Elastic properties of flowing polymer melts

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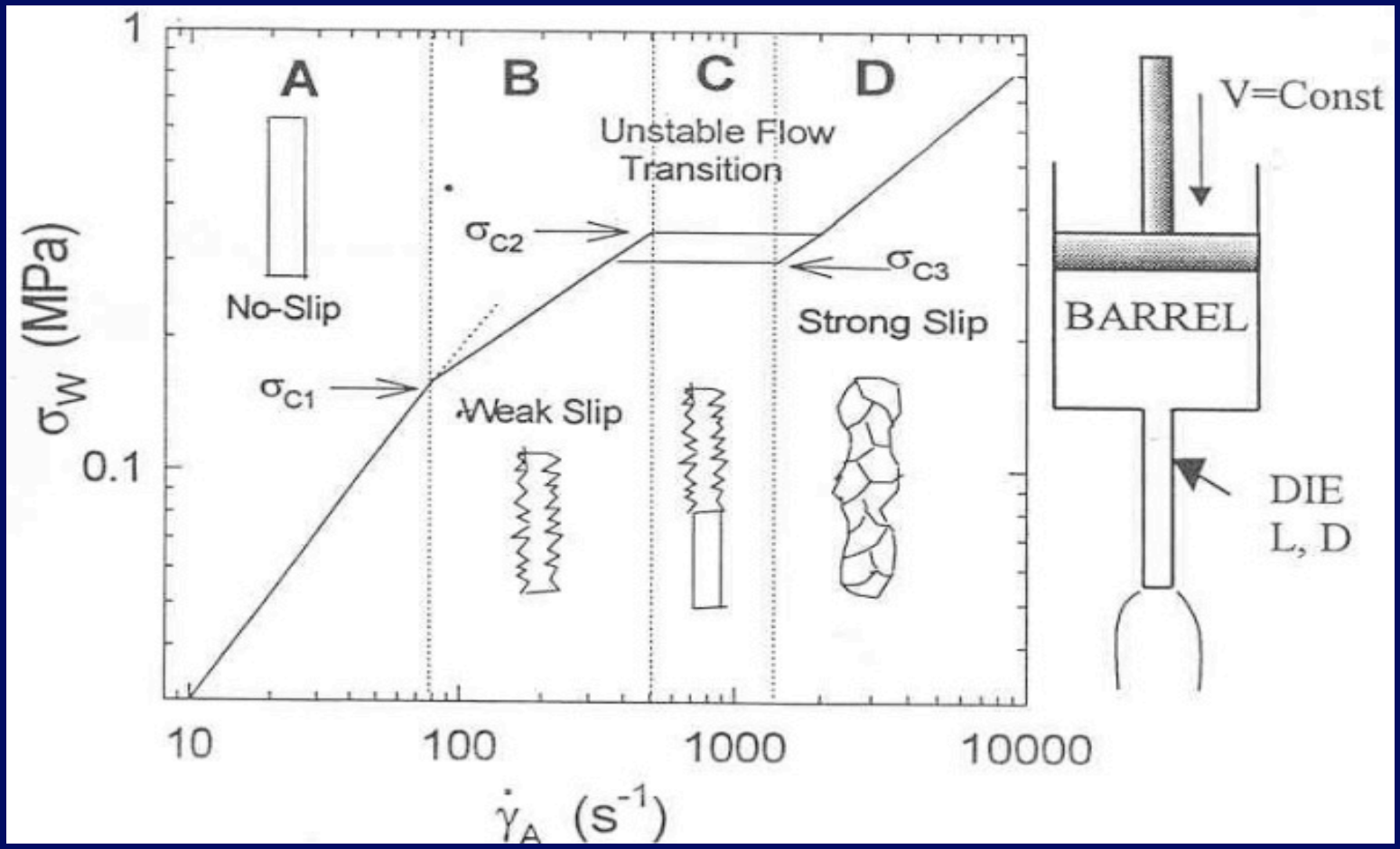
Polymer Melt Flow in an Extrusion Process



