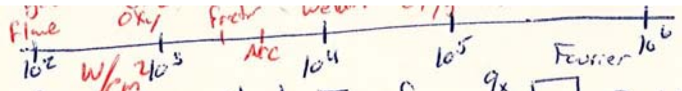
2.008 Quiz 1 Sheet

acetylen & hydrogen
→ Ethylene

get

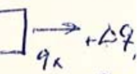
2Lecture: Process Planning : Parameters

- activity determine procedure for final product.
- Equipment
- Space
- People
- Material

+ Cost
+ Rate
+ Quality
+ Flexibility

DFM

- Part size
- Tolerances
- Variation
- Materials
- Surface quality
- Shapes & complexity
- Process

Heat Transfer


$$\rho C_p \frac{\partial T}{\partial t} = K\frac{\partial^2 T}{\partial x^2} \quad \text{or} \quad \frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}$$

B.C. $T(x=x') = \text{Constant}$

$-K\frac{\partial T}{\partial x}(x=x') = \text{Constant}$

$-K\frac{\partial T}{\partial x}(x=x') = h(T - T_\infty)$

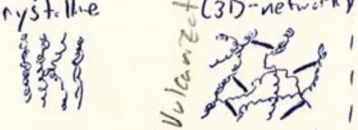
3Lecture : Injection Molding

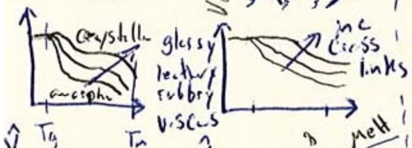
C_2H_4 poly [ethylene] chains

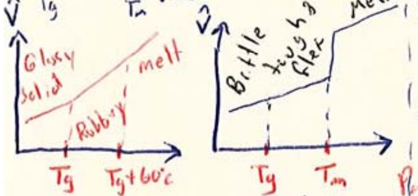
Thermoplastic vs. Thermoset

Amorphous
Crystalline

Cross-linked (3D-network)
Vulcanization

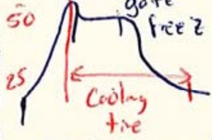






Amorphous Crystalline

(MPa) Pressure History Injection Mold



$$t_{cool} = \frac{(\ell/2)^2}{\alpha}$$

thickness

$\alpha = 10^{-3}$ cm/sec for polymers

Hold Pressure (packing)
150% injection pressure

Clamp p Force

Re #

$$= \frac{\text{inertial}}{\text{viscous}} = \frac{\rho V L}{\mu}$$

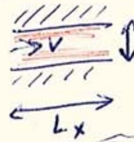
g/cm^3 m/s m

$N \cdot s/m^2$

Velocity = $\frac{\text{Part length}}{\text{fill time}}$

Non-Isothermal Flow

$$\frac{\text{Flow Rate}}{\text{Heat xfer Rate}} = \frac{V \cdot L_z}{4\alpha L_x}$$



low values require large runners

- Total force = Projected area x injection pressure
- ROT 4 to 5 ton/in²
-

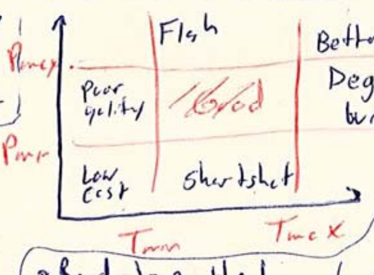
$A^2 \cdot P_{in} = F_{clamp}$

Flow Path Ratio
distance between gate & Farthest Point.

Melt delivery

- Sprue
- Runner
- Gate
- weldline
- Warpage

PE	280-100
PP	280-150
PVC	280 70
PS	300-220
PC	160-90



Flash

- mold quality
- low viscosity
- P_{inject} ↑
- P_{clamp} ↓

Shortshot

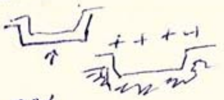
- Volume injection p not high

4Lecture Thermoforming

- Vaccum
- Pressure
- Plug assist pressure
- Match Mold
- Plug assist Vacuum Forming
- Free blowing

