ESE | GATE | PSUs

MECHANICAL ENGINEERING

PRODUCTION TECHNOLOGY

Text Book : Theory with worked out Examples and Practice Questions

Production Technology

(Solutions for Text Book Objective & Conventional Practice Questions)

Chapter 1

Metal Casting

01. Ans: (d)

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

For standard specimen H = D = 5.08 cm

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

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

02. Ans: (c)

Sol: Net buoyancy force = Weight of core – weight of the liquid which is displaced by core

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

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

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

= 193.6N

03. Ans: (a)

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

$$= \frac{2\times10^6}{200\times\sqrt{2\times10000\times175}}$$

= 5.34 sec

04. Ans: (a)

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

A = 800 mm^2

Q = A $\times$ V

$1.6\times 10^{-3} = (800\times10^{-6})\times V$

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

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

= 203 mm

05. Ans: (c)

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

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

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

h_t = 200+ 50 = 250 mm

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

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

G.R.= 1:1.5:2

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

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

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

06. Ans: (c)

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

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

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

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

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

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

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

For limiting condition $R_e = 2000$

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

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

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

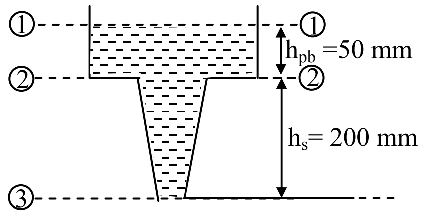
From (1) and (2)

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

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

07. Ans: (c)

Sol:



h = height of sprue = 200 mm

$A_2 = 650\ mm^2$

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

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

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

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

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

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

= 200 + 50mm

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

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

$\Rightarrow A_3 = 290.7\ mm^2$

08. Ans: (d)

Sol: d_{top} = 225 mm

h_t = 250 + 100 = 350 mm

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

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

= 2620 mm/s

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

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

$$d_{bottom} = \sqrt{\frac{4\times15267.17}{\pi}} = 139.42 \approx 140\ mm$$

09. Ans: (b)

Sol: $A_2V_2 = A_3V_3$

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

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

$\Rightarrow \quad d_b = 164.5mm$

So aspiration will not occur.

Common Data for 10 & 11

10. Ans: (a)

11. Ans: (b)

Sol: 3 castings of spherical, cylindrical and cubical

$V_{sp} = V_{cube}$

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

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

$V_{cyl} = V_{Sp}$

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

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

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

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

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

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

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

12. Ans: 1.205

Sol: Casting – 1 (circular)

Diameter = 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

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

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

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

$$= 15707.96\ mm^3$$

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

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

$$= 3769\ mm^2$$

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

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

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

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

Minor axis = 14.14mm

Major axis = 2 × minor axis = 28.3mm

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

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

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

Perimeter = 70.24 mm

Surface area of ellipse

= perimeter × length + 2× C.S. area

= 70.24×50 + 314 × 2

= 4140 mm^2 = A_{C2}

Volume of the ellipse

= C.S area × length

= 314 × 50 = 15708 mm^3 = V_{c2}

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

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

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

= 1.205

13. Ans: 50

Sol: m = 2 kg, Q = 10 kW

Time taken for removing latent heat

= 20 – 10 = 10 sec

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

Latent heat = time × Q

= 10 × 10 = 100 kJ

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

14. Ans: (a)

Sol: Circular disc casting Squared disc casting

$\frac{C_1}{d = 20\text{cm}}$; $t = 10\text{cm}$; $\frac{C_2}{a = 20\text{cm}}$; $t = 10\text{cm}$

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

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

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

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

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

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

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

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

15. Ans: (b)

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

V_{Sc} = shrinkage volume

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

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

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

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

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

$\tau_r \geq \tau_C$

where

τ_r = time taken for riser material to solidify

τ_C = time taken for casting to solidify

$M_r \geq M_c$

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

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

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

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

$\therefore \quad \tau_r > \tau_C$

Hence diameter of riser = 4 cm

Common Data for Q.16 & Q. 17

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

Sol: In centrifugal casting

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

$a = r\omega^2$

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

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

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

Constant = $N^2 D = 37273$

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

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

18. Ans: 51.84 mm

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

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

$m_c = 7.05$

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

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

$\Rightarrow$ d = 51.84 mm

19. Ans:

Sol: Given,

Gating ratio = 1:2:2

(Sprue : Runner : Ingate)

Mass, (m) = 30 kg,

Density (ρ) = 7.8 g/cc

Solidification time (τ) = 12.6 sec,

Pouring height (h_p) = 250 mm

Sprue height (h_s) = 200 mm

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

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

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

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

$$\frac{\pi}{4} d_s^2 = 102.73$$

d_s = 11.43 mm

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

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

20. Ans: 0.05 s

Sol: Momentum is considered as constant

Momentum of water = Momentum of liquid metal

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

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

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

21. Ans: (b)

Sol:

Porosity	→	Permeability test
Grain size	→	Sieve analysis
Cohesiveness	→	Shear test
Strength	→	UTM

22. Ans: (d)

Sol: Shell mold casting → Phenolic resin as mold material.

Investment casting → Upto 5 kg casting

Die casting → Only for low melting point materials

Centrifugal casting → Axis of rotation is only in horizontal

23. Ans: (c)

Sol: The main drawbacks of the investment casting process, which restrict its use to high quality and small sized castings only. Castings weighing from few grams to 5 kg.

24. Ans: (b)

Sol: For the gating system design is to fill the mould in the *smallest time.* The time for complete filling of mould termed as *pouring time,* is a very important criterion for design.

Too long a pouring time requires a higher pouring temperatures and too less a pouring time means turbulent flow in the mould which makes the casting defect prone. There is thus an optimum pouring time for any given casting.

25. Ans: (c)

Sol: For top riser, D = 2H

For side riser, D = H

26. Ans: (a)

27. Ans: (c)

Sol:

- Shrinkage cavity $\rightarrow$ Providing chills
- Misrun $\rightarrow$ High pouring temperature
- Sand inclusion $\rightarrow$ Splash core
- Blister $\rightarrow$ Providing vent holes

28. Ans: (a)

Sol:

- Saw dust or wood powder: They are added to increase the porosity property of moulding sand and collapsibility of moulding sand.
- Coal powder: Used for increasing the refractoriness of the moulding sand.
- Starch or dextrin: Used for increasing strength and resistance for deformation of moulding sand.

29. Ans: (d)

Sol:

- Skim bob is used for separating impurities present in molten metal.
- Riser is acting as a reservoir for supplying the molten metal to the casting cavity to compensate the liquid shrinkages taking place during solidification.

30. Ans: (b)

Sol:

- Shrinkage cavity $\rightarrow$ Providing chills
- Misrun $\rightarrow$ Increasing degree of super heat of molten metal
- Blister $\rightarrow$ Providing vent holes.
- Rat tail $\rightarrow$ Adding additives such as saw dust, cereals hulls, cow dung or horse manure.

31. Ans: (d)

Sol: Strainer $\rightarrow$ Filters the slag

Splash core $\rightarrow$ Avoids the sand erosion

Skin bob $\rightarrow$ Separates lighter and heavier impurities

Tapered sprue $\rightarrow$ Avoids sand erosion

32. Ans: (b)

Sol:

- Skim bob is used for separating impurities present in molten metal.
- Riser is acting as a reservoir for supplying the molten metal to the casting cavity to compensate the liquid shrinkages taking place during solidification.

33. Ans: (c)

Sol: Gating Ratio is the proportion of the cross-sectional areas between sprue, runner and ingate.

Gating ratio = Ratio of (sprue area: runner area: ingate area)

34. Ans: (a)

35. Ans: (b)

36. Ans: (c)

37. Ans: (b)

38. Ans: (a)

39. Ans: (a)

40. Ans: (a)

40. Ans: (a)

Sol: Riser is acting as a reservoir for supplying the molten metal to the casting cavity to compensate the liquid shrinkages taking place during solidification.

Conventional Practice Solutions

01.

Sol:

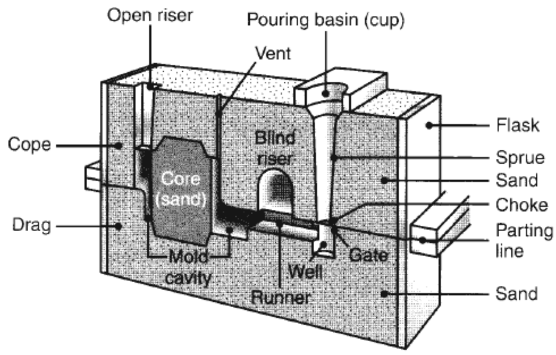


Fig: Sand mould sketch for hollow component

02.

Sol: Castings are generally cooled from all sides and, therefore, they are expected to have no directional properties. Hence the cast products are isotropic.

In forging, when plastic deformation occurs the metal appears to flow in the solid state along specific directions, which are dependent on the type of processing and the direction of applied force. The crystals or grains of the metal are elongated in the direction of metal flow. Since the grains are elongated in the direction of flow, they would be able to offer more resistance to stresses acting across them. As a result, the mechanically worked metals called wrought products would be able to achieve better mechanical strength in specific orientation, that of the flow direction.

The properties are anisotropic mechanical strength (tensile & compressive).

In most of engineering applications it requires anisotropic material because the stresses induced in the component in different directions are different.

Ex: In case of pressure vessel, even though uniform internal pressure is applied inside the pressure vessel, the stresses induced in the hoop direction is higher than the longitudinal direction.

03.

Sol: $t \propto V^2$

$$\frac{t_{cube}}{t_{sphere}} \times 100$$

$$\frac{t_{cylinder}}{t_{sphere}} \times 100$$

$$\frac{t_{cube}}{t_{sphere}} = \frac{V_{cube}^2}{V_{sphere}^2} = \left[\frac{\ell^3}{\frac{4}{3}\pi R^3}\right]^2$$

$A_{cube} = A_{sphere}$

$$\ell^2 = 4\pi R^2$$

$$\ell = \sqrt{\frac{2\pi R^2}{3}}$$

$$\ell = \sqrt{\frac{2\pi}{3}}R$$

$$\frac{t_{cube}}{t_{sphere}} = \left(\frac{\frac{2\pi}{3}R^2\sqrt{\frac{2\pi}{3}}R}{\frac{4}{3}\pi R^3}\right)^2$$

$$= \frac{\frac{4}{9} \times \frac{2\pi}{3}}{\frac{16}{9}} \Rightarrow \frac{\pi}{6} = 52.35\%$$

$$\frac{t_{cylinder}}{t_{sphere}} = \left(\frac{V_{cylinder}}{V_{sphere}}\right)^2 = \left(\frac{\frac{\pi}{4}d^2h}{\frac{4}{3}\pi R^3}\right)^2$$

$A_{cylinder} = A_{sphere}$

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

$$\frac{\pi}{2}d^2 + \pi d^2 = 4\pi R^2$$

$$3d^2 = 8R^2$$

$$d = \sqrt{\frac{8}{3}}R$$

$$\frac{t_{cylinder}}{t_{sphere}} = \left(\frac{\left(\frac{8}{3}\right)(R)^2\sqrt{\frac{8}{3}}R \times \frac{\pi}{4}}{\frac{4}{3}\pi R^3}\right)^2$$

$$= \frac{64}{9} \times \frac{8}{3} \times \frac{1}{16} \times \frac{9}{16} = 66.67\%$$

04.

Sol: (1) $\rightarrow$ 200×100×70mm

(2) $\rightarrow$ 200×100×10mm

$$\frac{t_2}{t_1}=\frac{\left(\frac{V_2}{A_2}\right)^2}{\left(\frac{V_1}{A_1}\right)^2}$$

$$=\frac{\left(\frac{200\times100\times10}{2(200\times100+100\times10+200\times10)}\right)^2}{\left(\frac{200\times100\times70}{2(200\times100+200\times70+100\times70)}\right)^2}$$

$$=\frac{\left(\frac{200000}{46000}\right)^2}{\left(\frac{1400000}{82000}\right)^2}=\frac{18.90359}{291.4931}$$

$t_2 = 0.6485\text{min}$

$t_2 = 38.91\text{sec}$

05.

Sol: $Q = A\times V$ $\quad\quad A_s:A_r:Ag = 1:4:2$

$$\frac{\text{Volume}}{t}=A_c\times V_c$$

$$\frac{3750000}{t}=A_c\sqrt{2gh_c}$$

$$\frac{3750000}{t}=\sqrt{2\times9.81\times10^3\times300}$$

$\Rightarrow \quad t = 3.09$ sec

06.

Sol: $t=k\left(\frac{V}{A}\right)^2$

$$t=k\left(\frac{a^3}{6a^2}\right)^2$$

$$t=k\left(\frac{a}{6}\right)^2$$

$t \propto a^2$

$t \propto T^2$

$T \propto \sqrt{t}$

$T = C_1\sqrt{t}+C_2$

$4\text{mm} = C_1\sqrt{30}+C_2$

$6.5\text{mm} = C_1\sqrt{80}+C_2$

$C_1 = 0.7210$

$C_2 = 0.0505$

$T = 0.7210\sqrt{150}+0.0505 = 8.88$ mm

07.

Sol: $V_c = 1000\text{cm}^3$

$$V_s=1000\times\frac{5}{100}=50\text{cm}^3$$

$V_r = 3V_s = 150\text{cm}^3$

$$\frac{\pi}{4}D^2h=150$$

$D = 5.758\text{cm}$

$$m_r=\frac{D}{6}=0.9598$$

$$m_c=\left(\frac{V}{A}\right)_c=\left(\frac{a^3}{6a^2}\right)_c=1.67$$

$m_r \not> m_c$

$$\frac{n.}{6}=1.67$$

$D = 10$ cm

08.

Sol: Shell molding can produce many types of castings with close dimensional tolerances and a good surface finish at low cost. Shell-molding applications include small mechanical parts requiring high precision, such as gear housings, cylinder heads, and connecting rods. The process also is used widely in producing high-precision molding cores.

In this process, a mounted pattern made of a ferrous metal or aluminum is

(a) heated to a range of 175° to 370°C,
(b) coated with a parting agent (such as silicone), and
(c) clamped to a box or chamber. The box contains fine sand, mixed with 2.5 to 4% of a thermosetting resin binder (such as phenol-formaldehyde) that coats the sand particles. Either the box is rotated upside down (shown in below Figure), or the sand mixture is blown over the pattern, allowing it to form a coating.

The assembly is then placed in an oven for a short period of time to complete the curing of the resin. In most shell-molding machines, the oven consists of a metal box with gas-fired burners that swing over the shell mold to cure it. The shell hardens around the pattern and is removed from the pattern using built-in ejector pins.

Two half-shells are made in this manner and are bonded or clamped together to form a mold. The thickness of the shell can be determined accurately by controlling the time that the pattern is in contact with the mold. In this way, the shell can be formed with the required strength and rigidity to hold the weight of the molten liquid. The shells are light and thin-usually 5 to 10 mm- and consequently, their thermal characteristics are different from those for thicker molds.

Shell sand has a much lower permeability than the sand used for green-sand molding, because a sand of much smaller grain size is used for shell molding. The decomposition of the shell-sand binder also produces a high volume of gas. Consequently, unless the molds are vented properly, trapped air and gas can cause serious problems in the shell molding of ferrous castings. The high quality of the finished casting can reduce cleaning, machining, and other finishing costs significantly. Complex shapes can be produced with less labor, and the process can be automated fairly easily.

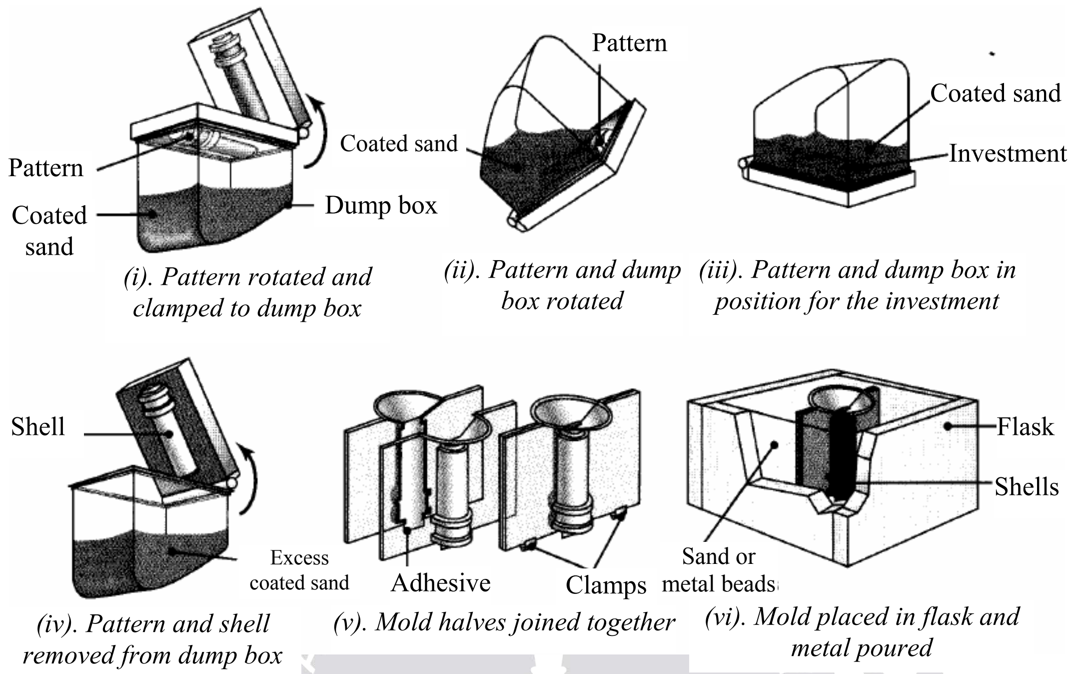


Fig : The shell moulding process(Dump box technique)

09.

Sol: The hot-chamber process (Fig. 1) involves the use of a piston, which forces a certain volume of metal into the die cavity through a gooseneck and nozzle. Pressures range up to 35 MPa, with an average of about 15 MPa. The metal is held under pressure until it solidifies in the die. To improve die life and to aid in rapid metal cooling (thereby reducing cycle time) dies usually are cooled by circulating water or oil through various passageways in the die block. Low-melting-point alloys (such as zinc, magnesium, tin, and lead) commonly are cast using this process. Cycle times usually range from 200 to 300 shots (individual injections) per hour for zinc, although very small components, such as zipper teeth, can be cast at rates of 18,000 shots per hour.

In the cold-chamber process (Fig. 2), molten metal is poured into the injection cylinder (shot chamber). The chamber is not heated-hence the term cold chamber. The metal is forced into the die cavity at pressures usually ranging from 20 to 70 MPa, although they may be as high as 150 MPa.

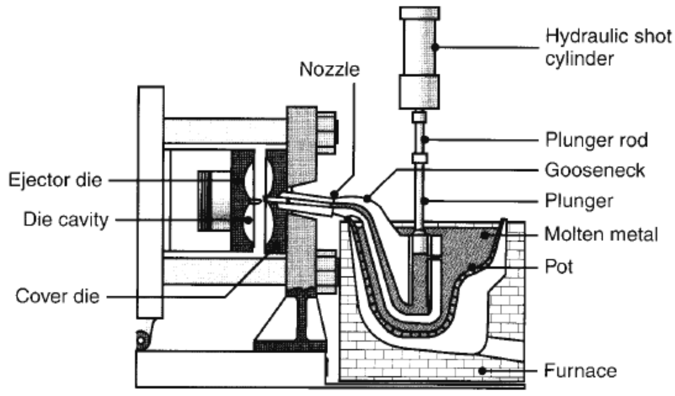


Figure : 1 The hot chamber die casting process.

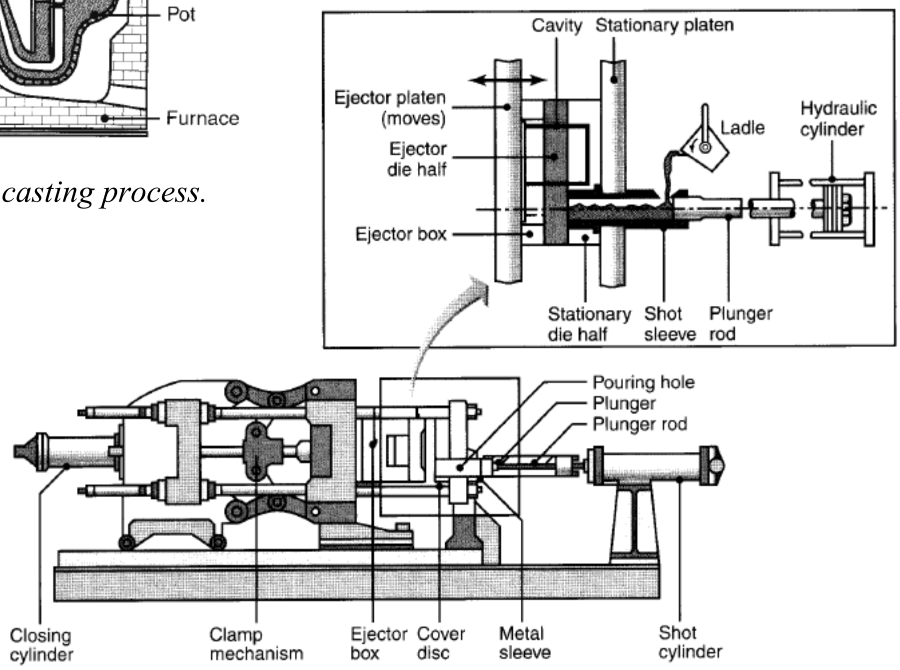


Figure: 2 Schematic illustration of the cold-chamber die-casting process.

These machines are large compared to the size of the casting, because high forces are required to keep the two halves of the dies closed under pressure.

The machines may be horizontal (as in the figure)-or vertical, in which case the shot chamber is vertical. High-melting-point alloys of aluminum, magnesium, and copper normally are cast using this method, although other metals (including ferrous metals) also can be cast. Molten-metal temperatures start at about 600°C for aluminum and some magnesium alloys, and increase considerably for copper based and iron-based alloys.

10.

Sol: $m_c = \dfrac{30\times30\times6}{2(180+180+900)}$

$\dfrac{D}{6} = 2.142\times1.2$

D = 15.428 cm

11.
Sol:

1. **Dross:** The presence of impurities or foreign particles inside the castings is called as dross.

This is due to

- Improper separation of impurities present in molten metal.
- It is eliminated by using
  - (i) providing projections in pouring basin
  - (ii) using strainer or skim bob
  - (iii) offsetting the axis of the runner & ingate.

2. **Inclusion or Sand inclusion.**

- Presence of sand particles inside the casting is called as sand inclusion
- This is due to sand erosion taking place during pouring of molten metal in casting cavity
- Sand erosion is due to
  - (i) allowing turbulent flow
  - (ii) not using the splash core
  - (iii) using top gating system for filling cavities in loose sand moulds
  - (iv) using top gating system for cavities having height more than 200 mm.

3. **Misrun:** It is due to non filling of projected portion of casting cavity using molten metal is called Misrun.

This is due to

- Solidification of molten metal has been started before complete filling of casting cavity.
- It is eliminated by reducing pouring time or increasing pouring temperature or degree of superheat.

4. **Shrinkage cavity or void:**

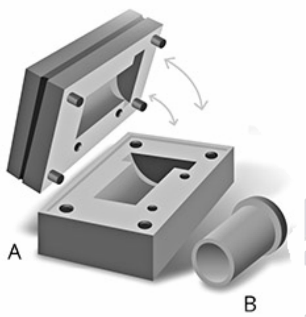
- A open space or void produced due to non-availability of molten metal for compensating liquid shrinkages taking place during solidification
- This is eliminated by directional solidification, i.e., by providing chills in the casting process.

5. **Shift:** The mismatches present between the cavities of cope and drag produce the step in the casting is called as shift defect.
   It is eliminated by using dowel pins

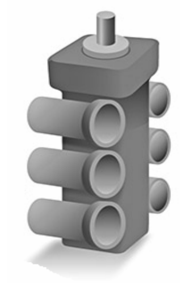
12.
Sol: Investment Casting:

Investment casting (also called "lost wax" or "precision" casting) is a manufacturing process in which a wax pattern is created, gated onto a sprue and repeatedly dipped into liquid ceramic slurry. Once the ceramic material hardens, its internal geometry takes the shape of the casting. The wax is melted out, and molten metal is poured into the cavity where the wax pattern was. The metal solidifies within the ceramic mold, and then the metal casting is broken out.

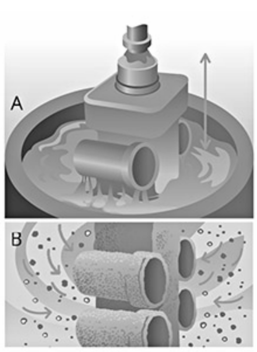
1. *Tooling and Pattern making :* A tool is built to customer provided specifications (A). Cold wax is then injected into the tool to create a wax pattern/prototype (B) that will hold precise dimensional requirements in the final casting.



2. *Pattern Assembly :* The wax patterns are assembled onto the sprue.



3. *Dipping and Coating :* Successive layers of ceramic (A) and stucco (B) are applied to the sprue assembly to form a hard shell.

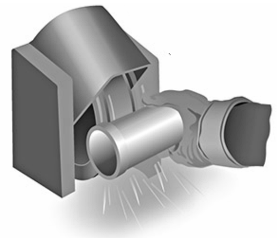


4. *De-Waxing and Firing :* The molds are flash-fired to remove the wax and sprue materials and then heated to 1800° and placed on a sand bed, ready for pouring.

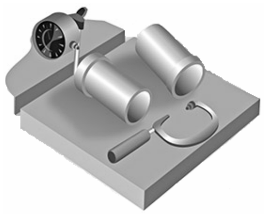
5. *Casting:* Molten metal, up to 3000°, is poured into the hollow mold and then cooled.

6. *Knockout :* The ceramic shell is broken off, and the individual castings are cut away.

7. *Finishing:* Excess metal is removed, surfaces are finished, and castings are heat treated.



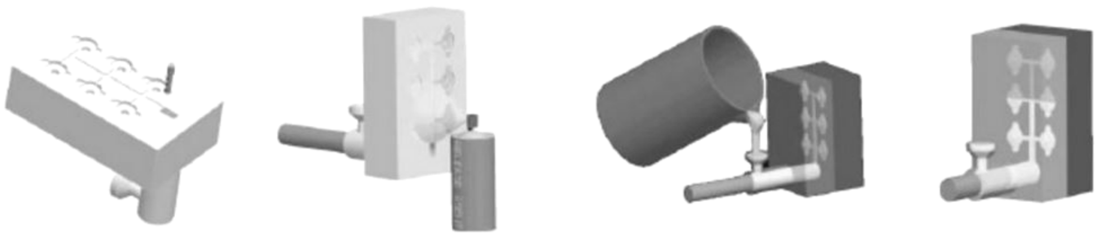
8. *Testing and Inspection:* Castings undergo through testing and inspection to ensure that they meet dimensional tolerances and specifications.



9. *Packing and Shipping:* Castings are securely packaged for shipping to the customer.

Die Casting:

Die casting is a manufacturing process for producing metal parts by forcing molten metal under high pressure into a die cavity. These die or mold cavities are typically created with hardened tool steel that has been previously machined to the net shape of the die cast parts.



Die inserts machined From tool steel

Release agent Applied to die

Shot sleeve filled With molten metal

Piston forces molten Metal into the die

Piston maintains pressure on molten metal when die is filled

When sufficiently cooled, die inserts are separated and the casting tree is removed

Individual cast parts are trimmed from the casting tree

Final machining operations performed to finish part

Investment Casting :

- Excellent precision, ideal for complex geometries
- Can meet tight tolerance requirements
- Superior surface finish, little additional machining required
- Higher total cost than other casting processes
- Lower tooling costs
- Suitable for both ferrous and non-ferrous metals
- Some product size restrictions

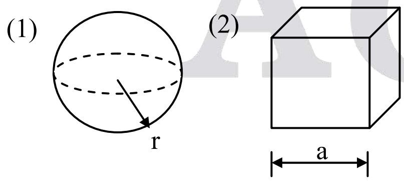
Die Casting

- Produces parts with good dimensional tolerance
- Little secondary machining required
- Ideal for large production runs and high-volume projects
- Excellent for producing consistent, repeatable parts
- High tooling costs

13.

Sol: $A_1 = A_2$

$4\pi r^2 = 6a^2$



$$\frac{r}{a} = \left(\frac{3}{2\pi}\right)^{1/2}$$

$$\frac{t_1}{t_2} = \left(\frac{v_1}{v_2}\right)^2 = \left(\frac{4}{3}\frac{\pi r^3}{a^3}\right)^2$$

$$= \left(\frac{4}{3}\pi\right)^2\left(\frac{3}{2\pi}\right)^3 = \frac{6}{\pi} = 1.909$$

Chapter 2 Welding

01. Ans: (a)

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

Let for arc welding, $V = a + bL$

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

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

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

02. Ans: 4860 W, 1.5 mm

Sol: For power source,

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

$$V_a = 2L + 27$$

At equilibrium conditions

$$V_a = V_P$$

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

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

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

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,

$V = 27 + 2 \times 1.5 = 27 + 3 = 30$ V

$I = 60\,(9 - 2 \times 1.5) = 360$ A

$P = 30 \times 360 = 10800$ W

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

$I = 60\,(9 - 1.5 \times 4) = 180$ A

$P = 33 \times 180 = 5940$ W

Change in power $= 10800 - 5940$

$= 4860$ W

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

03. Ans: 425

Sol: $V = 100 + 40\,L$,

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

$L = 1$, $I = 250$

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

$L = 2$, $I = 200$

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

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

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

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

$= 140 + 200 = 340$

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

04. Ans: 26.7 sec

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

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

$D_r = 50\%$ (rated duty cycle)

If $I_d = 1500$ A (desired current)

Desired duty cycle,

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

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

$= 26.7$ sec

05. Ans: 27.78 mm/sec

Sol: Power $= P = 4 + 0.8L - 0.1L^2$

For optimum power

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

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

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

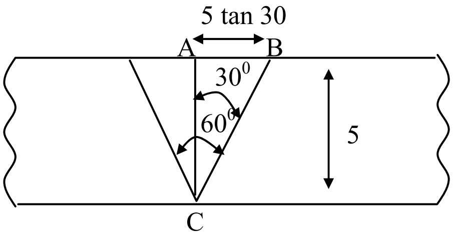
$= 4 + 0.8 \times 4 - 0.1 \times 4^2 = 5.6$ kW

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

$= 14433\ mm^3$

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

$= 115.5$ g

Heat required for melting of W.B

$= 115.5 \times 1400 = 161.66$ kW

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

Welding speed $= \dfrac{1000}{36}$

$= 27.78$ mm/sec

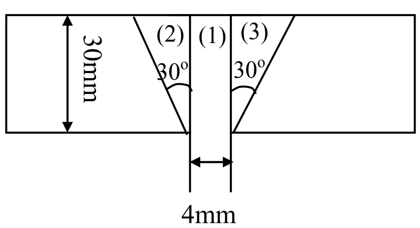
Common data for 06, 07 & 08.