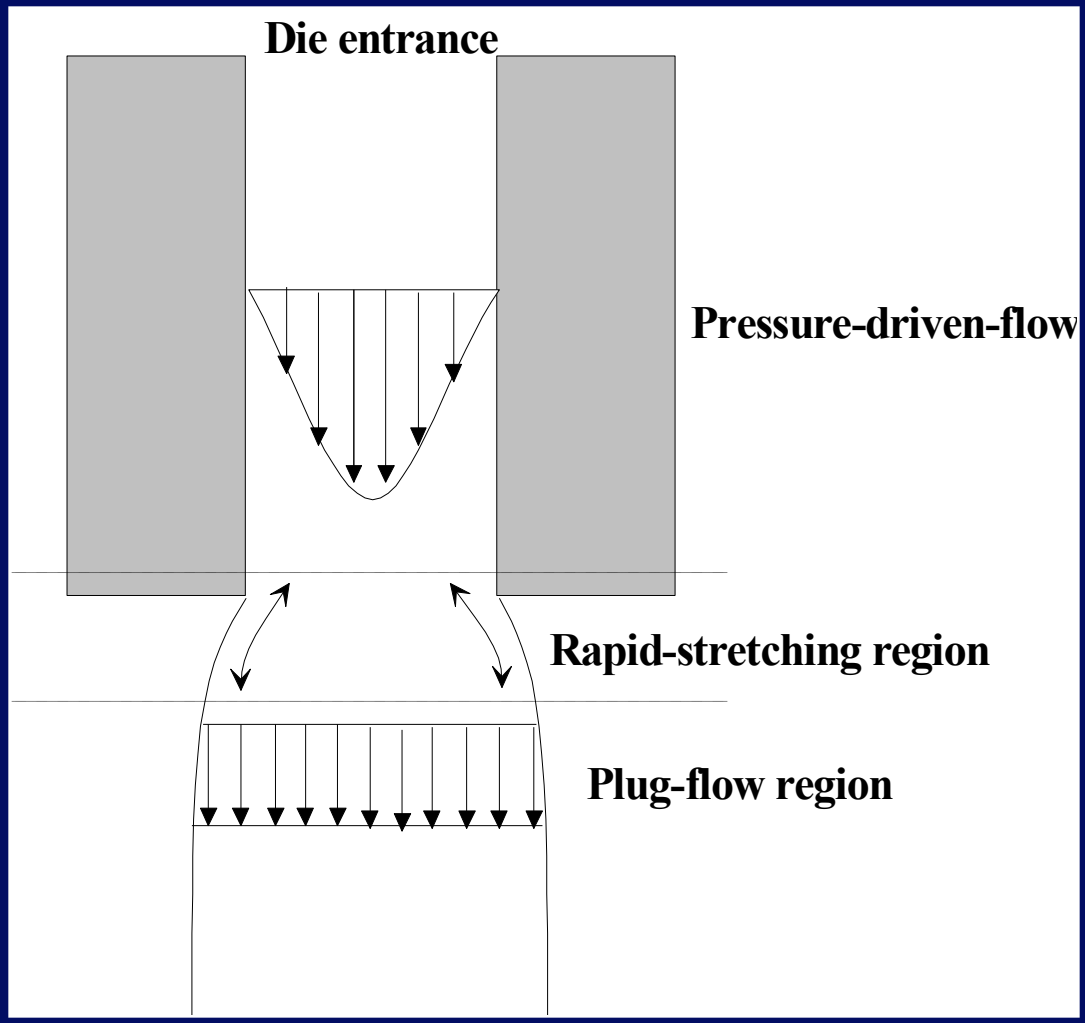
Fyrillas et al: Polym. Eng. Sci. (1999)

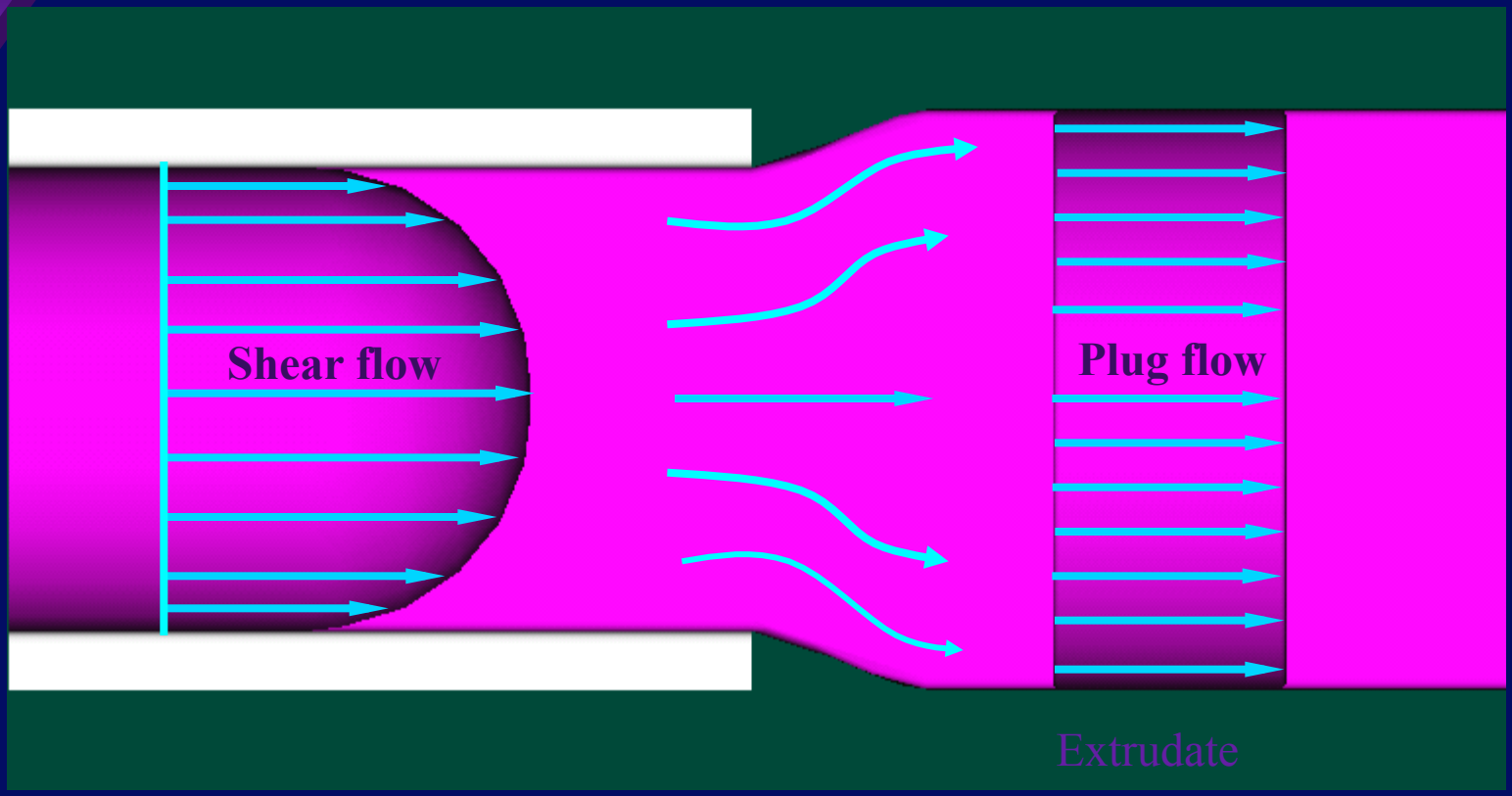
Extrudate swell

- Extrudate swell is also known as Barus effect.
- When a polymer melt is extruded through a die the cross-sectional area of the extrudate is greater than that of the die.
- The general explanation for die swell is related to the recoverable elastic deformation developed during flow through the die.
- Extrudate swell is alos linked with velocity profile development

