ACE Engineering Publications

SINCE 2011

GATE | PSUs

Mechanical Engineering

PRODUCTION TECHNOLOGY

Text Book :
Theory with worked out Examples and Practice Questions

Production Technology

(Solutions for Text Book Practice Questions)

Chapter 1 Metal Casting

01. Ans: (d)

Sol: Permeability number $= \dfrac{VH}{PAT}$

For standard specimen H = D = 5.08 cm

P = 5 gm/cm^2, V=2000 cc, T= 2 min

$$PN = \frac{2000 \times 5.08}{5 \times \frac{\pi}{4} \times 5.08^2 \times 2} = 50.12$$

02. Ans: (c)

Sol: Net buoyancy force

= Weight of core – weight of the liquid which is displaced by core

$= V.g\ (\rho - d)$

$$= \frac{\pi}{4} \times d^2 h \times g \times (\rho - d)$$

$$= \frac{\pi}{4} \times (0.12)^2 \times 0.18 \times 9.81 \times (11300 - 1600)$$

= 193.6N

03. Ans: (a)

Sol: Pouring time $= \dfrac{\text{Volume}}{A_C \times V_{max}}$

$$= \frac{2 \times 10^6}{200 \times \sqrt{2 \times 10000 \times 175}}$$

= 5.34 sec

04. Ans: (a)

Sol: $Q = 1.6 \times 10^{-3}$ m^3/sec

$A = 800$ mm^2

$Q = A \times V$

$1.6 \times 10^{-3} = (800 \times 10^{-6}) \times V$

$V = 2 \text{ m/sec} = \sqrt{2gh}$

$$h = \left(\frac{2}{\sqrt{2 \times 9.81}}\right)^2 = 0.203\text{m}$$

= 203 mm

05. Ans: (c)

Sol: Vol. of casting $= \dfrac{\pi}{4} D^2 \times L$

$$= \frac{\pi}{4} \times 150^2 \times 200$$

$$= 3534291 \text{ mm}^3$$

$h_t = 200 + 50 = 250$ mm

$A_C = A_{min}$ = sprue base area

$$= \frac{400}{2} = 200 \text{ mm}^2$$

G.R.= 1:1.5:2

Pouring time $= \dfrac{\text{Volume of Casting}}{A_{C.} \times V_{max}}$

$$= \frac{3534291}{200 \times \sqrt{2 \times 9810 \times 250}}$$

$$= \frac{17671}{\sqrt{2 \times 9810 \times 250}} = 8\ Sec$$

06. Ans: (c)

Sol: The dimension of pouring basin will not affect the pouring time

Let V = maximum velocity of molten metal in the gating system,

$d = d_{min}$ = dia. Sprue bottom

$$\text{Pouring time} = \text{P. T} = \frac{\text{volume of casting}}{A_c \times V_{max}}$$

$$= \frac{35^3}{\frac{\pi}{4} d^2 \times V} = 25$$

$$V = \frac{35^3}{\frac{\pi}{4} d^2 \times 25} = 2183.6/d^2 \ldots\ldots (1)$$

To ensure the laminar flow in the gating system $R_e \le 2000$

For limiting condition $R_e = 2000$

$$R_e = 2000 = \frac{\rho V d}{\mu} = \frac{Vd}{\nu}$$

$$\Rightarrow 2000 = \frac{Vd}{\nu}$$

$$V = \frac{2000\nu}{d} = \frac{2000 \times 0.9}{d} = \frac{1800}{d} \ldots (2)$$

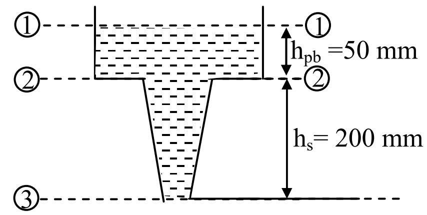
From (1) and (2)

$$\frac{2183.6}{d^2} = \frac{1800}{d}$$

$$d = \frac{2183.6}{1800} = 1.21\text{mm}$$

07. Ans: (c)

Sol:



h = height of sprue = 200 mm

$A_2 = 650\ mm^2$

Q = flow rate = $6.5 \times 10^5\ mm^3/s$

$g = 10^4\ mm/sec^2$

$$V_2 = \frac{6.5 \times 10^5}{650} = 1000\, mm^2 / Sec$$

$$= \sqrt{2gh_{pb}} = \sqrt{2 \times 10^4 \times h_{pb}}$$

h_{pb} = 50 mm = height of molten metal in the pouring basin

h_t = total height of molten metal above the bottom of the sprue

= 200 + 50mm

$$Q = A_2 V_2 = A_3 V_3 = A_3 \sqrt{2 \times 10^4 \times 250}$$

$$= 6.5 \times 10^5\ mm^3/s$$

$\Rightarrow A_3 = 290.7\ mm^2$

08. Ans: (d)

Sol: d_{top} = 225 mm

h_t = 250 + 100 = 350 mm

Volume flow rate Q = $40 \times 10^6\ mm^3/sec$

$$V_{bottom} = \sqrt{2 \times g \times h_t} = \sqrt{2 \times 9810 \times 350}$$

= 2620 mm/s

$Q = A_{top} \times V_{top} = A_{bottom} \times V_{bottom}$

$$A_{bottom} = \frac{40\times10^6}{2620} = 15267.17\text{ mm}^2$$

$$d_{bottom} = \sqrt{\frac{4\times15267.17}{\pi}} = 139.42\text{ mm}$$

09. Ans: (b)

Sol: $A_2V_2 = A_3V_3$

$$\frac{\pi}{4}\times2252\times\sqrt{2\times9810\times100}$$

$$= \frac{\pi}{4}\times d_b^2\times\sqrt{2\times9810\times350}$$

$\Rightarrow \quad d_b = 164.5\text{mm}$

So aspiration will not occur.

Common Data for 10 & 11

10. Ans: (a)

11. Ans: (b)

Sol: 3 castings of spherical, cylindrical and cubical

$V_{sp} = V_{cube}$

$$\frac{4}{3}\pi R^3 = a^3$$

$$a = R\sqrt[3]{\frac{4}{3}\pi} = 1.61\text{ R}$$

$V_{cyl} = V_{Sp}$

$$\frac{\pi}{4}D^2H = \frac{4}{3}\pi R^3$$

$$\frac{\pi}{4}D^3 = \frac{4}{3}\pi R^3 \quad (\because D=H)$$

$$D = \sqrt[3]{\frac{16}{3}R^3} = \left(\frac{16}{3}\right)^{\frac{1}{3}}R = 1.75R$$

$$\frac{\tau_{SP}}{\tau_{Cub}} = \left(\frac{M_{SP}}{M_{Cub}}\right)^2 = \left(\frac{D/6}{a/6}\right)^2 = \left(\frac{D}{a}\right)^2$$

$$= \left(\frac{2R}{a}\right)^2 = \left(\frac{2R}{1.61R}\right)^2 = 1.54$$

$$\frac{\tau_{SP}}{\tau_{cyl}} = \left(\frac{M_{SP}}{M_{cyl}}\right)^2$$

$$= \left(\frac{D/6}{D/6}\right)^2 = \left(\frac{D_{Sp}}{D_{cyl}}\right)^2 = \left(\frac{2R}{1.75R}\right)^2 = 1.306$$

12. Ans: 1.205

Sol: Casting – 1 (circular)

Diameter = 20 mm, length = 50 mm

Casting -2 (elliptical)

Major/Minor = 2, length = 50 mm,

C.S. area of the casting -1 = C.S area of the casting -2

$$\left[\frac{\text{solidification time of casting }-1}{\text{solidification time of casting }-2}\right]$$

$$= \left[\frac{M_{c1}}{M_{c2}}\right]^2 = \left[\frac{V_{c1}\times A_{c2}}{V_{c2}\times A_{c1}}\right]$$

$$V_{c1} = \frac{\pi}{4}\times d^2\times h = \left[\frac{\pi}{4}20^2\times50\right]$$

$$= 15707.96\text{ mm}^3$$

$$A_{c1} = 2\times\frac{\pi}{4}\times d^2 + \pi dh$$

$$= \left[\frac{\pi}{4}20^2\times2 + \pi\times20\times50\right]$$

$$= 3769\text{ mm}^2$$

C.S area of cylinder = C.S area of ellipse

$$\left[\frac{\pi}{4}\times 20^2\right] = \frac{\pi\times \text{maj.axis}\times \text{min.axis}}{4}$$

$$= \frac{\pi\times 2\times(\text{min.axis})^2}{4}$$

$$\Rightarrow \text{Minor axis} = \left[\frac{\pi}{4}\times 20^2\times\frac{4}{\pi\times 2}\right]^{\frac{1}{2}}$$

Minor axis = 14.14mm

Major axis = 2 × minor axis = 28.3mm

$$\text{Perimeter} = 2\pi\sqrt{\frac{a^2+b^2}{2}}$$

where a = major axis /2 $=\frac{28.3}{2}$ = 14.14 mm

b = minor axis /2 $=\frac{14.14}{2}$ = 7.07 mm

Perimeter = 70.24 mm

Surface area of ellipse

= perimeter × length + 2× C.S. area

= 70.24×50 + 314 × 2

= 4140 mm^2 = A_{C2}

Volume of the ellipse

= C.S area × length

= 314 × 50 = 15708 mm^3 = V_{c2}

$$\left[\frac{\text{solidification time of casting}-1}{\text{solidification time of casting}-2}\right]$$

$$= \left[\frac{M_{c1}}{M_{c2}}\right]^2$$

$$= \left[\frac{V_{c1}\times A_{c2}}{V_{c2}\times A_{c1}}\right]^2 = \left[\frac{15707.96\times 4140}{15708\times 3769.9}\right]^2$$

= 1.205

13. Ans: 50

Sol: m = 2 kg, Q = 10 kW

Time taken for removing latent heat

= 20 – 10 = 10 sec

$$\text{Time} = \frac{\text{Latent heat}}{Q}$$

Latent heat = time × Q

= 10 × 10 = 100 kJ

$$\text{Latent heat/kg} = \frac{100}{2} = 50 \text{ kJ/kg}$$

14. Ans: (a)

Sol: Circular disc casting Squared disc casting

$$\frac{C_1}{d = 20\text{cm}}; \qquad \frac{C_2}{a = 20\text{cm}}$$

$$t = 10\text{cm}; \qquad t = 10\text{cm}$$

$$\text{Freezing ratio (F.R)} = X_1 = \frac{\left(\frac{A_s}{V}\right)_{C1}}{\left(\frac{A_s}{V}\right)_R} = 1.4$$

$$\Rightarrow \left(\frac{A_s}{V}\right)_R = \frac{\left(\frac{A_s}{V}\right)_{C1}}{1.4}$$

$$X_1 = \frac{\left(\frac{A_s}{V}\right)_{C2}}{\left(\frac{A_s}{V}\right)_R} = \frac{\left(\frac{A_s}{V}\right)_{C2}}{\frac{\left(\frac{A_s}{V}\right)_{C1}}{1.4}} = 1.4$$

$$\left(\because \left(\frac{A_s}{V}\right)_{C2} = \left(\frac{A_s}{V}\right)_{C1} = 0.4\right)$$

$$\text{Volumetric ratio,(V.R)} = Y_1 = \frac{V_R}{V_C} = 0.8$$

$$\Rightarrow V_R = 0.8\ V_{C_1}$$

Now $Y_2 = \dfrac{V_R}{V_{C_2}} = \dfrac{0.8V_{C_1}}{V_{C_2}}$

$$= \frac{0.8\left(\frac{\pi}{4}\times 20^2 \times 10\right)}{20\times 20\times 10} = 0.628$$

15. Ans: (b)

Sol: $V_C = 40 \times 30 \times 0.3 = 360$ cc

V_{Sc} = shrinkage volume

$$= \frac{3}{100}\times 360 = 10.8\ cc$$

Volume of riser $V_r = \dfrac{\pi}{4}d^2 \times h$

$$= \frac{\pi}{4}\times 4^2 \times 4 = 50.24\,\text{cc}$$

$V_r \geq 3\ V_{sc} \Rightarrow V_r \geq 3\times 10.8 = 32.4$cc

$V_r \geq 3\ V_{Sc} \rightarrow$ Satisfied

$\tau_r \geq \tau_C$

where

τ_r = time taken for riser material to solidify

τ_C = time taken for casting to solidify

$M_r \geq M_c$

$$\Rightarrow \left(\frac{V}{A_s}\right)_r > \left(\frac{V}{A_s}\right)_{casting}$$

$$\frac{V}{A_s} = \frac{360}{2(40\times 30 + 30\times 0.3 + 0.3\times 40)}$$

$$= \frac{360}{2442} = 0.147$$

$$\Rightarrow \left(\frac{V}{A_s}\right)_r = \frac{d}{6} = \frac{4}{6} = 0.666$$

$\therefore \quad \tau_r > \tau_C$

Hence diameter of riser = 4 cm

Common Data for Q.16 & Q. 17

16. Ans: (a) **17. Ans: (a)**

Sol: In centrifugal casting

Centrifugal force = $F_C = ma = m\,r\,\omega^2$

$a = r\omega^2$

$$75\ g = \frac{D}{2}(2\pi\ N)^2$$

$$75 \times 9810 = N^2 D \times \frac{4\pi^2}{2}$$

$$\text{Constant} = N^2 D = \frac{75\times 9810}{2\pi^2} = 37273$$

Constant = $N^2 D = 37273$

$$D = \frac{0.5 + 0.52}{2} = 0.51 \text{ m} = 510 \text{ mm}$$

$$N = \sqrt{\frac{37273}{D}} = \sqrt{\frac{37273}{510}} = 8.55 \text{ RPS}$$

18. Ans: 51.84 mm

Sol: $\dfrac{\tau_R}{\tau_C} = \left(\dfrac{m_R}{m_C}\right)^2$

$$m_c = \frac{80\times 120\times 20}{2[(80\times 120)+(120\times 20)+(80\times 20)]}$$

$m_c = 7.05$

$m_R = \dfrac{d}{6}$ $[\because$ side riser given$]$

$$\Rightarrow \frac{m_R}{m_C} = \sqrt{1.5}$$

$\Rightarrow$ d = 51.84 mm

19. Ans: 11.43 mm

Sol: Given,

Gating ratio = 1:2:2 (Sprue: Runner: Ingate)

Mass, (m) = 30 kg,

Density (ρ) = 7.8 g/cc

Solidification time (τ) = 12.6 sec,

Pouring height (h_p) = 250 mm

Sprue height (h_s) = 200 mm

$$H = 250 + 200 = 450 \text{ mm} = 0.45 \text{ m}$$

$$\text{Choke area} = \frac{\text{Casting mass}}{\rho \times \tau \times \sqrt{2gH}}$$

$$= \frac{30}{7800 \times 12.6 \times \sqrt{2 \times 9.81 \times 0.45}}$$

Choke area = 102.73 mm^2 = Sprue area (A_s)

$$\frac{\pi}{4} d_s^2 = 102.73 \Rightarrow d_s = 11.43 \text{ mm}$$

Area of runner = 2 × 102.73 = 205.46 mm^2

Area of ingate = 2×102.73 = 205.46 mm^2

20. Ans: 0.05 s

Sol: Momentum is considered as constant

Momentum of water = Momentum of liquid metal

$$\frac{\text{pressure} \times \text{time}}{\text{density}} = \frac{\text{pressure} \times \text{time}}{\text{density}}$$

$$\frac{200 \times 0.05}{1000} = \frac{400 \times \text{time}}{2000}$$

$$\Rightarrow \quad \text{time} = 0.05 \text{ s}$$

21. Ans: (b, c, d)

Sol: Any gating system designed should aim at providing a defect-free casting. This can be achieved by making provision for certain requirements while designing the gating system. These are as follows:

- The mould should be completely filled in the smallest time possible without having to raise the metal temperatures or use higher metal heads.
- The metal should flow smoothly into the mould without any turbulence. A turbulent metal flow tends to form dross in the mould.
- Unwanted material such as slag, dross and other mould material should not be allowed to enter the mould cavity.
- The metal entry into the mould cavity should be properly controlled in such a way that aspiration of the atmospheric air is prevented.
- A proper thermal gradient be maintained so that the casting is cooled without any shrinkage cavities or distortions.
- Metal flow should be maintained in such a way that no gating or mould erosion takes place.
- The gating system should ensure that enough molten metal reaches the mould cavity.
- The gating system design should be economical and easy to implement and remove after casting solidification.
- Ultimately, the casting yield should be maximised.

Chapter 2

Welding

01. Ans: (a)

Sol: $V_0 = 80$ V, $I_S = 800$ A

Let for arc welding V = a+bL

For power source, $V_p = V_0 - \frac{V_0}{I_s} I$

For stable $V = V_p$

$$\Rightarrow a + bL = V_0 - \frac{V_0}{I_s} I$$

When L = 5, I = 500

$$\Rightarrow a + b \times 5 = 80 - \frac{80}{800} \times 500 = 30$$

$$a + 5b = 30$$

when L = 7, I = 460

$$a + b \times 7 = 80 - \frac{80}{800} \times 460 = 34$$

By solving, b = 2, a = 20

$\therefore$ V = a + bL = 20 + 2L

02. Ans: 4860 W, 1.5 mm

Sol: For power source,

$$V_p = 36 - \frac{I}{60}$$

$V_a = 2L + 27$

At equilibrium conditions

$$V_a = V_P$$

$$27 + 2L = 36 - \frac{I}{60}$$

$$\frac{I}{60} = 36 - 27 - 2L = 9 - 2L$$

$$I = 60(9 - 2L)$$

If current is 360 Amps

$$360 = 60(9 - 2L)$$

$$9 - 2L = \frac{360}{60} = 6$$

$$2L = 9 - 6 = 3$$

$$L = \frac{3}{2} = 1.5$$

If L = 1.5 mm,

V = 27 + 2 ×1.5 = 27+ 3 = 30 V

P = 30 ×360 = 10800 W

If L = 4 mm,

V = 27 + 1.5 ×4 = 33 V

I = 60 (9 – 1.5 ×4) = 180 A

P = 33 × 180 = 5940 W

Change in power = 10800 – 5940

= 4860 W

If the maximum current capacity is 360A, the maximum arc length is 1.5mm

03. Ans: 425

Sol: V = 100 + 40 L ,

L = 1 to 2 mm , I = 200 to 250 A

L = 1, I = 250

$$V = 100 + 40 \times 1 = 140 = V_0 - \frac{V_0}{I_s} \times 250$$

L = 2, I = 200

$$V = 100 + 40 \times 2 = 180 = V_0 - \frac{V_0}{I_s} \times 200$$

$$\Rightarrow 40 = 50 \times \frac{V_0}{I_s}$$

$$\frac{V_0}{I_s} = \frac{40}{50} = \frac{4}{5}$$

$$V_0 = 140 + \frac{4}{5} \times 250$$

$$= 140 + 200 = 340$$

$$\frac{V_0}{I_s} = \frac{4}{5} \Rightarrow I_s = \frac{V_0 \times 5}{4} = \frac{340 \times 5}{4} = 425\,A$$

04. Ans: 26.7 sec

Sol: Rated Power = $V_r I_r = 50 \times 10^3$

$$\Rightarrow \; I_r = \frac{50 \times 10^3}{25} = 2000\,A$$

D_r = 50% (rated duty cycle)

If I_d = 1500 A (desired current)

Desired duty cycle,

$$D_d = \frac{I_r^2 D_r}{I_d^{\,2}} = \left(\frac{2000}{1500}\right)^2 \times 0.5 = 0.89$$

$$D_d = \frac{\text{Arc on time}}{\text{Total welding time}} = 0.89 \times 30$$

$$= 26.7 \text{ sec}$$

05. Ans: 27.78 mm/sec

Sol: Power = P = 4 + 0.8L – 0.1L^2

For optimum power

$$\frac{dP}{dL} = 0 \Rightarrow 0.8 - 0.2L = 0$$

$$L = \frac{0.8}{0.2} = 4 \text{ mm}$$

$$P = 4 + 0.8L - 0.1\,L^2$$

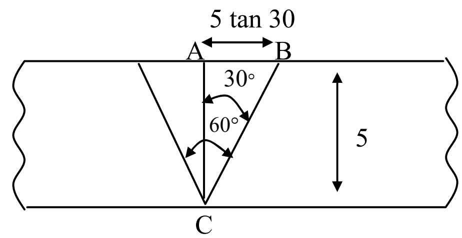
$$= 4 + 0.8 \times 4 - 0.1 \times 4^2 = 5.6 \text{ kW}$$

Energy losses = 20% , η = 80%

Area of weld bead (WB)

$$= 2 \times \frac{1}{2} \times AB \times AC$$

$$= 5 \tan 30 \times 5 = 14.43$$



Volume of W.B = 14.43 × 1000

= 14433 mm^3

Weight of W.B = 14433 × 10^{-6} × 8

= 115.5 g

Heat required for melting of W.B

= 115.5 ×1400 = 161.66 kW

$$\text{Time for welding} = \frac{161.66}{0.8 \times 5.6} = 36\,Sec$$

$$\text{Welding speed} = \frac{1000}{36}$$

$$= 27.78 \text{ mm/sec}$$

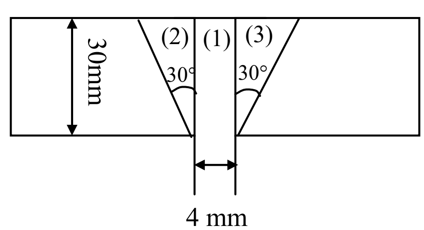
Common data for 06, 07 & 08.