06. Ans: (d)

07. Ans: (d)

08. Ans: (c)

Sol:



l = 1 m =1000 mm;

t = 30 mm,

d = 4 mm,

L_t = 450 mm;

L_S = 50 mm,

$A_1 = 4 \times 30 = 120\ mm^2$

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

Total volume of weld bead

= volume of weld bead + crowning

= 1.1 × volume of weld bead

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

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

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

Number of electrodes required

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

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

x = 200mm (given)

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

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

Total Arc on time

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

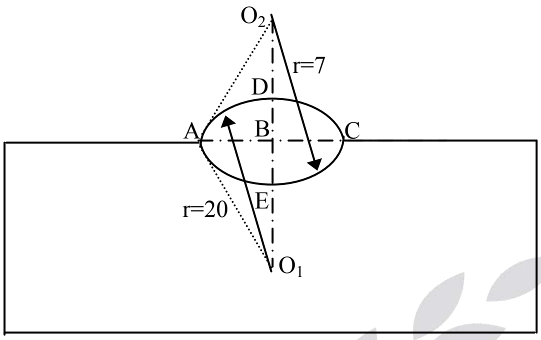
Total weld time $= \dfrac{280}{0.6} = 466.67$ minutes

09. Ans: 0.64 mm & 2.1 mm

Sol: Given AC = 10 mm,

$O_1A = O_1C = 7$ mm,

$O_2A = O_2C = 20$ mm



Height of Bead = BD = $O_1D - O_1B$

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

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

= 0.64 mm

Depth of Penetration = BE = $O_1E - O_1B$

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

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

Common Data Q. No 10 and 11

10. Ans: (c)

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

D = 1.2 mm, f = 4 m /min, η = 65%,

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

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

= 10.83 kJ / cm

11. Ans: (b)

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

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

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

Common data for 12 & 13

12. Ans: 2000 J

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

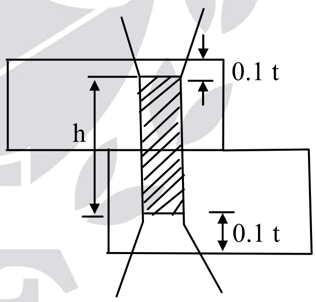
$= (10000)^2 \times 200 \times 10^{-6} \times \dfrac{5}{50} = 2000$ J

13. Ans: 1264 J

Sol: h = 2t – 2 × 0.1 t = 1.8 t

= 1.8 ×1.5 = 2.7 mm

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



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

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

Heat required = Volume ×ρ ×heat required /g

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

= 1264 J

14. Ans: 2.3 & 4.6 MJ

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

ρ = Resistivity of metal

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

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

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

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

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

15. Ans: (c)

Sol: Heat generated = Heat utilized

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

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

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

I = 4060 A

Common Data Q. 16 & Q. 17

16. Ans: (c)

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

Volume of nugget = 20 mm^3

Heat generation = $I^2R\tau$

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

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

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

= 344 J

17. Ans: (b)

Sol: Heat dissipated = 360 – 344 = 16 J

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

Sol: P = 2 kW = 2 × 10^3 Watt,

V = 200 mm/min, L = 300 mm

Heat required (HR) = 40 Kcal

$= 40\times 10^3\times 4.2$ Joule

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

= 90sec

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

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

= 93.33%

19. Ans: (d)

Sol: Heat supplied = Heat utilized

0.5 J = m (S.H. + L.H) = ρV (SH+LH)

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

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

$\Rightarrow$ h = 0.00385 m = 3.85 mm

20. Ans: (c)

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

$= 3298.66\ mm^3$

Total heat required

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

= 212.4 Joules

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

Total heat required = heat to be generated

$$212.4 = P\times t$$

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

21. Ans: (a)

Sol: Frictional force F = Pressure × Area ×μ

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

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

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

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

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

22. Ans: 0.065 sec

Sol: Given:

Volume = 80 mm^3,

Current (I) = 10000 A,

E = 10 J/mm^3,

Q_{lost} = Heat lost = 500 J,

R = 0.0002 ohms

Total energy supplied during process

= [(80 × 10) + 500] J

Q_{total} = 1300J = i^2Rt

1300 = $(10^4)^2$ × 0.0002 × t

⇒ t = 0.065 seconds

23. Ans: 61.53 %

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

Heat required = 10 × 80 = 800 J

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

24. Ans: 464.758 A

Sol: D_d = 100% = 1, I_r = 600A, D_r = 0.6

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

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

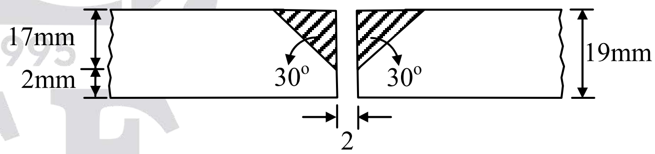
$$\Rightarrow I_d = 464.758\text{A}$$

25. Ans: 17

Sol: Number of electrodes

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

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



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

x = 9.814 mm

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

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

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

∴ Number of electrodes = 17

26. Ans:

Sol: Given, Butt-welding,

Arc power (Q) = 2.5 kVA = 2.5×10^3 J

Thickness (t) = 3 mm = 3×10^{-3} m

V-joint Angle (θ) = 60°

Efficiency (η_{arc}) = 0.85

2D – heat transfer :

$\alpha_{steel} = 1.2\times10^{-5}$ m²/sec ,

$k_{steel} = 43.6$ W/m°C

Assuming T_C = 1450°C

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

b = width of weld,

b = 2 × 3 × tan30° = 3.464×10^{-3} m

$$2.5\times10^3 = 8\times43.6\times1450\times3\times10^{-3}\left[0.2+\frac{V\times3.464\times10^{-3}}{4\times1.2\times10^{-5}}\right]$$

$$1.647 = [0.2+(V\times72.166)]$$

Welding speed, V = 20.06 mm/sec

27. Ans: (c)

28. Ans: (c)

Sol: The cheapest and safest method of producing oxygen is from atmospheric air.

Carburizing flame: $\frac{O_2}{C_2H_2} = 0.85$ to 0.95

29. Ans: (a)

30. Ans: (b)

Sol:

- Electro slag welding → Silicon based flux
- Laser beam welding → Absorptive of the material.
- Resistance welding → Without use of filler rod
- Soldering → Non fusion welding of metals having melting point < 427°C
- Brazing → Non fusion welding of metals having melting point > 427°C

31. Ans: (c)

Sol:

- In resistance welding, copper alloys used as electrode materials must exhibit, high electrical and thermal conductivities, combined with high strength at elevated temperatures.
- For the process to work properly, the contact resistance must be higher at the point to be welded than any where else.

32. Ans: (b)

Sol: At the intersection of inner and outer cone the maximum temperature induced is

(i) 3260°C in neutral flame

(ii) 3380°C in oxidizing flame and

(iii) 3040°C in carburizing flame.

33. Ans: (425A)

Sol: V = 100 + 40 L ,

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

L = 1, I = 250

$$V = 100 + 40\times1 = 140 = V_0 - \frac{V_0}{I_s}\times 250$$

L = 2, I = 200

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

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

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

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

$$= 140 + 200 = 340$$

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

34. Ans: (b)

35. Ans: (c)

Sol:

1. Preheating slows down the cooling rate of the weld and gives the metal more time to form a good microstructure, release internal stresses and dissipated hydrogen from the weld.
2. The major purpose of preheating and post heating of cast iron is to control the rate of temperature change. The level of temperature and the rate of change of temperature affect the hardness, brittleness, ductility and strength of iron carbon based metals such as steel and cast iron. Hence option (c) is correct.

36. Ans: (d)

Sol: Resistance welding can be used for welding of aluminium and its alloys but they require much higher welding currents because of high thermal and electrical conductivity compared with steel.

37. Ans: (a)

38. Ans: (c)

39. Ans: (c)

40. Ans: (c)

Sol:

- Process like laser beam welding and electron beam welding give a highly concentrated, limited amount of heat, resulting in a small HAZ.
- Electron beam welding is not typically used with lead, zinc, cast iron, thermoplastics and most other synthesis.

41. Ans: (b)

42. Ans: (b)

Conventional Practice Solutions

01.

Sol: Electroslag welding (ESW) process and its applications are shown in below figure (1). The main difference is that the arc is started between the electrode tip and the bottom of the part to be welded. Flux is added, which then melts by the heat of the arc. After the molten slag reaches the tip of the electrode, the arc is extinguished. Heat is produced continuously by the electrical resistance of the molten slag. Because the arc is extinguished, ESW is not strictly an arc-welding process. Single or multiple solid as well as flux-cored electrodes may be used. The guide may be non-consumable (conventional method) or consumable.

Electro slag Welding is capable of welding plates with higher thicknesses ranging from 50 mm to more than 900 mm, and Welding is done in one pass. The current required is about 600 A at 40V - 50 V although higher currents are used for thick plates. The travel speed of the weld is in the range from 12 to 36 mm/min and weld quality also good. This process is used for large structural-steel sections, such as heavy machinery, bridges, oil rigs, ships, and nuclear-reactor vessels.

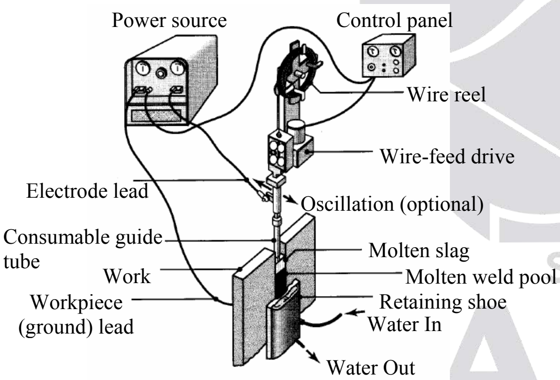


Fig 1: Electroslag welding (ESW)

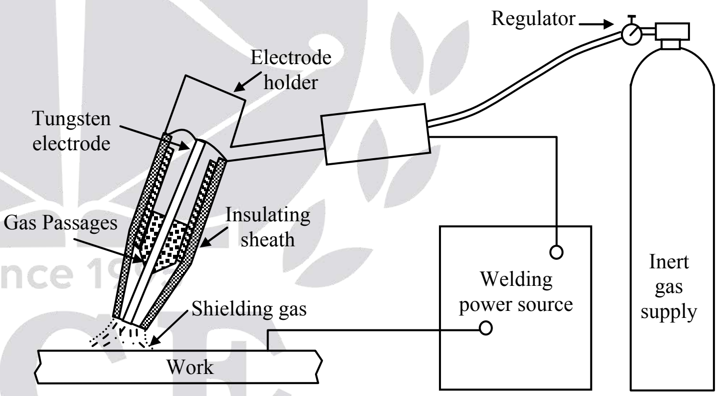


Fig 2: Tungsten inert gas welding setup

Gas Tungusten Arc Welding (GTAW) or Tungusten Inert Gas Welding (TIG) :

In this process a non-consumable tungsten electrode is used with an envelope of inert shielding gas around it. The shielding gas protects the tungsten electrode and the molten metal weld pool from the atmospheric contamination. The shielding gases generally used are argon, helium or their mixtures. Typical tungsten inert gas welding setup is shown in Fig.2.

Electrode materials :

The electrode material may be tungsten, or tungsten alloy (thoriated tungsten or zirconiated tungsten). Alloy-tungsten electrodes possess higher current carrying capacity, produce a steadier arc as compared to pure tungsten electrodes and high resistance to contamination.

Electric power source

Both AC and DC power source can be used for TIG welding. DC is preferred for welding of copper, copper alloys, nickel and stainless steel whereas DC reverse polarity (DCRP) or AC is used for welding aluminium, magnesium or their alloys. DCRP removes oxide film on magnesium and aluminium.

Inert gases :

The following inert gases are generally used in TIG welding:

1. Argon
2. Helium
3. Argon-helium mixtures
4. Argon-hydrogen mixtures

Tig Nozzle :

The nozzle or shield size (the diameter of the opening of the shroud around the electrode) to be chosen depends on the shape of the groove to be welded as well as the required gas flow rate. The gas flow rate depends on the position of the weld as well as its size. Too high a gas consumption would give rise to turbulence of the weld metal pool and consequently porous welds. Because of the use of shielding gases, no fluxes are required to be used in inert gas shielded arc welding. However for thicker sections, it may be desirable to protect the root side of the joint by providing a flux. The process is generally used for welding aluminium, magnesium and stainless steel.

Advantages:

- Non-consumable **electrodes -** It helps to provide flawless joints because it is not needed to stop for replacing the electrode as in consumable electrode welding. That also contributes to reducing downtime in production.
- No flux is required because inert gas shields molten metal. So no slag and slag inclusion problems.
- High quality and strong welding achieved by TIG.
- Cleaner and more appealing joints. Sometimes they don't need finishing process.
- They are suitable for welding of very thin sections.
- The versatility of method. They can work with and without filler metal.
- A wide range of metal can be welded. Nonferrous metals like aluminium, copper and dissimilar metal can be welded without any challenge.
- Non-corrosive and ductile joints.

- The minimum amount of flames and spark. Less distortion due to small heat zone.
- It can be done in both automatic and manual.

Disadvantages :

TIG is a time-consuming process - They are slower than any other welding process. Lower filler deposition rate.

1. More complicated - Highly skilled and professional workers are needed to perform TIG welding.
2. Safety issue - Welders, are exposed to high intensity of light which can cause eye damage.
3. High initial cost.
4. It cannot be used in thicker sheets of metal.

02.

Sol: $D_d = 100\% = 1$,

$I_r = 600A$, $D_r = 0.6$

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

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

$I_d = 464.758A$

03.

Sol: Commonly used resistance welding processes are spot, seam and projection welding which produce lap joints except in case of production of welded tubes by seam welding where edges are in butting position. In butt and flash welding, components are in butting position and butt joints are produced.

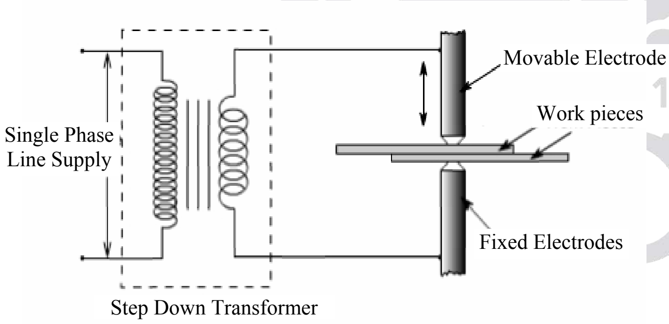


Fig (a): Sketch the set-up for spot welding showing details of power input and electrodes

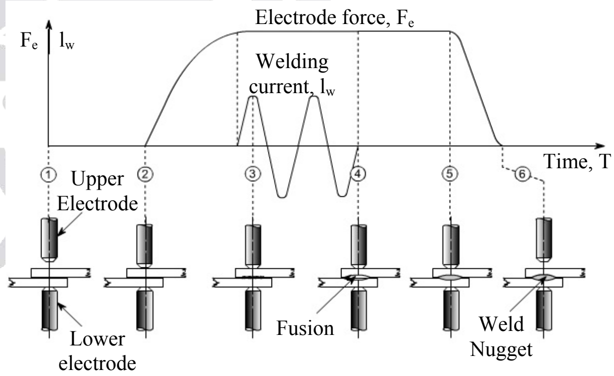


Fig (b): The force / time and current / time diagrams

The category of resistance welding (RW) covers a number of processes in which the heat required for welding is produced by means of electrical resistance across the two components to be joined. These processes have major advantages, such as not requiring consumable electrodes, shielding gases, or flux. The heat generated in resistance welding is given by the general expression

$$H = I^2Rt, \text{----------}(1)$$

where

H = Heat generated in joules (watt-seconds)

I = Current (in amperes)

R = Resistance (in ohms)

t = Time of current flow (in seconds).

Equation(1) is often modified so that it represents the actual heat energy available in the weld by including a factor K, which denotes the energy losses through conduction and radiation. The equation then becomes

$H = I^2RtK$,------------------ (2)

where the value of K is less than unity.

The total resistance is the sum of the following properties (see Figure 2 below) :

a. Resistances of the electrodes;
b. Electrode-workpiece contact resistance;
c. Resistances of the individual parts to be welded;
d. Contact resistance between the two workpieces to be joined faying surfaces.

The actual temperature rise at the joint depends on the specific heat and the thermal conductivity of the metals to be joined. For example, metals such as aluminum and copper have high thermal conductivity, so they require high heat concentrations.

Similar or dissimilar metals can be joined by resistance welding. The magnitude of the current in resistance-welding operations may be as high as 100,000 A, but the voltage is typically only 0.5 to 10 V

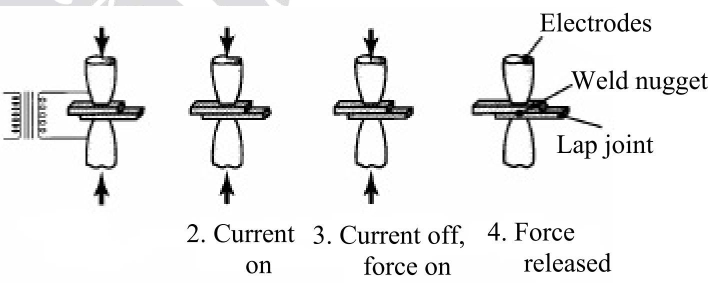


Fig. (a)

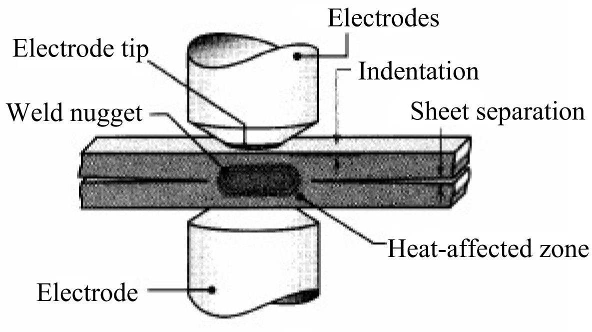


Fig. (b)

Fig.2(a) Sequence of events in resistance spot welding. (b) Cross section of a spot weld, showing the weld nugget and the indentation of the electrode on the sheet surfaces. This is one of the most commonly used processes in sheet-metal fabrication and in automotive body assembly.

The strength of the bond depends on surface roughness and on the cleanliness of the mating surfaces. Oil films, paint, and thick oxide layers should therefore be removed before welding. The presence of uniform, thin layers of oxide and of other contaminants is not as critical.

Applications : The applications of resistance welding are many. Some of them are: Automobile, Auto Ancillary, Auto Electrical, Electrical Industry, Defense & Railways, Electronics Industry Consumer Durables

Resistance Projection Welding:

The main difference as compared to spot welding: In resistance projection welding (RPW), high electrical resistance at the joint is developed by embossing one or more projections (dimples) on one of the surfaces to be welded (Fig. 3). The projections may be round or oval for design or strength purposes. High localized temperatures are generated at the projections, which are in contact with the flat mating part. The electrodes (typically made of copper-based alloys) are large and flat, and water cooled to keep their temperature low. Weld nuggets similar to those in spot welding are formed as the electrodes exert pressure to soften and compress the projections. Spot-welding equipment can be used for resistance projection welding by modifying the electrodes. Although the embossing of the workpieces adds expense, the process produces a number of welds in one pass, extends electrode life, and is capable of welding metals of different thicknesses, such as a sheet welded over a plate.

Nuts and bolts can be welded to sheets and plates by this process, with projections that are produced by machining or forging. Joining a network of rods and wires (such as the ones making up metal baskets, grills (below fig) oven racks, and shopping carts) also is considered resistance projection welding, because of the many small contact areas between crossing wires (grids).

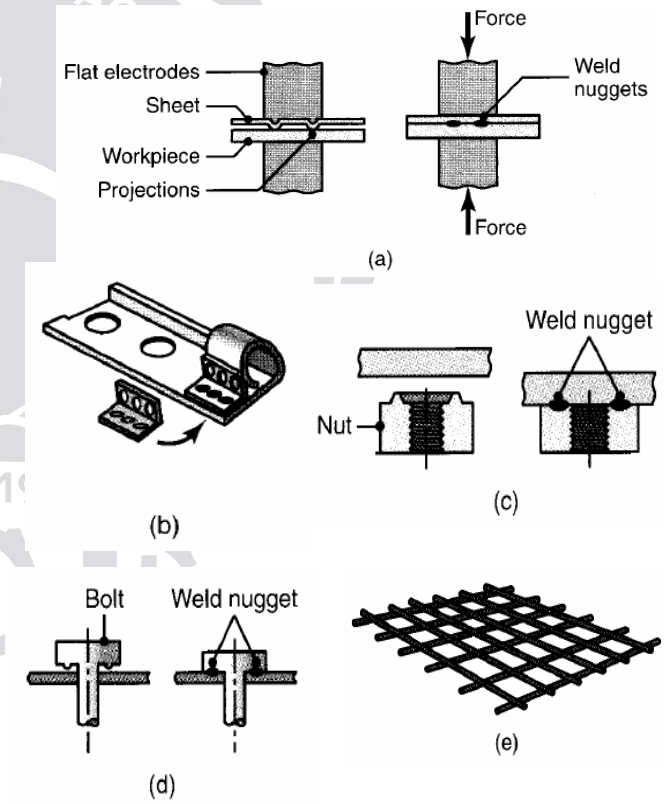


Fig:3 (a) Schematic illustration of resistance projection welding (b) A welded bracket. (c) and (d) Projection welding of nuts or threaded bosses and studs. (e) Resistance projection-welded grills.

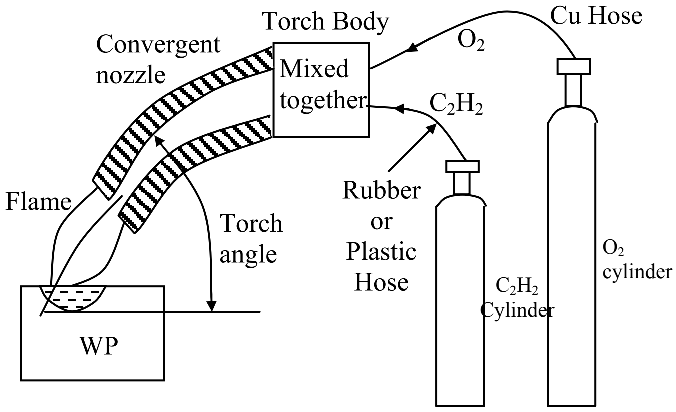
04.

Sol: The various fuel gases used for gas welding are Acetylene, Gasoline, Hydrogen, MPS and MAPP gas, Propylene and Fuel Gas, Butane, propane and butane/propane mixes.

Gas Welding :

i) Oxyacetylene Gas Welding:

- In this case heat required for melting of plate is obtained by burning of oxyacetylene gas mixture
- Oxygen and acetylene are drawn from their respective cylinders through hose pipe into the torch body.
- Both the gases are mixed together in the torch body so that the mixture is possessing certain higher pressure.
- When this high pressure mixture is passed through the convergent nozzle, the pressure energy gets converted into velocity energy and the mixture is coming out from the nozzle at very high velocity
- If this mixture is given initiation for burning, the continuous flame will be produced. So the heat available in the mixture is used for melting/Joining of work piece.



Oxygen cylinder: R.H Threads, Black colour, 120 KSC,

C_2H_2 Cylinder: L.H. Threads maroon colour/red, 15 KSC

Oxyacetylene welding

$$C_2H_2 + O_2 \rightarrow 2CO + H_2 + \text{Heat}$$

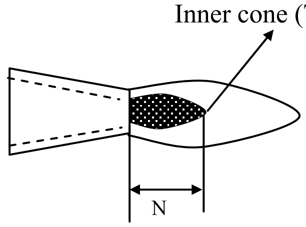
$$2CO + O_2 \rightarrow 2CO_2 + \text{Heat}$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O + \text{Heat}$$

Different Types of Flames used for Welding :

1. **Neutral Flame:** $\frac{O_2}{C_2H_2} = 1,$

   N = 10 to 15 mm (N = length of inner cone)



These two cones can be distinguished based on their colour. The inner cone will be yellow or red and outer cone will be light blue color

- Maximum temperature (3260°C) of flame is induced at the intersection of inner cone and outer cones.
- Average temperature is (2000-2100)^{o}C. It is the $\frac{2}{3}$ of maximum temperature

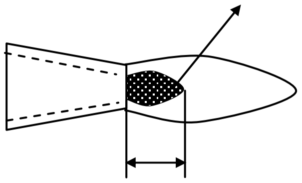
Applications:

- Neutral flame is used for joining and cutting of all ferrous and non ferrous metals expect brass.
- During Joining of Brass, the Zinc present in brass will get evaporated.

2. Oxidizing Flame: $\frac{O_2}{C_2H_2} = 1.15 \text{ to } 1.5$

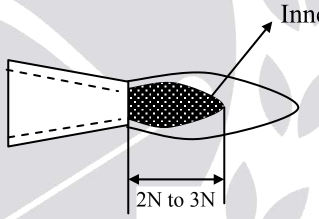
Here excess amount of oxygen is present

- The length of Inner cone is about $\frac{N}{3}$ to $\frac{N}{2}$



- Maximum temperature of flame in oxidizing flame is about 3380^{o}C
- Because excess supply of oxygen, there is a possibility of free oxygen may present in the flame
- If oxidizing flame is used for Joining of highly reactive metals; the oxidation will take place, hence it should not be used for Joining of highly reactive metals like Al & Mg etc.
- Because of higher average temperature, it can be used for joining of high melting point materials
- It is also used for joining brass workpiece.

Carburizing flame: $\frac{O_2}{C_2H_2} = 0.85 \text{ to } 0.95$



- Because of short supply of oxygen, the flame has to travel for a longer distance to completely burn acetylene i.e length of inner cone is increased to 2N to 3N.
- Maximum temperature is only about 3040 ^{o}C. Also T_{avg} = (1800 – 1900^{o}C)
- Because of lower average temperature, high melting point material can not be joined.
- This is mostly used for joining of high carbon steels.

- For connecting O_2 cylinder to torch body, the flexible hose is made by using copper as a material.
- Rubber hose pipes are used for connecting C_2H_2 cylinder
- If hose pipes are interchanged, then both of the pipes will fail. Hence to avoid the interchanging of hose pipes, color distinction, size distinction & type of thread distinction will be used.

05.

Sol: *Advantages and disadvantages of D.C welding machine:*

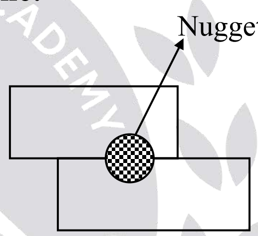
Advantages:

- Heat generated is different at the work and the electrode by changing the polarity.
- D.C. welding machine is suitable for welding all types of metals by changing the polarity.
- Both coated and bare electrode can be used in D.C. welding machine.
- It is used for all sorts of work as starting of the arc is easier comparatively.
- It can be used anywhere with engine driven D.C. generator or by rectified A.C. supply.
- The motor in a D.C. Welding has an advantage of high power factor of 0.6 to 0.7.

Disadvantages

- D.C. welding machine is two to three times costlier, larger in size, heavier in weight and is more complicated.
- Maintenance cost is higher because of many moving parts in it.
- Arc-blow is severe and difficulty to control.
- Voltage drop is relatively higher, it can be used only at a short distance from the power supply.
- Higher electric energy consumption per kg of metal deposited (6 to 10 kWh).
- Efficiency of D.C. Welding machine is low only 0.3 to 0.6.
- It has higher operating cost.

Hold Time:



Time during which force applied on plate will be continued to hold until liquid molten metal produced will get solidified.

S. No.	Arc Welding	Gas Welding
1	In the arc welding, electricity is used to generate heat.	In gas welding, fuel gases like acetylene, hydrogen are used to generate heat.
2.	This welding generator higher temperature than gas welding. The temperature is about 6000 °C.	This welding generates lower temperature than arc welding. The temperature is about 3600 °C.
3.	This welding generates stronger joint compare to gas welding.	It gives weaker joint.

4.	It gives poor surface finish	This welding gives good surface finish.
5.	In arc welding consumable electrode is used.	In gas welding non consumable electrode is used.
6.	The electrode is combined with the filler metal.	A filler rod is used separately if required.
7.	It can be used in welding alone.	It can be used in welding, brazing and soldering.
8.	There is risk of explosion due to high voltage.	There is risk of explosion due to high pressure.
9.	It is mostly used to joint similar material.	It is mostly use to join both similar and different metals.
10.	The heat is concentrate in arc welding.	The heat is distributing according to the flame. There is higher loss of energy.
11.	It is more efficient.	It is less efficient.
12.	Speed of welding is high.	Speed of welding is low.
13.	The initial cost of arc welding is high.	The setup cost of gas welding is low.

06.

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

$V_a = 2L_a + 27 = L_a$:mm

L_a	I	V	P
2	300	31	9300
4	60	35	2100

$\Delta P = 9300 - 2100$

$\Delta P = 7200$ W

$$I - 300 = \frac{300-60}{2-4}(L_a - 2)$$

$I = 540 - 120$ L

When I = 300 A

$$L = \frac{540-300}{120}$$

$L_a = 2$ mm

07.

Sol: V = 20+40L, $V_0 = 80V$, $I_S = 1000a$

$$V = V_0 - \frac{V_0}{I_s} I, \quad P = VI$$

$$20 + 40L = V_0 - \frac{V_0}{I_s} I, \quad \frac{dP}{d\ell} = 0$$

$$20 + 40L = 80 - \frac{80}{1000} I$$

$20 + 40L = 80 - 0.08I$

$-60 + 40L = -0.08I$

$I = 750 - 500L$

$P = (20 + 40L)(750 - 500L)$

$= 15000 - 10000L + 30000L - 20000L^2$

$= 15000 - 20000L - 20000L^2$

L = 0.5cm

08.

Sol: $L_w = 300$ mm

$H_s = 2$ kW

$V_w = 200$ mm/min

$$H_m = \frac{40 \times 4.2}{t} \text{kW}$$

$\eta = ?$

$$\Rightarrow t = \frac{L_w}{V_w} = \frac{300}{200} \times 60$$

t = 90 sec

$\therefore\ H_m = 1.867$ kW

$$\eta = \frac{H_m}{H_s} = \frac{1.867}{2} = 93.35\%$$

09.

Sol: V = 20 + 4L

L	I	V
4 mm	550 A	36 V
6 mm	450 A	44 V

$$\Rightarrow I - 550 = \frac{550-450}{4-6}$$

$\Rightarrow I - 550 = -50\,(L-4)$

$\Rightarrow I - 550 = -50\,L + 200$

$\Rightarrow I = 750 - 50\,L$

I @ L = 5 mm = 750 – 250 = 500 A

V @ L = 5 mm = 20 + 20 = 40 V

$\therefore$ P @ L = 5 mm = 500 × 40

$\Rightarrow$ P @ L = 5 mm = 20 kW

Now: Voltage current characteristics

$$I - 550 = \frac{550-450}{36-44}(V-36)$$

$\Rightarrow I - 550 = -12.5\,(V-36)$

$$\frac{I}{1000} + \frac{V}{80} = 1$$

$\therefore$ OCV = 80 V

10.

Sol: $V_0 = 62V$; $I_s = 130A$;

L = 4mm; $\eta = 0.85$

$$\nu = \frac{15\text{cm}}{\text{min}} \Rightarrow \frac{15}{60}\frac{\text{cm}}{\text{sec}} \Rightarrow \frac{150}{60}\frac{\text{mm}}{\text{sec}} = 2.5\frac{\text{mm}}{\text{sec}}$$

V = 20+1.5L

V = 26V

$$V = V_0 - \frac{V_0}{I_s}I$$

$$26 = 62 - \frac{62}{130}I$$

I = 75.48A

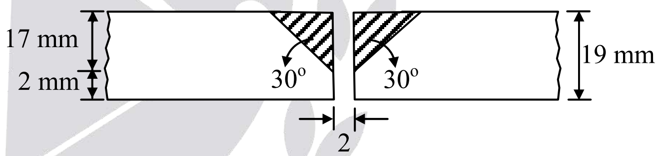
$$\frac{H}{\ell} = 667.277\frac{J}{mm}$$

11.

Sol: No. of electrodes

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

$$= \frac{\text{Total Volume of metal deposited}}{\frac{\pi}{4}\left(3\times10^{-3}\right)^2 \times (0.45-0.05)}$$



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

x = 9.814 mm

$$\text{Area} = \left(\frac{1}{2}\times9.814\times17\times2+(2\times19)\right)\times1.1\times1.15$$

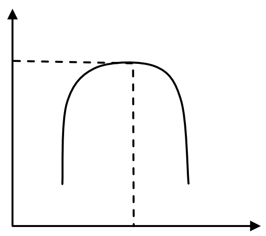
$$\text{Volume} = \left(204.85\text{mm}^2\right)\times1.1\times1.15\times180$$

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

No of electrodes = 17

12.

Sol: $V = 80 - \frac{80}{1000} I$



$V = 20+4L$

$P = VI$

$P = 80i - \frac{80I^2}{1000}$

$\frac{dP}{dI} = 0$

$80 - \frac{160I}{1000} = 0$

$I = 500A$

$V = 80 - \frac{80}{1000} \times 500$

$V = 40V$

$40V = 20+4L$

$\Rightarrow L = 5$ mm

13.

Sol: *3 – dimensional heat transfer:*

$$q = 1.25\pi wkT_c\left[\frac{2}{3} + \frac{\upsilon w}{4\alpha}\right]$$

2 – dimensional

$$q = 8kT_c t\left[0.2 + \frac{\upsilon w}{4\alpha}\right]$$

k = thermal conductivity

$T_c = T_m - T_R$

t = thickness of sheet

υ = maximum welding speed

w = width of weld

α = thermal diffusivity –k/sec

$$q = 8kT_c t\left[0.2 + \frac{\upsilon w}{4\alpha}\right]$$

$T_c = 1450^oC$

$q = \eta DVI = 1\times0.85\times2.5\times10^3 = 2125W$

$w = 3\tan(30^o)\times2$

$$2125 = 8\times43.6\times3\times10^{-3}\times 1450 \left[0.2 + \frac{v3.464\times10^{-3}}{4\times1.2\times10^{-5}}\right]$$

$$1.40 = \frac{9.6\times106 + \upsilon(3.46\times10^{-3})}{4\times1.2\times10^{-5}}$$

$6.722\times10^{-5} = 9.6\times10^{-6} + \upsilon(3.464\times10^{-3})$

$\Rightarrow \upsilon = 0.0166$m/sec

14.