Extrudate swell

Velocity profiles and die swell relationship




Shear flow
Plug flow
Extrudate

Why extrudate swell is so important!!!

- Control the size and shape of the extruded products. [Quality]
- Determine the productivity of the extruded products. [Quantity]
- Associated with the occurrences of sharkskin and melt fracture

General information in extrudate swell

- Most techniques rely on direct measurement of the size of the melt extruded from the die.
- Extrudate swell increases: as the die length decreases, as the shear rate or shear stress increase, and the molar mass of the polymer increases.
- Extrudate swell can be minimised by reducing increasing die temperature and die land length or reducing the shear rate or shear stress.

Factors affecting the extrudate swell

- Residence flow time
- Die temperature
- Shear rate
- Die length or die land
- L/D radio
- Additives
- Molar mass
- Flow patterns
- Die geometry and number of flow channel
- Magnetic field*
- Radial profiles*

** Separate slides from P-PROF research outputs*

Resideence flow time

Relaxation time – the characteristic timescale for which a melt has memory

-describe as its viscous and elastic responses to an applied stress

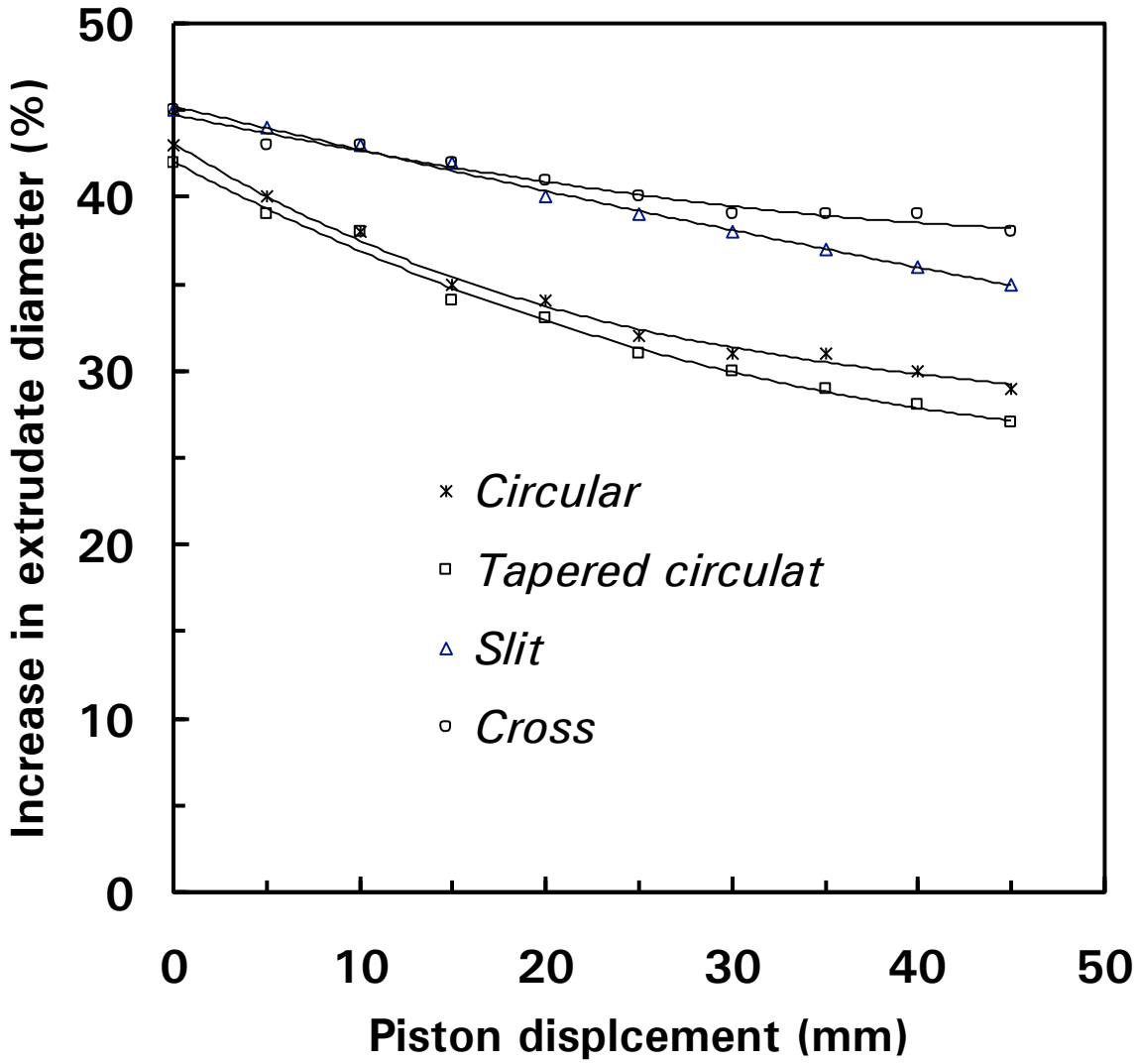
$$relaxation\_time = \frac{vis\cos ity}{\mathrm{mod}\,ulus} = \frac{Ns \times m^2}{m^2 \times N} = s$$

$$N_{deb} = \frac{relaxation\_time\_of\_material,in\_process}{timescale\_of\_process}$$

