TECHNICAL SERVICE REPORT Number 7

EXTRUSION OF GEON® RIGID CELLULAR VINYL

INTRODUCTION

Processors are continuously seeking ways to reduce their product costs. One way is to design the product around rigid cellular vinyl.

Rigid cellular vinyl has a low density as compared to solid material. The compounds are unplasticized PVC cubes and powders containing a chemical blowing agent. Due to a closed, uniform microcellular structure, rigid cellular vinyl is lightweight with inherent PVC properties - moisture and chemical resistance, electrical non-conductiveness, low thermal conductivity and low maintenance.

In many applications, rigid cellular vinyl has helped reduce the cost per foot for a profile by simply reducing the density from, for example, 1 .4g/cc to 0.7g/cc.

Rigid cellular vinyl helps reduce the weight per unit length for a profile. However, compared to solid PVC, some physical properties are affected. The most obvious changes are a reduction in skin hardness and tensile strength as the density is lowered. In general, the mechanical properties of unsupported rigid cellular vinyl are not suitable for load bearing applications. Therefore, it is important for the designer to consider the sacrifice in physical properties obtained with a weight reduction.

EXTRUSION EQUIPMENT

Rigid cellular vinyl tends to run hotter and is more difficult to size than solid rigid PVC. A typical extrusion line consists of an extruder, tooling (hot die and sizer), vacuum sizer take off (puller) and a cut off saw. Requirements for each element of the extrusion line will be reviewed in more detail.

EXTRUDER

The extruder must be capable of providing sufficient heat and mechanical shear to convert the compound into a homogeneous melt at a temperature high enough to decompose the chemical blowing agent and deliver the melt to the die system. Rigid cellular vinyl can be extruded on both single and twin screw non-vented machines.

HOPPER DRYER

A hopper dryer is not considered to be a necessity when extruding cellular vinyl cubes. However, several processors have found that a hopper dryer is a comparatively inexpensive way to improve the consistency of their process (dimensions/finish). A hopper dryer can be useful when extruding 100% regrind and when the virgin cubes are stored for an extended period of time in a humid environment.

Extruder Size	Compression Ratio	Feed Depth	Metering Depth
2-1/2 inches	2.4:1	.500 inches	.210 inches
3-1/2 inches	2.4:1	.625 inches	.260 inches

Regardless of size, the extruder should have a good variable speed drive with accurate speed control. Motor requirements are similar to those for solid PVC extrusions. The following are recommended powder train requirements:

Extruder Size	Horsepower
2-1/2 inches	40
3-1/2 inches	75

For any extruder designed for rigid PVC, the screw is probably the most important consideration. Its characteristics affect the amount of shear, melt temperature and uniformity of the melt. This same consideration applies to rigid cellular vinyl.

A non-vented, single-screw extruder equipped with a single-stage, chrome-plated, high-shear, mixing screw is recommended. The LID ratio should be 24:1. The screw's compression ratio should be 2.4:1. The first row of mixing pegs should start five inches from the screw tip and each row should be 6-1/4 inches apart. The pegs should be .125 inches in diameter and .125 inches apart. For example, a typical screw for a 2-1/2 inch extruder with a 24:1 LID would have:

- 5 feed flights - .500 inch depth
- 7 transition flights
- 12 metering flights - constant .210 inch depth
- 4 row mixing pegs

The use of a breaker plate with .125 inch chamfered holes is recommended. A screen pack should not be necessary. The following is a list of rates that have been achieved on gravity-feed, single-screw extruders. Rates are limited by the profile's cross-sectional area and the downstream cooling capacity.

Extruder Size	Rate O.5g/cc Specific Gravity	Profile Cross Sectional Area
2-1/2 inches	130 lb./hr.	1.00 in^2
3-1/2 inches	300 lb./hr.	1.50 in^2

TOOLING

Tooling for rigid cellular vinyl materials is different than tooling used for solid PVC extrusions. Design is very important. The hot die should be designed to allow the extrudate to expand to nearly the exact size and shape of the finished product upon leaving the die. The die approach and inventory must be streamlined as much as possible. This prevents material stagnation and facilitates long production runs.

