

Polyolefin Plastics
Still a challenge for Chemical
Engineers?

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Dow Benelux BV



Polyolefin Plastics

- What does it take to make it
- Applications
- Processing
- Chemistry
- Feedstock
- History
- Future

What does it take to make Plastics?

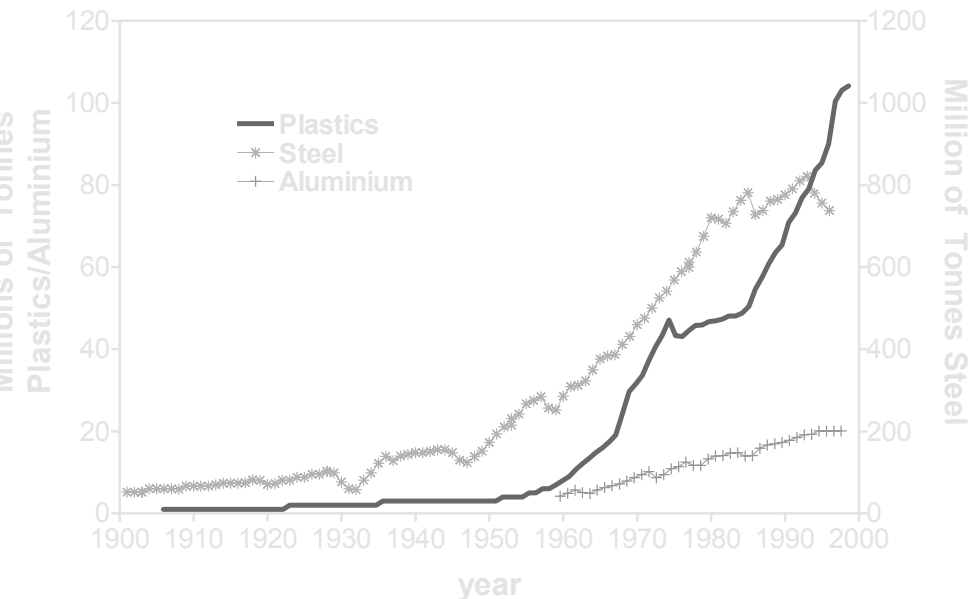
- **Plastics**
 - An ensemble of polymers and other organic and/or inorganic components
- **Polymers**
 - An ensemble of macromolecules of equal chemical composition but of different molecular mass
- **Macromolecules**
 - An ensemble of large molecules of same chemical composition and molecular mass

What does it take to make Plastics?



What does it take to make Plastics?

The Plastics Industry



- Western Europe
 - 1.1 mm employed
 - 135 billion Euro
 - 45 Global Companies
 - 30,000 SME
- World
 - > 120 mm T
 - 5% average growth

What does it take to make Plastics?

Primary Resource Development

Raw Materials
Mineral oil,
Natural gas,
coal, minerals,
animal &
vegetable
products,
salt

Plastic Products
Powder, granules,
pastes, liquids,
dispersions,
compounded
polymers and
resin systems for
structural uses

Plastic Processing
Extrusion,
injection and
compression,
moulding,
calendering,
casting, foaming,
laminating

Fabrication and use
Assembly into
finished products
for consumer and
industrial use

End Use
&
Recycling

Pressure

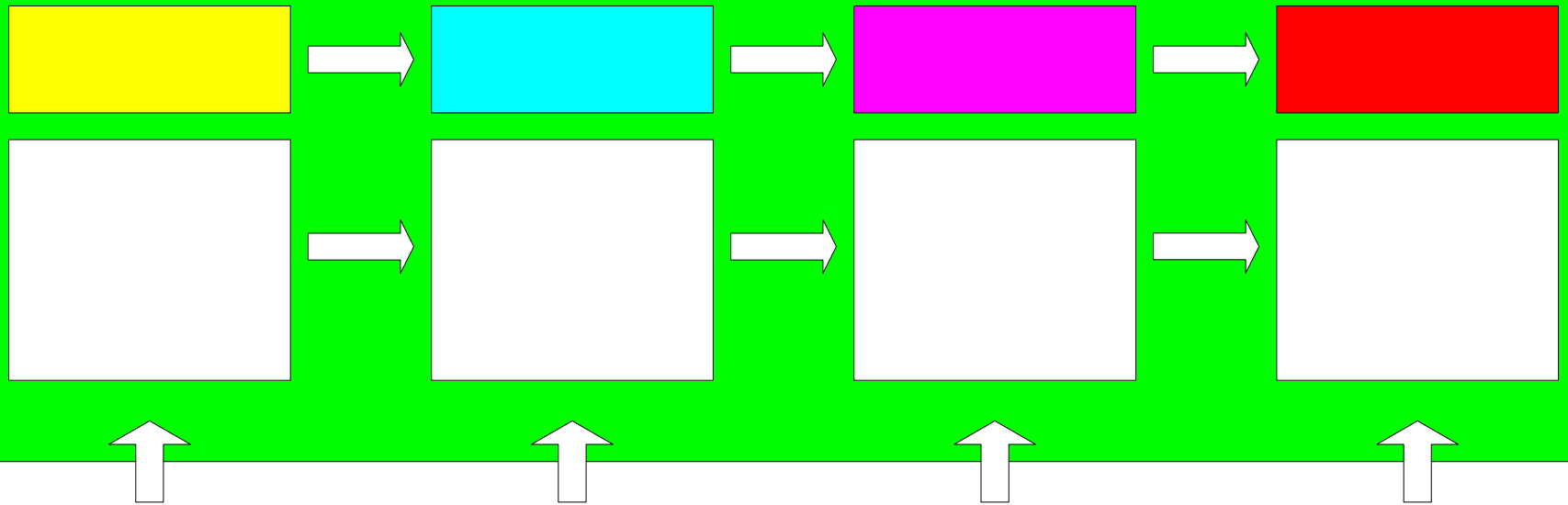
Heat

Additives
Plasticisers,
lubricants,
stabilisers,
colourants,
antioxidants

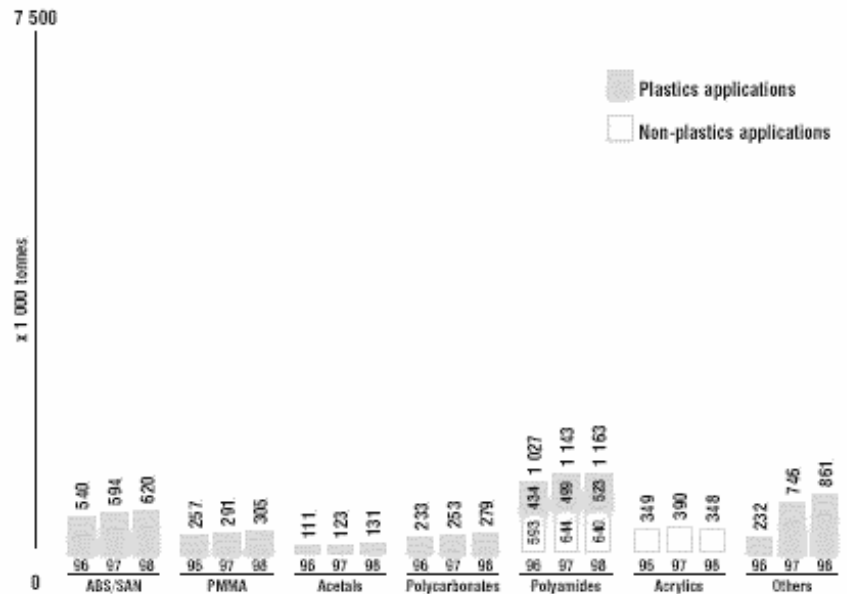
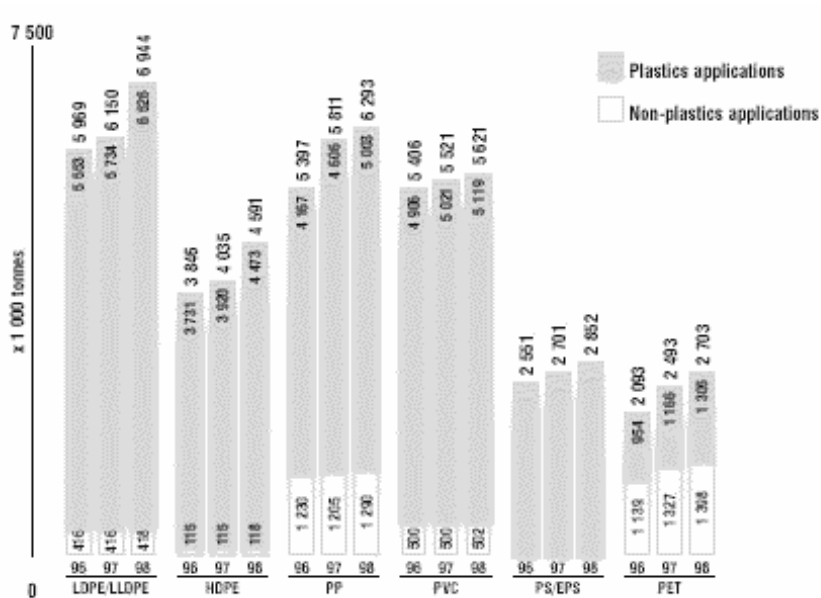
Heat