Sol:

1. **Porosity :**

It is common type. In this defect, air bubbles or gases are present in the weld zone. The distribution of air bubbles in weld zone is random. Porosity caused by gases release during melting of the weld area but trapped during solidification, chemical reaction during welding or by contaminants.

This defect can be minimized by the proper selection or electrode, filler material, improve welding techniques, more attention to weld area during welding preparation and slower speed to allow gases time to escape. The effect of porosity on performance depends on quality, size and orientation to stresses.

2. **Spatter:**

Metal drop expelled from the weld that stick to surrounding surface is known as spatter. Spatter can be minimize by correcting the welding condition and should be eliminated by grinding.

Causes:

- Welding current too high.
- Arc is too long.
- Incorrect polarity.
- Insufficient gas shielded.

Remedies:

- Reduce welding current and arc length.
- Use correct polarity according to the welding condition.
- Increase torch to plate angle and use correct gas shielding.

3. **Slag inclusions:**

Slag inclusions are compound such as oxides, fluxes and electrode contains material that is trapped in the weld zone. These defect are commonly associated with undercut, incomplete penetration and lack of fusion in weld. Insufficient cleaning between multi-pass welds and incorrect electrode and current can leave slag and unfused section along the weld joint. Slag inclusion not only reduces cross section area strength of joint but also may serve as initiation point for serious cracking.

Remedy: This defect can only be repaired by grinding down or gouging out and re-welding.

4. **Incomplete fusion:**

In this types of welding defect gap is not totally filled by molten metal. It is due to inaccuracy of the welder so pre solidification of welding metal.

Causes:

- Heat input is too low.
- Weld pool is too large and running ahead of the arc.
- Joint included angle is too low.
- Electrode and torch angle is incorrect.
- Unfavorable bead position.

Remedies:

- Increase welding current and decrease the travel speed.
- Reduce deposition rate.
- Increase joint include angle.
- Position electrode or plate angle such a way so the plate edges will melt.
- Position bead in such a way that the sharp edges with other bead or plate are avoided.

15.

Sol: Given data,

Resistance spot welding (Al)

$T = 2$ mm,

$I = 5000$ A

$t = 0.15$ sec ,

$R = 75\ \mu\Omega$

$d_n = 5$ mm,

$t_n = 2.5$ mm

$$\eta = \frac{\text{Heat used}}{\text{Heat generated}} \times 100$$

Heat Generated = I^2RT

$= 5000 \times 75 \times 10^{-6} \times 0.15$

$= 0.05625$ J

$$\text{Heat Used} = 29 \times \frac{\pi}{4} \times s^2 \times 2.5 = 142.353\text{J}$$

$$\eta = \frac{142.353}{0.05625} \times 100$$

$\eta = 0.039$

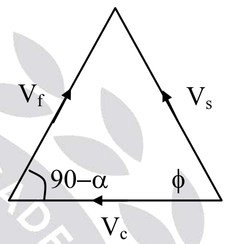
Chapter 3	Metal Cutting

Common Data for Q. 01 & 02

01. Ans: (a)

02. Ans: (d)

Sol:



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

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

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

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

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

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

03. Ans: 10°

Sol: $f = 0.25$ mm/rev,

$t_1 = 0.25$, $i = 10°$, $\alpha = ?$

$t_1 = f\cos C_S$

$0.25 = 0.25\cos C_S$

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

$\lambda = 90 - C_S = 90°$

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

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

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

$\Rightarrow \alpha_b = i = 10°$

Common Data for Q.04, 05 & 06

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

06. Ans: (d)

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

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

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

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

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

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

$= 1200$ W

Length of shear plane = L_S

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

07. Ans: (a)

Sol: For theoretically minimum possible shear strain to occur

$2\phi - \alpha = 90$

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

Common Data for Q. 08 & 09

08. Ans: (c)

09. Ans: (c)

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

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

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

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

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

For minimum energy condition use

$2\phi + \beta - \alpha = 90°$

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

$= 24.76°$

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

$V_f = rv_c = 0.67 \times 1 \times 60$

$= 40.2 \text{m/min}$

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

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

Common Data for Q. 10 & 11

10. Ans: (d)

11. Ans: (d)

Sol: $D_0 = 32$ mm, $\alpha = 35°$, $K_1 = 0.1$ mm,

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

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

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

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

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

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

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

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

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

(In general $\mu < 1$)

Hence by applying classical friction theorem

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

$$= \frac{0.5276}{1.04} = 0.55$$

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

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

$$= 8.42\,\text{m/min}$$

12. Ans: 56.23°

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

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

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

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

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

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

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

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

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

13. Ans: 272 N & 436 W

Sol: $S_0 = 0.12$ mm $= t_1$,

$t = 2.0$ mm, $a_2 = t_2 = 0.22$

Major cutting for, $b = p_z = F_c$

$$= S_0.t.\tau_S(\xi\sec\gamma - \tan\gamma + 1)$$

$S_0 = 0.12$, $\tau_S = 400$

$t = 2 - 0$,

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

$\gamma = 0$

$P_z = 0.12\times2.0\times400(1.83\sec0 - \text{Tan}0+1)$

$= 272$ N

$$\text{Power} = p = F_C \times V_C = p_Z \times \frac{V_f}{r}$$

$$= p_Z \times V_f \times \xi = 271\times\frac{52.6}{60}\times1.83$$

$= 436$ W

14. Ans: (d)

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

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

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

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

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

Common Data for Q. 15 & 16

15. Ans: (a)

16. Ans: (b)

Sol: D = 100 mm, f = 0.25 mm/sec,

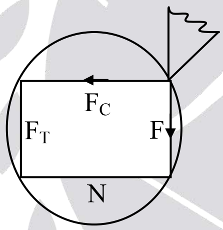
d = 4 mm

V = 90 m/min

$F_C = 1500$ N

$F_C = N = 1500$

$F_T = F$



Common Data for Q. 17 & 18

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

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

a = 0, 3 b = 0, 3, c = 0, 15

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

$$T_1 = T_2 = 60$$

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

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

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

$$V_2 = 1.11\,V_1$$

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

Productivity is proportional to MRR

% change in productivity

$$= \frac{\text{MRR}_2-\text{MRR}_1}{\text{MRR}_1}$$

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

19. Ans: 49.2 %

Sol: T_0 , V_0 = original tool life and velocity

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

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

$$V_1T_1^n = V_0T_0^n$$

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

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

$$V_0T_0^n = V_2T_2^n$$

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

% change in tool life

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

20. Ans: (b)

Sol: Let Q = no. of parts produced

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

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

$$40Q = 500+16Q$$

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

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

21. Ans: (a)

Sol: n = 0.12, C = 130

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

$V = V^1 = 90$ m/min

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

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

Increased tool life = 47.4 min

Increase in tool life = 47.4 – 21.4 = 26 min

22. Ans: (a)

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

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

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

The feed and depth of are same in both cases

$$V_1T_1^n = V_2T_2^n$$

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

$$V_1T_1^n = V_3T_3^n$$

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

23. Ans: 30.8 m/min

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

L_m = Rs. 0.5/min

Depreciation of tool regrind = Rs 0.5

C = 60, n = 0.2

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

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

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

24. Ans: 57.91

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

$TC = k + C_m + C_t$

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

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

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

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

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

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

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

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

$\therefore$ V = 57.91 m/min

25. Ans: 2.5 & 23°

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

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

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

chip reduction coefficient = t_2/t_1

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

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

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

26. Ans: (*)

Sol: Given data:

$z = 15$; $\alpha = 10°$;

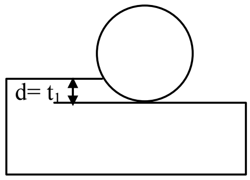
$N = 200$ rpm; $D = 80$ mm;

$f_m = 75$ mm/min; $d = 5$ mm;

$b = 50$ mm; $\tau_u = 420$ MPa;

$\phi + \beta - \alpha = 45°$;

$\mu = 0.7$ (assumption)



$\mu = \tan\beta = \tan^{-1}(0.7) = 34.99°$

$\phi = 45 + \alpha - \beta$

$= 45 + 10 - 34.99° = 20.00°$

$$\tau = \tau_u = \frac{F_S}{A_0} \times \sin\phi$$

$A_0 = t_1 \times b = 5 \times 50 = 250\ mm^2$

$$F_S = \frac{\tau_u \times A_0}{\sin\phi}$$

$$= \frac{420\times 250}{\sin(20.00°)} = 306.99\,kN$$

By using merchant circle

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

$$= \frac{306.99\times\cos(34.99-10)}{\cos(20+34.99-10)}$$

$$= \frac{306.99}{\cos(44.99)} \times \cos(24.99°) = 393.43\ kN$$

$$V_C = \frac{\pi DN}{1000\times 60}$$

$$= \frac{\pi\times 80\times 200}{1000\times 60} = 0.837$$

$P = W.D = F_C \times V_C$

$= 393.43 \times\ 0.837 = 329.30$ W

27. Ans: 0.944

Sol: T = 60 min

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

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

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

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

28. Ans: 12°

Sol: Given, $t_1 = 0.2$ mm,

$w = 2.5$ mm,

$F_c = 1177$ N,

$F_t = 560$ N

As the cutting is approximated to be orthogonal.

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

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

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

$$\Rightarrow \quad \alpha_s = 12°$$

29. Ans: 298

Sol: The given problem is the oblique machining problem.

Hence, $t_1.b = f.d$

$= 0.25 \times 4 = 1\ \text{mm}^2$

Specific cutting energy

$$= \frac{F_c \times V_c}{t_1 \times b \times V_c \times 1000} = 1.49$$

$F_c = 1.49 \times t_1 \times b \times 1000 = 1490$N

Because the power consumption is taking place only in the cutting stroke,

Velocity of tool in the cutting stroke

= length of work or stroke length × RPM of the crank

= 200 × 60 = 12m/min

Power required = F_c × cutting velocity

$$= \frac{(1490 \times 12)}{60} = 298\,\text{Watts}$$

30. Ans: (*)

Sol:

1. HCS	2. HSS
3. Stellite	4. Carbides
5. Ceramics	6. Cermets
7. Diamond	8. CBN
9. UCON	10. Sialon

Above list of cutting tool material is in increasing order with respect to most of condition and property except toughness.

If toughness is considered, the correct sequence in decreasing order will be HCS > HSS > Stellite > Diamond > CBN > UCONS > Sialon > Carbides > Ceramet > Ceramics

31. Ans: (a)

32. Ans: (b)

Sol: In machine process, a cutting fluid that removes a larger amount of heat.

33. Ans: (d)

Sol:

Ranges of *n* values for the Taylor equation for various tool materials	
High-speed steels	0.08-0.2
Cast alloys	0.1-0.15
Carbides	0.2-0.5
Coated carbides	0.4-0.6
Ceramics	0.5-0.7

34. Ans: (c)

35. Ans: (c)

36. Ans: (a)

37. Ans: (d)

Sol: Machinability of a material cannot be quantified directly in the form of some absolute value; rather it is given in some relative form. Hence option (d) is correct.

38. Ans: (a)

Conventional Practice Solutions

01.

Sol: Given data:

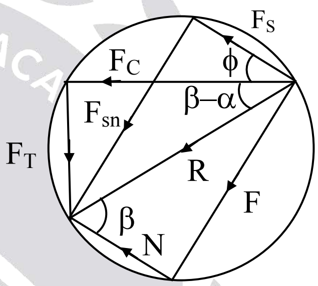
$t_2 = 0.4$ mm; $b = 2.5$ mm;

$f = 0.2$ mm/rev; $F_c = 1100$ N;

$F_t = 290$ N, $v = 2.5$ m/sec;

$\alpha = 10°$; $F_S = ?$; $\mu = ? = t_1$

$$r = \text{chip thickness ratio} = \frac{t_1}{t_2} = \frac{0.2}{0.4} = 0.5$$



From merchant circle;

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

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

$$\beta = 10° + \tan^{-1}\left(\frac{290}{1100}\right)$$

$$\beta = 24.76°$$

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{0.5\cos(10°)}{1-(0.5)\sin 10°}$$

$$\phi = 28.33° = \text{shear angle}$$

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

$$\frac{F_S}{\cos(43.09°)} = \frac{1100}{\cos(14.76°)}$$

$F_S = 830.72$ N

μ = coefficient of friction = $\tan\beta$

$= \tan(24.76°) = 0.461$

02.

Sol: Orthogonal cutting: $\alpha = 10°$;

$t_1 = 0.5$ mm ; $t_2 = 1.125$

Chip thickness ratio $= r = \frac{t_1}{t_2} = \frac{0.5}{1.125} = 0.44$

$$\phi = \text{shear angle} = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = 25.13°$$

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

$= \cot(25.13) + \tan(15.13)$

$= 2.40$

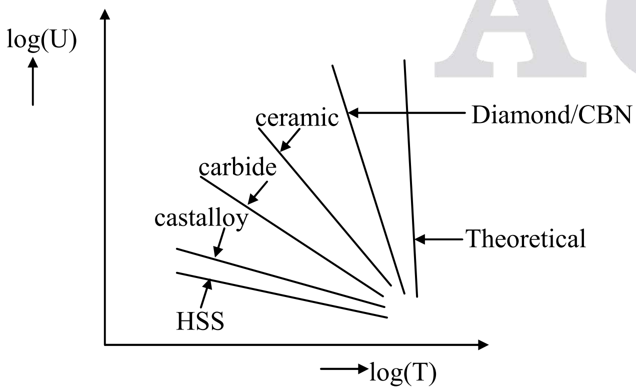
03.

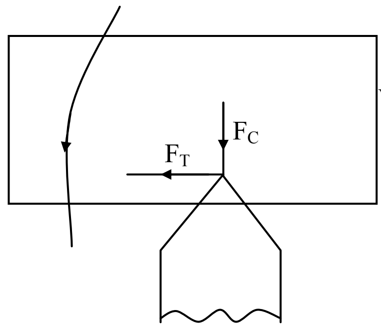
Sol: $VT^n = C$

Where v = cutting velocity in m/min

T = Tool life in min

n = Taylor's exponent depending on the cutting tool material





W.D = E = $F_C \times V$ + $F_T \times$ feed velocity

The effect of thrust force in machining are

1. It is not influencing the work done or energy required for machining.
2. The thrust force is increasing wear and tear on the tool. Therefore the tool life is reducing.
3. The thrust force is varying only due to variation of depth of cut but it is not influenced by cutting velocity and feed.
4. In thread cutting operation, the thrust force is trying to shear off the threads, therefore the threads will become weak. To avoid this problem it is required to minimise the thrust force and it is possible by minimising the depth of cut.

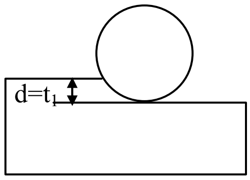
04.

Sol: Given data:

$z = 15$;	$\alpha = 10°$;
$N = 200$ rpm;	$D = 80$ mm;
$f_m = 75$ mm/min;	$d = 5$ mm;
$b = 50$ mm;	$\tau_u = 420$ MPa;

$\phi + \beta - \alpha = 45°$;

$\mu = 0.4$ (assumption)



$\mu = \text{Tan}\,\beta \Rightarrow = \tan^{-1}(0.4) = 21.80°$

$\phi = 45 + \alpha - \beta$

$= 45 + 10 - 21.80 = 33.19°$

$$\tau = \tau_u = \frac{F_S}{A_0} \times \sin\phi$$

$$F_S = \frac{\tau_u \times A_0}{\sin\phi}$$

$$= \frac{420 \times 250}{\sin(33.19°)} = 191.80\,\text{kN}$$

$A_0 = t_1 \times b = 5 \times 50 = 250$ mm^2

By using merchant circle

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

$$= \frac{191.80}{\cos(44.99)} \times \cos(11.8°) = 265.46\text{ kN}$$

$P = W.D = F_C \times V_C = 222.397$

05.

Sol: The effects of lowering friction at the tool-chip interface:-

1. Due to reduction in friction the energy lost in overcoming the friction will be reduced and hence power consumption for machining operation is reduced.
2. Efficiency of energy utilization is increasing.
3. When friction is reducing, wear and tear of the tool is reducing and therefore tool life will be increasing.
4. Due to reduction of μ; B(friction angle) is reducing so that ϕ (shear angle) is increasing and due to this MRR is increasing

   $2\phi + \beta - \alpha = 90°$ (merchant equation)

   $$\uparrow \phi = \frac{90° + \alpha - \beta \downarrow}{2}$$

5. When the friction becomes zero; Friction angle (β) becomes zero so that $2\phi - \alpha = 90°$. This is corresponding to the minimum shear strain condition. i.e., as the shear strain is minimum, the amount of energy required for deforming the chip is minimised. Hence the machining becomes more effective and efficient.
6. When lubricant or cutting fluid is used for reducing the friction, the heat generated in the machining will be carried away by the cutting fluid so that no heat treatment effects will be taking place. Hence no change in mechanical properties of workpiece will takes place.
7. Lubricant or cutting fluid is forming as a protective layer over the workpiece surface and it avoids the atmospheric contamination.

Disadvantages:

- Due to usage of cutting fluid or lubricant it may chemically react with workpiece surface and damages the surface of the workpiece.

06.

Sol: Orthogonal cutting:

$t_1 = 0.128$ mm; $b = 6.36$ mm;

$V_C = 2$ m/sec; $\alpha = 10°$;

$F_C = 568$ N; $F_t = 228$ N;

$t_2 = 0.228$ mm

r = chip thickness ratio = $\frac{t_1}{t_2}$

$$= \frac{0.128}{0.228} = 0.561$$

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

$$= \tan^{-1}\left(\frac{0.561\cos(10°)}{1 - 0.561\sin(10°)}\right)$$

$= 31.47°$

From merchant circle;

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

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

$\beta = 31.87°$

$P = F_C \times V$

$= 568 \times 2 = 1.136$ kW

07.

Sol: Orthogonal cutting:

$\alpha = 10°$; $r = 0.31$;

$F_C = 1200$ N; $F_T = 650$ N;

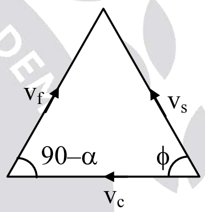
$d = 2$ mm; $f = 0.2$ mm/rev;

$V_C = 200$ m/min; $2\phi + \beta - \alpha = 90°$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = 17.88°$$

$$\beta = \alpha + \tan^{-1}\left(\frac{F_T}{F_C}\right) = 38.44°$$

$$F = \frac{F_C}{\cos(\beta - \alpha)}\sin\beta = 848.47 \text{ N}$$



$v_f = rV_C = 0.31 \times 200 = 62$ m/min

Work done in friction = $F \times V_f = 876.75$ W

$$F_S = \frac{F_C}{\cos(\beta - \alpha)} \times \cos(\phi + \beta - \alpha) = 942.50 \text{ N}$$

08.

Sol: $V_1 = 100$ m/min; $T_1 = 120$ min

$V_2 = 130$ m/min; $T_2 = 50$ min

$$\left(\frac{T_1}{T_2}\right)^n = \frac{V_2}{V_1}$$

Taking log on both sides

$$n\log\left(\frac{T_1}{T_2}\right) = \log\left(\frac{V_2}{V_1}\right)$$

$n = 0.299$

$V_3 = 2.5 \times 60 = 150$ m/min

$V_3T_3^n = V_1T_1^n$

$150 \times (T_3)^{0.299} = 100 \times (120)^{0.299}$

$T_3 = 30.92$ min

$V_4T_4^n = V_1T_1^n$

$$V_4 = V_1\left(\frac{T_1}{T_4}\right)^n$$

$$= 100\left(\frac{120}{80}\right)^{0.299} = 112.88 \text{ m/min}$$

09.

Sol:

(a) Under similar conditions of machining; the work piece on which discontinuous chips are produced will indicate better machinability workpiece. This is because the discontinuous are easy to dispose.

(b) Present day technology needs to develop some non conventional machining processes because the available traditional manufacturing processes can not serve purpose such as

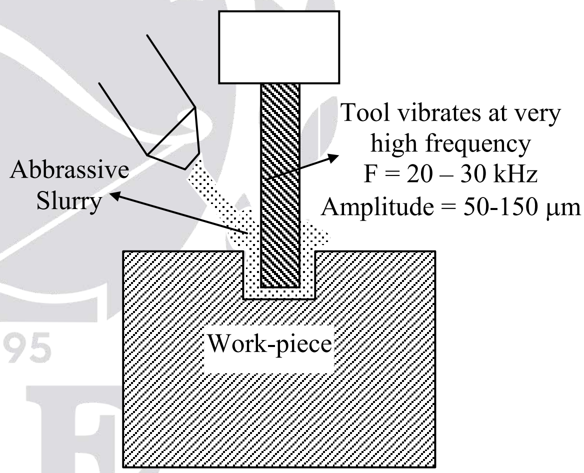
(i) New materials with a low machinability

(ii) Dimensional accuracy requirements

(iii) A higher production rate and economy

Ultrasonic Machining (USM)

- The basic process involves a tool vibrating with a very high frequency and a continuous flow of abrasive slurry in the small gap between the tool and the work surface.
- When the tool is vibrating at high frequency, the impact loads produced by the tool will be acting onto the abrasive particles which inturn produce impact loads on to the work piece and due to higher brittleness and lower toughness the work is getting fracturing.
- The chips produced due to this will be moving along with the abrasive slurry. From the above the mechanism by which chip formation taking place is brittle fracturing
- The impact of the hard abrasive grains fractures the hard and brittle work surface resulting in metal removal in the form of small wear particles, which are carried away by slurry.



The tool material used in USM:

To withstand for the reaction impact loads acting by the abrasives, the tool must be made by using very soft material the most commonly used tool material is Cu, BRASS, and M.S etc.

The MRR in USM is given by

$$Q \propto V\,Z\,f$$

Where,

Q = Volume of MRR,

V = Volume of material dislodged/impact,

Z = No. of particles making impact/cycle,

f = Frequency

On simplification of the above equation

Application of USM:

(i) Used to produce holes as small as 0.1 mm.

(ii) Used for drilling, grinding, profiling, coining etc on materials like SS, glass, ceramic, carbide quartz, semiconductors etc.

(iii) Dental doctor uses USM for producing holes in human teeth because it is a painless drilling methodology

(iv) Also used for piercing of dies and for parting off operations.

10.

Sol: **Tool Life:** The tool life can be defined in three different methods.

- The actual machining time between two successive regrinding of a cutting tool is called tool life. It is most commonly expressed in minutes.
- Volume of metal removed (in rough machining)
- Number of work pieces machined (in mass production)

Factors Influencing tool life:

1. Properties of work piece material:
2. Tool Geometry:
3. Use of Cutting Fluid:
4. Process Parameters:
   (i) Cutting speed
   (ii) Feed
   (iii) Depth of cut

- Because of uniqueness of process parameters, the researchers tried to establish relationship between process parameters and tool life.
- Taylor has assumed that cutting velocity is the major parameter influencing the tool life.

Taylor's tool life equation:

$$VT^n = \text{constant} = C$$

Where V = Cutting velocity in m/min

T = tool life in minutes

C = Taylor's constant

= Cutting velocity for 1 minute tool life

n = Taylor's exponent depending mainly on cutting tool material

= 0.05 to 0.1 for H.C steels

= 0.1 to 0.2 for H.S.S

= 0.2 to 0.4 $\rightarrow$ carbides

= 0.4 to 0.6 $\rightarrow$ ceramics

= 0.7 to 0.9 $\rightarrow$ diamond/ CBN

Modified Taylor's Tool life equation:

$$V T^n f^p d^q = C$$

f = Feed mm/rev

d = depth of cut in mm

p, q are constants < 1

q < p indicates that tool life is more sensitive to the uncut chip thickness than to the width of cut

Effect of tool life on cutting parameters is

$$V > f > d.$$

11.

Sol: The machinability of a material is usually defined in terms of four factors:

1. Surface finish and surface integrity of the machined part
2. Tool life
3. Force and power requirements
4. The level of difficulty in chip control after it is generated

Thus, good machinability indicates good surface finish and surface integrity, a long tool life, and low force and power requirements.

T = 60 min

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

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

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

Drawbacks: This method is applicable only when more than one material is given but if only one material is given this method cannot be used.

For maximum production rate (or) minimum production time.

$$V_{opt} = C\left[\frac{n}{1-n}.\frac{1}{T_C}\right]^n$$

$$V_{A_{opt}} = 67\left[\frac{0.11}{1-0.11}.\frac{1}{1.5}\right]^{0.11} = 50.91\,\text{m/min}$$

$$V_{B_{opt}} = 77\left[\frac{0.13}{1-0.13}.\frac{1}{1.5}\right]^{0.13} = 57.05\,\text{m/min}$$

12.

Sol: Orthogonal machining:

$t_1 = 0.25$ mm; $t_2 = 0.75$ mm;

$b = 2.5$ mm; $\alpha = 0°$;

$F_C = 900$ N; $F_T = 400$ N

$$r = \frac{t_1}{t_2} = 0.33$$

As $\alpha = 0°$; $F_C = N$;

$F_T = F$; $\tan\beta = \mu = F/N$

$$\tan(\beta - \alpha) = \frac{F_T}{F_C} = \frac{400}{900} = 0.44$$

$\therefore$ $\beta = 23.96°$

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

$$= \frac{900}{\cos(23.96)}\cos(42.39) = 729.37\,\text{N}$$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = 18.26°$$

$A_0 = t_1 \times b = 0.625$

$$\tau = \frac{F_S}{A_0} \times \sin\phi = 365.65\ \text{N/mm}^2$$

By assuming that machining is taking place under minimum energy criteria machining, the shear stress induced can be taken as ultimate shear stress.

$\therefore \tau = \tau_u = 365.65\ \text{N/mm}^2$

13.

Sol: ASA $\rightarrow 7 - \alpha_S - 6 - 6 - 8 - 30 - 1$

$t_1 = 0.2$ mm; $b = 2.5$ mm;

$i = 0$; $F_C = 1177$ N;

$F_T = 560$ N

(1) $\alpha_b(\text{ASA}) = \alpha(\text{ORS}) = 7°$

$\lambda = 90 - C_S = 90 - 30 = 60°$

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

$\tan\alpha_S = -\cos\lambda \tan i + \sin\lambda \tan\alpha$

$\alpha_S = 6.06°$

(2) $$\beta = \alpha + \tan^{-1}\left(\frac{F_T}{F_C}\right) = 31.50°$$

$\mu = \tan(32.44°) = 0.612$

(3) Minimum workdone criteria

$2\phi + \beta - \alpha = 90°$

$$\phi = \frac{90 + \alpha - \beta}{2}$$

$$= \frac{90 + 6.06 - 31.5}{2} = 32.28°$$

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

$$= \frac{1177}{\cos(25.44)}\cos(57.72) = 696.08\ \text{N}$$

$A_0 = t_1 \times b$

$= 0.2 \times 2.5 = 0.5\ \text{mm}^2$

$$\tau = \tau_u = \frac{F_S}{A_0}\sin\phi = 743.49\ \text{MPa}$$

14.

Sol: $VT^{0.13}f^{0.6}t^{0.3} = C$

$(40)(60)^{0.13}(0.25)^{0.6}(2)^{0.3} = C$

$C = 36.49$

$V_1 = 1.25 \times 40 = 50$ m/min

$f_1 = 1.25 \times 0.25 = 0.3125$ mm/rev

$t_1 = 1.25 \times 2 = 2.5$ mm

$$T_1\left(\frac{C}{v_1 f_1^{0.6} t_1^{0.3}}\right)^{\frac{1}{0.13}} = 2.29\ \text{min}$$

$$T_2 = \left(\frac{C}{v_1 f^{0.6} t^{0.3}}\right)^{\frac{1}{0.13}} = 10.75\ \text{min}$$

$$T_3 = \left(\frac{C}{v f_1^{0.6} t_1^{0.3}}\right)^{\frac{1}{0.13}} = 21.37\ \text{min}$$

$$T_4 = \left(\frac{C}{v f^{0.6} t_1^{0.3}}\right)^{\frac{1}{0.13}} = 35.77\ \text{min}$$

15.

Sol: For maximum production rate;

$$v_{opt} = C\left[\frac{n}{1-n} \times \frac{1}{T_C}\right]^n$$

$$= 100\left[\frac{0.5}{0.5} \times \frac{1}{9}\right]^{0.5} = 33.33\ \text{m/min}$$

Chapter 4

Machining

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

Sol: Time / cut = $\frac{L}{fN} = \frac{576}{0.2\times144} = 20$ min

$$V = \frac{\pi DN}{1000} = \frac{\pi\times100\times144}{1000} = 45.2 \text{ m/min}$$

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

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

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

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

Total change time / piece = 20 + 10 × 3

= 50 min

02. Ans: (a)

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

03. Ans: (b)

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

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

$$= \frac{3.175\times40}{6\times40} = \frac{127}{240} \rightarrow \text{not possible}$$

$$= \frac{127}{40}\times\frac{1\times20}{6\times20}$$

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

04. Ans: (c)

Sol: → Plane turning → Taper turning → Under cutting → Thread cutting

05. Ans: (d)

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

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

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

P = pitch

$$\frac{N_{Spindle}}{N_{L.S}} = \frac{P_{L.S}}{P_{Spindle/job}} = \frac{6}{2\times2} = \frac{3}{2}$$

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

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 m /sec,

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

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

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

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 mm / min

= 12 m / min

10. Ans: (c)

Sol: Total depth to be removed = 30 – 27

= 3 mm

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

feed = 0.5,

depth = 2

V = 60 m/min

$\left.\begin{array}{l}\text{Approach} = 50\,\text{m}\\ \text{Over time} = 50\,\text{min}\end{array}\right\}$ length wise

$\left.\begin{array}{l}\text{Approach} = 5\,\text{m}\\ \text{Over time} = 5\,\text{m}\end{array}\right\}$ width wise

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

l = 800,

L = 800 + 50 + 50 = 900

B = 400 + 5 + 5 = 410

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

= 20.5 min

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

Total time = 20.5×2 = 41 mins

11. Ans: (b)

Sol: Time per hole = L/f.N

= 25/(0.25× 300)

= 1/3 min = 20sec.

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

12.

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

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

N = 425rpm

f = 0.2 mm /rev

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

Time for idle time = 20s

Tool change time = 300 s

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

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

= T_m = machining time

i) No. of holes produced / drill

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

ii) Total time/hole

= T_m + idle time + Tool change time

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

= 0.9812 min = 58.87 = 59 sec

13. Ans: (b)

14. Ans: (b)

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

D_{min} = 6.25 mm

V = 18 m/min

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

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

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

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

= 1.3195 = 1.32

15. Ans: (d)

Sol: Hobbing process

No. of teeth = 30 (Not required)

Module = 3 mm

Pressure angle = 20^0 (Not required)

Radial depth= Addendum+1m+1.25m

= 2.25 module = 2.25 × 3

Radial depth = 6.75 mm

16.

Sol: Part size = 200 × 80 × 60 mm

D = 100 mm, Z = 12,

V = 50 m/min,

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

f_t = 0.1 mm, AP = OR = 5 mm

i) With symmetrical milling

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

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

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

= 200 + 20 + 5 + 5 = 230

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

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

ii) If offset = 5mm with asymmetrical milling

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

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

$= 80 + 2 \times 5 = 90$

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

$= 28.2$ mm

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

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

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

17. Ans: (b)

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

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

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

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

1 complete revolution and 9 holes in 21 hole circle.

