



ACE
GATE | PSUs

MECHANICAL

ENGINEERING



MECHANICAL ENGINEERING

PRODUCTION TECHNOLOGY

Volume-1 : Study Material with Classroom Practice Questions

Production Technology

Solutions for Volume – I _ Classroom Practice Questions

Chapter- 1 Metal Casting

01. Ans: (d)

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

For standard specimen $H = D = 5.08 \text{ cm}$

$P = 5 \text{ gm/cm}^2$, $V = 2000 \text{ cc}$, $T = 2 \text{ min}$

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

02. Ans: (c)

Sol: Net buoyancy force = Weight of core – weight of the liquid

which is displaced by core

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

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

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

$$= 193.6 \text{ N}$$

03. Ans: (a)

$$\begin{aligned} \text{Sol: Pouring time} &= \frac{\text{Volume}}{A_c \times V_{\max}} \\ &= \frac{2 \times 10^6}{200 \times \sqrt{2 \times 10000 \times 175}} \\ &= 5.34 \text{ sec} \end{aligned}$$

04. Ans: (a)

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

$$A = 800 \text{ mm}^2$$

$$Q = A \times V$$

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

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

$$\begin{aligned} h &= \left(\frac{2}{\sqrt{2 \times 9.81}} \right)^2 = 0.203 \text{ m} \\ &= 203 \text{ mm} \end{aligned}$$

05. Ans: (c)

$$\begin{aligned} \text{Sol: Vol. of casting} &= \frac{\pi}{4} D^2 \times L \\ &= \frac{\pi}{4} \times 150^2 \times 200 \\ &= 3534291 \text{ mm}^3 \end{aligned}$$

$$h_t = 200 + 50 = 250 \text{ mm}$$

$$A_c = A_{\min} = \text{sprue base area}$$

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

$$G.R. = 1:1.5:2$$

$$\text{Pouring time} = \frac{\text{Volume of Casting}}{A_c \times V_{\max}}$$

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

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



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

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

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

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

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

For limiting condition $R_e = 2000$

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

$$\Rightarrow 2000 = \frac{V d}{\nu}$$

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

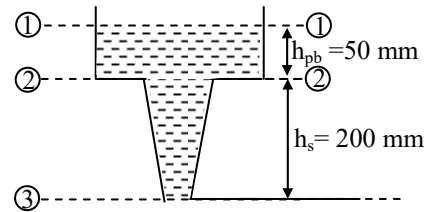
From (1) and (2)

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

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

07. Ans: (c)

Sol:



h = height of sprue = 200 mm

$$A_2 = 650 \text{ mm}^2$$

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

$$g = 10^4 \text{ mm/sec}^2$$

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

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

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

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

$$= 200 + 50 \text{ mm}$$

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

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

$$\Rightarrow A_3 = 290.7 \text{ mm}^2$$

08. Ans: (d)

Sol: $d_{\text{top}} = 225 \text{ mm}$

$$h_t = 250 + 100 = 350 \text{ mm}$$

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

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

$$= 2620 \text{ mm/s}$$

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

$$A_{\text{bottom}} = \frac{40 \times 10^6}{2620} = 15267.17 \text{ mm}^2$$



$$d_{\text{bottom}} = \sqrt{\frac{4 \times 15267.17}{\pi}} = 139.42 \text{ mm}$$

09. Ans: (b)

Sol: $A_2 V_2 = A_3 V_3$

$$\begin{aligned} \frac{\pi}{4} \times 2252 \times \sqrt{2 \times 9810 \times 100} \\ = \frac{\pi}{4} \times d_b^2 \times \sqrt{2 \times 9810 \times 350} \end{aligned}$$

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

So aspiration will not occur.

Common Data for 10 & 11

10. Ans: (a)

11. Ans: (b)

Sol: 3 castings of spherical, cylindrical and cubical

$$V_{\text{sp}} = V_{\text{cube}}$$

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

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

$$V_{\text{cyl}} = V_{\text{sp}}$$

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

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

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

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

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

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

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

12. Ans: 1.205

Sol: Casting - 1 (circular)

Diameter = 20mm, length = 50mm

Casting -2 (elliptical)

Major/Minor = 2, length = 50mm,

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

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

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

$$\begin{aligned} V_{\text{c1}} &= \frac{\pi}{4} \times d^2 \times h = \left[\frac{\pi}{4} 20^2 \times 50 \right] \\ &= 15707.96 \text{ mm}^3 \end{aligned}$$

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

$$= \left[\frac{\pi}{4} 20^2 \times 2 + \pi \times 20 \times 50 \right]$$

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



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

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

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

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

Perimeter = 70.24 mm

Surface area of ellipse

$$= \text{perimeter} \times \text{length} + 2 \times \text{C.S. area}$$

$$= 70.24 \times 50 + 314 \times 2$$

$$= 4140 \text{ mm}^2 = A_{c2}$$

Volume of the ellipse

$$= \text{C.S area} \times \text{length}$$

$$= 314 \times 50 = 15708 \text{ mm}^3 = V_{c2}$$

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

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

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

$$= 1.205$$

13. Ans: 50

Sol: m = 2 kg, Q = 10 kW

Time taken for removing latent heat

$$= 20 - 10 = 10 \text{ sec}$$

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

Latent heat = time × Q

$$= 10 \times 10 = 100 \text{ kJ}$$

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

14. Ans: (a)

Sol: Circular disc casting Squared disc casting

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

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

$$\frac{C_2}{a = 20\text{cm}}$$

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

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

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

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

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

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

$$\Rightarrow V_R = 0.8 V_{C1}$$



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

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

15. Ans: (b)

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

$V_{Sc} = \text{shrinkage volume}$

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

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

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

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

$$V_r \geq 3 V_{sc} \rightarrow \text{Satisfied}$$

$$\tau_r \geq \tau_c$$

where

τ_r = time taken for riser material to solidify

τ_c = time taken for casting to solidify

$$M_r \geq M_c$$

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

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

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

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

$$\therefore \tau_r > \tau_c$$

Hence diameter of riser = 4 cm

Common Data for Q.16 & Q. 17

16. Ans: (a)

17. Ans: (a)

Sol: In centrifugal casting

$$\text{Centrifugal force} = F_C = ma = m r \omega^2$$

$$a = r\omega^2$$

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

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

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

$$\text{Constant} = N^2 D = 37273$$

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

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

18. Ans: 51.84 mm

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

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

$$m_c = 7.05$$

$$m_R = \frac{d}{6} \quad [\because \text{side riser given}]$$

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

$$\Rightarrow d = 51.84 \text{ mm}$$



20. Ans: 0.05 s

Sol: Momentum is considered as constant
Momentum of water = Momentum of liquid metal

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

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

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

Chapter- 2 Welding

01. Ans: (a)

Sol: $V_0 = 80 \text{ V}$, $I_s = 800 \text{ A}$

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,

$$V = 27 + 2 \times 1.5 = 27 + 3 = 30 \text{ V}$$

$$I = 60(9 - 2 \times 1.5) = 360 \text{ A}$$

$$P = 30 \times 360 = 10800 \text{ W}$$

$$\text{If } L = 4 \text{ mm, } V = 27 + 1.5 \times 4 = 33 \text{ V}$$

$$I = 60(9 - 1.5 \times 4) = 180 \text{ A}$$

$$P = 33 \times 180 = 5940 \text{ W}$$

$$\begin{aligned} \text{Change in power} &= 10800 - 5940 \\ &= 4860 \text{ W} \end{aligned}$$

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

03. Ans: 425

$$\text{Sol: } V = 100 + 40L,$$

$$L = 1 \text{ to } 2 \text{ mm, } I = 200 \text{ to } 250 \text{ A}$$

$$L = 1, I = 250$$

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

$$L = 2, I = 200$$

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

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

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

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

$$= 140 + 200 = 340$$

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

04. Ans: 26.7 sec

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

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

$$D_r = 50\% \text{ (rated duty cycle)}$$

$$\text{If } I_d = 1500 \text{ A (desired current)}$$

Desired duty cycle,

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

$$\begin{aligned} D_d &= \frac{\text{Arcon time}}{\text{Total welding time}} = 0.89 \times 30 \\ &= 26.7 \text{ sec} \end{aligned}$$

05. Ans: 27.78 mm/sec

$$\text{Sol: Power} = P = 4 + 0.8L - 0.1L^2$$

For optimum power

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

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

$$\begin{aligned} P &= 4 + 0.8L - 0.1L^2 \\ &= 4 + 0.8 \times 4 - 0.1 \times 4^2 = 5.6 \text{ kW} \end{aligned}$$

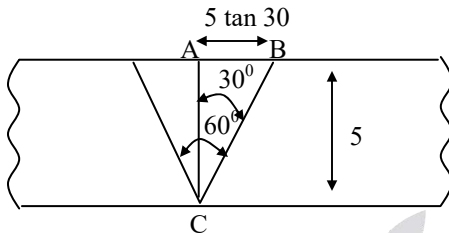
$$\text{Energy losses} = 20\%, \eta = 80\%$$



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

$$= 14433 \text{ mm}^3$$

Weight of W.B = $14433 \times 10^{-6} \times 8$

$$= 115.5 \text{ g}$$

Heat required for melting of W.B

$$= 115.5 \times 1400 = 161.66 \text{ kW}$$

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

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

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

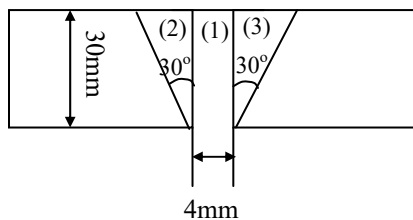
Common data for 06, 07 & 08.

06. Ans: (d)

07. Ans: (d)

08. Ans: (c)

Sol:



$$l = 1 \text{ m} = 1000 \text{ mm};$$

$$t = 30 \text{ mm},$$

$$d = 4 \text{ mm},$$

$$L_t = 450 \text{ mm};$$

$$L_s = 50 \text{ mm},$$

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

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

Total volume of weld bead

$$= \text{volume of weld bead} + \text{crowning}$$

$$= 1.1 \times \text{volume of weld bead}$$

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

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

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

No of electrodes required

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

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

$$x = 200 \text{ mm (given)}$$

$$\text{No of electrodes/pass} = \frac{1000}{200} = 5$$

$$\text{No of passes} = \frac{140}{5} = 28$$

Total Arc on time

$$= \frac{1000}{100} \times 28 = 280 \text{ minutes}$$

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

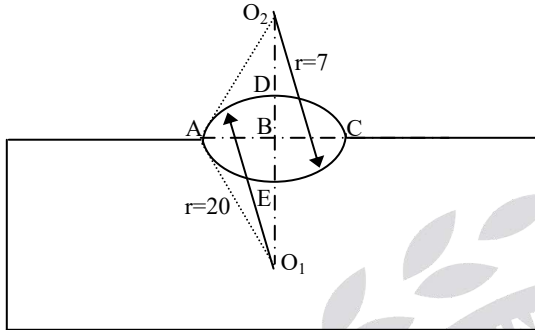


09. Ans: 0.64 mm & 2.1 mm

Sol: Given AC = 10 mm,

$$O_1A = O_1C = 7 \text{ mm},$$

$$O_2A = O_2C = 20 \text{ mm}$$



$$\begin{aligned} \text{Height of Bead} &= BD = O_1D - O_1B \\ &= O_1D - \sqrt{O_1A^2 - AB^2} \\ &= 20 - \sqrt{20^2 - 5^2} \\ &= 0.64 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Depth of Penetration} &= BE = O_1E - O_1B \\ &= (O_1E) - \sqrt{(O_2A)^2 - (AB)^2} \\ &= 7 - \sqrt{7^2 - 5^2} = 2.10 \text{ mm} \end{aligned}$$

Common Data Q. No 10 and 11

10. Ans: (c)

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

$$D = 1.2 \text{ mm}, f = 4 \text{ m /min}, \eta = 65\%,$$

$$\begin{aligned} \text{Heat input} &= \frac{V \times I \times \eta}{\text{speed}} \\ &= \frac{25 \times 200 \times 0.65 \times 60}{18} \\ &= 10.83 \text{ kJ / cm} \end{aligned}$$

11. Ans: (b)

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

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

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

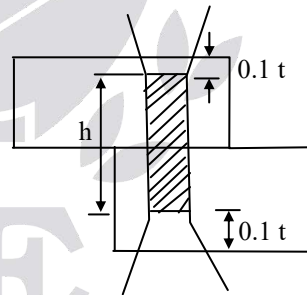
Common data for 12 & 13

12. Ans: 2000 J

$$\begin{aligned} \text{Sol: } H.G &= I^2 R \tau \\ &= (10000)^2 \times 200 \times 10^{-6} \times \frac{5}{50} = 2000 \text{ J} \end{aligned}$$