Pressure

What does it take to make Plastics?

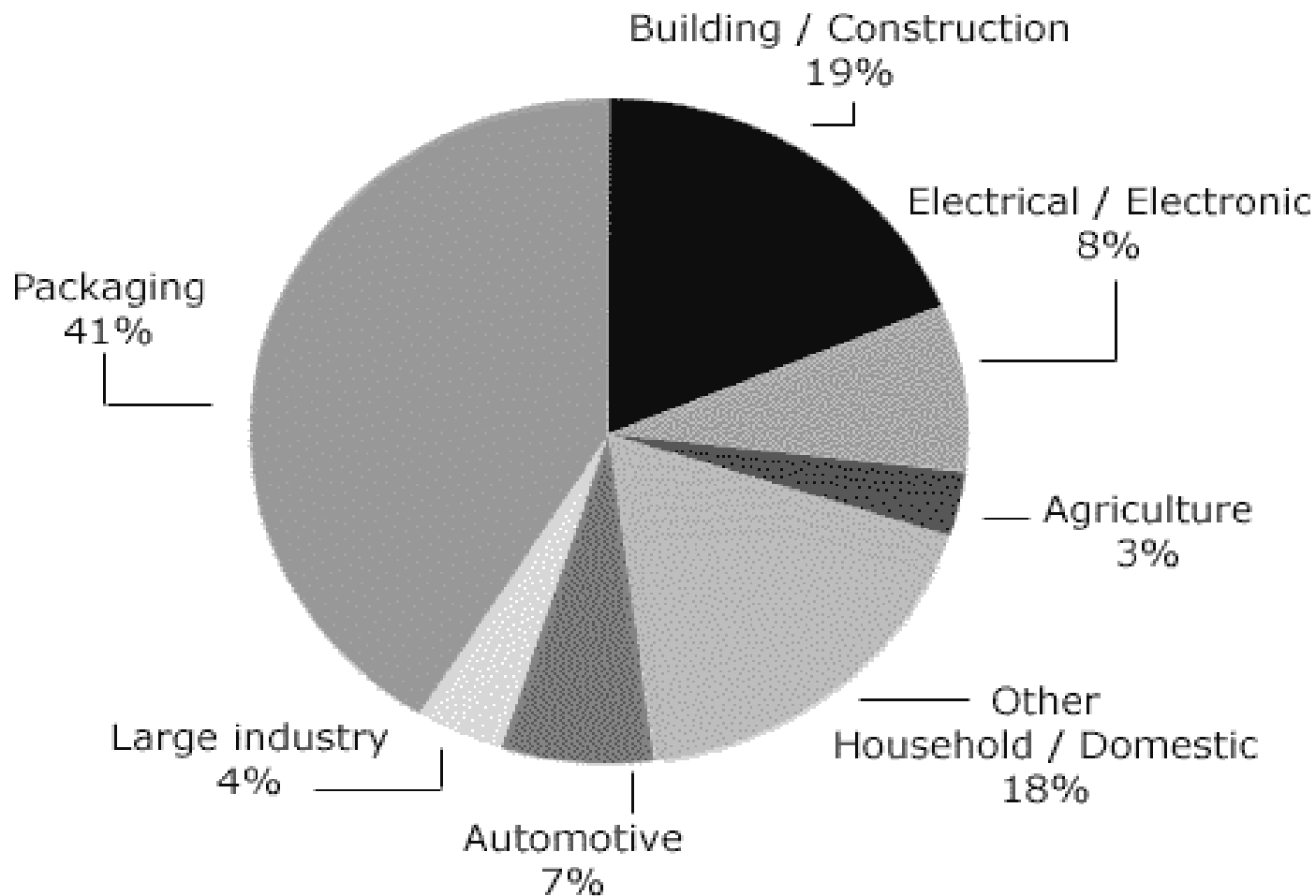


Plastics Applications & Use by Sectors in Europe



- Thermoplastics
 - Commodity plastics
 - Engineering plastics
- Thermosets

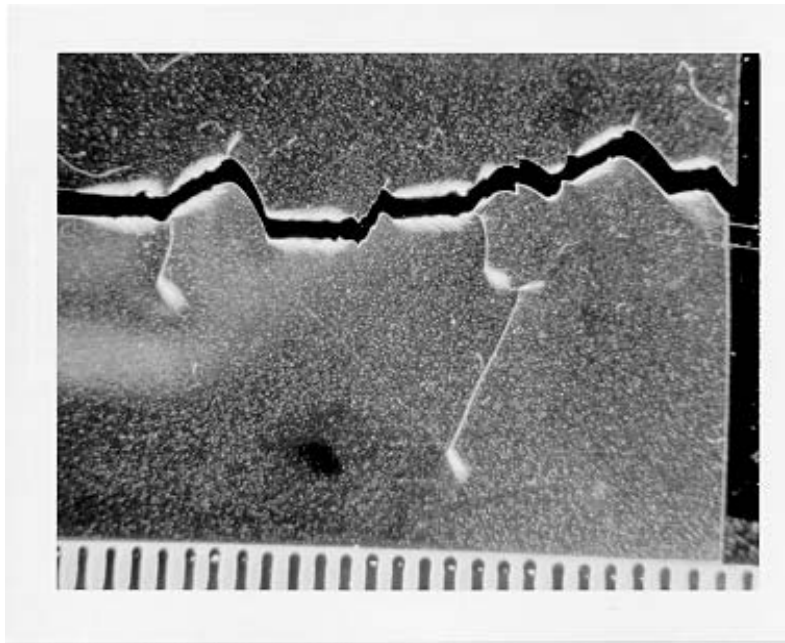
Plastics Applications & Use by Sectors in Europe