18. Ans: (d)

Sol: d = 70 mm ,   Z = 12 teeth

V = 22 m/min

$f_t = 0.05$ mm/tooth

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

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

19. Ans: (b)

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

$= 480°$

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

20. Ans: (b)

Sol: Given,

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

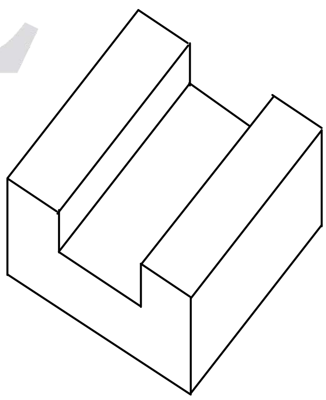
Feed = 0.08 mm/rev

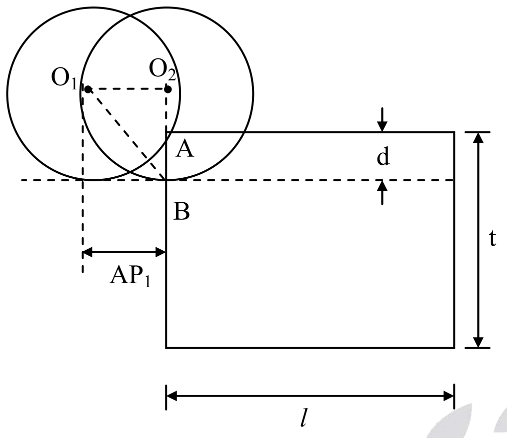
$Depth_{max} = 0.5$ mm = d

Length of workpiece, $l = 200$ mm

Cutting Velocity, V = 120 m/min

Total depth to be cut = 2 mm





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

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

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

Total time/machining

= No. of cuts×Time/cut

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

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

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

Total time = 10.227 × 4 = 40.91

= 41 min

21. Ans: 8.05 min

Sol: Broaching machine

P = 1.5 kW

$d_1 = 20$ mm enlarged to $d_f = 26$ mm

t = 25 mm

p = 10 mm/tooth

h = 0.075 mm/tooth

V = 0.5 m/min

Equation for time for broaching operation

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

Length of tool travel = L

$= t + L_e + AP + OR$

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

L_e = effective length or cutting length

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

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

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

$L_e = 400$ mm

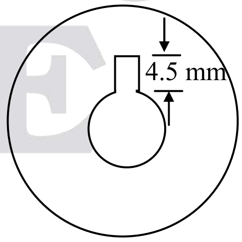
Time for broaching $= \frac{t + L_e}{V}$

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

Time for broaching = 8.05 min

22. Ans: (c)

Sol:



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

$d_f = 0$

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

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

$= 4.5 - 0.1 = 4.4$

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

Cutting length = effective length = L_e

$= L_r + L_S + L_f$

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

$= 1208$mm

23. Ans: (b)

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

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

24. Ans: (a)

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

Runout is used in lathe.

Parallelism used in shaper.

25. Ans: (a)

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

26. Ans: 18

Sol: The output per annum = 800×52

= 41600 units.

The rejection rate is 20%.

$\therefore$ The quantity to be produced (including rejection) = $\frac{\text{Required output}}{(1 - \text{rejection rate})}$

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

Total time required for turning

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

$= 34666.6$ hours

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

Time available per lathe per annum

$= 48 \times 52 = 2496$ hrs

$\therefore$ Number of lathes required

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

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

$\therefore$ No. of lathes required = 18

27. Ans: & 28. Ans:

Sol: Hole = $31.75^{+0.01}$ mm

Hole diameter before = $31.24^{+0.005}$ mm

p = 15 mm; t = 25 mm

h = 0.025 mm;

Approach = 5 mm

$$d = \frac{D_f - D_i}{2} = \frac{31.75 - 31.42}{2} = 0.165\,\text{mm}$$

$$n = \frac{d}{h} = \frac{0.165}{0.025} = 6.6 \simeq 7$$

$D_f = 31.24 + (7 \times 0.025 \times 2) = 31.59$ mm

$= 31.29 + (7 \times 0.025 \times 2) = 31.64$ mm

i) $L_c = n \times p = 7 \times 15 = 105$ mm

$L = t + L_c + A_p = 25 + 105 + 5 = 135$ mm

ii) No. of teeth in contact at any point of time

$$= \frac{t}{p} = \frac{25}{15} = 1.67 \approx 2$$

Force required = 5000 × 2 = 10 kN

29. Ans: (c)

30. Ans: (a)

Sol:

- Half centre: The half centre is similar to an ordinary centre except that a little less than half of the centre has been ground away. This feature facilitates facing of the bar ends without removal of the centre.
- In the tipped centre, a hard alloy tip is brazed into a steel shank. The hard tip is wear resistance.
- Ball centre is particularly suitable for taper turning.
- Pipe centre is used for supporting pipes, shells and hallow end jobs.

31. Ans: (c)

Sol: In twist drill the helix angle varies from minimum near the center to the maximum towards the periphery and rake is directly proportional to the helix angle.

32. Ans: (c)

33. Ans: (b)

34. Ans: (b)

Sol: Counter boring is internal turning operation used for enlarging end of the hole is called as counter boring.

35. Ans: (b)

Sol: Lathe machine → Reducing diameter of cylindrical job

Milling machine → Key ways on shaft

Broaching → Rectangular holes

36. Ans: (b)

37. Ans: (d)

38. Ans: (a)

39. Ans: (d)

Sol: Glazing takes place if the wheel is rotated at very high speeds and is made with harder bonds.

40. Ans: (c)

Conventional Practice Solutions

01.

Sol: By using taper turning operation in a Lathe machine.

TAPER TURNING

When the diameter of a piece changes uniformly from one end to the other, the piece is said to be tapered. Taper turning as a machining operation is the gradual reduction in diameter from one part of a cylindrical workpiece to another part, tapers can be either external or internal. If a workpiece is tapered on the outside, it has an external taper; if it is tapered on the inside, it has an internal taper.

There are three basic methods of turning tapers with a lathe. Depending on the degree, length, location of the taper (internal or external), and the number of pieces to be done, the operator will either use the compound rest, offset the tailstock, or use the taper attachment. With any of these methods the cutting edge of the tool bit must be set exactly on center with the axis of the workpiece or else the work will not be truly conical and the rate of taper will vary with each cut.

Compound Rests

The compound rest is favorable for turning or boring short, steep tapers, but it can also be used for longer, gradual tapers providing the length of taper does not exceed the distance the compound rest will move upon its slide. This method can be used with a high degree of accuracy, but is somewhat limited due to lack of automatic feed and the length of taper being restricted to the movement of the slide.

The compound rest base is graduated in degrees and can be set at the required angle for taper turning or boring. With this method, it is necessary to know the included angle of the taper to be machined. The angle of the taper with the centerline is one-half the included angle and will be the angle the compound rest is set for. For example, to true up a lathe center which has an included angle of 60°, the compound rest would be set at 30° from parallel to the ways (Figure 1).

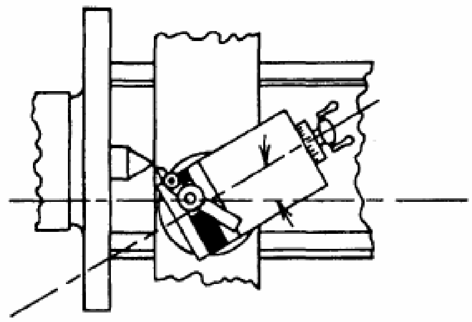


Fig 1: Turning of soft center true with the compound rest.

If there is no degree of angle given for a particular job, then calculate the compound rest setting by finding the taper per inch, and then calculate the tangent of the angle (which is the compound rest setting) .

For example, the compound rest setting for the workpiece shown in Figure 2 would be calculated with these two formulas:

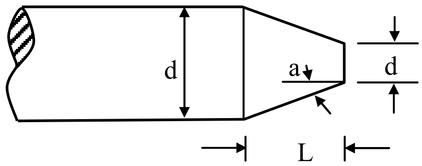


Fig: 2 Taper

$$TPI = \frac{D-d}{L}$$

Where,

TPI = taper per inch,

D = large diameter,

d = small diameter,

L = length of taper

$a = \tan^{-1}$ (TPI / 2)

Where:

a = angle (compound rest setting) in degrees

$\tan^{-1}$ = the tangent function

TPI = taper per inch

The problem is actually worked out by substituting numerical values for the letter variables:

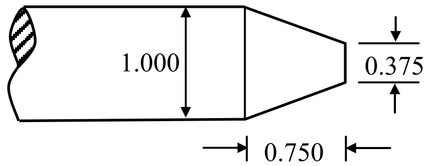
Example:

$$TPI = \frac{D-d}{L} = \frac{1.000-0.375}{0.750}$$

$$= \frac{0.625}{0.750} = 0.833$$

$$a = \tan^{-1}\left(\frac{TPI}{2}\right)$$

$$= \tan^{-1}\left(\frac{0.833}{2}\right) = \tan^{-1}(0.41650)$$



Using a handheld calculator, you will see that $\tan^{-1}(0.41650) = 22.61°$

The included angle of the workpiece is double that of the tangent of angle (compound rest setting). In this case, the double of 22° 37’ would equal the included angle of 45°14’.

To machine a taper by this method, the tool bit is set on center with the workpiece axis. Turn the compound rest feed handle in a counterclockwise direction to move the compound rest near its rear limit of travel to assure sufficient traverse to complete the taper. Bring the tool bit into position with the workpiece by traversing and cross-feeding the carriage. Lock the carriage to the lathe bed when the tool bit is in position. Cut from right to left, adjusting the depth of cut by moving the cross feed handle and reading the calibrated collar located on the cross feed handle. Feed the tool bit by hand-turning the compound rest feed handle in a clockwise direction

02.

Sol: Given:

$W = 20$ mm; $N = 60$ rpm

$z = 10$; $d = 5$ mm

$D = 75$ mm; $\mu = 0.5$

$\alpha = 10$; $\tau = 400$ N/mm^3

$f_m = 100$ mm/min;

$\Rightarrow$ This is the case of redundant data

$\Rightarrow$ Q (Metal Removal Rate) = $w.d.f_m$

$$Q = \frac{2cm \times 0.5cm \times 10cm}{60} = 0.166\,cm^3/s$$

Milling power, (from Machinery's handbook)

$$P = K_p QCW \text{ (hp)}$$

where, K_p = Power constant

C = Feed factor

W = tool-wear factor

By using Machinery's handbook

$K_p = 2$; $C = 1.13$; $W = 1$

$\therefore P = 2 \times 0.166 \times 1.13 \times 1$

$P = 0.375$ hp

03.

Sol:

$$\text{Grinding ratio} = \frac{\text{volume of material removed on workpiece}}{\text{volume of Grinding wheel wear}}$$

$$G.R = \frac{b \times d \times \ell}{\frac{\pi}{4} w^2 \left(D_i^2 - D_f^2\right)}$$

Soft (or) Hard grinding wheel is indicated by using a grade of grinding wheel. Even through size of abrasive % of abrasives on bonding material are same, it is possible to vary the grade of a grinding wheel by varying a pressure applied in the contacting of powder. Metallurgical process used for manufacturing of grinding wheel. i.e., when large amount of pressure is applied hard wheels are contained and when small amount of pressure is applied soft wheels are obtained.

It is always desirable to have higher G.R. because in a given machining operation it is always expected to have higher volume of material removed from the workpiece and the lower tool wear.

04.

Sol: Hole = $31.80^{+0.01}$ mm

Hole diameter before = $31.25^{+0.005}$ mm

$p = 15$ mm; $t = 25$ mm

$h = 0.025$ mm; F_C/teeth = 5000 N

Approach = 5 mm

$$d = \frac{D_f - D_i}{2} = \frac{31.8 - 31.25}{2} = 0.275\,mm$$

$$n = \frac{d}{h} = \frac{0.275}{0.025} = 11$$

$D_f = 31.25 + 11 \times 0.025 \times 2 = 31.8$ mm

$D_f = 31.255 + 11 \times 0.025 \times 2 = 31.805$ mm

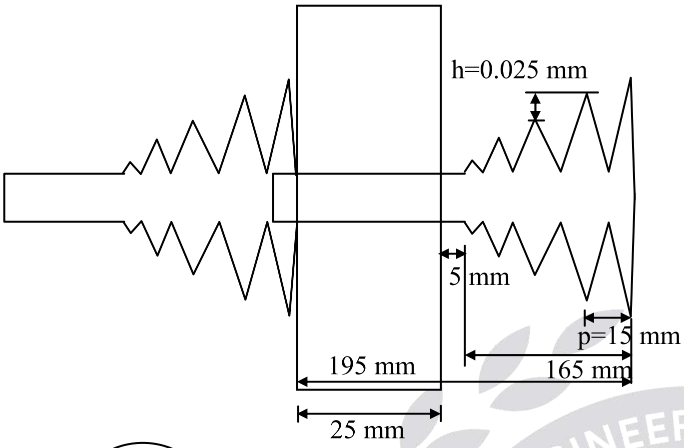
11 teeth is sufficient and no change of teeth is required

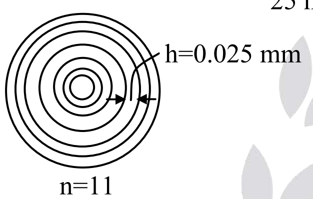
i) $L_e = n \times p = 11 \times 15 = 165$ mm

$L = t + L_e + Ap = 25 + 165 + 5 = 195$ mm

ii) No. of teeth in contact at any point of time

$$= \frac{t}{p} = \frac{25}{15} = 1.67 \approx 2$$





Force required = 5000 × 2 = 10 kN

05.

Sol: Conventional Milling and Climb Milling:

The cutter rotation can be either clockwise or counter-clockwise; this is significant in the milling operation.

In conventional milling, also called *up milling,* the maximum chip thickness is at the end of the cut as the tooth leaves the workpiece surface. Consequently,

(a) tooth engagement is not a function of workpiece surface characteristics and
(b) contamination or scale (oxide layer) on the surface does not adversely affect tool life. This is the more common method of milling, where the cutting operation is smooth. However, the cutter teeth must be sharp, as otherwise the tooth will rub against the surface being milled and smear it for some distance before it begins to engage and cut. There may also be a tendency for the cutter to chatter, and the workpiece has a tendency to be pulled upward (because of the cutter rotation direction), thus necessitating proper clamping of the workpiece on the table of the machine.

In climb milling, also called *down milling,* cutting starts at the surface of the workpiece, where the chip is thickest. The advantage of this method is that the direction of rotation of the cutter will push the workpiece downward, thus holding the workpiece in place, a factor particularly important for slender parts. However, because of the resulting impact force when a tooth engages the workpiece, this operation must have a rigid work-holding setup, and gear backlash in the table feed mechanism must be eliminated. Climb milling is not suitable for machining of workpieces with surface scale, such as metals that have been hot worked, forged, or cast. The scale is hard and abrasive, and thus causes excessive wear and damage to the cutter teeth, and shortening tool life.

$$t_{1max} = \frac{2f_m}{N_z}\sqrt{\frac{d}{D}} = \frac{2f}{Nn_t}\sqrt{\frac{d}{D}}$$

$$t_{1min} = 0$$

$$t_{1avg} = \frac{t_{1max} + t_{1min}}{2} = \frac{f}{Nn_t}\sqrt{\frac{d}{D}}$$

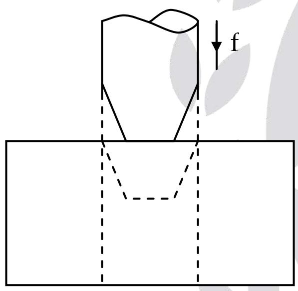
$$A_m = t_{1avg} \times b$$

$$= t_{1_{avg}} \times w = \frac{f}{Nn_t}\sqrt{\frac{d}{D}} \times w$$

$$= \frac{fw}{Nn_t}\sqrt{\frac{d}{D}}$$

06.

Sol:



i) D = 10 mm, f = 0.2 mm/rev, N = 500 rpm

Specific cutting energy = 1.9 J/mm^3

Material removal rate = $A_C \times f \times N$

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

$$= \frac{\pi}{4}(10)^2 \times 0.2 \times N$$

$$= 15.70\text{mm} \times \frac{N}{60} = 130.83\text{mm}^3/\text{sec}$$

Specific cutting energy = $\frac{F_C \times V_C}{MRR}$

$F_C \times V_C$ = 24.85 = workdone = power

$$F_C = \frac{\text{workdone}}{V_C}$$

F_C = 952.10 N

$$V_C = \frac{\pi DN}{1000 \times 60}$$

$$= \frac{\pi \times 10 \times 500}{1000 \times 60} = 0.261\text{mm/sec}$$

T = Torque = 0.6 × F_C × D

= 5712.64 N-mm

$$Q = \frac{\pi}{4}D^2 fN$$

$$= \frac{\pi}{4} \times \frac{10^2 \times 0.2 \times 500}{60} = 130.899 \text{ mm}^3/\text{sec}$$

P = u × Q

= 1.9 × 130.899

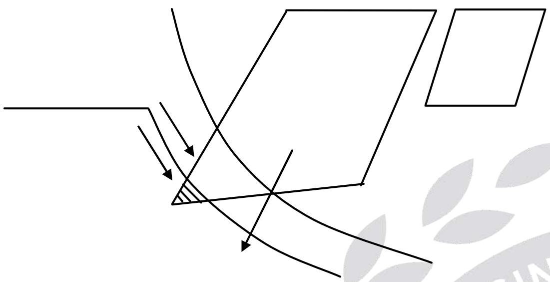
P = 248.7 W

And $P = \frac{2\pi NT}{60}$

$$\therefore 248.7 = \frac{2\pi \times 500 \times T}{60}$$

T = 4.75 N-m

ii) As the grinding process continues the forces are acting onto the abrasive particles, so the abrasive is experiencing wear and tear. Due to this when the wear on the abrasive particle becomes considerable; it is started rubbing onto the workpiece producing rubbing forces. These rubbing forces will be pulling out the blunt abrasive particle so that the wear of the grinding wheel will be taking place. As the blunt abrasive particle is pulled out, the fresh and new abrasive particle present behind will be started contacting the workpiece and removing the material from the workpiece. This is also called as "self-sharpening of grinding wheel".



Out of the four abrasive particles (Al_2O_3, SiC, B_4C, Diamond) are available, because of very poor performance in machining B_4C is not preferable. Due to very high cost the diamond is not preferable. Hence most commonly used abrasives in grinding wheel are Al_2O_3, SiC.

Diamond wheel means the grinding wheel (G.W) is made with diamond abrasive particles. When diamond is in contact with the ferrous work piece. i.e., steel because of presence of atomic attraction, the C-atoms are diffusing from the diamond abrasive and depositing onto the steel workpiece called as diffusion wear. Therefore when diamond wheels are used for grinding of steel workpieces, the diffusion wear is high and hence it is not recommended.

07.

Sol: *Effects of vibration: (during turning operation)*

1. The surface finish produced on the workpiece is poor.
2. The dimensional variations produced on the component is very high. Therefore accuracy is poor. Hence it is required to provide large amount of tolerance on the component dimensions.
3. Due to vibrations, the impact loads are induced on the tool tip and because of lower toughness of carbide tools, the tool tip may fail abnormally.
4. Presence of vibrations will increase the forces in machining the tool wear is increasing and tool life is decreasing.

Reasons for inducing the vibrations:-

1. High feed and inducing the vibrations.
2. Improper vibration Isolation of Lathe machine.
3. If bed of a machine tool is not made by grey cast iron as a material.
4. During fixing the tool, large overhang is used.
5. The presence of spindle runout in the lathe machine.

08.

Sol: Finish cut:

$d = 1$ mm; $f = 0.1$

$V_C = 50$ m/min; $L = 200$

$D = 44 + 2 \times 1 = 46$ mm

$N = \frac{1000V}{\pi D} = 345.95\,\text{rpm}$

$T_{finish\ cut} = \frac{L}{f\,N} = 5.78\,\text{min}$

Rough cut:

No. of cut = $\frac{52-46}{2\times 3} = \frac{6}{6} = 1$

$N = \frac{1000V}{\pi D} = \frac{1000\times 30}{\pi \times 52} = 183.64\,\text{rpm}$

$T_{rough\ cut} = \frac{L}{f\,N} = \frac{200}{0.3\times 183.64} = 3.63\,\text{min}$

Total time = $T_{finish} + T_{rough}$ = 9.41 min

09.

Sol: Cutting stroke = 100 mm × 150 mm

m = 0.7; V_C = 20 m/min;

d = 3 mm; f = 0.3 mm/stroke

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

$= \frac{100}{0.3}\times\frac{150}{20000}(1+0.7) = 4.25$ min

MRR = f × d × V_C

= 0.3 × 3 × 20 × 10^3

= 18 × 10^3 mm/min

10.

Sol: Time/cut = $\frac{B}{f}\times\frac{L}{V}(1+m)$

$= \frac{1000}{0.5}\times\frac{1200}{24000}(1+0.75)$ = 175 min

(No. of cuts = 10 ,

Total time = Time/cut × 10 + 1.2 × 9) → applicable for multiple cuts

MRR = f × d × V_C = 0.5 × 4 × 24 × 10^3

= 48 × 10^3 mm/min

11.

Sol: D = 12 mm; t = 50 mm

No.of pieces = 100; $T_{set\ up}$ = 30 sec

$T_{drill\ set\ up}$ = 10 sec; $T_{bringing\ back}$ = 5 sec

(Peck drilling operation)

Assume V_C = 30 m/min (bellow 40 m/min)

HSS

f = 0.1 mm/rev

Time/hole = $\frac{L}{fN} = \frac{t+CAP}{f_N}$

$= \frac{50+0.5\times 12}{0.1\times\frac{1000\times 30}{\pi\times 12}}$ = 0.703 min

Total time/hole = T_m × 60 + 30 + 10 + 5

= 87.22 sec

Total time = Total time/hole × 100

= 8722.30 sec = 145.37 min.

12.

Sol: **I[st] drill :**

D = 15 mm; t = 40 mm

$T_{withdrawl}$ = 5 sec; V_C = 25 m/min;

f = 0.1; T_{ap} = 10 sec

$T_m = \frac{L}{f_N} = \frac{t+CAP}{f_N}$

$= \frac{40+150.3}{0.1\times\frac{1000\times 25}{\pi\times 15}} = 0.279\,\text{min}$

Time/hole = T_m × 60 + 5 + 10 = 31.77 sec

II[nd] drill:

D = 22 mm;

t = 30

$$T_m = \frac{t+0.30}{f_N} = \frac{30+0.3\times 22}{0.1\times\frac{1000\times 20}{\pi\times 22}} = 1.26\,\text{min}$$

Time/hole = T_m × 60 + 10 = 85.88 sec

T.T = 117.65 sec.

13.

Sol: Lead Screw -0.2 thread/mm

$$P = \frac{1}{0.2} = 5\text{mm}$$

Reverse stroke → paul indexing Ratchet by 1 teeth

No. of teeth on ratchet = 20

$$f = \frac{mm}{D.S}$$

1 revolution of ratchet → 20 teeth to be indexed

→ 20 D.S or R.S

→ 1 rev L.S

→ 1 p or Lead

→ 5 mm

20 D.S. → 5 mm

$$1\text{D.S.} = \frac{5}{20} = 0.25\text{mm} = f$$

B = 100 mm; T_m = 10 min;

$m = \frac{1}{2}$; L = 150

$$T_m = \frac{B}{f}\times\frac{L}{V}(1+m)$$

$$10\text{ min} = \frac{100}{0.25}\times\frac{150}{V}(1+0.5)\text{mm/min}$$

V = 9 m/sec

14.

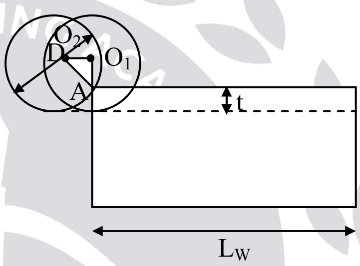
Sol: L = L_w;

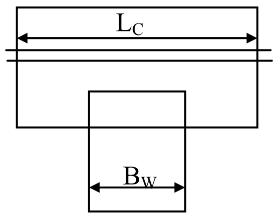
B = B_w;

d = t;

Width of cuter = $L_C > B_W$

D = diameter; $f_t = S_o$





$$\text{Time/cut} = \frac{L}{f_N} = \frac{L}{f_t zN} = \frac{L_w + CAP}{f_t zN}$$

$$N = \frac{1000V}{\pi D} = \frac{1000V_C}{\pi D}$$

$$CAP = O_1O_2 = \sqrt{O_1A^2 - O_2A^2}$$

$$= \sqrt{R^2-(R-t)^2}$$

$$= \sqrt{2Rt-t^2}$$

$$= \sqrt{t(2R-t)} = \sqrt{t(D-t)}$$

$$\text{Time/cut} = \frac{L_w+\sqrt{t(D-t)}}{f_t\times z\times\frac{1000V_C}{\pi D}}$$

Chapter 5
Metal Forming Process

01. Ans: (a)

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

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

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

02. Ans: (b)

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

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

$= 0.7\ A_{0p}$

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

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

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

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

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

$= 0.5\ A_{0Q}$

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

03. Ans: (a)

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

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

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

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

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

04. Ans: 1.98 MN

Sol: Given: $H_0 = 4.5$ mm

$H_1 = 2.5$ mm

$\Delta H = 2$

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

Strip wide = 450 mm = b

Average coefficient of friction = 0.1

$\sigma_y = 180$ MPa

RSF = P_{avg} × projected area

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

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

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

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

RSF = 1982.64 kN = 1.98 MN

05. Ans: (a)

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

N = 100 rpm.

Velocity of strip at neutral point

= Surface Velocity of rollers

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

= 1.57 m/sec

06. Ans: (a)

Sol: $H_o = 20$ mm,

$b = 100$ mm

$H_1 = 18$ mm,

$R = 250$ mm,

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

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

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

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

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

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

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

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

$= 795$ kN.

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

Where

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

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

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

$= 7110$ kN-mm

$= 7.11$ kN-m

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

$= 7.44$ kW / roller

Total Power $= 7.44 \times 2 = 14.88$ kW

07. Ans: (d)

Sol: $H_o = 16$ mm,

$H_1 = 10$ mm,

$R = 200$ mm

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

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

08. Ans: (a)

Sol: Given rolling process

Initial thickness $H_0 = 30$ mm

Final thickness $= H_1 = 14$ mm

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

$\sigma_y = 200$ MPa

Thickness at neutral $H_n = 17.2$

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

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

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

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

09. Ans: (b)

Sol: Roll separation distance

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

$= 625$ mm

10. Ans: (b)

Sol: $d_o = 15$ mm,

$d_f = 0.1$ mm

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

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

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

a) 3 stages with 80% reduction at each stage

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

$d_1 = 0.2\, d_o = 3$ mm

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

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

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

$d_1 = 0.2.\, d_0 = 3$

$d_2 = 0.2.\, d_1 = 0.6$

$d_3 = 0.2.\, d_2 = 0.12$

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

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

$d_1 = 0.2.\, d_0 = 3$

$d_2 = 0.2.\, d_1 = 0.6$

$d_3 = 0.6.\, d_2 = 0.36$

$d_4 = 0.6.\, d_3 = 0.0216$

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

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

11. Ans: (a)

Sol: Given wire drawing process

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

Die angle = 18^0, diameter land = 4 mm

Coefficient of friction = 0.15

Yield dress = 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

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

$B = \mu \cot\alpha$

$\alpha = \frac{1}{2}$ Die angle $= \frac{1}{2} \times 18 = 9^0$

$\alpha = 9$

$B = 0.15 \times \cot 9^0 = 0.947$

$\sigma_2 = 126.958$MPa

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

$= 260(2.056)(0.2375)$

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

(By considering friction)

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

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

Total drawing load = $\sigma_t \times A_1$

$= 178.05 \times 21.237$

$= 3.781$ kN

Common data for Q 12, 13 & 14

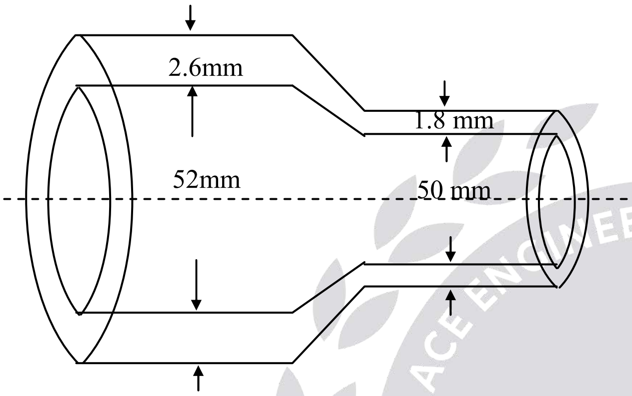
12. Ans: (b) , 13. Ans: (c), 14. Ans: (a)

Sol: Initial inside diameter of tube

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

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

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



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

$$B = \frac{0.12 + 0.12}{\text{Tan}(12°)} = 1.29$$

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

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

$\sigma_2/\sigma_y = 0.64$

13. Movable mandrel

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

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

14. Floating mandrel

$B = 0$

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

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

Common data for Q 15. & 16.

15. Ans: 6 & 16. Ans: 3.4

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

Given ideal condition

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

$\sigma_f = 60$ MPa

Maximum reduction condition

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

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

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

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

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

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

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

$d_1 = 4.53$ ……… (1) stage

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

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

Dia of wire in 2nd stage = 3.424 mm

$d_1 = d_0 \times c$

$d_2 = d_1 \times c = 4.53 \times 0.756$

$= 3.424 > 1.34$

$d_3 = d_2 \times c$

$= 3.424 \times 0.756$

$= 2.589 > 1.34$

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

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

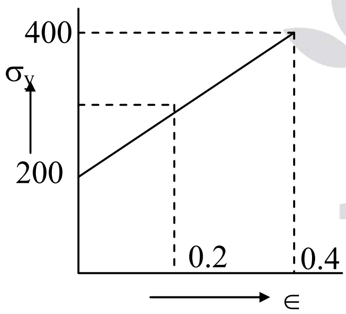
$d_6 = d_5 \times c = 1.1186 < d_f$

$\therefore$ Hence No. of stages = 6

Common data for Q 17, 18

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

Sol:



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

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

σ_y before $= 200$ MPa ,

σ_y after $= 400$ MPa

$A_o L_o = A_f L_f$

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

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

True strain in the drawing process

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

From the graph σ_y at $\in = 0.2$,

$\sigma_y = 300$ MPa

19. Ans: (b)

20. Ans: (c)

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

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

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

= 196346.5 N

= 196 Tons

21. Ans: (b)

Sol: Extrusion constant = K = 250

$d_o = 100$ mm, $d_f = 50$ mm

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

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

22. Ans: 1

Sol: Let, $d_1 = d_2 = d$

h_1 = height of first cylinder

h_2 = height of second cylinder

Assume $h_1 < h_2$

Let % reduction in height = 10%

Ist cylinder

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

$h_0 - h_f = 0.1\ h_0$

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

$A_0h_0 = A_f h_f$

$d_0^2h_0 = d_f^2\ h_f$

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

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

IInd cylinder

$A_0h_0 = A_fh_f$

$d_0^2h_0 = d_f^2\ h_f$

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

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

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

Common data for Q 23 & 24

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

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

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

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

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

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

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

$= 785.350$ kN

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

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

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

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

25. Ans: (b)

26. Ans: 58%

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

$= 0.6\ A_0$

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

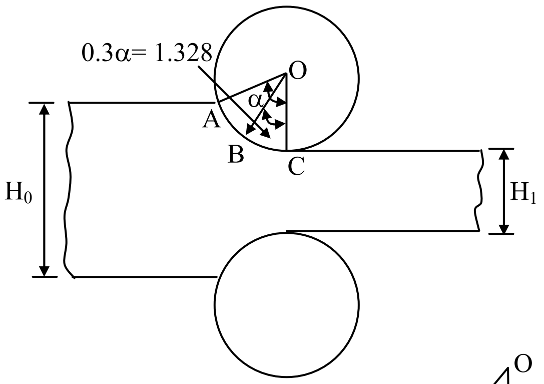
$= 0.7 \times 0.6 \times A_0 = 0.42\ A_0$

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

$= 58$ %

27. Ans: 7.26

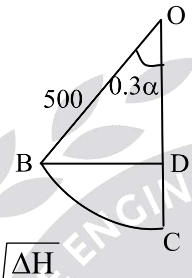
Sol:



H_o = 10 mm,

H_1 = 7 mm,

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



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

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

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

OD = 500×cos1.328 = 499.865

DC = 500 – OD = 0.1343 mm

Thickness of neutral point = At point B

= 7 + 2 × 0.1343 = 7.2686 mm

28. Ans:

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

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

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

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

From , the drawing force is

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

Where,

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

F = 0.002459 MN

Power = F × V

= 0.002459 × 0.6

= 0.001475 MN m/s

= 0.001475 MW = 1475 W

and the actual power will be 35% higher, or

Actual power = 1.35 × 1475 = 1.992 kW

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

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

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

In this equation,

σ is the drawing stress, σ_d.

Hence, using the actual force, we have

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

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

= 470 MPa

Therefore, the die pressure at the exit is

p = 748 – 470 = 278 MPa.

