Vector Forces in Extrusion Design

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Sometimes ignored in various stages of extrusion is the vector force generated at various stages of the extrusion process. It is the type of force that splits a block of wood when driving a wedge. The force normal to the wedge becomes greater than the force of the sledge, even though friction interferes.

Frederick Zenz devised a nice experiment, using sand, but plastic powder works the same way. Even pellets, at times.

His experiment started with a glass tube fitted with a piston, close fitted to prevent leakage, but free moving. As increments of sand were added to the tube, the piston continued to move freely until the sand reached a critical height. Then the piston "locked up" and could not be moved further. More and more force ended in rupturing the tube. All of the force was transmitted normal to the thrust and none in an axial direction.

The author observed this in the screw flight. With certain liberties in getting the column to "lock up," it then appeared that the force generated in the compression zone of the screw became many times higher than the 600 psi normally obtainable in an ordinary feed section. This plastic column, unlike sand, did not have the rigidity and collapsed on itself, resulting in deformation and shear and beginning the melting process. The idea of stick-slip has been accepted by many screw designers.

Further in developing the NRM wedged and keyed hopper, very large normal forces are developed in the feed zone. This is similar to the force developed in a tapered pin, where it can be driven in, but will not come back out after the force is released. This happens only if the angle of the pin is less than the coefficient of friction developed between the two metals. Here again, with plastic, the deformation takes place because of the wide discrepancy between the strength of hot plastic and the same temperature of hardened steel.

This same logic seems to follow with action in the compression section of the screw. If the plastic is too stiff, or if it contains fillers, the collapsing does not occur soon enough and excessive screw and barrel wear results.

Finally, as the melt leaves the end of a die, particularly a pipe die, it should exhibit hydraulic pressure and also develop laminar flow. Neither seems to occur. The pipe may show some after swell, but more often, particularly at slower rates, the parison will leave the die at close to the die diameter. Again, exceptions occur, but there is strong evidence that often the extrudate leaves as a column.

Critical analyses, following the same reasoning as above, would indicate that the normal forces generated particularly in the compression section of the die, produce a tightly packed matrix that is under much higher circumferential pressure than axial pressure.

— Robert L. Miller

See also:

- Designing high performance screws
- Extrusion evaluation through pressure and melt temperature analysis
- Pressure gauge
- The effect of pressure on output
- Thrust bearings

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