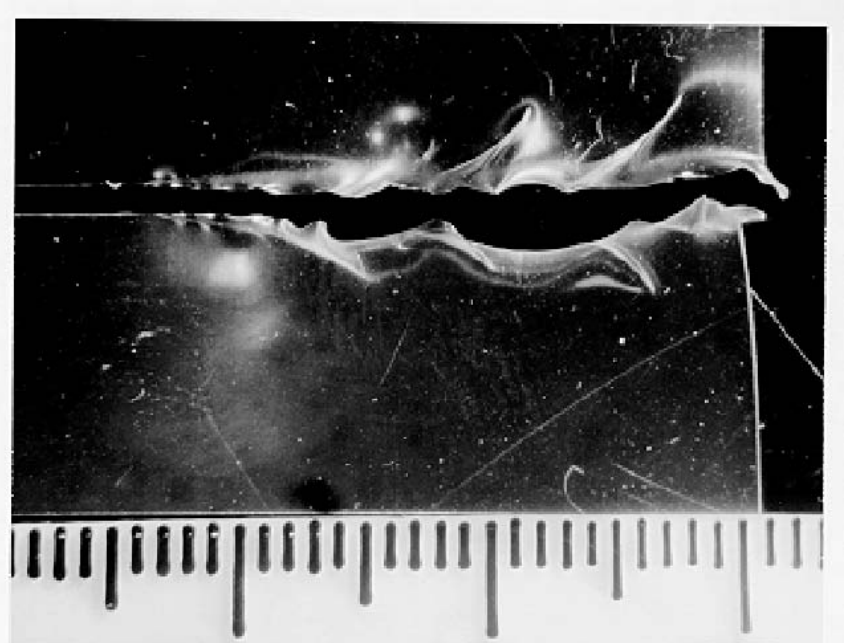
Application Performance

- Low Cost
- Light Weight
- Tough
- Easy processing
- Sustainable – recyclable
-

Applications: Brittle and Ductile failure

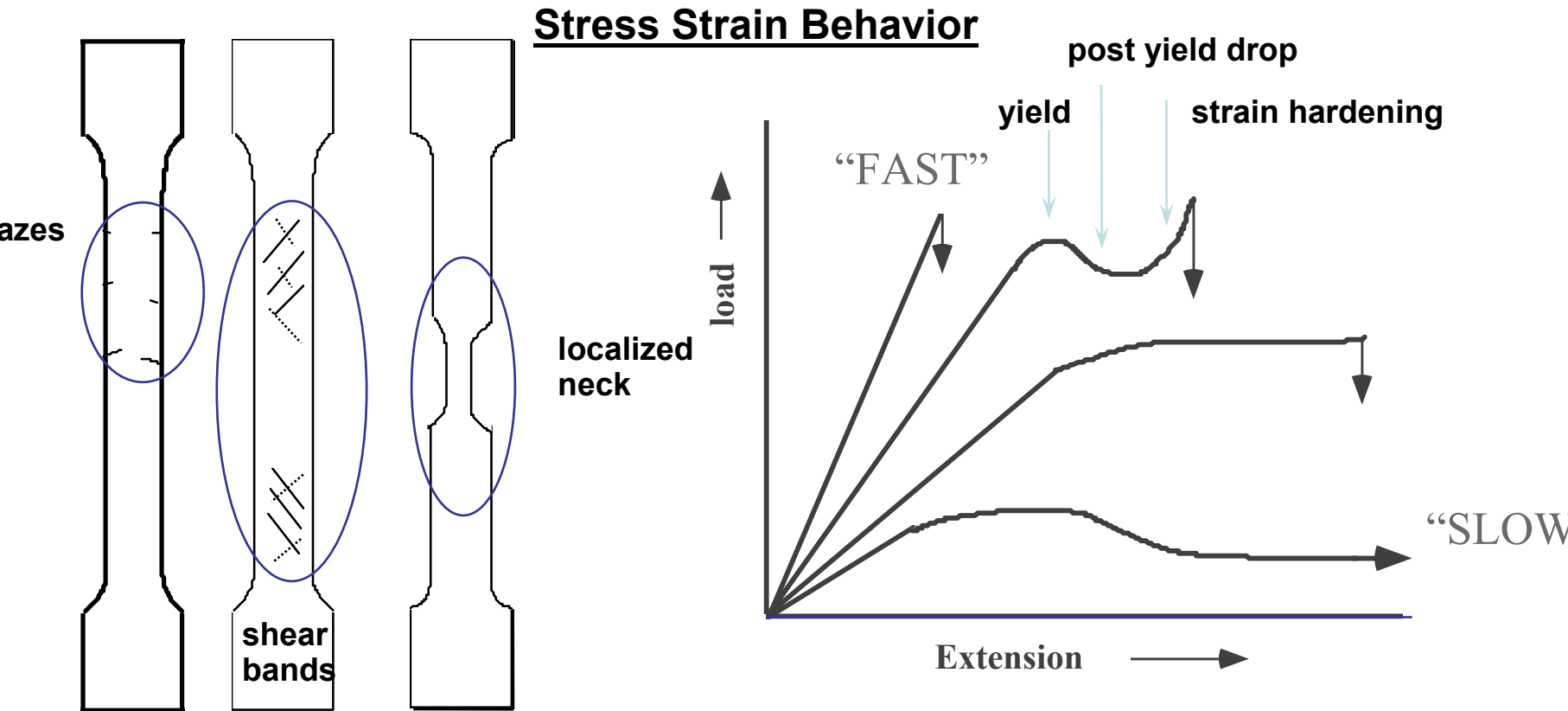


Brittle tear



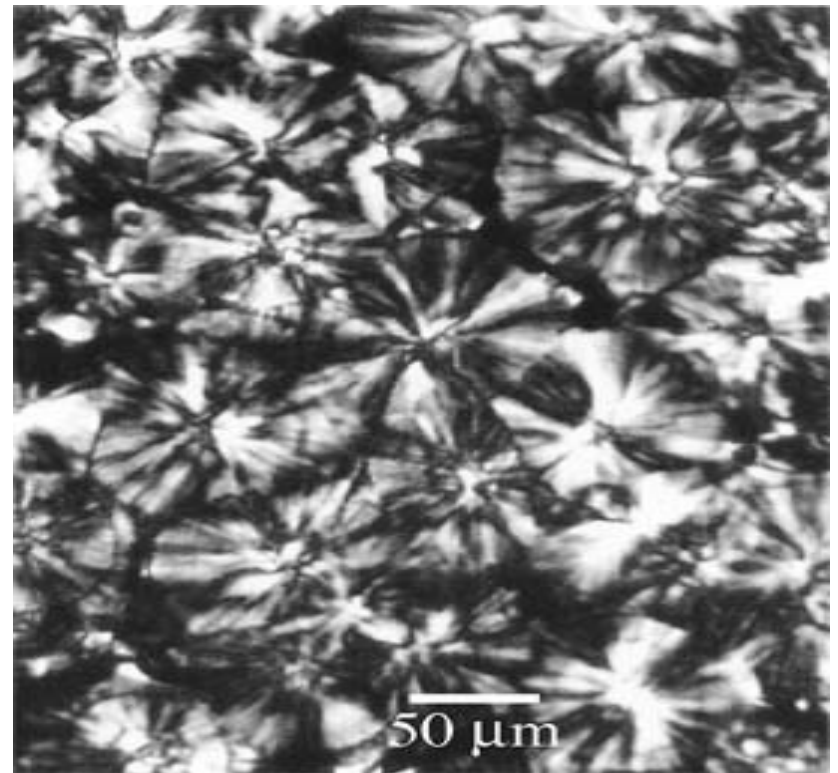
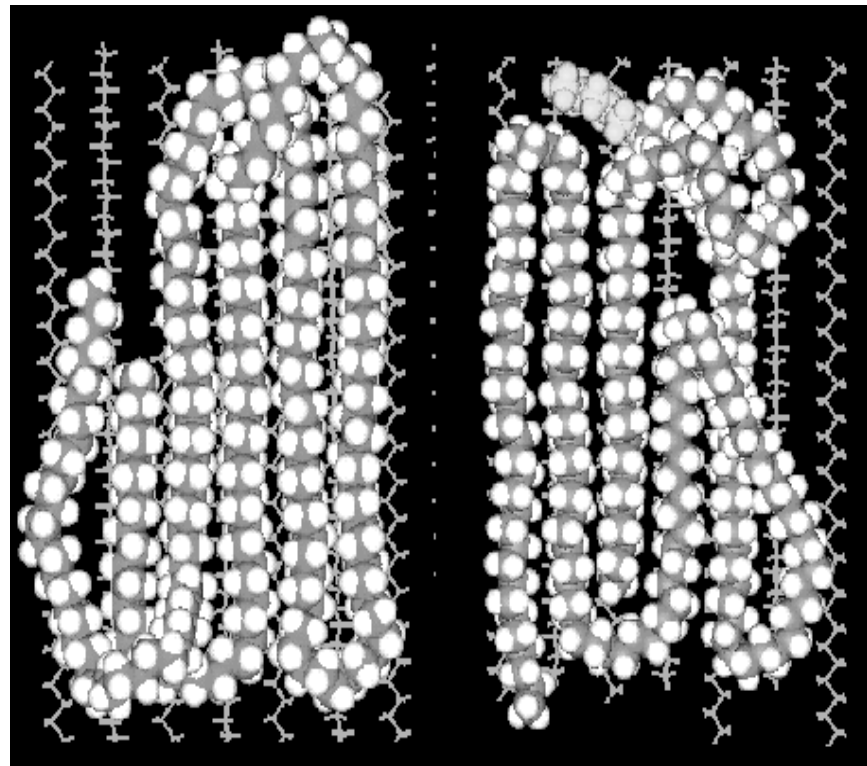
Ductile tear