13. Ans: 1264 J

$$\begin{aligned} \text{Sol: } h &= 2t - 2 \times 0.1 t = 1.8 t \\ &= 1.8 \times 1.5 = 2.7 \text{ mm} \\ D &= 6\sqrt{t} = 6\sqrt{1.5} = 7.35 \text{ mm} \end{aligned}$$



$$\begin{aligned} \text{Vol. of nugget} &= \frac{\pi}{4} D^2 h \\ &= \frac{\pi}{4} (7.35)^2 \times 2.7 = 114.5 \text{ mm}^3 \end{aligned}$$

$$\begin{aligned} \text{Heat required} &= \text{Volume} \times \rho \times \text{heat required /g} \\ &= 114.5 \times 10^{-3} \times 8 \times 1380 \\ &= 1264 \text{ J} \end{aligned}$$



14. Ans: 2.3 & 4.6 MJ

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

ρ = Resistivity of metal

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

$$R_{c_1} = \frac{0.85 \times 2 \times 10^{-5}}{25 \times \pi \times 0.02} = 1.082 \times 10^{-5}$$

$$R_{c_2} = \frac{0.85 \times 2 \times 10^{-5}}{50 \times \pi \times 0.02} = 5.41 \times 10^{-6}$$

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

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

15. Ans: (c)

Sol: Heat generated = Heat utilized

$$I^2 R \tau = \text{Vol. of nugget} \times \rho \times H. R/g$$

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

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

$$I = 4060 \text{ A}$$

Common Data Q. 16 & Q. 17

16. Ans: (c)

Sol: $I = 3000 \text{ A}, \tau = 0.2, R = 200 \mu\Omega$

Volume of nugget = 20 mm^3

Heat generation = $I^2 R \tau$

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

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

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

$$= 344 \text{ J}$$

17. Ans: (b)

Sol: Heat dissipated = $360 - 344 = 16 \text{ J}$

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

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

$V = 200 \text{ mm/min}, L = 300 \text{ mm}$

Heat required (HR) = 40 Kcal

$$= 40 \times 10^3 \times 4.2 \text{ Joule}$$

$$\text{Welding time} = \frac{300}{200} = 1.5 \text{ min} = 1.5 \times 60$$

$$= 90 \text{ sec}$$

Heat input = $2 \times 10^3 \times 90 \text{ Joule}$

$$\eta_{HI} = \frac{HR}{HI} = \frac{40 \times 10^3 \times 4.2}{2 \times 10^3 \times 90} = 0.9333$$

$$= 93.33\%$$

19. Ans: (d)

Sol: Heat supplied = Heat utilized

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

$$= (a \times h) \rho (C_p (T_m - T_r) + \text{LH})$$

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

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

20. Ans: (c)

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

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

Total heat required

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

$$= 212.4 \text{ Joules}$$

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



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 $F = \text{Pressure} \times \text{Area} \times \mu$

$$= 200 \times \frac{\pi}{4} \times 10^2 \times 0.5 = 7854$$

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

$$\text{Torque} = 7854 \times \frac{3}{4} \times 5 \times 10^{-3} = 29.45$$

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

$$= \frac{2\pi \times 4000 \times 29.45}{60000} = 12.33 \text{ kW}$$

22. Ans: 0.065 sec

Sol: Given:

$$\text{Volume} = 80 \text{ mm}^3,$$

$$\text{Current (I)} = 10000 \text{ A},$$

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

$$Q_{\text{lost}} = \text{Heat lost} = 500 \text{ J},$$

$$R = 0.0002 \text{ ohms}$$

Total energy supplied during process

$$= [(80 \times 10) + 500] \text{ J}$$

$$Q_{\text{total}} = 1300 \text{ J} = i^2 R t$$

$$1300 = (10^4)^2 \times 0.0002 \times t$$

$$\Rightarrow t = 0.065 \text{ seconds}$$

23. Ans: 61.53 %

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

$$\text{Heat required} = 10 \times 80 = 800 \text{ J}$$

$$\eta_{\text{thermal}} = \frac{800}{1300} \times 100 = 61.53 \%$$

24. Ans: 464.758 A

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

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

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

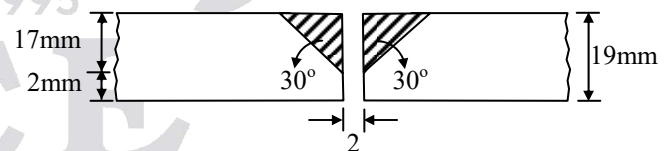
$$\Rightarrow I_d = 464.758 \text{ A}$$

25. Ans: 17

Sol: Number of electrodes

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

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



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

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

$$\text{Area} = \left(\frac{1}{2} \times 9.814 \times 17 \times 2 + (2 \times 19) \right) \times 1.1 \times 1.15$$

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

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

$$\therefore \text{Number of electrodes} = 17$$



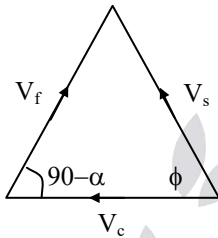
Chapter- 3 Metal Cutting

Common Data for Q. 01 & 02

01. Ans: (a)

02. Ans: (d)

Sol:



$$V_c = 40 \text{ m/min}; \quad V_f = 20 \text{ m/min}$$

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

$$\begin{aligned} \phi &= \tan^{-1} \left(\frac{r \cos \alpha}{1 - r \sin \alpha} \right) \\ &= \tan^{-1} \left(\frac{0.5 \cos 10}{1 - 0.5 \sin 10} \right) = 28.33^\circ \end{aligned}$$

$$\begin{aligned} V_s &= \frac{V_f}{\sin \phi} \times \cos \alpha \\ &= \frac{20}{\sin 28.33} \times \cos 10 = 41.5 \text{ m/min} \end{aligned}$$

03. Ans: 10°

Sol: $f = 0.25 \text{ mm/rev}$,

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

$$t_1 = f \cos C_s$$

$$0.25 = 0.25 \cos C_s$$

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

$$\lambda = 90 - C_s = 90^\circ$$

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

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

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

$$\Rightarrow \alpha_b = i = 10^\circ$$

Common Data for Q.04, 05 & 06

04. Ans: (c)

05. Ans: (b)

06. Ans: (d)

Sol: $d = t_1 = 2 \text{ mm}$, $w = b = 15 \text{ mm}$

$$V_c = 0.5 \text{ m/s}, \quad \alpha = 0$$

$$F_c = 1200, \quad F_T = 800, \quad \phi = 30^\circ$$

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

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

$$\begin{aligned} \text{Power} = P &= F_c \times V_c = 1200 \times \frac{60}{60} \\ &= 1200 \text{ W} \end{aligned}$$

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

$$2\phi - \alpha = 90$$

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



Common Data for Q. 08 & 09

08. Ans: (c)

09. Ans: (c)

Sol: $\alpha = 6^\circ$, $V_c = 1 \text{ m/s}$

$b = w = 3$, $d = t_1 = 1 \text{ mm}$

$t_2 = 1.5 \text{ mm}$; use $2\phi + \beta - \alpha = 90^\circ$

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

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

For minimum energy condition use

$$2\phi + \beta - \alpha = 90^\circ$$

$$\begin{aligned} \beta = 90 + \alpha - 2\phi &= 90 + 6 - 2 \times 35.62 \\ &= 24.76^\circ \end{aligned}$$

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

$$\begin{aligned} V_f = r v_c &= 0.67 \times 1 \times 60 \\ &= 40.2 \text{ m/min} \end{aligned}$$

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: $D_0 = 32 \text{ mm}$, $\alpha = 35^\circ$, $K_1 = 0.1 \text{ mm}$,

$F_C = 200 \text{ N}$, $V_C = 10 \text{ m/min}$,

$L_2 = 60 \text{ mm}$, $F_T = 80 \text{ N}$

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

$$r = \frac{t_1}{t_2} \Rightarrow t_2 = \frac{t_1}{r} = \frac{0.1}{0.59} = 0.169$$

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

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

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

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

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

(In general $\mu < 1$)

Hence by applying classical friction theorem

$$\begin{aligned} \mu &= \frac{\ln \left(\frac{1}{r} \right)}{\frac{\pi}{2} - \alpha} = \frac{\ln \left(\frac{1}{0.59} \right)}{\frac{\pi}{2} - 35 \times \frac{\pi}{180}} \\ &= \frac{0.5276}{1.04} = 0.55 \end{aligned}$$

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

$$\begin{aligned} V_s &= \frac{V_f}{\sin \phi} \cos \alpha = \frac{5.9}{\sin 36.15} \times \cos 35 \\ &= 8.42 \text{ m/min} \end{aligned}$$

12. Ans: 56.23°

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

$F_c = 517 \text{ N}$; $F_T = 217 \text{ N}$

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



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

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

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

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

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

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

13. Ans: 272 N & 436 W

Sol: $S_0 = 0.12 \text{ mm} = t_1$,

$$t = 2.0 \text{ mm}, \quad a_2 = t_2 = 0.22$$

Major cutting for, $b = p_z = F_c$

$$= S_0 \cdot t \cdot \tau_s (\xi \sec \gamma - \tan \gamma + 1)$$

$$S_0 = 0.12, \quad \tau_s = 400$$

$$t = 2 - 0,$$

$$\xi = \frac{t_2}{t_1} = \frac{a_2}{S_0} = \frac{0.22}{0.12} = 1.83$$

$$\gamma = 0$$

$$P_z = 0.12 \times 2.0 \times 400 (1.83 \sec 0 - \tan 0 + 1)$$

$$= 272 \text{ N}$$

$$\text{Power} = p = F_c \times V_c = p_z \times \frac{V_f}{r}$$

$$= p_z \times V_f \times \xi = 271 \times \frac{52.6}{60} \times 1.83$$

$$= 436 \text{ W}$$

14. Ans: (d)

Sol: $\phi = 30^\circ$, $F_T = 800 \text{ N}$, $F_C = 1200 \text{ N}$

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

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

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

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

Common Data for Q. 15 & 16

15. Ans: (a)

16. Ans: (b)

Sol: $D = 100 \text{ mm}$, $f = 0.25 \text{ mm/sec}$,

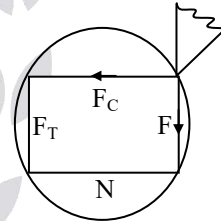
$$d = 4 \text{ mm}$$

$$V = 90 \text{ m/min}$$

$$F_C = 1500 \text{ N}$$

$$F_C = N = 1500$$

$$F_T = F$$



Common Data for Q. 17 & 18

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

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

$$a = 0, 3 \quad b = 0, 3, \quad c = 0, 15$$

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

$$T_1 = T_2 = 60$$

$$V_1 T_1^a f_1^b d_1^c = V_2 T_2^a f_2^b d_2^c$$



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

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

$$V_2 = 1.11 V_1$$

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

Productivity is proportional to MRR

% change in productivity

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

$$= \frac{f_2 d_2 V_2 - f_1 d_1 V_1}{f_1 d_1 V_1} = 11\%$$

19. Ans: 49.2 %

Sol: T_0, V_0 = original tool life and velocity

$$\text{If } V_1 = 1.2 V_0 \quad T_1 = 0.5 T_0$$

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

$$V_1 T_1^n = V_0 T_0^n$$

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

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

$$V_0 T_0^n = V_2 T_2^n$$

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

% change in tool life

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

20. Ans: (b)

Sol: Let Q = no. of parts produced

$$T.C \text{ on E.L} = T.C \text{ on T.L}$$

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

$$40Q = 500 + 16Q$$

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

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

21. Ans: (a)

Sol: $n = 0.12, C = 130$

$$C^1 = 1.1 \times 130 = 143,$$

$$V = V^1 = 90 \text{ m/min}$$

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

$$V^1 T^{1n} = C^1 \Rightarrow T^1 = \left(\frac{143}{90} \right)^{\frac{1}{0.12}} = 47.4 \text{ min}$$

$$\text{Increased tool life} = 47.4 \text{ min}$$

$$\text{Increase in tool life} = 47.4 - 21.4 = 26 \text{ min}$$

22. Ans: (a)

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

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

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

The feed and depth of are same in both cases

$$V_1 T_1^n = V_2 T_2^n$$



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

$$V_1 T_1^n = V_3 T_3^n$$

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

23. Ans: 30.8 m/min

Sol: $T_C = 3 \text{ min}, \quad T_g = 3 \text{ min},$

$L_m = \text{Rs. } 0.5/\text{min}$

Depreciation of tool regrind = Rs 0.5

$C = 60, \quad n = 0.2$

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

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

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

24. Ans: 57.91

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

$TC = k + C_m + C_t$

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

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

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

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

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

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

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

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

$\therefore V = 57.91 \text{ m/min}$

25. Ans: 2.5 & 23°

Sol: $\alpha = 10^\circ$

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

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

chip reduction coefficient = t_2/t_1

$\Rightarrow \frac{1}{r} = K = 2.5$

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

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



27. Ans: 0.944

Sol: $T = 60 \text{ min}$

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

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

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, $t_1 = 0.2 \text{ mm}$,
 $w = 2.5 \text{ mm}$,
 $F_c = 1177 \text{ N}$,
 $F_t = 560 \text{ N}$

As the cutting is approximated to be orthogonal.

