Tubing from Flexible PVC

Introduction

Flexible PVC (polyvinyl chloride) for use in the manufacture of small diameter tubing is a relatively easy compound to process. It lends itself to use in the medical field for tubing used on IV sets, kidney dialysis, oxygen systems and drainage units, to name a few. It also can be formulated for use in the electrical field as primary insulation or as harnessing tubing. Another area of PVC tubing use is industrial, such as pneumatics and chemical conveying.

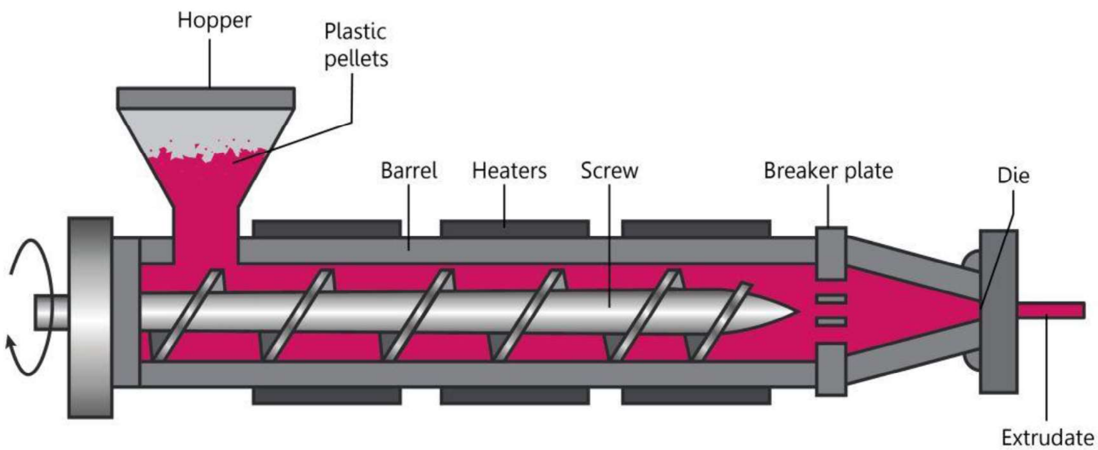
Although PVC, as compounded by Alphagary, is used diversely, we must be aware of its process parameters. To discuss these parameters, we will consider the importance of the process equipment and its effect on the PVC compound.

Screw Design

PVC, as normally supplied for tubing, comes in the form of a pellet. There are many shapes, however, and they all have one thing in common – they are reasonably tough and must be converted into a formable mass. This is done by means of the extruder screw. The screw must combine mechanical energy with heat from the extruder barrel to masticate the material and allow it to be shaped into tubing by means of the head and die.

Flexible PVC generally withstands processing temperatures in the 340-350 °F range before starting to degrade. With this in mind, the screw design must be such that the material will be fully masticated when exiting the screw at the aforementioned temperatures. Alphagary’s PVC is best processed in a screw having a 3 to 1 compression ratio with a metering depth of 100 mils. We recommend a 24 to 1 L/D screw with at least 15 turns of constant metering. This type of screw, combined with Alphagary’s clear compound will give a crystal clear tubing, free of hard particles or unmasticated lumps. The use of mixing pins or Maddox sections all work well as long as design parameters previously mentioned are followed.

SINGLE SCREW EXTRUDER



There are many who will say they can produce good product with different style screws by adding screw cooling or very fine screen packs to develop backpressure. Tubing might be extruded this way. Alphagary's PVC compounds extrude best and produces exceptional product when the proper screw is used.

Poor or improper screw design will result in:

1) **Tubing With Gels or Unmasticated Lumps**

   Gels – Although there are many opinions as to what constitutes a gel, they are most commonly very fine hard particles imbedded in the surface of the tubing.

   Unmasticated Lumps – These are pieces of PVC that are not completely mixed and appear as small lumps or inclusions in the tube. They are quite frequently clear.

2) **Poor Size Control**

   Simply this is a variation in finished tubing dimension. The variation can be a matter of 5 to 10 thousandths....or more severe. 50 to 100 thousandths, quite frequently called "surge". Both of these size problems relate to screw design.

Small changes can be an indication of too short a metering section in that the flow is not fully stabilized when entering the head or die. Severe changes point to the compression ratio as well as incorrect ratio of feed, transition and metering or pump length. In short, you are either starving the pump or feeding too much material to the pump which causes irratic working and, thus, irratic flow.

Another consideration when size control is a problem, is screw wear. You might believe you have the proper screw design, but still size is a problem. Inspect the clearance between the screw and cylinder. Excessive wear causes backflow over the flights and, thus, erratic output.

3) **Over temperature Condition in Compression Zone**

You may find an over-ride in temperature in the compression zone which causes high melt temperature and difficulty in controlling the process. This generally occurs when this zone is too short, and the screw compression ratio is too high.

The material is being conveyed too quickly by the feed zone and cannot move out into the metering section. Essentially, you are getting a jam-up in the zone. Quite frequently, the barrel cooling system will keep this condition under control. If not, a screw change should be considered.

Ways To Circumvent Inadequate Screw Design

Above are mentioned a few things which occur when screw design is improper. But there are a number of “tricks” or ways to circumvent inadequate screw design or excessive wear when the necessity arises.

a) If mixing is the problem, increasing the number of fine screens may help by giving more backpressure.
b) Another approach is to use screw cooling to change the flight depth and, thus compression ratio.

Both of these “tricks” may solve the problem – either individually or together – but should be looked upon only as stop-gap measures. If at all possible – get the proper screw.

