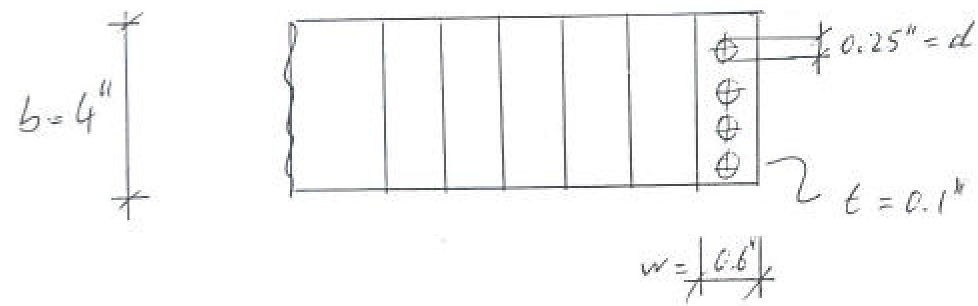
2.810 Sheet Forming

HW#7 - Solutions

Problem 3.)



$UTS = 100,000 \cdot 0.5^{0.5} = 70,710$ psi

a) Sequence of operations:

- Cutting : Cutting Die, Press Brake, 1 operator
- Hole Punching : Punching Die, Press Brake
- Bending : V-Die, Mech. Press, 1 operator

Operators : 2

Machines : 1 Press Brake, 1 Mech. Press

Material : sheet metal strip 4" wide

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5) Size and Equipment cost

Cutting: Shearing Forces

$F_S = 0.7 \cdot b \cdot t \cdot UTS$

$= 0.7 \cdot 4'' \cdot 0.1'' \cdot 70{,}710 = 19{,}800 \text{ lbs}$

$\hat{=}\ 88 \text{ kN}$

Hole Punching: Shearing Forces

$F_{S/Hole} = 0.7 \cdot \pi \cdot d \cdot t \cdot UTS$

$= 0.7 \cdot \pi \cdot 0.25 \cdot 0.1 \cdot 70{,}710 \approx 3900 \text{ lbs}$

$F_{S\,total} = 4 \cdot 3900 \text{ lbs} = 15{,}600 \text{ lbs}$

$\hat{=}\ 69 \text{ kN}$

Bending: Bending Forces

$$F_B = \frac{UTS \cdot w \cdot t^2}{b} = \frac{70{,}710 \cdot 0.6'' \cdot 0.1''^2}{4''}$$

$F_B = 110 \text{ lbs.} \hat{=}\ 490 \text{ N}$

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b) Die Costs : Cutting + 4 Hole Punch

Die sets : $C_{ds} = \$120 + 0.36 \cdot A_u$

$$A_u = 5'' \cdot 2.5 \frac{cm}{in} \cdot 1'' \cdot 2.5 \frac{cm}{in} = 31.25\,cm^2$$

$\Rightarrow C_{ds} \approx \$135$

Labor for Die Making

$$M_{po} = 23 + 0.036\,W$$

$$= 23 + 0.03 \cdot 4'' \cdot 2.5 \frac{cm}{in} \cdot 0.6 \cdot 2.5 \frac{cm}{in}$$

$$\approx 24\,hrs$$

$$M_{pc} = 8 + 0.6\,P_p + 3 \cdot N_p$$

$$= 8 + 0.6\left(0.25 \cdot 2.5 \frac{cm}{in}\right)\pi \cdot 4 + 3 \cdot 4$$

$$\cong 25\,hrs$$

$$M_{ps} = K \cdot N_p + 0.4\,N_d$$

$$= 2 \cdot 4 + 0 = 8\,hrs$$

Total Costs for Cutting + Piercing Die :

$$C_n = \$135 + (24 + 25 + 8) \cdot \$40/hrs = \$2,600$$

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b) <u>Die Cost : Bending (V-Die)</u>

Die Sets : $C_{ds} \approx \$135$ (see above)