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

$$\begin{aligned} \tan 0^\circ &= \cos \psi \tan \alpha_b - \sin \psi \tan \alpha_s \\ &= \cos 30^\circ \tan 7^\circ - \sin 30^\circ \tan \alpha_s \end{aligned}$$

$$\Rightarrow \alpha_s = 12^\circ$$

Chapter- 4 Machining

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

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

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

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

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

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

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

$$\begin{aligned} \text{Total change time / piece} &= 20 + 10 \times 3 \\ &= 50 \text{ min} \end{aligned}$$

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 = $\frac{N_{\text{follower}}}{N_{\text{Driver}}}$

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

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

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

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

04. Ans: (c)

Sol: 1. Plane turning 2. Taper turning
3. under cutting 4. Thread cutting

05. Ans: (d)

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

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

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

P = pitch

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

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 min, 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 = 2m

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

B = 300 + 5 + 5 = 310

f = 1 mm/stroke, $V_C = 1 \text{ m /sec,}$

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

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

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

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

09. Ans: (d)

Sol: Shaping operation

M = 0.6 , L = 500 mm

Double stroke / time = 15

N = time / D.S = 1/15

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

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

$$= 12 \text{ m / min}$$



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

Approach = 50 m } length wise
Over time = 50 min }

Approach = 5 m } width wise
Over time = 5 m }

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

$l = 800$,

$L = 800 + 50 + 50 = 900$

$B = 400 + 5 + 5 = 410$

$$\begin{aligned} \text{Time / cut} &= \frac{900}{60000} \left(1 + \frac{2}{3} \right) \times \frac{410}{0.5} \\ &= 20.5 \text{ min} \end{aligned}$$

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

Total time = $20.5 \times 2 = 41$ mins

11. Ans: (b)

Sol: Time per hole = $L/f.N$

$$= 25 / (0.25 \times 300)$$

$$= 1/3 \text{ min} = 20 \text{ sec.}$$

Because dia of drill bit was not given, hence

AP_1 is zero.

12.

Sol: $D = 15$ mm, $V_c = 20$ m/min,

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

$N = 425$ rpm

$f = 0.2$ mm / rev

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

Time for idle time = 20s

Tool change time = 300 s

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

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

= 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

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

$$= 0.9812 \text{ min} = 58.87 = 59 \text{ sec}$$

13. Ans: (b)

14. Ans: (b)

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

$D_{\min} = 6.25$ mm

$V = 18$ m/min

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



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

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

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

$$= 1.3195 = 1.32$$

15. Ans: (d)

Sol: Hobbing process

No. of teeth = 30 (Not required)

Module = 3 mm

Pressure angle = 20° (Not required)

Radial depth = Addendum + 1m + 1.25m

$$= 2.25 \text{ module} = 2.25 \times 3$$

Radial depth = 6.75 mm

16.

Sol: Part size = $200 \times 80 \times 60$ mm

$D = 100$ mm, $Z = 12$,

$V = 50$ m/min,

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

$f_t = 0.1$ mm, $AP = OR = 5$ mm

i) With symmetrical milling

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

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

$$L = l + AP_1 + AP + OR$$

$$= 200 + 20 + 5 + 5 = 230$$

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

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

ii) If offset = 5mm with asymmetrical milling

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

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

$$= 80 + 2 \times 5 = 90$$

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

$$= 28.2 \text{ mm}$$

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

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

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

17. Ans: (b)

$$\text{Sol: Crank rotation} = \frac{40}{\text{No. of teeth}}$$

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

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

$$= 1 \left(\frac{9}{21} \right)$$

1 complete revolution and 9 holes in 21 hole circle.



18. Ans: (d)

Sol: $d = 70 \text{ mm}$, $Z = 12 \text{ teeth}$

$V = 22 \text{ m/min}$

$f_t = 0.05 \text{ mm/tooth}$

$$f_m = f_t ZN, N = \frac{1000 V}{\pi d}$$

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

19. Ans: (b)

$$\text{Sol: Crank rotation} = 1 \frac{10}{30} = 1 \frac{1}{3} = \frac{4}{3} \times 360$$

$$= 480^\circ$$

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

20. Ans: (b)

Sol: Given,

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

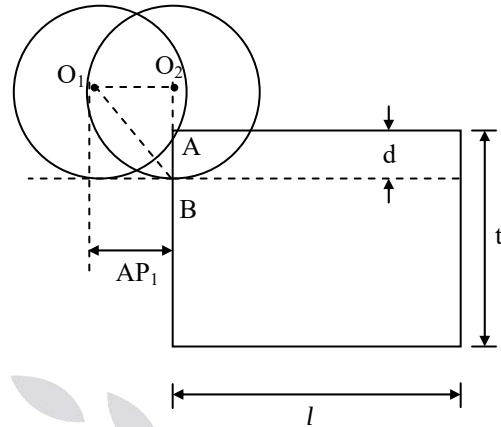
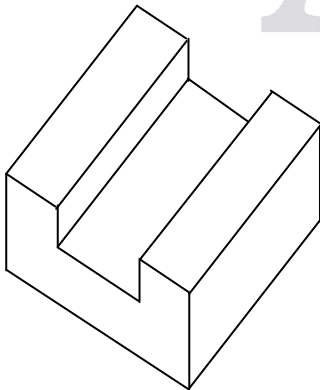
Feed = 0.08 mm/rev

$\text{Depth}_{\text{max}} = 0.5 \text{ mm} = d$

Length of workpiece, $l = 200 \text{ mm}$

Cutting Velocity, $V = 120 \text{ m/min}$

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

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

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

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

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

$$\text{Total time} = 10.227 \times 4 = 40.91$$

$$= 41 \text{ min}$$

21. Ans: 8.05 min

Sol: Broaching machine

$P = 1.5 \text{ kW}$

$d_1 = 20 \text{ mm}$ enlarged to $d_f = 26 \text{ mm}$

$t = 25 \text{ mm}$

$p = 10 \text{ mm/tooth}$

$h = 0.075 \text{ mm/tooth}$



$$V = 0.5 \text{ m/min}$$

Equation for time for broaching operation

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

$$\text{Length of tool travel} = L$$

$$= t + L_e + AP + OR$$

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

L_e = effective length or cutting length

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

$$n = \text{no. of teeth} = d/h = 3 / 0.075 = 40$$

$$L_e = n \times p = 40 \times 10 = 400 \text{ mm}$$

$$L_e = 400 \text{ mm}$$

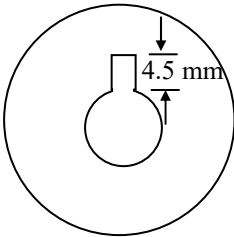
$$\text{Time for broaching} = \frac{t + L_e}{V}$$

$$= \frac{25 + 400}{0.5 \times 100} = 8.05 \text{ min}$$

$$\text{Time for broaching} = 8.05 \text{ min}$$

22. Ans: (c)

Sol:



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

$$d_f = 0$$

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

$$d_r = d_{\text{total}} - (d_f + d_s) \\ = 4.5 - 0.1 = 4.4$$

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

$$\text{Cutting length} = \text{effective length} = L_e$$

$$= L_r + L_s + L_f$$

$$= 44 \times 22 + 8 \times 20 + 4 \times 20$$

$$= 1208 \text{ mm}$$

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: 18

Sol: The output per annum = 800×52
= 41600 units.

The rejection rate is 20%.

∴ The quantity to be produced (including

$$\text{rejection}) = \frac{\text{Required output}}{(1 - \text{rejection rate})}$$

$$= \frac{41600}{(1 - 0.2)} = 52,000 \text{ units}$$

$$\text{Total time required for turning}$$

$$= 52,000 \times 40/60$$

$$= 34666.6 \text{ hours}$$

Production time required with 80 per cent efficiency = $34666.6 / 0.8 = 43333.3$ hours

$$\text{Time available per lathe per annum}$$

$$= 48 \times 52 = 2496 \text{ hrs}$$

∴ Number of lathes required

$$= \frac{\text{Time required (hrs)}}{\text{Time available (hrs)}}$$

$$= \frac{43333.33}{2496} = 17.36 = 18$$

∴ No. of lathes required = 18

Chapter- 5 Metal Forming Process

01. Ans: (a)

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

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

$$A_{1p} = \text{C.S area of P after 1}^{\text{st}} \text{ reduction}$$

$$= 0.7 A_{0p}$$

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

$$\epsilon_p = \text{True strain in "P"} = \ln \left(\frac{A_{0p}}{A_{2p}} \right)$$

$$= \ln \left(\frac{A_{0p}}{0.56 A_{0p}} \right) = 0.58$$

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

$$A_{1Q} = \text{C.S area of Q after 1}^{\text{st}} \text{ reduction}$$

$$= 0.5 A_{0Q}$$

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

03. Ans: (a)

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

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



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

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

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

04. Ans: 1.98 MN

Sol: Given: $H_0 = 4.5 \text{ mm}$

$$H_1 = 2.5 \text{ mm}$$

$$\Delta H = 2$$

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

$$\text{Strip wide} = 450 \text{ mm} = b$$

$$\text{Average coefficient of friction} = 0.1$$

$$\sigma_y = 180 \text{ MPa}$$

$$\text{RSF} = P_{\text{avg}} \times \text{projected area}$$

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

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

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

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

$$\text{RSF} = 1982.64 \text{ kN} = 1.98 \text{ MN}$$

05. Ans: (a)

Sol: $H_0 = 4, H_1 = 3 \text{ mm}, R = 150 \text{ mm},$

$$N = 100 \text{ rpm.}$$

Velocity of strip at neutral point

= Surface Velocity of rollers

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

$$= 1.57 \text{ m/sec}$$

06. Ans: (a)

Sol: $H_0 = 20 \text{ mm},$

$$b = 100 \text{ mm}$$

$$H_1 = 18 \text{ mm},$$

$$R = 250 \text{ mm},$$

$$N = 10 \text{ rpm}, \quad \sigma_y = 300 \text{ MPa}$$

$$\Delta H = 20 - 18 = 2 \text{ mm}$$

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

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

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

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

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

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

$$= 795 \text{ kN.}$$

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

Where

$$a = \text{moment arm} = \lambda L$$

$$= 0.3L \text{ to } 0.4 \times L$$

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

$$= 7110 \text{ kN-mm}$$

$$= 7.11 \text{ kN-m}$$

$$P_{\text{avg}} = \frac{2\pi NT}{60} = \frac{2\pi \times 10 \times 7.110}{60}$$

$$= 7.44 \text{ kW / roller}$$

$$\text{Total Power} = 7.44 \times 2 = 14.88 \text{ kW}$$



07. Ans: (d)

Sol: $H_0 = 16 \text{ mm}$,

$H_1 = 10 \text{ mm}$,

$R = 200 \text{ mm}$

$$\begin{aligned}\text{Angle of Bite} = \alpha &= \tan^{-1} \sqrt{\frac{\Delta H}{R}} \\ &= \tan^{-1} \sqrt{\frac{16-10}{200}} = 9.9\end{aligned}$$

08. Ans: (a)

Sol: Given rolling process

Initial thickness $H_0 = 30 \text{ mm}$

Final thickness $= H_1 = 14 \text{ mm}$

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

$\sigma_y = 200 \text{ MPa}$

Thickness at neutral $H_n = 17.2$

$$\begin{aligned}\text{Forward slip} &= \frac{V_1}{V_n} - 1 = \frac{H_n}{H_1} - 1 \\ &= \frac{17.2}{14} - 1 = 0.2285 = 23\%\end{aligned}$$

$$\begin{aligned}\text{Backward slip} &= 1 - \frac{V_0}{V_n} = 1 - \frac{H_n}{H_0} \\ &= 1 - \frac{17.2}{30} = 42.6\% \approx 43\%\end{aligned}$$

09. Ans: (b)

Sol: Roll separation distance

$$\begin{aligned}&= 2 \times R + H_1 = 2 \times 300 + 25 \\ &= 625 \text{ mm}\end{aligned}$$