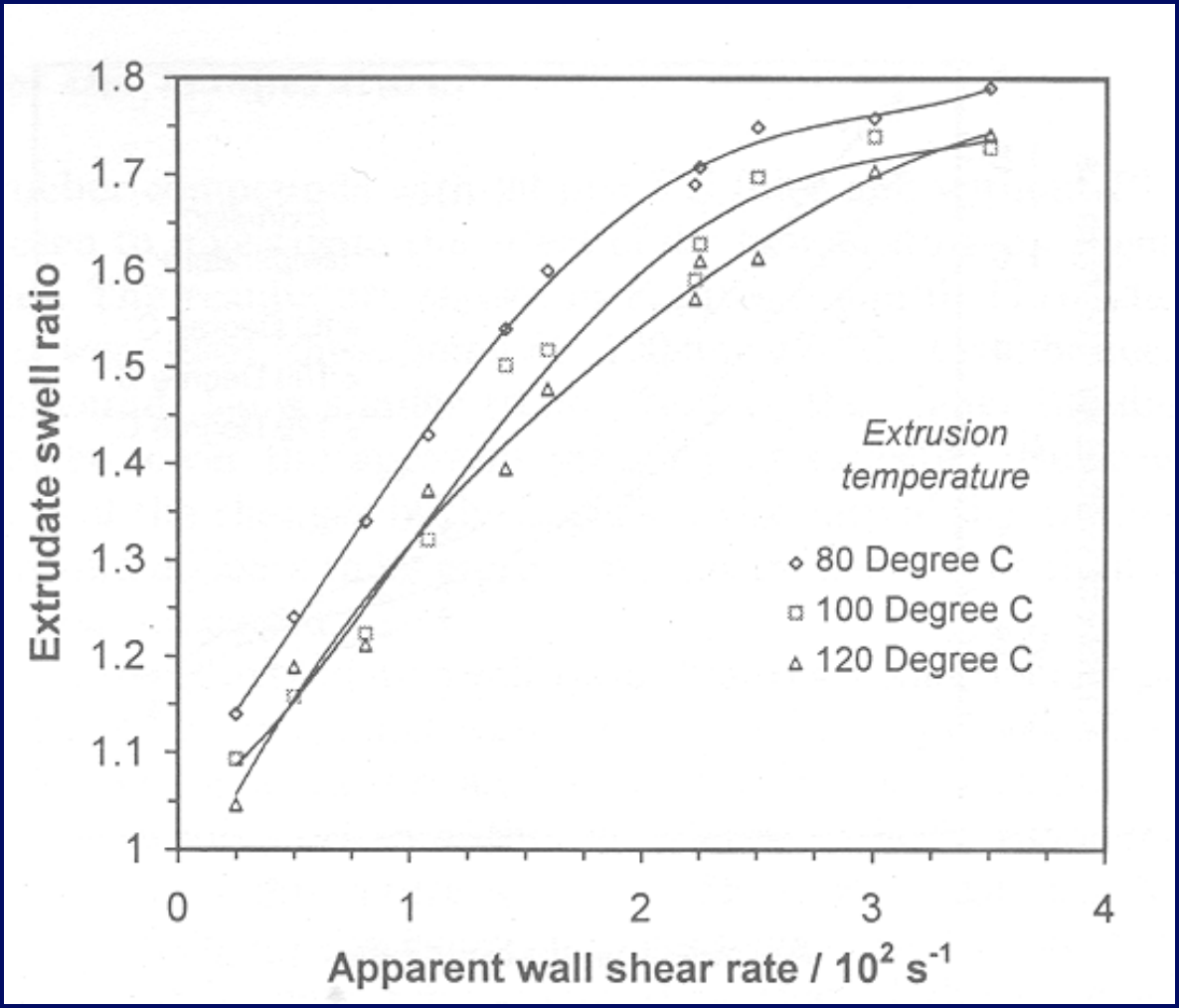
If N_{deb}>1, process is dominantly elastic.

If N_{deb}<1, process is predominantly viscous.