The most desirable method of producing the hot die is to burn the land section into the die by electric discharge machining (EDM). This allows a very accurate shape to be produced that would be difficult to produce by other machining techniques. Usually, the land section is burned to a depth of 0.5 inches. The hot die blank is bored out from the opposite side to meet the machined shape. The die is then "balanced" or contoured using hand tools to facilitate a smooth even flow. This allows the extrudate to expand to the proper shape upon leaving the die.

Balancing the hot die is an important process that is almost an art. It should be done carefully and recuts should be done from the approach end. As many as six recuts may be necessary. Widening the approach and shortening the land length will induce more flow into a particular area. On a finished hot die, the land length is approximately 0.250 inches.

The profile shape on the discharge side of the die is somewhat similar but smaller than the shape of the sizing die. The cross-sectional area of the hot die at the land should be approximately 35% of the cross-sectional area of the sizing die in the vertical plane and 60% in the horizontal plane. Another factor to remember is that the percent of expansion is greater in the narrow direction and flats tend to bulge. Therefore, to produce a flat, the die shape should be concave.

A typical hot die can be made with 6061 aluminum and, once balanced, should be anodized to reduce wear. Chrome-plated steel and stainless steel hot dies have been used successfully.

The sizing die is normally 18 inches long and split lengthwise to facilitate easy start up. The profile shape is machined into the two interior surfaces of the die at exactly the same dimensions for the entire length. To allow for thermal contraction, the dimensions should be approximately 15 mil/inch larger than the profile shape. For example, if the final profile shape is to be one inch wide, the sizing die dimension should be 1.015 inches wide.

The sizing die is normally equipped with two rings of vacuum holes around the profile circumference to help maintain dimensional accuracy as the material "freezes". The first ring should be located about 3.5 inches from the face of the sizer and the exit ring should be located about 1.0 inch prior to the exit.

The sizing die can also be made from 6061 aluminum and anodized to reduce wear. To reduce frictional drag, a satin finish is desirable.

VACUUM SIZING

Sizing of the expanded profile can be accomplished by either applying a vacuum to the water cooled sizer die(s) or by locating the sizing die in a vacuum cooling tank and applying vacuum to the tank. The cooling water should be chilled to approximately 40°F and be turbulent. Additional water bath cooling may be necessary. This water does not have to be chilled; however, it should be as cool as possible. Proper cooling of rigid cellular vinyl is very important since this material has excellent insulating properties and releases heat slowly. When extruding profiles with legs, it is recommended to run them with the legs facing up. This allows heat to escape more readily.

TAKE-OFF MACHINE

A take-off machine (puller) is required and it should be slip proof without distorting, scratching, or otherwise marring the profile. The machine should have a variable speed drive and be able to maintain a set speed. A speed range of 0-50 ft/min. is suggested. A grip belt type machine approximately 30 inches long should be satisfactory. It is also suggested that a remote speed control be provided and located near the die system.

CUT-OFF SAW

An automatic traveling cut-off saw is recommended, although any saw capable of cutting rigid PVC smoothly and squarely will be sufficient. A fly knife or guillotine cut off is not recommended.

PROCESSING COMMENTS

Geon® rigid cellular vinyl compounds are designed to obtain their intended nominal density at a melt temperature of 188-193°C (370-380°F). At these temperatures, the chemical blowing agent decomposes, releasing a gas which is contained in the fluxing material by the pressure in the extruder barrel. As the material emerges from the hot die, it undergoes a pressure drop to atmospheric conditions and rapidly expands. Exhibiting good hot strength, the material will expand to the proper size and shape within approximately 3 inches. A hot die that is 22-23°C (40-60°F) cooler than the melt temperature and is also streamlined with minimal land length aids in making a smooth, tough profile surface. The extrudate then enters the sizing die and cooling tank.

Positioned up to approximately 5-6 inches from the hot die, the sizer contains and cools the extrudate enough to maintain dimensional stability. The sizer should be fully filled by the extrudate without stuffing. This can be accomplished by adjusting the line speed. Approximately 5-8 inches Hg vacuum on the sizer will maintain accurate sizing. If vacuum tank is used, a range of 3-5 inches Hg should prevent sink marks, but not great enough to cause excessive swelling.