10. Ans: (b)

Sol: $d_0 = 15 \text{ mm}$,

$d_f = 0.1 \text{ mm}$

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

$$= \frac{d_0 - d_1}{d_0} \rightarrow \text{1st draw}$$

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

a) 3 stages with 80% reduction at each stage

$$0.8 = \frac{d_0 - d_1}{d_0}$$

$$d_1 = 0.2 d_0 = 3 \text{ mm}$$

$$d_2 = 0.2 d_1 = 0.6 \text{ mm}$$

$$d_3 = 0.2 d_2 = 0.12 \text{ mm} \quad (\text{Error is } 20\%)$$

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

$$d_1 = 0.2 d_0 = 3$$

$$d_2 = 0.2 d_1 = 0.6$$

$$d_3 = 0.2 d_2 = 0.12$$

$$d_4 = 0.8 d_3 = 0.096 \quad (\text{Error is } 4\%)$$

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

$$d_1 = 0.2 d_0 = 3$$

$$d_2 = 0.2 d_1 = 0.6$$

$$d_3 = 0.6 d_2 = 0.36$$

$$d_4 = 0.6 d_3 = 0.216$$

$$d_5 = 0.8 d_4 = 0.1728 \quad (\text{Error is } 72\%)$$

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



11. Ans: (a)

Sol: Given wire drawing process

$$d_0 = 6 \text{ m}, \quad d_1 = 5.2 \text{ mm}$$

Die angle = 18° , diameter land = 4 mm

Coefficient of friction = 0.15

Yield stress = 260 MPa

$$A_0 = \frac{\pi}{4} 6^2 = \frac{\pi}{4} 136 = 21.237$$

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

Drawing stress = σ_2

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

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

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

$$\alpha = 9$$

$$B = 0.15 \times \cot 9^\circ = 0.947$$

$$\sigma_2 = 126.958 \text{ MPa}$$

$$= (260) \left(\frac{1+0.947}{0.947} \right) \left(1 - \left(\frac{21.27^0}{28.270} \right)^{0.947} \right)$$

$$= 260(2.056)(0.2375)$$

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

(By considering friction)

$$= 260 + (130 - 260) e^{\frac{-2 \times 0.15 \times 4}{2.6}}$$

$$\sigma_{\text{total}} = 260 - 81.94 = 178.05 \text{ MPa}$$

$$\text{Total drawing load} = \sigma_t \times A_1$$

$$= 178.05 \times 21.237$$

$$= 3.781 \text{ kN}$$

Common data for Q 12, 13 & 14

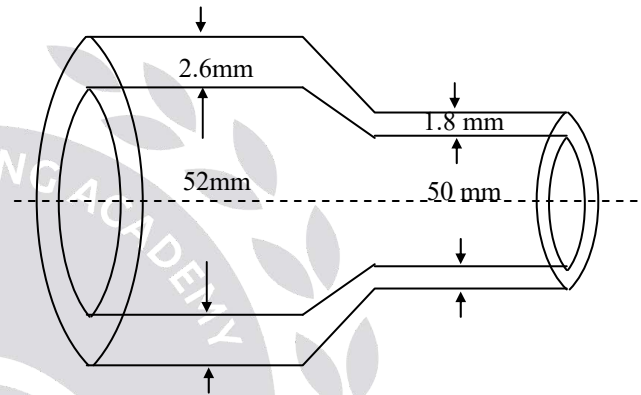
12. Ans: (b), 13. Ans: (c), 14. Ans: (a)

Sol: Initial inside diameter of tube

$$d_0 = 52 \text{ mm}, \quad H_0 = 2.6$$

$$H_1 = 1.8, \quad D_1 = 50 \text{ mm}$$

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



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

$$B = \frac{0.12 + 0.12}{\tan(12^\circ)} = 1.29$$

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

$$\sigma_2 / \sigma_y = \left[\frac{1+1.29}{1.129} \right] \left[1 - \left(\frac{1.8}{2.6} \right)^{1.19} \right]$$

$$\sigma_2 / \sigma_y = 0.64$$

13. Movable mandrel

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

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



14. Floating mandrel

$$B = 0$$

$$\begin{aligned}\frac{\sigma_2}{\sigma_y} &= \ln\left(\frac{h_0}{h_1}\right) \\ &= \ln\left(\frac{2.6}{1.8}\right) = 0.367\end{aligned}$$

Common data for Q 15. & 16.

15. Ans: 6 & 16. Ans: 3.4

Sol: $d_0 = 6 \text{ mm}$, $d_f = 1.34 \text{ mm}$

Given ideal condition

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

$$\sigma_f = 60 \text{ MPa}$$

Maximum reduction condition

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

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

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

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

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

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

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

$$d_1 = 4.53 \dots \dots \dots (1) \text{ stage}$$

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

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

Dia of wire in 2nd stage = 3.424 mm

$$d_1 = d_0 \times c$$

$$\begin{aligned}d_2 &= d_1 \times c = 4.53 \times 0.756 \\ &= 3.424 > 1.34\end{aligned}$$

$$\begin{aligned}d_3 &= d_2 \times c \\ &= 3.424 \times 0.756 \\ &= 2.589 > 1.34\end{aligned}$$

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

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

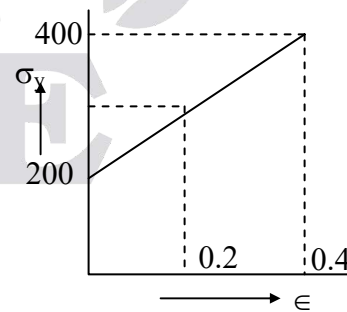
$$d_6 = d_5 \times c = 1.1186 < d_f$$

$\therefore$ Hence No. of stages = 6

Common data for Q 17, 18

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

Sol:



$$d_0 = 12.214, \quad L_0 = 100 \text{ m}$$

$$d_f = 10 \text{ mm}, \quad L_f = ?$$

$$\sigma_y \text{ before} = 200 \text{ MPa},$$

$$\sigma_y \text{ after} = 400 \text{ MPa}$$



$$A_o L_o = A_f L_f$$

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

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

True strain in the drawing process

$$= \epsilon = \ln \frac{A_o}{A_f} = \ln \left(\frac{d_o}{d_f} \right)^2 = 0.4$$

From the graph σ_y at $\epsilon = 0.2$,

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

19. Ans: (b)

20. Ans: (c)

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

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

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

$$= 196346.5 \text{ N}$$

$$= 196 \text{ Tons}$$

21. Ans: (b)

Sol: Extrusion constant = $K = 250$

$$d_o = 100 \text{ mm}, \quad d_f = 50 \text{ mm}$$

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

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

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

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

$$h_o - h_f = 0.1 h_o$$

$$h_f = h_o - 0.1 h_o = 0.9 h_o$$

$$A_o h_o = A_f h_f$$

$$d_o^2 h_o = d_f^2 h_f$$

$$d_f = d_o \sqrt{\frac{h_o}{h_f}} = d_o \sqrt{\frac{h_o}{0.9 h_o}}$$

$$= 1.054 d_o = 1.054 (d_o)_1$$

IInd cylinder

$$A_o h_o = A_f h_f$$

$$d_o^2 h_o = d_f^2 h_f$$

$$d_f = d_o \sqrt{\frac{h_o}{h_f}}$$

$$= d_o \sqrt{\frac{h_o}{0.9 h_o}} = 1.054 (d_o)_2$$

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



Common data for Q 23 & 24

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

Sol: $d_o = 100 \text{ mm}$, $h_o = 50 \text{ mm}$,
 $h_f = 40 \text{ mm}$, $\sigma_y = 80 \text{ MPa}$

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

$$F_{i \min} = A_o \times \sigma_y$$

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

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

$$= 785.350 \text{ kN}$$

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

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

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

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

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 = $A_2 = (1 - 0.3)A_1$

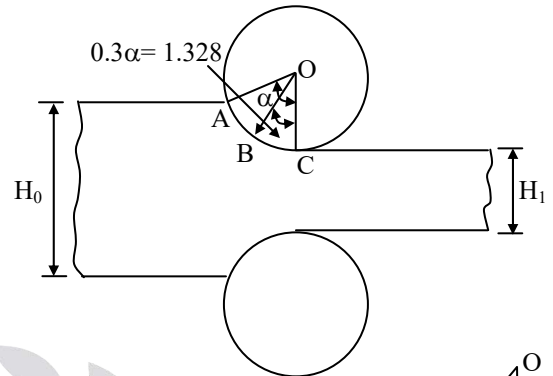
$$= 0.7 \times 0.6 \times A_0 = 0.42 A_0$$

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

$$= 58 \%$$

27. Ans: 7.26

Sol:



$H_o = 10 \text{ mm}$,

$H_1 = 7 \text{ mm}$,

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

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

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

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

$$OD = 500 \times \cos 1.328 = 499.865$$

$$DC = 500 - OD = 0.1343 \text{ mm}$$

Thickness of neutral point = At point B

$$= 7 + 2 \times 0.1343 = 7.2686 \text{ mm}$$

29. Ans: 7.687 MPa, 19.7 %

Sol: $d_0 = 6.25 \text{ mm}$; $d_1 = 5.60 \text{ mm}$;

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

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

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



By applying L – Hospital rule

$$\begin{aligned}\sigma_2 &= \sigma_y \ln \left(\frac{A_0}{A_1} \right) \\ &= \sigma_y \times 2 \ln \left(\frac{d_0}{d_1} \right) \\ &= 7.687 \text{ MPa}\end{aligned}$$

$$\begin{aligned}\% \text{ reduction in area} &= \frac{A_0 - A_1}{A_0} = \frac{d_0^2 - d_1^2}{d_0^2} \\ &= 19.71\%\end{aligned}$$

30. Ans: 29.85 tons

Sol: Initial size = 25×25×150mm

Final size = 6.25×100×150mm

$$\mu = 0.25;$$

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

As given piece is pressed; height is reduced

$$h_0 = 25;$$

$$h_f = 6.25$$

$$A_0 = 25 \times 150;$$

$$A_f = 100 \times 150$$

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

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

$$\pi r_f^2 = 100 \times 150$$

$$r_f = 69.098 \text{ mm}$$

Forging force

$$\begin{aligned}&= 0.7 \times 15 \times 10^3 \left[1 + \frac{2 \times 0.25 \times 69.098}{3 \times 6.25} \right] \\ &= 29847.44 \text{ kg} = 292.80 \text{ kN}\end{aligned}$$

31. Ans: 20.52 kW

Sol: $d_0 = 10 \text{ mm};$

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

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

$$d_1 = 8.36 \text{ mm}$$

$$B = \mu \cot \alpha = 0.1 \cot(6^\circ) = .951$$

$$\begin{aligned}\sigma_2 &= \sigma_y \left(\frac{1+B}{B} \right) \left(1 - \left(\frac{A_1}{A_0} \right)^B \right) \\ &= 240 \left(\frac{1+0.951}{0.951} \right) \left(1 - (0.7)^{0.951} \right) \\ &= 141.687 \text{ MPa}\end{aligned}$$

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

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

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

$$P(\text{motor}) = \frac{F_d \times v}{\eta_{\text{motor}}}$$

$$P = \frac{7.8 \times 2.5}{0.95}$$

$$\Rightarrow P = 20.52 \text{ kW}$$



Chapter- 6 Sheet Metal Operation

Common data for Q. 1 to 5

01. Ans: (b)

Sol: For punching operation

$$\text{Punch size} = \text{Hole size} = 12.7$$

$$\text{Die size} = \text{punch size} + \text{clearance}$$

$$= 12.7 + 2 \times 0.04 = 12.78$$

02. Ans: (a)

Sol: Die size = Blank size = 25.4mm

$$\text{Punch size} = \text{Die size} - 2(\text{radial clearance})$$

$$= 25.4 - 2(0.04)$$

$$\text{Punch size} = 25.32 \text{ mm}$$

03. Ans: (b)

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

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

$$= 40 + 80 = 120 \text{ kN}$$

04. Ans: (c)

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

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

$$\Rightarrow \text{force required} = 80 \text{ kN}$$

05. Ans: (b)

$$\text{Sol: } F_p = \frac{F_{p \max} \cdot Kt}{Kt + I}$$

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

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

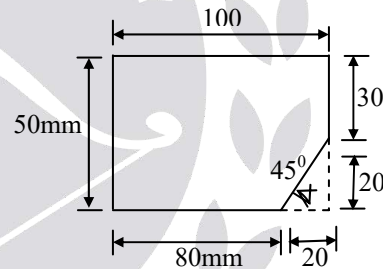
$$= \frac{80 \times 0.6 \times 1.25}{0.6 \times 1.25} = 34.28 \text{ kN}$$

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

Common data for Q. 06, 07 & 08

06. Ans: 83.6 N

Sol:



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

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

07. Ans: 66.88 J

Sol: Work done in blanking open

$$= F_{\max} \cdot K \cdot t$$

$$= 83.6 \times 10^3 \times 0.4 \times 2 \times 10^3$$

$$= 66.88 \text{ J}$$

08. Ans: 1.98 mm

Sol: $I = ?$

$$F = 24 \text{ kN}$$



$$F_{\max} = 83.6 \text{ kN}$$

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

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

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

09. Ans: (a)

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

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

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

$$= \pi \times 1.5 \times 0.4 \times \frac{2}{\pi} = 3 \text{ kN}$$

Common Solution for Q. 10 & 11

10. Ans: (a)

11. Ans: (b)

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

$$K = 0.2$$

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

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

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

Shear provided over a length of

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

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

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

12. Ans: (d)

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

$$\tau_u = 350 \text{ MPa}$$

Diameter clearance = C

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

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

In piercing

$$P.S = H.S = 25 \text{ mm.}$$

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

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

$$= 68.72 \text{ kN.}$$

13. Ans: (a)

Sol: Die size = Blank size = $25 - 0.05$

$$= 24.95$$

Punch size = Die size – clearance

$$= 24.95 - 2 \times 0.06 = 24.83$$

Common data for Q. 14 & 15

14. Ans: (b)

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

$$\Rightarrow d_1 = \frac{13.22}{1.8} = 7.34 > 5 \text{ cm}$$

$$\Rightarrow d_2 = \frac{7.34}{1.8} = 4.08 < 5 \text{ cm}$$

$$n = 2$$

15. Ans: (a)

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



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

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

$$P_1 = \pi D t \sigma_y$$

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

$$= 196238 \text{ N} = 196.238 \text{ kN}$$

$$E = P_1 h_1 = 196.238 \times 4.11 \times 10^{-3} = 806.6 \text{ kJ}$$

16. Ans: (b)

$$\text{Sol: } \text{DRR}_1 = 0.4 = \frac{D - d_1}{D}$$

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

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

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

$$d_3 < 12 \Rightarrow n = 3$$

17. Ans: (b)

$$\text{Sol: } P_1 = \pi D t \sigma_y = \pi \times 30.2 \times 2 \times 35 = 6641.3$$

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

$$= \frac{6641.3}{\frac{\pi}{4}(18.12^2 - (18.12 - 2 \times 2)^2)}$$

$$= 65.5 \text{ MPa}$$

Common data for 18 & 19

18. Ans: 6

$$\text{Sol: } D = \sqrt{d^2 + 4dh} = \sqrt{30^2 + 4 \times 30 \times 150} \\ = 137.47$$

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

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

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

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

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

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

$$n = 6$$

19. Ans: 52.7 mm

$$\text{Sol: } d_3 = 52.7 \text{ mm}$$

20. Ans: 144.42

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

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

$$= 138.42 + 2 \times 3$$

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

21. Ans: (d)

22. Ans: (c)

$$\text{Sol: } \text{Number of earing defects produced} = 2^n$$

Where n is an integer

So possible option is 64.

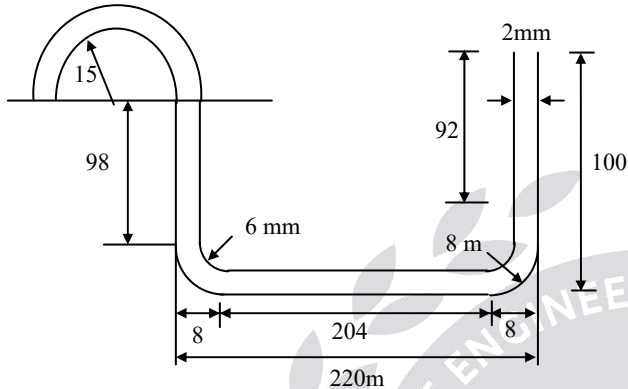
23. Ans: 467 mm

$$\text{Sol: } B_1 = (15 + 0.5 \times 2) \times 180 \times \frac{\pi}{180} \\ = 50.265 \text{ mm}$$



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

$$L_0 = 98 + 204 + 92 + B_1 + 2B_2 \\ = 466.245 \text{ mm}$$



$$C = \text{Clearance} = 0.0032t\sqrt{\tau}$$

$$t = \text{thickness} = 1 \text{ mm}$$

$$\text{where, } \tau = 240 \text{ N/mm}^2$$

$$C = 0.0032 \times 1 \times \sqrt{240}$$

$$= 0.0495 \text{ mm} = 0.05 \text{ mm}$$

$$\text{Die size} = 10 + 2 \times 0.05 = 10.1 \text{ mm}$$

$$\text{Force required} = \tau_s \times \pi d \times t$$

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

$$= 7.536 \text{ kN}$$

24. Ans: (b)

25. Ans: 3

$$\text{Sol: } D = \sqrt{d^2 + 4dh} \\ = \sqrt{50^2 + 4 \times 50 \times 100} = 150 \text{ mm}$$

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

$$0.4 \times 150 = 150 - d_1$$

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

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

$$d_3 = 32.4 < 50$$

$$\therefore n = 3$$

26. Ans: 7.536 kN

Sol: Punching a 10 mm circular hole from 1 mm thickness sheet:

$$\text{Punch size} = \text{Blank size} = 10 \text{ mm}$$

$$\text{Die size} = \text{Punch size} + 2C$$



Chapter- 7 Metrology

7.1 Limits, Fits & tolerances

01. Ans: (a)

Sol: For Clearance fit
L- hole > H- shaft

02. Ans: (c)

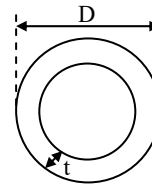
Sol: Hole = $40^{+0.050}_{+0.000}$ mm ,
Min. clearance = 0.01 mm,
Tolerance on shaft = 0.04 mm ,
Max. clearance of shaft = ?
 $0.01 = \text{L.hole} - \text{H.shaft}$
 $0.01 = 40.000 - \text{H.shaft}$
 $\Rightarrow \text{H.shaft} = 40.000 - 0.01 = 39.99\text{mm}$
 $\text{H.shaft} - \text{L.shaft} = 0.04$
 $\text{L.shaft} = 39.99 - 0.04 = 39.95$
Max. clearance = H.hole – L.shaft
 $= 40.05 - 39.95 = 0.10 \text{ mm}$

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:



$$t = 0.01 \text{ to } 0.015 \text{ mm}$$

When, $t = 0.01 \text{ mm}$

$$D = 30.01 + 2 \times 0.01 = 30.03 \text{ mm}$$

$$= 30.05 + 2 \times 0.01 = 30.07 \text{ mm}$$

When, $t = 0.015 \text{ mm}$

$$D = 30.01 + 2 \times 0.015 = 30.04 \text{ mm}$$

$$= 30.05 + 2 \times 0.015 = 30.08 \text{ mm}$$

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

05. Ans: (d)

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

$$B = 30.4 \pm 0.01$$

$$C = 32.7 \pm 0.02$$

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

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

$$= 29.83 = 30^{-0.17}$$

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

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

$$= 29.57$$

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

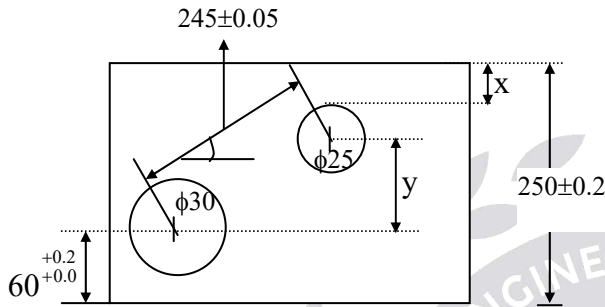
$$\therefore T = 30^{-0.43}$$



06. Anc: (c)

07. (i) Ans: (d)

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



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

$$y_{\max} = 245_{\max} \times \sin 30_{\max} \\ = (245 + 0.05) \sin(30 + 15/60) = 123.45$$

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

(ii) Ans: (c)

$$X_{\max} = 250_{\max} - (60_{\min} + (30/2)_{\min} + y_{\min} + (25/2)_{\min}) \\ = (250 + 0.2) - (60 + 15 + 121.55 + 12.5) \\ = 41.15 \text{ mm}$$

$$X_{\min} = 250_{\min} - (60_{\max} + (30/2)_{\max} + y_{\max} + (25/2)_{\max}) \\ = (250 - 0.2) - (60.2 + 30.025/2 + 123.45 + 25.025/2) \\ = 38.625 \text{ mm}$$

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

08.

Sol: L Hole = BS = 65 mm

$$\text{H Hole} = \text{BS} + \text{Tolerance} = 65.05 \text{ mm}$$

(i) Ans: (c)

$$\text{Allowance} = (L.L.)_{\text{hole}} - (H.L.)_{\text{shaft}}$$

$$\Rightarrow 0.09 = 65 - (H.L.)_{\text{shaft}}$$

$$\Rightarrow (H.L.)_{\text{shaft}} = 65 - 0.09 = 64.91 \text{ mm}$$

$$\text{Tolerance} = (H.L.)_{\text{shaft}} - (L.L.)_{\text{shaft}}$$

$$\Rightarrow 0.05 = 64.91 - (L.L.)_{\text{shaft}}$$

$$\Rightarrow (L.L.)_{\text{shaft}} = 64.86 \text{ mm}$$

$$\text{Shaft} = \text{piston} = 65^{+0.09}_{-0.14}$$

(ii) Ans: (a)

$$(L.L.)_{\text{hole}} = 65 \text{ mm}$$

$$(\text{Tolerance})_{\text{hole}} = (H.L.)_{\text{hole}} - (L.L.)_{\text{hole}}$$

$$\Rightarrow 0.05 = (H.L.)_{\text{hole}} - 65$$

$$\Rightarrow (H.L.)_{\text{hole}} = 65.05 \text{ mm}$$

$$\text{Hole} = \text{Bore} = 65^{+0.05}_{+0.00}$$

(iii) Ans: (b)

$$\text{Max Clearance} = 65.05 - 64.86 \\ = 0.19 \text{ mm}$$

09.

$$\text{Sol: } A_{\max} = 15_{\max} + 30_{\max} \\ = 15.06 + 30.1 = 45.16$$

$$A_{\min} = 15_{\min} + 30_{\min} = 44.84$$

$$A = 45 \pm 0.16 = A \pm \Delta A$$

$$B_{\max} = A_{\max} - 20_{\min}$$

$$= 45.16 - 19.93 = 25.23 \text{ mm}$$

$$B_{\min} = A_{\min} - 20_{\max}$$

$$= 44.84 - 20.07 = 24.77 \text{ mm}$$

$$\Rightarrow B \pm \Delta B = 25 \pm 0.23.$$

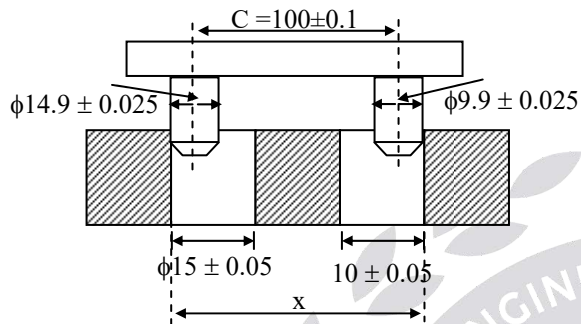


10.

Sol: Let

C = center distance between holes

$C_{\max}$ = max. Outer distance of pins –
sum of min rod holes.



$$X_{\max} = 100_{\max} + \left(\frac{9.9}{2}\right)_{\max} + \left(\frac{14.9}{2}\right)_{\max}$$

$$= 100.1 + \frac{9.925}{2} + \frac{14.925}{2}$$

$$= 112.525 \text{ mm}$$

$$X_{\min} = 100_{\min} + \left(\frac{9.9}{2}\right)_{\min} + \left(\frac{14.9}{2}\right)_{\min}$$

$$= 99.9 + \frac{9.875}{2} + \frac{14.875}{2}$$

$$= 112.275 \text{ mm}$$

$$C_{\max} = X_{\max} - \left[\left(\frac{15}{2}\right)_{\min} + \left(\frac{10}{2}\right)_{\min} \right]$$

$$= 112.525 - \left(\frac{14.95}{2} + \frac{9.95}{2} \right)$$

$$= 100.075 \text{ mm}$$

$$C_{\min} = X_{\min} - \left[\left(\frac{15}{2}\right)_{\max} + \left(\frac{10}{2}\right)_{\max} \right]$$

$$= 112.525 - \left(\frac{15.05}{2} + \frac{10.05}{2} \right)$$

$$= 99.725 \text{ mm}$$

$$\therefore C = 100^{+0.075}_{-0.275}$$

11.

