Lecture 17

# Polymer Processing

→ Defects in injection molded parts:

1) Sink marks:

→ small depressions or recesses

→ occur on flat and consistent surfaces

→ shrinking of solidifications.

* Volumetric change of plastic from melt to solid is about 25%

↳ In injection molding compressibility is only 1.5%.

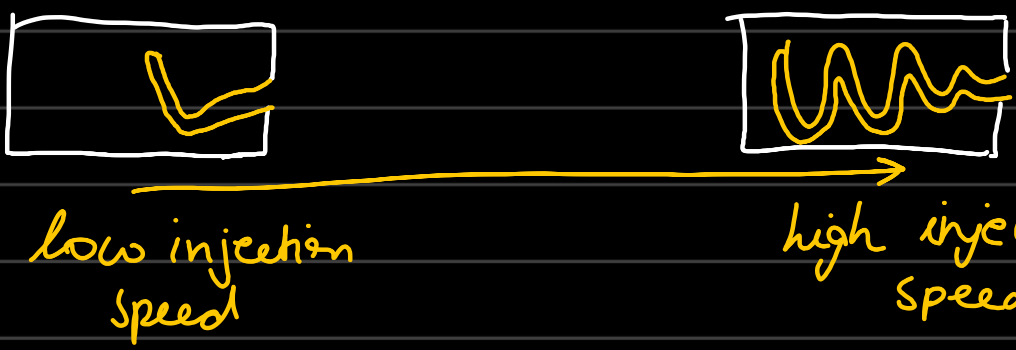
To reduce sink marks:

↳ reduce the thick wall size of the mold material

↳ increase holding time and pressure.

2) Jetting:

↳ depicts behaviour of how molten material is entering mold by jet.




→ The jet of

3) Short Shot: incomplete mold
→ molten material does not flow into all sections of mold.
→ common for high viscosity melts,
→ trapped air pockets hinder melt flow.

* 5 parts/min for complex geometries
100 parts/min for simple geometries
↳ hence industrially favourable for mass production of thermoplasts.
↳ has minimal wastage of material, minimal tolerances.

# Compression Moulding:

↳ typically used for thermosets.
↳ low cost molding methods.
↳ high pressure forming process.
↳ The charge (thermosets) is heated by means of the hot mold to polymerize under heat and pressure.

Lubricants used: Teflon / Silicone.

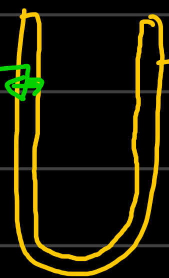
Disadvantages:
↳ Low production rate
↳ reject parts cannot be reprocessed.
→ limited largely to simple geometries with no undercuts. (flat products)

# Blow Moulding:

↳ Extruder + Air hose
↓
produce charge (molten materials)
for the moulding unit.

* Parison: charge for blow moulding.

Wall thickness



Thermoset

→ produced by extrusion.

↳ hollow parts are made like bottle or sphere

→ Disadvantages:

↳ Limited to hollow parts

↳ Thick parts can't be manufactured.

Blow-Up ratio: $BUR = \dfrac{D_{final}}{D_{parison}}$,

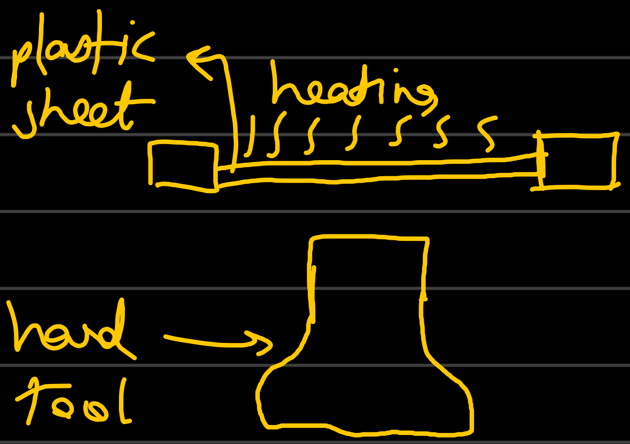
area ratio $= BUR^2$

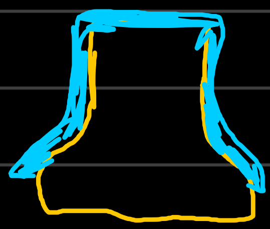
↳ relation between stretch and thickness (incompressible material)

$$t_f = \frac{t_o}{\lambda_\theta \lambda_z}$$

# Thermoforming:

↳ restricted to thermoplastics.



