but which can be subsequently hardened for durability. Good die materials would be AISI-SAE 0-6 or A-6, hardened after machining and then chrome plated. Alternate materials not requiring chrome plating would be stainless steels such as Armco 17-4PH, Armco 15-5PH or Carpenter Cartech Custom 450, hardened after machining and finally polished. There are many other materials that can be used successfully, provided they are chosen for good chemical resistance and are easily machined. Aluminum, brass and Copper dies, spacers, etc are not recommended since they are reactive with PVC and can cause burning of the compound.

COOLING AND SIZING

Profile cooling and sizing can be accomplished by using a combination of vacuum sizers, finger sizers, air-cooling, water immersion or water spray. The exact combination is determined by the ultimate cooling and shaping requirements of the extruded profile.

PULLERS AND CUTTERS

Profiles must be pulled down the line using a constant tension and constant speed puller. Variations in puller speed will cause dimensional variations which will jam vacuum sizers.

Profiles can be cut using a sharp high speed saw, a fly knife or guillotine cutter prior to packaging.

Trouble Shooting Guide for Profile Extrusions Made with Rigid Geon® Vinyls

Problem	Typical Cause	Suggestive Corrective Action
Orange Peel, Alligator Skin	Too much fusion	Reduce melt temperature Reduce Rate Increase die temperature Increase melt temperature Check for proper screw/barrel fit
Small Chunks	Too little fusion	Increase screw RPM Use tighter screen pack Check for proper screw/barrel fit
	Poor regrind quality	Use correct compound Use sharp blades in grinder Cool regrind properly Check for contamination Run 10°F hotter than 100% virgin
Sandpaper Finish	Sticking in die	Reduce die temperature Reduce melt temperature Chrome die land Polish die
Swirls	Melt flow problems	Use breaker plate Use pins on screw Reduce barrel temperature Reduce rate Increase inventory behind die lips to allow thermal uniformity Check for proper screw and barrel fit
Colored Streaks	Degradation	Break in new barrel or screw Refer to TSB #13 for equipment recommendations Reduce barrel temperatures Increase barrel temperatures Use converging/diverging breaker plate
	Sizer wear	Use anodized aluminum or stainless steel Reduce vacuum in sizer
	Incomplete dispersion of color concentrate	Use correct screw design Check compatibility of color concentrate and compound Use precolored compound
	Degradation in center of profile (colored line down center)	Use screw cooling Use offset screw tip Allow 1/2" clearance between screw tip and breaker plate
Dull Surface	Low temperature	Increase melt temperature Increase screw RPM Polish and chrome plate die Check compound selection
Bubbles	Moisture	Dry the cubes/pellets Decrease rear zone temperature
	Trapped Air	Decrease rear zone temperature
	Degradation	Reduce melt temperature Check barrel, screw and die temperature controls

Problem	Typical Cause	Suggestive Corrective Action
Die Lines	Nicked die/approach	Polish Die Use brass tools during cleaning Remove scratches/gouging in adapter
	Plate-out	See plate-out
Dirt Attraction	Static	Pass profile through 5% soap solution
Edge tear	Uneven velocity across profile	Increase die temperature Increase RPM Increase melt temperatures Radius inside corners Avoid blowing air on die Use finer screens
	Contamination	Eliminate contamination
Build-Up in Die (Plate-out)	Compound ingredient sticking to metal	Reduce head pressure Reduce die land length Chrome plate adapter Polish adapter Check compound selection
High Head Pressure	Long Die Land	Reduce land length
	Using restrictor	Eliminate restrictor
	High melt viscosity	Increase melt temperature Check temperature controls Use lower viscosity compound
	Improper breaker plate and/or screen pack	Change screen pack Use coarser screens Use larger holes in breaker plate
	Excessive adapter length	Reduce adapter length
	Oversize extruder/small profile	Match extruder size to profile cross section
High Drive Motor Amps	Cold Melt	Increase die temperature Increase melt temperature Slowly increase RPM
	Plugged screen	Change screen pack Use coarser screen
	Incorrect gear box ratio	Use correct gearing to increase motor RPM
	Motor too small	Use recommended HP motor
	Oversize extruder/small profile	Match extruder size to profile cross section
Lip Bleed	Compound ingredients exuding	Radius exit of die land Reduce head pressure Reduce melt temperature Verify compatibility of color concentrate
Brittleness	Poor Fusion	Increase Screw RPM Increase melt temperature Use finer screens
	Excessive drawdown	Recut die
	Poor profile design	Check interior corners for radius Reduce depth of embossing
Inconsistant Die Flow	Uneven die temperatures	Check die temperature (side to side, top to bottom) Check heater bands & controllers (operational, location, staggered, calibration) Eliminate drafts across dieInsulate die
	Thermocouple Placement	Locate die thermocouple closer to die opening and have it well seated.
	Set-up	Confirm set-up is same as last good run Purge barrel if a different material was run previously

Problem	Typical Cause	Suggestive Corrective Action
Dimensional Control	Surging	Verify constant puller speed Determine if profile is slipping in puller Reduce vacuum in calibrator Verity constant screw RPM Maintain constant hopper level Use feed throat cooling Check for stingers/tailings in compound Increase screw cooling temperature Check screw/barrel wear Use correct screw (see TSB #13) Reduce feed zone temperature
	Temperature variation	Check, calibrate and tune temperature controllers Eliminate drafts on die Check thermocouples (seating, operation, connection, zone to controller matching, placement)
Profile Warping	Non-uniform profile cooling	Adjust cooling
	Insufficient profile cooling	Increase cooling capacity Reduce rate
	One side of profile retaining more heat	Improve cooling efficiency Heat the cooler side (thinner wall)
	Equipment misalignment	Line up extruder, cooling, puller, etc.
Excessive Thermal Shrinkage	High residual stresses	Reduce draw down Reduce cooling rate

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Updated: 05.2005