29. Ans: 7.687 MPa, 19.7 %

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

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

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

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

By applying L – Hospital rule

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

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

$= 7.687$ MPa

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

$= 19.71\%$

30. Ans: 29.85 tons

Sol: Initial size = 25×25×150mm

Final size = 6.25×100×150mm

$\mu = 0.25$;

$\sigma_y = 0.7$kg/mm^2

As given piece is pressed; height is reduced

$h_0 = 25$;

$h_f = 6.25$

$A_0 = 25\times150$;

$A_f = 100\times150$

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

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

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

$r_f = 69.098$mm

Forging force

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

$= 29847.44$kg $= 292.80$kN

31. Ans: 20.52 kW

Sol: $d_0 = 10$ mm;

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

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

$d_1 = 8.36$ mm

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

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

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

$= 141.687$ MPa

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

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

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

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

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

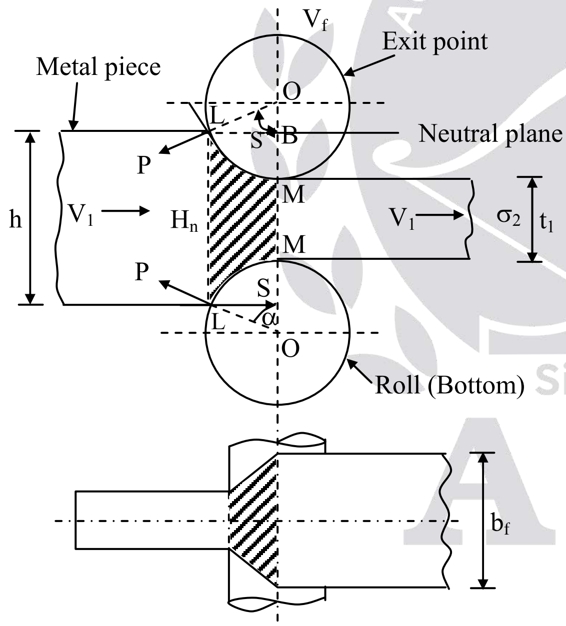
$\Rightarrow$ P = 20.52 kW

32. Ans: (b)

Sol: The roll separating force in the rolling can be reduced by reducing roller diameter, reducing the friction, heating the material and providing back and front tensions.

33. Ans: (d)

Sol: The pressure exerted over the metal by the roller is not uniform throughout, it is minimum at both the extremeties *L* and *M* and maximum at a point known as *no-slip point* or *the point of maximum pressure.* At this point the surfaces of the metal and the roll move at the same speed.



34. Ans: (c)

Sol: Strain hardening is higher in cold forming, while it is very low in hot working. Cold forming or working process requires a low coefficient of friction (μ_i) of about 0.1, while hot working requires as high 0.6 approximately. It is also a fact that hot forming or working requires less energy even for bulk deformation, while cold forming requires more energy even for lesser degree of deformation.

35. Ans: (d)

Sol: In indirect extrusion, the direction of flow of the extruded metal is in the opposite direction of the ram movement. Hence, the name is given as indirect (or) backward extrusion.

The travel speed of the extruded product is greater than that of the ram. The travel speed of the extruded product is greater than that of the ram.

36. Ans: (d)

37. Ans: (d)

Sol: Hydrostatic extrusion is similar to direct extrusion. So given assertion is incorrect.

38. Ans: (c)

39. Ans: (c)

40. Ans: (b)

Sol: Both statements are correct, but statement (II) is not correct explanation of statement(I).

41. Ans: (a)

42. Ans: (a)

Sol:

- *Rolling* is used for production in large quantities of standard item such as sheets and plates.
- *Extrusion* more widely used in the manufacture of solid profiles, hollow profiles (such as tubes), from (non ferrous metals and their alloys, copper, brass and bronzes etc), but steel and other ferrous alloys can also be successfully processed with the development of molten glass lubricant.
- *Forging* is more suited for production of relatively simple shapes.
- *Spinning* operation of forming sheet metal into circular shapes by means of a lathe, forms and hand tools which press and shape the metal about the revolving form.

43. Ans: (d)

Sol: Graphite powder $\rightarrow$ Bright shining surface

Air $\rightarrow$ Burnt surface

Soap solutions $\rightarrow$ Dull surface

44. Ans: (b)

Sol: Hot working is well suited for forming large parts, since the metal has a low yield strength and high ductility at elevated temperatures. So statement (2) is incorrect.

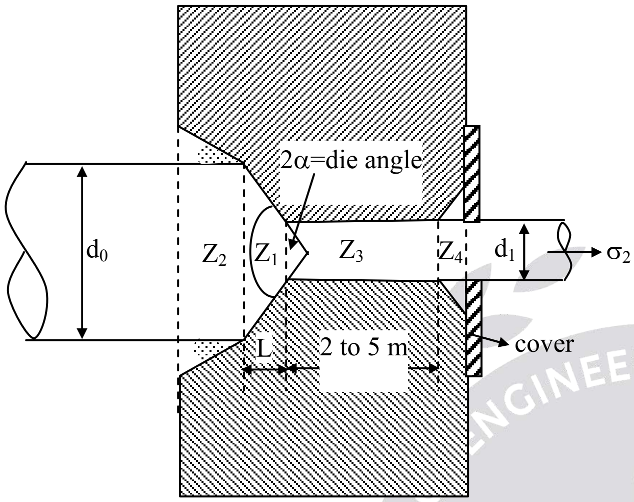
45. Ans: (a)

Sol:

- Edgering $\rightarrow$ Collecting the material at localized areas.
- Upsetting $\rightarrow$ Rod is deformed so that diameter increased.
- Fullering $\rightarrow$ Distributing the material from centre.
- Trimming $\rightarrow$ Removing flash from the forged part.

Conventional Practice Solutions

01.
Sol:



Zone – 1: Deformation zone:
Zone – 2 Entry (or) lubricating zone:
Zone – III Sizing zone:
Zone – IV exit zone

2α = die angle
d_0 = Rod diameter
d_1 = wire diameter

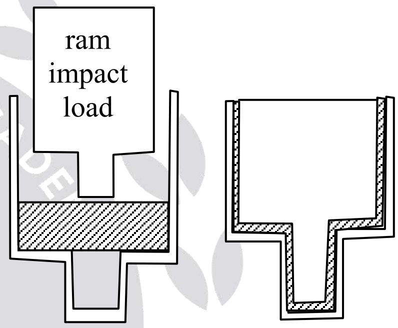
The process variables in wire drawing operations are

1. Presence of friction at the interface of die and surface of wire.
2. The mechanical properties i.e., yield stress of the work material.
3. Die angle and Die land.
4. Length of the sizing zone.
5. Velocity at which the wire is pulled (influencing the power required)
6. Back and front tensions.

- *Recrystalisation temperature (RCT):* is the minimum temperature at which formation of new crystals has been completed.

IMPACT EXTRUSION:

- It is a process in which very thin wall tubes will be produced from solid rods which are made by very soft materials by using impact load as extrusion load.



- Impact extrusion is mainly used for producing collapsible tubes like tubes, cosmetic tubes etc.

02.
Sol:

(i) **Bite angle**: The angle made by the deformation zone with respect to the centre of the rollers is called deformation angle (or) Angle of bite. This depends on the reduction in thickness and diameter of rollers.

(ii) **Neutral point**: At the neutral point the relative velocity and slip becomes equal to zero.

(iii) Camber: The rolls are often ground so that they are thicker towards the center in such a way as to exactly offset the deflection that will occur during the process. This extra thickness is called *camber*.

(iv) Draft refers to reduction in thickness.

Draft = $h_o - h_f$

03.

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

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

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

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

By applying L – Hospital rule

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

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

$$= 7.687 \text{ MPa}$$

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

$= 19.71\%$

For maximum reduction

$$\frac{\sigma_2}{\sigma_y} = 1 = \ell n\left(\frac{A_0}{A_1}\right)$$

$$\frac{A_0}{A_1} = e^1 = 2.718$$

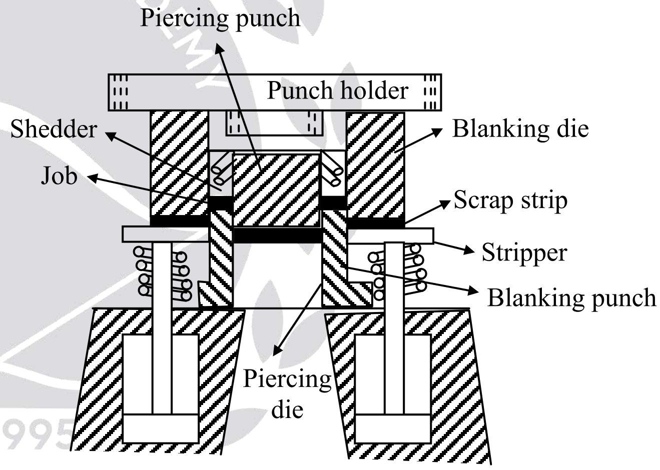
% Reduction in area = $\dfrac{A_0 - A_1}{A_0}$

$$= 1 - \frac{A_1}{A_0} = 63.21\%$$

04.(i)

Sol: **Simple die:** If only operation is performed in one stroke at one stage it is called as a simple die.

Compound dies: In these dies, two or more cutting operations may be performed at one station and at one stroke. The example is washer is provided by blanking and piercing operations simultaneously. These are accurate and economical in mass production



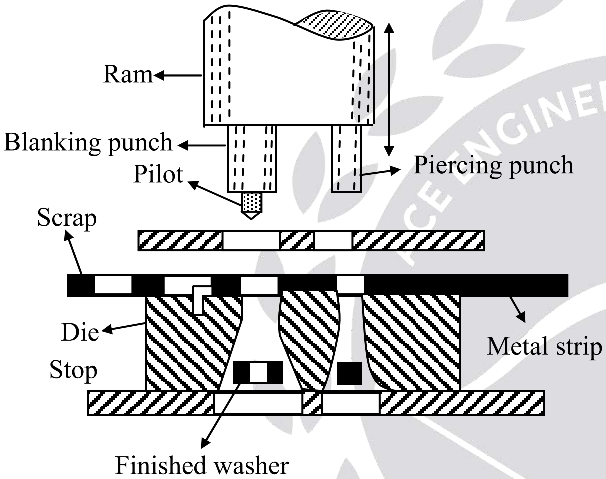
Compound die assembly

Limitations:

- Both the methods of reducing the punch cannot be used. Hence the force required is higher
- It is difficult to design and manufacturing the punch and die combination for producing more than 3 operations.

Progressive die:

- In progressive die also more than one cutting operation is performed in one stroke but at different stages and blanking will be the last operation.
- In progressive die, because the operations are performed at different stages, either the provision of shear or staggering of punches method will be used for reducing the punch force.



- Same production rate
- Manufacturing is easy.

Disadvantage:

- Balancing of force on punch head is difficult

Transfer die:

- In transfer die more than one cutting operation is performed in one stroke at different stages.
- But here the blanking operation will be the first operation and blank produced in first stage is traveling from one to another stage for completing the remaining punching operation.
- Out of two progressive dies are preferable because sheet need to be set for every stage at every time.

Combination die:

- If more than one cutting and forming operations are performed in one stroke at one stage is called as combination die.
  For ex: blanking combined with deep drawing operation, blanking combined with bending and punching combined with drawing etc

Multiple Die:

To produce more than one component per stroke, more than one die are kept in parallel called as multiple die.

Ex: To produce 10 washers per stroke, then 10 compound die or 10 progressive dies are kept in parallel.

04(ii).

Sol: d = 40 mm ; h = 60 mm;
r = 2mm ; t = 0.6 mm

$$\frac{d}{r} = \frac{40}{2} = 20 \quad (\text{Neglecting corner radius})$$

$$D = \sqrt{d^2 + 4dh} = \sqrt{40^2 + 4 \times 40 \times 60} = 105.83\text{mm}$$

Because nothing is mentioned about the draw ratio and draw reduction ratio values it is assumed that the draw ratio method with limiting draw ratio = 2.

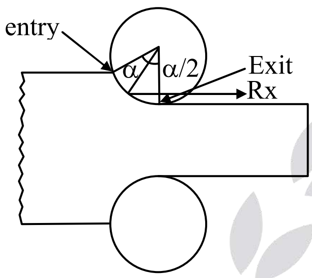
$$d_1 = \frac{D}{DR_1} = \frac{105.83}{2} = 52.95 > 40$$

$$d_2 = \frac{d_1}{DR_2} = \frac{52.915}{2} = 26.4575 < 40$$

$n = 2$

05.

Sol:



Angle of bite :

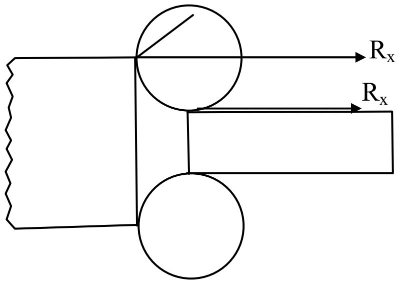
The angle made by the deformation zone w.r.t center of the roller is called as angle of bite or deformation angle.

$$\text{Tan}\alpha = \frac{\sqrt{\Delta H}}{R} \; ; \; \Delta H = D(1 - \cos\alpha)$$

As angle of bite is increasing reduction in thickness of the strip is increasing. To ensure that the strip is pulled by the rollers, the resultant resolved horizontal component of frictional forces must be ≥ 0. Based on this maximum value of α

$\alpha_{max} = \beta =$ Friction angle in a given rolling operation

Once the rolling operation is started, the location at which the resultant resolved horizontal component of force acting is shifting towards the exit and when complete deformation zone is forming, the resultant force is acting on the centre of the deformation zone. Based on this, to ensure that the strip is pulled by the rollers



$$\frac{\alpha}{2} \le \beta$$

$$\alpha \le 2\beta(\text{angle of nip})$$

06.

Sol: $b = 250$ mm; $H_0 = 2.5$ mm;

$H_1 = 2.0$ mm; $R = \frac{350}{2} = 175\,\text{mm}$,

$\mu = 0.05$; $\sigma_y = 180\text{MPa}$.

$$n = \frac{2\mu L}{\Delta H}$$

$$\Delta H = 2.5 – 2.0 = 0.5$$

$$L = \sqrt{R\Delta H} = \sqrt{175 \times 0.5} = 9.354\text{mm}$$

$$n = \frac{2 \times 0.05 \times 9.354}{0.5} = 1.87$$

At neutral plane;

$$(P_N)_{lagging} = (P_N)_{leading}$$

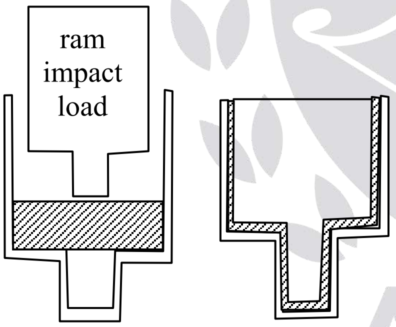
$$\left(\frac{\sigma_y}{n}\right)\left[(n-1)\left(\frac{H_0}{H_n}\right)^n + 1\right] = \left(\frac{\sigma_y}{n}\right)\left[(n+1)\left(\frac{H_n}{H_1}\right)^n - 1\right]$$

$$(1.87-1)\left(\frac{2.5}{H_n}\right)^{1.87}+1=(1.87+1)\left(\frac{H_n}{2}\right)^{n}-1$$

$$0.87\left(\frac{2.5}{H_n}\right)^{1.87}+1=2.87\left(\frac{H_n}{2}\right)^{n}-1$$

07.

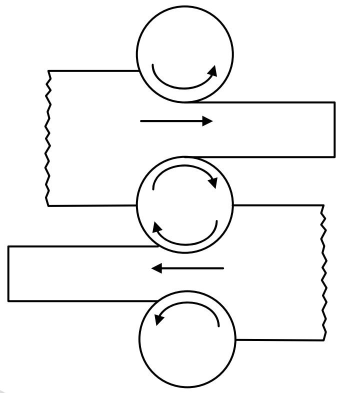
Sol: The tooth paste tubes (also called as collapsible tubes) are manufactured by using impact extrusion process. Impact extrusion is the metal forming process in which the solid rod can be converted into thin wall tube with the application of impact loads. In this process only very soft materials like aluminium, copper, brass etc. can be extruded.



- Impact extrusion is mainly used for producing collapsible tubes like tubes, cosmetic tubes etc.

08.

Sol:



In rolling operation the coefficient of friction must be as maximum as possible because friction is the mechanism by which the strip is pulled by the roller. Also the reduction per pass in the rolling operation depends upon μ.

$$(\Delta h)_{max}=\mu^2 R$$

09.

Sol:

(i) The angle made by the deformation zone with respect to the centre of the rollers is called *deformation angle (or) Angle of bite.*

(ii) Percentage reduction in thickness

- % Reduction in area (J) $=\dfrac{A_0-A_1}{A_0}$
- Cross section area of rod $A_0=\dfrac{\pi}{4}d_0^2$
- Cross section of the wire $A_1=\dfrac{\pi}{4}d_1^2$

(iii) Elongation coefficient Draft (or) coefficient of elongation, $K = \frac{A_0}{A_1}$

(iv) The neutral point defined in the deformation zone is dividing the deformation zone into two zones

- The zone between the entry and neutral points is called *"lagging zone"*
- The zone between neutral point and exit is called *"leading zone"*

(v) *Forward slip:* The maximum % slip taking place in the leading zone is called as ***"forward slip".***

Forward slip = $\frac{V_1 - V}{V} = \frac{V_1}{V} - 1$

10.

Sol: $H_0 = 300$ mm, $b_0 = 600$ mm,

$\Delta H = 50$ mm; $D = 1000$ mm

$\Delta h = h_0 - h_1 = 15$, $\Delta b = b_1 - b_0 = 5$ mm

$\alpha = ?$

$\cos\alpha = 1 - (\Delta h/2R) = 1 - \frac{50}{2\times 500}$

$\Rightarrow \alpha = 18.2°$

And, $\%\,\text{Reduction} = \frac{h_0 - h_1}{h_0} = 16.67\,\%$

Now, $h_0 b_0 l_0 = h_1 b_1 l_1$

$\Rightarrow \frac{\ell_1}{\ell_0} = \frac{h_0 b_0}{h_1 b_1} = \frac{300\times 600}{250\times 605}$

$\Rightarrow \frac{\ell_1}{\ell_0} = 1.19$

11.

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

$h_0 = 25$; $h_f = 6.25$

$A_0 = 25\times 150$; $A_f = 100\times 150$

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

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

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

$r_f = 69.098$mm

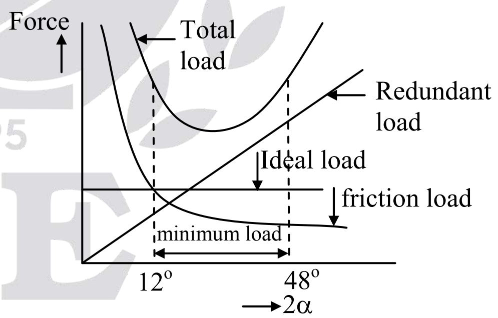
Forging force

$= 0.7\times 15\times 10^3\left[1 + \frac{2\times 0.25\times 69.098}{3\times 6.25}\right]$

= 29847.44kg = 292.80kN

12.

Sol:



In drawing,

$$\sigma_d = \sigma_y \ell n_e \frac{A_i}{A_f}$$

For maximum reduction,

$$\sigma_d = \sigma_y$$

$$\therefore \ \ell n_e \frac{A_i}{A_f} = 1$$

$$\Rightarrow \frac{A_i}{A_f} = 2.718$$

$$\therefore \frac{A_{fi}}{A_i} = 0.3678$$

% in reduction = $1 - \frac{A_f}{A_i} = 63.2\%$

13.

Sol: t = thickness

d = diameter

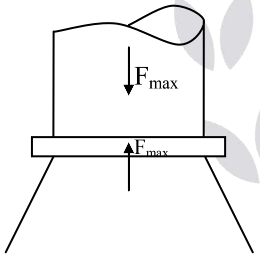
Total clearance = c = diametral clearance

Blanking:

Die size = blank size = d

Punch size = d – c = Die size – c

Punching:



Punch size = Hole size = d

Die size = Punch size+c = d+c

$$\sigma_{cp} = \frac{F_{max}}{A_{cp}} = \frac{\pi d t \tau}{\frac{\pi}{4} d^2}$$

$$\sigma_{cp} = \frac{4t\tau}{d} = \sigma$$

$$d_{min} = \frac{4t\tau}{\sigma}$$

14.

Sol: d_0 = 10mm;

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

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

d_1 = 8.36mm

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

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

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

= 141.687 MPa

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

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

$$\left(\frac{d_1}{d_0}\right)^2 = 0.7$$

$$d_1 = 10 \times \sqrt{0.7}$$

d_1 = 8.366 mm

$\therefore$ F_d = 7.8 kN

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

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

P = 20.52 kW

Chapter 6

Sheet Metal Operations

Common data for Q. 1 to 5

01. Ans: (b)

Sol: For punching operation

Punch size = Hole size = 12.7

Die size = punch size + clearance

= 12.7 + 2 × 0.04 = 12.78

02. Ans: (a)

Sol: Die size = Blank size = 25.4mm

Punch size = Die size – 2(radial clearance)

= 25.4 – 2(0.04)

Punch size = 25.32 mm

03. Ans: (b)

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

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

= 40 +80 = 120 kN

04. Ans: (c)

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

⇒ force required is Max [40, 80]

⇒ force required = 80 kN

05. Ans: (b)

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

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

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

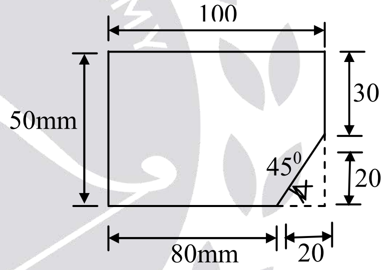
$= \dfrac{80 \times 0.6 \times 1.25}{0.6 \times 1.25} = 34.28\,\text{kN}$

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

Common data for Q. 06, 07 & 08

06. Ans: 83.6 N

Sol:



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

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

07. Ans: 66.88 J

Sol: Work done in blanking open

$= F_{max}.K.t$

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

= 66.88 J

08. Ans: 1.98 mm

Sol: I = ?

F = 24 kN

$F_{max} = 83.6$ kN

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

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

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

09. Ans: (a)

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

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

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

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

Common Solution for Q. 10 & 11

10. Ans: (a)

11. Ans: (b)

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

$K = 0.2$

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

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

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

Shear provided over a length of

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

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

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

12. Ans: (d)

Sol: $d = 25$ mm, $t = 2.5$ mm → piercing

$\tau_u = 350$ 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 mm.

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

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

$= 68.72$ kN.

13. Ans: (a)

Sol: Die size = Blank size = 25 – 0.05

= 24.95

Punch size = Die size – clearance

= 24.95 – 2 × 0.06

= 24.83

Common data for Q. 14 & 15

14. Ans: (b)

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

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

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

$n = 2$

15. Ans: (a)

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

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

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

$P_1 = \pi D t \sigma_y$

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

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

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

$= 806.6 \text{ kJ}$

16. Ans: (b)

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

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

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

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

$d_3 < 12 \Rightarrow n = 3$

17. Ans: (b)

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

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

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

$= 65.5 \text{ MPa}$

Common data for 18 & 19

18. Ans: 6

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

$= 137.47$

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

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

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

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

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

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

$n = 6$

19. Ans: 52.7 mm

Sol: $d_3 = 52.7$ mm

20. Ans: 144.42

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

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

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

$= 138.42 + 2\times 3$

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

21. Ans: (d)

22. Ans: (c)

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

Where n is an integer

So possible option is 64.

23. Ans: 467 mm

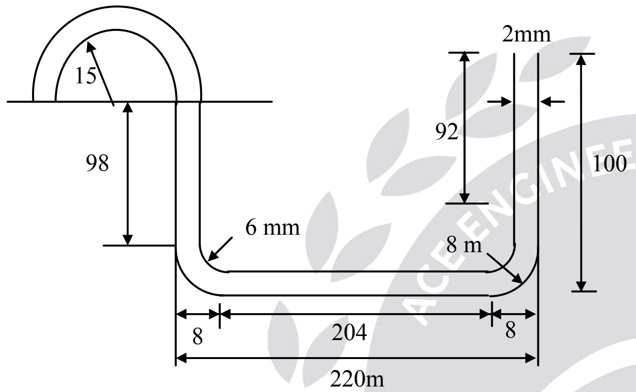
Sol: $B_1 = (15 + 0.5 \times 2) \times 180 \times \dfrac{\pi}{180}$

$= 50.265$ mm

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

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

$= 466.245$ mm



24. Ans: (b)

25. Ans: 3

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

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

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

$0.4 \times 150 = 150 - d_1$

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

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

$d_3 = 32.4 < 50$

$\therefore$ **n = 3**

26. Ans: 7.536 kN

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

Punch size = Blank size = 10 mm

Die size = Punch size + 2 C

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

t = thickness = 1 mm

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

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

$= 0.0495$ mm $= 0.05$ mm

Die size = 10 + 2 × 0.05 = 10.1 mm

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

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

$= 7.536$ kN

Conventional Practice Solutions

01.

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

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

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

$0.4 \times 150 = 150 - d_1$

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

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

$d_3 = 32.4 < 50$

$\therefore$ n = 3

02.

Sol: Circular hole: d = 10mm

Rectangular blank: 50×200mm

t = 1 mm;

$$\tau_u = 240\frac{N}{mm^2}$$

Punching :

Punch size = Hole size = 10 mm

Die size = 10 + 2×0.05

$F_{max} = Pt\tau_u = \pi dt\times\tau_u$

$= \pi\times10\times1\times240 = 7.539$ kN

Blanking :

Die size = Blank size = 50×200(rectangular)

Punch size = Die size –2c

= (50–2c)×(200–2c)

= 49.9×199.9

$F_{max} = pt\tau_u = 2(50+200)\times1\times240 = 120$

Chapter 7

Metrology

7.1 Limits, Fits & tolerances

01. Ans: (a)

Sol: For Clearance fit

L- hole > H- shaft

02. Ans: (c)

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

Min. clearance = 0.01 mm,

Tolerance on shaft = 0.04 mm ,

Max. clearance of shaft = ?

0.01 = L.hole – H.shaft

0.01 = 40.000 – H.shaft

⇒ H.shaft = 40.000 – 0.01 = 39.99mm

H.shaft – L.shaft = 0.04

L.shaft = 39.99 – 0.04 = 39.95

Max. clearance = H.hole – L.shaft

= 40.05 – 39.95 = 0.10 mm

03. Ans: (d)

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

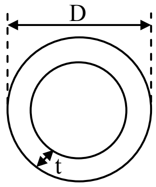
$X_{min} = 49.98 - (38.015 + 10.01) = 1.955$

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

Dimension X = 2 ± **0.045**

04. Ans: (c)

Sol:



t = 0.01 to 0.015mm

When, t = 0.01 mm

D = 30.01 + 2×0.01 = 30.03 mm

= 30.05 + 2× 0.01 = 30.07 mm

When, t = 0.015 mm

D = 30.01 + 2×0.015 = 30.04 mm

= 30.05 + 2× 0.015 = 30.08 mm

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

05. Ans: (d)

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

$B = 30.4 \pm 0.01$

$C = 32.7 \pm 0.02$

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

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

$= 29.83 = 30^{-0.17}$

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

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

$= 29.57$

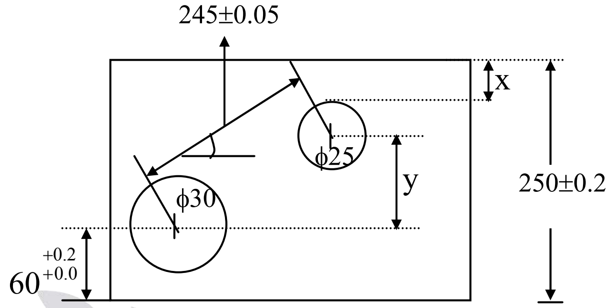
$T_{min} = 30^{-0.43}$

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

06. Anc: (c)

07. (i) Ans: (d)

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



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

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

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

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

(ii) Ans: (c)

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

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

$= 41.15$mm

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

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

$= 38.625$ mm

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

08.

Sol: L Hole = BS = 65mm

H Hole = BS + Tolerance = 65.05mm

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

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

$\Rightarrow \quad 0.09 = 65 - (H.L)_{shaft}$

$\Rightarrow (H.L)_{shaft} = 65 - 0.09 = 64.91$ mm

Tolerance = $(HL)_{shaft} - (LL)_{shaft}$

$\Rightarrow \quad 0.05 = 64.91 - (LL)_{shaft}$

$\Rightarrow (LL)_{shaft} = 64.86$ mm

Shaft = piston = $65^{-0.09}_{-0.14}$

(ii) **Ans: (a)**

$(L.L)_{hole} = 65$ mm

$(Tolerance)_{hole} = (HL)_{hole} - (LL)_{hole}$

$\Rightarrow \quad 0.05 = (HL)_{hole} - 65$

$\Rightarrow (HL)_{hole} = 65.05$ mm

Hole = Bore = $65^{+0.05}_{0.00}$

(iii) **Ans: (b)**

Max Clearance = 65.05 – 64.86

= 0.19 mm

09.

Sol: $A_{max} = 15_{max} + 30_{max}$

$= 15.06 + 30.1 = 45.16$

$A_{min} = 15_{min} + 30_{min} = 44.84$

$A = 45 \pm 0.16. = A \pm \Delta A$

$B_{max} = A_{max} - 20_{min}$

$= 45.16 - 19.93 = 25.23$ mm

$B_{min} = A_{min} - 20_{max}$

$= 44.84 - 20.07 = 24.77$ mm

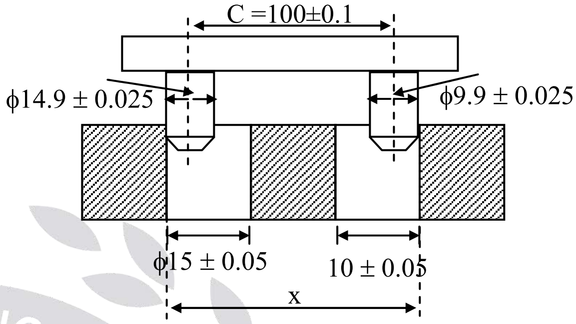
$\Rightarrow B \pm \Delta B = 25 \pm 0.23.$

10.

Sol: Let

C = center distance between holes

C_{max} = max. Outer distance of pins – sum of min rod holes.



$$X_{max} = 100_{max} + \left(\frac{9.9}{2}\right)_{max} + \left(\frac{14.9}{2}\right)_{max}$$

$$= 100.1 + \frac{9.925}{2} + \frac{14.925}{2}$$

$= 112.525$ mm

$$X_{min} = 100_{min} + \left(\frac{9.9}{2}\right)_{min} + \left(\frac{14.9}{2}\right)_{min}$$

$$= 99.9 + \frac{9.875}{2} + \frac{14.875}{2}$$

$= 112.275$ mm

$$C_{max} = X_{max} - \left[\left(\frac{15}{2}\right)_{min} + \left(\frac{10}{2}\right)_{min}\right]$$

$$= 112.525 - \left(\frac{14.95}{2} + \frac{9.95}{2}\right)$$

$= 100.075$ mm

$$C_{min} = X_{min} - \left[\left(\frac{15}{2}\right)_{max} + \left(\frac{10}{2}\right)_{max}\right]$$

$$= 112.525 - \left(\frac{15.05}{2} + \frac{10.05}{2}\right)$$

$= 99.725$ mm

$$\therefore C = 100^{+0.075}_{-0.275}$$

11.

Sol: For the given conditions

$$X = 100.1 + \frac{14.875}{2} + \frac{9.875}{2}$$

$= 112.475$ mm

$$C = X - \left(\frac{15.05}{2} + \frac{10.05}{2}\right)$$

$C = 99.925$ mm

Because C is lying in between the limits, the assembly is possible.

12. Ans: (b)

Sol: Fundamental deviation of hole 'h' is zero.

13.

Sol: Hole = $20^{+0.03}_{-0.00}$

Min. interference = 0.03mm,

Max. interference = 0.08 mm

0.03 = L.shaft – H.hole

L.shaft = 0.03 + 20.03 = 20.06 mm

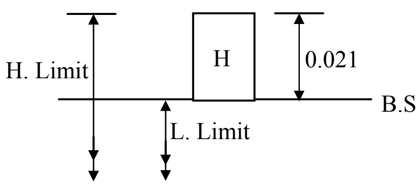
0.08 = H.shaft – L.hole

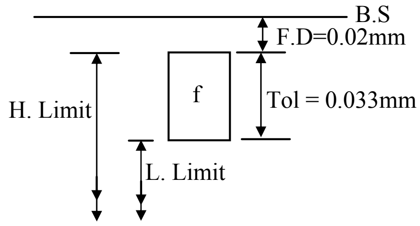
H.shaft = 0.08 + 20.00 = 20.08mm

$$\text{shaft} = 20^{+0.08}_{+0.06}$$

14.