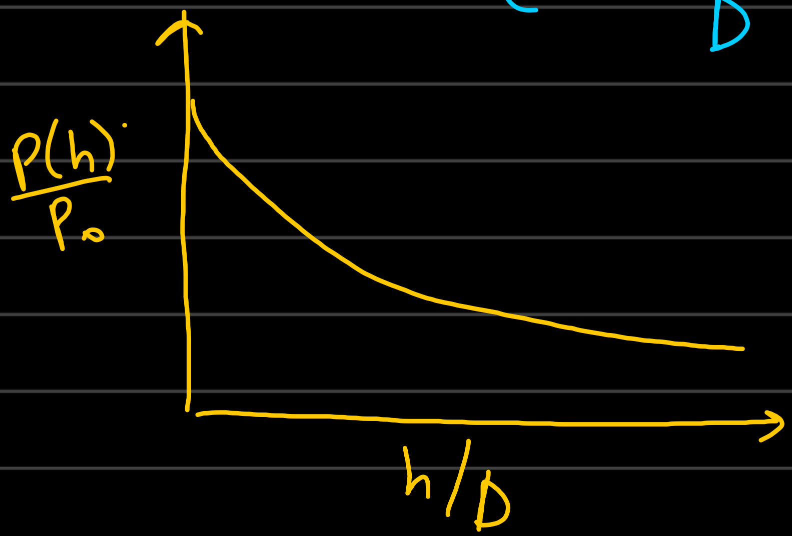



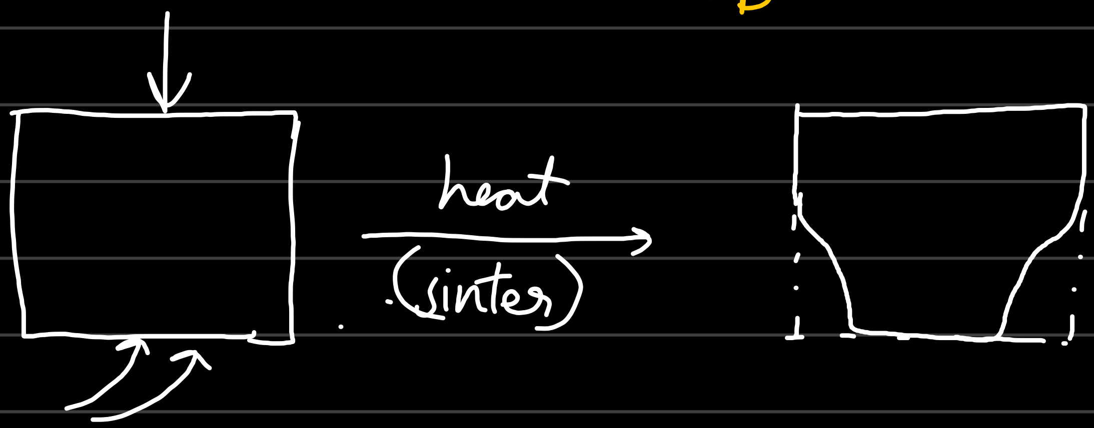
↳ Disadvantages:
- ↳ limited shape complexity
- ↳ internal stresses are produced.
- ↳ Trimming is required.

Resume

# Powder Compaction

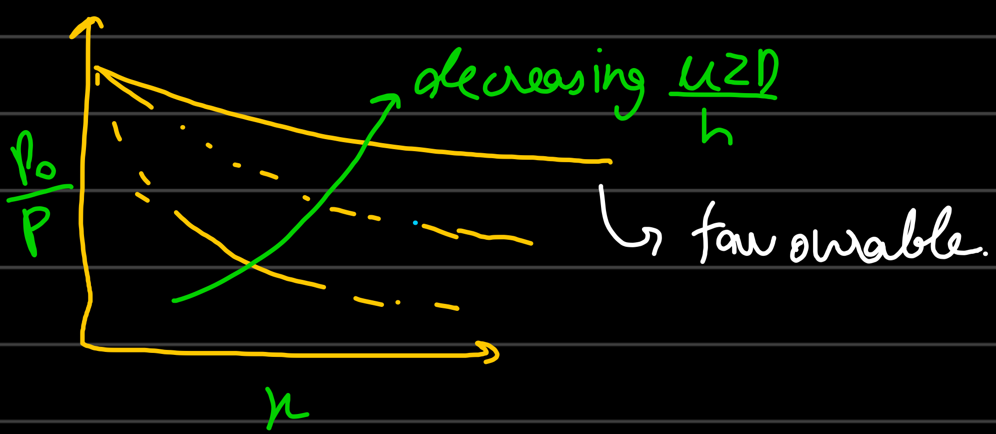
$$p(h) = p_0 \exp\left(-\frac{4\mu z h}{D}\right)$$



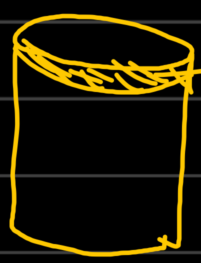

shrinkage due to solidification.

→ can be minimized by h/D is low.