REGRIND

Extruded rigid cellular vinyl can be ground and re-extruded on a 100% basis or it can be blended in any ratio with virgin material. To avoid "bridging" in the hopper, the regrind particles should not be larger than 0.125 inches.

A hopper dryer is useful since moisture can be picked up from the water bath or storage in a humid atmosphere.

In order to get the specific gravity down to the desired range, it may be necessary to raise the barrel temperature 6-8°C (10-15°F).

TROUBLE SHOOTING GUIDE FOR RIGID CELLULAR VINYL

Problem	Possible Cause	Solution
Small blisters and/or pits on profiles.	Excessive melt.	Lower melt temperature.
	Contamination.	Remove contaminant.
	Moisture in material.	Dry the material.
Material breaks, poor hot strength.	Poorly fluxed material.	Increase melt temperature.
	Barrel temperature low.	Increase barrel temperature.
	Screw too deep; ratio.	Use recommended screw.

Problem	Possible Cause	Solution
Profile color too dark.	Density too high.	Reduce density by increasing melt temperature or increase screw RPM.
	Color match off.	Adjust color.
Profile color too light.	Density too low.	Raise density by decreasing melt temperature or decrease RPM.
	Color match off.	Adjust color.
Water marks on bottom of extrudate.	Air bubbles collecting on bottom of profiles at sizer.	Set up brush to remove air bubbles or introduce very high velocity water under profile.
	Sizer not filled.	Slow down puller or increase vacuum.
Poor angle control or legs tucking	Development of hot spots.	Run profiles upside down to allow heat to escape.
	Linear line speed too high for adequate cooling.	Slow line speed, or increase cooling efficiency.
	Hot die out of balance.	Rebalance hot die.
Surging.	Bridging or sticking in hopper throat.	Cool hopper throat by circulating water. In the use of regrind, size of regrind should not exceed 1/8 inch.
	Inconsistent hopper level.	Maintain constant level in hopper.
	Sticking and stretching in sizer.	Determine if hot die is too big and/or decrease puller speed, or lower water temperature to 4°C (40°F) and increase turbulence.
	Rear zones too high.	Reduce temperature of barrel at feed zone.
	High polish on sizer.	Sand blast and reanodize sizer.
	Profile slipping in puller.	Increase pressure on profile.
	Motor on puller too weak to maintain a constant RPM.	Increase motor horsepower.
Fold or creases on profile.	Stuffing sizer.	Speed take-up.
	Unbalanced hot die.	Balance die.
Profile slightly undersize.	Not filling sizer.	Slow take-up.
	Insufficient blowing.	Increase melt temperature.
	Stretching due to profile not adequately cooled before entering puller.	Improve cooling efficiency.
	Stuffing sizer and stretching.	Balance die.

Problem	Possible Cause	Solution
Specific gravity too high.	Melt temperature too low. Low RPM.	Increase melt temperature. Increase RPM.
Specific gravity too low.	Melt temperature too high. High RPM.	Decrease melt temperature. Decrease RPM.
Void or hole in cross section.	Die not balanced properly. Material "too hot" in center. Underworked melt.	Balance die. Reduce melt temperature, or use air or oil cooling on screw tip. Increase RPM.
Rough surface, brittle, high density.	Moisture in material. Underworked melt.	Dry material. Increase RPM.
Degraded material in profile.	Material sticking to die. Dead spot in hot die and/or insert. Malfunctioning controller. Thermocouple, poor contact. Stagnation behind mixing pins. Melt temperature too high.	Reduce die temperature after shutdown and complete clean-up, or check wear of system. Modify die to streamline material flow. Repair controller. Adjust spring tension, or clean thermocouple well. Shutdown and clean screw or use recommended screw. Lower melt temperature and check zone controls.
Sink marks.	Too low a vacuum to insure full product dimension. Unbalanced die. Profile design.	Increase vacuum on tank and/or sizer. Balance hot die, more fill in sink section. Avoid large differences of cross-sectional areas.
Compound sticking to screw.	Excessive melt temperature. Screw condition.	Reduce melt temperature. Clean dirty screw or check chrome plating.
Orange peel.	Compound overworked. Die too hot. Hot die land too long.	Reduce melt temperature. Lower die temperature. Reduce land length.