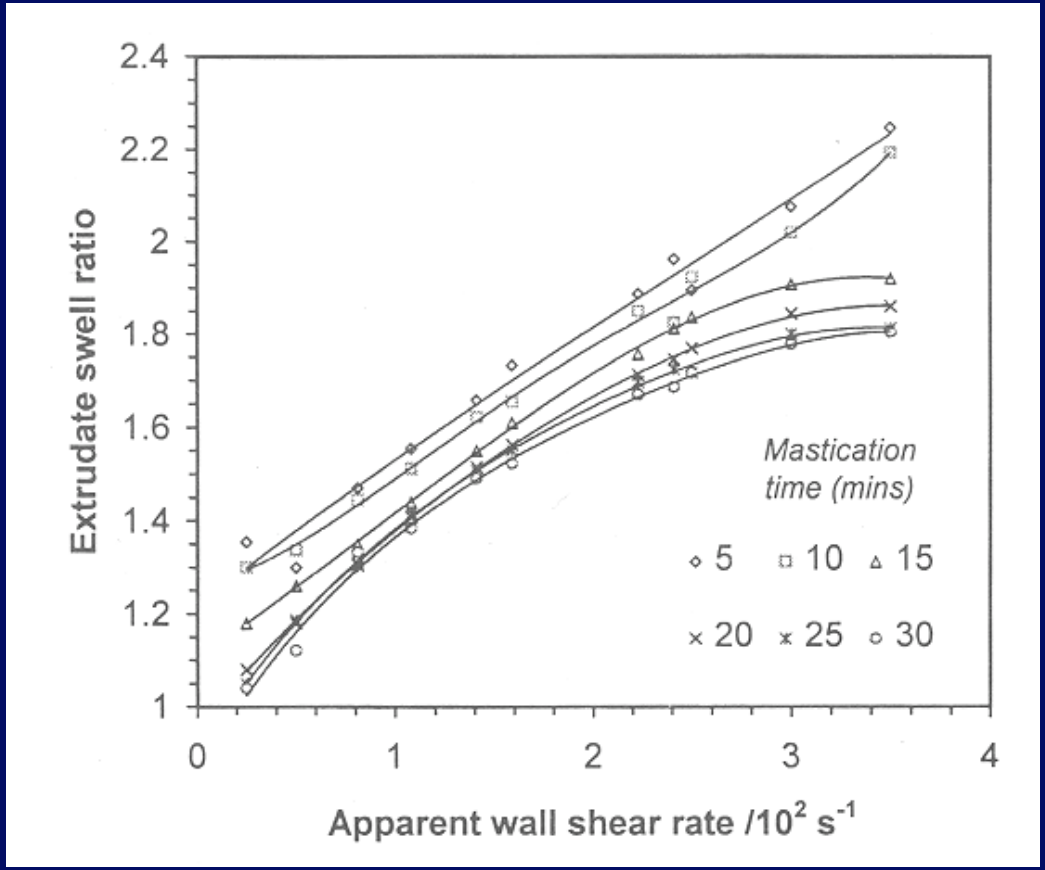
Extrudate swell results as a function of extrusion displacement (time)



Effect of die temperature

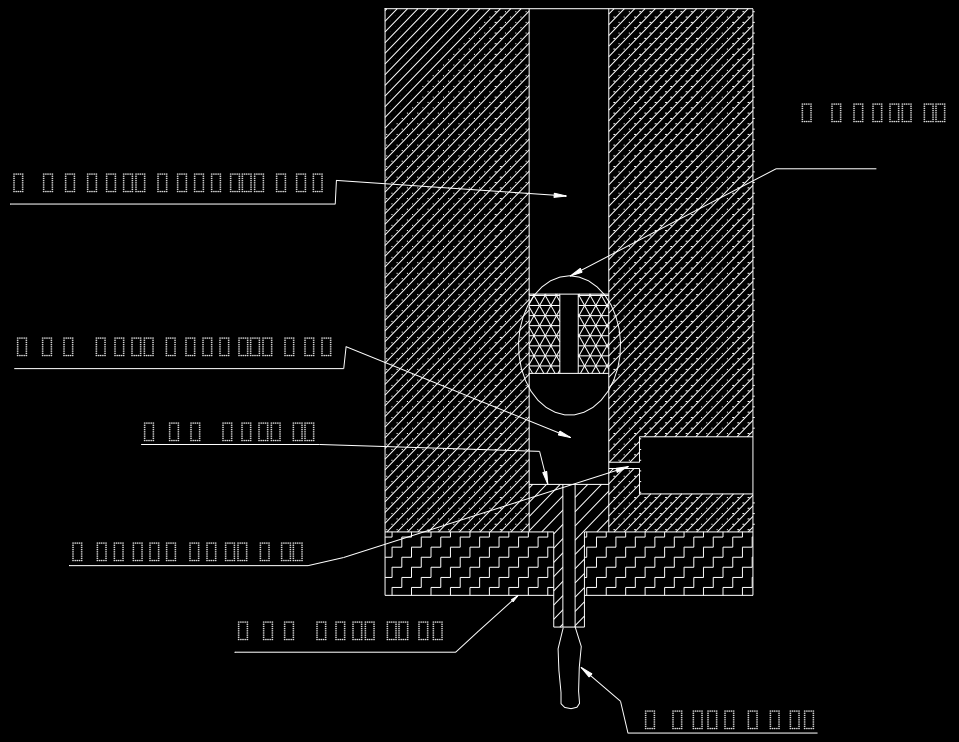


Effect of shear rate



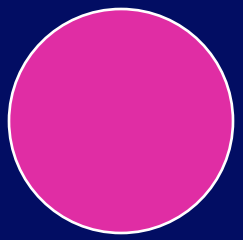
Effect of flow patterns

Drawing of the rheometer with two dies inserted

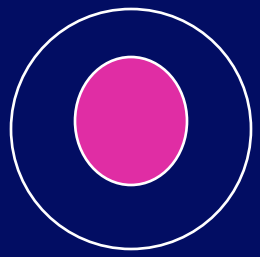


Die design

Circular (L/D = 45/6)



Circular (L/D = 25/6)