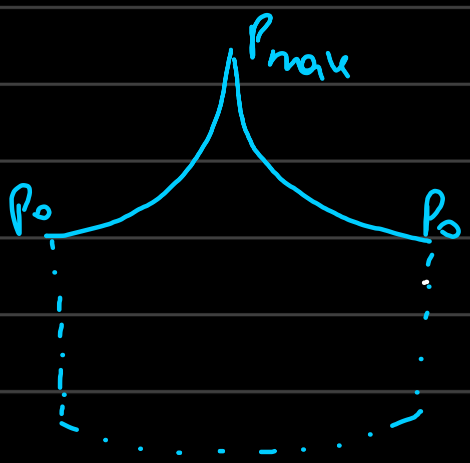
Green density gradient:

* End Capping:



→ easily chips off

called end capping.




→ surface distribution of pressure.

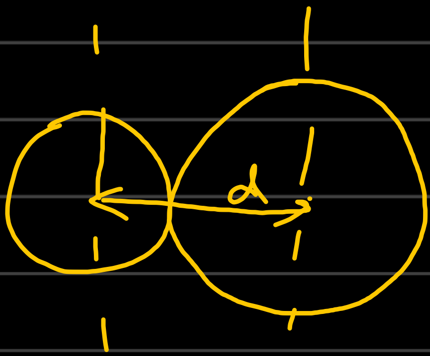
* complex stress state generated on surface.
  ↳ trying to negate two friction forces.
  {combination of tensile + compression}

↳ Activation of stress state upon release of pressure results in chipping of sample.

↳ Can be taken care of by controlling 'μ'.

# Sintering:

↳ coalescence of particles (densification may or may not occur). Effectively it is joining of particles.




* How to justify densification

If d reduces ⇒ it implies densification.

→ does not mean sintering has occurred.

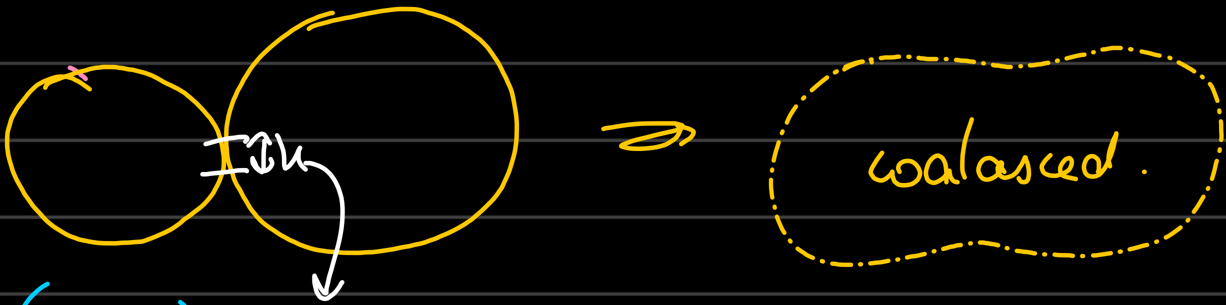
→ Sintering is a coalescence process.

↳ Occurs by mass transport

- lattice diffusion.
  - vacancy
  - ring mechanism (high driving force
    ↳ at high temperature
- grain-boundary diffusion:
  ↓ easier diffusion relatively open structure.
- evaporation & condensation

* Plastic Flow: compressive stresses induced due to Surface Tension (ST) when

powder is heated by sintering.




(n↑ses) Neck → grows as sintering continues.
↳ eventually neck disappears.

* liquid & solid phase sintering:

one phase is liquid or amorphous phase

particles of two kinds (crystalline + polycrystalline phases)

Why do particles coalesce? :

* Surface Tension is the driving force for coalesce {thermodynamic aspect}
* underlying atomic mechanisms. (how atoms move around).

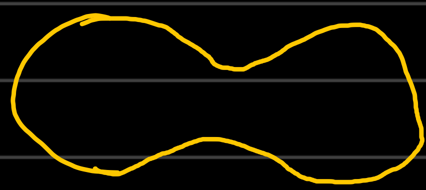
$$\sigma(ST) = \frac{2\gamma}{R}$$

$$\sigma = \gamma\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

radius of 2 adjacent powder particles

radius of neck.

$$r_n = \frac{x^2}{4D}$$ → neck length



$$\sigma_2 = \gamma\left[\frac{2}{D} + \left(-\frac{4D}{x^2}\right)\right]$$

$$\sigma_1 = \gamma\left[\frac{2}{D} + \frac{2}{D}\right] = \frac{4\gamma}{D}$$

$D = 10\,\mu m$, $X = 2\,\mu m$, $\gamma = 1\,MPa.m$

$$\sigma_1 = \frac{4 \times 1\,MPa.m}{10\times10^{-6}} = 4\times10^{5}\,MPa = 0.4 \times 10^{6}$$

$$\sigma_2 = 1\,MPa.m\left[\frac{2}{10\times10^{-6}} - \frac{\cancel{4}\times10\times10^{-6}}{\cancel{4}\times10^{-12}}\right]$$

$$= 1\,MPa.m\left[-0.98\times10^{+6}\right]$$