Twin Screw Extruders Design and Operating Characteristics

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Twin-screw extruders have become very popular for the manufacture of rigid PVC pipe during the last few years in the United States. There are now six U.S. suppliers of twin-screw machines designed for PVC pipe extrusion. Five of these designs are of European origin. A distinction should be made between twin-screw extruders designed for compounding and those designed for finished product extrusion. Compounding machines are designed to provide higher levels of shear which is required to obtain good dispersion. Finished product machines for PVC pipe extrusion are designed to provide lower levels of shear in order to control stock temperature build-up. Because of the differences in design the following comments only apply to intermeshing, counter-rotating twin screw extruders designed for the production of PVC pipe.

Since twin-screw extruders designed for PVC pipe extrusion employ inter-meshing screws with limited clearance between the screws, the pumping characteristic closely approximates that of a volumetric pump. Pressure flow (back flow) is very limited and is not greatly increased by increased die pressure. These machines therefore have excellent metering characteristics and wall tolerances can be readily held to one-half that possible on single-screw extruders.

Because of its volumetric pumping characteristic, throughput of the feed section is independent of friction forces between polymer and barrel and polymer and screw surfaces. The machines are designed to utilize powder dry-blends, but can utilize chopped scrap material of higher bulk density by either blending the scrap with virgin material or employing a starve feeder.

Compression is effected by diameter reduction (tapered screws), changes in pitch and number of flights and various combinations. Satisfactory operation is possible over a limited range of bulk density and excessively high bulk density can overload the machine unless a starve feeder is employed.

Venting is readily accomplished and vent flooding is not a problem, due to the positive conveying characteristics of intermeshing twin-screws. This contrasts with the difficulties of vent flooding experienced on two-stage, vented single screw extruders when excessive die pressure is encountered.

Melting, under optimum conditions, occurs on the last few flights of the screws and appreciable temperature rise is experienced, in passing through the die. Most dies employ internal mandrel heaters as well as external heaters to bring the material up to its final temperature. A typical extrudate temperature is 380°F vs. 430°F for single-screw operation.

Drive power requirement is typically one-half that required for single-screw extruders. Due to the low level of shear about half the energy required to heat the polymer is derived from mechanical work, the remaining heat being conducted into the polymer through the barrel and screw surfaces and through the die.

Dies are designed to provide in creased dwell time to increase heat transfer in the die. Due to the low stock temperature, increased dwell time can be tolerated without degradation. This is opposed to die designed for single screw extruders where dwell time must be minimized due to the high stock temperature employed.

The pressure capability of twin-screw extruders is limited by thrust bearing capacity. Because of limited space, thrust bearings are smaller on twin screw machines, but modern machines employ various innovations which provide satisfactory thrust bearing life. Some machines employ force gauges and limit switches on the screws to maintain the thrust within tolerable limits.

Sizing and cooling of the extrudate is simplified due to the lower stock temperature. Either vacuum sizers or water jacketed sizing sleeves are employed and diameter tolerances are readily maintained. The practice of drawing down the wall thickness to produce a range of thicknesses from one die is limited because of the limited melt ductility of the low temperature extrudate. About 25% drawdown can be tolerated but if this is exceeded, internal surface cracks, which are not visible on the outside surface, may develop. Drawdown can

be improved by addition of acrylic processing aid, but at a formulation cost penalty. Wall tolerances in terms of eccentricity and lineal variation are reduced as com pared to single2screw operation.

Screw and barrel life employing nitrided surfaces has been found to be 2 to 3 times that of a single screw machine due to the lower operating RPM. Integral cast alloy barrel liners are stellite flighted screws should improve this performance. Of course, screw and barrel replacement is more expensive for the twin-screw machines.

Being more complex machines, we would expect twin-screw extruders to have higher maintenance costs. How ever, this is not a significant factor and on an overall balance the industry has found that PVC pipe is more economically produced on these machines.

Reduced formulation cost is the key to reduced manufacturing cost of PVC pipe produced on twin-screw extruders. Because of the low extrudate temperatures employed, stabilizer level can be reduced by 0.75 phr. With stabilizer priced at $2.25/lb. this represents a $1.53 /lb. savings. On a 600 lb./hr. machine operating 8000 hours/year, annual savings will be $73,440, for a machine costing about $80,000. Additional savings can be obtained by reduced requirement for processing aid and by reduction of product weight by better tolerance control.

Twin-screw machines are beginning to be employed in this country in the extrusion of rigid PVC profiles and extrusion of rigid PVC sheet will probably follow. As processors become more familiar with the capabilities of twin-screw extruders we will probably see chlorinated PVC, polyvinylidene chloride and other degradable polymers processed on those machines. Materials having low frictional characteristics, such as TFE, are good candidates for twin-screw extruders, because of the excellent feeding characteristics of these machines.

- Leonard F Sansone

See also:

- Distributive mixing and energy distribution in twin screw extruders
- Downstream mixing in twin screw extruders
- Polymer devolatilization
- Solvents and thermoplastics separated in CRT extruders
- Twin screw extruder operating range
- Twin screw extruders screw design: one, two, three
- Twin screw extrusion system compounds high levels of metal fillers into polymers
- Vent flow in twin screw extruders

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