Naming screws for materials, compression ratios

Naming screws for materials, compression ratios and other ways to avoid dealing with real dimensions
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The ancient Greek, Archimedes, who lived in Syracuse (then a Greek colony on the island of Sicily), is credited with inventing the screw pump as a device to empty the bilge of Greek ships. He is the same guy who yelled "Eureka" when he figured out the laws of buoyancy, burned holes in the sides of enemy ships by concentrating sunlight with multiple mirrors, and calculated the value of "pi" more accurately than anyone else before (the Greeks didn’t have zero nor a decimal system, remember).

Archimedes didn’t have to pump hot plastic, although the people in those boats did have a need for high output. When thermoplastic melts came along, it turned out that the screw pump was ideal — the rear end grabs, the middle melts and the front end homogenizes and pumps out.

From this comes the classic 3-zone concept of how to make a screw: feed zone, compression zone and metering zone. It’s still the best starting point for those who need to understand screw design, and the basis of the vast majority of screws, single screws at least.

Screw design ought to be written as a single word. It’s one of the ways our industry has improved its technology and productivity, and has been the focus of many an inventor, experimenter and fluid-flow engineer. We’ve come a long way, Archie.

However, the word carries a mystique that implies a little magic, or else a lot of computer-age math, which leave screw users and buyers like medical patients - they know the names of things and what they do in general (mix, melt, etc.) - but don’t have a good idea of how they work, nor do many of them care.

As an engineer committed to the principle that the devil you understand is less dangerous than the devil you don’t, I want ‘people to understand the basics of screw construction. Although I certainly recognize the work of Maddock, Maillefer, Kruder and many others whose specific designs have advanced our field so much, I am still reluctant to speak of "screw design" because I want to de-mystify the process, and prefer the phrase "screw dimensions" as quantifiable and more conceptually digestible to the people who have to deal with them.

OK, so what are these dimensions? They fall into three areas: zone, balance, channel depths special features.

Zone balance means the division of the entire length into the three zones, by specifying the length of the feed and metering zones (the constant depth zones), which in turn sets the compression length as whatever is left. Plastics which need a lot of heat to melt should have long feed zones where the mass can move more slowly and soak up more heat, while plastics that decompose easily need as short a metering zone as possible to avoid such decomposition.

Normally, a long and gradual compression zone is a good thing. Some plastics melt rapidly once the melt temperature is reached, and it is often thought that such materials need only a short compression zone. However, the particles reach melt temperature at varying positions along the screw, not all at once, so gradual compression is good for those fast-melters, too.

Optimum feed and metering zone length also depend on what goes on before and after the screw. If there is preheating, for example, less feed length is needed, and if there is a static mixer, or even a high pressure die such as a spiral-mandrel film die, less mixing and uniformity need be produced in the screw and the metering zone can be shorter.

Channel Depths are very important. The two key numbers are the depths in the first and last zones, which in turn can be related to intake and output capability. Do not, repeat, do not get seduced by the concept of compression ratio which manages to convert two useful numbers into one ambiguous one. The compression ratio is the ratio of volumes of first and last flights, which in constant-pitch screws (the usual case) becomes the ratio of the two channel depths. If a car costs half as much as another, that can’t tell us if it’s a bargain until we know more. Yet, people cite compression ratio as a "requirement" for a job. It may be correct, but it is never enough to understand and predict screw performance.

The metering depth, in particular, can help in problem diagnosis by calculating ideal drag flow in lb./hr. as:

(2.64)D2Nhp where

D = nominal diameter, inches

N = screw speed, rpm

h = metering zone channel depth, inches

p = melt density, g/cc

If real output is equal to or greater than drag flow, look for an overactive feed zone and possible poor mixing or over heating. If real output is substantially less than drag flow, look for a feed problem, sticking to screw root, or a very high-resistance die.

Special Features are the options. These include Maddock fluted sections, various barrier screw systems, proprietary add-ons. Some of these ideas can be put in as retrofits and others require new-screw service and calculations. A thorough list of such options is beyond the scope of this paper, but whatever the option, remember that just because something works well at one rate or with one resin, it still may perform miserably at another condition. Also, these devices have dimensions, too. For example, in a Maddock section, someone has to decide the numbers of pairs of flutes, the clearance over which the melt passes, the length and location of the section, and the handedness (a left-handed Maddock-material enters flutes and turns left-is a more severe treatment than a right-handed one).

The dimensioning of a melt-extraction barrier screw is even more complicated, and although these can be designed by computer, the assumptions needed to handle mixtures of solids, shear-thinning melt and air in the first 50-75% of the screw need to be verified by practical experience, so that a combination of such experience and calculations are needed.

Naming Screws - Watch for screws which have names connected to some resin (a poly screw, etc.). This can be misleading; bottle grade. HDPE is a much different material than coating grade LDPE, and neither will do its best on a "poly" screw even though they are both polyethylenes.

Just for the record, a poly screw is a conservative’s delight--nothing radical or surprising, and equal or near-equal division of flights among the three basic zones (feed, compression, metering), a rather shallow metering depth, and (unless very small) fully-bored for internal temperature control.

A nylon screw has that short compression zone mentioned above, and is some times recommended for polypropylene, too. Nylon doesn’t need a long compression, and the desire to get as much heat into the feed means a long feed zone, hence the short compression, but I’m always suspicious of doing things too fast, and prefer at least 20% of screw length in that zone, if not more.

A vinyl screw is likely to have a short feed zone, long/gradual compression, a deep metering depth, and if for rigids, it may be fully-bored to get circulating hot oil to the tip. Of course, there are many different vinyl formulations that no one screw is ideal for all. There is no ideal screw, even for a specific resin and product, just going up or down 25% in out put may change the "ideal" dimensions, and combination of experience and understanding before cutting metal may help avoid trouble.

A word on wear: don’t be afraid of it. Keep an eye on it by direct and periodic measurement of screw and barrel, and by indirect monitoring of output/ rpm for the same material and conditions. Don’t be too quick to rebuild/replace a screw (heat transplant syndrome) unless you can prove the old screw is costing you money and the new one will save significantly more than it costs. Don’t forget the barrel; they wear more slowly than a screw, but many screws have been rebuilt to original dimensions only to perform poorly because they are still "rattling around" in the barrel which has expanded (crept) in service. (For more on this topic, see my article "Where's the Wear?" in an Extrusion Division 1993 newsletter).

To return to the main point of this article: know your dimensions. Know whether your metering depth is deep, shallow, or intermediate, and know why it was picked. Apply the drag flow formula as given above to see if you can realistically expect the output you want (typically 80-100% of drag flow, but there are exceptions). For small machines, make sure the feed depth is big enough to take the particles you intend to feed it (including scrap). Know original clearances between screw flights and barrel wall, so you can tell when they have increased. Know and understand how the zones are divided and why this division is suited to the job to be done. Understand their functions. Finally, when a new screw is received from its maker, measure everything right away to make sure it was indeed made to specifications.

- Allan Griff

See also:

- How to buy a screw - Part I
- How to buy a screw - Part II
- How to buy a screw - part III
- Retrofitting a screw into an existing extruder
- Screen/barrel clearance
- Where's the wear, Part II

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