06. Ans: (d)

07. Ans: (d)

08. Ans: (c)

Sol:



l = 1 m =1000 mm;

t = 30 mm,

d = 4 mm,

L_t = 450 mm;

L_S = 50 mm,

$A_1 = 4 \times 30 = 120\ \text{mm}^2$

$A_2 = A_3 = \dfrac{1}{2} \times 30 \tan 30 \times 30 = 259.8\ \text{mm}^2$

Total volume of weld bead

= volume of weld bead + crowning

= 1.1 × volume of weld bead

$= 1.1 \times (A_1 + 2A_2) \times 1000 = 703560\ \text{mm}^3$

Volume /Electrode $= \dfrac{\pi}{4} \times D^2 \times L_e$

$= \dfrac{\pi}{4} \times 4^2 \times (450 - 50) = 1600\pi$

Number of electrodes required

$= \dfrac{\text{Total volume of weld bead}}{\text{volume / Electrode}}$

$= \dfrac{703560}{1600\pi} = 139.96 = 140$

x = 200mm (given)

Number of electrodes/pass $= \dfrac{1000}{200} = 5$

Number of passes $= \dfrac{140}{5} = 28$

Total Arc on time

$= \dfrac{1000}{100} \times 28 = 280$ minutes

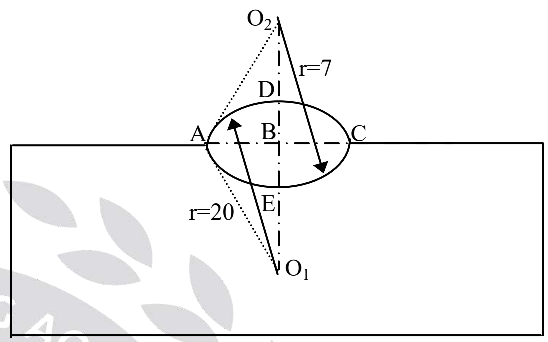
Total weld time $= \dfrac{280}{0.6} = 466.67$ minutes

09. Ans: 0.64 mm & 2.1 mm

Sol: Given AC = 10 mm,

$O_1A = O_1C = 7$ mm,

$O_2A = O_2C = 20$ mm



Height of Bead = BD = $O_1D - O_1B$

$= O_1D - \sqrt{O_1A^2 - AB^2}$

$= 20 - \sqrt{20^2 - 5^2}$

= 0.64 mm

Depth of Penetration = BE = $O_1E - O_1B$

$= (O_1E) - \sqrt{(O_2A)^2 - (AB)^2}$

$= 7 - \sqrt{7^2 - 5^2} = 2.10$ mm

Common Data Q. No 10 and 11

10. Ans: (c)

Sol: I = 200 A, V = 25 V, speed = 18 cm/min

D = 1.2 mm, f = 4 m /min, η = 65%,

Heat input $= \dfrac{V \times I \times \eta}{\text{speed}}$

$= \dfrac{25 \times 200 \times 0.65 \times 60}{18}$

= 10.83 kJ / cm

11. Ans: (b)

Sol: Filling rate of weld bead = filled rate by electrode

Area of W.B × Speed = $\frac{\pi}{4}d^2 \times f$

Area of W.B= $\frac{\frac{\pi}{4}\times 1.2^2 \times 4000}{180} = 25.12\ \text{mm}^2$

Common data for 12 & 13

12. Ans: 2000 J

Sol: H.G = $I^2 R \tau$

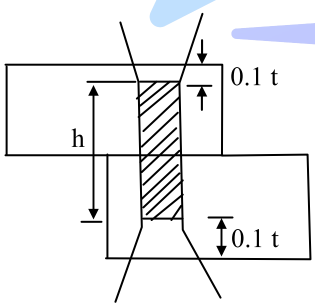
$= (10000)^2 \times 200\times 10^{-6} \times \frac{5}{50} = 2000\ \text{J}$

13. Ans: 1264 J

Sol: h = 2t – 2 × 0.1 t = 1.8 t

= 1.8 ×1.5 = 2.7 mm

$D = 6\sqrt{t} = 6\sqrt{1.5} = 7.35\ \text{mm}$



Vol. of nugget = $\frac{\pi}{4}D^2 h$

$= \frac{\pi}{4}(7.35)^2 \times 2.7 = 114.5\ \text{mm}^2$

Heat required = Volume ×ρ ×heat required /g

$= 114.5\times 10^{-3} \times 8 \times 1380$

= 1264 J

14. Ans: 2.3 & 4.6 MJ

Sol: $R_C = 0.85\left(\frac{\rho}{n\pi r}\right)$

ρ = Resistivity of metal

$(\text{Heat generation})_1 = I^2R = \left(\frac{V}{R}\right)^2 \times R = \frac{V^2}{R}$

$R_{C_1} = \frac{0.85\times 2\times 10^{-5}}{25\times \pi \times 0.02} = 1.082\times 10^{-5}$

$R_{C_2} = \frac{0.85\times 2\times 10^{-5}}{50\times \pi \times 0.02} = 5.41 \times 10^{-6}$

$(\text{H.g})_1 = \frac{5^2}{1.082\times 10^{-5}} = 2310546.04$

$(\text{H.g})_2 = \frac{5^2}{5.41\times 10^{-6}} = 4621072.08$

15. Ans: (c)

Sol: Heat generated = Heat utilized

$I^2R\tau$ = Vol. of nugget ×ρ × H. R/g

$I^2 \times 200\times 10^{-6} \times 0.1$

$= \frac{\pi}{4}(0.005)^2 \times 1.5\times 10^{-3} \times 8000 \times 1400\times 10^3$

I = 4060 A

Common Data Q. 16 & Q. 17

16. Ans: (c)

Sol: I = 3000 A, τ = 0.2, R = 200 μΩ

Volume of nugget = 20 mm^3

Heat generation = $I^2R\tau$

$= 3000^2 \times 200\times 10^{-6} \times 0.2 = 360\ \text{J}$

Heat required $= \rho V\left[c_p\left(T_m - T_r\right) + LH\right]$

$= 8000\times 20\times 10^{-9}\times[500\times(1520 - 20)+1400\times 10^3]$

= 344 J

17. Ans: (b)

Sol: Heat dissipated = 360 – 344 = 16 J

18. (i) Ans: (a), (ii) Ans: (b)

Sol: $P = 2\text{ kW} = 2 \times 10^3$ Watt,

$V = 200$ mm/min, $L = 300$ mm

Heat required (HR) = 40 Kcal

$= 40\times10^3\times4.2$ Joule

Welding time $= \frac{300}{200} = 1.5\text{ min} = 1.5\times60$

$= 90$sec

Heat input $= 2\times10^3 \times 90$ Joule

$$\eta_{HI} = \frac{HR}{HI} = \frac{40\times10^3\times4.2}{2\times10^3\times90} = 0.9333$$

$= 93.33\%$

19. Ans: (d)

Sol: Heat supplied = Heat utilized

$0.5\text{ J} = m\,(S.H. + L.H) = \rho V\,(SH+LH)$

$= (a\times h)\,\rho\,(C_p\,(T_m - T_r)+LH)$

$= 0.05 \times 10^{-6} \times h \times 2700\,[896 \times (933 - 303) + 398 \times 10^3]$

$\Rightarrow h = 0.00385\text{ m} = 3.85\text{ mm}$

20. Ans: (c)

Sol: Volume to be melted $= \frac{\pi}{4}(110^2 - 100^2)\times 2$

$= 3298.66\ \text{mm}^3$

Total heat required

$= 3298.66 \times 10^{-9} \times 64.4 \times10^6$

$= 212.4$ Joules

$$P = VI = V\times\frac{V}{R} = \frac{V^2}{R} = \frac{30^2}{42} = 21.43$$

Total heat required = heat to be generated

$212.4 = P\times t$

$$t = \frac{212.4}{21.43} = 10\,\text{sec}$$

21. Ans: (a)

Sol: Frictional force F = Pressure × Area ×μ

$$= 200\times\frac{\pi}{4}\times10^2\times0.5 = 7854\text{ N}$$

$$\text{Torque} = F\times\frac{3}{4}\times\text{Radius}$$

$$\text{Torque} = 7854\times\frac{3}{4}\times5\times10^{-3} = 29.45$$

$$\text{Power, } P = \frac{2\pi NT}{60000}$$

$$= \frac{2\pi\times4000\times29.45}{60000} = 12.33\text{ kW}$$

22. Ans: 0.0675 sec

Sol: Given:

Volume = 80 mm^3,

Current (I) = 10000 A,

$E = 10\text{ J/mm}^3$,

Q_{lost} = Heat lost = 550 J,

R = 0.0002 ohms

Total energy supplied during process

$= [(80 \times 10) + 550]$ J

$Q_{total} = 1350\text{J} = i^2Rt$

$1350 = (10^4)^2 \times 0.0002 \times t$

$\Rightarrow$ t = 0.0675 seconds

23. Ans: 59 %

Sol: Thermal efficiency $= \dfrac{\text{Heat required}}{\text{Heat supplied}} \times 100$

Heat required = 10 × 80 = 800 J

$$\eta_{\text{thermal}} = \frac{800}{1350} \times 100 = 59\ \%$$

24. Ans: 464.758 A

Sol: $D_d = 100\% = 1$, $I_r = 600\text{A}$, $D_r = 0.6$

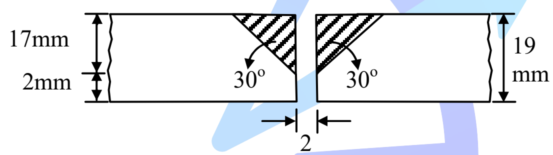
$$\frac{D_d}{D_r} = \frac{I_r^2}{I_d^2}$$

$$\frac{1}{0.6} = \frac{600^2}{I_d^2} \Rightarrow I_d^2 = 600^2 \times 0.6$$

$\Rightarrow I_d = 464.758\text{A}$

25. Ans: 17

Sol:



$$\tan 30^\circ = \frac{x}{17\text{mm}}$$

$$x = 9.814\text{ mm}$$

$$\text{Area} = \left(\frac{1}{2} \times 9.814 \times 17 \times 2 + (2 \times 19)\right)$$

$$\text{Volume} = \left(204.85\text{mm}^2\right) \times 1.1 \times 1.15 \times 180$$

$$= 46645.30767\text{ mm}^3$$

Number of electrodes

$$= \frac{\text{Total volume of metal deposited}}{\text{Volume deposited from one electrode}}$$

$$= \frac{\text{Total Volume of metal deposited}}{\frac{\pi}{4}\left(3^2\right) \times (450 - 50)}$$

∴ Number of electrodes = 17

26. Ans: (*)

Sol: Given, Butt-welding,

Arc power (Q) = 2.5 kVA = 2.5 × 10^3 J

Thickness (t) = 3 mm = 3×10^{-3} m

V-joint Angle (θ) = 60°

Efficiency (η_{arc}) = 0.85

2D – heat transfer :

$\alpha_{steel} = 1.2 \times 10^{-5}$ m²/sec ,

K_{steel} = 43.6 W/m°C

Assuming T_C = 1450°C

$$Q = 8\,K\,T_c\,t\left[0.2 + \frac{Vb}{4\alpha}\right]$$

b = width of weld,

b = 2 × 3 × tan30° = 3.464 × 10^{-3} m

$$2.5 \times 10^3 = 8 \times 43.6 \times 1450 \times 3 \times 10^{-3}\left[0.2 + \frac{V \times 3.464 \times 10^{-3}}{4 \times 1.2 \times 10^{-5}}\right]$$

$$1.647 = \left[0.2 + (V \times 72.166)\right]$$

Welding speed, V = 20.06 mm/sec

27. Ans: (a, c)

Sol: **Forehand or left hand welding techniques:**

The flame is focused towards the non-welded portion hence the preheating of weld bead taking place. In FHWT, the force of the flame is pushing back the molten slag particles, hence some slag particle will retain inside the weld bead

Some of the factors that cause slag inclusion are:

- High viscosity of weld metal
- Rapid solidification
- Insufficient welding heat
- Improper manipulation of the electrode
- Undercut on previous pass

The presence of slag inclusions reduces the strength of the joint

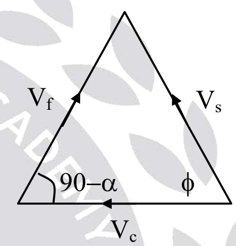
Chapter 3 Metal Cutting

Common Data for Q. 01 & 02

01. Ans: (a)

02. Ans: (d)

Sol:



$V_c = 40$ m/min; $V_f = 20$ m/min

$\alpha = 10^\circ$; $r = \dfrac{V_f}{V_c} = 0.5$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$$

$$= \tan^{-1}\left(\frac{0.5\cos 10}{1 - 0.5\sin 10}\right) = 28.33^\circ$$

$$V_s = \frac{V_f}{\sin\phi} \times \cos\alpha$$

$$= \frac{20}{\sin 28.33} \times \cos 10 = 41.5 \text{ m/min}$$

03. Ans: 10°

Sol: f = 0.25 mm/rev,

$t_1 = 0.25$, $i = 10^\circ$, $\alpha = ?$

$t_1 = f \cos C_S$

$0.25 = 0.25 \cos C_S$

$\cos C_S = 1 \Rightarrow C_s = 0$

$\lambda = 90 - C_S = 90°$

$$\begin{bmatrix} \tan\alpha_b \\ \tan\alpha_s \end{bmatrix} = \begin{bmatrix} \sin\lambda & \cos\lambda \\ -\cos\lambda & \sin\lambda \end{bmatrix} \begin{bmatrix} \tan i \\ \tan\alpha \end{bmatrix}$$

$\tan\alpha_b = \sin\lambda \tan i + \cos\lambda \tan\alpha$

$\tan\alpha_b = \sin 90 \tan i + 0$

$\Rightarrow \alpha_b = i = 10°$

Common Data for Q.04, 05 & 06

04. Ans: (c) **05. Ans: (b)**

06. Ans: (d)

Sol: $d = t_1 = 2$ mm, $w = b = 15$ mm

$V_C = 60\,\text{m/min}$, $\alpha = 0$

$F_C = 1200$, $F_T = 800$, $\phi = 30^0$

$$\beta = \alpha + \tan^{-1}\frac{800}{1200} = 33.69^0$$

$\mu = \tan\beta = \tan 33.69 = 0.67$

$$\text{Power} = P = F_C \times V_C = 1200 \times \frac{60}{60}$$

$$= 1200\text{ W}$$

Length of shear plane $= L_S$

$$= \frac{t_1}{\sin\phi} = \frac{2}{\sin 30} = 4\text{mm}$$

07. Ans: (a)

Sol: For theoretically minimum possible shear strain to occur

$2\phi - \alpha = 90$

$$\phi = \frac{90+\alpha}{2} = \frac{90+6}{2} = 48°$$

Common Data for Q. 08 & 09

08. Ans: (c)

09. Ans: (c)

Sol: Given data: $\alpha = 6°$, $V_C = 1\,\text{m/s}$

$b = w = 3$, $d = t_1 = 1$ mm

$t_2 = 1.5$ mm; use $2\phi + \beta - \alpha = 90°$

$$r = \frac{t_1}{t_2} = \frac{1}{1.5} = \frac{2}{3} = 0.67$$

$$\phi = \tan^{-1}\left(\frac{0.67\cos 6}{1 - 0.67\sin 6}\right) = 35.62^0$$

For minimum energy condition use

$2\phi + \beta - \alpha = 90°$

$\beta = 90 + \alpha - 2\phi = 90 + 6 - 2 \times 35.62$

$= 24.76°$

$\mu = \tan\beta = \tan 24.76 = 0.461$

$V_f = rv_c = 0.67 \times 1 \times 60 = 40.2\,\text{m/min}$

Area of shear plane $= A_s = L_s \times b$

$$= \frac{t_1 \times b}{\sin\phi} = \frac{1\times 3}{\sin 35.62} = 5.2\,\text{mm}^2$$

Common Data for Q. 10 & 11

10. Ans: (d)

11. Ans: (d)

Sol: $D_0 = 32$ mm, $\alpha = 35°$,

$K_1 = 0.1$ mm,

$F_C = 200$ N, $V_C = 10$ m/min,

$L_2 = 60$ mm, $F_T = 80$ N

$$r = \frac{t_1}{t_2} = \frac{L_2}{L_1} = \frac{60}{\pi D_0} = \frac{60}{\pi \times 32} = 0.59$$

$$\phi = \tan^{-1}\left(\frac{0.59\cos 35}{1 - 0.59\sin 35}\right) = 36.15^0$$

$$\tan(\beta - \alpha) = \frac{F_T}{F_C} = \frac{80}{200}$$

$$\beta = \alpha + \tan^{-1}\left(\frac{80}{200}\right)$$

$$= 35 + 21.8 = 56.8^\circ$$

$$\mu = \tan\beta = \tan 56.8 = 1.52$$

(In general $\mu < 1$)

Hence by applying classical friction theorem

$$\mu = \frac{ln\left(\frac{1}{r}\right)}{\frac{\pi}{2} - \alpha} = \frac{ln\left(\frac{1}{0.59}\right)}{\frac{\pi}{2} - 35 \times \frac{\pi}{180}}$$

$$= \frac{0.5276}{0.96} = 0.55$$

$$\frac{V_f}{V_C} = r \Rightarrow V_f = rV_c = 0.59 \times 10 = 5.9 \text{ m/min}$$

$$V_s = \frac{V_f}{\sin\phi}\cos\alpha = \frac{5.9}{\sin 36.15} \times \cos 35$$

$$= 8.2 \text{ m/min}$$

12. Ans: 56.23°

Sol: $\alpha = 10$, $t_1 = 0.125$,

$F_c = 517$ N; $F_T = 217$ N

$t_2 = 0.43$; $C_m = 2\phi + \beta - \alpha$

$$r = \frac{t_1}{t_2} = \frac{0.125}{0.43} = 0.29$$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$$

$$= \tan^{-1}\left(\frac{0.29\cos 10}{1 - 0.29\sin 10}\right) = 16.73^\circ$$

$$\beta = \alpha + \tan^{-1}\left(\frac{F_T}{F_C}\right)$$

$$= 10^\circ + \tan^{-1}\left(\frac{217}{517}\right) = 32.77^\circ$$

$$C_m = 2 \times 16.73 + 32.77 - 10 = 56.23^\circ$$

13. Ans: 2573.4

Sol: Cutting speed (V) = 4m/sec

Orthogonal rake angle (α) = 5°

Uncut chip thickness (t_1) = 0.2 mm

Width of cut (w) = 3 mm

Friction angle (β) = 45°

Shear angle (ϕ) = 25°

Shear strength (τ_0) = 1000 MPa

Cutting force (F_c) = ?

$$\because F_S = R\cos(\phi + \beta - \alpha)$$

$$R = \frac{\tau_0 . A_s}{\cos(\phi + \beta - \alpha)}$$

$$R = \frac{\tau_0 . wt_1}{\sin\phi\cos(\phi + \beta - \alpha)}$$

$$= \frac{\tau_0 . w . t_1 . \cos(\beta - \alpha)}{\sin\phi . \cos(\phi + \beta - \alpha)}.$$

$$F_c = R.\cos(\beta - \alpha)$$

$$= \frac{\tau_0 . w . t_1 . \cos(\beta - \alpha)}{\sin\phi . \cos(\phi + \beta - \alpha)}$$

$$= \frac{1000 \times 3 \times 0.2 \times \cos(45^\circ - 5^\circ)}{\sin 25 . \cos(25^\circ + 45^\circ - 5^\circ)} = 2573.4 \text{ N}$$

14. Ans: (d)

Sol: $\phi = 30^o$, $F_T = 800$ N, $F_c = 1200$ N

$$F_s = \frac{F_C}{\cos(\beta-\alpha)}\cos(\phi+\beta-\alpha)$$

$$\tan(\beta-\alpha) = \frac{F_T}{F_C}$$

$$\beta-\alpha = \tan^{-1}\left(\frac{800}{1200}\right) = 33.69^o$$

$$F_s = \frac{1200}{\cos 33.69}\times\cos(30+33.69) = 639.23\text{N}$$

Common Data for Q. 15 & 16

15. Ans: (a)

16. Ans: (b)

Sol: D = 100 mm,

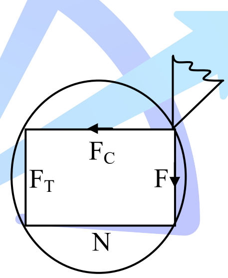
f = 0.25 mm/sec,

d = 4 mm

V = 90 m/min

F_C = 1500 N

F_C = N = 1500 N



Common Data for Q. 17 & 18

17. Ans: (b) & 18. Ans: (b)

Sol: $VT^a f^b d^c = K$

a = 0.3 b = 0.3, c = 0.15

$$f_2 = \frac{f_1}{2}, \qquad d_2 = 2d$$

$$T_1 = T_2 = 60$$

$$V_1T_1^a f_1^b d_1^c = V_2T_2^a f_2^b d_2^c$$

$$\frac{V_2}{V_1} = \left(\frac{f_1}{f_2}\right)^b\left(\frac{d_1}{d_2}\right)^c$$

$$= 2^{0.3}\left(\frac{1}{2}\right)^{0.15} = 1.11$$

$$V_2 = 1.11\,V_1$$

$$\%\text{ change in speed} = \frac{V_2-V_1}{V_1} = 11\%$$

Productivity is proportional to MRR

% change in productivity

$$= \frac{MRR_2 - MRR_1}{MRR_1}$$

$$= \frac{f_2d_2V_2 - f_1d_1V_1}{f_1d_1V_1} = 11\ \%$$

19. Ans: 49.2 %

Sol: T_0, V_0 = original tool life and velocity

If $V_1 = 1.2V_0$ $\quad T_1 = 0.5T_0$

$V_2 = 0.9V_0$, $\quad T_2 = ?$

$$V_1T_1^n = V_0T_0^n$$

$$\left(\frac{T_1}{T_0}\right)^n = \frac{V_0}{V_1}$$

$$n = \frac{ln\left(\frac{V_0}{V_1}\right)}{ln\left(\frac{T_1}{T_0}\right)} = \frac{ln\left(\frac{1}{1.2}\right)}{ln(0.5)} = 0.263$$

$$V_0T_0^n = V_2T_2^n$$

$$T_2 = T_0\left(\frac{V_0}{V_2}\right)^{1/n} = T_0\left(\frac{V_0}{0.9V_0}\right)^{\frac{1}{0.263}} = 1.4927T_0$$