Sol:





$D = \sqrt{18 \times 30} = 23.24$mm

$i = 0.45\sqrt[3]{D} + 0.0010 = 1.3\mu m$

FD of hole H = 0

FD Shaft = $-5.5(23.24)^{0.41} = -20\mu m$

Hole tolerance, IT7 =16i = 20.8μm

= 21μm = 0.021 mm

Shaft tolerance, IT 8 = 25i

= 32.5μm = 33μm

= 0.033mm

L - hole = basic size =25 mm

H - hole = 25 + 0.021 = 25.021 mm

H - shaft = 25 – 0.02 = 24.98 mm

L - shaft = 24.98 – .033 = 24.947 mm

(i) **Ans: (a)**

L- hole > H- shaft → Clearance fit

(ii) **Ans: (b)**

Allowance = difference between max. material limits = L.hole – H.shaft

= 25.00 – 24.98 = 0.02 mm

(iii) **Ans: (b)**

$$\text{Shaft} = 25^{-0.02}_{-0.053}, \quad \text{Hole} = 25^{+0.021}_{+0.00}$$

Max clearance = different between minimum material limits

= H.hole – L.shaft

= (25.021) – (24.947)

= 0.074 mm

(iv) **Ans: (a)**

Size of the GO plug gauge = max. material limit of hole = L.hole = 25 mm

(v) **Ans: (b)**

Size of the NOGO plug gauge = min. material limit of hole = H.hole = 25.021 mm

(vi) **Ans: (c)**

Size of the GO ring gauge = max. material limit of shaft = H.shaft = 24.98 mm

(vii) **Ans: (d)**

Size of the NOGO ring gauge = min. material limit of shaft = L.shaft = 24.947 mm

(viii) **Ans: (a)**

15. Ans: (c)

Sol: $D = \sqrt{18 \times 30} = 23.2$

$i = 0.45\,3\sqrt{D} + 0.001\,D = 1.3$

IT8 = 26i = 26 × 1.3 = 33.8

= 34 μm = 0.034 mm

$\text{Hole size} = 25H_8 = 25^{+0.034}_{+0.000}$

16. Ans: (a)

Sol: $D = \sqrt{50 \times 80} = 63.24$ mm

i = 1.86 microns = 1.9 microns

IT8 = 25i = 47.5 microns

Tolerance = 0.0475 mm

$F.D = -5.5\,D^{0.41} = -5.5 \times 63.24^{0.41}$

= 30 Microns = 0.03 mm

H. shaft = 60 – F.D = 60 – 0.03 = **59.97 mm**

L. shaft = H. shaft – Tolerance

= 59.97 – 0.047 = **59.923 mm.**

17. Ans: (d)

Sol: Case (i) $25H_7$

L.L = 25.00

U.L = 25.021

Case (2) 25 H_8

UL = 25.033

Case (3) $25H_6$, UL - ?

$(UL)_{H8} - (UL)_{H7} = (UL)_{H7} - (UL)_{H6}$

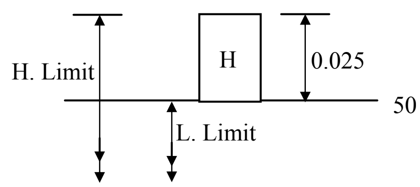
25.033–25.021 = 25.021 – (25 + x)

x = 0.009

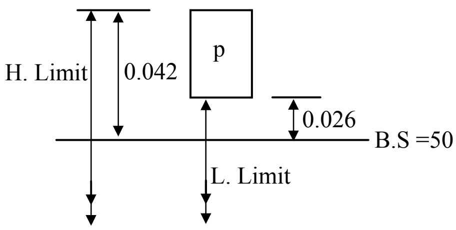
$\therefore \quad (UL)_{H6} = 25.009$

18. (i) Ans: (a) , (ii) Ans: (a), (iii) Ans: (a), (iv) Ans: (c)

Sol:



$\text{Hole} = 50^{+0.025}_{+0.000}$



Shaft $= 50^{+0.042}_{+0.026}$

L.hole = B.S = 50

H.hole – L.hole = Tolerance = 0.025 mm

H.hole = L.hole + Tolerance = 50.025 mm

Max. interference = difference between max. material limits = H.shaft – L.hole

= 50.042 – 50.00 = 0.042 mm

Min. interference = difference between min. material limits = L.shaft - H.hole

= 50.026 – 50.025 = 0.001 mm

19. Ans: (c)

20. Ans: (b)

Sol: To calculate exactly the data was not given in the problem. But for shaft "h",

H – Shaft = 25.000

L – Shaft = less than 25.

And $h_7 \rightarrow 7$ indicates IT 7 not 7 microns.

21. Ans: (a)

Sol: GO size = max. material limit of hole

= 20.01 mm

NOGO size = min. material limit of hole

= 20.05 mm

22. Ans: (d)

Sol: To produce an interference fit, L-shaft must be greater than H-hole. For this with multiple choice D it is possible because

For D: L-shaft = 20 – 0.02 = 19.98 mm,

H-shaft = 20 + 0.02 = 20.02 mm

L-hole = 20 – 0.035 = 19.965mm,

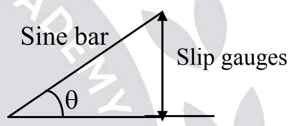
H-hole = 20 – 0.03 = 19.97mm,

Hence, **L-shaft (19.98) > H-hole (19.97)**

7.2 Angular Measurements

01. Ans: (a)

Sol:



Given sine bar length = 200 = l

Angle $\theta = 32°5'6'' = 32.085°$

Slip gauge height = h say

$$\sin\theta = \frac{h}{\ell}$$

$$\sin(32.085^0) = \frac{h}{200}$$

$$\Rightarrow \quad h = 106.235$$

02. Ans: i-(b), ii-(a)

Sol: $l = 50$, L = 500

$50 \rightarrow 0.08$

$$200 \rightarrow 200 \times \frac{0.08}{50} = 0.32$$

$$h' = h + 0.32 = 28.87 + 0.32 = 29.19$$

$$\sin\theta = \frac{h'}{L} = \frac{29.19}{200} = 8'23'32''$$

03. Ans: (d)

04. (i) Ans: (c)

Sol: $\sin\theta = \dfrac{h}{L}$

$h = \sin 30^o \times 125 = 62.5$ mm

(ii)

(A) Ans: (a)

$$d\theta = \tan 30°\left[\frac{0}{62.5} - \frac{0.005}{125}\right] = 4.76''$$

(B) Ans: (a)

$$dh = r_2 - r_1 = \frac{d_2 - d_1}{2} = \frac{0.002}{2} = 0.001$$

$$d\theta = \tan 30°\left[\frac{0.001}{62.5} - \frac{0}{125}\right] = 2''$$

(C) Ans: (b)

$dh = 0.002$

$$d\theta = \tan 30°\left(\frac{0.002}{62.5} - \frac{0}{125}\right) = 4''$$

(D) Ans: (d)

$dh = \pm 0.005$

$$d\theta = \tan 30°\left(\frac{\pm 0.005}{62.5} - \frac{0}{125}\right) = \pm 10''$$

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)

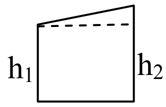
$$\sin\theta = \frac{h_2 - h_1}{w}$$

$h_2 - h_1 = 100\sin 30 = 50$

$h_2 = h_1 + 50 = 75$

(ii) Ans: (d)

$$\sin(30) = \frac{h - 25}{100.005}$$



$\Rightarrow$ $h = 75.0025$ mm

$\Rightarrow$ $h_2 = 75.0025 + 0.005 = 75.0075$ mm

08. Ans: (a)

Sol: L = 250 mm,

d = 20 mm

h = 100 – (d/2) = 100 – 10 = 90 mm

$$\sin\theta = \frac{90}{250}$$

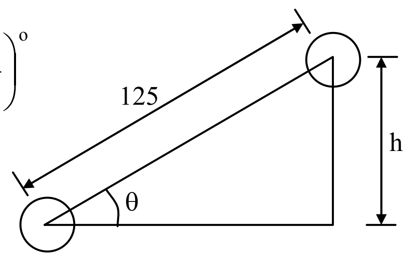
$\Rightarrow \theta = 21.2$ deg

09. Ans: 11.556 mm

Sol: $\theta = 27°32'$

$$= 27^o + \left(\frac{32}{60}\right)^o$$

$= 27.533°$



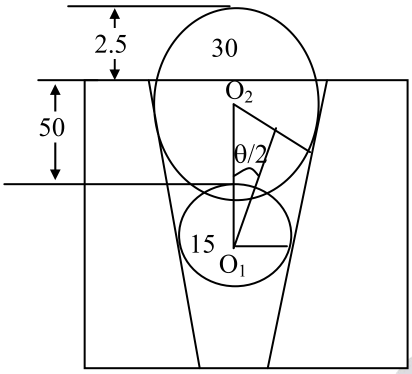
$$\sin\theta = \frac{h}{25}$$

h = 11.556 mm

7.3 Taper Measurement

01. Ans: 19.2°

Sol:



$$\sin(\theta/2) = \frac{d_2 - d_1}{2(h_1 - h_2) - (d_2 - d_1)}$$

$$\sin(\theta/2) = \frac{30-15}{2(52.5)-(30-15)}$$

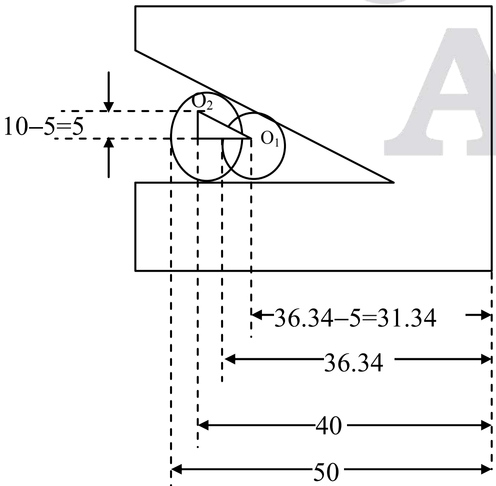
$$= \frac{15}{105-15} = 1/6$$

$\therefore \quad \theta = 19.2°$

02. Ans: 60

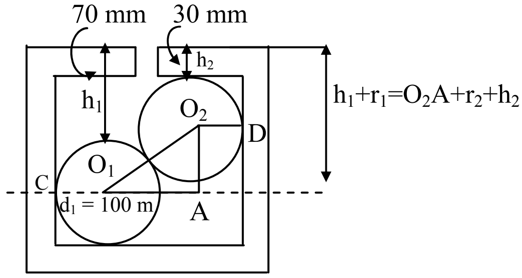
Sol: $\tan(\theta/2) = \dfrac{5}{8.66}$

$\Rightarrow \quad \theta = 60°$



03. Ans: 112.41 mm

Sol:



Diameter = $O_1C+O_1A+O_2D$

$$= \frac{d_1}{2} + \sqrt{(O_1O_2)^2 - (O_2A)^2} + \frac{d_2}{2}$$

$O_1O_2 = r_1 + r_2 = 75$

$O_2A = h_1 + r_1 - r_2 - h_2$

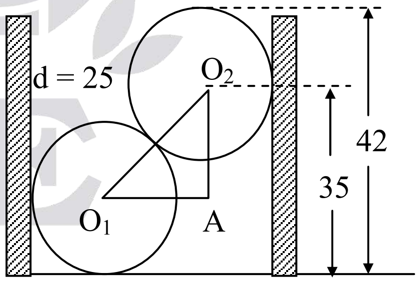
$= 70 + 50 - 30 - 25 = 65$

$D = 50 + \sqrt{75^2 - 65^2} + 25$

$= 112.4165$ mm

04. Ans: 43.33 mm

Sol:



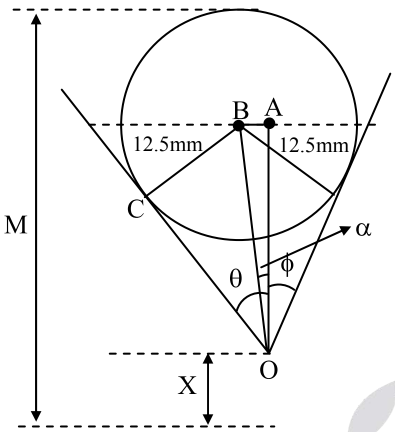
$O_1A = \sqrt{25^2 - 17^2} = 18.33$

$D = r + O_1A + r$

$= 25 + 18.33 = 43.33$ mm

05. Ans: 78.074 mm

Sol:



$\theta + \phi = 45°50' + 29°10' = 75°$

$$\frac{\theta+\phi}{2} = 37.5°$$

$$\alpha = \frac{75}{2} - \phi = 37.5 - \phi = 37.5° - 29°10'$$

$$= 8°20'$$

Δle OBC

$$\sin 37.5 = \frac{BC}{OB}$$

$$\Rightarrow OB = \frac{BC}{\sin 37.5} = \frac{12.5}{\sin 37.5} = 20.533$$

Δle OAB

$$\cos 8°20' = \frac{OA}{OB}$$

$\Rightarrow OA = OB \cos 8°20' = 20.316$ mm

$X = M - (OA + R)$

$= 110.89 - (20.316 + 12.5)$

$= 78.074$ mm

06. Ans: 1.1

Sol: $d_2 - d_1 = 10$; $h_2 - h_1 = 12.138$

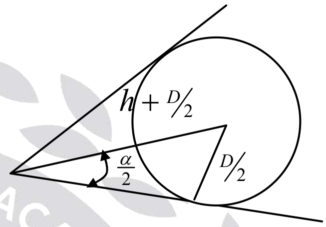
$$\sin\left[\frac{\theta}{2}\right] = \frac{d_2 - d_1}{2\times(h_2 - h_1) - (d_2 - d_1)}$$

$\theta = 88.9$

Error $= 90 - 88.9 = 1.1$

07. Ans: 38.94

Sol:



$$\text{Sin}\left[\frac{\alpha}{2}\right] = \frac{D/2}{h + D/2} = \frac{D}{2h + D}$$

$$\text{Sin}\frac{\alpha}{2} = \frac{D}{2h + D}$$

If $D = 0$, $h = 0$

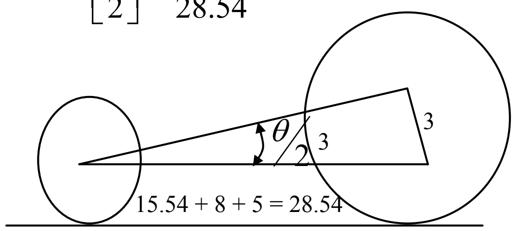
$D = 1$, $h = 1$

$$\text{Sin}\left[\frac{\alpha}{2}\right] = \frac{1}{2\times1+1} = \frac{1}{3}$$

$$\left[\frac{\alpha}{2}\right] = 19.47 \Rightarrow \alpha = 38.94$$

08. Ans: (d)

Sol: $$\text{Tan}\left[\frac{\theta}{2}\right] = \frac{3}{28.54}$$



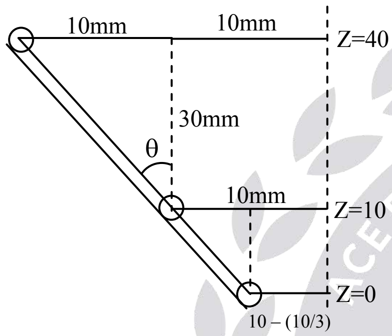
$$\frac{\theta}{2} = Tan^{-1}\left(\frac{3}{28.54}\right) = 6$$

Taper angle $\left(\frac{\theta}{2}\right) = 6^0$

Included angle = 12^0

09. Ans: (c)

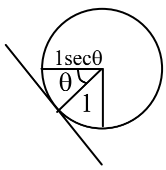
Sol: $\tan\theta = \frac{10}{30} \Rightarrow \theta = \tan^{-1}(1/3) \Rightarrow \theta = 18.434°$



Distance at Z = 0,

$$D_0 = 2(10 - 10\tan 30) = 2\left(10 - \frac{10}{3}\right)$$

$= 6.67 \times 2 = 13.33$ mm



With probe diameter compensation

$D_{actual} = 13.334 + 2 \times r \sec\theta$

$= 13.334 + 2 \times (1 \sec \times 18.435)$

$= 15.442$ 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 mm

02. Ans: (a)

Sol: Minor diameter

= 30.5 + (15.3768 – 13.5218)

= 32.355 mm

03. Ans: (a)

Sol: best wire diameter, $d = \left(\frac{p}{2}\right)\sec\left(\frac{\theta}{2}\right)$

$$= \left(\frac{3.5}{2}\right)\sec\left(\frac{60}{2}\right) = 2$$

M = 30.5 + (12.2428 – 13.3768)

= 29.366 mm

$$D_e = M - \left(d + \frac{p}{2}\tan\frac{\theta}{2}\right)$$

$$= M - \left(2 + \frac{3.5}{2} \times \tan 30\right)$$

= 29.366 – 3.010366 = 26.355 mm

04. Ans: (a)

Sol: VED = $D_e \pm$ VC

$$VC = \delta P \cos\frac{\theta}{2} + 0.0131P(\delta\theta_1 + \delta\theta_2)$$

δP = pitch error

$\delta\theta_1$, $\delta\theta_2$ – flank angle errors in deg

$\delta\theta_1 = 7^1 = 0.11667 - 2.04\times10^{-3}$

$\delta\theta_2 = 9^1 = 0.15 - 2.618\times10^3$

$\delta P = 0.004$

$D_e = 30.6651$

$\theta = 60°$ (metric thread)

Virtual correction

VC = (0.004 × cos30) + (0.0131 × 3.5(0.11667 + 0.15))

VC = 0.01569

VED = D_e + VC

= 30.6651 + 0.01569 = 30.6807

05. Ans: (a)

06. Ans: (d)

Sol: $\text{Sin}\left[\frac{\theta}{2}\right] = \frac{R_2 - R_1}{M_2 - M_1 - (R_2 - R_1)}$

$= \frac{1.4434 - 0.8660}{22.06 - 20.32 - (1.4434 - 0.8660)}$

$\theta = 59.5566 = 59°33'23''$

07. Ans: 16.433 mm

Sol: $D_e = M - \left(d + \frac{p}{2}\tan\frac{\theta}{2}\right)$

$M = 14.701 + (1.155 + \frac{2}{2}\tan 30) = 16.433$

08. Ans: (d)

Sol: Lead = pitch × no of starts

$\text{Pitch} = \frac{\text{lead}}{\text{no of starts}} = \frac{3}{2} = 1.5$ mm

09. Ans: (d)

Sol: Rollers will not used to measure pitch diameter.

Best size diameter $d = \left(\frac{p}{2}\right)\sec\left(\frac{\theta}{2}\right)$

$= \left(\frac{2}{2}\right)\sec\left(\frac{60}{2}\right)$

$= 1.1547 = 1.155$

10. Ans: (d)

Sol: $V.C = \delta P.\cos\left(\frac{\theta}{2}\right) + 0.0131P(\delta\theta_1 + \delta\theta_2)$

$= 0.2 \cos 30 = 0.346$

Common data Q 11 & 12

11. Ans: (a)

Sol: Best size diameter, $d = \left(\frac{p}{2}\right)\sec\left(\frac{\theta}{2}\right)$

$= \left(\frac{2}{2}\right)\sec\left(\frac{60}{2}\right) = 1.155$ mm

12. Ans: (a)

Sol: $D_{eff} = M - \left(d + \frac{p}{2}\tan\frac{\theta}{2}\right)$

$= 16.455 - 1.155.\tan 30 = 14.7226$ mm

13. Ans: 1.732 mm

Sol: The best wire size = $(p/2)\sec(\alpha/2)$

$= (3/2)\sec(60/2)$

$= 1.732$ mm

7.5 Surface Finish Measurement

01.

(i) Ans: (c)

Sol: R_t = maximum peak – minimum valley

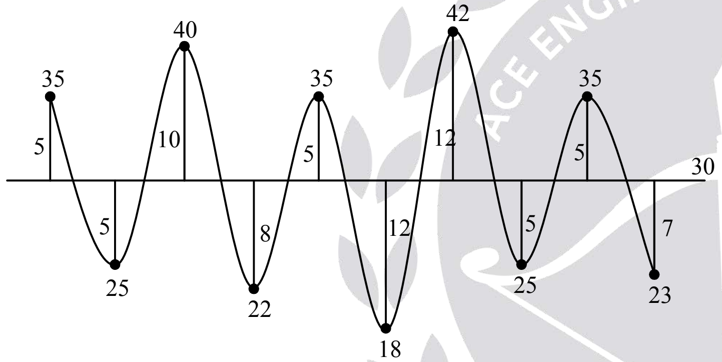
$= 42 - 18 = 24\ \mu m$

(ii) Ans: (d)

Sol:

$$\text{Mean} = \frac{18+22+23+25+25+35+35+35+40+42}{10}$$

$= 30\ \mu m$



$$\text{CLA} = R_a = \frac{5+5+10+8+5+12+12+5+5+7}{10}$$

$= 7.4\ \mu m = 7.5\ \mu m$

(iii) Ans: (b)

Sol: R_z 10 point height method

$$= \frac{\text{Sum of highest five peaks} - \text{Sum of lowest five peaks}}{5}$$

$$= \frac{(35+40+35+42+35)-(25+22+18+25+23)}{5}$$

$= 14.8\ \mu m = 15\ \mu m$

(iv) Ans: (d)

Sol: $$\text{RMS} = \sqrt{\frac{h_1^2+h_2^2+h_3^2+........+h_n^2}{n}}$$

$$R_s = \sqrt{\frac{5^2+5^2+10^2+8^2+5^2+12^2+12^2+5^2+5^2+7^2}{10}}$$

$= 7.91\ \mu m = 8\ \mu m$

$\therefore R_a < R_s < R_z < R_t$

(v) Ans: (c)

Sol: If R_a value from 18.75 to 37.5 international grade of roughness is given by N11.

02. Ans: (c)

Sol: $$R_a = \frac{\sum A}{w} \times \frac{1}{HM} \times \frac{1000}{VM}$$

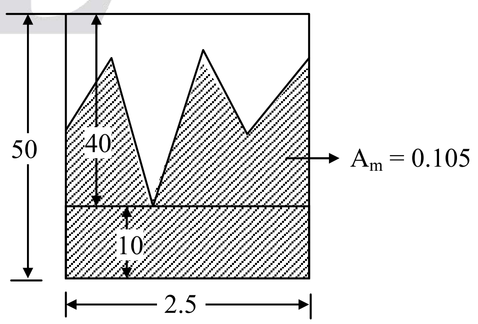
$$= \frac{480+480}{0.8} \times \frac{1}{100} \times \frac{1000}{15000} = 0.8$$

03. Ans: (d)

Sol: $$R_t = \frac{0.05}{\tan 45} = 50\ \mu m$$

04. Ans: (c)

Sol:



$A_{m\,act} = 0.105 - 0.01 \times 2.5$

$= 0.08$

$$K = \frac{A_{m\,act}}{(10^{-3} \times 2.5) \times 0.04}$$

$$= \frac{0.08^2}{\left(2.5 \times 10^{-3} \times 0.04\right)} \times \frac{1}{1000} = 0.8$$

05. Ans: (a)

06. Ans: (c)

07. Ans: (a)

08. Ans: 2

Sol: $R_a = \frac{\Sigma h}{n}$

$$= \frac{16 \times 4 + 16 \times 0}{32}$$

$$= \frac{64}{32} = 2\ \mu m$$

Conventional Practice Solutions

01.

Sol: Basis of a system:

(i) Hole base system

(ii) Shaft base system

Hole base system :

- In hole based system the hole is made the constant member, provision being made in the size of the shaft to accommodate the unavoidable variations (tolerances).
- Various fits are obtained by mating with the tolerances are so disposed as to produce the desired fit.
- In a shaft based system the position is reversed and shaft becomes the constant member.
- All the modern systems in the world are hole based systems.

Shaft base system:

- In the shaft based system the above advantage is not there because we need a no. of reamers and other tools required for obtaining different sized holes.
- However the argument in support of shaft based system is that the cost of reamers etc can be treated as a negligible one because the reamers come under the category of consumables.

- Whatever may be the arguments in favour of each of the two systems the fact remains that majority of the limit system in the world are hole based.
- However provision is made for shaft based system, so that any user industry can use it because of its own preference for the system.

  The main advantage of the hole base system is that the no. of reamers and other tools required is very less, accordingly the cost of such tools is very much reduced.

02.

Sol:

Interchangeable assembly (Interchangeability):

It is one which can be substituted for a similar part manufactured to the same drawing.

The interchangeability is obviously depends upon 2 factors.

(i) The first factor is that it is necessary for the relevant mating parts to be designed incorporating specified limits of size.

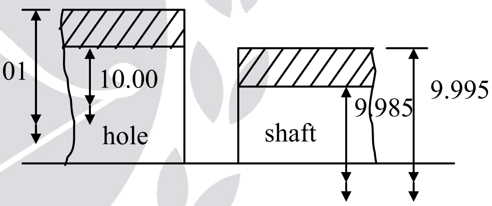
(ii) The second factor is that the parts must be manufactured within the specified limits of size, which must be controlled rigidly.

- In practice there are degrees of interchangeability for instance, universal and local interchangeabilities.
- In the first case it is assumed that similar parts derived from any source in the world are interchangeable.

In the second case the parts are made at specific source (for example in a particular factory) are interchangeable, but such parts are not necessary interchangeable with the parts made any where else.

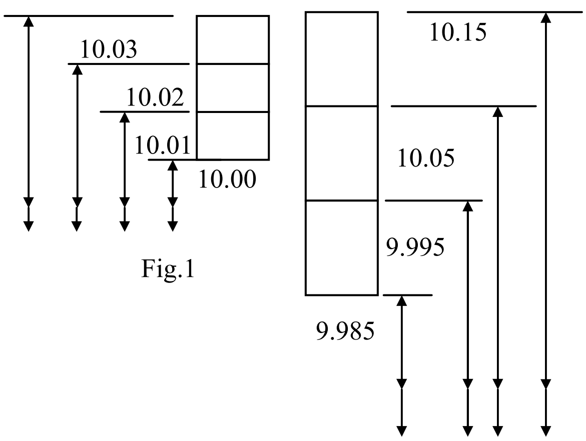
Selective assembly:

- In certain component designs the maximum permissible tolerance as determined by the functional requirements may be considerably smaller than that can be achieved by the manufacturing process it is desired to use.
- For example consider two mating components having an allowance of 0.005 mm and tolerance of 0.01 mm.



- Tolerance on hole = 10.01 – 10 = 0.01 mm
- Tolerance on shaft = 9.995 – 9.985

  = 0.01 mm
- Min clearance = 10 – 9.995 = 0.005
- Max clearance = 10.01 – 9.985 = 0.025
- The max possible clearance allowed is 0.025 mm.
- These clearances are fixed such that the assembly functions reasonably well and therefore they should not be altered.
- The sizes of the hole and shaft thus required are shown in figure.



- After manufacturing the components are sorted out into 3 groups A, B and C each grade of external diameter having the same relationship to its correspondingly lettered grade of internal diameters nearly 0.025 maximum clearance and 0.005 minimum clearance
- Assembly of external diameters with internal diameters of the same grade will thus satisfy the theoretical requirement.
- The method of selective assembly has a great advantage in enabling unsuitable manufacturing methods or the machines which have high process capability.
- Example of selective assembly:

Ball bearing: A ball bearing essentially consists of an inner ring, outer ring are separated by steel balls, both the types of rings and balls are graded and when assembled allow the following conditions

(i) Large balls are assembled into large outer ring and small inner ring

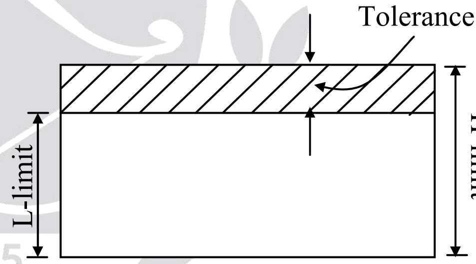
(ii) Medium balls are assembled into medium outer and inner rings (or) large inner and large outer rings or small inner and small outer rings.

(iii) Small balls are assembled into small outer and large inner ring.

03.

Sol: Tolerance:

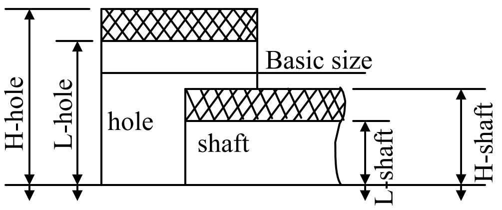
- The tolerance is the amount by which the given dimension is permitted to vary.
- It is the difference between the high and low limits of size.
- It is allowed in order to cover the reasonable imperfection in workmen-ship and the inevitable inaccuracy of the manufacturing process.



In actual practice it is impossible to make the component for accurate dimension because

- Variations in the properties of the material being machined introduce errors.
- The production machines themselves have some inherent inaccuracies built into them
- It is impossible for an operator to make perfect settings.

Allowance:



- *Allowance* is defined the difference between the maximum material limits of the components. Hence it is taken as the minimum clearance between the mating parts, and is equal to difference between L.limit of hole and H.limit of shaft.
- It is also equal to max interference between the mating parts.

  From the above diagram

  Min clearance

  = L.limit of hole – H.limit of shaft

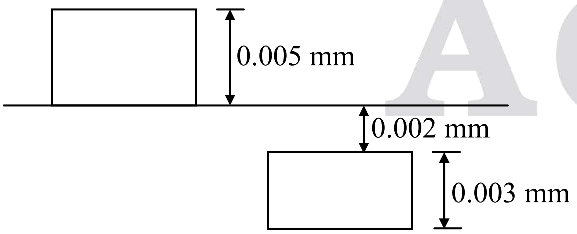
  Max interference

  = H.limit of shaft – L.limit of hole

04.

Sol:

(i) Hole-basis system



Hole:

UL = 20.005 mm

LL = 20

$\therefore$ Hole can be written as $20^{+0.005}_{+0.00}$

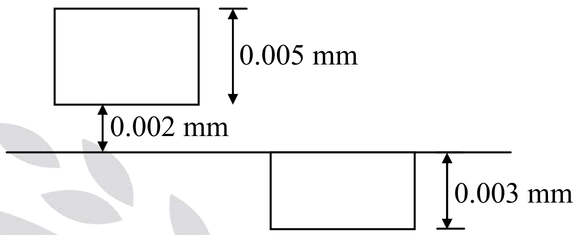
Shaft:

UL = 19.998 mm

LL = 19.995 mm

$\therefore$ Shaft can be written as $20^{-0.002}_{-0.005}$

(ii) Shaft-basis system:



Hole:

UL = 20.007 mm

LL = 20.002 mm

$\therefore$ Hole can be written as $20^{+0.007}_{+0.002}$

Shaft:

UL = 20.000sssssss

LL = 19.997 mm

$\therefore$ Shaft can be written as $20^{-0.00}_{-0.003}$

05.

Sol: Methods of measurements of linear dimensions:

1. LINE STANDARDS:

When the length being measured is expressed as the distance between two lines, then it is called "*Line Standard*".

Ex: Measuring scales, Imperial standard yard, International prototype meter.

***Features of line standards*:**

- The scales can be accurately engraved but it is difficult to take full advantage of this accuracy. For example a steel rule can be used to read upto ± 0.5 mm of true dimension.
- A scale is quick and easy to use over a wide range because only one is required.
- The scale markings are not subjected to wear
- A scale does not posses a built in datum which would allow easy scale alignment with the axis of measurement.
- Subjected to parallax error which are a source of + ve and –ve reading errors.
- Not commitment for close tolerance on length measurement except in combination with micrometer.

2. *END STANDARDS:*

When the length being measured is expressed as the distance between two parallel faces, then it is called *'End standard'*.

Ex: Slip gauges, Gap gauges, Ends of micrometer anvils, etc.

***Features of End standards*:**

- The end standards are highly accurate and are well suited for measurement of close tolerances.
- They are time consuming in use and provide only one dimension at a time.
- They are not subjected to the parallax effect since their use depends on "feel".
- End standards are highly accurate and are well suited for measurements of close tolerances as small as 0.0005 mm
- These end standards are subject to wear of their measuring faces
- Groups of slip gauges wrung together to provide a given size therefore frequently wringing leads to damage or inaccuracy.
- End standards have a built in datum because their measuring faces are flat and parallel and can be +ve ly located on the datum surface
- The end standards are not subject to parallax errors, because their use depends on "feel of hand"

Role of Standards:

The role of standards is to achieve uniform, consistent and repeatable measurements throughout the world. Today our entire industrial economy is based on the interchangeability of parts and the method of manufacture.

To achieve this, a measuring system adequate to define the features to the accuracy required & the standards of sufficient accuracy to support the measuring system are necessary.

06.