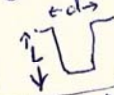
Forming

Vacuum or Pressure 14.5 to 300 psi



- Radiative Heating absorption rate ↑

Draw Ratio $\frac{\text{height}}{\text{diameter}}$

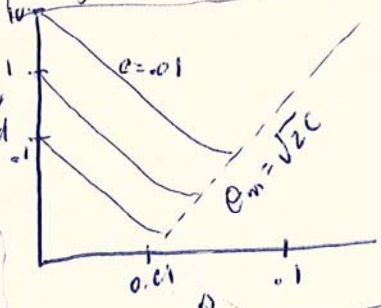


$$C = \frac{D-d}{D}$$

$$\frac{\ell}{d} = C/\theta$$

Billow Vacuum Forming

- Better thickness uniformity
- Longer Cycle time
- Deep draw ratio



Errors Effect $e = ar^K$

Production rate = r / time

Error rate = e scrap / time

Net production = r − e good

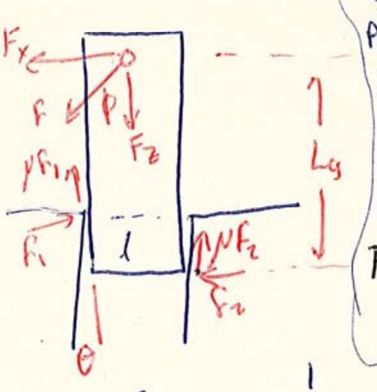
max net : $\frac{d\,net}{dr} = 0 = 1 - Kar^{K-1}$

$$r^{K-1} = \frac{1}{Ka}$$

Assembly efficiecie-cy

$$= \frac{3 * \#\text{ theoretical Parts}}{\text{total predicted assembly time using all Parts}}$$

5% bad 30% Good



$$\tan\phi = \frac{F_x}{F_z} = \frac{1}{\mu\left[2\frac{L_g}{\ell} - 1 - 2\mu\frac{r}{\ell}\right]}$$

Joining

Press fit

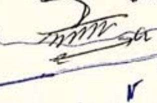
$F_{insert} = \mu p\, 2\pi R X_{insert}$

interface pressure

$\delta_{thermal} = \alpha R \cdot \Delta T$

Stefan equation

$$F t = \frac{3\mu \pi a^4}{4}\left[\frac{1}{h_f^2} - \frac{1}{h_i^2}\right]$$



Start low viscosity
Finish w/ high viscosity

Brazing T > 450°

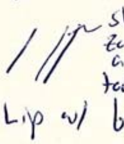
Soldering < 450°

① Covalent Bond ② Vander Waals

Chip types

1) Continuous chip
- Ductile material @ high speed
- Bad for automation

2) Secondary shear zone at chip tool interface.



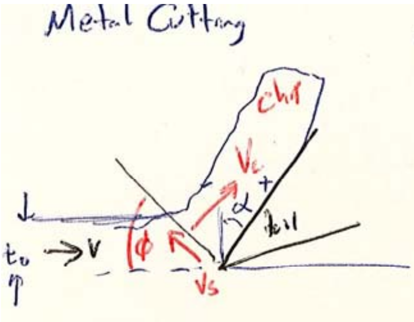
3) Continuous Chip w/ built up edge
- High plastic working bad for automation

4) serrated Chip
- Low thermal conductivity

5) Discontinuous Chip
- low ductility materials
- 0 or neg rake ∠

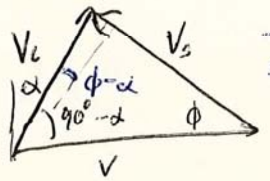
α 10^{-3} cm^2/s

Metal Cutting



$$V\Big|_{\frac{\text{material}}{\text{tool}}} + V\Big|_{\frac{\text{chip}}{\text{material}}} = V\Big|_{\frac{\text{chip}}{\text{tool}}}$$

C → Cutting S → Shear
t → thrust N → Normal
f → friction F_n → Chip Normal



$$\frac{V}{\sin(\frac{\pi}{2} - \phi + \alpha)} = \frac{V_s}{\sin(\frac{\pi}{2} - \alpha} = \frac{V_c}{\sin(\phi)}$$

Cutting Ratio

$$\frac{V_c}{V} = \frac{t_o}{t_c} = r = \frac{\sin\phi}{\cos(\phi - \alpha}$$

Analysis of shear strain

$\phi \downarrow = \gamma \uparrow$ & $\alpha \downarrow = \gamma \uparrow$

$$\gamma = \frac{\Delta X}{A} = \frac{bc + cd}{ac}$$

$$= \cot\phi + \tan(\phi - \alpha)$$

Rake ∡ ⇕ or Friction ∡ ↑
- Shear ∡ ↓
- Chip thickness ↑
- Energy dissipation via Shear ↑
- Heat generat ↑
- Temp ↑

Shear plane forces

$$F_s = F_c \cos(\phi) - F_t \sin(\phi)$$
$$F_n = F_c \sin(\phi) - F_t \cos(\phi)$$