% change in tool life

$$= \frac{T_2-T_0}{T_0} = \frac{1.4927T_0 - T_0}{T_0} = 0.4927$$

20. Ans: (b)

Sol: Let Q = no. of parts produced

T.C on E.L = T. C on T.L

$$\frac{30}{60}\times Q\times 80 = 500+\frac{6}{60}\times Q\times 160$$

$$40Q = 500+16Q$$

$$40Q-16Q = 24Q = 500$$

$$\Rightarrow \quad Q = \frac{500}{24} = 20.83 = 21$$

21. Ans: (a)

Sol: n = 0.12, C = 130 m/min

C_1 = 1.1 × 130 = 143,

V = V_1 = 90 m/min

$$VT^n = C \Rightarrow T = \left(\frac{130}{90}\right)^{\frac{1}{0.12}} = 21.4\,\text{min}$$

$$V_1T_1^n = C_1 \Rightarrow T_1 = \left(\frac{143}{90}\right)^{1/0.12} = 47.4\,\text{min}$$

Increased tool life = **47.4 min**

Note: Increase in tool life = 47.4 – 21.4 = 26 min

22. Ans: (a)

Sol: Tool life = $T_1 = \frac{500}{10} = 50,$

$$T_2 = \frac{122}{10} = 12.2,$$

$V_1 = 50\text{rpm}$, $V_2 = 80\,\text{rpm}$

The feed and depth of are same in both cases

$$V_1T_1^n = V_2T_2^n$$

$$n = \frac{\ln\frac{V_2}{V_1}}{\ln\frac{T_1}{T_2}} = \frac{\ln\frac{80}{50}}{\ln\frac{50}{12.2}} = \frac{0.47}{1.41} = 0.333$$

$$V_1T_1^n = V_3T_3^n$$

$$\Rightarrow T_3 = T_1\left(\frac{V_1}{V_3}\right)^{1/n} = 50\left(\frac{50}{60}\right)^{\frac{1}{0.333}} = 29$$

23. Ans: 30.8 m/min

Sol: T_C = 3 min, T_g = 3 min,

L_m = Rs. 0.5/min

Depreciation of tool regrind = Rs 0.5

C = 60, n = 0.2

$C_g = (3+3) \times 0.5 + 0.5 = 3.5$

$$V_{Opt} = C\left[\frac{n}{1-n}.\frac{L_m}{C_g}\right]^n$$

$$= 60\left[\frac{0.2}{1-0.2}.\frac{0.5}{3.5}\right]^{0.2} = 30.8\text{ m/min}$$

24. Ans: 57.91

Sol: $C_m = \frac{18C}{V}$, $C_t = \frac{270C}{TV}$, $VT^{0.5} = 150$

$TC = k + C_m + C_t$

$$= k+\frac{18C}{V}+\frac{270C}{TV}$$

$$= k+\frac{18C}{V}+\frac{270C}{V\times\left(\frac{C}{V}\right)^{\frac{1}{n}}}$$

$$= k+\frac{18C}{V}+\frac{270C\,V^{\left(\frac{1}{n}-1\right)}}{C^{\frac{1}{n}}}$$

For min TC, $\dfrac{d(TC)}{dV} = 0$

$$\frac{-18C}{V^2} + \frac{270C\ V^{\left(\frac{1}{n}-2\right)} \times \left(\frac{1}{n}-1\right)}{C^{\frac{1}{n}}} = 0$$

$$\frac{270C\ V^{\left(\frac{1}{0.25}-2\right)} \times \left(\frac{1}{0.25}-1\right)}{C^{\frac{1}{n}}} = \frac{18C}{V^2}$$

$$\frac{270\times 3}{150^4} \times V^2 = \frac{18}{V^2}$$

$$V^4 = \frac{18\times 150^4}{270\times 3}$$

$\therefore$ V = 57.91 m/min

25. Ans: 2.48 & 23°

Sol: $\alpha = 10^{o}$

$t_1 = f.\sin\lambda = 0.15 \sin 75 = 0.144$

$t_2 = 0.36$, $\quad r = \dfrac{t_1}{t_2} = 0.402$

Chip reduction coefficient = t_2/t_1

$$\Rightarrow \frac{1}{r} = K = 2.48$$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1-r\sin\alpha}\right)$$

$$= \tan^{-1}\left(\frac{0.402\cos 10}{1-0.402\ \sin 10}\right) = 23.18^{o}$$

26. Ans: 31.4

Sol: Given data,

Cylindrical tube thickness (t) = 1 mm

Diameter (D) = 100 mm

Orthogonal cutting such that entire wall thickness of tube is cut in single pass.

Tube thickness = depth of cut = d = 1 mm

Axial feed of the tool = 1 m/min = f.N

Specific cutting Energy (U) = 6 J/mm^3

Specific cutting energy

$$(I) = 6\ \text{J/mm}^3 = \frac{\text{Power}}{\text{MRR}}$$

Power = 6 × MRR

= 6 × f.d.v. = 6 × f.d.π.D.N.

= 6 × d × π × D × f. N

$= 6\times 1\times \pi \times 100 \times 1 \times \dfrac{100}{60}$

= 31415.9 J/sec (or) Watt

= 31.4 kW

27. Ans: 0.944

Sol: T = 60 min

$$V_A = \frac{67}{(60)^{0.11}} = 42.70\ \text{m/min}$$

$$V_B = \frac{77}{(60)^{0.13}} = 45.22\ \text{m/min}$$

Under similar conditions with same tool life cutting velocity on material B is greater than the material A. Hence the machinability of material 'B' is higher than the material 'A'.

$$\frac{V_A}{V_B} = \frac{42.7}{45.22} = 0.944$$

28. Ans: 12°

Sol: Given, $t_1 = 0.2$ mm, $w = 2.5$ mm,

$F_c = 1177$ N, $F_t = 560$ N

As the cutting is approximated to be orthogonal.

$$\tan i = \cos\psi \tan\alpha_b - \sin\psi \tan\alpha_s$$

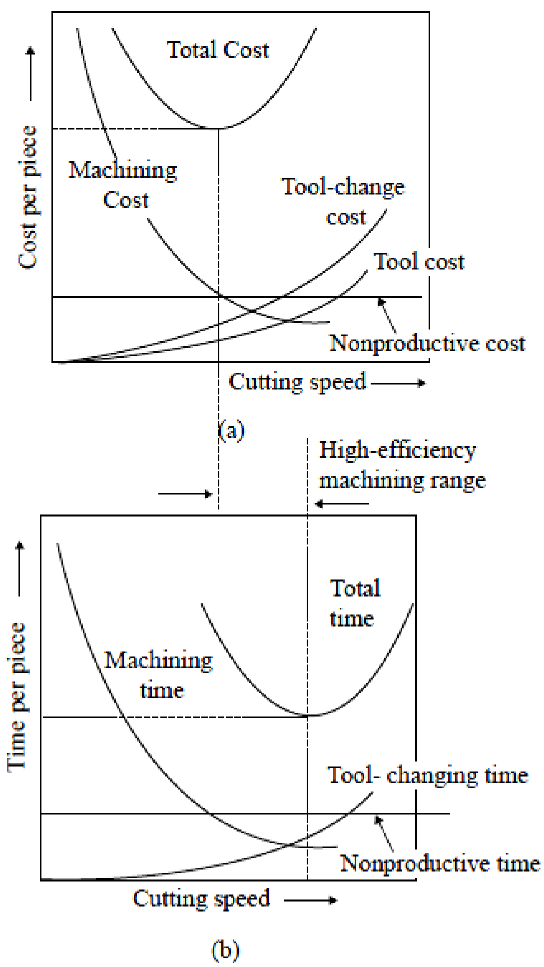
$$\tan 0° = \cos\psi \tan\alpha_b - \sin\psi \tan\alpha_s$$

$$= \cos 30° \tan 7° - \sin 30° \tan\alpha_s$$

$$\Rightarrow \alpha_s = 12°$$

29. Ans: (b, d)

Sol:



As shown in above figure, as the cutting speed increases, the cost of production initially reduces, then after an optimum cutting speed it increases. For higher feed rate the cost of production reduces for same cutting speed, but the surface finish will suffer.

30. Ans: (a)

Sol: $F_c = 3000$ N,

$F_t = 1200$ N, $\alpha = 32°$,

$$\tan(\beta - \alpha) = \frac{F_t}{F_c}$$

$$\Rightarrow \beta = \alpha + \tan^{-1}\left(\frac{F_t}{F_c}\right) = 53.8°$$

Coefficient of friction $\mu = \tan(\beta) = 1.37$

(Strictly speaking no answer because $\beta > 45$, $\mu > 1$ and it requires use classical friction theorem, For this data is insufficient and no answer is given with less than 1).

31. Ans: 636.72

Sol: $V_C = 90$ m/min

$\alpha = 10°$

$F_C = 750$ N

$F_T = 390$ N

Orthogonal machining

Shear angle, $\phi = 35°$

$$\beta = \alpha + \tan^{-1}\frac{F_T}{F_C}$$

$$\beta = 37.47°$$

Now, $F_S = \dfrac{F_C \times \cos(\phi + \beta - \alpha)}{\cos(\beta - \alpha)}$

$= \dfrac{750 \times \cos(35 + 27.47)}{\cos(27.47)}$

$= 390.65$ N

And $V_s = \dfrac{V_c}{\cos(\phi - \alpha)} \times \cos\alpha$

$= \dfrac{90 \times \cos 10}{\cos 25}$

$= 97.79$ m/min $= 1.629$ m/s

Power required for shearing,

$W_s = F_S \times V_S$

$W_s = 636.72$ W

Chapter 4 Machining

01. Ans: (i) 20 min, (ii) 50 min

Sol: Time / cut $= \dfrac{L}{fN} = \dfrac{576}{0.2 \times 144} = 20$ min

$V = \dfrac{\pi DN}{1000} = \dfrac{\pi \times 100 \times 144}{1000} = 45.2$ m/min

$VT^{0.75} = 75 \Rightarrow T = \left(\dfrac{75}{V}\right)^{\frac{1}{0.75}}$

$= \left(\dfrac{75}{45.2}\right)^{1.333} = 1.96$ min

No. of tool changes $= \dfrac{20}{1.96} - 1 = 9.2 \approx 10$

(Because 1 tool is already mounted on W.P)

Total change time / piece = 20 + 10 × 3

= 50 min

02. Ans: (a)

Sol: For producing RH threads the direction of rotation of job and lead screw must be in the same direction, for this if the designed gear train is simple gear train use 1, 3, 5 odd number idle gear to get same direction of rotation, if the designed gear train is compound gear train use 0, 2, 4,.. even number of idle gears to get same direction. In the given problem the designed gear train is a compound gear train, to change the hand of the thread it requires to change the direction of rotation of job and lead screw for this use 1, 3, 5… odd number of idle gears.

03. Ans: (b)

Sol: Train value = Gear ratio = $\frac{N_{follower}}{N_{Driver}}$

$$= \frac{\text{pitch of job threads}}{\text{pitch of lead screw threads}}$$

$$= \frac{3.175\times 40}{6\times 40} = \frac{127}{240} \rightarrow \text{not possible}$$

$$= \frac{127}{40}\times\frac{1\times 20}{6\times 20}$$

$$= \frac{127}{40}\times\frac{20}{120} \rightarrow \text{possible}$$

04. Ans: (c)

Sol: $\rightarrow$ Plane turning $\rightarrow$ Taper turning

$\rightarrow$ Under cutting $\rightarrow$ Thread cutting

05. Ans: (d)

Sol: Gear Ratio = Train value = $\frac{N_{follower}}{N_{driver}}$

$$= \frac{T_{driver}}{T_{follower}} = \frac{P_{driver}}{P_{follower}}$$

$$G.R = \frac{P_{job}}{P_{L.S}} = \frac{P_{spindle}}{P_{Ls.S}} = \frac{N_{L.S}}{N_{Spindle}}$$

P = pitch

$$\frac{N_{Spindle}}{N_{L.S}} = \frac{P_{L.S}}{P_{Spindle/job}} = \frac{6}{2\times 2} = \frac{3}{2}$$

06. Ans: (d)

Sol: With this any change in U_V will also changes the speed of lead screw, the pitch of the threads produced depends on the speed of work and speed of lead screw. U_s will not affect the speed of the work

07. Ans: (b)

Sol: No. of D.S/min = 10

B = 300 mm, f = 0.3 mm /stroke

$$\text{Time/cut} = \frac{B}{f}\times\frac{1}{\text{No. of D.S}}$$

$$= \frac{300}{0.3} = \times\frac{1}{10} = 100\,\text{min}$$

08. Ans: (b)

Sol: L = 2 m

= 50 + 900 + 50 + 50 + 900 + 50

B = 300 + 5 + 5 = 310

f = 1 mm/stroke, V_C = 1 m /sec,

$$M = \frac{1}{2}$$

$$\text{Time per two pieces} = \frac{B}{f}\times\frac{1}{V}(1+M)$$

$$= \frac{310}{1}\times\frac{2000}{1000}(1+0.5) = 930 \text{ sec}$$

$$\text{Time/piece} = \frac{930}{2} = 465\,\text{sec}$$

09. Ans: (d)

Sol: Shaping operation

M = 0.6 , L = 500 mm

Double stroke / time = 15

N = time / D.S = 1/15

$$\text{Average speed, } V = \frac{L}{V}(1+M)$$

$$= \frac{500}{\left(\frac{1}{15}\right)}(1+0.6) = 12000 \text{ mm / min}$$

= 12 m / min

10. Ans: (c)

Sol: Total depth to be removed = 30 – 27

= 3 mm

Given, $m = \frac{2}{3} = 0.67$

feed = 0.5,

depth = 2

V = 60 m/min

$$\left.\begin{matrix}\text{Approach} = 50\,\text{mm} \\ \text{Over travel} = 50\,\text{mm}\end{matrix}\right\}\text{length wise}$$

$$\left.\begin{matrix}\text{Approach} = 5\,\text{mm} \\ \text{Over travel} = 5\,\text{mm}\end{matrix}\right\}\text{width wise}$$

$$\text{Time/cut} = \frac{L}{V}(1+M)\times\frac{B}{f}$$

$l = 800$,

L = 800 + 50 + 50 = 900

B = 400 + 5 + 5 = 410

$$\text{Time / cut} = \frac{900}{60000}\left(1+\frac{2}{3}\right)\times\frac{410}{0.5}$$

= 20.5 min

$$\text{No. of cuts} = \frac{3}{2} = 1.5 \approx 2\text{cuts}$$

Total time = 20.5×2 = 41 min

11. Ans: (b)

Sol: Time per hole = L/f.N

= 25/(0.25× 300)

= 1/3 min = 20sec.

Because dia of drill bit was not given, hence AP_1 is zero.

12. Ans: 162, 59 sec

Sol: D = 15 mm,

V_c = 20 m/min,

$$N = \frac{1000\,V}{\pi\times D} = \frac{1000\times 20}{\pi\times 15} = 425 \text{ rpm}$$

N = 425rpm

f = 0.2 mm /rev

T = 100 min, $l = 45\ mm$

Time for idle time = 20s

Tool change time = 300 s

$$\text{Time/hole} = \frac{L}{fN} = \frac{\ell + 0.5D}{fN}$$

$$= \frac{45+\frac{15}{2}}{0.2\times 425} = 0.617 \text{ min}$$

= T_m = machining time

(i) No. of holes produced / drill

$$= \frac{100}{0.617} = 162$$

(ii) Total time/hole

= T_m + idle time + Tool change time

$$= 0.617 + \frac{20}{60} + \frac{300}{162\times 60}$$

= 0.9812 min = 58.87 = 59 sec

13. Ans: (b)

Sol: Helical provide rake angle which is zero at centre and increase to helical angle at the periphery form which space chips are coming out.

14. Ans: (b)

Sol: Given n = 6, D_{max} = 25 mm

D_{min} = 6.25 mm

V = 18 m/min

$$r = \sqrt[n-1]{\frac{N_{max}}{N_{min}}}$$

$$N_{max} = \frac{1000V}{\pi D_{min}} = \frac{1000 \times 18}{\pi \times 6.25}$$

$$N_{min} = \frac{1000V}{\pi D_{max}} = \frac{1000 \times 18}{\pi \times 25}$$

$$r = \sqrt[6-1]{\frac{N_{max}}{N_{min}}} = \sqrt[5]{\frac{25}{6.25}}$$

= 1.3195 = 1.32

15. Ans: 1.5

Sol: Given,

Slot size = 25 mm × 25 mm

Length, ℓ = 300 mm,

Diameter, D = 100 mm,

Width of milling cutter, b = 25 mm,

No. of teeth, Z = 20 teeth,

Depth of cut, d = 5 mm,

Feed per tooth, f_t = 0.1 mm

v = 35 m/min,

AP = OR = 5 mm,

Because width of slot and width of milling cutter are equal, it is considered as peripheral milling cutter.

Hence, $CAP = \sqrt{d(D-d)} = \sqrt{5(100-5)}$

= 21.7945 mm

Length of tool travel,

$L = \ell + AP + OR + CAP$

= 300 + 5 + 5 + 21.7945

Feed/him, $f_m = f_t \times Z \times N$

$$= 0.1 \times 20 \times \frac{1000 \times 35}{\pi \times 100} = 222.93$$

$$\text{Time per cut} = \frac{L}{f_m} = \frac{331.7945}{222.93} = 1.5\,\text{min}$$

16. Ans: (i) 1.2 min, (ii) 1.25 min

Sol: Part size = 200 × 80 × 60 mm

D = 100 mm, Z = 12,

V = 50 m/min,

$$N = \frac{1000\,V}{\pi D} = \frac{1000 \times 50}{\pi \times 100} = 159 \text{ rpm}$$

f_t = 0.1 mm, AP = OR = 5 mm

i) With symmetrical milling

$$AP_1 = \frac{1}{2}\left(D - \sqrt{D^2 - w^2}\right)$$

$$= \frac{1}{2}\left(100 - \sqrt{100^2 - 80^2}\right) = 20\,\text{mm}$$

$L = l + AP_1 + AP + OR$

= 200 + 20 + 5 + 5 = 230

$$\text{Time/cut} = \frac{L}{f_t NZ}$$

$$= \frac{230}{0.1 \times 159 \times 12} = 1.2 \text{ min}$$

ii) If offset = 5mm with asymmetrical milling

$$AP_1 = \frac{1}{2}\left(D - \sqrt{D^2 - w_i^2}\right)$$

Where, $w_i = w + 2(O_f)$

= 80 + 2 × 5 = 90

$$AP_1 = \frac{1}{2}\left(100 - \sqrt{100^2 - 90^2}\right) = 28.2 \text{ mm}$$

$$L = 200 + 28.2 + 5 + 5 = 238.2$$

$$\text{Time/cut} = \frac{L}{f_t N z}$$

$$= \frac{238.2}{0.1 \times 12 \times 159} = 1.25 \text{ min}$$

17. Ans: (b)

Sol: Crank rotation $= \dfrac{40}{\text{No. of teeths}}$

$$= \frac{40}{28}$$

$$= 1\left(\frac{12}{28}\right) = 1\frac{3}{7} = 1\left(\frac{9}{21}\right)$$

1 complete revolution and 9 holes in 21 hole circle.