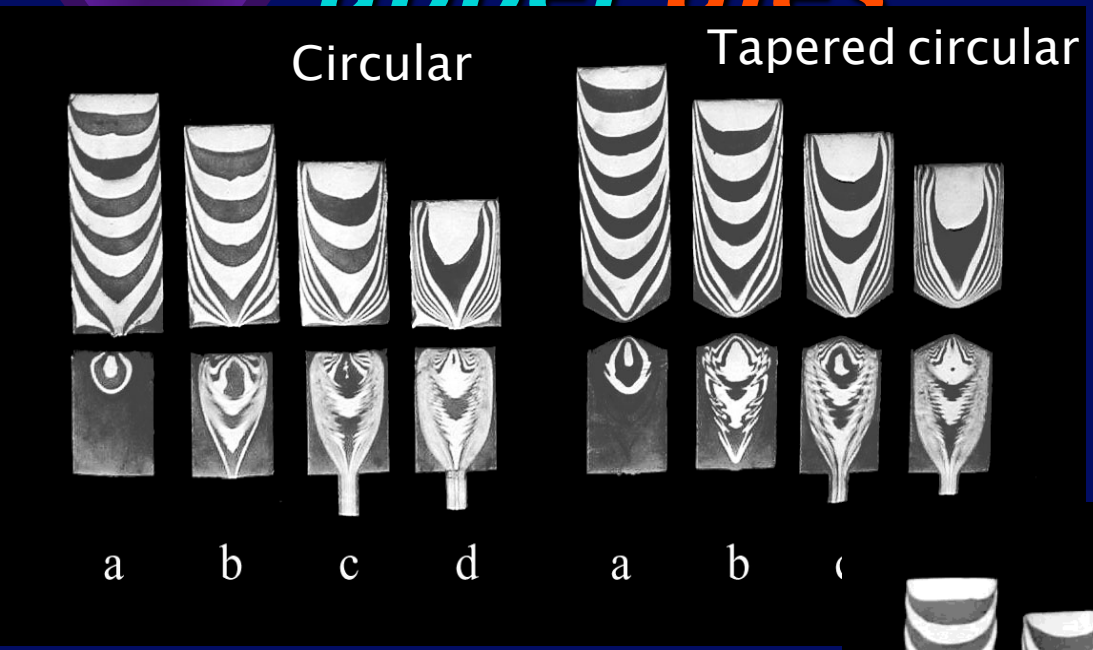


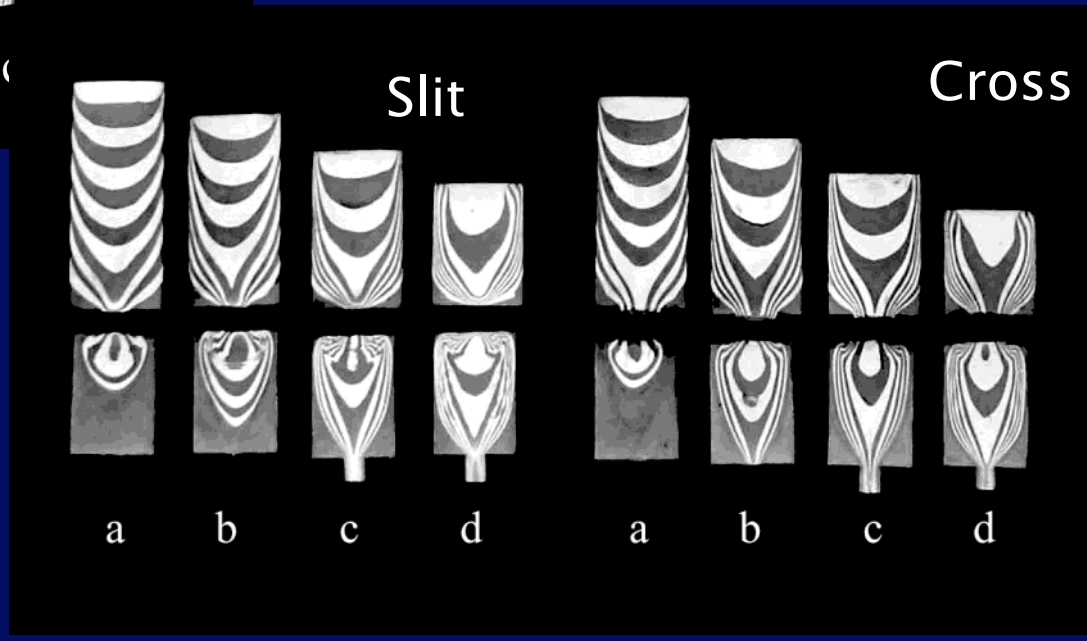
Tapered circular (L/D = 25/4)

Slit (L/H/W = 25/4/8)

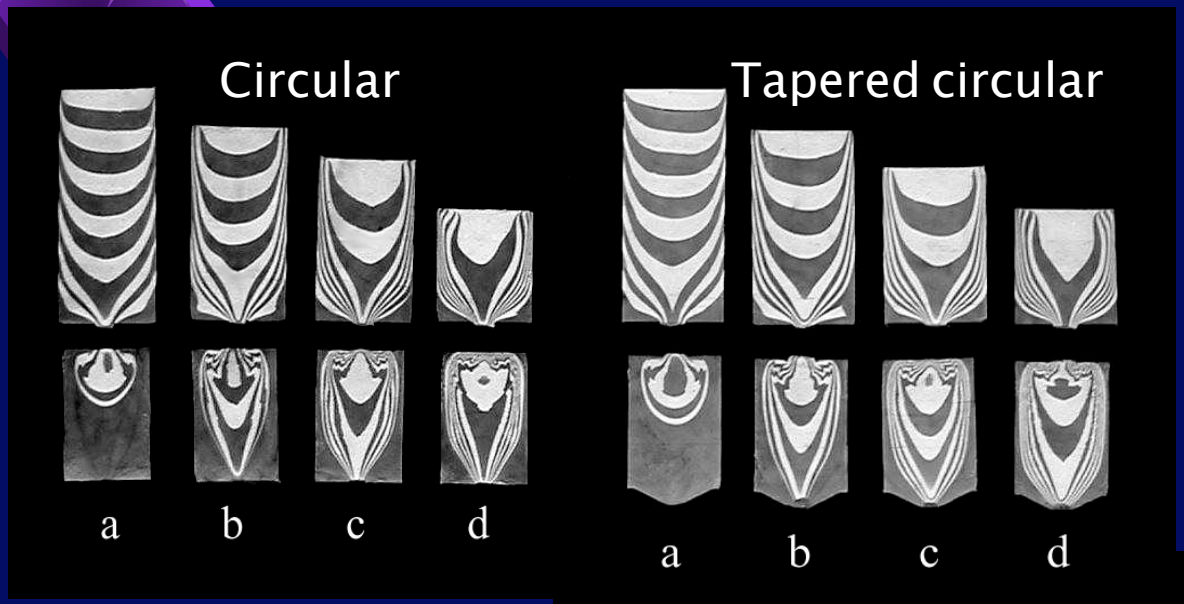
Cross (L/S = 25/6)

