

10 Key Principles of Extrusion

No. 2: The Thermal Principle

Thermo – Plastic = Heat + Moldable (flowable)

Heat to melt (what does “melting” mean?)
(semi)crystalline and amorphous polymers

How much needed above “melt” temp
depends on
material, product, cooling, application.



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No. 2: The Thermal Principle (cont.)

Where does the heat come from?

Feed temp + barrel/die heaters + MOTOR

The “profile” (heats, settings)

Motor most important (shear heating)

except for
TWM, Slow rpm, coating, HTPs, some twins



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No. 2: The Thermal Principle (cont.)

Where does it go?

- radiation/convection/conduction losses
- +/- heat of reaction (foams, reactive extrusion)

Into the air (loss from equipment, hot plastic)

Into cooling water (via rolls or directly)

Can we save it? Should we bother?

Go figure.



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No. 3: Speed Reduction

Most motors run max 1750 rpm

Field-weakening can get 15-30% more

Screw speeds typically 25-100 rpm

Extremes: 5 ... 200, some CPD more

Need reduction of 10-60x

Done with gears, pulleys (2), motor choice

Retrofit pulleys, change gears. ... Why?

Don't forget torque limits in system



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No. 4: The plastic is the Coolant

The material absorbs the heat in the extruder.

Sometimes too much is produced (override).
(4 evils of overheating)

Front end hotter even if profile level or falling

Stop machine and front heats up rear,
may get sticking to screw in feed zone.



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No. 5: Stick to the Barrel, Slip on the Screw

Valid in feed zone, single-screw extrusion.

If slip on barrel, no push forward.

If stick to screw, will stay there, degrade, reduce inpush.

Rear barrel temperature is critical for inpush.

Don't forget pellets that don't touch either surface
They should stick or otherwise connect, so

Irregular shape feed better than round (less slip).

Grooved barrels good for slippery feeds.



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No. 6: Material is the Primary Cost

Thou shall not waste resin.

For common plastics, 50-75% mfg cost,

For specials, as high as 90%

Conversion costs NOT proportional
(analogy to petroleum vs resin costs)

Therefore,

1. Use scrap and trim to replace new purchase
(this is true recycling)
2. "Weight Watchers" - control thickness closely.
3. Test incoming materials and be prepared to run cheaper ones, fillers, blends.

ULS-FOS-TANA



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No. 7: Don't Worry about Power Costs

Extrusion is very efficient, heating enclosed system, most of the heat needed to bring to extrusion temp.

Typical efficiency 50% (2 kW-hr used for each needed)

Example using real motor power requirement:

7 lb/hr per HP using 20 HP = 4 kg/hr per kW using 15 kW
and if power is \$0.10/kW-hr,

power cost is around \$0.01cent/lb = \$0.022/kg

Compare to resin costs of \$0.60/lb (\$1.22/kg)!

Other devices (dryers, formers, air chillers) are less efficient, deserve more attention.

Beware "percentitis"(using percentages and ratios to avoid real numbers).



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No. 8: Components of Output Rate

Displacement of last flight of screw (drag flow)
= $2.64 \times D^2 N h \rho$
minus effect of head/die resistance
plus effect of inpush (pressure peak)

Leakage over flights can be in either direction
Screw beat depends on
pressure peak and pressure at end of screw

Gear pump (melt pump) takes over.



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No. 9: The Vital Signs

Pressure at tip of screw:

safety, power, temperature, mixing, leakage.

Temperature of melt (not metal):

degradation, cooling, sizing, additives.

Motor Amperes:

watch the wiggle, shows stability, viscosity.



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No. 10: Shear-thinning

Viscosity falls as melt moves faster

... double speed, 4 to 8 times the flow

... water viscosity doesn't depend on speed

True for all plastics, some more than others.

Shear rate = speed/distance

Shear-thinning enables easier flow through
small holes and narrow flight-to-wall clearances

Power-law factor can help predict flow
through dies.



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No. 11: The Motor Opposes the Barrel and vice versa

If barrel is heated, viscosity at the barrel wall goes down, and the motor works less.

If the barrel is cooled, the reverse is true, the motor must work harder to turn in the cooler melt, and its energy input increases.

This explains why barrel heating/cooling is not very effective.

In the head, there is nothing moving and the rule doesn't hold.



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FAQ and other Qs

How did this list come about?

Why are there really eleven principles?

Are they published anywhere?

Are they valid for twin-screw extrusion?

Is it true that they have been set to music?



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Thank you for attending.

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