18. Ans: (d)

Sol: $d = 70$ mm , $Z = 12$ teeth

$V = 22$ m/min

$f_t = 0.05$ mm/tooth

$f_m = f_t Z N$, $N = \dfrac{1000\,V}{\pi\, d}$

$$f_m = 0.05 \times 12 \times \frac{1000 \times 22}{3.14 \times 70} = 60 \text{ mm/min}$$

19. Ans: (b)

Sol: Crank rotation $= 1\dfrac{10}{30} = 1\dfrac{1}{3} = \dfrac{4}{3} \times 360 = 480°$

$$\text{Job rotation} = \frac{CR}{40} = \frac{480}{40} = 12°$$

20. Ans: (b)

Sol: Given,

$D_{tool} = 15$ cm $= 150$ mm

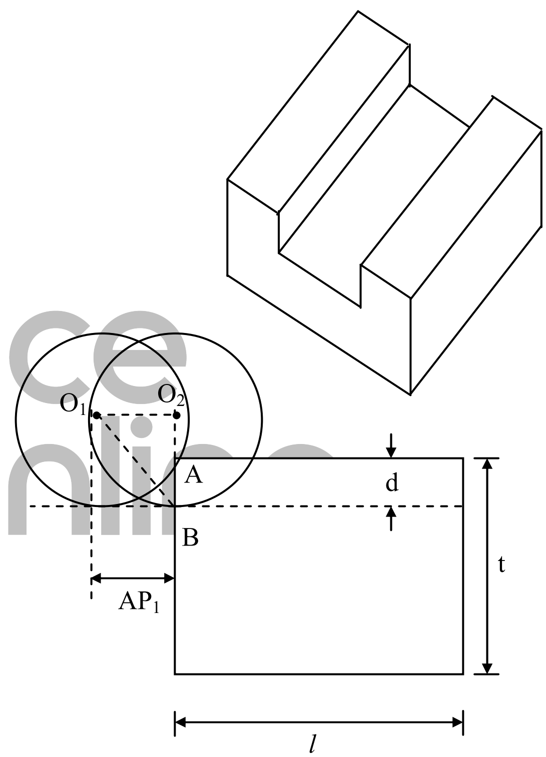
Feed $= 0.08$ mm/rev

Depth $= 0.5$ mm $= d$

Length of workpiece, $l = 200$ mm

Cutting Velocity, $V = 120$ m/min

Total depth to be cut $= 2$ mm



$$N = \frac{1000V}{\pi D} = \frac{1000 \times 120}{\pi \times 150} = 254.64 \text{ rpm}$$

$$\text{Approach} = AP_1 + O_1O_2 = \sqrt{d(D-d)}$$

$$= \sqrt{0.5(150 - 0.5)} = 8.645 \text{ mm}$$

Total time/machining

$$= \text{No. of cuts} \times \text{Time/cut}$$

$$\text{No. cuts} = \frac{\text{Total depth}}{\text{depth per cut}} = \frac{2}{0.5} = 4$$

$$\text{Time/cut} = \frac{L}{fN} = \frac{\ell + AP}{fN}$$

$$= \frac{200 + 8.645}{0.08 \times 255} = 10.227 \text{ min}$$

Total time = 10.227 × 4 = 40.91

= 41 min

21. Ans: 8.5 min

Sol: Broaching machine

P = 1.5 kW

d_1 = 20 mm enlarged to d_f = 26 mm

t = 25 mm

p = 10 mm/tooth

h = 0.075 mm/tooth

V = 0.5 m/min

Equation for time for broaching operation

$$= \frac{\text{Length of tool travel}}{\text{Linear velocity of tool}}$$

Length of tool travel = L

$= t + L_e + AP + OR$

As (AP + OR) is not given so take it zero

L_e = effective length or cutting length

$$\text{Depth of cut } d = \frac{26 - 20}{2} = 3$$

n = no. of teeth = d/h = 3 / 0.075 = 40

$L_e = n \times p = 40 \times 10 = 400$mm

$L_e = 400$ mm

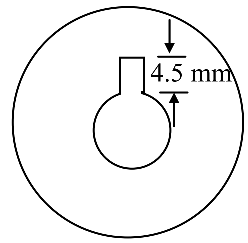
$$\text{Time for broaching} = \frac{t + L_e}{V}$$

$$= \frac{25 + 400}{0.5 \times 100} = 8.5 \text{ min}$$

Time for broaching = 8.5 min

22. Ans: (c)

Sol:



$d_{total} = 4.5\,\text{mm}$

$d_f = 0$

$d_S = n_s \times h_s = 0.0125 \times 8 = 0.1$

$d_r = d_{total} - (d_f + d_s)$

$= 4.5 - 0.1 = 4.4$

$$n_r = \frac{d_r}{h_r} = \frac{4.4}{0.1} = 44 \text{ teeth}$$

Cutting length = effective length = L_e

$= L_r + L_S + L_f$

= 44 × 22 + 8 × 20 + 4 × 20

= 1208 mm

23. Ans: (b)

Sol: Out of all conventional method grinding is one which required largest specific cutting energy.

1) Because of random orientation of abrasive particles, rubbing energy losses will be very high
2) Lower penetration of abrasive particle
3) Size effect of the larger contact areas between wheel and work.

24. Ans: (a)

Sol: Common alignment test for shaper and lathe are (1) Straightness (2) Flatness.

Runout is used in lathe.

Parallelism used in shaper.

25. Ans: (a)

Sol: The curvature given is the concave curvature hence it increases the stress concentration factor therefore it is used for supply of lubricating oil to bearing mounting

26. Ans: 38.4

Sol: Given, Surface Grinding,

Cast Iron plate dimension = $300\times10\times50$ mm^3

Alumina wheel diameter (D) = 150 mm

Wheel width (b) = 12 mm

Wheel velocity (V_w) = 40 m/s

= 4×1000 mm/s

Table speed (V_T) = 5 m/min = $\dfrac{5\times1000}{60}$

Depth of cut (d) = 50 μm

Number of passes = 20

Average tangential force (F_c) = 40 N

Normal force (F_N) = 62 N

Power = $F_c \times V_w = 40 \times 40 = 1600$ W

MRR = b×d×v

$$=10\times0.050\times\left(\frac{5000}{60}\right)=41.67\,\text{mm}^3/\text{s}$$

Specific grinding energy,

$$u=\frac{\text{Power}}{\text{MRR}}=\frac{1600}{41.67}=38.40\,\text{J}/\text{mm}^3$$

27. Ans: 2.5

Sol: Given data, No. of teeth (n) = 4

Diameter of cutter (D) = 200 mm

Rotational speed (N) = 100 rpm

Linear feed to work piece = 1000 mm/min

Width of work piece (w) = 100 mm

Cutting force/tooth = F = K t_c w

Specific cutting force = K = 10 N/mm^2

Depth of cut (d) = $\dfrac{D}{2}$

Feed (f) = $\dfrac{1000}{100}$ = 10 mm/rev

Uncut chip thickness = t_c

Maximum uncut chip thickness $(t_c)_{max}$

$$=\frac{2f}{n}\sqrt{\frac{d}{D}\left(1-\frac{d}{D}\right)}$$

$$=\frac{2\times10}{4}\sqrt{\frac{D/2}{D}\left(1-\frac{D/2}{D}\right)}$$

$$=5\sqrt{\frac{1}{2}\left(1-\frac{1}{2}\right)}=2.5\,\text{mm}$$

Maximum force

$$(F)_{max}=K(t_c)_{max}.w=10\times2.5\times100$$

$$=2500\,\text{N}=2.5\,\text{kN}$$

28. Ans: (c)

Sol: C L = 200 mm, Z = 4,

f_m = 200 m /min , D = 100 mm,

N = 100 rpm, d= 2 mm

AP + OR = 5 mm

$$t_{1avg}=\frac{t_{1max}+t_{1min}}{2}=t_{1max}/2$$

$$= \frac{f_m}{NZ}\sqrt{\frac{d}{D}} = \frac{200}{4\times100}\sqrt{\frac{2}{100}}$$

$$= 0.0707\,\text{mm} = 71\ \text{microns}$$

$$AP_1 = \frac{1}{2}\left(D - \sqrt{D^2 - w^2}\right)$$

$$= \left(\sqrt{2(100-2}\right) = 14\,\text{mm}$$

$$\text{Time /cut} = \frac{L}{f_m}$$

$$= \frac{200+5+14}{200}\times 60 = 65.7\,\text{sec}$$

29. Ans: (b, c, d)

Sol: In conventional milling (also called up milling); the maximum chip thickness is at the end of the cut as the tooth leaves the work piece surface.

The advantages to conventional milling are :

(a) tooth engagement is not a function of work piece surface characteristics and

(b) contamination or scale (oxide layer) on the surface does not adversely affect tool life. This is the more common method of milling.

The cutting process is smooth, provided that the cutter teeth are sharp. Otherwise, the tooth will rub against and smear the surface for some distance before it begins to cut. Also, there may be a tendency for the tool to chatter, and the work piece has a tendency to be pulled upward (because of the cutter rotation direction), necessitating proper clamping.

30. Ans: (a, b, c, d)

Sol: **Honing:** Honing is an operation that is used primarily to improve the surface finish of holes produced by processes such as boring, drilling, and internal grinding. The honing tool consists of a set of aluminium-oxide or silicon-carbide bonded abrasive sticks, usually called stones

Superfinishing: In this process, the pressure applied is very light and the motion of the honing stone has a short stroke. The motion of the stone is controlled so that the grains do not travel along the same path on the surface of the work piece.

Lapping: This is an operation used for finishing flat, cylindrical, or curved surfaces. The lap is relatively soft and porous and usually is made of cast iron, copper, leather, or cloth. The abrasive particles either are embedded in the lap or may be carried in a slurry. Lapping of spherical objects and glass lenses is done with specially shaped laps.

Buffing: It is similar to polishing in appearance, but its function is different. Buffing is used to provide attractive surfaces with high luster. Buffing wheels are made of materials similar to those used for polishing wheels—leather, felt, cotton, etc. — but buffing wheels are generally softer. The abrasives are very fine and are contained in a buffing compound that is pressed into the outside surface of the wheel while it rotates. This contrasts with polishing in which the abrasive grits are glued to the wheel surface. As in polishing, the abrasive particles must be periodically replenished. Buffing is usually done manually, although machines have been designed to perform the process automatically. Speeds are generally 2400 to 5200 m/min.

31. Ans: (d)

Sol: **Centerless Grinding:** Centerless grinding is an alternative process for grinding external and internal cylindrical surfaces. As its name suggests, the work piece is not held between centers. This results in a reduction in work handling time; hence, centerless grinding is often used for high-production work.

Honing: Honing is an operation that is used primarily to improve the surface finish of holes produced by processes such as boring, drilling, and internal grinding. The honing tool consists of a set of aluminium-oxide or silicon-carbide bonded abrasive sticks, usually called stones

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32. Ans: (d)

Sol: **Ball burnishing**: In this type of burnishing, one or more spherical balls are supported in shank by the hydraulic pressure of a fluid, spring, or the relative force of the work piece. The ball is continuously kept in contact with the work piece by a fluid circulated using a hydraulic pump. As the tool is fed along the work piece, the ball becomes pressed against it, resulting in a burnishing operation. Depending on the desired effect, the force of burnishing can then be controlled by varying the fluid's hydraulic pressure.

Advantages of Ball Burnishing

- This process allows parts to be produced with high control over the dimension and allowing for very accurate sizes.
- It produces a very smooth surface finish
- Saves cost and is more economical compared to the other burnishing processes
- Creates improvements in physical properties and increases the fatigue life of components

33. Ans: (a, b)

Sol: **Grain Size:** The grain size of the abrasive particle is important in determining surface finish and material removal rate. Small grit sizes produce better finishes, whereas larger grain sizes permit larger material removal rates. Thus, a choice must be made between these two objectives when selecting abrasive grain size. The selection of grit size also depends to some extent on the hardness of the work material. Harder work materials require smaller grain sizes to cut effectively, whereas softer materials require larger grit sizes.

34. Ans: (a, b, c)

Sol: Superfinishing is an abrasive process similar to honing. Both processes use a bonded abrasive stick moved with a reciprocating motion and pressed against the surface to be finished.

Superfinishing differs from honing in the following respects:

(1) the strokes are shorter, 5 mm

(2) higher frequencies are used, up to 1500 strokes per minute

(3) lower pressures are applied between the tool and the surface, below 0.28 MPa

(4) work piece speeds are lower, 15 m/min or less

(5) grit sizes are generally smaller.

Chapter 5 Metal Forming Process

01. Ans: (a)

Sol: $\sigma_y = 1400 \in^{0.33}$

At maximum load, true strain $= \frac{1}{3}$

$$\sigma_y = 1400\left(\frac{1}{3}\right)^{0.33} = 971 \text{ MPa}$$

02. Ans: (b)

Sol: A_{0p} = C.S area of P originally

A_{1p} = C.S area of P after 1st reduction

$= 0.7\ A_{0p}$

$A_{2p} = 0.8 \times 0.7 \times A_{0p} = 0.56\ A_{0p}$

$$\in_p = \textit{True strain in "P"} = \ln\left(\frac{A_{op}}{A_{2p}}\right)$$

$$= \ln\left(\frac{A_{op}}{0.56\ A_{op}}\right) = 0.58$$

A_{0Q} = C.S area of Q originally

A_{1Q} = C.S area of Q after 1st reduction

$= 0.5\ A_{0Q}$

$$\in_Q = \ln\left(\frac{A_{0Q}}{A_{1Q}}\right) = \ln\left(\frac{1}{0.5}\right) = 0.693$$

03. Ans: (a)

Sol: $d_o = 25$, $\quad d_i = 5\text{mm}$

$\sigma_y = 315 \in^{0.54}$

$$\in = \ell n\frac{A_o}{A_1} = \ell n\left(\frac{d_o}{d_i}\right)^2$$

$$= \ell n\left(\frac{25}{5}\right)^2 = 3.22$$

$$\sigma_y = 315\,(3.22)^{0.54} = 592 \text{ MPa.}$$

04. Ans: 1.98 MN

Sol: Given: $H_0 = 4.5$ mm

$H_1 = 2.5$ mm

$\Delta H = 2$

$D_{roll} = 350$, $R_{roller} = 175$ mm

Strip wide = 450 mm = b

Average coefficient of friction = 0.1

$\sigma_y = 180$ MPa

RSF = P_{avg} × projected area

$$= \frac{2}{\sqrt{3}} \times \sigma_y\left(1+\frac{\mu L}{4H}\right) \times b \times L$$

$$L = \sqrt{R\Delta H} = \sqrt{175 \times 2} = 18.7$$

$$4 = \frac{H_0 + H_1}{2} = \frac{4.5+2.5}{2} = 3.5$$

$$= \frac{2}{\sqrt{3}} \times 180\left(1+\frac{0.1\times 18.7}{4\times 3.5}\right) \times 450 \times 18.7$$

RSF = 1982.64 kN = 1.98 MN

05. Ans: (a)

Sol: $H_o = 4$, $H_1 = 3$mm, $R = 150$mm,

N = 100 rpm.

Velocity of strip at neutral point

= Surface Velocity of rollers

$$= \frac{\pi DN}{1000\times 60} = \frac{\pi \times 300 \times 100}{1000 \times 60}$$

= 1.57 m/sec

06. Ans: (a)

Sol: $H_o = 20$ mm,

b = 100 mm

H_1=18 mm,

R = 250 mm,

$N = 10$ rpm, $\sigma_y = 300$ MPa

$\Delta H = 20 - 18 = 2$mm

$$\mu = \sqrt{\frac{\Delta H}{R}} = 0.089$$

$$L = \text{length of deformation zone} = \sqrt{R\Delta H}$$

$$= \sqrt{250\times 2} = 22.36 \text{ mm}$$

$$H = \frac{20+18}{2} = 19$$

$$F_{avg} = \text{R.S.F} = \frac{2}{\sqrt{3}}\sigma_y b \times L\left[1+\frac{\mu L}{4H}\right]$$

$$= \frac{2}{\sqrt{3}} \times 300 \times 100 \times 22.36\left[1+\frac{0.089\times 22.36}{4\times 19}\right]$$

= 795 kN.

$T = F_{avg} \times a$,

Where

a = moment arm = λ L

$= 0.3L$ to $0.4 \times L$

$$T = F_{avg} \times 0.4L = 795\times 10^3 \times 0.4 \times 22.36$$

= 7110 kN-mm

= 7.11 kN-m

$$P_{av\delta} = \frac{2\pi\, NT}{60} = \frac{2\pi \times 10 \times 7.110}{60}$$

= 7.44 kW / roller

Total Power = 7.44 × 2 = 14.88 kW

07. Ans: (d)

Sol: $H_o = 16$ mm,

$H_1 = 10$ mm,

$R = 200$ mm

$$\text{Angle of Bite} = \alpha = \tan^{-1}\sqrt{\frac{\Delta H}{R}}$$

$$= \tan^{-1}\sqrt{\frac{16-10}{200}} = 9.9$$

08. Ans: (a)

Sol: Given rolling process

Initial thickness $H_0 = 30$ mm

Final thickness $= H_1 = 14$ mm

$D_{roller} = 680 = R = 340$ mm

$\sigma_y = 200$ MPa

Thickness at neutral $H_n = 17.2$

$$\text{Forward slip} = \frac{V_1}{V_n} - 1 = \frac{H_n}{H_1} - 1$$

$$= \frac{17.2}{14} - 1 = 0.2285 = 23\%$$

$$\text{Backward slip} = 1 - \frac{V_0}{V_n} = 1 - \frac{H_n}{H_0}$$

$$= 1 - \frac{17.2}{30} = 42.6\% \approx 43\%$$

09. Ans: (b)

Sol: Roll separation distance

$= 2 \times R + H_1 = 2 \times 300 + 25$

$= 625$ mm

10. Ans: (b)

Sol: $d_o = 15$ mm,

$d_f = 0.1$ mm

$$\%\text{Reduction} = \frac{\text{dia reduced in the draw}}{\text{dia before draw}}$$

$$= \frac{d_0 - d_1}{d_o} \rightarrow \text{Ist draw}$$

$$= \frac{d_1 - d_2}{d_1} \rightarrow \text{2nd draw}$$

a) 3 stages with 80% reduction at each stage

$$0.8 = \frac{d_o - d_1}{d_o}$$

$d_1 = 0.2\, d_o = 3$ mm

$d_2 = 0.2.\, d_1 = 0.6$ mm

$d_3 = 0.2\, .d_2 = 0.12$ mm (Error is 20%)

b) 4 stages with 80% reduction in 1st 3 stages followed by 20% in 4th stage

$d_1 = 0.2.\, d_0 = 3$

$d_2 = 0.2.\, d_1 = 0.6$

$d_3 = 0.2.\, d_2 = 0.12$

$d_4 = 0.8.\, d_3 = 0.096$ (Error is 4%)

c) 5 stages, with 80, 80, 40, 40, 20 etc

$d_1 = 0.2.\, d_0 = 3$

$d_2 = 0.2.\, d_1 = 0.6$

$d_3 = 0.6.\, d_2 = 0.36$

$d_4 = 0.6.\, d_3 = 0.0216$

$d_5 = 0.8.\, d_4 = 0.1728$ (Error is 72%)

From the given multiple choice B, the final diameter of wire close to 0.1 mm.

11. Ans: (d)

Sol: Given wire drawing process

$d_0 = 6$ m, $d_1 = 5.2$ mm

Die angle = 18°, diameter land = 4 mm

Coefficient of friction = 0.15

Yield dress = 260 MPa

$$A_0 = \frac{\pi}{4} \times 6^2 = 28.27$$

$$A_1 = \frac{\pi}{4} \times 5.2^2 = 21.237$$

Drawing stress = σ_2

$$= \sigma_y \left(\frac{1+B}{B}\right)\left(1-\left(\frac{A_1}{A_0}\right)^B\right)$$

$B = \mu\cot\alpha$

$$\alpha = \frac{1}{2} \text{ Die angle} = \frac{1}{2} \times 18 = 9°$$

$\alpha = 9$

$B = 0.15 \times \cot(9°) = 0.947$

$$\sigma_2 = (260)\left(\frac{1+0.947}{0.947}\right)\left(1-\left(\frac{21.237°}{28.27°}\right)^{0.947}\right)$$

$= 260(2.056)(0.2373)$

$= 125.48$ MPa

Total drawing stress $\sigma_2 = \sigma_y + (\sigma_2 - \sigma_y)\, e^{\frac{-2\mu L}{R_1}}$

(By considering friction)

$$= 260 + (125.48 - 260)\, e^{\frac{-2\times 0.15\times 4}{2.6}}$$

$\sigma_{total} = 260 - 84.79 = 175.21$ MPa

Total drawing load $= \sigma_t \times A_1$

$= 175.21 \times 21.237$

$= 3.72$ kN

Common data for Q 12, 13 & 14

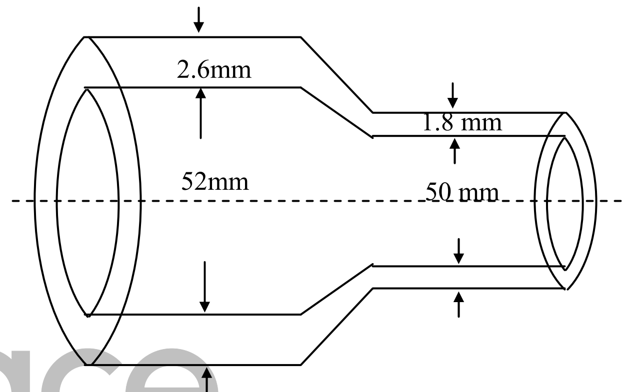
12. Ans: (b) , 13. Ans: (c), 14. Ans: (a)

Sol: Initial inside diameter of tube

$d_0 = 52$ mm, $H_0 = 2.6$

$H_1 = 1.8$ mm, $D_1 = 50$ mm

$2d = 24° \Rightarrow \alpha = 12°$, $\mu = 0.12$



For stationary mandrel $B = \dfrac{\mu_1 + \mu_2}{\tan\alpha}$

$$B = \frac{0.12+0.12}{\tan(12°)} = 1.129$$

$$\sigma_2 = \sigma_y\left[\frac{1+B}{B}\right]\left[1-\left(\frac{H_1}{H_0}\right)^B\right]$$

$$\sigma_2/\sigma_y = \left[\frac{1+1.129}{1.129}\right]\left[1-\left(\frac{1.8}{2.6}\right)^{1.129}\right]$$

$\sigma_2/\sigma_y = 0.64$

13. Movable mandrel

$B = \mu\cot\alpha = (0.12)\cot(12°) = 0.564$

$$\sigma_2/\sigma_y = \left[\frac{1+0.564}{0.564}\right]\left[1-\left(\frac{1.8}{2.6}\right)^{0.564}\right] = 0.519$$

14. Floating mandrel

$B = 0$

$$\frac{\sigma_2}{\sigma_y} = \ell n\left(\frac{h_0}{h_1}\right)$$

$$= \ell n\left(\frac{2.6}{1.8}\right) = 0.367$$

Common data for Q 15. & 16.