Sol: For the given conditions

$$X = 100.1 + \frac{14.875}{2} + \frac{9.875}{2}$$

$$= 112.475 \text{ mm}$$

$$C = X - \left(\frac{15.05}{2} + \frac{10.05}{2} \right)$$

$$C = 99.925 \text{ mm}$$

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 = 0.03 mm,

Max. interference = 0.08 mm

$$0.03 = L_{\text{shaft}} - H_{\text{hole}}$$

$$L_{\text{shaft}} = 0.03 + 20.03 = 20.06 \text{ mm}$$

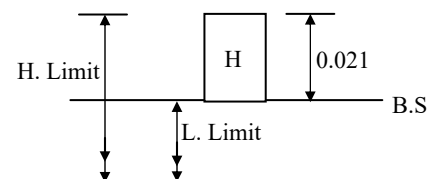
$$0.08 = H_{\text{shaft}} - L_{\text{hole}}$$

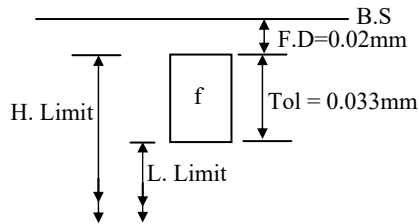
$$H_{\text{shaft}} = 0.08 + 20.00 = 20.08 \text{ mm}$$

$$\text{shaft} = 20^{+0.08}_{+0.06}$$

14.

Sol:





$$D = \sqrt{18 \times 30} = 23.24 \text{ mm}$$

$$i = 0.45 \sqrt[3]{D} + 0.0010 = 1.3 \mu\text{m}$$

$$\text{FD of hole } H = 0$$

$$\text{FD Shaft} = -5.5(23.24)^{0.41} = -20 \mu\text{m}$$

$$\begin{aligned} \text{Hole tolerance, IT7} &= 16i = 20.8 \mu\text{m} \\ &= 21 \mu\text{m} = 0.021 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Shaft tolerance, IT 8} &= 25i \\ &= 32.5 \mu\text{m} = 33 \mu\text{m} \\ &= 0.033 \text{ mm} \end{aligned}$$

$$L - \text{hole} = \text{basic size} = 25 \text{ mm}$$

$$H - \text{hole} = 25 + 0.021 = 25.021 \text{ mm}$$

$$H - \text{shaft} = 25 - 0.02 = 24.98 \text{ mm}$$

$$L - \text{shaft} = 24.98 - 0.033 = 24.947 \text{ mm}$$

(i) **Ans: (a)**

L - hole > H - shaft → Clearance fit

(ii) **Ans: (b)**

Allowance = difference between max.

$$\begin{aligned} \text{material limits} &= L.\text{hole} - H.\text{shaft} \\ &= 25.00 - 24.98 = 0.02 \text{ mm} \end{aligned}$$

(iii) **Ans: (b)**

$$\text{Shaft} = 25_{-0.053}^{-0.02}, \text{ Hole} = 25_{+0.00}^{+0.021}$$

Max clearance = difference between
minimum material limits

$$= H.\text{hole} - L.\text{shaft}$$

$$= (25.021) - (24.947)$$

$$= 0.074 \text{ mm}$$

(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)

$$\text{Sol: } D = \sqrt{18 \times 30} = 23.2$$

$$i = 0.45 \sqrt[3]{D} + 0.001 D = 1.3$$

$$\text{IT8} = 26i = 26 \times 1.3 = 33.8$$

$$= 34 \mu\text{m} = 0.034 \text{ mm}$$

$$\text{Hole size} = 25H_8 = 25_{+0.000}^{+0.034}$$



16. Ans: (a)

Sol: $D = \sqrt{50 \times 80} = 63.24 \text{ mm}$

$i = 1.86 \text{ microns} = 1.9 \text{ microns}$

$IT8 = 25i = 47.5 \text{ microns}$

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) 25H₇

L.L = 25.00

U.L = 25.021

Case (2) 25 H₈

UL = 25.033

Case (3) 25H₆, UL - ?

$(UL)_{H8} - (UL)_{H7} = (UL)_{H7} - (UL)_{H6}$

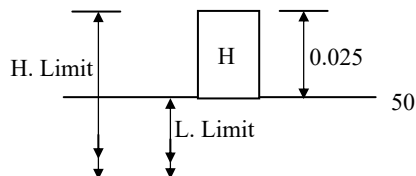
$25.033 - 25.021 = 25.021 - (25 + x)$

$x = 0.009$

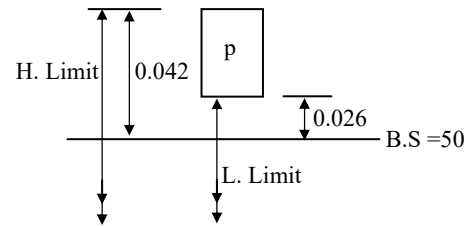
$\therefore (UL)_{H6} = 25.009$

**18. (i) Ans: (a), (ii) Ans: (a),
(iii) Ans: (a), (iv) Ans: (c)**

Sol:



Hole = $50^{+0.025}_{+0.000}$



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 = $20 - 0.035 = 19.965$ mm,

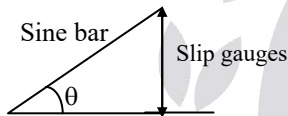
H-hole = $20 - 0.03 = 19.97$ mm,

Hence, **L-shaft (19.98) > H-hole (19.97)**

7.2 Angular Measurements

01. Ans: (a)

Sol:



Given sine bar length = $200 = l$

Angle $\theta = 32^\circ 5' 6'' = 32.085^\circ$

Slip gauge height = h say

$$\sin \theta = \frac{h}{l}$$

$$\sin(32.085^\circ) = \frac{h}{200}$$

$$\Rightarrow h = 106.235$$

02. Ans: i-(b), ii-(a)

Sol: $l = 50$, $L = 500$

$$50 \rightarrow 0.08$$

$$200 \rightarrow 200 \times \frac{0.08}{50} = 0.32$$

$$h' = h + 0.32 = 28.87 + 0.32 = 29.19$$

$$\sin \theta = \frac{h'}{L} = \frac{29.19}{500} = 8'23'32''$$

03. Ans: (d)

04. (i) Ans: (c)

$$\text{Sol: } \sin \theta = \frac{h}{L}$$

$$h = \sin 30^\circ \times 125 = 62.5 \text{ mm}$$

(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: 0.048 mm/m

Sol: Gradient of spirit level

= Sensitivity specified in mm/m

$$= \frac{10}{3600} \times \frac{\pi}{180} \times 1000 = 0.04845 \text{ mm/m.}$$

06. Ans: (d)



07.

Sol: (i) Ans: (b)

$$\sin\theta = \frac{h_2 - h_1}{w}$$

$$h_2 - h_1 = 100\sin 30 = 50$$

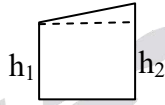
$$h_2 = h_1 + 50 = 75$$

(ii) Ans: (d)

$$\sin(30) = \frac{h - 25}{100.005}$$

$$\Rightarrow h = 75.0025 \text{ mm}$$

$$\Rightarrow h_2 = 75.0025 + 0.005 = 75.0075 \text{ mm}$$



08. Ans: (a)

Sol: L = 250 mm, d = 20 mm

$$h = 100 - (d/2) = 100 - 10 = 90 \text{ mm}$$

$$\sin\theta = \frac{90}{250}$$

$$\Rightarrow \theta = 21.2 \text{ deg}$$

09. Ans: 11.556 mm

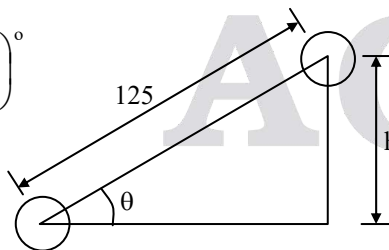
Sol: $\theta = 27^\circ 32'$

$$= 27^\circ + \left(\frac{32}{60}\right)^\circ$$

$$= 27.533^\circ$$

$$\sin\theta = \frac{h}{25}$$

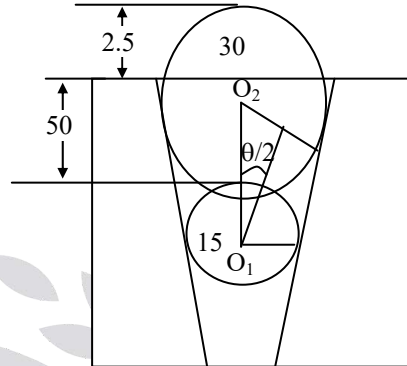
$$h = 11.556 \text{ mm}$$



7.3 Taper Measurement

01. Ans: 19.2°

Sol:



$$\sin(\theta/2) = \frac{d_2 - d_1}{2(h_1 - h_2) - (d_2 - d_1)}$$

$$\sin(\theta/2) = \frac{30 - 15}{2(52.5) - (30 - 15)}$$

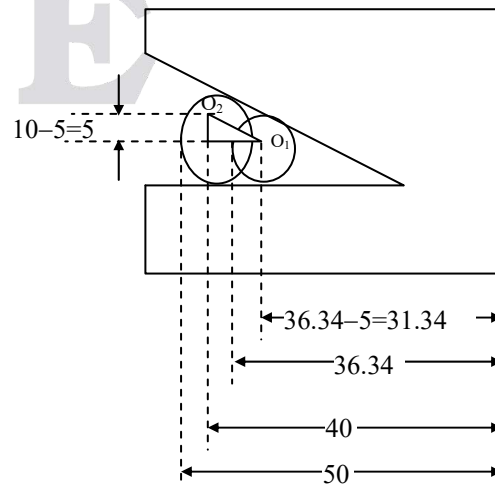
$$= \frac{15}{105 - 15} = 1/6$$

$$\therefore \theta = 19.2^\circ$$

02. Ans: 60

$$\text{Sol: } \tan(\theta/2) = \frac{5}{8.66}$$

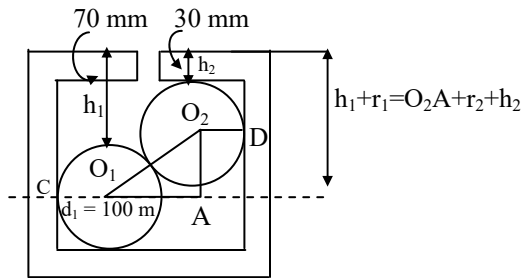
$$\Rightarrow \theta = 60^\circ$$





03. Ans: 112.41 mm

Sol:



$$\text{Diameter} = O_1C + O_1A + O_2D$$

$$= \frac{d_1}{2} + \sqrt{(O_1O_2)^2 - (O_2A)^2} + \frac{d_2}{2}$$

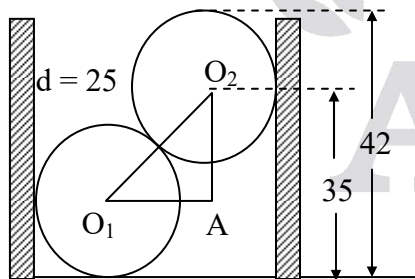
$$O_1O_2 = r_1 + r_2 = 75$$

$$\begin{aligned} O_2A &= h_1 + r_1 - r_2 - h_2 \\ &= 70 + 50 - 30 - 25 = 65 \end{aligned}$$

$$\begin{aligned} D &= 50 + \sqrt{75^2 - 65^2} + 25 \\ &= 112.4165 \text{ mm} \end{aligned}$$

04. Ans: 43.33 mm

Sol:

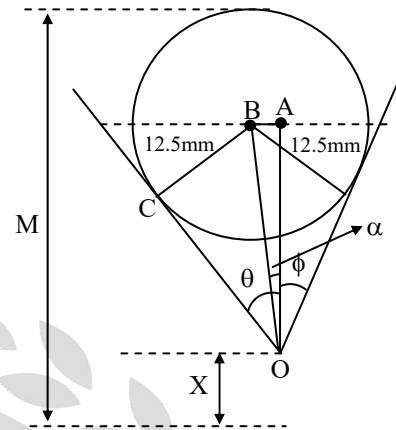


$$O_1A = \sqrt{25^2 - 17^2} = 18.33$$

$$\begin{aligned} D &= r + O_1A + r \\ &= 25 + 18.33 = 43.33 \text{ mm} \end{aligned}$$

05. Ans: 78.074 mm

Sol:



$$\theta + \phi = 45^\circ 50' + 29^\circ 10' = 75^\circ$$

$$\frac{\theta + \phi}{2} = 37.5^\circ$$

$$\begin{aligned} \alpha &= \frac{75}{2} - \phi = 37.5 - \phi = 37.5^\circ - 29^\circ 10' \\ &= 8^\circ 20' \end{aligned}$$

Δ le OBC

$$\sin 37.5 = \frac{BC}{OB}$$

$$\Rightarrow OB = \frac{BC}{\sin 37.5} = \frac{12.5}{\sin 37.5} = 20.533$$

Δ le OAB

$$\cos 8^\circ 20' = \frac{OA}{OB}$$

$$\Rightarrow OA = OB \cos 8^\circ 20' = 20.316 \text{ mm}$$

$$\begin{aligned} X &= M - (OA + R) \\ &= 110.89 - (20.316 + 12.5) \\ &= 78.074 \text{ mm} \end{aligned}$$