Tool-chip forces

$$F_f = F_c \sin\alpha + F_t \cos\alpha$$
$$N = F_c \cos\alpha - F_t \sin\alpha$$

$$\mu = \frac{F_f}{N} = \tan\beta$$

$$0.5 < \mu < 2$$

Cutting & Thrust Forces

$$F_t = F_c \tan(\beta - \alpha)$$

$\beta < \alpha$ tool pulled into part
$\beta > \alpha$ tool pushed
$\beta = \alpha$ no thrust

Merchant's minimum energy

$$\tau_s = \frac{F_s}{A_s} = \frac{F_c\cos\phi - F_t\sin\phi}{\left[t_o/\sin\phi\right] \cdot w}$$

$$\phi = \frac{\pi}{4} - \underbrace{\frac{\beta}{2}}_{\text{w friction ∡}} + \frac{\alpha}{2}$$

t_c Chip thickness

Power input

$P_{\text{machine}} \Rightarrow P_c = F_c \cdot V$

Power dissipation

Shear = $P_s = F_s \cdot V_s$

Friction : ~~[illegible]~~ $P_f = F_f \cdot V_c$

Material Removal Rate

$$\text{MRR} = V \cdot \underset{\substack{\uparrow \\ \text{depth of cut}}}{t_o} \cdot W$$

$\text{MRR} \cdot U_t = V t_o w \cdot U_t$

$P_{\text{lathe}} = F_c \cdot (R\,\omega)$

grain size

$$\sigma_y = \sigma_0 + \frac{K_y}{d^{1/2}}$$

Hall Petch equation

Power & Specific energy

Shear

$$u_s = \frac{F_s V_s}{w\, t_o V}$$

Friction

$$u_f = \frac{F_f \cdot V_c}{w \cdot t_o \cdot V}$$

~ shearing velocity
~ cutting speed

total

$$u_t = \frac{F_c V}{w \cdot t_o \cdot V}$$

Power Shear

$$F_s \cdot V \cdot \frac{\cos(\alpha)}{\cos(\phi - \alpha)}$$

Power Friction

$$F_f \cdot V \cdot \frac{\sin\phi}{\cos(\phi - \alpha)}$$

$$u_s = \frac{\tau_s}{\sin\phi}\,\frac{V_s}{V}$$

$$u_s = \tau_s\,\gamma$$

Forging force & friction

$$\sigma_z = -Y \exp\left[\frac{2\mu}{\underset{\substack{\uparrow \\ \text{height}}}{h}}(R - r)\right]$$

$$F_z = \pi R^2 Y \left[1 + \left(\frac{2}{3}\,\frac{\mu R}{h}\right)\right]$$

Steps are done for ductility of material

Tool Wear Relationship

n
Steels ~0.1
Ceramics ~0.6

$$V \cdot t^n = C$$

↑ Cutting Velocity (fpm)
↑ time failure (min)

Energy
$E = i^2 R \cdot \text{time}$

Propagation of Heat for Solids

$$X \sim (\alpha t)^{1/2}$$

Weld Pool

$$J_a = C_p \frac{(T_m - T_i)}{h_{fs}}$$

$$\alpha = \frac{K}{\rho C_p}$$

Melt impact

$$S = \sqrt{2\alpha J_a t}$$

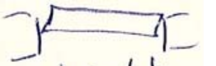
$\underbrace{\leftarrow d \rightarrow}_{V_{\min} = d/t_{\max}}$

$V_{\text{weld}} >$ t

$$t_{\max} = \frac{S_{\max}^2}{2\alpha J_a}$$

$$V_{\min} = d/t_{\max}$$

wedging



2 pt contact
$\theta > c/\mu$

Jamming force wrong
Jamming ∡

$$\text{Power} = \underset{\sim\text{cutting force}}{F_c} \cdot \underset{\sim\text{cutting velocity}}{V} = \underset{\text{material removal rate}}{\text{MRR}} \cdot \underset{\sim\text{total specific energy of cutting}}{U}\ ; \quad F_c = \frac{\text{MRR} \cdot U}{V}\ ; \quad \text{MRR} = \underset{\text{Feed Rate}}{F}\ \underset{\text{Depth Cut}}{W}\ \pi\ \underset{\text{Part Diameter}}{D} \cdot \underset{\text{Spindle Speed}}{\Omega}$$

$$\therefore F_c = \frac{F \cdot w \cdot \pi \cdot D \cdot \Omega \cdot U}{\pi \cdot D \cdot \Omega} = \boxed{F \cdot W \cdot U = F_c}$$

$$U_s = \frac{F_s V_s}{w t_o V}$$

$$\text{RPM} = \frac{V}{\pi D}$$

$$\mu = \tan\underset{\substack{\uparrow \\ \text{friction ∡}}}{\beta}$$

Change
- Chamfers
- Clearance Ratio
- Friction

Wedging