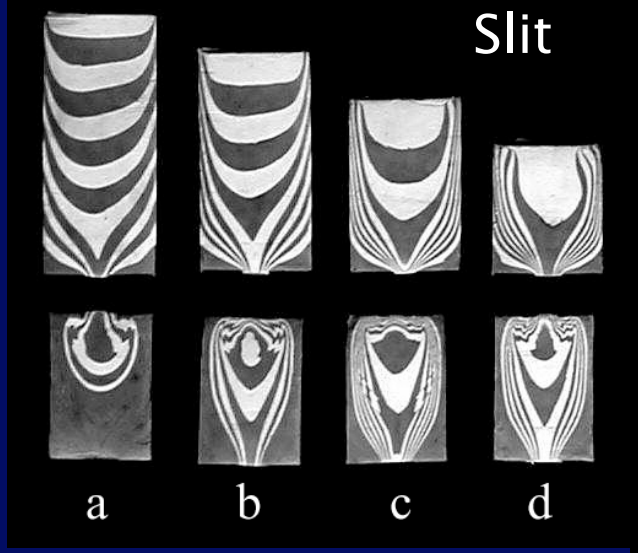
Flow patterns with various upper dies

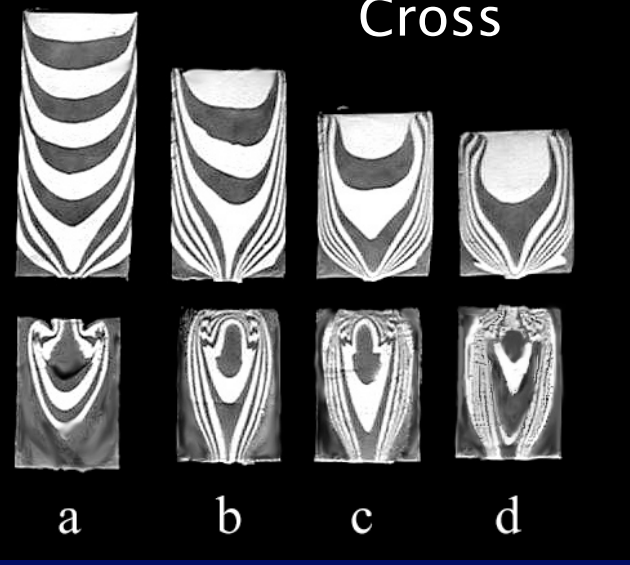




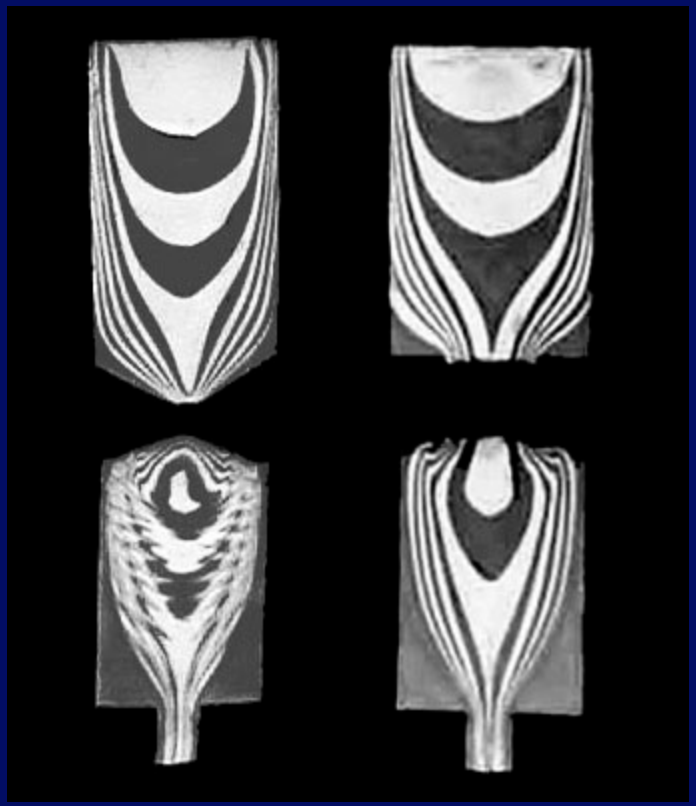
Flow patterns with various lower dies



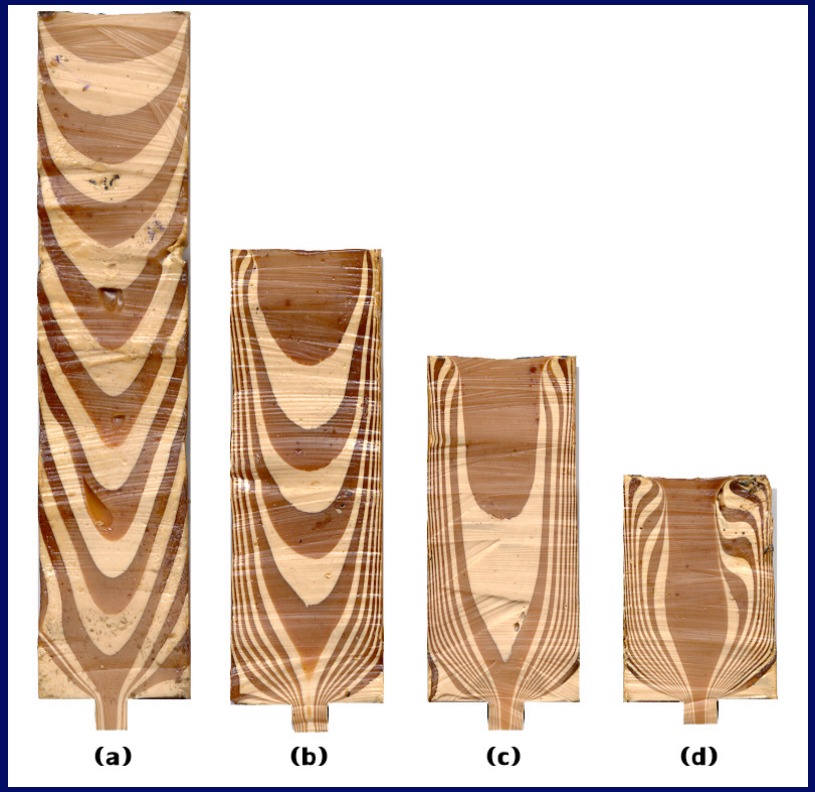