15. Ans: 6 & 16. Ans: 3.4

Sol: $d_0 = 6$ mm, $d_f = 1.34$ mm

Given ideal condition

$\mu = 0.2$ $\alpha = 6^0$

$\sigma_f = 60$ MPa

Maximum reduction condition

$$\frac{\sigma_2}{\sigma_y} = 1 \Rightarrow 1 = \left(\frac{1+B}{B}\right)\left(1-\left(\frac{d_1}{d_0}\right)^{2B}\right)$$

$B = \mu\cot\alpha$; $B = 1.9$

$$\frac{B}{1+B} = 1-\left(\frac{d_1}{d_0}\right)^{2B}$$

$$\left(\frac{d_1}{d_0}\right)^{2B} = 1-\frac{B}{1+B}$$

$$= \frac{1}{1+B}$$

$$\frac{d_1}{d_0} = \sqrt[2B]{\frac{1}{1+B}}$$

$$d_1 = d_0\left(\sqrt[2B]{\frac{1}{1+B}}\right) = 6\left(\frac{1}{1+1.9}\right)^{\frac{1}{2\times1.9}}$$

$d_1 = 4.53$ ……… (1) stage

$$d_2 = d_1\sqrt[2B]{\frac{1}{1+B}}$$

$$C = \left(\frac{1}{1+B}\right)^{\frac{1}{2B}} = 0.756$$

Dia of wire in 2nd stage = 3.424 mm

$d_1 = d_0 \times c$

$d_2 = d_1 \times c = 4.53\times0.756$

$= 3.424 > 1.34$

$d_3 = d_2 \times c$

$= 3.424 \times 0.756$

$= 2.589 > 1.34$

$d_4 = d_3\times c = 1.957 > 1.34$

$d_5 = d_4 \times c = 1.4797 > d_f$

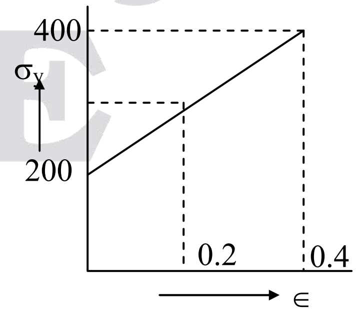
$d_6 = d_5\times c = 1.1186 < d_f$

$\therefore$ Hence No. of stages = 6

Common data for Q 17, 18

17. Ans: (c) & 18. Ans: (b)

Sol:



$d_o = 12.214$, $L_o = 100$m

$d_f = 10$mm, $L_f = ?$

σ_y before = 200 MPa ,

σ_y after = 400 MPa

$A_o L_o = A_f L_f$

$$L_f = L_o \times \frac{A_o}{A_f} = L_o\left(\frac{d_o}{d_f}\right)^2$$

$$= 100 \times \left(\frac{12.214}{10}\right)^2 = 150\text{m}$$

True strain in the drawing process

$$= \in = \ell n\frac{A_o}{A_1} = \ell n\left(\frac{d_o}{d_1}\right)^2 = 0.4$$

From the graph σ_y at $\in = 0.2$,

$$\sigma_y = 300 \text{ MPa}$$

19. Ans: (b)

20. Ans: (c)

Sol: (Extrusion force)$_{min} = \sigma_y \times A_0$

$$= 10 \times \frac{\pi}{4} \times 100^2 = 78539.8\text{N}$$

$$\text{Extrusion force} = \frac{(\text{E.F})_{min}}{\eta_{ext}} = \frac{78539.8}{0.4}$$

= 196346.5 N

= 196 Tons ≈ 200 Tons

21. Ans: (b)

Sol: Extrusion constant = K = 250

d_o = 100 mm, d_f = 50 mm

$$\text{Extrusion Force} = A_o\ K \ln\frac{A_o}{A_f}$$

$$= \frac{\pi}{4}100^2 \times 250 \ln\left(\frac{100}{50}\right)^2 = 2.72 \text{ MN.}$$

22. Ans: 1

Sol: Let, $d_1 = d_2 = d$

h_1 = height of first cylinder

h_2 = height of second cylinder

Assume $h_1 < h_2$

Let % reduction in height = 10%

Ist cylinder

$$\frac{h_0 - h_f}{h_0} = 0.1$$

$h_0 - h_f = 0.1\ h_0$

$h_f = h_0 - 0.1\ h_0 = 0.9\ h_0$

$A_0 h_0 = A_f h_f$

$d_0^2 h_0 = d_f^2 h_f$

$$d_f = d_0\sqrt{\frac{h_0}{h_f}} = d_0\sqrt{\frac{h_0}{0.9 h_0}}$$

$= 1.054\ d_0 = 1.054\ (d_0)_1$

IInd cylinder

$A_0 h_0 = A_f h_f$

$d_0^2 h_0 = d_f^2 h_f$

$$d_f = d_0\sqrt{\frac{h_0}{h_f}}$$

$$= d_0\sqrt{\frac{h_0}{0.9h_0}} = 1.054\ (d_0)_2$$

$$\text{Ratio} = \frac{(d_0)_1}{(d_0)_2} = \frac{1.054(d_0)_1}{1.054(d_0)_2} = 1$$

Common data for Q 23 & 24

23. Ans: 7068 J & 24. Ans: 0.354 m

Sol: $d_o = 100$ mm, $h_o = 50$ mm,

$h_f = 40\,\text{mm}$, $\sigma_y = 80$ MPa

$$d_f = d_o\sqrt{\frac{h_o}{h_f}} = 100\sqrt{\frac{50}{40}} = 111.8\text{mm}$$

$$F_{i\,min} = A_0 \times \sigma_y$$

$$= \frac{\pi}{4}\times 100^2 \times 80 = 628.318 \text{ kN}$$

$$F_{f\,min} = A_f \times \sigma_y = \frac{\pi}{4}(111.8)^2 \times 80$$

$$= 785.350 \text{ kN}$$

$$F_{min} = \frac{F_{i\,min} + F_{f\,min}}{2} = 706.834 \text{ kN}$$

$$\text{W.D} = F_{min} \times (h_o - h_f) = 7068\text{J}$$

$$= 2 \times W \times H$$

$$H = \frac{7068}{2\times 10\times 10^3} = 0.354 \text{ m}$$

25. Ans: (b)

26. Ans: 58%

Sol: Area after 1st pass = $A_1 = (1 - 0.4)A_0$

$= 0.6\ A_0$

Area after 2nd pass = $A_2 = (1 - 0.3)A_1$

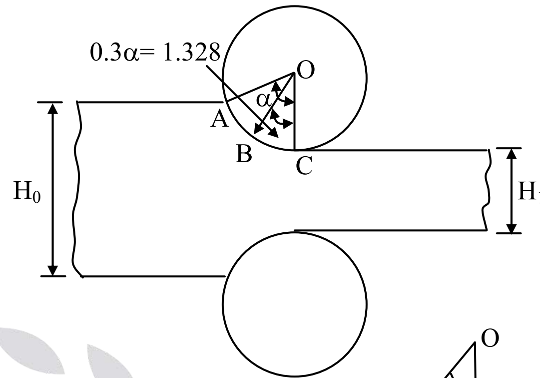
$= 0.7 \times 0.6 \times A_0 = 0.42\ A_0$

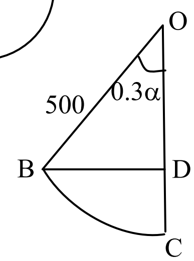
Overall % reduction = $(1 - 0.42) \times 100$

$= 58\ \%$

27. Ans: 7.269 mm

Sol:





$H_o = 10$ mm,

$H_1 = 7$ mm,

$$R = \frac{1000}{2} = 500 \text{ mm}$$

$$\text{Angle of bite } (\alpha) = \tan^{-1}\sqrt{\frac{\Delta H}{R}}$$

$$= \tan^{-1}\sqrt{\frac{10-7}{500}} = 4.429$$

$$1.328 = \frac{OD}{OB}$$

OD = 500×cos1.328 = 499.865

DC = 500 – OD = 0.1343 mm

Thickness of neutral point = At point B

$= 7 + 2 \times 0.1343 = 7.269$ mm

28. Ans: (*)

Sol: The true strain that the material undergoes in this operation is

$$\varepsilon_1 = \ell n\left(\frac{6^2}{3^2}\right) = 0.6931$$

Assume that for this material and condition, K = 895 MPa and n = 0.49. Hence,

$$\overline{Y} = \frac{K\varepsilon_1^{\ n}}{n+1} = \frac{895\times(0.6931)^{0.49}}{1.49} = 502\,\text{MPa}$$

From , the drawing force is

$$F = \overline{Y}\,A_f\,\ell n\left(\frac{A_i}{A_f}\right)$$

Where,

$$F = 502\left[\frac{\pi}{4}\times\left(\frac{3}{1000}\right)^2\times 0.6931\right]$$

$F = 0.002459$ MN

Power = F × V

= 0.002459 × 0.6

= 0.001475 MN m/s

= 0.001475 MW = 1475 W

and the actual power will be 35% higher, or

Actual power = 1.35 × 1475 = 1.992 kW

The die pressure, $p = Y_f = \sigma_a$

where Y_f = the flow stress of the material at the exit of the die.

$Y_f = K\,\varepsilon_t^{\ n} = 895 \times (0.6931)^{0.49} = 748$ MPa

In this equation,

σ is the drawing stress, σ_d.

Hence, using the actual force, we have

$$\sigma_d = \frac{F}{A_f}$$

$$= \frac{1.35\times(0.002459)\times 1000^2\times 4}{\pi\times 3^2}$$

= 470 MPa

Therefore, the die pressure at the exit is

p = 748 – 470 = 278 MPa.

29. Ans: 7.687 MPa, 19.7 %

Sol: $d_0 = 6.25$ mm; $d_1 = 5.60$ mm;

$\mu = 0$; $\tau_y = 35\ \text{N/mm}^2$

$B = \mu\cot\alpha = 0$

$$\tau_2 = \tau_y\left(\frac{1+B}{B}\right)\left(1-\left(\frac{A_1}{A_0}\right)^B\right) = \frac{0}{0}$$

By applying L – Hospital rule

$$\sigma_2 = \sigma_y\,\ell n\left(\frac{A_0}{A_1}\right)$$

$$= \sigma_y \times 2\ell n\left(\frac{d_0}{d_1}\right)$$

= 7.687 MPa

$$\%\ \text{reduction in area} = \frac{A_0 - A_1}{A_0} = \frac{d_0^2 - d_1^2}{d_0^2}$$

= 19.71%

30. Ans: 29.85 tons

Sol: Initial size = 25×25×150 mm

Final size = 6.25×100×150 mm

$\mu = 0.25$;

$\sigma_y = 0.7\ \text{kg/mm}^2$

As given piece is pressed; height is reduced

$h_0 = 25$;

$h_f = 6.25$

$A_0 = 25\times150$;

$A_f = 100\times150$

$$\text{Forging force} = \sigma_y A_f\left[1+\frac{2\mu\,r_f}{3h_f}\right]$$

$(A_c)_{circular} = (A_c)_{non-circular}$

$$\pi r_f^2 = 100\times150$$

$r_f = 69.098$mm

Forging force

$$= 0.7\times15\times10^3\left[1+\frac{2\times0.25\times69.098}{3\times6.25}\right]$$

$= 29847.44$kg $= 292.80$kN

31. Ans: 20.52 kW

Sol: $d_0 = 10$ mm;

$$0.3 = \frac{A_0 - A_1}{A_0} = 1-\frac{A_1}{A_0}$$

$$0.3 = 1-\frac{d_1^2}{d_0^2}$$

$d_1 = 8.36$ mm

$B = \mu\cot\alpha = 0.1\cot(6^o) = 0.951$

$$\sigma_2 = \sigma_y\left(\frac{1+B}{B}\right)\left(1-\left(\frac{A_1}{A_0}\right)^B\right)$$

$$= 240\left(\frac{1+0.951}{0.951}\right)\left(1-(0.7)^{0.951}\right)$$

$= 141.687$ MPa

Drawing load $= \sigma_2\times A_1 = 141\times\frac{\pi}{4}\left(d_1^2\right)$

$$F_d = 141.687\frac{\pi}{4}d_1^2$$

$$= 141\times\frac{\pi}{4}\left(8.36^2\right) = 7777.364 = 7.8\text{ kN}$$

P (motor) $= \dfrac{F_d\times V}{\eta_{motor}}$

$$P = \frac{7.8\times2.5}{0.95}$$

$\Rightarrow$ P = 20.52 kW

32. Ans: (a, c, d)

Sol: Hot rolling, have a number of disadvantages. Due to the high temperatures, the surface oxidises, producing a scale which results in a *poor surface finish*, making it difficult to maintain *dimensional accuracy*.

Where close dimensional accuracy and good surface finish are not of great importance, e.g. structural shapes for construction work, a descaling operation is carried out and the product is used as-rolled. Alternatively, further work can be carried out by cold rolling. So given option (b) is Incorrect.

33. Ans: (a, b, c)

Sol: The simplest method for eliminating wrinkling in deep-drawn parts is using a blank holder.

Ironing is a very useful process when employed in combination with deep drawing to produce a uniform wall thickness and to increase the wall height.

Draw beads are commonly used to control material flow during the drawing operation in order to achieve the optimal forming of a part without cracks and wrinkles.

34. Ans: (a, d)

Sol:

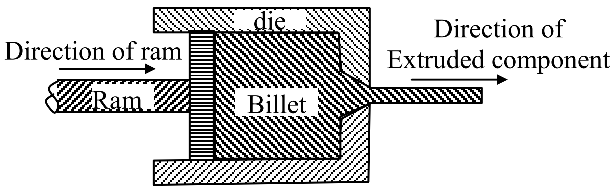


Fig. Forward extrusion

In direct extrusion or forward extrusion, the flow of metal through the die is in the same direction as the movement of ram. Hot billet is placed within the container that has die at one end. A ram forces the billet through the die opening, producing the extruded product. The die may be round or it may have various other shapes. The ram is close fitted to the container cavity consequently preventing the backward flow of metal and controlling the flow of the material in the same direction as the ram.

35. Ans: (a, b, c)

Sol: In a forging process, under high pressure, a metal workpiece undergoes large plastic deformation, resulting in an appreciable change in shape or cross section.

Chapter 6

Sheet Metal Operations

Common data for Q. 1 to 5

01. Ans: (b)

Sol: For punching operation

Punch size = Hole size = 12.7

Die size = punch size + clearance

$= 12.7 + 2 \times 0.04 = 12.78$

02. Ans: (a)

Sol: Die size = Blank size = 25.4mm

Punch size = Die size – 2(radial clearance)

$= 25.4 - 2(0.04)$

Punch size = 25.32 mm

03. Ans: (b)

Sol: $F_{max} = F_{p\,max} + F_{b\,max}$

$= \pi \times 12.7 \times 1.25 \times 800 + \pi \times 25.4 \times 1.25 \times 800$

$= 40 + 80 = 120$ kN

04. Ans: (c)

Sol: Force required is Max $[F_{punch}, F_{blank}]$

$\Rightarrow$ force required is Max [40, 80]

$\Rightarrow$ force required = 80 kN

05. Ans: (d)

Sol: $F_p = \dfrac{F_{p\max}.Kt}{Kt + I}$

$$= \frac{40 \times 0.6 \times 1.25}{0.6 \times 1.25 + 1} = 17.14 \text{ kN}$$

$$F_b = \frac{F_{b\max} kt}{kt + I}$$

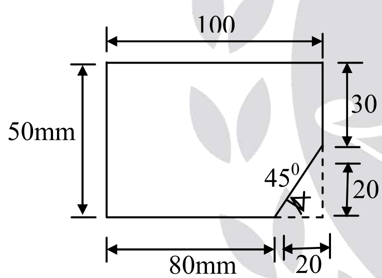
$$= \frac{80 \times 0.6 \times 1.25}{0.6 \times 1.25 + 1} = 34.28 \text{ kN}$$

$$F = F_P + F_b = 51.42 \text{ kN}$$

Common data for Q. 06, 07 & 08

06. Ans: 83.6 N

Sol:



$$P = 100 + 30 + 20\sqrt{2} + 80 + 50 = 288.28$$

$$F_{max} = Pt\tau_u = 288.28 \times 2 \times 145 = 83.6 \text{kN}$$

07. Ans: 66.88 J

Sol: Work done in blanking open

$= F_{max}.K.t$

$= 83.6 \times 10^3 \times 0.4 \times 2 \times 10^{-3}$

$= 66.88$ J

08. Ans: 1.98 mm

Sol: I = ?

F = 24 kN

$F_{max} = 83.6$ kN

$F(Kt + I) = F_{max} \times Kt$

$$I = \frac{F_{max} \times Kt}{F} - Kt$$

$$= \left(\frac{83.6 \times 0.4 \times 2}{24} - 0.4 \times 2\right) = 1.98 \text{ mm}$$

09. Ans: (a)

Sol: $F_{max} = 5 = \pi dt\,\tau_u \Rightarrow dt\tau_u = \dfrac{5}{\pi}$

$$F_{max} = \pi \times 1.5d \times 0.4t \times \tau_u$$

$$= \pi \times 1.5 \times 0.4 \times dt\tau_u$$

$$= \pi \times 1.5 \times 0.4 \times \frac{5}{\pi} = 3 \text{kN}$$

Common Solution for Q. 10 & 11

10. Ans: (a)

11. Ans: (b)

Sol: t = 5 mm, L = 200 mm, $\tau_u = 100$ MPa,

K = 0.2

W.D $= F_{max}\,Kt = L \times t \times \tau_u \times K.t$

$= 200 \times 5 \times 100 \times 0.2 \times 5$

$$= \frac{100 \times 10^3}{1000} = 100 \text{ N} - \text{m (or) J only}$$

Shear provided over a length of

$$200\ mm \rightarrow \frac{20}{400} \times 200 = 10 \text{ mm}$$

$F_{max}\,Kt = F\,(Kt + I)$

$$F = \frac{100 \times 10^3 \times 0.2 \times 5 \times 10^{-3}}{0.2 \times 5 + 10} = 9.09 = 10 \text{ kN}$$

12. Ans: (d)

Sol: $d = 25$ mm, $t = 2.5$ mm $\rightarrow$ piercing

$\tau_u = 350$ MPa

Diameter clearance $= C$

$= 0.0064\,K\sqrt{t}$

$= 0.0064 \times 2.5\sqrt{350} = 0.3$ mm

In piercing

P.S = H.S = 25 mm.

D.S = P.S + C = 25 + 0.3 = 25.3

$F_{max} = \pi dt\,\tau_u = \pi \times 25 \times 2.5 \times 350$

$= 68.72$ kN.