Sol: Given: Interference assembly

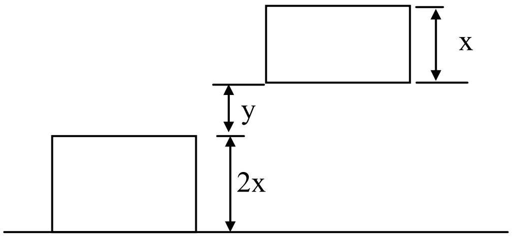
Nominal diameter = 20 mm

Let tolerance of shaft = x

Tolerance of hole = 2x

Minimum interference = 0.03 mm

Maximum interference = 0.09 mm



$2x + y + x = 0.09$

$3x + y = 0.09$ ………. (1)

$y = 0.03$ ……….. (2)

$\therefore 3x = 0.06$

$\Rightarrow x = 0.02$ mm

Hole:

UL = 20.04 mm

LL = 20 mm

$\therefore$ Hole can be written as $20^{+0.04}_{+0.00}$

Shaft:

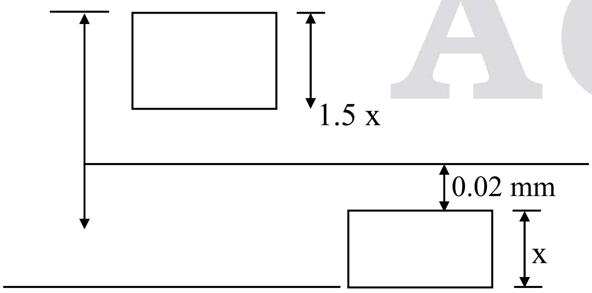
UL = 20.09 mm

LL = 20+ 0.04 + 0.03 = 20.07 mm

$\therefore$ Shaft can be written as $20^{+0.09}_{+0.07}$

07.

Sol: (i) Hole-basis system



$1.5x + 0.02 + x = 0.04$

$\Rightarrow x = 0.008$ mm

Hole:

UL = 30.012 mm

LL = 30

$\therefore$ Hole can be written as $30^{+0.012}_{+0.00}$

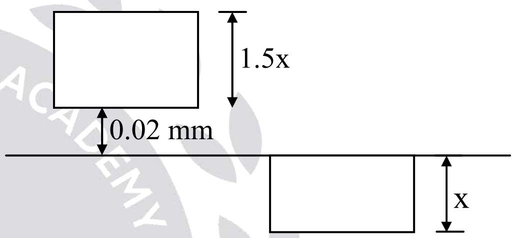
Shaft:

UL = 29.98 mm

LL = 29.972 mm

$\therefore$ Shaft can be written as $30^{-0.02}_{-0.028}$

(ii) Shaft-basis system:



Again $x = 0.008$ mm

Hole:

UL = 30.032 mm

LL = 30.02 mm

$\therefore$ Hole can be written as $30^{+0.032}_{+0.02}$

Shaft:

UL = 30 mm

LL = 29.992 mm

$\therefore$ Shaft can be written as $30^{+0.00}_{-0.008}$

08.

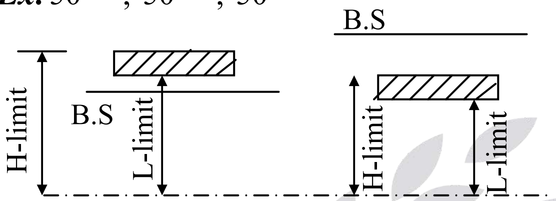
Sol: *Distinguish between allowance and tolerance (Refer Q.No 3)*

Tolerances are two types

1. Unilateral tolerances:

- When the two limit dimensions are only on one side of the nominal size, (either above or below) the tolerances are said to be unilateral.
- Normally used in case of mating parts.
  Ex: Shaft and bearing, piston & cylinder etc

Ex: $50^{+0.2}_{+0.2}$, $50^{+0.2}_{+0.0}$, $50^{-0.2}_{-0.0}$

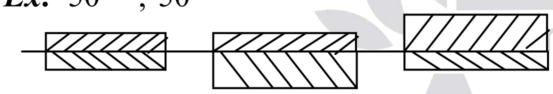


Unilateral Tolerance

2. ***Bilateral tolerances***:

- When the two limit dimensions are above and below nominal size, (i.e., on either side of the nominal size) the tolerances are said to be bilateral.
- Normally applied to non mating parts.
  Ex: thickness of flywheel, outer diameter of flange in flange coupling etc

Ex: $50^{\pm0.1}$, $50^{+0.2}_{-0.2}$



Bilateral Tolerance

The tolerances on a component can be arrived by considering 2 factors

1. Functional requirement
2. Cost of production

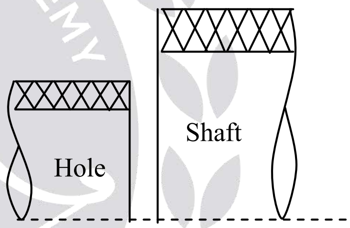
} A compromise is need among this 2 factors

After arriving at a compromised value, the nearest tolerance should be adapted.

Conditions for a force fit or an interference fit between mating parts is

Interference fit:

- In this type of fit, the minimum permitted diameter of the shaft is larger than the maximum allowable diameter of the hole, i.e. when H.limit of hole is smaller than L.limit of shaft.
- There always the non mating parts will assembled only with application force, called interference fit.
- Here allowance is greater than sum of tolerances on hole and shaft.
  Ex: Bearing bushes fitted into housings



L Hole and L shaft $\Rightarrow$ S > H

L Hole and H. shaft $\Rightarrow$ S > H

H Hole and L shaft $\Rightarrow$ S > H

H Hole and H shaft $\Rightarrow$ S > H

Maximum interference (H. shaft – L. hole)
= Difference between maximum material limits of hole and shaft.

Minimum interference (L. shaft – H hole)
= Difference between minimum material limit of hole and shaft.

Hole basis system preferred over a shaft basis system (Refer Q. No 1)

09.

Sol:

(i) ***Waviness:*** Waviness is the longer wavelength irregularities upon which roughness is super imposed. Waviness may be induced by vibration, hard spots, imperfect turning of a grinding wheel, chatter, heat treatment etc.

These are the irregularities arising because of:

(a) Inaccuracies in the machine tool.
Ex: lack of straightness in the guide ways.

(b) Deformation of work under cutting force

(c) Deformation of work due to its own weight.

(d) These are the irregularities caused by vibration of any kind, for example tool chatter.

- ***Roughness:*** Roughness is the short wavelength irregularities arising from the production process which comprise individual scratch or tool marks such as that produced by a single traverse of a planning tool across the surface. Such marks contain within them further small irregularities which are also included in the definition. The reasons are

a) These are the irregularities caused by machining itself process parameters.

b) These are the irregularities arising from rupture of the material during the separation of the chip.

(ii). *Peak to valley height (R_t or R_{max}):* It is the difference between highest peak and deepest valley. This measurement may not give the true characteristic of any surface because due to some sudden jerk peak to valley height value is high in a very small region otherwise the entire surface is quite all right.

Average Roughness:

- This is also called '*Centre Line Average*' (CLA) and denoted by 'R_a'.

$$R_a = \frac{[(h_1+h_2+h_3+h_4+h_5)+(v_1+v_2+v_3+v_4+v_5)]}{10}$$

$$R_a = \frac{(A_1+A_2+A_3+\ldots..+A_n)}{L}\times\frac{1}{H.M}\times\frac{1000}{VM}$$

$$\therefore R_a = \frac{\Sigma A}{L}\times\frac{1}{H.M}\times\frac{1000}{V.M}$$

Where, L = sample length, A = total area.

$$R_a = \left(\frac{1}{L}\right)\int_0^L hdL$$

V.M. = vertical magnification,

H.M. = Horizontal magnification,

h_1, h_2, h_3 … are max peaks (in mm)

v1, v_2, v_3 …are valley's (in mm).

(iii) *Redundant data :*

$H_{max} = R_t$ = Maximum peak valley height

$$= \frac{f}{\tan C_S + \cot C_e}$$

$$H_{max} = \frac{0.3}{\tan 30 + \cot 10} = 0.048\,\text{mm}$$

H_{max} = 48 microns.

(iv) To improve surface finish the following methods can be used:

1. **Increase the speed:** Increasing surface feed per minute (SFM) reduces built-up edge (BUE). This will prolong tool life and reduce the chance that catastrophic tool failure will damage a finished part.
2. **Reduce the Feed:** Reducing the inch per revolution (IPR) will reduce flank wear and also prolong insert life.
3. **Increase the top Rake Angle:** Rake angle is a variable in the insert's design that can be tailored to achieve the best surface finish.
4. **Use a Chip Breaker:** Chip breakers can reduce cutting pressures and produce chips that can be evacuated more easily. In materials that produce long, stringy chips, a chip breaker can help produce smaller chips that exit the cutting zone quickly and easily.
5. **Use a Large Nose Radius:** There is a direct relationship between the size of the insert's nose radius and the surface finish produced. While it's true that a smaller nose radius decreases the pressure on a tool, it also limits the feed rate that can be used.
6. **Use a Wiper:** "By using an insert with a Wiper , you can create a smoother surface in the milling pass."
7. **Use the Correct Technique:** Technique also plays a role in achieving fine surface finishes, and creating a chip that is thick-to-thin should be the goal.
8. **Use Different Tools to Rough and Finish:**
9. **Clear the Chips:**
10. **Check the Tool holding and Work holding:**

    Chatter caused by improper toolholding and fixturing, or by a machine tool that is not rigid, will create nothing but problems.

    Rigid, stable work holding is also key. As, the higher the metal removal rate, the more important stable work holding becomes.

(v). The approximate value of R_a is $\frac{H_{max}}{4}$

$$\therefore\ R_a = \frac{48}{4} = 12\text{microns}$$

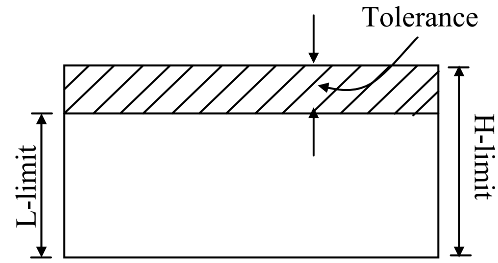
10.

Sol: ***Limits:*** The maximum and minimum permissible sizes within which the actual size of a component lies are called *Limits.*

In any manufacturing company, making a component to the exact size is difficult and costly.

Tolerance:

- The tolerance is the amount by which the given dimension is permitted to vary.
- It is the difference between the high and low limits of size.
- It is allowed in order to cover the reasonable imperfection in workmen-ship and the inevitable inaccuracy of the manufacturing process.



In actual practice it is impossible to make the component for accurate dimension because

- Variations in the properties of the material being machined introduce errors.
- The production machines themselves have some inherent inaccuracies built into them
- It is impossible for an operator to make perfect settings.

Fit: Fit is defined as the relationship between hole and shaft during assembly.

These are of 3 types:

(i) Clearance fit,

(ii) Interference fit,

(iii) Transition fit.

50 H7g6

Basic size = 50

H = fundamental deviation of hole 'H'

7 = grade of tolerance IT7 for hole.

g = fundamental deviation of shaft 'g'

6 = grade of tolerance IT6 for shaft.

Limit Gauges

These are the gauges which are used to check the limits of a part.

These are two types.

1. *GO Gauge* , 2. *NOGO Gauge*

For Holes:

- Plug gauge will be employed to check the limits of holes.
- The plug gauge made to the lower limit of the hole is known as a go plug gauge and this smaller than the L-limit allowed.
- The plug gauge made to the upper limit is known as **NOGO** or **NOTGO** plug gauge and will not enter any hole which is not larger than the upper limit of the hole allowed.

NOTE: The length of GO gauge should be at least equal to the length or depth of the part to be inspected.

For Shafts:

- Ring gauges or Gap gauges are used. The gauge made to the upper limit of the shaft is called GO gauge and will enter any shaft which is not larger than the H-limit of shaft.
- The gauge made to the lower limit of the shaft is called NOGO gauge and it will not enter any shaft which is not smaller than the lower limit allowed.

Generalizing both for holes and shafts it can be clearly stated that

Max material Limit of a Component
- Smallest hole (L-limit of hole)
- Largest shaft (H-limit of shaft)

} Checked by GO gauge

Min material Limit of a Component
- Largest hole (H-limit)
- Smallest shaft (L-limit)

} Checked by NOGO gauge

Advantages:

- The inspection is rapid
- Even unskilled labor can use them
- The gauges are usually robust in construction and so this does not get damaged easily.

Disadvantages:

- A close watch on the wear of gauges is a must.
- No warning possible trouble until the gauges start rejecting the components, by which time a considerable no. of components would have been manufactured.

11.

Sol: ***Accuracy*****:** It refers nearest to true value

For Ex: If an instrument of accuracy ± 0.01 mm indicates the dimension of part is 20 mm, it means that true dimension could lie between 19.99 and 20.01 mm.

Thus saying accuracy of ± 0.01 mm means that measurement can be inaccurate by ± 0.01 mm or there is uncertainty about the true value to the extent of ± 0.01 mm.

Precision: It represents the degree of repetitiveness or reproducibility.

Resolution: It is the ability of the measurement system to detect and faithfully indicate small changes in the characteristics of the measurement result.

Sensitivity: It is the ratio of change in output of an instrument to the change in input.

12.

Sol: Surface Profilograph:

- In this method a drum is wrapped with a sensitized paper, on which the reflected image of light has been focused so that the mirror is attached to the tracer and which follows the surface roughness profile.
- By measuring profile on the drum we can estimate the surface roughness.

Average Roughness:

- This is also called '*Centre Line Average*' (CLA) and denoted by 'R_a'.

$$R_a = \frac{[(h_1+h_2+h_3+h_4+h_5)+(v_1+v_2+v_3+v_4+v_5)]}{10}$$

$$R_a = \frac{(A_1+A_2+A_3+\ldots..+A_n)}{L}\times\frac{1}{H.M}\times\frac{1000}{VM}$$

$$\therefore R_a = \frac{\Sigma A}{L}\times\frac{1}{H.M}\times\frac{1000}{V.M}$$

Where, L = sample length, A = total area.

$$R_a = \left(\frac{1}{L}\right)\int_0^L h\,dL$$

V.M. = vertical magnification,

H.M. = Horizontal magnification,

h_1, h_2, h_3 … are max peaks (in mm)

v_1, v_2, v_3 …are valley's (in mm).

13.

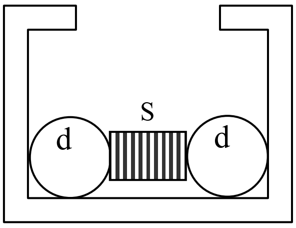
Sol: Internal diameter measurements:

1. Inside Micrometer:

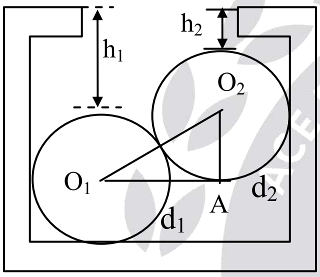
Measurement of internal diameter using inside micro meter is similar to that of the outside micrometer. But used for measurement of plane inside diameter only. But not for recessed holes

2. ***Two balls of dia 'd'" and slip:***

$D = 2d + S$



3. ***Two balls of d_1, d_2 and depth gauge***

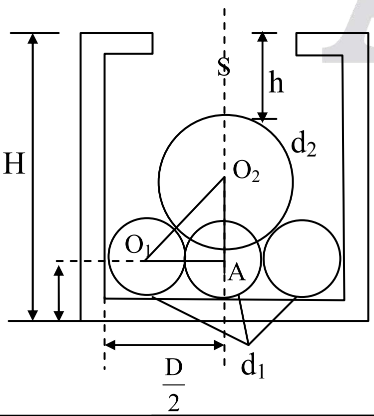


$D = r_2 + r_1 + O_1A$

$O_1A = O_1\,O_2^2 - D_2A^2$

$= (r_1 + r_2)^2\ (h_1+r_1) - (h_2+r_2)$

4. ***3 balls of diameter d_1, 4^{th} ball of diameter d_2 and depth gauge:***



$\frac{D}{2} = r_1 + O_1A$

$D = 2(r_1 + O_1A)$

$O_1A = \sqrt{O_1O_2^2 - O_2A^2}$

$= \sqrt{(r_1 + r_2)^2 - (H - -(r_1 + r_2 + h))^2}$

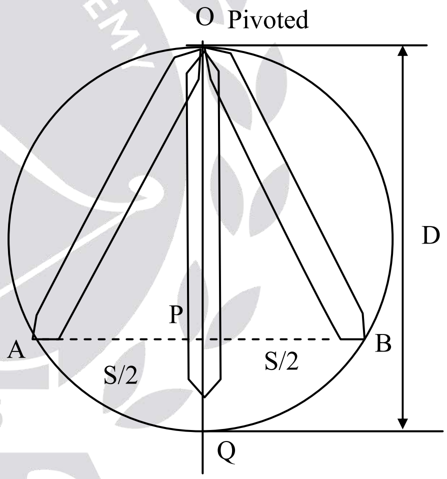
5. ***Pin method:***

(Dynamic method of measurement of inside diameter)

$OQ = OP + PQ \qquad [\Delta^{le}\ OPA]$

$OP = \sqrt{OP^2 - AP^2}$

$= \sqrt{L^2 - (S/2)^2}$



$OP \times PQ = AP \times PB$

$PQ = \frac{AP \times PB}{OP}$

$= \frac{S/2 \times S/2}{OP} = \frac{S/2 \times S/2}{\sqrt{L^2 - (S/2)^2}}$

Maximum material limit of a component is checked by GO gauge.

∴ Dimension of GO gauge is equal to largest rod size i.e. 70.05 mm.

Minimum material limit of a component is checked by NO GO gauge

∴ Dimension of NO GO gauge is equal to smallest rod size i.e. 69.90 mm.

14.

Sol: **<u>According to the purpose:</u>**

According to the purpose, the gauges may be classified as:

(a) Workshop Gauges,

(b) Inspection Gauges, and

(c) Master Gauges (Reference Gauges)

(a). <u>Workshop Gauges:</u>

Workshop gauges are used by the machine operator to check the dimensions of the components as they are being produced. Theses gauges are designed to keep the size of the component near the centre line of the tolerance.

(b) <u>Inspection Gauges:</u>

Inspection gauges are used by the inspectors for the final acceptance of manufactured components when finished. These gauges have slightly larger tolerance than the workshop gauges so as to accept component slightly nearer the tolerance limit than the workshop gauges.

(c). <u>Master Gauges:</u>

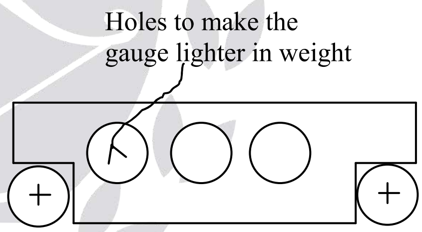
Master gauges are also referred as reference gauges. These are used only for checking of other gauges. Due to expenditure involved, master gauges are seldom used and gauges are checked by convectional measuring instruments like, comparators, slip gauges, optimizers etc.

15.

Sol:

SINE BAR :

- Rollers of diameter "d" are used
- The distance between the centers of the rollers is taken as length of sine bar and it is used for specification of sine bar.



Feature:

- The upper surface should be flat
- Each roller should be round and of same size
- The two axes of rollers must be parallel
- Centre distance must be exact
- Roller axes must parallel to the upper surface
- Size of the sine bar is specified with distance between the centers of rollers

Uses:

- To set an angle in the horizontal plane or vertical plane
- To check/measure unknown angles
- Checking of unknown angles of heavy component

Errors in Setting (or) measuring with sine Bar

As "θ" increases sinθ does not increase at the same rate, hence for higher levels of "θ" even a small error in "h" or "L" will cause greater errors than at lower values of "θ"

Let h = height of slip gauge combination
L = length of sine bar
θ = setting/measuring angle

∴ Sin θ = h/L,

Chapter 8 Advanced Machining Methods Numerical Control (NC) Machines

01. Ans: (a)

Sol: Pitch of lead screw = 5mm

1 rev = 5mm

1mm = 1/5 rev

200mm = 1/5 × 200 = 40rev

= 40 ×360 = 14400 deg.

02. Ans: (b)

Sol: Pitch of lead screw = 5mm,

BLU = 0.005mm

⇒ Distance travelled /pulse

Length of travel = 9mm

No.of pulses = L/BLU = 9 / 0.005

= 1800 pulse.

03. Ans: (b)

Sol: For 1 rev of motor ⇒360° are required

⇒ 360 pulses are required

When motor is rotated by 1 rev

⇒ lead screw will rotate by 1 rev

When Lead screw is rotated by 1 rev ⇒3.6 mm distance is travelled by axis

In total

For 360 pulses ⇒ 360 deg of motor

⇒ 1 rev of motor

⇒1 rev of lead screw

⇒ 3.6 mm of linear movement of axis

360 pulses = 3.6mm

1 pulse = 3.6/360 = 0.01mm = 10 microns

04. Ans: (b)

Sol: 10V = 100 rpm

= 100 × 5 = 500 mm/min

That is for 500mm/min = 10V

1mm /min = 10/500

3000mm/min = 10 × 3000 / 500=60 V

Common Data 05 & 06

05. Ans: (b) & 06. Ans: (a)

Sol: A, Stepper motor ⇒ 200 steps / rev

⇒ 200 pulses /rev

Pitch = 4 mm, no. of starts = 1,

Gear ratio = N_0/N_i= 1/4 = U

F = 10000 pulses per min

200 pulses ⇒ 1 rev of motor

⇒ 1/4 rev of lead screw

= 1/4 × 4 × 1 mm linear distance.

= 1mm linear distance

1 pulse = 1/200 = 0.005mm

= 5 microns = 1 BLU

Feed = BLU × pulse /min

= 0.005 × 10000 = 50mm/min

For changing BLU = 10 microns

= 0.01mm

⇒ Gear ratio has to be reduced to 1/2

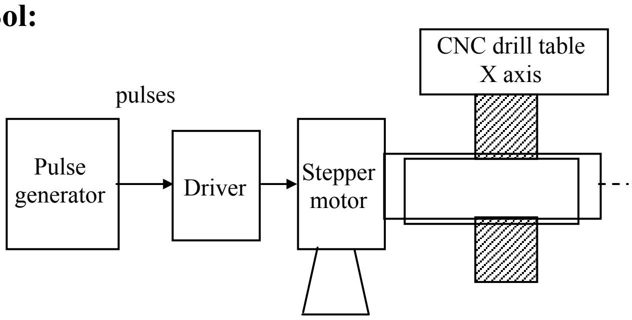
Feed = BLU × pulse /min

⇒ Pulses per min = feed / BLU

= 50/0.01 = 5000

07. Ans: (c)

Sol:



BLU = the distance traveled by the table for one pulse of electrical energy input to the motor.

Hence 200 pulse = 1 revolution of motor

= 1 revolution of lead screw = 4mm

That is 1 pulse = 4/200 = 1/50 = 0.02mm, hence BLU does not depends on the frequency of pulse generator

∴ When frequency of pulse generator is doubled, feed rate of table or tool will double but BLU remains same.

Correct answer is (c)

08. Ans: 20

Sol: p = 5 mm

1000 pulses → 1 rev of motor

→ 1 rev of lead screw

Velocity of table = 6 m/min

= 6000 mm/min

= 100 mm/sec

1000 pulses → 1 rev of lead screw → 5 mm

$$1\,\text{pulse} \rightarrow \frac{5}{1000} = 0.005\,\text{mm}$$

BLU = 0.005 mm

Table speed = BLU × Rate of Pulses

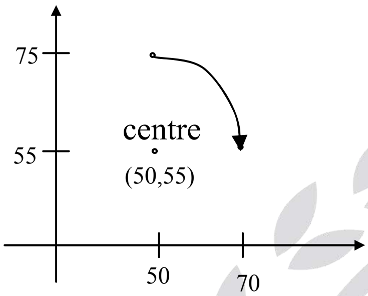
Rate of pulses = $\dfrac{100}{0.005}$

$= 20000$ pulses/sec

$= 20000$ Hz $= 20$ kHz

09. Ans: (c)

Sol:



10. Ans: (b)

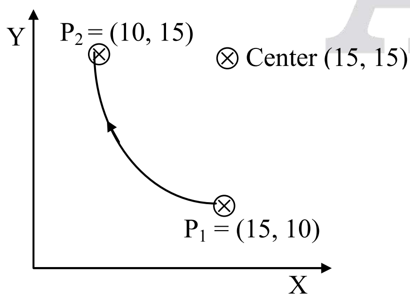
11. Ans: (a)

Sol: G02 – circular interpolation clockwise

G03 – circular interpolation counter clockwise

12. Ans: (c)

Sol: Because the tool has to travel from P_1 to P_2 in clock wise.



13. Ans: (d)

Sol: Appropriate answer but the correct answer is

N05 X5 Y5

N10 G02 X10 Y10 R5

Because in CNC part program we are not suppose to indicate information about one axis more than once in one block.

14. Ans: 60

Sol: In the combined movement, the tool is moving for 50mm with a speed of 100mm/min. whereas in the same time tool is traveling x-axis by only 30mm.

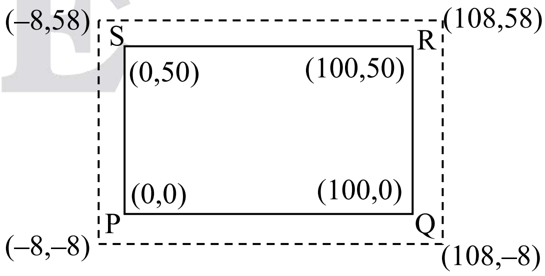
Hence,

For 50mm ⇒100mm/min

For 30mm $\Rightarrow \dfrac{100}{50} \times 30 = 60\text{mm}/\text{min}$

15. Ans: (a)

Sol: Because diameter of milling cutter is 16mm, the radius is 8mm. the dotted line indicates cutter center position, which is shifted by 8 mm all around the rectangular slot

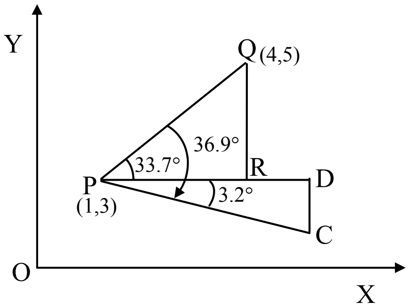


If the given shape is rectangular hole, then the answer is

(8,8), (92,8), (92,42), (8,42), (8,8)

16. Ans: (a)

Sol:



$$PQ = \sqrt{2^2 + 3^2} = 3.6055 = PC$$

PD = PC × cos 3.2 = 3.6

x co-ordinate of point C = 1 + 3.6 = 4.6

DC = 3.6 sin 3.2 = 0.2

y co-ordinate of point C = 3.0 – 0.2 = 2.8

17. Ans: (a)

Sol: "P" after translation = (1+2, 3+3, –5 –4)

= (3, 6, –9)

Rotation about z- axis means

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 6 \\ -9 \\ 1 \end{bmatrix}$$

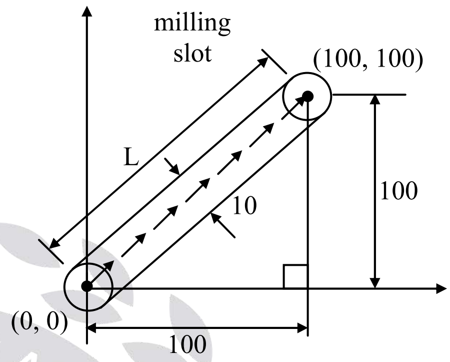
$$= \begin{bmatrix} 0-6+0+0 \\ 3+0+0+0 \\ 0+0-9+0 \\ 0+0+0+1 \end{bmatrix} = \begin{bmatrix} -6 \\ 3 \\ -9 \\ 1 \end{bmatrix}$$

Final point = [–6, 3, –9]

18. Ans: (b)

19. Ans: (b)

Sol: Given coordinates (0,0) to (100, 100)



Depth, d = 2 mm,

Diameter, D = 10 mm

L = actual distance travel by tool

$$L = \sqrt{100^2 + 100^2} = 141.42 \text{ mm}$$

$$\text{Time} = \frac{\text{disatnce}}{\text{speed}}$$

$$= \frac{141.42}{50 \text{ m/min}} \times 60$$

$$= 169.70 \approx 170 \text{ sec}$$

Correct answer is (b)

20. Ans: 54.166 mm/sec, 10 micron

Sol: f = 500 pulse/rev

p = 5 mm,

N = 650 rpm

(i) $v = Np = \dfrac{650 \times 5}{60}$

v = 54.166 mm/sec

Now, 1 min = 650 rev

$$1 \text{ sec} = \frac{650}{60} \text{rev}$$

$$\therefore f = 500 \times \frac{650}{60}$$

f = 5416.66 pulse/sec

And, v = B.L.U.× f

$$= 54.166 = BLU \times 5416.66$$

B.L.U. = 0.01 mm

B.L.U. = 10 microns

21. Ans: 287

Sol: $\alpha = 0.9°$

0.9° = 1 pulse

$$360° = \frac{360}{0.9} \text{pulse} = 400 \text{pulses}$$

$\therefore$ 1 revolution = 4 mm pitch = 400 pulses

$\Rightarrow$ $\therefore$ 2.87 mm = 287 pulses

22. Ans: 100 pulse, 60 mm/min

Sol: Pulse rate = N × pulse/rev

$$= 15 \times \frac{400}{60} = 100 \text{pulse/sec}$$

Feed rate = 15 rpm × 4 mm/rev

= 60 mm/min

23. Ans: (b)

Sol: M03 or M02: This indicates that program has ended. Be sure to specify MO2 or M30 at the end of the program specify this code in a block by itself. Never include any other words in the same block.

24. Ans: (d)

Sol: G90 → specifies absolute input dimensions

G91 → Specifies incremental input dimensions

G70 → Dimensioning in inch units

G71 → Dimensioning in metric units

25. Ans: (c)

26. Ans: (d)

Sol: M00 → Program stop, spindle and coolant off.

M01 → Optional programmable stop.

M06 → Tool change

M10 → Clamp

27. Ans: (d)

28. Ans: (b)

Sol: G90 specifies absolute input dimensions.

29. Ans: (d)

Sol: The track Numbers on paper tape are:

Track Number	Meaning
1 to 4	Alphabets
5	Parity check
6 to 7	Numerals
8	End of block

30. Ans: (c)

31. Ans: (a)

32. Ans: (a)

Sol: Post processor statements: These statements are applicable to specific machine tools and are used to define machining parameters like feed, speed, coolant on/off, etc.

Ex: COOLNT/ON, RAPID, END, SPINDLE/500, FEDRAT/2000.

33. Ans: (a)

Sol:

- If a machine is capable of carrying out many number of operations in one machine itself is called as General Purpose Machine (GPM). i.e., on GPM it is possible to carryout turning, drilling, milling, grinding etc operations.
- If CNC is implemented in GPM it is called as machining centre. At general purpose, CNC machine tool capable of carrying many number of operations is called as machining centre.
- To carry out the different types of operations the different types of tools are required. All these tools will be stored in a tool storage unit called as *tool magazine,* which can be stored maximum number of tools as 32.

34. Ans: (a)

Sol: The deflection on the machine structure is due to large acceleration is mostly unknown for the CNC controller. It is possible feedback to report the amount of vibration back to the CNC and counter act against the vibration. If the body of the machine is modeled properly the feedback makes the machine stiffer and allows it to run faster, smoother and with better accuracy.

35. Ans: (b)

Sol: Direct Numerical Control distributed numerical control is common manufacturing term for networking CNC machine tools.

An FMS, (flexible manufacturing system) is only a part of the CIM concept. An FMS is a programmable production system consisting of a set of automatic work stations mutually connected by material handling systems and governed by a mostly hierarchical control system.

36. Ans: (c)

Sol: In *incremental programming* the present position of tool can be taken as reference for programming to the next position. Hence given reason is incorrect.

37. Ans: (b)

Sol: In the given part program,

G71 $\rightarrow$ Dimensioning in metric units.

G91 $\rightarrow$ Specifies incremental input dimensions.

38. Ans: (a)

Sol: **Type of NC machine** — **Feature**

PTP $\rightarrow$ Drilling machine

Contour Control $\rightarrow$ Making a spherical end

Closed loop control $\rightarrow$ Feed back system

4D control $\rightarrow$ Two tools can work simultaneously.

Conventional Practice Solutions

01.

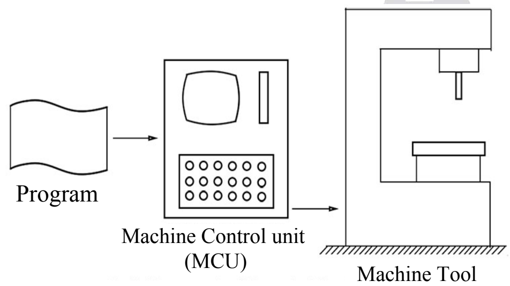
Sol: Components of the Numerical Control System:

There are three important components of the numerical control or NC system. These are:

1) Program of instructions
2) Controller unit, also called as the machine control unit (MCU) and
3) Machine tool

All these have been shown in the figure below and also described in the subsequent sections.

Parts of the Numerical Control Machine:



Basic Components of Numerical Control System

The basic elements and operation of a typical NC machine in numerical control and the components basically involved of data input, data processing and data output. For data input, numerical information is read and stored in the tape reader or in computer memory. In data processing, the programs are read into machine control unit for processing. For data output, this information is translated into commands, typically pulsed commands to the motor. The motor moves the table on which the work piece is placed to specified positions, through linear or rotary movements, by the motors, ball screw, and others devices.