Applications: Tensile Testing



Consider temperature also

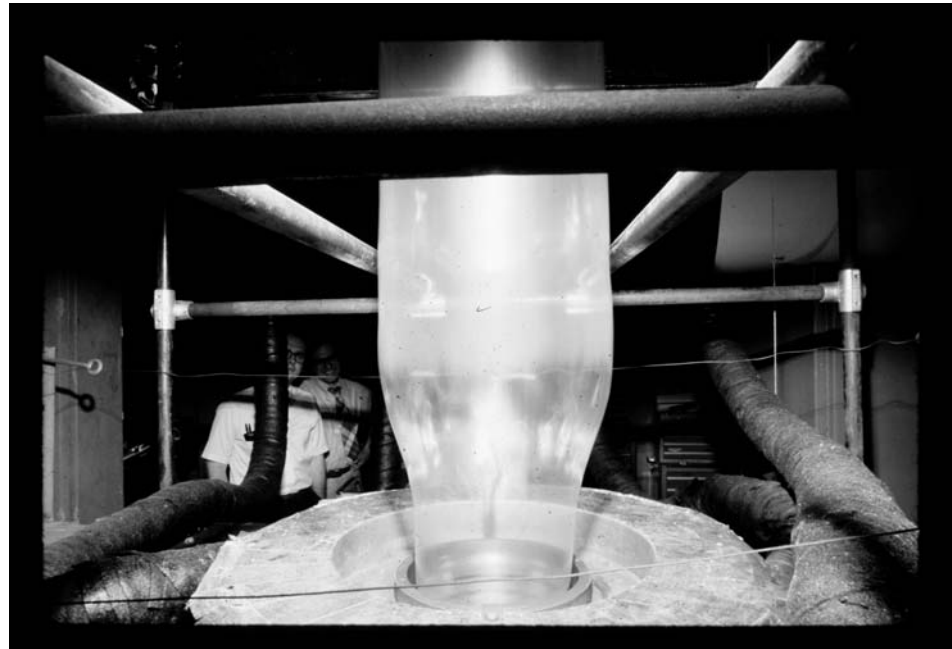
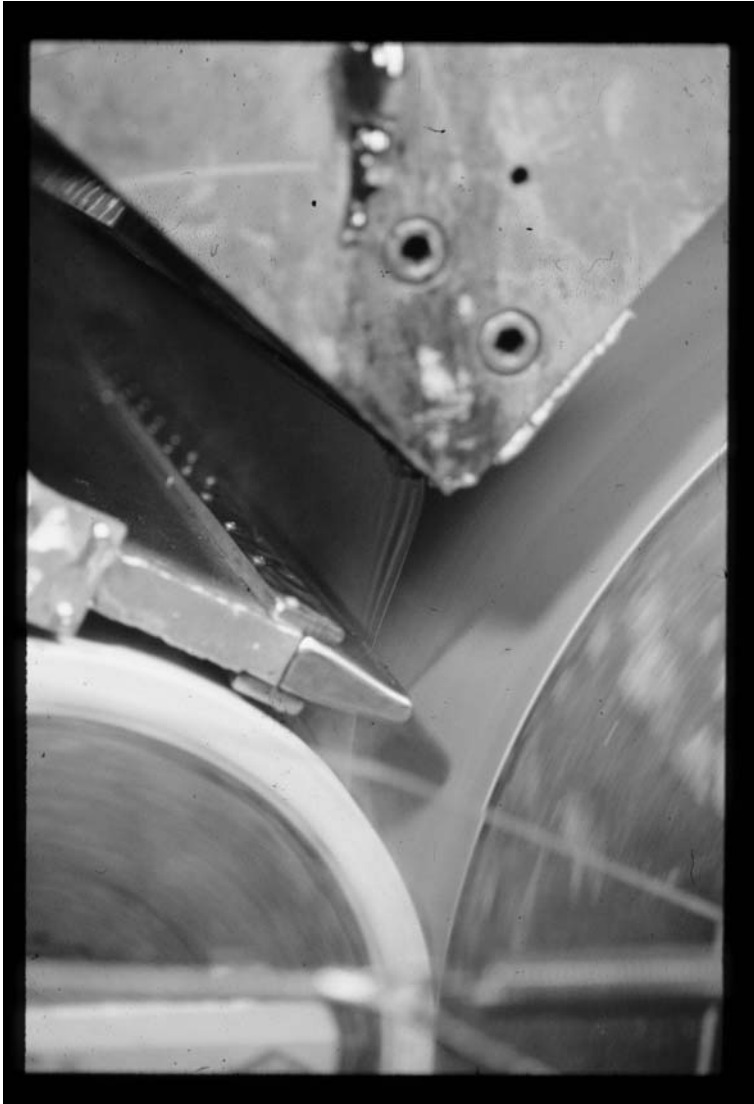
Applications: Crystallisation