13. Ans: (a)

Sol: Die size = Blank size = 25 – 0.05

= 24.95

Punch size = Die size – clearance

= 24.95 – 2 × 0.06 = 24.83

Common data for Q. 14 & 15

14. Ans: (b)

Sol: Dia. before, $D^2 = 4dh + d^2$

$= 4 \times 5 \times 7.5 + 5^2 = 175$

$\Rightarrow D = 13.23$

$$\text{Draw Ratio} = \frac{\text{Dia.before}}{\text{Dia.after}}$$

$$\Rightarrow d_1 = \frac{13.23}{1.8} = 7.35 > 5\text{cm}$$

$$\Rightarrow d_2 = \frac{7.35}{1.8} = 4.08 < 5\text{ cm}$$

$n = 2$

15. Ans: (a)

Sol: $D = \sqrt{d_1^2 + 4d_1h_1}$

$4d_1h_1 = D^2 - d_1^2$

$$h_1 = \frac{D^2 - d_1^2}{4 \times d_1} = \frac{13.22^2 - 7.34^2}{4 \times 7.34} = 4.11\text{ mm}$$

$P_1 = \pi D t \sigma_y$

$= \pi \times 132.22 \times 1.5 \times 315$

$= 196238$ N = 196.238 kN

$E = P_1h_1 = 196.238 \times 4.11 \times 10^{-3} = 806.6$ kJ

16. Ans: (b)

Sol: $DRR_1 = 0.4 = \dfrac{D - d_1}{D}$

$D = \sqrt{4dh + d^2}$

$= \sqrt{4 \times 12 \times 16 + 12^2} = 30.2$

$d_1 = D(1 - 0.4) = 30.2 \times 0.6 = 18.12$

$d_2 = d_1(1 - 0.25) = 18.12(0.75) = 13.59$

$d_3 = d_2(1 - 0.25) = 13.59(0.75) = 10.19$

$d_3 < 12 \Rightarrow n = 3$

17. Ans: (b)

Sol: $P_1 = \pi D t \sigma_y = \pi \times 30.2 \times 2 \times 35 = 6641.3$ N

$$\sigma_{21} = \frac{P_1}{\frac{\pi}{4}\left(d_1^2 - (d_1 - 2t)^2\right)}$$

$$= \frac{6{,}641.3}{\frac{\pi}{4}\left(18.12^2 - (18.12 - 2 \times 2)^2\right)}$$

$= 65.5$ MPa

Common data for 18 & 19

18. Ans: 6

Sol: $D = \sqrt{d^2 + 4dh} = \sqrt{30^2 + 4 \times 30 \times 150}$

$= 137.47$

$d_1 = D \times 0.6 = 137.47 \times 0.6 \;\; = 82.48 > 30$

$d_2 = 82.48 \times 0.8 = 65.984 > 30$

$d_3 = 65.984 \times 0.8 = 52.7 > 30$

$d_4 = 52.7 \times 0.8 = 42.2 > 30$

$d_5 = 42.2 \times 0.8 = 33.7 > 30$

$d_6 = 33.7 \times 0.8 = 27 < 30$

$n = 6$

19. Ans: 52.7 mm

Sol: $d_3 = 52.7$ mm

20. Ans: 144.42

Sol: $\frac{d}{r} = \frac{100}{6} = 16.66 \approx 15 \text{ to } 20$

$D = \sqrt{d^2 + 4dh} - \frac{r}{2}$

$= \sqrt{100^2 + 4 \times 100 \times 25} - \frac{6}{2}$

$= 138.42 + 2 \times 3$

$D_{total} = D + 2 \times 3 = 144.42 \text{ mm}$

21. Ans: (d)

22. Ans: (c)

Sol: Number of earing defects produced $= 2^n$

Where n is an integer

So possible option is 64.

23. Ans: 467 mm

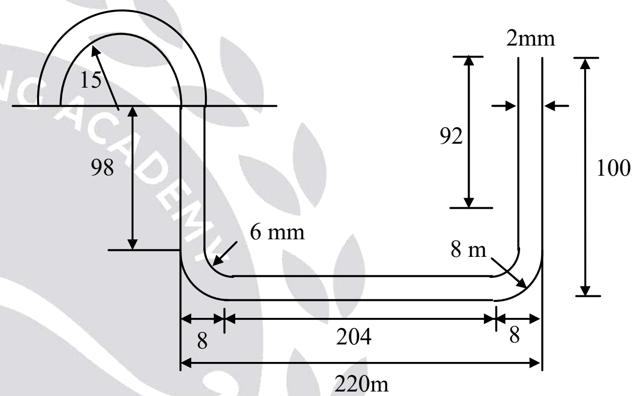
Sol: $B_1 = (15 + 0.5 \times 2) \times 180 \times \frac{\pi}{180}$

$= 50.265$ mm

$B_2 = (6 + 0.5 \times 2) \times 90 \times \frac{\pi}{180} = 10.99$ mm

$L_0 = 98 + 204 + 92 + B_1 + 2B_2$

$= 466.245$ mm



24. Ans: (b)

25. Ans: 3

Sol: $D = \sqrt{d^2 + 4dh}$

$= \sqrt{50^2 + 4 \times 50 \times 100} = 150\text{mm}$

$0.4 = \frac{D - d_1}{D}$

$0.4 \times 150 = 150 - d_1$

$d_1 = 90\text{mm} > 50$

$d_2 = d_1(1 - 0.4) = 54 > 50$

$d_3 = 32.4 < 50$

$\therefore$ **n = 3**

26. Ans: 127.536 kN

Sol: Force required for punching

$= \tau_s \times \pi d \times t$

$= 240 \times \pi \times 10 \times 1$

$= 7.536$ kN

Force required for cutting $= 2(L + B) \times Zt$

$= 2 \times (50 + 200) \times 1 \times 240$

$= 120$ kN

Force required $= 120 + 7.536 = 127.536$ kN

27. Ans: (c, d)

Sol: Many sheet metal forming operations are complex and consist of different types of basic forming operations — bending, flanging, bend and straighten, stretching, deep drawing, ironing, coining, and embossing.

28. Ans: 185.1

Sol: Given data:

$l = 2.5$ mm, $l_1 = 70$ mm

$l_2 = 110$ mm, R = 3.25 mm

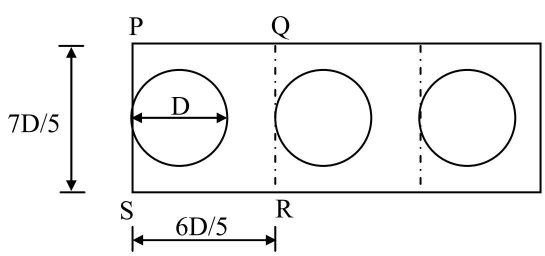
Bending allowance (BA) $= \dfrac{2\pi R}{4} = 5.10$

Total length $= l_1 + BA + l_2$

$= 70 + 5.1 + 110 = 185.1$ mm

29. Ans: 53.25

Sol:



Rectangle PQRS keeps repeating

$$A_{total} = A_{PQRS} = \frac{7D}{5} \times \frac{6D}{5} = 1.68\ D^2$$

$$A_{disk} = \frac{\pi}{4} D^2 = 0.7853\ D^2$$

$$\text{Percentage of scrap} = \frac{A_{total} - A_{disc}}{A_{total}}$$

$$= \frac{1.68D^2 - 0.7853D^2}{1.68D^2}$$

$= 53.25$ %

30. Ans: 10.9 kN

Sol: Given:

t = 3.2 mm,

w = 44.5 mm,

$\sigma = 450$ MPa

Opening dimension, D = 25 mm

$$\text{Force} = \frac{k_{bf} \times \sigma \times w \times t^2}{D}$$

$$= \frac{1.33 \times 450 \times 44.5 \times (3.2)^2}{25}$$

$= 10909$ N $= 10.9$ kN

Chapter 7

Metrology

7.1 Limits, Fits & tolerances

01. Ans: (a)

Sol: For Clearance fit

L- hole > H- shaft

02. Ans: (c)

Sol: Hole = $40^{0.050}_{0.000}$ mm ,

Min. clearance = 0.01 mm,

Tolerance on shaft = 0.04 mm ,

Max. clearance of shaft = ?

0.01 = L.hole – H.shaft

0.01 = 40.000 – H.shaft

⇒ H.shaft = 40.000 – 0.01 = 39.99mm

H.shaft – L.shaft = 0.04

L.shaft = 39.99 – 0.04 = 39.95

Max. clearance = H.hole – L.shaft

= 40.05 – 39.95 = 0.10 mm

03. Ans: (d)

Sol: $X_{max} = 50.02 - (37.985 + 9.99) = 2.045$

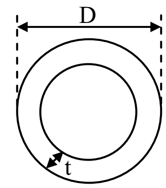
$X_{min} = 49.98 - (38.015 + 10.01) = 1.955$

$X = X_{max} - X_{min} = 0.09$

Dimension X = 2 ± **0.045**

04. Ans: (c)

Sol:



t = 0.01 to 0.015mm

When, t = 0.01 mm

D = 30.01 + 2×0.01 = 30.03 mm

= 30.05 + 2× 0.01 = 30.07 mm

When, t = 0.015 mm

D = 30.01 + 2×0.015 = 30.04 mm

= 30.05 + 2× 0.015 = 30.08 mm

$D = 30^{+0.08}_{+0.03}$ mm

05. Ans: (d)

Sol: $A = 25.2^{+0.01}_{-0.02}$

$B = 30.4 \pm 0.01$

$C = 32.7 \pm 0.02$

$T_{max} = L_{max} - A_{min} - B_{min} - C_{min}$

$= (118 + 0.08) - (25.2 - 0.02) - (30.4 - 0.01) - (32.7 - 0.02)$

$= 29.83 = 30^{-0.17}$

$T_{min} = L_{min} - A_{max} - B_{max} - C_{max}$

$= (118 - 0.09) - (25.2 + 0.01) - (30.4 + 0.01) - (32.7 + 0.02)$

$= 29.57$

$T_{min} = 30^{-0.43}$

$\therefore\ T = 30^{-0.17}_{-0.43}$

06. Anc: (c)

Sol: Shaft $65^{+0.01}_{-0.05}$ mm

Locating $\rightarrow$ 0.05 ± 0.005 mm

U.L = 65.01 + 2×0.055 = 65.12

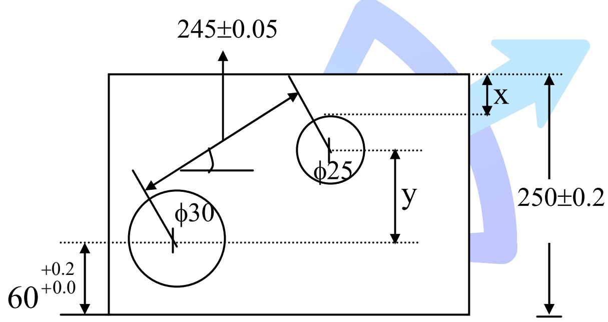
L.L = 64.95 + 2×0.045 = 65.04

Min hole dia to provide clearance fit is

Upper limit of shaft after coating i.e. = 65.12 mm

07. (i) Ans: (d), (ii) Ans: (c)

Sol: Let the vertical distance between the holes is 'y'



$$\sin 30 = \frac{y}{245} \Rightarrow y = 245\sin 30$$

$y_{max} = 245_{max} \times \sin 30_{max}$

$= (245 + 0.05)\sin(30 + 15/60) = 123.45$

$y_{min} = (245 - 0.05)\sin(30^0 - 15/60) = 121.55$

(ii) Ans: (c)

$x_{max} = 250_{max} - (60_{min} + (30/2)_{min} + y_{min} + (25/2)_{min})$

$= (250 + 0.2) - (60 + 15 + 121.55 + 12.5)$

$= 41.15$mm

$x_{min} = 250_{min} - (60_{max} + (30/2)_{max} + y_{max} + (25/2)_{max})$

$= (250 - 0.2) - (60.2 + 30.025/2 + 123.45 + 25.025/2)$

$= 38.625$ mm

Tolerance on X = $X_{max} - X_{min}$ = 2.525 mm

08.

Sol: L Hole = BS = 65 mm

H Hole = BS + Tolerance = 65.05 mm

(i) **Ans: (c)**

Allowance = $(L.L)_{hole} - (H.L)_{Shaft}$

$\Rightarrow \quad 0.09 = 65 - (H.L)_{shaft}$

$\Rightarrow (H.L)_{shaft} = 65 - 0.09 = 64.91$ mm

Tolerance = $(HL)_{shaft} - (LL)_{shaft}$

$\Rightarrow \quad 0.05 = 64.91 - (LL)_{shaft}$

$\Rightarrow (LL)_{shaft} = 64.86$ mm

Shaft = piston = $65^{-0.09}_{-0.14}$

(ii) **Ans: (a)**

$(L.L)_{hole} = 65$ mm

$(Tolerance)_{hole} = (HL)_{hole} - (LL)_{hole}$

$\Rightarrow \quad 0.05 = (HL)_{hole} - 65$

$\Rightarrow (HL)_{hole} = 65.05$ mm

Hole = Bore = $65^{+0.05}_{0.00}$

(iii) **Ans: (b)**

Max Clearance = 65.05 – 64.86

= 0.19 mm

09.

Sol: $A_{max} = 15_{max} + 30_{max}$

$= 15.06 + 30.1 = 45.16$

$A_{min} = 15_{min} + 30_{min} = 44.84$

$A = 45 \pm 0.16 = A \pm \Delta A$

$B_{max} = A_{max} - 20_{min}$

$= 45.16 - 19.93 = 25.23$ mm

$B_{min} = A_{min} - 20_{max}$

$= 44.84 - 20.07 = 24.77$ mm

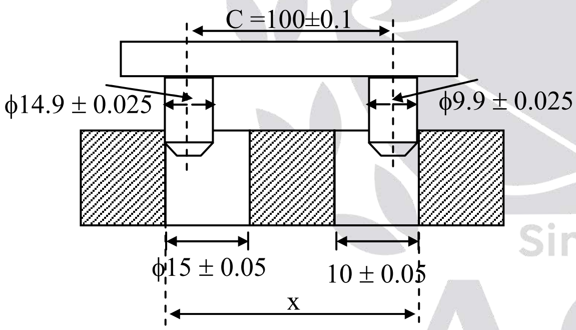
$\Rightarrow B \pm \Delta B = 25 \pm 0.23$

10.

Sol: Let

C = center distance between holes

C_{max} = max. Outer distance of pins – sum of min rod holes.



$$X_{max} = 100_{max} + \left(\frac{9.9}{2}\right)_{max} + \left(\frac{14.9}{2}\right)_{max}$$

$$= 100.1 + \frac{9.925}{2} + \frac{14.925}{2}$$

$= 112.525$ mm

$$X_{min} = 100_{min} + \left(\frac{9.9}{2}\right)_{min} + \left(\frac{14.9}{2}\right)_{min}$$

$$= 99.9 + \frac{9.875}{2} + \frac{14.875}{2}$$

$= 112.275$ mm

$$C_{max} = X_{max} - \left[\left(\frac{15}{2}\right)_{min} + \left(\frac{10}{2}\right)_{min}\right]$$

$$= 112.525 - \left(\frac{14.95}{2} + \frac{9.95}{2}\right)$$

$= 100.075$ mm

$$C_{min} = X_{min} - \left[\left(\frac{15}{2}\right)_{max} + \left(\frac{10}{2}\right)_{max}\right]$$

$$= 112.525 - \left(\frac{15.05}{2} + \frac{10.05}{2}\right)$$

$= 99.725$ mm

$$\therefore C = 100^{+0.075}_{-0.275}$$

11.

Sol: For the given conditions

$$X = 100.1 + \frac{14.875}{2} + \frac{9.875}{2}$$

$= 112.475$ mm

$$C = X - \left(\frac{15.05}{2} + \frac{10.05}{2}\right)$$

C = 99.925 mm

Because C is lying in between the limits, the assembly is possible.

12. Ans: (b)

Sol: Fundamental deviation of hole 'h' is zero.

13.

Sol: Hole = $20^{+0.03}_{-0.00}$

Min. interference = 0.03mm,

Max. interference = 0.08 mm

$$0.03 = \text{L.shaft} - \text{H.hole}$$

$$\text{L.shaft} = 0.03 + 20.03 = 20.06 \text{ mm}$$

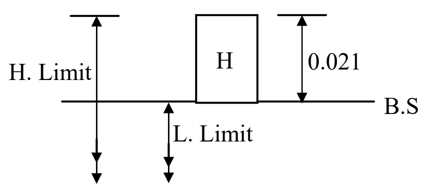
$$0.08 = \text{H.shaft} - \text{L.hole}$$

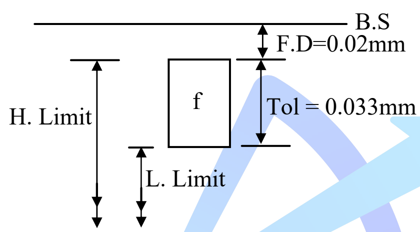
$$\text{H.shaft} = 0.08 + 20.00 = 20.08\text{mm}$$

$$\text{shaft} = 20^{+0.08}_{+0.06}$$

14.

Sol:





$$D = \sqrt{18 \times 30} = 23.24\text{mm}$$

$$i = 0.45\sqrt[3]{D} + 0.0010 = 1.3\mu\text{m}$$

FD of hole H = 0

FD Shaft $= -5.5(23.24)^{0.41} = -20\mu\text{m}$

Hole tolerance, IT7 $= 16i = 20.8\mu\text{m}$

$= 21\mu\text{m} = 0.021$ mm

Shaft tolerance, IT 8 $= 25i$

$= 32.5\mu\text{m} = 33\mu\text{m}$

$= 0.033\text{mm}$

L - hole = basic size = 25 mm

H - hole = 25 + 0.021 = 25.021 mm

H - shaft = 25 – 0.02 = 24.98 mm

L - shaft = 24.98 – .033 = 24.947 mm

(i) **Ans: (a)**

L- hole > H- shaft → Clearance fit

(ii) **Ans: (b)**

Allowance = difference between max.

material limits = L.hole – H.shaft

= 25.00 – 24.98 = 0.02 mm

(iii) **Ans: (b)**

$$\text{Shaft} = 25^{-0.02}_{-0.053}, \quad \text{Hole} = 25^{+0.021}_{+0.00}$$

Max clearance = different between

minimum material limits

= H.hole – L.shaft

= (25.021) – (24.947) = 0.074 mm

(iv) **Ans: (a)**

Size of the GO plug gauge = max. material limit of hole = L.hole = 25 mm

(v) **Ans: (b)**

Size of the NOGO plug gauge = min. material limit of hole = H.hole = 25.021 mm

(vi) **Ans: (c)**

Size of the GO ring gauge = max. material limit of shaft = H.shaft = 24.98 mm

(vii) **Ans: (d)**

Size of the NOGO ring gauge = min. material limit of shaft = L.shaft = 24.947 mm

(viii) **Ans: (a)**

15. Ans: (c)

Sol: $D = \sqrt{18 \times 30} = 23.2$

$i = 0.45\,3\sqrt{D} + 0.001\,D = 1.3$

IT8 = 26i = 26 × 1.3 = 33.8

= 34 μm = 0.034 mm

Hole size = $25H_8 = 25^{+0.034}_{+0.000}$

16. Ans: (a)

Sol: $D = \sqrt{50 \times 80} = 63.24$ mm

i = 1.86 microns = 1.9 microns

IT8 = 25i = 47.5 microns

Tolerance = 0.0475 mm

$F.D = -5.5\,D^{0.41} = -5.5 \times 63.24^{0.41}$

= 30 Microns = 0.03 mm

H. shaft = 60 – F.D = 60 – 0.03 = **59.97 mm**

L. shaft = H. shaft – Tolerance

= 59.97 – 0.047 = **59.923 mm.**

17. Ans: (d)

Sol: Case (i) $25H_7$

L.L = 25.00

U.L = 25.021

Case (2) 25 H_8

UL = 25.033

Case (3) $25H_6$, UL - ?

$(UL)_{H8} - (UL)_{H7} = (UL)_{H7} - (UL)_{H6}$

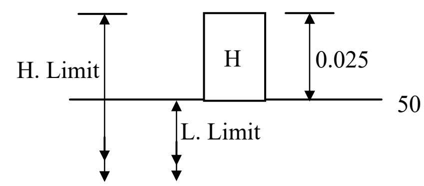
25.033–25.021 = 25.021 – (25 + x)

x = 0.009

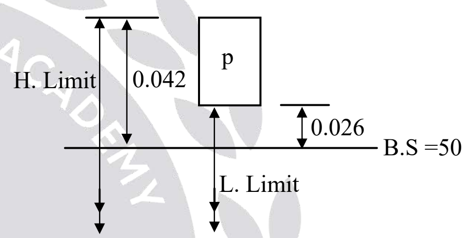
$\therefore \quad (UL)_{H6} = 25.009$

18. (i) Ans: (a) , (ii) Ans: (a), (iii) Ans: (a), (iv) Ans: (c)

Sol:



$\text{Hole} = 50^{+0.025}_{+0.000}$



$\text{Shaft} = 50^{+0.042}_{+0.026}$

L.hole = B.S = 50

H.hole – L.hole = Tolerance = 0.025 mm

H.hole = L.hole + Tolerance = 50.025 mm

Max. interference = difference between max. material limits = H.shaft – L.hole

= 50.042 – 50.00 = 0.042 mm

Min. interference = difference between min. material limits = L.shaft - H.hole

= 50.026 – 50.025 = 0.001 mm

19. Ans: (c)

20. Ans: (b)

Sol: To calculate exactly the data was not given in the problem. But for shaft "h", H – Shaft = 25.000

L – Shaft = less than 25.

And $H_7 \rightarrow$ 7 indicates IT 7 not 7 microns.

21. Ans: (a)

Sol: GO size = max. material limit of hole

= 20.01 mm

NOGO size = min. material limit of hole

= 20.05 mm

22. Ans: (d)

Sol: To produce an interference fit, L-shaft must be greater than H-hole. For this with multiple choice D it is possible because

For D: L-shaft = 20 – 0.02 = 19.98 mm,

H-shaft = 20 + 0.02 = 20.02 mm

L-hole = 20 – 0.035 = 19.965mm,

H-hole = 20 – 0.03 = 19.97mm,

Hence, **L-shaft (19.98) > H-hole (19.97)**

23. Ans: (b, c)

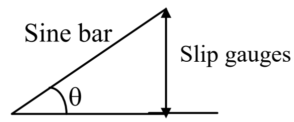
Sol: Press fit or shrink fit bushing design and installation is a common method of retaining bearings by use of interference between the bushing and the bushing hole.

Clearance fit: In this fit, the size of the Hole is always greater than the size of the shaft.