Labor for Die Making:

$$M_{po} = (18 + 0.023\ bw) \times [0.9 + 0.02\ D]$$

$$= \left(18 + 0.023 \cdot 4'' \cdot 2.5 \tfrac{cm}{in} \cdot 0.6 \cdot 2.5 \tfrac{cm}{in}\right) \cdot \left(0.9 + 0.02 \cdot \frac{2''}{\sqrt{2}} \cdot 2.5 \tfrac{cm}{in}\right)$$

$$\approx 17 \text{ hrs}$$

$$M_{pn} = 0.68 \cdot L_b + 5.8\ N_b$$

$$= 0.68 \cdot 0.6'' \cdot 2.5 \tfrac{cm}{in}$$

$$\approx 1 \text{ hr.}$$

Total V Die Costs:

$$C_{VD} = \$135 + (17 + 1) \cdot \$40/\text{hrs} = \underline{\$855}$$

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b) <u>Press Costs</u>

- Press Brake : $C_{PB} = \$2/lb \cdot$ Force Cap.

$$C_{cp} \approx \$2 lb \cdot (19,800 + 15,000) lbs$$
$$\approx \$80,000$$

- Bending Press: -

$$C_{PB} \approx \$5,000 \quad \text{(estimation)}$$
operational Cost

<u>Material Costs</u>

$$C_M = \frac{1}{15} lbs \cdot \$0.25 = \$0.017 / part$$

<u>Labor Costs</u>

$C_L = \$30 / hr.$

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c) Time Estimate ≈ 1 part / sec.

d) Costs per Bracket:

$$\text{Unit Costs} = \frac{C_{FIX}}{N} + C_{var} \cdot N$$

$$= \frac{C_{CP} + C_{PB} + C_{ED} + C_{VD}}{N} +$$

$$(C_{Labor} + C_{Material})\, N$$

$$= \frac{\$88500}{N} + (\$8.34 \cdot 10^{-3} + \$17 \cdot 10^{-3})$$

Production Time 1 year ≙ 10^7 parts

=> Unit Costs = \$0.034 ≙ **3.5 cents / p.**

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e) Minimum Bend Radius

with bending strain:

$$e_{max} = \frac{t}{2 R_{min} + t}$$

$$\Leftrightarrow R_{min} = \frac{(1 - e_{max}) \cdot t}{2 \cdot e_{max}}$$

here $e_{max} = n = 0.5$ and $t = 0.$

$$\Rightarrow R_{min} = 0.05''$$

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f) Spring Back

$R_0 = 1.5\ R_{min} = 0.075''$

$t = 0.1''$

from chart $Y/E_{steel} = \frac{1}{909}$

$Y/E_{Ti} = \frac{1}{188}$

$Y/E_{Al} = \frac{1}{212}$

and $\frac{1}{R_1} = \frac{1}{R_0} - 3\frac{Y}{tE} - 4R_0^2\left(\frac{Y}{tE}\right)^3$

$\Rightarrow R_{1\,steel} = 7.52 \cdot 10^{-2}\,''$

$R_{1\,Al} = 7.58 \cdot 10^{-2}\,''$

$R_{1\,Ti} = 7.59 \cdot 10^{-2}\,''$

↓ spring back increases

Note: For small R_0, the $1/R_0$ is dominating → very little spring back.

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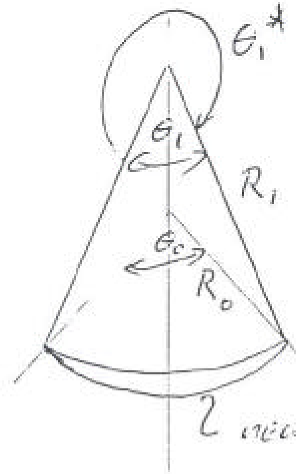
f) Spring Back cont'd

Angle:



$$R_0\theta_0 = s = R_1\theta_1$$

$$\Rightarrow \theta_1^* = 180° - \frac{R_0\theta_0}{R_1} \quad w/\ \theta_0 = 90°$$

$$\Rightarrow \theta_{1_{st}}^* = 90.2°$$

$$\theta_{1_{Al}}^* = 90.9°$$

$$\theta_{1_{Ti}}^* = 91.1°$$

↓ increasing spring back

Compensation Methods:

a) over bending b) bottoming c) stretch bending