A NC machine can be controlled through two types of circuits, which is open loop and closed loop. In the open loop system, the signals are given to the motor by the processor, but the movements and final destinations of the worktable are not accurate. The open loop system cannot accurate, but it still can produce the shape that is required. The closed loop system is equipped with various transducers, sensors, and counters that measure the position of the table accurately. Through feedback control, the position of the worktable is compared against the signal. Table movements terminate when the proper coordinates are reached. For the close loop system normally servomotor is utilized. For open loop system normally the stepper motor is utilized. The closed loop system is more complicated and more expensive than the open loop.

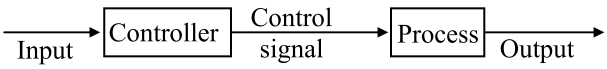


Fig: *Open Loop System*

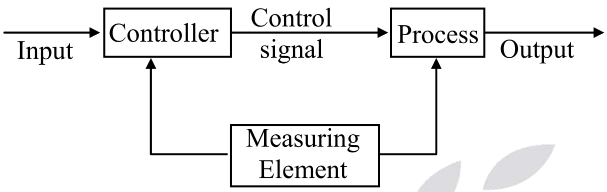
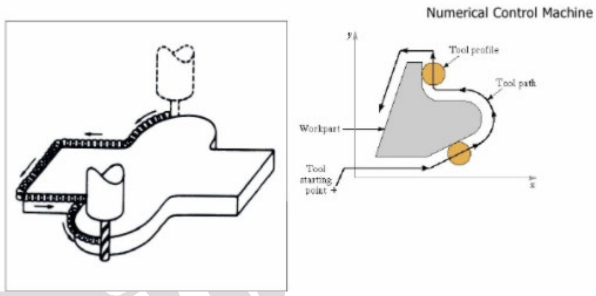


Fig: *Closed Loop System*

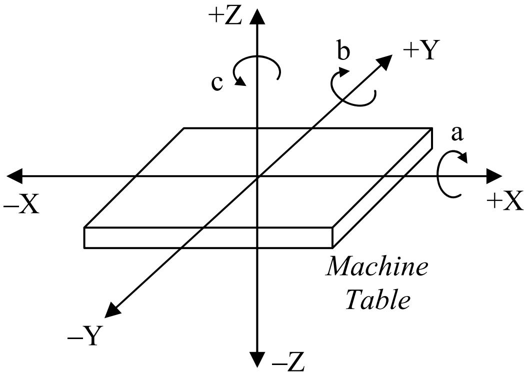
There are two basic types of control systems in numerical control, point-to-point and contouring. In point-to-point system, also called positioning, each axis of the machine is driven separately by ball screw, depending on the type of operation, at different velocities. The machine moves initially at maximum velocity in order to reduce nonproductive time, but decelerates as the tool reaches its numerically defined position. Thus in an operation such as drilling or punching, the positioning and cutting take place sequentially. The time required in the operation is minimized for efficiency. Point-to-point systems are used mainly in drilling, punching, and straight milling operations.

In the contouring system, also known as the continuous path system, positioning and cutting operations are both along controlled paths but at different velocities. Because the tool cuts as it travels along the path, accurate control and synchronization of velocities and movements are important. The contouring system is used on lathes, milling machines, grinders, welding machinery and machining centers.



The Coordinate system and Machine Motions:

In order for the part programmer to plan the sequence of position and movements of the cutting tool relative to the workpiece, it is necessary to establish a standard axis system by which relative position can be specified. Using an NC drill press as an example, the drill spindle is fixed in vertical position and the table is moved and controlled relative to the spindle. However to make things easier for the programmer we adopt the viewpoint that the workpiece is stationary while the drill is moved relative to it. According, the coordinate system of axes is established with respect to the machine table. Two axis are defined as shown in figure.



Two axes x and y are defined in the plane of the table. The z axis is defined in the plane perpendicular to the table and the movement in the z direction is controlled by the vertical motion of the spindle. The positive and negative directions of motion of the cutting tools are relative to the table along these axes. NC drill presses are classified as either two axis or the three axis machines, depending on whether or not they have the capability to control the z-axis. A numerical control machine and similar machine tools use the axis system similar to the drill system. However in addition to the three linear axes, these machines may posses the capacity to control one or more rotational axes. These axes are used to specify the angle about the x, y and z axes respectively. To distinguish positive from negative angular motions the right hand rules can be used. Using the right hand with thumb pointing in the direction of positive linear axis direction the fingers of the hand are curled to point the positive rotational direction. For turning operations two axes are required to command the movement of the tool relative to the rotational work piece the arrangement is illustrated in figure.

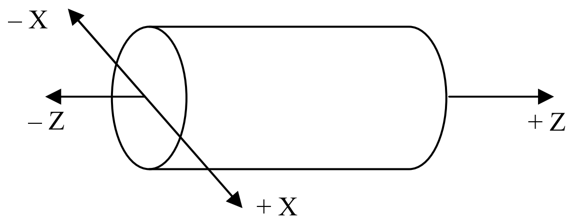


Fig: The X and Z-axes in NC turning

Other features of the Location system. The purpose of the coordinate system is to provide a means of locating the tool in relation to the workpiece. Depending on the NC machine the part programmer may have several different options available for specifying this location.

The programmer must determine the position of the tool relative to the origin (zero point) of the coordinate system. NC machines have either of two methods for specifying the zero point. The first possibility is for the machines to have *fixed zero*. In this case the origin is always located at the same position is for the machine table. Usually that position is the southwest corner of the table and all the tool locations will be defined by positive *x* and *y* coordinates.

The second and more common feature on modern NC machines allows the machine operator to set the zero point at any position on the machinable. This feature is called

"Floating Point Zero". The part programmer is the one who decides where the zero point should be located. The decision is based on part programming convenience. For example, the work part may be symmetrical and the zero point should be established at the center of symmetry.

02.

Sol: NC machine operation:

In this NC machine

G00	:	Point to point movement (Rapid tranverse)
G01	:	Linear interpolation
G90	:	Programming in absolute coordinates
G94	:	Specify feed per minute in drilling
T01	:	Tool No. 1
F150	:	Feed rate = 150 mm/ min
S	:	Spindle speed
EOB	:	End of Block
M03	:	spindle speed clockwise
M02	:	End of program machine stop
M05	:	Spindle stop

Then program for the operation

```
N01   G71   G90   G94   x-100 y-0
                        z-100 to F200 S3200 EOB
N02   G00   x 150  y 150  EOB
N03   G01   Z-115  M03   M07   EOB
N04   G00   Z 100  M09   EOB
N05   G00   X-100  y0-0  z100  M05   EOB
N06   M00   EOB
```

03.

Sol: Advantages of Numerical Control machine tools :

- *Greater process capability:* Greater accuracy and precision is built into the machine resulting in better quality and a high order of repeatability.
- *Higher production rates:* Optimum feeds and speeds can be determined for each operation with less time spent in non-cutting functions.
- *Less lead time:* Programs can be prepared in less time than conventional jigs and templates, less setup time is required.
- *Flexibility:* It is easy to change from one part to another or to change part design.
- *Lowe tooling constants:* Expensive jigs and templates may not be needed. More general purpose work holders can be used.
- *Fewer setups per workpiece:* More operations can be done at each setup of the workpiece.
- *Reduced inventory:* The overall inventory level may be reduced if parts can be run economically in smaller quantities.
- *Less setup:* Operator errors are reduced substantially. The first part of the machine can be a good part. Follow-on runs of parts previously manufactured can readily be duplicated.
- *Less skill required for the operator:* Program planning in preparing tapes reduces the necessity for operator decisions.

Limitations of Numerical Control (NC) :

There are some problems inherent in conventional NC which has motivated tool builders seek improvements in the basic NC system. The difficulties occurred by using conventional NC machines are following.

- NC manufacturing requires training of personnel both for software as well as hardware. Part programmers are trained to write instructions in desired language for the machines on the shop floor.
- The cost of NC manufacturing setups could be several times more than for their conventional counter parts. As NC is a complex and sophisticated technology. It also required higher investments for maintenance in terms of wages of highly skilled personnel and expensive spares.
- In preparing a punched tape part programming mistakes are common. The mistakes can be either syntax or numerical errors and it is not uncommon for three or more passes to be required before the NC tape is correct.
- Paper tape is especially fragile and susceptibility to wear and tear causes it to be un-reliable NC component for repeated use on the shop floor, more durable tape materials. Such as 'Mylar' and 'Aluminium Foil' are used to overcome this difficulty. How over these materials are relatively expensive.

Advantages of CNC Systems over Conventional NC Systems :

- Because the computer can be readily and easily reprogrammed, therefore, the system is very flexible. The machine can manufacture a part followed by other parts of different designs.
- More versatility, Editing and debugging programs, reprogramming; and plotting and printing part shapes are simpler.
- Program to manufacture a component can be easily called. This saves time and eliminates errors due to tape reading.
- Greater accuracy.

04.

Sol: The first basic component of NC system is the *Controller Unit.* This consists of electronics and hardware that read and interpret the program of instructions and convert it to mechanical actions of the machine tool. This works like human brain. i.e. it takes the input information from input devices such as tape reader system, feed back device, manual controls etc. , analyze the data, taking decisions and these decisions will be implemented through the output device such as drive unit. For converting low level language to high level language and vice versa an ALU (Arithmetic Logic Unit) will be used.

Table speed, $V = p\times \text{rpm} = 5 \times 650$

$= 3250$ mm/min $= 3.25$ m/min

$$\text{BLU} = \frac{5}{500} = 0.01\,\text{mm}$$

RPM= 650 = (60f)/N = (60f)/500 = 5416 Hz

05.

Sol: Cellular manufacturing refers to the use of work cells that specialize in the production of families of parts or products made in medium quantities. Parts (and products) in this quantity range are traditionally made in batches, and batch production requires downtime for setup change over and has high inventory carrying costs. Cellular manufacturing is based on an approach called group technology (GT), which minimizes the disadvantages of batch production by recognizing that although the parts are different, they also possess similarities. When these similarities are exploited in production, operating efficiencies are improved. The improvement is typically achieved by organizing the production around manufacturing cells. Each cell is designed to produce one part family (or a limited number of part families), thereby following the principle of specialization of operations. The cell includes special production equipment and custom designed tools and fixtures, so that the production of the part families can be optimized. In effect, each cell becomes a factory within the factory.

Cellular manufacturing, which is actually an application of group technology, has been described as a stepping stone to achieving world class manufacturing status. The objective of cellular manufacturing is to design cells in such a way that some measure of performance is optimized. This measure of performance could be productivity, cycle time, or some other logistics measure. Measures seen in practice include pieces per man hour, unit cost, on-time delivery, lead time, defect rates, and percentage of parts made cell-complete.

Cellular Manufacturing:

Whether part families have been determined by intuitive grouping, parts classification and coding or production flow analysis, there are advantages in producing those parts using GT machine cells rather than a traditional process-type machine layout. When the machines are grouped, the term cellular manufacturing is used to describe this work organization. Cellular manufacturing is an application of group technology in which dissimilar machines or processes have been aggregated into cells, each of which is dedicated to the production of a part or product family, or a limited group of families. Typical objectives in cellular manufacturing are similar to those group technology.

- To shorted manufacturing lead times by reducing setup, work-part handling, waiting times and batch sizes.
- To reduce work-in-process inventory. Smaller batch sizes and shorter lead times reduce work-in-process.
- To improve quality. This is accomplished by allowing each cell to specialize in producing a similar number of different parts. This reduces process variability.
- To simplify production scheduling. The similarity among parts in the family reduces the complexity of production scheduling. Instead of scheduling parts through a sequence of machines in a process-type shop layout, the system simply schedules the parts through the cell.
- To reduce setup times. This is accomplished by using group tooling (cutting tools, jigs, and fixtures) that have been designed to process the part family, rather than part tooling, which is designed for an individual part. This reduces the number of individual tools required as well as the time to change tooling between parts.

Cell design:

Cells are created in a workplace to facilitate flow. This is accomplished by bringing together operations (or machines, or people) involved in a processing sequence of a products natural flow and grouping them close to one another, distinct from other groups. This grouping is called a cell. These cells are used to improve many factors in a manufacturing setting by allowing one-piece flow to occur.

An example of one-piece flow would be in the production of a metallic case part that arrives at the factory from the vendor in separate pieces, requiring assembly. First, the pieces would be moved from storage to the cell, where they would be welded together, then polished, then coated, and finally packaged.

All of these steps would be completed in a single cell, so as to minimize various factors (called non-value-added processes/steps) such as time required to transport materials between steps. Some common formats of single cells are: the U-shape (good for communication and quick movement of workers), the straight line, or the L-shape. The number of workers inside these formations depend on current demand and can be modulated to increase or decrease production.

For example, if a cell is normally occupied by two workers and demand is doubled, four workers should be placed in the cell. Similarly, if demand halves, one worker will occupy the cell. Since cells have a variety of differing equipment, it is therefore a requirement that any employee is skilled at multiple processes.

06.

Sol: FLEXIBLE MANUFACTURING SYSTEM (FMS):

- FMS is an integrated approach to automating a production operation.
- The primary characteristic of an FMS is that it is a computer controlled manufacturing system that ties together automated production machines and materials handling equipment.
- The FMS is designed to be flexible so that it can fabricate a variety of different products of relatively low volumes.
- Flexible manufacturing systems used to get varieties at small batch and at lowest cost.

Applications:

The best application of an FMS is found in the production of small sets of products like those from a mass production.

07.

Sol: $\alpha = 0.9°$

(i) $0.9° = 1$ pulse

$$360° = \frac{360}{0.9}\text{pulse} = 400\,\text{pulses}$$

$\therefore$ 1 revolution = 4 mm pitch = 400 pulses

$\Rightarrow \therefore$ 2.87 mm = 287 pulses

(ii) Pulse rate = N × pulse/rev

$$= 15 \times \frac{400}{60} = 100\,\text{pulse/sec}$$

Feed rate = 15 rpm × 4 mm/rev

= 60 mm/min

08.

Sol: p = 3 mm

$\alpha = 1.8° \Rightarrow 200$ steps

$$\text{B.L.U.} = 1.8 \times \frac{3}{360} = 15\,\text{mm}$$

Table speed = B.L.U. × frequency

$$\therefore \frac{100 \times 10^3}{60} = 15 \times f$$

$$f = 111.11\,\text{pulse/sec}$$

v = Np

$$\therefore N = \frac{100}{3} = 33.33\,\text{rpm}$$

09(i).

Sol: Point to point control:

- In point to point control, the machining is done at specific positions, here work is stationary and tool moves from point to point.

Ex: drilling holes at different positions on a plate.

Contour control:

- In contour control, there are continuous, simultaneous and co-ordinate motions of the tool and the work piece along diff co-ordinate axes.

Ex: contours, curved surfaces etc.

09(ii).

Sol: p = 3 mm

B.L.U. =0.01 mm

f = 200 pulse/sec

v = B.L.U.× f = 0.01 × 200 = 2 mm/sec

0.01 mm = 1 pulse

$$1\text{ mm} = \frac{1}{0.01}\text{pulse}$$

$$3\text{mm} = \frac{3}{0.01} = 300\,\text{pulse}$$

$\therefore$ Frequency of pulse = $300\,\text{pulse/rev}$

Now, step angle,

$$\alpha = \frac{360°}{\text{pulse/rev}}$$

$$\alpha = \frac{360}{300}$$

$\therefore\quad \alpha = 1.2°$

10.

Sol: The modern form of control is computer numerical control (CNC), in which the machine tool operations are controlled by a ''program of instructions'' consisting of alpha numeric code. CNC provides a more sophisticated and versatile means of control than mechanical devices. This has led to the development of machine tools capable of more complex machining cycles and part geometries and a higher level of automated operation than conventional screw machines and chucking machines. The CNC lathe is an example of these machines in turning. It is especially useful for contour turning operations and close tolerance work. Today, automatic checkers and bar machines are implemented by CNC.

Point-to-Point Systems: Point-to-point systems are those that move the tool or the workpiece from one point to another and then the tool performs the required task. Upon completion, the tool (or workpiece) moves to the next position and the cycle is repeated (Figure). The simplest example for this type of system is a drilling machine where the workpiece moves.

In this system, the feed rate and the path of the cutting tool (or workpiece) have no significance on the machining process. The accuracy of positioning depends on the system's resolution in terms of BLU (basic length unit) which is generally between "0.001 and 0.0001".

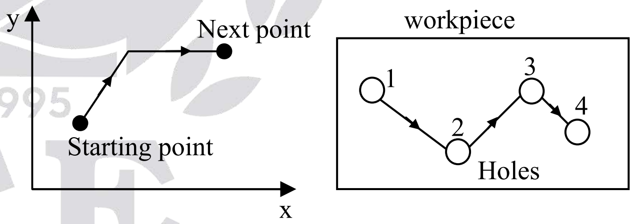
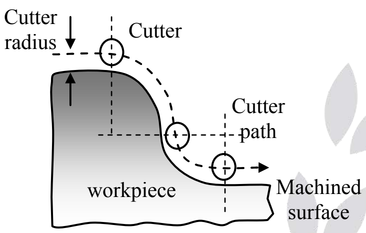
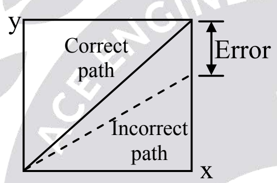


Fig: Cutter path between holes in a point-to-point system

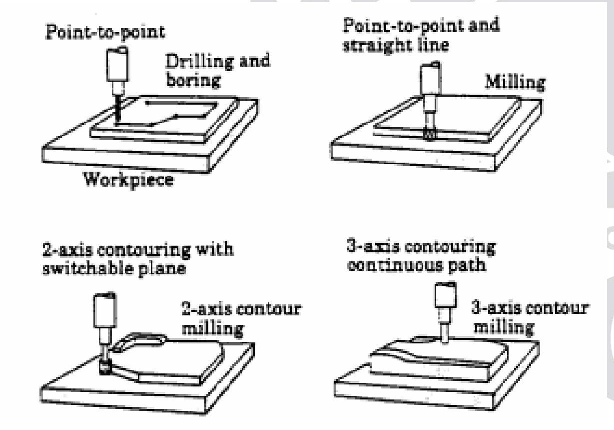
Continuous Path Systems (Straight cut and Contouring systems) These systems provide continuous path such that the tool can perform while the axes are moving, enabling the system to generate angular surfaces, two-dimensional curves, or three dimensional contours . Example is a milling machine where such tasks are accomplished (Figure). Each axis might move continuously at a different velocity. Velocity error is significant in affecting the positions of the cutter (Figure). It is much more important in circular contour cutting where one axis follows sine function while the other follows cosine function. Figure 6 illustrates point-to-point and continuous path for various machines.



(a) Continuous path cutting



(b) Position error caused by the velocity error



11(i).

Sol: Feed back transducer is provided to check whether the required lengths of tool travel has obtained. The feed back transducer sends the information of the actual position achieved to the control unit. If there is any diff between the input command and the actual position achieved, the drive unit is actuated by suitable amplifier from the error signal.

Feed back device gives the feed back to the MCU for exact control of the axis of NC machines. This will help in obtaining the component dimensions within the limits specified.

11(ii).

Sol: G90 - Absolute Programming

M03 - Clock wise Spindle rotation

12.

Sol: f = 500 pulse/rev,

p = 5 mm, N = 800 rpm

(i) $v = Np = \frac{800\times 5}{60}$

$v = 66.67$ mm/sec

Now, 1 min = 800 rev

$1 \text{ sec} = \frac{800}{60}\text{rev}$

$\therefore\ f = 500\times\frac{800}{60}$

$f = 6666.67$ pulse/sec

And, v = B.L.U.× f

$= \frac{800\times 5}{60} = BLU\times\frac{500\times 800}{60}$

B.L.U. = 0.01 mm

B.L.U. = 10 microns

13.

Sol: Error Detection:

Electrical noise can create errors in data communication. In a telephone conversation, the receiver can judge whether the message was error-free. In case of an error, the receiver responds: could you repeat that please? In computer communications with no human reasoning capability, the software is designed to detect errors.

There are two techniques for error detection: parity check and cyclic redundancy check (CRC). In the parity technique, a bit, called a parity bit is appended to the character bits at the left in the most significant position. The parity bit is either 0 (zero) or 1. Parity check may be odd or even. In the odd method, the parity bit renders the number of 1's in the character to the odd.

In the even parity method, the number of 1's in the eight-bit group is even parity method. The number of 1's in the eight-bit group is even.

Error detection based on parity is effective when one bit has suffered transmission error. If two bits are in error, the transmission error will go undetected. In fact the parity scheme is able to detect only when an odd number of errors have occurred. In general, this methods works well, since the chance of two or more bits out of eight being in error simultaneously is extremely low.

The CRC technique detects errors by performing calculations on the bits. The sender appends the results of he calculation to the message. The receiver carries out the same calculation and compares it with the appended results to determine whether the transmission was error-free.

Flexible Manufacturing System (FMS)

- FMS is an integrated approach to automating a production operation.
- The primary characteristic of an FMS is that it is a computer controlled manufacturing system that ties together automated production machines and materials handling equipment.
- The FMS is designed to be flexible so that it can fabricate a variety of different products of relatively low volumes.
- Flexible manufacturing systems used to get varieties at small batch and at lowest cost.

Difference between CNC and DNC:

- In CNC, remote controlling of operation is not possible.
- DNC facilitate the remote control.
- CNC is an integral part of the machine.
- DNC is not integral to machines, DNC computer can locate at a distance from machines.
- CNC transferring machining instruction.

- DNC manage the information distribution to the number of machines.
- CNC computer control one NC machine.
- Using DNC programmer can control more than one NC machine as required.
- CNC have low processing power when compared to DNC
- DNC have high processing power when compared to CNC
- CNC software is to increase the capability of the particular machine tool.
- DNC not only control the equipment but also serve as a part of management information system.

14.

Sol: Part Programming :

- CNC part programming language consists of a software package plus the special rules, conventions and vocabulary words for using that language.
- It is used to communicate part geometry and tool information to the computer, so that the designed part program can be prepared.

  N code: A word that acts as the name or title for a program block.

  S code: A word that determines the speed during a cutting operation.

  T code: A word that determines which specific cutting tool will be selected during a tool change

  X code: A word that describes a specific position along the X-axis.

  X-axis: The linear axis representing motions and positions that travel the longest distance parallel to the worktable.

  Y code: A word that describes a specific position along the Y-axis.

  Y-axis: The linear axis representing motions and positions that travel the shortest distance parallel to the worktable.

  Z code: A word that describes a specific position along the Z-axis.

  Z-axis: The linear axis that represents motions and positions perpendicular to the worktable. The Z-axis is always parallel to the spindle.

15.

Sol:

(a) Linear interpolation – G01
(b) Circular interpolation CCW rotation – G03
(c) Dwell – G04
(d) Hold / delay – G05
(e) Thread cutting – G 33, G 34, G 35
(f) End of program – M02
(g) Spindle on CW rotation – M03
(h) Tool change – M06
(i) Coolant supply No.1 on – M07, M08
(j) Coolant supply off – M09

Chapter 9

NTM, Jigs and Fixtures

01. Ans (c) **02. Ans: (d)**

03. Ans: (c)

Sol: In EDM the mechanism of MR is due to melting and vaporization associated with cavitation and also erosion & cavitation or spark erosion and cavitation

04. Ans: (d)

Sol: The high thermal conductivity of the tool material will have high electrical conductivity hence the heat generated with in the tool is low and what ever heat generated it will be distributed easily therefore tool melting rate reduces and tool wear reduces. Where as due to specific heat of work material, the rise in temp of W.P is faster and more amount of MR is possible.

05. Ans: (b)

Sol: Given w = 1 + (2×0.5) = 2

t =5, f = 20 mm/rev

MRR = wtf = 2.5.20 = 200 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 temps of tool material up to MP.

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

Sol: D = 12mm, t = 50mm, R = 40 Ω,

C = 20 μF, V_s = 220V, V_d = 110V

$$\text{Cycle time} = R.C \ln\left[\frac{V_s}{V_s - V_d}\right] = t_c$$

$$= 40 \times 20\times10^{-6} \times \ln\left[\frac{220}{110}\right]$$

$$= 554\times10^{-6} \text{ sec} = 0.55\, milli \text{ sec}$$

Average power input = W

$$= \left[\frac{E}{t_c}\right] = \left[\frac{0.5\times CV_d^{\;2}}{t_c}\right]$$

= 218 W = 0.218 kW

08. Ans: (b)

Sol: For Rough machining i.e. stock removal the electrolyte should have high electrical conductivity, called passivity electrolyte, where as for finish machining the electrolyte should have low electrical conductivity called non–passivity electrolyte will be used.

09. Ans: (b)

Sol: In ECM

MRR $\propto$ gram atomic weight of material

MRR $\propto$ Current density

$$MRR \propto \frac{1}{\text{distance between tool and work}}$$

MRR $\propto$ Thermal conduction of electrolyte.

10. Ans: (a)

Sol: In ECM

MRR $\propto$ gram atomic weight of material

$\propto$ Current density

$$\propto \frac{1}{\text{distance between tool and work}}$$

$\propto$ Thermal conduction of electrolyte.

11. Ans: (b)

Sol: I = 5000 A

A = 63, Z = 1, F = 96500

$$\text{MRR} = \frac{AI}{ZF} = \frac{5000\times 63}{1\times 96500}$$

$$= 3.264 \text{ g/sec}.$$

12. Ans: (a)

Sol: A = 55.85, Z = 2, F = 96540

Specific resistance = 2Ω-cm

Voltage = 12V

Inter electrode gap = 0.2 mm

Resistance

$$R = \frac{\text{Sp. Resistance} \times \text{Inter electrode gap}}{\text{Suface area}}$$

$$= \frac{2\times 10\times 0.2}{20\times 20} = 0.01$$

$$I = \frac{V}{R} = \frac{12}{0.01} = 1200\text{A}$$

$$\text{MRR} = \frac{AI}{ZF} = \frac{55.85\times 1200}{2\times 96540}$$

$$= 0.3471 \text{ g/sec}$$

13. Ans: 51.542

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 μm = 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 perform the Zig – Zag hole.

16. Ans: (b) (Both are Correct)

Sol: In EBM Vacuum is provided to avoid the dispersion of electrons after the magnetic lense, but this vacuum is giving an addition function of providing efficient shield to the weld bead.

17. Ans: (d)

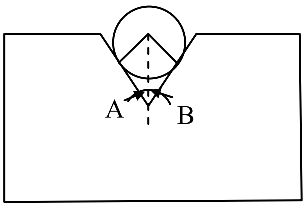
Sol: Out of all the NTM's ECM will give large MRR and EBM will give very small MRR.

18. Ans: (d)

Sol: Relative motion between tool and work piece is not necessary.

19. Ans: (c)

Sol:



If $D = D_{min} = 59.9$

X_1 = distance between center of shaft and

corner of V – block $= \dfrac{\frac{59.9}{2}}{\sin 60} = 34.583$

$$X_2 = \frac{\frac{60.1}{2}}{\sin 60} = 34.698$$

Error in depth = $2(X_2 - X_1) = 0.223$ mm

20.

Sol: Resolving the force "F" into Horizontal

$F \sin\alpha = 100$ ………. (1)

$F \cos\alpha = 100 + 100 = 200$ …… (2)

$$\frac{(1)}{(2)} = \tan\alpha = \frac{100}{200}$$

$$\alpha = \tan^{-1}\left(\frac{1}{2}\right) = 26.565$$

$$F = \frac{100}{\text{Sin}\,\alpha} = 223.6\text{ kg}$$

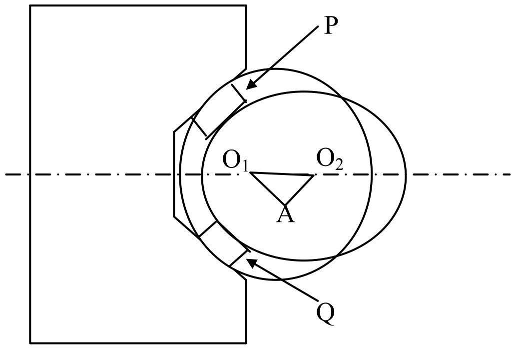
Taking the moments about vertical axis

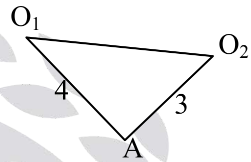
$xF\cos\alpha + 100\times 30 = 100\times 30 + 100\times 20$

$\Rightarrow$ x = 10 mm

21. (i) Ans: (d), (ii) Ans: 10.6 mm

Sol:





$O_1O_2 = \sqrt{4^2 + 3^2} = 5$

$O_1O_2 = 5 = \sqrt{x^2 + x^2}$

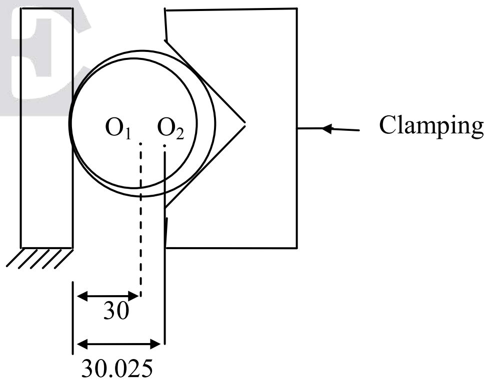
x = 3.5

Block of uniform thickness is preferable because of balanced condition.

22.

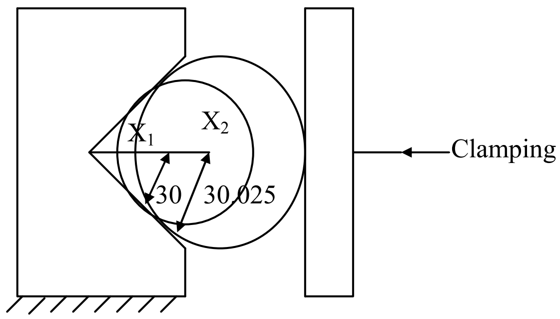
Sol:

(a) Fixed rectangular block and movable V – clamp.



Positional error = 30.025 – 30 = 0.025 mm

(b) Fixed V – block and movable rectangular block



$$x_1 = \frac{30}{\text{Sin } 60} = 34.64$$

$$x_2 = \frac{30.025}{\text{Sin } 60} = 34.66$$

(c) Positional error = $x_2 - x_1 = 0.0298$ mm

The positional error is mainly depends on the fixed element. So when fixed V – block and marble V – block is used, the positional error is remains same as (b).

Out of the 3 cases, case (a) is giving lower positional error, hence preferable.

23. Ans: (b)

Sol: In USM abrasive slurry is used as medium, EDM The dielectric fluid kerosene is used as medium, ECM conducting electrolyte is used as medium and EBM vacuum is used as medium for avoiding dispersion of electrons.

24. Ans: (c)

Sol: Hardening → Sub zero treatment → Tempering → EDM

25. Ans: (b)

Sol:

- The main drawback of USM process involves relative high tool wear than MRR, uneconomical nature for soft material machining and frequent tuning of machine.
- EBM requires vacuum.
- The main disadvantage of ECM process is that only electrical conductive materials can be machined and high specific energy consumption.

26. Ans: (c)

Sol:

- The main drawback of USM process involves relative high tool wear than MRR, un economical nature for soft material machining and frequent tuning of machine.
- EBM requires vacuum.
- The main disadvantage of ECM process is that only electrical conductive materials can be machined and high specific energy consumption.

27. Ans: (b)

Sol: A WJM is not used in electronic industry. Hence statement (3) is incorrect.

The applications areas, where water jet machining and abrasive water jet machining are: paint removal, cleaning, cutting soft material, cutting frozen meat, leather industry, mass immunization, surgery, peening, cutting, pocket milling, drilling, turning.

28. Ans: (c)

Sol: Turbine blades $\rightarrow$ ECM process.

Cutting of granite $\rightarrow$ AJM, USM.

29. Ans: (b)

Sol: ECM gives highest MRR - out of all the NTM processes. So statement (1) is incorrect.

30. Ans: (b)

Sol: EDM $\rightarrow$ Fusion & vaporization.

ECM $\rightarrow$ ION displacement

31. Ans: (c)

Sol: The following location principles are to be ensured during pin location of Cartesian co-ordinate system component:

1. Principle of perpendicular planes
2. Principle of minimum locating pins
3. Principle of extreme positions

32. Ans: (d)

33. Ans: (c)

Sol: *Selection factor:*

1. **Time taken for Manufacturing:** welding < Assembling using standard parts < Casting.
2. **Damping qualities:** Casting > Welding > Assembling using standard parts.
3. **Expandability:** Assembling using standard parts > welding > casting.

34. Ans: (b)