7.2 Angular Measurements

01. Ans: (a)

Sol:



Given sine bar length = 200 = l

Angle $\theta = 32°5'6'' = 32.085°$

Slip gauge height = h say

$$\sin\theta = \frac{h}{\ell}$$

$$\sin\left(32.085^0\right) = \frac{h}{200}$$

$\Rightarrow$ h = 106.235

02. Ans: i-(b), ii-(a)

Sol: $l = 50$, L = 500

$50 \rightarrow 0.08$

$$200 \rightarrow 200 \times \frac{0.08}{50} = 0.32$$

$h' = h + 0.32 = 28.87 + 0.32 = 29.19$

$$\text{Sin}\,\theta = \frac{h'}{L} = \frac{29.19}{200} = 8'23'32''$$

03. Ans: (d)

04. (i) Ans: (c)

Sol: $\sin\theta = \dfrac{h}{L}$

$h = \sin 30^o \times 125 = 62.5$ mm

(ii).

(A) Ans: (a)

$$d\theta = \tan 30^\circ\left[\frac{0}{62.5} - \frac{0.005}{125}\right] = 4.76''$$

(B) Ans: (a)

$$dh = r_2 - r_1 = \frac{d_2 - d_1}{2} = \frac{0.002}{2} = 0.001$$

$$d\theta = \tan 30^\circ\left[\frac{0.001}{62.5} - \frac{0}{125}\right] = 2''$$

(C) Ans: (b)

$dh = 0.002$

$$d\theta = \tan 30^\circ\left(\frac{0.002}{62.5} - \frac{0}{125}\right) = 4''$$

(D) Ans: (d)

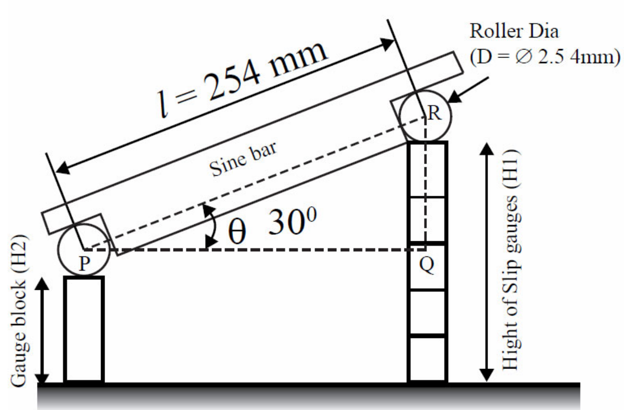
$dh = \pm\, 0.005$

$$d\theta = \tan 30^\circ\left(\frac{\pm 0.005}{62.5} - \frac{0}{125}\right) = \pm 10''$$

05. Ans: 203.2

Sol: $H_2 = 76.2$ mm

$\theta = 30°$



From triangle PQR

$$\sin\theta = \frac{H_1 - H_2}{\ell}$$

$$\sin 30^\circ = \frac{H_1 - 76.2}{254}$$

The required height of gauge blocks at the other end of sine bar (H_1) = 203.2 mm

06. Ans: (d)

07.

Sol: (i) Ans: (b)

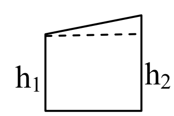
$$\sin\theta = \frac{h_2 - h_1}{w}$$

$h_2 - h_1 = 100\sin 30 = 50$

$h_2 = h_1 + 50 = 75$

(ii) Ans: (d)

$$\sin(30) = \frac{h - 25}{100.005}$$



$\Rightarrow \quad h = 75.0025$ mm

$\Rightarrow \quad h_2 = 75.0025 + 0.005$

$= 75.0075$ mm

08. Ans: (a)

Sol: L = 250 mm,

d = 20 mm

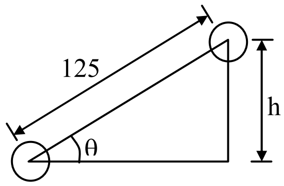
h = 100 – (d/2) = 100 – 10 = 90 mm

$$\sin\theta = \frac{90}{250}$$

$\Rightarrow \theta = 21.2$ deg

09. Ans: 11.556 mm

Sol:



$\theta = 27°32'$

$= 27° + \left(\frac{32}{60}\right)^{o}$

$= 27.533°$

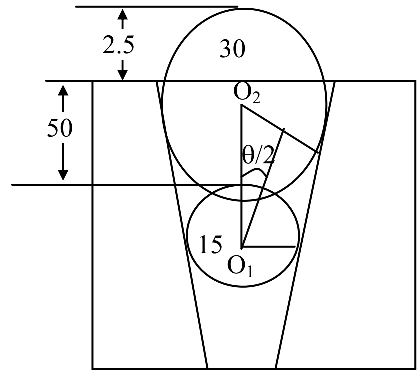
$\sin\theta = \frac{h}{25}$

$\Rightarrow h = 11.556$ mm

7.3 Taper Measurement

01. Ans: 19.2°

Sol:



$$\sin(\theta/2) = \frac{d_2 - d_1}{2(h_1 - h_2) - (d_2 - d_1)}$$

$$\sin(\theta/2) = \frac{30 - 15}{2(52.5) - (30 - 15)}$$

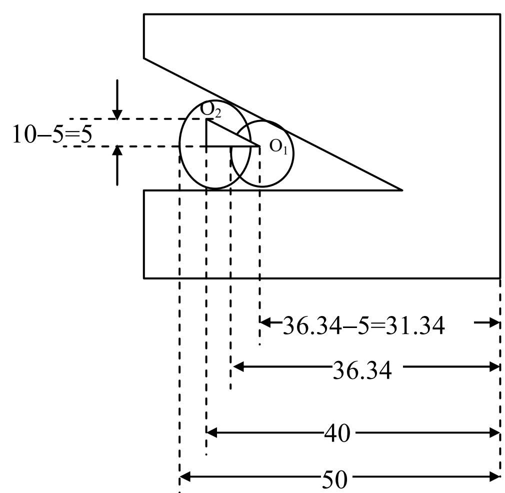
$$= \frac{15}{105 - 15} = 1/6$$

$\therefore \quad \theta = 19.2°$

02. Ans: 60

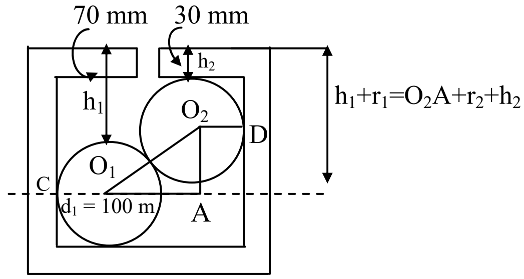
Sol: $\tan(\theta/2) = \frac{5}{8.66}$

$\Rightarrow \quad \theta = 60°$



03. Ans: 112.41 mm

Sol:



Diameter = $O_1C+O_1A+O_2D$

$$=\frac{d_1}{2}+\sqrt{(O_1O_2)^2-(O_2A)^2}+\frac{d_2}{2}$$

$O_1O_2 = r_1 + r_2 = 75$

$O_2A = h_1 + r_1 - r_2 - h_2$

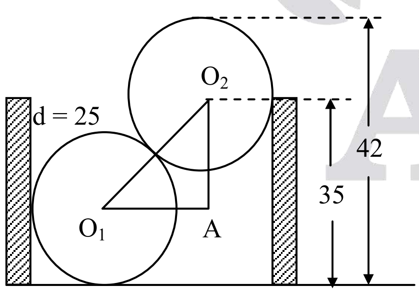
$= 70 + 50 - 30 - 25 = 65$

$D = 50 + \sqrt{75^2 - 65^2} + 25$

$= 112.4165$ mm

04. Ans: 43.33 mm

Sol:



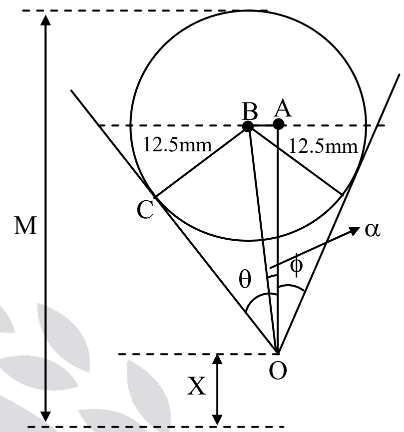
$O_1A = \sqrt{25^2 - 17^2} = 18.33$

$D = r + O_1A + r$

$= 25 + 18.33 = 43.33$ mm

05. Ans: 78.074 mm

Sol:



$\theta + \phi = 45°50' + 29°10' = 75°$

$\frac{\theta+\phi}{2} = 37.5°$

$\alpha = \frac{75}{2} - \phi = 37.5 - \phi = 37.5° - 29°10'$

$= 8°20'$

Δle OBC

$\sin 37.5 = \frac{BC}{OB}$

$\Rightarrow OB = \frac{BC}{\sin 37.5} = \frac{12.5}{\sin 37.5} = 20.533$

Δle OAB

$\cos 8°20' = \frac{OA}{OB}$

$\Rightarrow OA = OB \cos 8°20' = 20.316$ mm

$X = M - (OA + R)$

$= 110.89 - (20.316 + 12.5)$

$= 78.074$ mm

06. Ans: 1.1

Sol: $d_2 - d_1 = 10$; $h_2 - h_1 = 12.138$

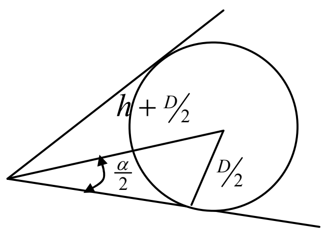
$$\sin\left[\frac{\theta}{2}\right] = \frac{d_2 - d_1}{2\times(h_2 - h_1) - (d_2 - d_1)}$$

$\theta = 88.9$

Error = 90 – 88.9 = 1.1

07. Ans: 38.94

Sol:



$$\text{Sin}\left[\frac{\alpha}{2}\right] = \frac{D/2}{h + D/2} = \frac{D}{2h + D}$$

$$\text{Sin}\,\frac{\alpha}{2} = \frac{D}{2h + D}$$

If D = 0, h = 0

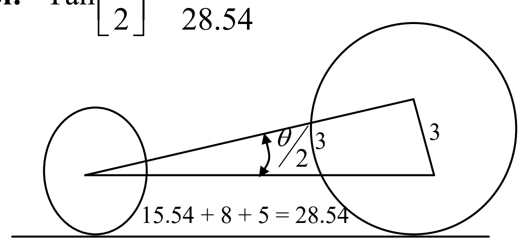
D = 1, h = 1

$$\text{Sin}\left[\frac{\alpha}{2}\right] = \frac{1}{2\times1+1} = \frac{1}{3}$$

$$\left[\frac{\alpha}{2}\right] = 19.47 \Rightarrow \alpha = 38.94$$

08. Ans: (d)

Sol: $$\text{Tan}\left[\frac{\theta}{2}\right] = \frac{3}{28.54}$$



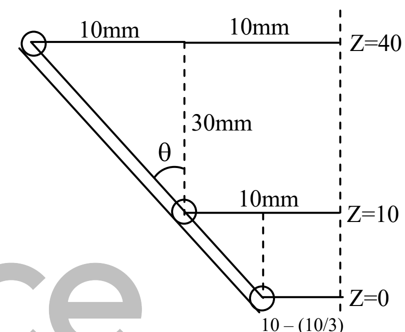
$$\frac{\theta}{2} = Tan^{-1}\left(\frac{3}{28.54}\right) = 6$$

Taper angle $\left(\frac{\theta}{2}\right) = 6^0$

Included angle = 12^0

09. Ans: (c)

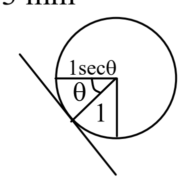
Sol: $\tan\theta = \frac{10}{30} \Rightarrow \theta = \tan^{-1}(1/3) \Rightarrow \theta = 18.434°$



Distance at Z = 0,

$$D_0 = 2(10 - 10\tan 30) = 2\left(10 - \frac{10}{3}\right)$$

$= 6.67 \times 2 = 13.33$ mm



With probe diameter compensation

$D_{actual} = 13.334 + 2\times r\sec\theta$

$= 13.334 + 2 \times 1 \times \sec(18.435)$

$= 15.442$ mm

10. Ans: (d)

Sol: $H = (R + r) + \sqrt{2D(R + r) - D^2}$

7.4 Screw Thread Measurements

01. Ans: (d)

Sol: Major diameter = s + (R_2 – R_1)

= 35.5 + (11.8708 – 9.3768)

= 37.994 mm

02. Ans: (a)

Sol: Minor diameter

= 30.5 + (15.3768 – 13.5218)

= 32.355 mm

03. Ans: (a)

Sol: best wire diameter, $d = \left(\frac{p}{2}\right)\sec\left(\frac{\theta}{2}\right)$

$= \left(\frac{3.5}{2}\right)\sec\left(\frac{60}{2}\right) = 2$

M = 30.5 + (12.2428 – 13.3768)

= 29.366 mm

$D_e = M - \left(d + \frac{p}{2}\tan\frac{\theta}{2}\right)$

$= M - \left(2 + \frac{3.5}{2} \times \tan 30\right)$

= 29.366 – 3.010366 = 26.355 mm

04. Ans: (a)

Sol: VED = D_e ± VC

$$VC = \delta P \cos\frac{\theta}{2} + 0.0131P(\delta\theta_1 + \delta\theta_2)$$

δP = pitch error

$\delta\theta_1$, $\delta\theta_2$ – flank angle errors in deg

$\delta\theta_1 = 7^1 = 0.11667 - 2.04\times10^{-3}$

$\delta\theta_2 = 9^1 = 0.15 - 2.618\times10^3$

δP = 0.004

D_e = 30.6651

θ = 60° (metric thread)

Virtual correction

VC = (0.004 × cos30) + (0.0131 × 3.5(0.11667 + 0.15))

VC = 0.01569

VED = D_e + VC

= 30.6651 + 0.01569 = 30.6807

05. Ans: (a)

06. Ans: (d)

Sol: $\sin\left[\frac{\theta}{2}\right] = \frac{R_2 - R_1}{M_2 - M_1 - (R_2 - R_1)}$

$= \frac{1.4434 - 0.8660}{22.06 - 20.32 - (1.4434 - 0.8660)}$

θ = 59.5566 = 59°33′23″

07. Ans: 16.433 mm

Sol: $D_e = M - \left(d + \frac{p}{2}\tan\frac{\theta}{2}\right)$

$M = 14.701 + (1.155 + \frac{2}{2}\tan 30) = 16.433$

08. Ans: (d)

Sol: Lead = pitch × no of starts

$\text{Pitch} = \frac{\text{lead}}{\text{no of starts}} = \frac{3}{2} = 1.5$ mm

09. Ans: (d)

Sol: Rollers will not used to measure pitch diameter.

$$\text{Best size diameter } d = \left(\frac{p}{2}\right)\sec\left(\frac{\theta}{2}\right)$$

$$= \left(\frac{2}{2}\right)\sec\left(\frac{60}{2}\right)$$

$$= 1.1547 = 1.155$$

10. Ans: (d)

Sol: $V.C = \delta P.\cos\left(\frac{\theta}{2}\right) + 0.0131P(\delta\theta_1 + \delta\theta_2)$

$= 0.2 \cos 30 = 0.346$

Common data Q 11 & 12

11. Ans: (a)

Sol: Best size diameter, $d = \left(\frac{p}{2}\right)\sec\left(\frac{\theta}{2}\right)$

$$= \left(\frac{2}{2}\right)\sec\left(\frac{60}{2}\right) = 1.155 \text{ mm}$$

12. Ans: (a)

Sol: $D_{eff} = M - \left(d + \frac{p}{2}\tan\frac{\theta}{2}\right)$

$= 16.455 - 1.155.\tan 30 = 14.7226$ mm

13. Ans: 1.732 mm

Sol: The best wire size $= (p/2)\sec(\alpha/2)$

$= (3/2)\sec(60/2)$

$= 1.732$ mm

7.5 Surface Finish Measurement

01.

(i) Ans: (c)

Sol: R_t = maximum peak – minimum valley

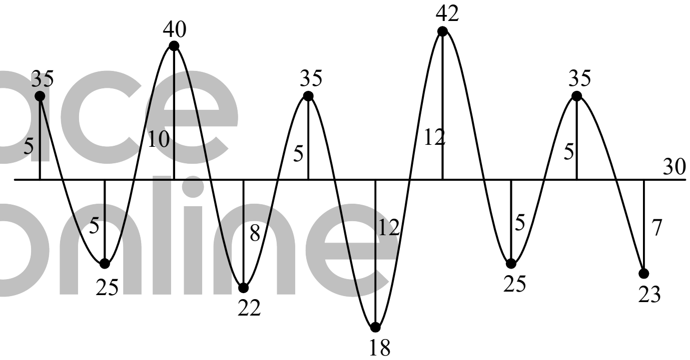
$= 42 - 18 = 24\ \mu m$

(ii) Ans: (d)

Sol:

$$\text{Mean} = \frac{18+22+23+25+25+35+35+35+40+42}{10}$$

$= 30\ \mu m$



$$\text{CLA} = R_a = \frac{5+5+10+8+5+12+12+5+5+7}{10}$$

$= 7.4\ \mu m = 7.5\ \mu m$

(iii) Ans: (b)

Sol: R_z 10 point height method

$$= \frac{\text{Sum of highest five peaks} - \text{Sum of lowest five peaks}}{5}$$

$$= \frac{(35+40+35+42+35)-(25+22+18+25+23)}{5}$$

$= 14.8\ \mu m = 15\ \mu m$

(iv) Ans: (d)

Sol: $$\text{RMS} = \sqrt{\frac{h_1^2 + h_2^2 + h_3^2 + ... + h_n^2}{n}}$$

$$R_s = \sqrt{\frac{5^2 + 5^2 + 10^2 + 8^2 + 5^2 + 12^2 + 12^2 + 5^2 + 5^2 + 7^2}{10}}$$

$= 7.91\ \mu\text{m} = 8\ \mu\text{m}$

$\therefore\ R_a < R_s < R_z < R_t$

(v) Ans: (c)

Sol: If R_a value from 18.75 to 37.5 international grade of roughness is given by N11.

02. Ans: (c)

Sol: $$R_a = \frac{\sum A}{w} \times \frac{1}{HM} \times \frac{1000}{VM}$$

$$= \frac{480 + 480}{0.8} \times \frac{1}{100} \times \frac{1000}{15000}$$

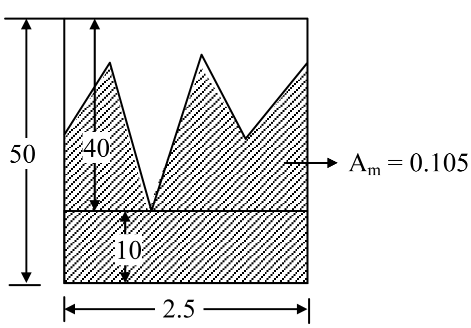
$R_a = 0.8$

03. Ans: (d)

Sol: $$R_t = \frac{0.05}{\tan 45} = 50\ \mu\text{m}$$

04. Ans: (c)

Sol:



$A_{m\ act} = 0.105 - 0.01 \times 2.5 = 0.08$

$$K = \frac{A_{m\ act}}{(10^{-3} \times 2.5) \times 0.04}$$

$$= \frac{0.08^2}{\left(2.5 \times 10^{-3} \times 0.04\right)} \times \frac{1}{1000} = 0.8$$

05. Ans: (a)

06. Ans: (c)

07. Ans: (a)

08. Ans: 2

Sol: $$R_a = \frac{\Sigma h}{n}$$

$$= \frac{16 \times 4 + 16 \times 0}{32} = \frac{64}{32} = 2\ \mu\text{m}$$

7.6 Coordinate Measuring Machines

01. Ans: (b, c, d)

Sol: To measure a complex component quickly and accurately often requires sophisticated, programmable equipment dedicated to inspection.

This is made possible by mounting probe devices on a computer-controlled *multi-axis machine* frame to produce a coordinated measuring machine.

02. Ans: (d)

Sol: All CMMs have three orthogonal axes, X, Y and Z which operate in a 3D coordinate system. Some use contact probes whereas others use non-contact probes.

03. Ans: (c)

Sol: Bridge type CMM is more difficult to load. It less sensitive to mechanical errors. Horizontal boring mill type is best suited for heavy and large workpieces.

04. Ans: (a, b, c)

Sol: Two types of accuracies are defined in connection with coordinate measuring machines ; viz

(i) geometrical accuracy (determined by independent measurement because they make major contribution to overall accuracy of machine) and

(ii) total measuring accuracy (determined by utilising the entire measuring machine system as applied to master gauges).

Geometrical accuracy concerns the straightness of axes, squareness of axes, and position accuracy. Total measuring accuracy concerns axial length measuring accuracy, and volumetric length measuring accuracy.

Chapter 8 Advanced Machining Methods Numerical Control (NC) Machines

01. Ans: (a)

Sol: Pitch of lead screw = 5mm

1 rev = 5mm

1mm = 1/5 rev

200mm = 1/5 × 200 = 40rev

= 40 ×360 = 14400 deg.

02. Ans: (b)

Sol: Pitch of lead screw = 5 mm,

BLU = 0.005 mm

⇒ Distance travelled /pulse

Length of travel = 9 mm

No.of pulses = L / BLU = 9 / 0.005

= 1800 pulse.