Die Design

Die design for use on PVC is important in that the internal parts must be highly polished to eliminate hang-up and eventual degradation, and inventory must be kept to a minimum to ensure there is no stagnant material. Chrome plating is recommended on all internal surfaces. The support for the mandrel or core pin, called the spider, should utilize the 3-leg design. This makes cleanup easier while reducing the possibility of knit or weld lines in the tubing. The important factor with die design as related to PVC is to keep the material moving.

Avoid corners and turns as much as possible in design so the material cannot stagnate. Streamline as much as possible; be sure all mating surfaces blend properly.

Core and Die

Cores and Dies used to regulate tubing size should be polished and chromed. Generally, the land length, or constant dimension of the Core and Die should not exceed ¼”.

The O.D. of the Core and I.D. of the Die are determined by adding 10% to the tubing wall thickness. Example:

Desired tubing size	- .125 I.D.
	- .250 O.D.
	- .0625 Wall
Dimension of Core	- .137
Die	- .275

We have found these to be optimum draw-down ratios for good size control, as well as reduced shrink-back of final product. Excessively high draw-down ratios when combined with short-landed tools can result in poor surface finish on the tubing and excessive shrink-back of the finished tube.

Shrinkage is important in electrical tubing, especially in the electronics industry where application requires the use of soldering guns. Many times, the heat generated during soldering will cause the tube to shrink, thus exposing bare wire.

Screen Packs

The use of screen packs in extrusion is to screen out foreign material from the compound. They will, of course, develop some backpressure at the end of the screw, but should not be used as an aid to mastication as discussed under screw design. Stainless Steel screens are recommended for PVC.

Tube Size

The size of the finished tubing is controlled by three major factors:

1) Die and Core dimensions.
2) The amount of air inserted in the tube.
3) The take-up of puller speed.

If the previously mentioned Core and Die sizing parameters are used, the amount of air inserted can be kept to a minimum. Air adjustment in inches of water is made by means of a regulator and is set to required level for correct tubing I.D. This adjustment must be coordinated with the puller speed to arrive at the right tubing wall thickness. Incorrect Core and Die selection will result in high air requirement or oval tubing due to the lack of air. Air insertion, as mentioned is the means by which fine dimensional adjustment is made, but also supports the tube to reduce ovality.

Cooling of Hot Tubing

Obviously when the extruded tube exits the die, it has little or no melt strength. It therefore must be cooled as quickly and uniformly as possible to eliminate distortion. This is accomplished by means of a water trough containing cooled water. The tube must be immersed totally or at least flooded with water. It is desirable to use water at a temperature of 40-50 °F.

The length of the water trough is determined by the wall thickness of the tube and its lineal speed. This must be predetermined when the line is set up for production. Insufficient cooling can cause:

1) Distortion of finished parts in packaging.
2) Surface imperfections sometimes called gels, but in reality are watermarks.
3) Poor size due to stretching.

Tubing must be held under water by means of small rollers or guides that create little or no friction. If the tubing drags or has to pull over a roller or guide, size control problems can result. This drag produces uneven pull and can develop a “rubber-band” effect in the total length of tubing.

Down Stream Equipment

Aside from the puller used to move the tubing, the tubing can be either cut to length or coiled, depending on the customer’s requirement.

Compound Handling

In order to produce top quality product in a trouble-free process, the compound must be properly handled.

1) Keep the compound clean by storing it in a clean area. Keep dust and dirt off the bags or cartons.
2) Keep the compound dry.

Dirty compound can obviously result in foreign particles in the finished tube. Moist or wet compound can cause a variety of problems depending on the moisture level.

1) The extrudate will exhibit small air bubbles or voids.

2) It will, in extreme cases, exit the die as foam totally uncontrollable.

It is also desirable to keep the extruder hoppers covered at all times to avoid contamination.

Determining Equipment Size

We have spent considerable time discussing the effects of screw and die design as well as general processing parameters and their effect on the product.

We must, however, consider the size of the entire line relative to the product to be manufactured. This is to say, you don't buy a ½ -ton pickup truck if 5-ton loads need to be hauled.

An intelligent look at the product line must be taken:

- What range of tube size is to be produced? If the intention is to produce small tubing (1/16" ID x 1/8" OD) or larger tubing (1/2" OD x ¾ OD), the extruder and line should be sized accordingly.

- The quality of the extrudate is affected by the screw rpm, as well as screw design. Therefore, if the product to be produced requires an output of 50 lbs./hour, do not purchase a machine that has a 200 lbs./hour output. Also, a large machine creates excessive residence time, which can result in degraded material, as well as poorly masticated material when run as low rpm.

- Obviously, it is not expedient to be locked in too tightly when sizing the extruder, therefore use a safety factor of 50% when figuring output. The machine supplier will be able to give details of machine output by screw design. Approximately 85% of the quoted output will be attained.

- Downstream equipment, such as water trough, puller, cutter and take-up, must also be sized to handle the output of the extruder.

The following example is the calculation to determine extruder output for a given size tubing:

Tubing size 1/8” ID x ¼” OD
Formula 340 (OD + ID) (OD – ID) Specific Gravity + lbs./m feet
340 (.250 + 125) (.250 - .125) 1.23 =
340 (.375) (.125) (1.23) = 19.60 LBS./M FEET

To achieve running 6,000 feet per hour, multiply 6 x 19.60 = 117.6 lbs./hour, which is the output required from the extruder.

There are many other factors to be considered with equipment sizing, too numerous to be listed. If further assistance is needed, please contact us to discuss.

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