06. Ans: 1.1

Sol: $d_2 - d_1 = 10$; $h_2 - h_1 = 12.138$

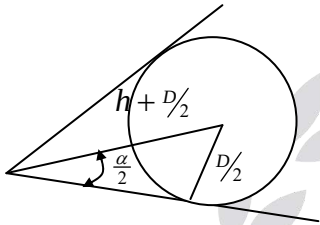
$$\sin\left[\frac{\theta}{2}\right] = \frac{d_2 - d_1}{2 \times (h_2 - h_1) - (d_2 - d_1)}$$

$$\theta = 88.9$$

$$\text{Error} = 90 - 88.9 = 1.1$$

07. Ans: 38.94

Sol:



$$\sin\left[\frac{\alpha}{2}\right] = \frac{D/2}{h + D/2} = \frac{D}{2h + D}$$

$$\sin\left[\frac{\alpha}{2}\right] = \frac{D}{2h + D}$$

If $D = 0$, $h = 0$

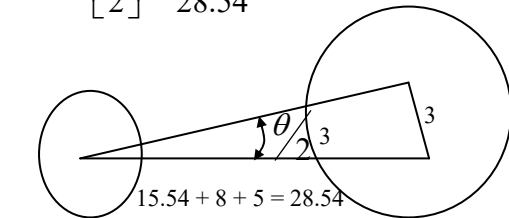
$D = 1$, $h = 1$

$$\sin\left[\frac{\alpha}{2}\right] = \frac{1}{2 \times 1 + 1} = \frac{1}{3}$$

$$\left[\frac{\alpha}{2}\right] = 19.47 \Rightarrow \alpha = 38.94$$

08. Ans: (d)

Sol: $\tan\left[\frac{\theta}{2}\right] = \frac{3}{28.54}$



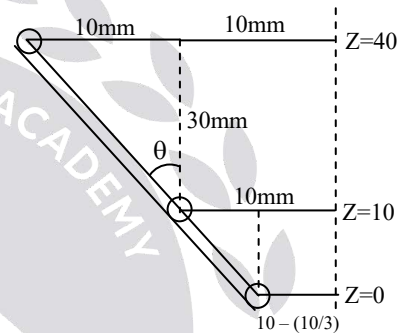
$$\frac{\theta}{2} = \tan^{-1}\left(\frac{3}{28.54}\right) = 6^\circ$$

$$\text{Taper angle} \left(\frac{\theta}{2}\right) = 6^\circ$$

$$\text{Included angle} = 12^\circ$$

09. Ans: (c)

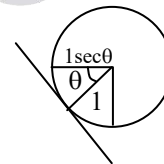
Sol: $\tan \theta = \frac{10}{30} \Rightarrow \theta = \tan^{-1}(1/3) \Rightarrow \theta = 18.434^\circ$



Distance at $Z = 0$,

$$D_0 = 2\left(10 - 10 \tan 30^\circ\right) = 2\left(10 - \frac{10}{3}\right)$$

$$= 6.67 \times 2 = 13.33 \text{ mm}$$



With probe diameter compensation

$$D_{\text{actual}} = 13.334 + 2 \times r \sec \theta$$

$$= 13.334 + 2 \times (1 \text{ sec} \times 18.435)$$

$$= 15.442 \text{ mm.}$$

10. Ans: (d)



7.4 Screw Thread Measurements

01. Ans: (d)

Sol: Major diameter = $s + (R_2 - R_1)$
 $= 35.5 + (11.8708 - 9.3768)$
 $= 37.994 \text{ mm}$

02. Ans: (a)

Sol: Minor diameter
 $= 30.5 + (15.3768 - 13.5218)$
 $= 32.355 \text{ mm}$

Correct answer is (a)

03. Ans: (a)

Sol: best wire diameter, $d = \left(\frac{p}{2}\right) \sec\left(\frac{\theta}{2}\right)$
 $= \left(\frac{3.5}{2}\right) \sec\left(\frac{60}{2}\right) = 2$

$M = 30.5 + (12.2428 - 13.3768)$
 $= 29.366 \text{ mm}$

$D_e = M - \left(d + \frac{p}{2} \tan \frac{\theta}{2}\right)$
 $= M - \left(2 + \frac{3.5}{2} \times \tan 30\right)$
 $= 29.366 - 3.010366 = 26.355 \text{ mm}$

04. Ans: (a)

Sol: $VED = D_e \pm VC$

$VC = \delta P \cos \frac{\theta}{2} + 0.0131P(\delta\theta_1 + \delta\theta_2)$

$\delta P = \text{pitch error}$

$\delta\theta_1, \delta\theta_2 - \text{flank angle errors in deg}$

$\delta\theta_1 = 7^1 = 0.11667 - 2.04 \times 10^{-3}$

$\delta\theta_2 = 9^1 = 0.15 - 2.618 \times 10^{-3}$

$\delta P = 0.004$

$D_e = 30.6651$

$\theta = 60^\circ$ (metric thread)

Virtual correction

$VC = (0.004 \times \cos 30) + (0.0131 \times 3.5(0.11667 + 0.15))$

$VC = 0.01569$

$VED = D_e + VC$
 $= 30.6651 + 0.01569 = 30.6807$

05. Ans: (a)

06. Ans: (d)

Sol: $\sin \left[\frac{\theta}{2}\right] = \frac{R_2 - R_1}{M_2 - M_1 - (R_2 - R_1)}$
 $= \frac{1.4434 - 0.8660}{22.06 - 20.32 - (1.4434 - 0.8660)}$
 $\theta = 59.5566 = 59^\circ 33' 23''$

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 $\times$ no of starts

$\text{Pitch} = \frac{\text{lead}}{\text{no of starts}} = \frac{3}{2} = 1.5$



09. Ans: (d)

Sol: Rollers will not used to measure pitch diameter.

$$\begin{aligned}\text{Best size diameter } d &= \left(\frac{p}{2}\right) \sec\left(\frac{\theta}{2}\right) \\ &= \left(\frac{2}{2}\right) \sec\left(\frac{60}{2}\right) \\ &= 1.1547 = 1.155\end{aligned}$$

10. Ans: (d)

$$\begin{aligned}\text{Sol: } V.C &= \delta P \cdot \cos\left(\frac{\theta}{2}\right) + 0.0131P(\delta\theta_1 + \delta\theta_2) \\ &= 0.2 \cos 30 = 0.346\end{aligned}$$

Common data Q 11 & 12

11. Ans: (a)

$$\begin{aligned}\text{Sol: Best size diameter, } d &= \left(\frac{p}{2}\right) \sec\left(\frac{\theta}{2}\right) \\ &= \left(\frac{2}{2}\right) \sec\left(\frac{60}{2}\right) = 1.155 \text{ mm}\end{aligned}$$

12. Ans: (a)

$$\begin{aligned}\text{Sol: } D_{\text{eff}} &= M - \left(d + \frac{p}{2} \tan \frac{\theta}{2}\right) \\ &= 16.455 - 1.155 \cdot \tan 30 = 14.7226 \text{ mm}\end{aligned}$$

13. Ans: 1.732 mm

$$\begin{aligned}\text{Sol: The best wire size} &= (p/2) \sec(\alpha/2) \\ &= (3/2) \sec(60/2) \\ &= 1.732 \text{ mm}\end{aligned}$$

7.5 Surface Finish Measurement

01.

(i) Ans: (c)

$$\begin{aligned}\text{Sol: } R_t &= \text{max. peak} - \text{min. valley} \\ &= 42 - 18 = 24\end{aligned}$$

(ii) Ans: (c)

$$\begin{aligned}\text{Sol: } CLA(R_a) &= (h_1 + h_2 + h_3 + \dots + h_{10})/n \\ &= \frac{300}{10} = 30\end{aligned}$$

(iii) Ans: (b)

$$\begin{array}{l} \text{Sol: Peaks } 35 \quad 40 \quad 35 \quad 42 \quad 35 \\ \text{Valley } 25 \quad 22 \quad 18 \quad 25 \quad 23 \end{array}$$

$$\begin{aligned}R_z &= \frac{\Sigma \text{peaks} - \Sigma \text{valleys}}{\text{no of peaks}} \\ &= \frac{(35 + 40 + 35 + 42 + 35) - (25 + 22 + 18 + 25 + 23)}{5} = 15\end{aligned}$$

(iv) Ans: (b)

$$\text{Sol: } RMS = \sqrt{\frac{h_1^2 + h_2^2 + h_3^2 + \dots + h_n^2}{n}} = 33$$

$$\text{(or) } RMS = 1.1 \times R_a = 1.1 \times 30 = 33$$

(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)

$$\begin{aligned}\text{Sol: } R_a &= \frac{\sum A}{w} \times \frac{1}{HM} \times \frac{1000}{VM} \\ &= \frac{480 + 480}{0.8} \times \frac{1}{100} \times \frac{1000}{15000} = 0.8\end{aligned}$$

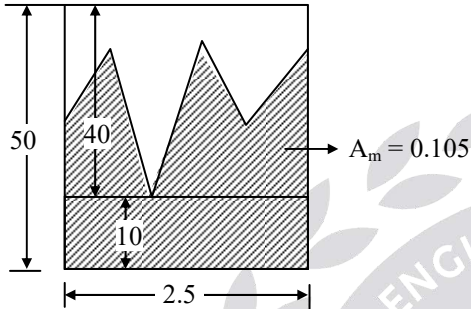


03. Ans: (d)

$$\text{Sol: } R_t = \frac{0.05}{\tan 45} = 50 \mu\text{m}$$

04. Ans: (c)

Sol:



$$A_{m \text{ act}} = 0.105 - 0.01 \times 2.5 = 0.08$$

$$K = \frac{A_{m \text{ act}}}{(10^{-3} \times 2.5) \times 0.04}$$

$$= \frac{0.08^2}{(2.5 \times 10^{-3} \times 0.04)} \times \frac{1}{1000} = 0.8$$

05. Ans: (c)

06. Ans: (c)

07. Ans: (a)

08. Ans: 2

$$\text{Sol: } R_a = \frac{\Sigma h}{n} = \frac{16 \times 4 + 16 \times 0}{32} = \frac{64}{32} = 2 \mu\text{m}$$

Chapter- 8 Advanced Machining Methods Numerical Control (NC)

01. Ans: (a)

Sol: Pitch of lead screw = 5mm

$$1 \text{ rev} = 5\text{mm}$$

$$1\text{mm} = 1/5 \text{ rev}$$

$$200\text{mm} = 1/5 \times 200 = 40\text{rev}$$

$$= 40 \times 360 = 14400 \text{ deg.}$$

02. Ans: (b)

Sol: Pitch of lead screw = 5mm,

$$\text{BLU} = 0.005\text{mm}$$

⇒ Distance travelled /pulse

Length of travel = 9mm

$$\text{No. of pulses} = L/\text{BLU} = 9 / 0.005$$

$$= 1800 \text{ pulse.}$$

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



$\Rightarrow 3.6$ mm of linear movement of axis

360 pulses = 3.6mm

1 pulse = $3.6/360 = 0.01$ mm

= 10 microns

04. Ans: (b)

Sol: $10V = 100$ rpm

= $100 \times 5 = 500$ mm/min

That is for 500mm/min = 10V

1mm /min = $10/500$

$3000\text{mm/min} = 10 \times 3000 / 500 = 60$ V

Common Data 05 & 06

05. Ans: (b) & 06. Ans: (a)

Sol: A, Stepper motor $\Rightarrow 200$ steps / rev

$\Rightarrow 200$ pulses / rev

Pitch = 4 mm, no. of starts = 1,

Gear ratio = $N_0/N_f = 1/4 = U$

$F = 10000$ pulses per min

200 pulses $\Rightarrow 1$ rev of motor

$\Rightarrow 1/4$ rev of lead screw

= $1/4 \times 4 \times 1$ mm linear distance.

= 1mm linear distance

1 pulse = $1/200 = 0.005$ mm

= 5 microns = 1 BLU

Feed = BLU $\times$ pulse /min

= $0.005 \times 10000 = 50$ mm/min

For changing BLU = 10 microns

= 0.01mm

$\Rightarrow$ Gear ratio has to be reduced to $1/2$

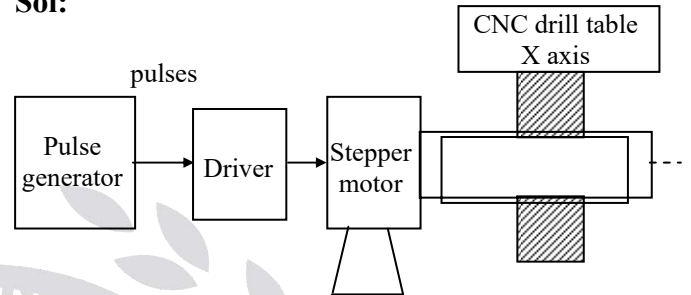
Feed = BLU $\times$ pulse /min

$\Rightarrow$ Pulses per min = feed / BLU

= $50/0.01 = 5000$

07. Ans: (a)

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 = $4/200 = 1/50 = 0.02$ mm, hence BLU does not depends on the frequency of pulse generator. But if the speed of the table means it will get doubled.