Extrusion Blown Film Application



Processing

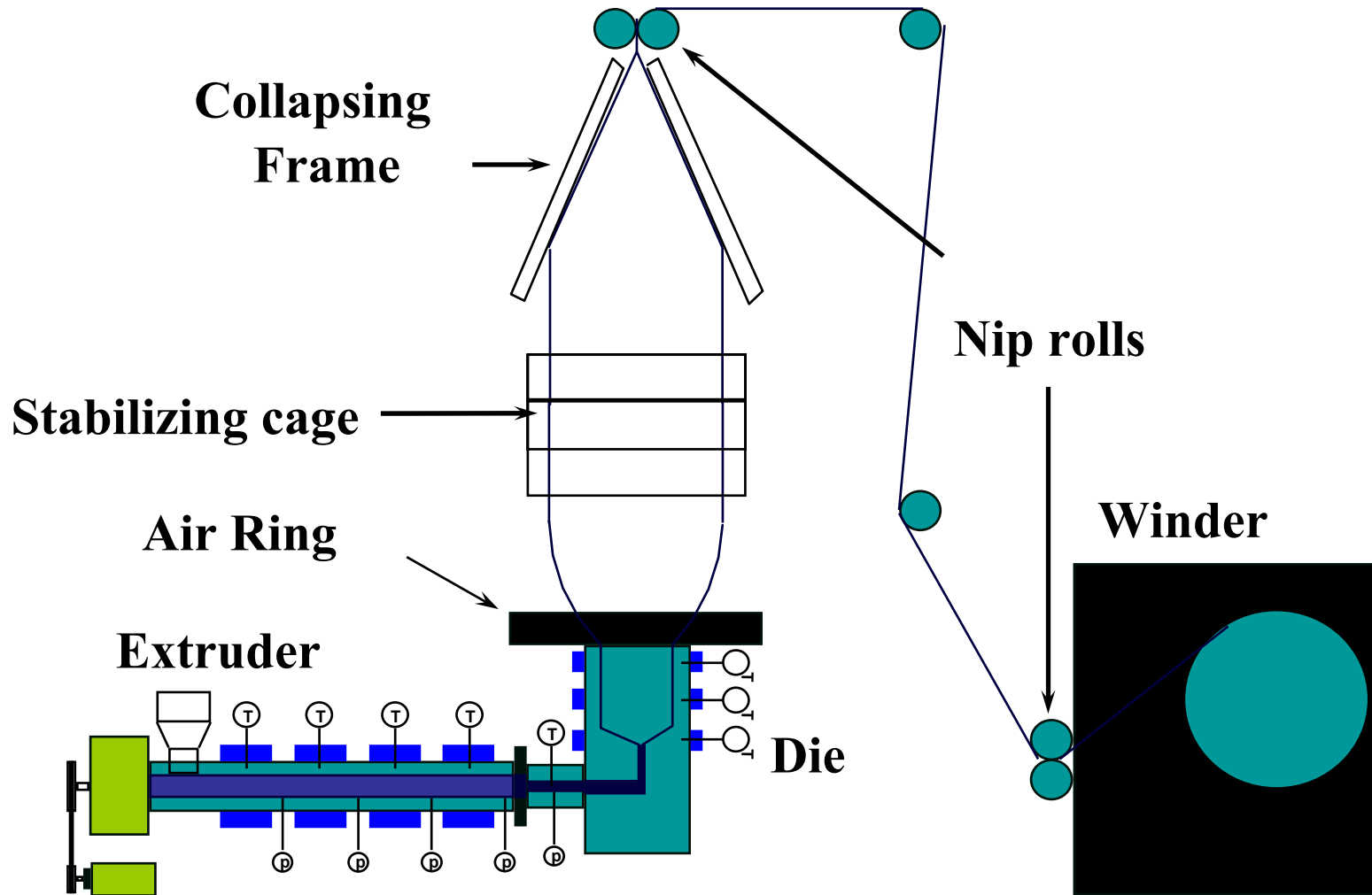


Processing of Film:
Extrusion Casting process
Extrusion Blowing process



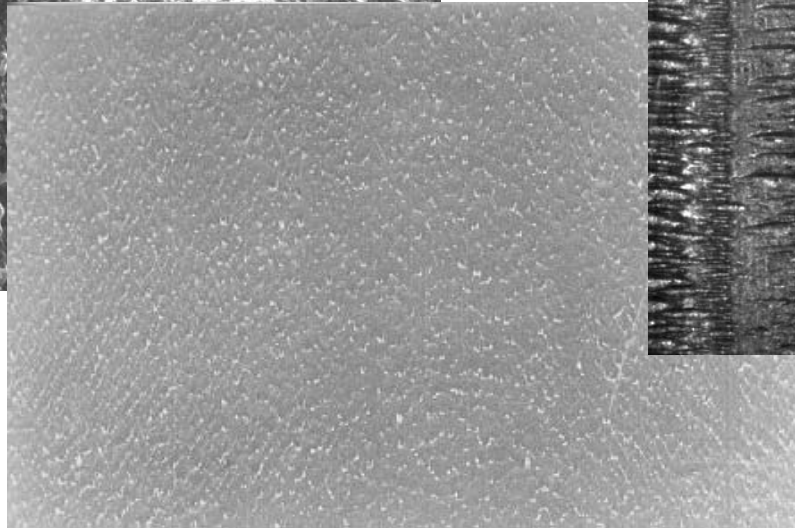
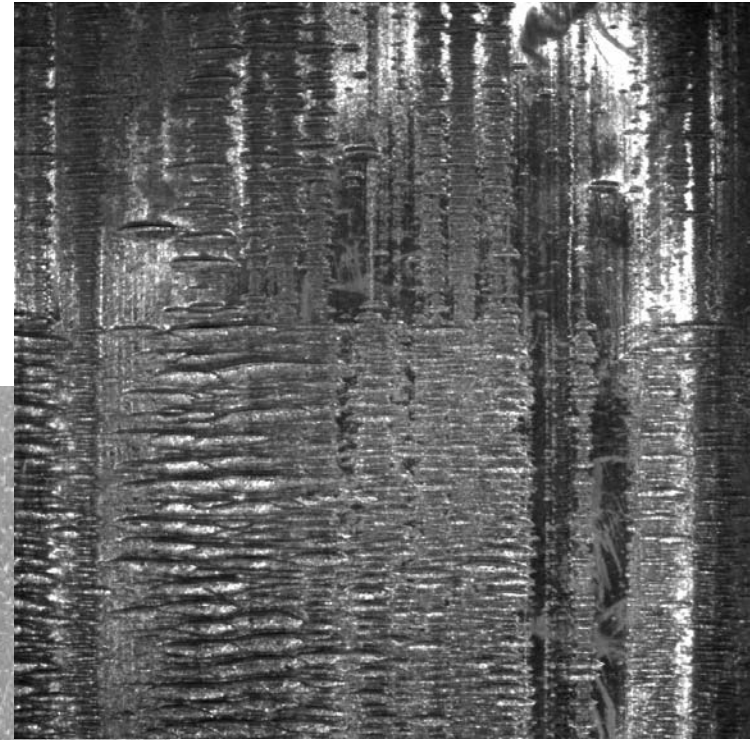
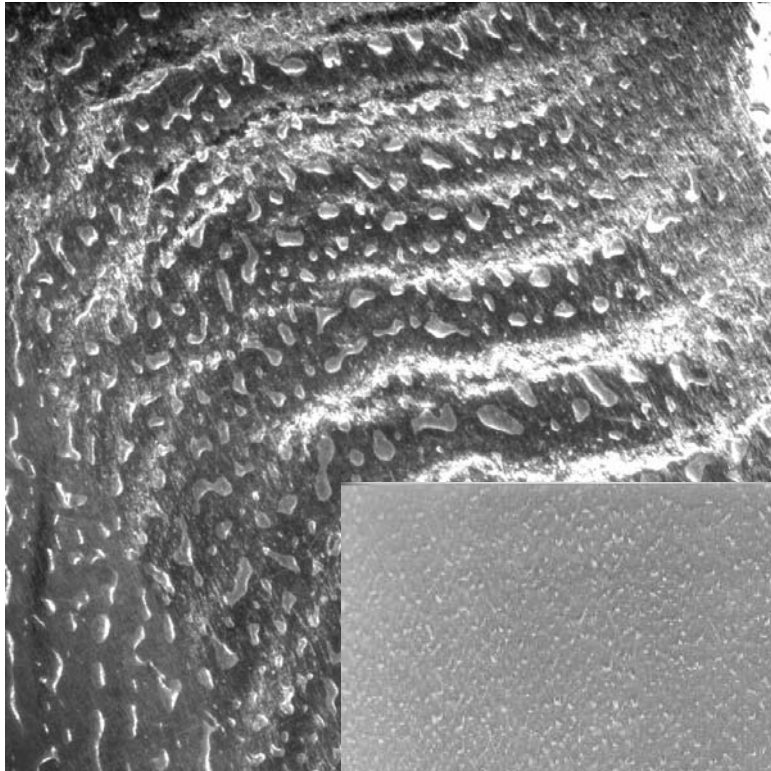
Output driven