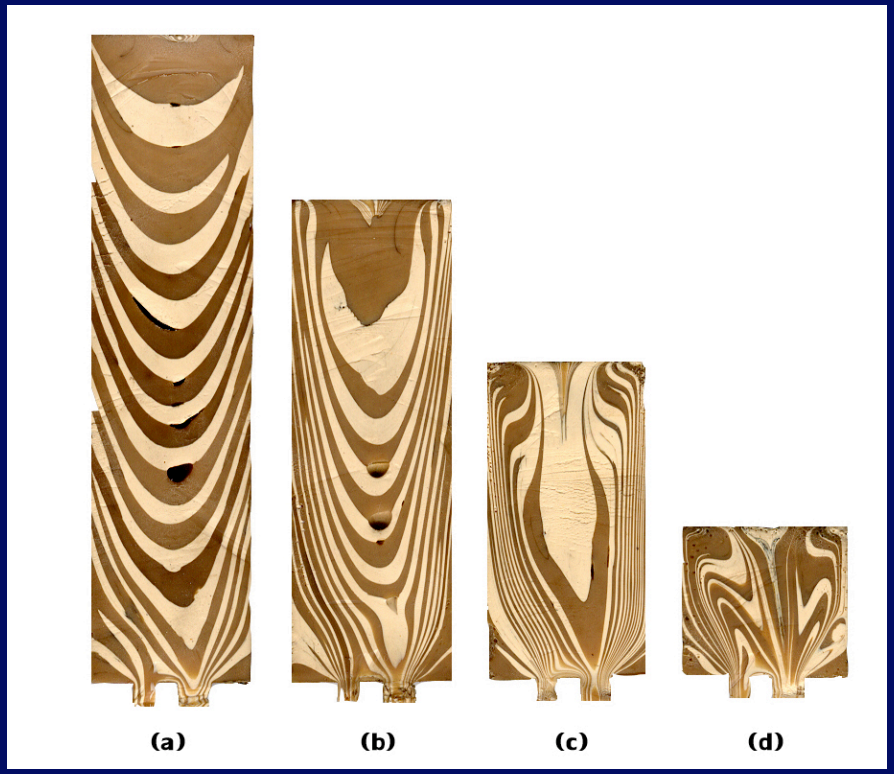


Effect of flow patterns

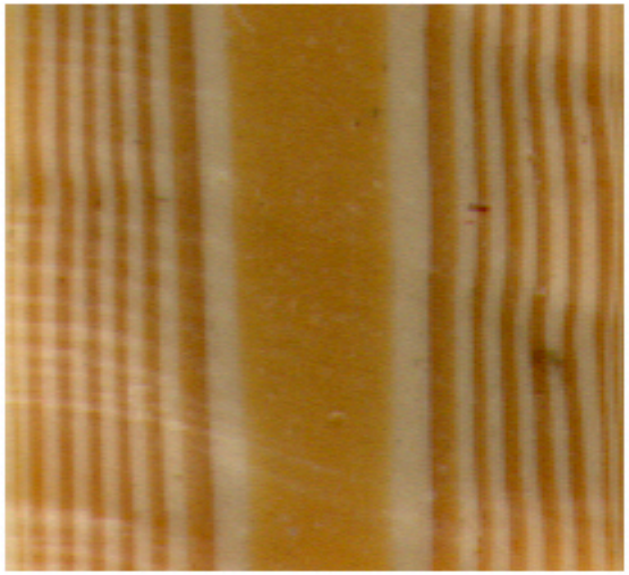


Flows in the barrel of single (left) and dual (right) capillary dies





Flows in the die of single (left) and dual (right) capillary dies



(a)

(b)