03. Ans: (b)

Sol: For 1 rev of motor ⇒360° are required

⇒ 360 pulses are required

When motor is rotated by 1 rev

⇒ lead screw will rotate by 1 rev

When Lead screw is rotated by 1 rev ⇒3.6 mm distance is travelled by axis

In total

For 360 pulses ⇒ 360 deg of motor

⇒ 1 rev of motor

⇒1 rev of lead screw

⇒ 3.6 mm of linear movement of axis

360 pulses = 3.6 mm

$$1 \text{ pulse} = \frac{3.6}{360}$$

$= 0.01$ mm $= 10$ microns

04. Ans: (b)

Sol: $10V = 100$ rpm

$= 100 \times 5 = 500$ mm/min

That is for 500mm/min = 10V

1mm /min = 10/500

3000mm/min = $10 \times 3000 / 500 = 60$ V

05. Ans: (a, b, d)

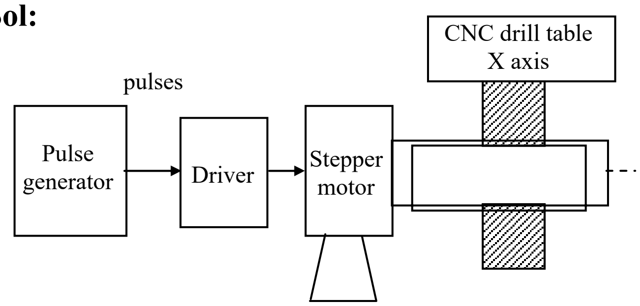
Sol: The ballistic particle manufacturing system uses piezo-driven inkjet mechanism to shoot droplets of molten materials, which get cold welded together on a previously deposited layer.

06. Ans: (a)

Sol: Fused-Deposition Modeling Fused-deposition modeling (FDM) is an RP process in which a ***filament of wax or polymer*** is extruded onto the existing part surface from a workhead to complete each new layer.

07. Ans: (c)

Sol:



BLU = the distance traveled by the table for one pulse of electrical energy input to the motor.

Hence 200 pulse = 1 revolution of motor

= 1 revolution of lead screw = 4mm

That is 1 pulse = 4/200 = 1/50 = 0.02mm, hence BLU does not depends on the frequency of pulse generator

$\therefore$ When frequency of pulse generator is doubled, feed rate of table or tool will double but BLU remains same.

08. Ans: 20

Sol: p = 5 mm

1000 pulses $\rightarrow$ 1 rev of motor

$\rightarrow$ 1 rev of lead screw

Velocity of table = 6 m/min

= 6000 mm/min

= 100 mm/sec

1000 pulses $\rightarrow$ 1 rev of lead screw $\rightarrow$ 5 mm

$$1\,\text{pulse} \rightarrow \frac{5}{1000} = 0.005\,\text{mm}$$

BLU = 0.005 mm

Table speed = BLU × Rate of Pulses

$$\text{Rate of pulses} = \frac{100}{0.005}$$

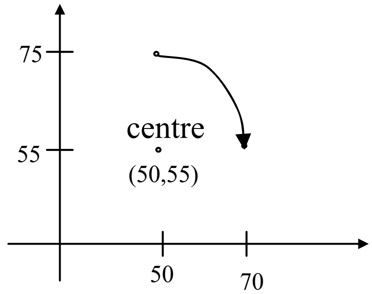
= 20000 pulses/sec

= 20000 Hz

= 20 kHz

09. Ans: (c)

Sol:



10. Ans: (b)

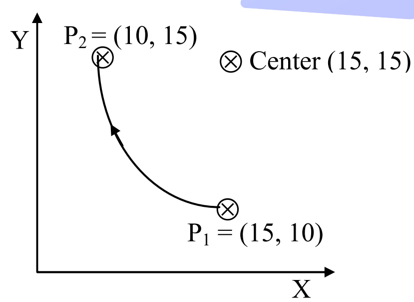
11. Ans: (a)

Sol: G02 – circular interpolation clockwise

G03 – circular interpolation counter clockwise

12. Ans: (c)

Sol: Because the tool has to travel from P_1 to P_2 in clock wise.



13. Ans: (d)

Sol: Appropriate answer but the correct answer is

N05 X5 Y5

N10 G02 X10 Y10 R5

Because in CNC part program we are not suppose to indicate information about one axis more than once in one block.

14. Ans: 60

Sol: In the combined movement, the tool is moving for 50mm with a speed of 100mm/min. whereas in the same time tool is traveling x-axis by only 30mm.

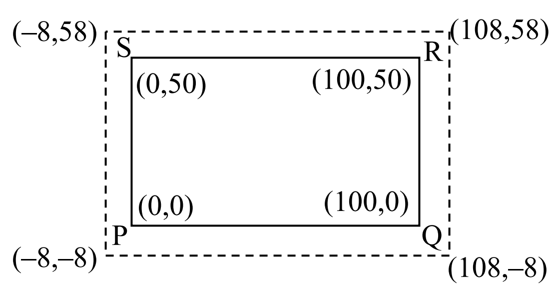
Hence,

For 50 mm $\Rightarrow$ 100 mm/min

For 30 mm $\Rightarrow \frac{100}{50} \times 30 = 60\text{mm/min}$

15. Ans: (a)

Sol: Because diameter of milling cutter is 16mm, the radius is 8mm. the dotted line indicates cutter center position, which is shifted by 8 mm all around the rectangular slot

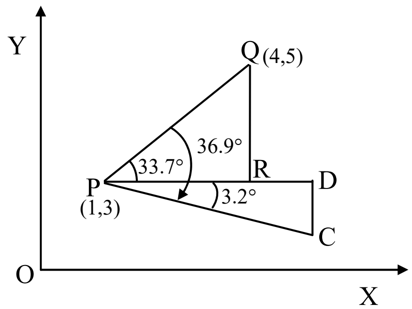


If the given shape is rectangular hole, then the answer is

(8,8), (92,8), (92,42), (8,42), (8,8)

16. Ans: (a)

Sol:



$$PQ = \sqrt{2^2 + 3^2} = 3.6055 = PC$$

PD = PC × cos 3.2 = 3.6

x co-ordinate of point C = 1 + 3.6 = 4.6

DC = 3.6 sin 3.2 = 0.2

y co-ordinate of point C = 3.0 – 0.2 = 2.8

17. Ans: (a)

Sol: "P" after translation = (1+2, 3+3, –5 –4)

= (3, 6, –9)

Rotation about z- axis means

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 6 \\ -9 \\ 1 \end{bmatrix}$$

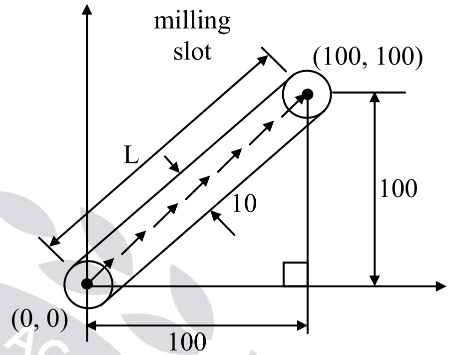
$$= \begin{bmatrix} 0-6+0+0 \\ 3+0+0+0 \\ 0+0-9+0 \\ 0+0+0+1 \end{bmatrix} = \begin{bmatrix} -6 \\ 3 \\ -9 \\ 1 \end{bmatrix}$$

Final point = [–6, 3, –9]

18. Ans: (b)

19. Ans: (b)

Sol: Given coordinates (0,0) to (100, 100)



Depth, d = 2 mm,

Diameter, D = 10 mm

L = actual distance travel by tool

$$L = \sqrt{100^2 + 100^2} = 141.42 \text{ mm}$$

$$\text{Time} = \frac{\text{disatnce}}{\text{speed}}$$

$$= \frac{141.42}{50 \text{ m/min}} \times 60$$

$$= 169.70 \approx 170 \text{ sec}$$

20. Ans: 54.166 mm/sec, 10 micron

Sol: f = 500 pulse/rev

p = 5 mm,

N = 650 rpm

(i) $v = Np = \dfrac{650 \times 5}{60}$

v = 54.166 mm/sec

Now, 1 min = 650 rev

$$1 \text{ sec} = \frac{650}{60} \text{ rev}$$

$\therefore f = 500 \times \frac{650}{60}$

$f = 5416.66$ pulse/sec

And, $v = B.L.U. \times f$

$= 54.166 = BLU \times 5416.66$

B.L.U. = 0.01 mm

B.L.U. = 10 microns

21. Ans: 287

Sol: $\alpha = 0.9°$

$0.9° = 1$ pulse

$360° = \frac{360}{0.9}\text{pulse} = 400\,\text{pulses}$

$\therefore$ 1 revolution = 4 mm pitch = 400 pulses

$\Rightarrow \therefore$ 2.87 mm = 287 pulses

22. Ans: 100 pulse, 60 mm/min

Sol: Pulse rate = N × pulse/rev

$= 15 \times \frac{400}{60} = 100\,\text{pulse/sec}$

Feed rate = 15 rpm × 4 mm/rev

= 60 mm/min

23. Ans: (b, d)

Sol: CNC is a computer assisted process to control general purpose machines from instructions generated by a processor and stored in a memory system.

24. Ans: (c)

Sol: **Laminated Object Manufacturing (LOM):** Solid physical model made by stacking layers of sheet stock, each an outline of the cross-sectional shape of a CAD model that is sliced into layers.

25. Ans: (a, b, c)

Sol: The principal emphasis in RP technologies, all of which work by adding layers of material one at a time to build the solid part from bottom to top. Starting materials include:

- liquid monomers that are cured layer by layer into solid polymers;
- powders that are aggregated and bonded layer by layer; and
- solid sheets that are laminated to create the solid part.

26. Ans: (c, d)

Sol: **Stereo- lithography (STL)** is a process for fabricating a solid plastic part out of a photosensitive liquid polymer using a directed laser beam to solidify the polymer.

SOLID GROUND CURING (SGC): It is a type of additive technique in which laser polymerizes successive layers of resin through a stencil using ultraviolet light to selectively harden photosensitive polymers.

27. Ans: (b, c, d)

Sol: The principal problems with current RP technologies include:

(1) part accuracy,

(2) limited variety of material, and

(3) mechanical performance of the fabricated parts.

Material-related errors include shrinkage and distortion. An allowance for shrinkage can be made by enlarging the CAD model of the part based on previous experience with the process and materials.

Common Data 28 & 29

28. Ans: (b) & 29. Ans: (a)

Sol: A, Stepper motor ⇒ 200 steps / rev

⇒ 200 pulses /rev

Pitch = 4 mm, no. of starts = 1,

Gear ratio = N_0/N_i = 1/4 = U

F = 10000 pulses per min

200 pulses ⇒ 1 rev of motor

⇒ 1/4 rev of lead screw

= 1/4 × 4 × 1 mm linear distance.

= 1mm linear distance

1 pulse = 1/200 = 0.005mm

= 5 microns = 1 BLU

Feed = BLU × pulse /min

= 0.005 × 10000 = 50mm/min

For changing BLU = 10 microns = 0.01mm

⇒ Gear ratio has to be reduced to 1/2

Feed = BLU × pulse /min

⇒ Pulses per min = feed / BLU

= 50/0.01 = 5000

Chapter 9 NTM, Jigs and Fixtures

01. Ans (c) **02. Ans: (d)**

03. Ans: (c)

Sol: In EDM the mechanism of MR is due to melting and vaporization associated with cavitation and also erosion & cavitation or spark erosion and cavitation

04. Ans: (d)

Sol: The high thermal conductivity of the tool material will have high electrical conductivity hence the heat generated with in the tool is low and what ever heat generated it will be distributed easily therefore tool melting rate reduces and tool wear reduces. Where as due to specific heat of work material, the rise in temp of W.P is faster and more amount of MR is possible.

05. Ans: (b)

Sol: Given w = 1 + (2×0.5) = 2

t =5, f = 20 mm/min

MRR = w t f = 2×5×20 = 200 mm^3/min

06. Ans: (a)

Sol: As the thermal conductivity of tool material is high the heat dissipation from the tool is taking place and if the specific heat is high, it needs large amount of heat for raising the temps of tool material up to MP.

07. (i) Ans: (a) , (ii) Ans: (c)

Sol: D = 12 mm, t = 50 mm, R = 40 Ω,

C = 20 μF, V_s = 220 V, V_d = 110 V

$$\text{Cycle time} = R.C \ln\left[\frac{V_s}{V_s - V_d}\right] = t_c$$

$$= 40 \times 20\times10^{-6} \times \ln\left[\frac{220}{110}\right]$$

$$= 554\times10^{-6}\ \text{sec} = 0.55\ milli\,\text{sec}$$

Average power input = W

$$= \left[\frac{E}{t_c}\right] = \left[\frac{0.5\times CV_d^{\ 2}}{t_c}\right]$$

= 218 W = 0.218 kW

08. Ans: (b)

Sol: For Rough machining i.e. stock removal the electrolyte should have high electrical conductivity, called passivity electrolyte, where as for finish machining the electrolyte should have low electrical conductivity called non–passivity electrolyte will be used.

09. Ans: (b)

Sol: In ECM

MRR $\propto$ gram atomic weight of material

MRR $\propto$ Current density

$$MRR \propto \frac{1}{\text{distance between tool and work}}$$

MRR $\propto$ Thermal conduction of electrolyte.

10. Ans: (a)

Sol: In ECM

MRR $\propto$ gram atomic weight of material

$\propto$ Current density

$$\propto \frac{1}{\text{distance between tool and work}}$$

$\propto$ Thermal conduction of electrolyte.

11. Ans: (b)

Sol: I = 5000 A

A = 63, Z = 1, F = 96500

$$MRR = \frac{AI}{ZF} = \frac{5000\times63}{1\times96500}$$

$$= 3.264\ \text{g/sec}.$$

12. Ans: (a)

Sol: A = 55.85, Z = 2, F = 96540

Specific resistance = 2Ω-cm

Voltage = 12V

Inter electrode gap = 0.2 mm

Resistance

$$R = \frac{\text{Sp. Resistance} \times \text{Inter electrode gap}}{\text{Suface area}}$$

$$= \frac{2\times10\times0.2}{20\times20} = 0.01$$

$$I = \frac{V}{R} = \frac{12}{0.01} = 1200\text{A}$$

$$MRR = \frac{AI}{ZF} = \frac{55.85\times1200}{2\times96540}$$

$$= 0.3471\ \text{g/sec}$$

13. Ans: 51.542

Sol: $R = \frac{\rho L}{Area} = \frac{\frac{1}{0.02}\times 0.009}{Area} = \frac{50\times 0.009}{Area}$

$I = \frac{V}{R} = \frac{(12-1.5)\times Area}{50\times 0.009} = 23.333\times Area$

L = 3 + 6 = 9 μm = 0.009

$MRR = \frac{AI}{\rho ZF} = \frac{55.85\times 23.333\times Area}{7860\times 10^{-6}\times 2\times 96500}$

$= 0.98189 \times Area$

$\frac{MRR}{Area} = 0.8590\,mm/sec$

$= 0.8590\times 60\,mm/min$

= 51.542 mm/min

14. Ans: 680

Sol: Velocity of water, V_w = 800 m/s

Mass flow rate of water

$\dot{m}_w = 3.4\,kg/min = 0.0567\,m/s$

Mass flow rate of abrasives

$\dot{m}_a = 0.6\,kg/min = 0.01\,m/s$

Velocity of abrasives is negligible $V_a = 0$

From the conservation of momentum

$\dot{m}_a V_a + \dot{m}_w V_w = (\dot{m}_a + \dot{m}_w)V$

Where V is the velocity of abrasive jet

$(0.01\times 0)+(0.0567\times 800)=(0.0567+0.01)\times V$

45.36 = 0.0667 V

⇒ V = 680.06 m/s

∴ The velocity of abrasive water jet at the end of the focusing tube is 680.06 m/s

15. Ans: (c)

Sol: EDM, ECM and AJM are used for producing straight holes only but in LBM by maneuvering or bending laser gun slightly it is possible perform the Zig – Zag hole.

16. Ans: (b) (Both are Correct)

Sol: In EBM Vacuum is provided to avoid the dispersion of electrons after the magnetic lense, but this vacuum is giving an addition function of providing efficient shield to the weld bead.

17. Ans: (d)

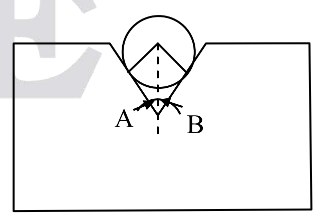
Sol: Out of all the NTM's ECM will give large MRR and EBM will give very small MRR.

18. Ans: (d)

Sol: Relative motion between tool and work piece is not necessary.

19. Ans: (c)

Sol:



If D = D_{min} = 59.9

X_1 = distance between center of shaft and

corner of V – block $= \frac{\frac{59.9}{2}}{\sin 60} = 34.583$

$$X_2 = \frac{\frac{60.1}{2}}{\sin 60} = 34.698$$

Error in depth = $2(X_2 - X_1) = 0.223$ mm

20.

Sol: Resolving the force "F" into Horizontal

$F \sin\alpha = 100$ .... (1)

$F \cos\alpha = 100 + 100 = 200$ ...... (2)

$$\frac{(1)}{(2)} = \tan\alpha = \frac{100}{200}$$

$$\alpha = \tan^{-1}\left(\frac{1}{2}\right) = 26.565^{\circ}$$

$$F = \frac{100}{\sin\alpha} = 223.6 \text{ kg}$$

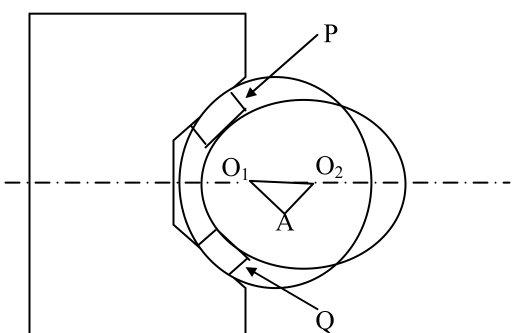
Taking the moments about vertical axis

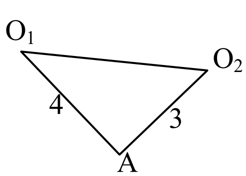
$xF\cos\alpha + 100 \times 30 = 100 \times 30 + 100 \times 20$

$\Rightarrow$ x = 10 mm

21. (i) Ans: (d), (ii) Ans: 10.6 mm

Sol:





$$O_1O_2 = \sqrt{4^2 + 3^2} = 5$$

$$O_1O_2 = 5 = \sqrt{x^2 + x^2}$$

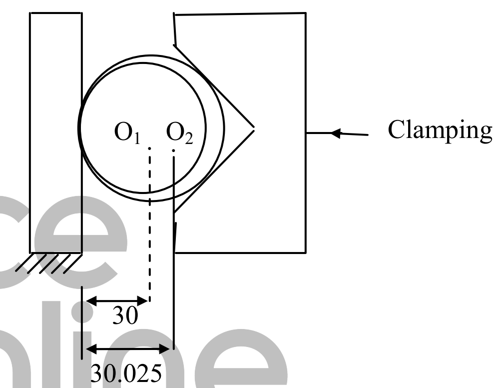
x = 3.5

Block of uniform thickness is preferable because of balanced condition.

22.

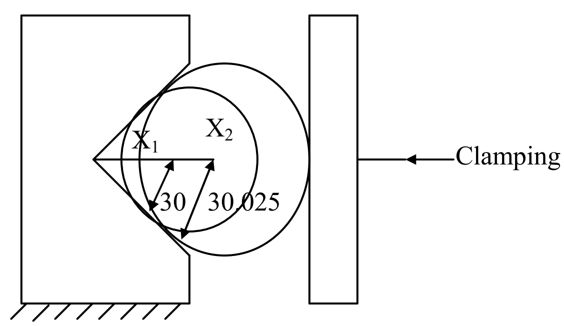
Sol:

(a) Fixed rectangular block and movable V – clamp.



Positional error = 30.025 – 30 = 0.025 mm

(b) Fixed V – block and movable rectangular block



$$x_1 = \frac{30}{\sin 60} = 34.64$$

$$x_2 = \frac{30.025}{\sin 60} = 34.66$$

(c) Positional error = $x_2 - x_1$ = 0.0298 mm

The positional error is mainly depends on the fixed element. So when fixed V – block and marble V – block is used, the positional error is remains same as (b).

Out of the 3 cases, case (a) is giving lower positional error, hence preferable.

23. Ans: (a, b)

Sol: Limitations for the occurrence of Non-Traditional Machining Methods:

- The tool must be at least 30 to 50% harder than the workpiece material but the workpiece itself is very hard, there is no cutting tool available harder than the one-piece material. For example, die Steel, Tool Steel, tungsten, etc.
- Poor machinability material can't be machined by a conventional method. For example, Alloys
- The machinery of highly brittle material like glass, ceramic, etc. is not possible.
- Machining of very soft material like Rubber is not possible by a conventional method.
- It is not possible to produce very small holes less than 1 mm in conventional by the drilling operation.
- Small size noncircular holes are not possible by broaching operation.
- Producing Complex, Concave curvature components like turbine blades is not possible by conventional methods.
- Making the zigzag hole in the component is not possible with conventional methods.