Extrusion Blown Film Process

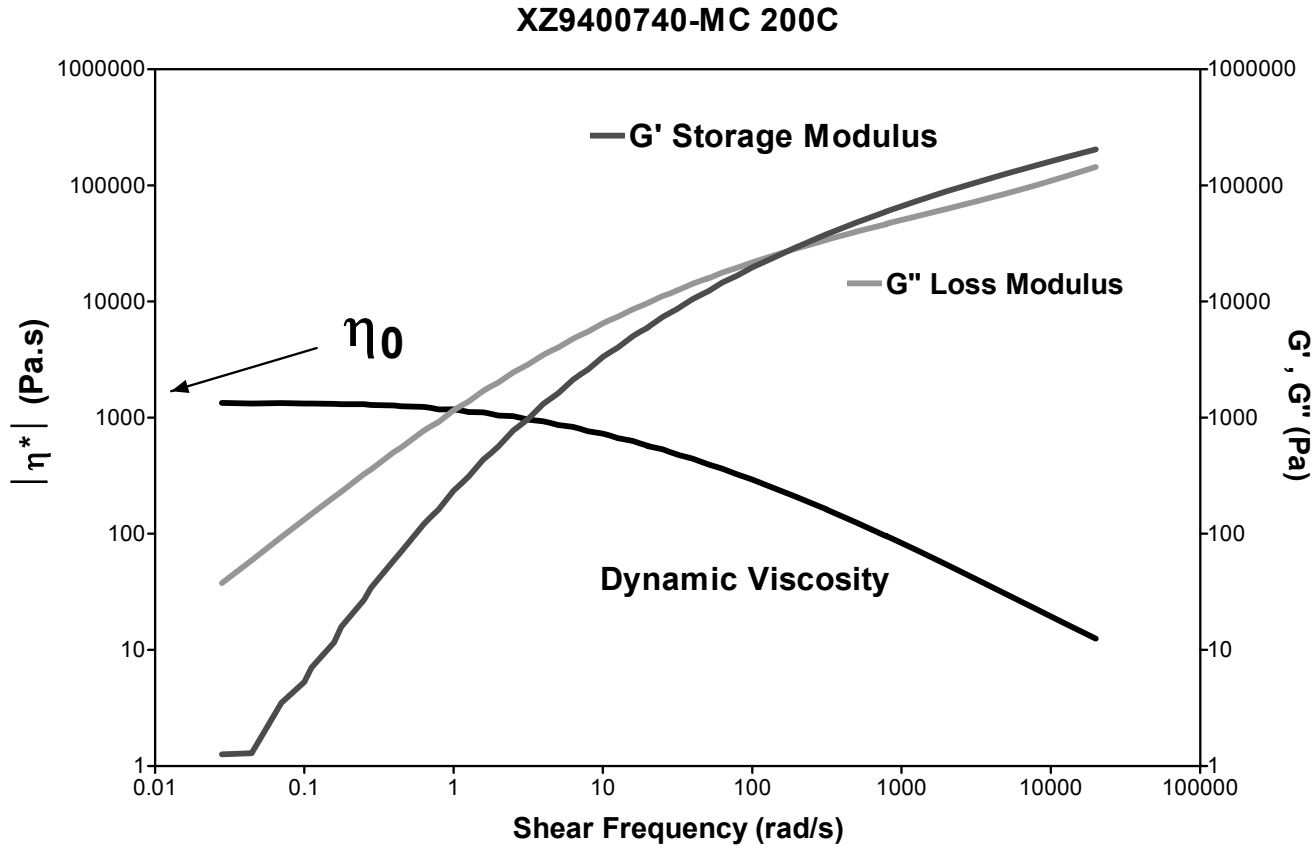


Processing Challenges

Film distortions come in many shapes

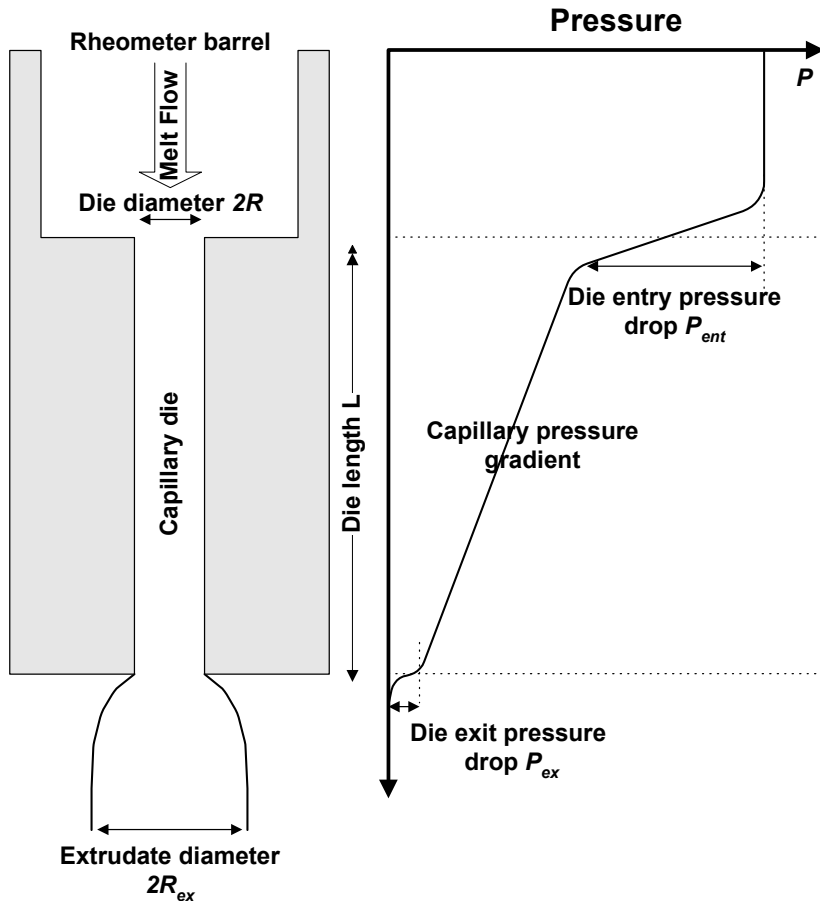


Melt Flow Instabilities



η_0 key metric of the flow curve

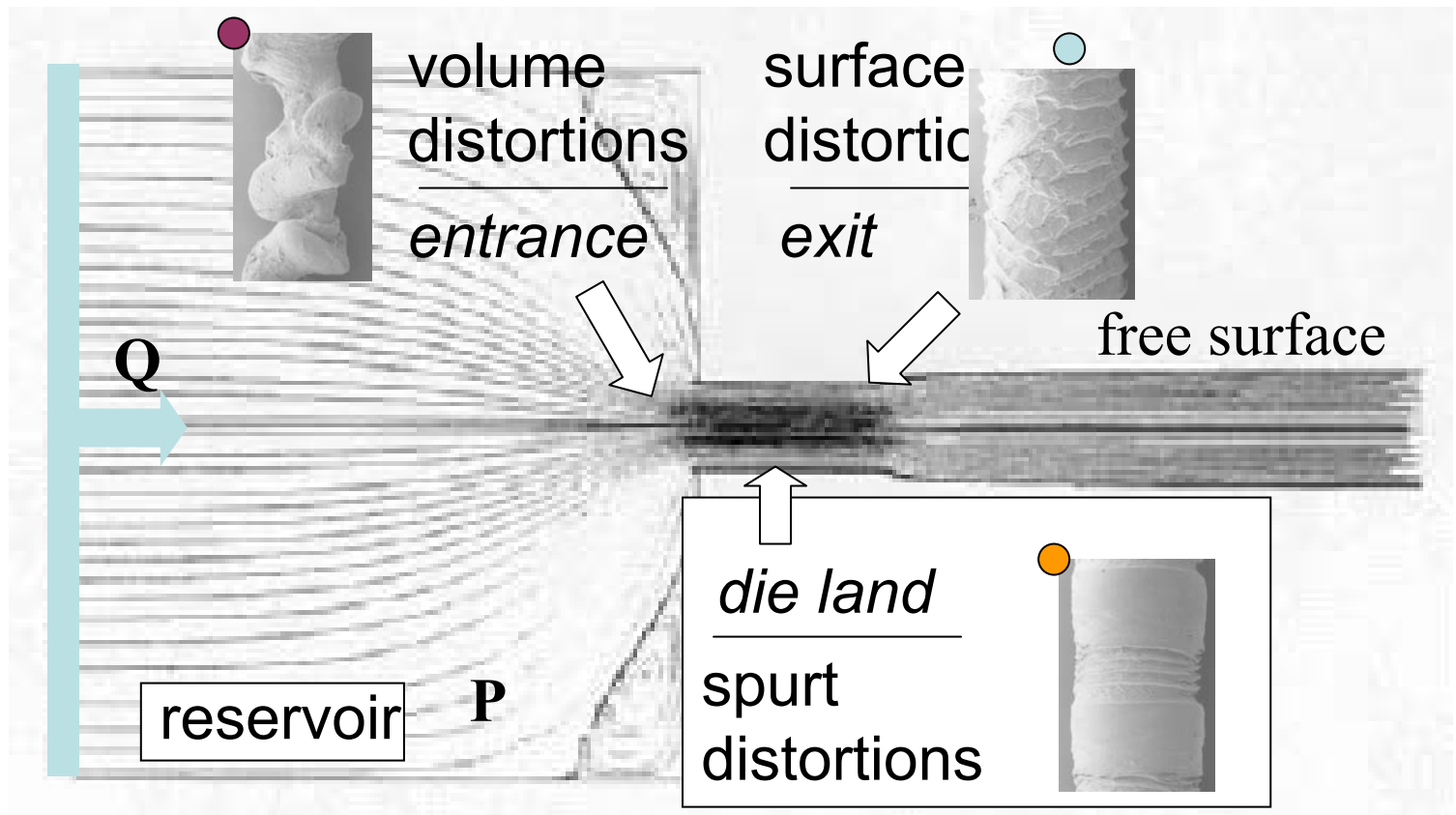
Capillary Rheometer



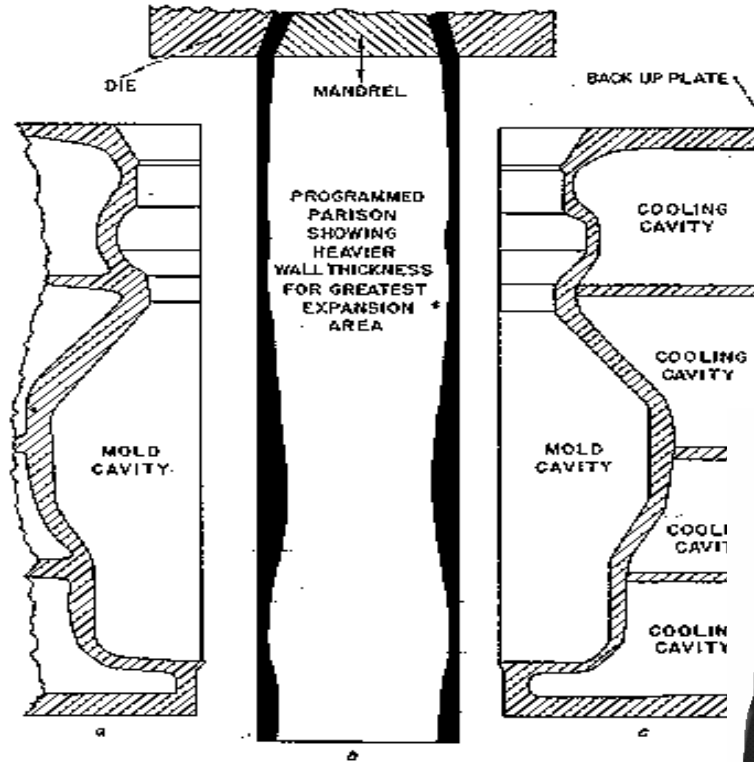