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 pulse $\rightarrow \frac{5}{1000} = 0.005$ mm

BLU = 0.005 mm

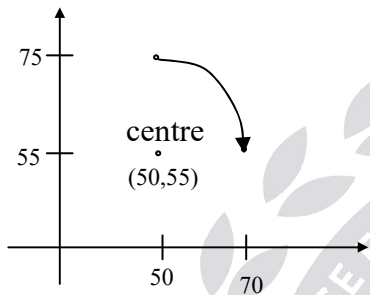


Table speed = BLU $\times$ Rate of Pulses

$$\begin{aligned}\text{Rate of pulses} &= \frac{100}{0.005} \\ &= 20000 \text{ pulses/sec} \\ &= 20000 \text{ Hz} = 20 \text{ kHz}\end{aligned}$$

09. Ans: (c)

Sol:



10. Ans: (b)

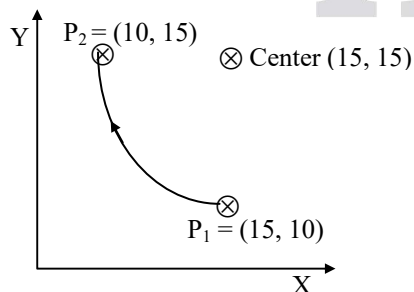
11. Ans: (a)

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.

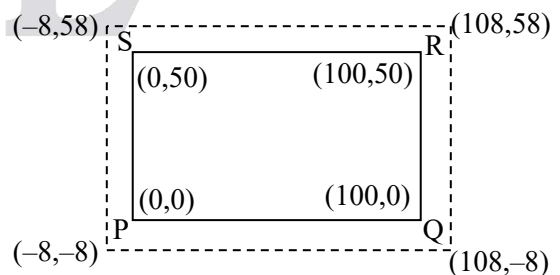
Hence,

For 50mm $\Rightarrow$ 100mm/min

For 30mm $\Rightarrow \frac{100}{50} \times 30 = 60 \text{ mm/min}$

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



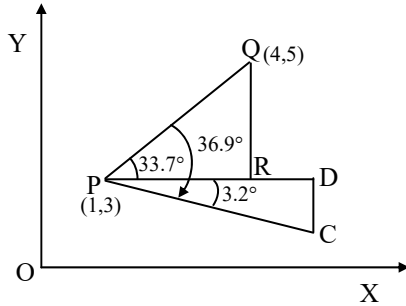
If the given shape is rectangular hole, then the answer is

(8,8), (92,8), (92,42), (8,42), (8,8)



16. Ans: (a)

Sol:



$$PQ = \sqrt{2^2 + 3^2} = 3.6055 = PC$$

$$PD = PC \times \cos 3.2 = 3.6$$

$$x \text{ co-ordinate of point } C = 1 + 3.6 = 4.6$$

$$DC = 3.6 \sin 3.2 = 0.2$$

$$y \text{ co-ordinate of point } C = 3.0 - 0.2 = 2.8$$

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: (a)

Sol: Given coordinates (0,0) to (100, 100)

Mean, $L = 100$, depth, $d = 2$ m

Diameter, $D = 10$

$$AP_C = \sqrt{d(D-d)} \\ = \sqrt{2(10-2)} = 4$$

$$\text{Time/slot} = \frac{104}{f_N} = \frac{104}{50}$$

$$= 2.08 \text{ min}$$

$$= 124.8 \text{ sec} \approx 120$$

20. Ans: 54.166 mm/sec, 10 micron

Sol: $f = 500$ pulse/rev

$p = 5$ mm, $N = 650$ rpm

$$(i) \quad v = Np = \frac{650 \times 5}{60}$$

$$v = 54.166 \text{ mm/sec}$$

Now, 1 min = 650 rev

$$1 \text{ sec} = \frac{650}{60} \text{ rev}$$

$$\therefore f = 500 \times \frac{650}{60}$$

$$f = 5416.66 \text{ pulse/sec}$$

And, $v = \text{B.L.U.} \times f$

$$= 54.166 = \text{BLU} \times 5416.66$$

$$\text{B.L.U.} = 0.01 \text{ mm}$$

$$\text{B.L.U.} = 10 \text{ microns}$$



21. Ans: 287

Sol: $\alpha = 0.9^\circ$

$$0.9^\circ = 1 \text{ pulse}$$

$$360^\circ = \frac{360}{0.9} \text{ pulse} = 400 \text{ pulses}$$

$$\therefore 1 \text{ revolution} = 4 \text{ mm pitch} = 400 \text{ pulses}$$

$$\Rightarrow \therefore 2.87 \text{ mm} = 287 \text{ pulses}$$

22. Ans: 100 pulse, 60 mm/min

Sol: Pulse rate = $N \times \text{pulse/rev}$

$$= 15 \times \frac{400}{60} = 100 \text{ pulse/sec}$$

$$\text{Feed rate} = 15 \text{ rpm} \times 4 \text{ mm/rev}$$

$$= 60 \text{ mm/min}$$

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 within the tool is low and whatever heat generated it will be distributed easily therefore tool melting rate reduces and tool wear reduces. Whereas 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 $w = 1 + (2 \times 0.5) = 2$

$$t = 5, f = 20 \text{ mm/rev}$$

$$\text{MRR} = wtf = 2.5.20 = 200 \text{ mm/min}$$

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 temp of tool material up to MP.



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

Sol: $D = 12\text{mm}$, $t = 50\text{mm}$, $R = 40\ \Omega$,

$C = 20\ \mu\text{F}$, $V_s = 220\text{V}$, $V_d = 110\text{V}$

$$\text{Cycle time} = R.C \ln \left[\frac{V_s}{V_s - V_d} \right] = t_c$$

$$= 40 \times 20 \times 10^{-6} \times \ln \left[\frac{220}{110} \right]$$

$$= 554 \times 10^{-6} \text{ sec} = 0.55 \text{ milli sec}$$

Average power input = W

$$= \left[\frac{E}{t_c} \right] = \left[\frac{0.5 \times C V_d^2}{t_c} \right]$$

$$= 218 \text{ W} = 0.218 \text{ kW}$$

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

$\text{MRR} \propto \text{gram atomic weight of material}$

$\text{MRR} \propto \text{Current density}$

$\text{MRR} \propto \frac{1}{\text{distance between tool and work}}$

$\text{MRR} \propto \text{Thermal conduction of electrolyte.}$

10. Ans: (a)

Sol: In ECM

$\text{MRR} \propto \text{gram atomic weight of material}$

$\propto \text{Current density}$

$\propto \frac{1}{\text{distance between tool and work}}$

$\propto \text{Thermal conduction of electrolyte.}$

11. Ans: (b)

Sol: $I = 5000 \text{ A}$

$A = 63$, $Z = 1$, $F = 96500$

$$\text{MRR} = \frac{AI}{ZF} = \frac{5000 \times 63}{1 \times 96500}$$

$$= 3.264 \text{ g/sec.}$$

12. Ans: (a)

Sol: $A = 55.85$, $Z = 2$, $F = 96540$

Specific resistance = $2\ \Omega\text{-cm}$

Voltage = 12V

Inter electrode gap = 0.2 mm

Resistance

$$R = \frac{\text{Sp. Resistance} \times \text{Inter electrode gap}}{\text{Surface area}}$$

$$= \frac{2 \times 10 \times 0.2}{20 \times 20} = 0.01$$

$$I = \frac{V}{R} = \frac{12}{0.01} = 1200\text{A}$$

$$\text{MRR} = \frac{AI}{ZF} = \frac{55.85 \times 1200}{2 \times 96540}$$

$$= 0.3471 \text{ g/sec}$$



13. Ans: 51.542

$$\text{Sol: } R = \frac{\rho L}{\text{Area}} = \frac{\frac{1}{0.02} \times 0.009}{\text{Area}} = \frac{50 \times 0.009}{\text{Area}}$$

$$I = \frac{V}{R} = \frac{(12 - 1.5) \times \text{Area}}{50 \times 0.009} = 23.333 \times \text{Area}$$

$$L = 3 + 6 = 9 \mu\text{m} = 0.009$$

$$\text{MRR} = \frac{AI}{\rho ZF} = \frac{55.85 \times 23.333 \times \text{Area}}{7860 \times 10^{-6} \times 2 \times 96500}$$

$$= 0.98189 \times \text{Area}$$

$$\frac{\text{MRR}}{\text{Area}} = 0.8590 \text{ mm/sec}$$

$$= 0.8590 \times 60 \text{ mm/min}$$

$$= 51.542 \text{ mm/min}$$

14. Ans: 680

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 to 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 additional function of providing efficient shield to the weld bead.

17. Ans: (d)

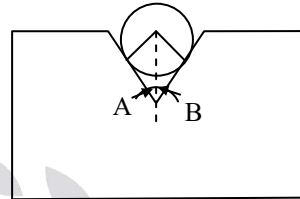
Sol: Out of all the NTM's ECM will give large MRR and EBM will give very small MRR.

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

$$\text{corner of V-block} = \frac{\frac{59.9}{2}}{\sin 60} = 34.583$$

$$X_2 = \frac{\frac{60.1}{2}}{\sin 60} = 34.698$$

$$\text{Error in depth} = 2(X_2 - X_1) = 0.223 \text{ mm}$$

20.

Sol: Resolving the force "F" into Horizontal

$$F \sin \alpha = 100 \quad \dots\dots\dots (1)$$

$$F \cos \alpha = 100 + 100 = 200 \quad \dots\dots (2)$$

$$\frac{(1)}{(2)} = \tan \alpha = \frac{100}{200}$$

$$\alpha = \tan^{-1}\left(\frac{1}{2}\right) = 26.565$$

$$F = \frac{100}{\sin \alpha} = 223.6 \text{ kg}$$

Taking the moments about vertical axis

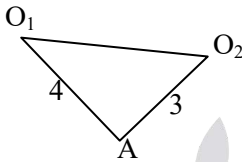
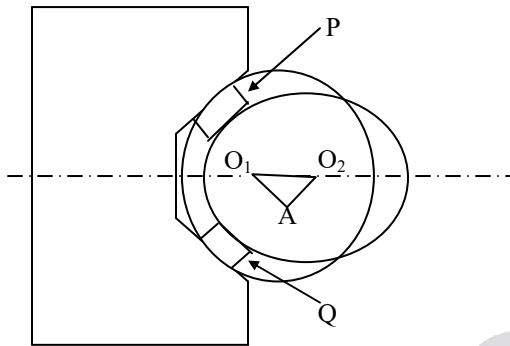
$$xF \cos \alpha + 100 \times 30 = 100 \times 30 + 100 \times 20$$

$$\Rightarrow x = 10 \text{ mm}$$



21. (i) Ans: (d), (ii) Ans: 10.6 mm

Sol:



$$O_1O_2 = \sqrt{4^2 + 3^2} = 5$$

$$O_1O_2 = 5 = \sqrt{x^2 + x^2}$$

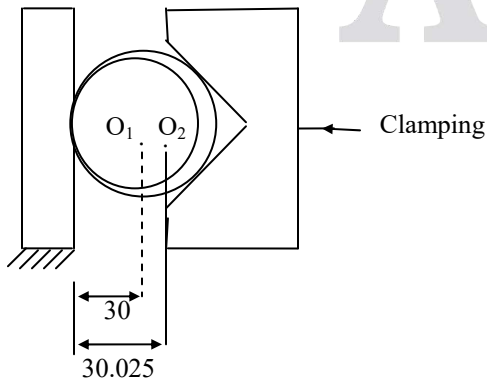
$$x = 3.5$$

Block of uniform thickness is preferable because of balanced condition.

22.

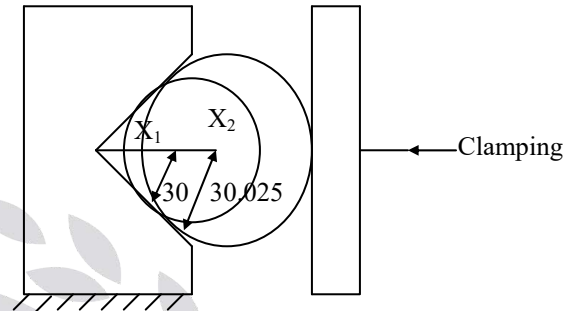
Sol:

(a) Fixed rectangular block and movable V – clamp.



$$\text{Positional error} = 30.025 - 30 = 0.025 \text{ mm}$$

(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 = $x_2 - x_1 = 0.0298 \text{ mm}$

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.