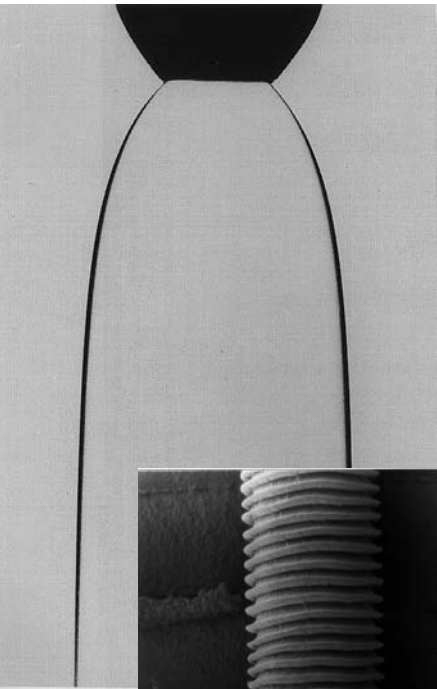
Shear Viscosity Only !

Melt Flow Instabilities

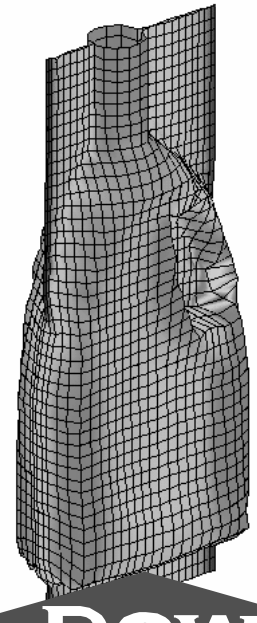
- Examples: LLDPE, HDPE, PP, PS
 - all distortion types



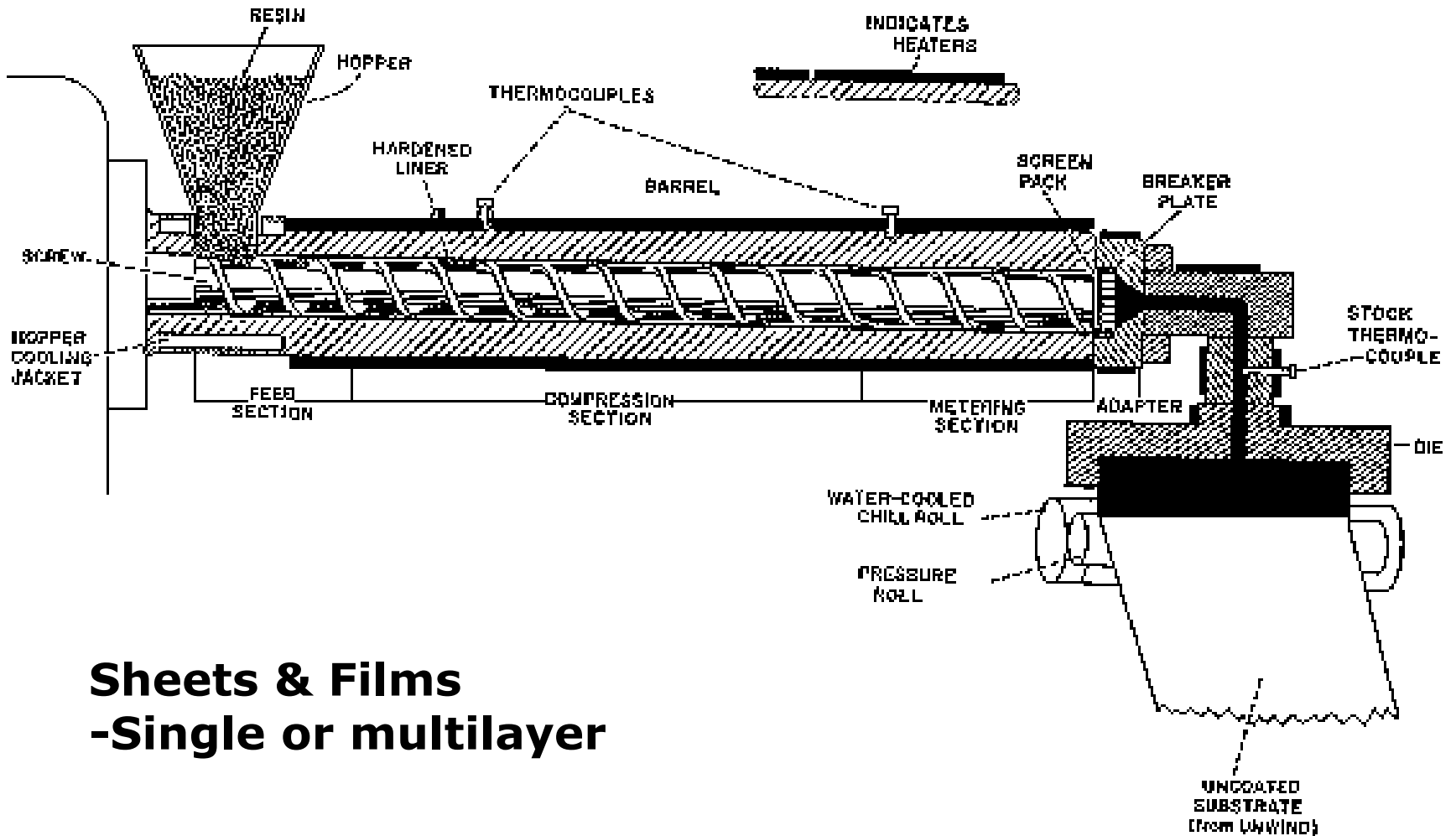
Extrusion Blow Molding of Bottles



A programmed parison designed to fit a particular mold configuration.

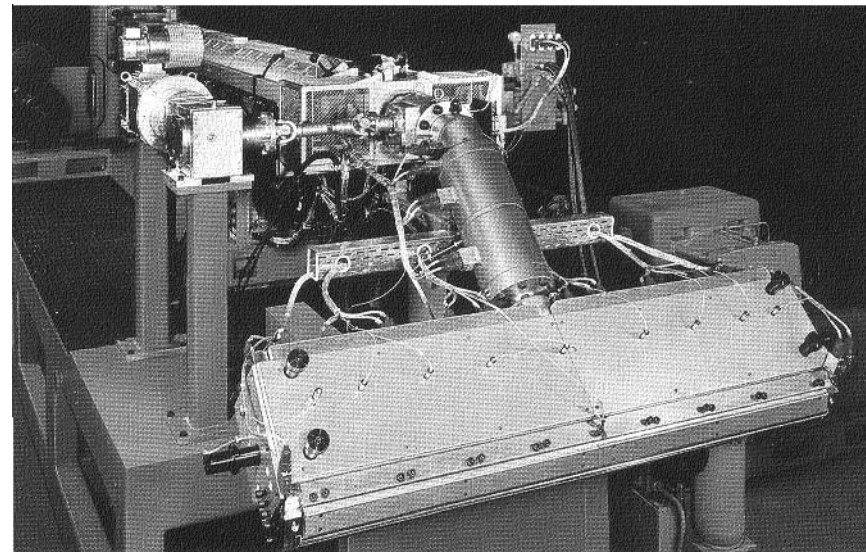
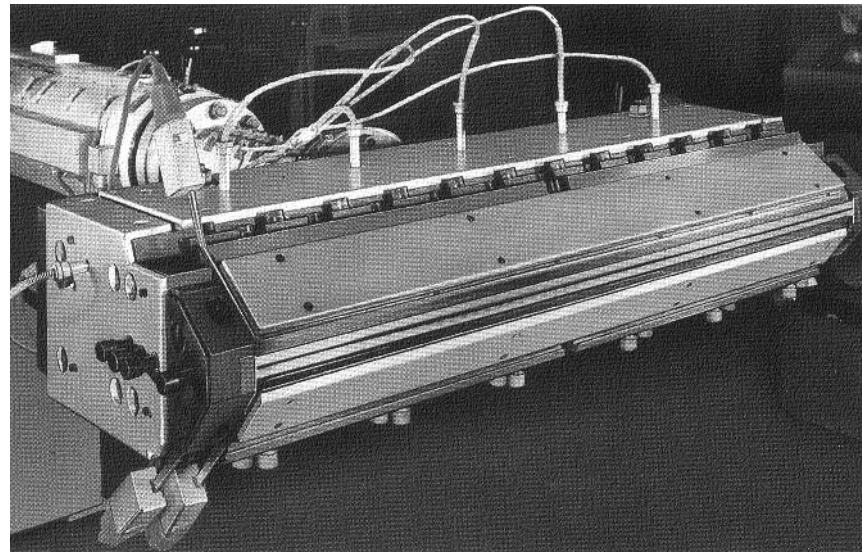


Cast Extrusion



Sheets & Films
-Single or multilayer

Cast Sheet Extrusion



Cast Extrusion

Kinematic hypotheses:

Elongation

$$\dot{\epsilon} = \begin{bmatrix} \frac{du}{dx} & 0 & 0 \\ 0 & f(x) & 0 \\ 0 & 0 & g(x) \end{bmatrix}$$

Membrane approximation ($\sigma \cdot e_z \sim 0$)

$$u(x); v(x, y) = y \cdot f(x); w(x, z) = z \cdot g(x)$$

Mass conservation:

$$\frac{\partial(eL)}{\partial t} + \frac{\partial(eLu)}{\partial x} = 0$$

Force Equilibrium:

$$\text{div}(\mathbf{e} \cdot \boldsymbol{\sigma}) = \mathbf{0}$$

(inertia, gravity, surface tension \ll drawing force)

Constitutive equations:

$$\begin{cases} \boldsymbol{\sigma} = \boldsymbol{\sigma}' - p\mathbf{I} \\ H(\boldsymbol{\sigma}')\boldsymbol{\sigma}' + \lambda \frac{\delta \boldsymbol{\sigma}'}{\delta t} = 2\eta \dot{\boldsymbol{\epsilon}} & H(\boldsymbol{\sigma}) = \exp\left[\frac{\varepsilon \lambda}{\eta} \text{tr}(\boldsymbol{\sigma})\right] \mathbf{I} \\ \frac{\delta \boldsymbol{\sigma}'}{\delta t} = \frac{\partial \boldsymbol{\sigma}}{\partial t} + (\mathbf{u} \cdot \nabla) \boldsymbol{\sigma}' - \nabla \cdot \mathbf{u} \boldsymbol{\sigma}' - \boldsymbol{\sigma}' \nabla \cdot \mathbf{u} \end{cases}$$

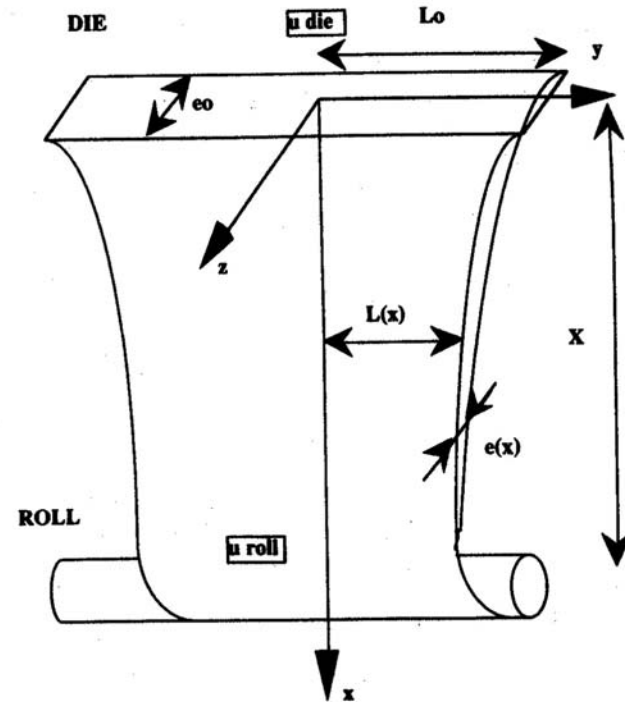
Boundary conditions:

$$\boldsymbol{\sigma} \cdot \mathbf{n} = \mathbf{0}, \quad \mathbf{U} \cdot \mathbf{n} = 0$$

(Edge of the film is a free surface)

Dimensionless numbers:

$$Dr = \frac{u_{roll}}{u_0}, \quad A = \frac{X}{L_0}, \quad De = \frac{\lambda u_0}{X}, \quad \frac{1}{E} = \frac{FX}{\eta e_0 L_0 u_0}$$



Cast Film Stability Map

