CBCS SCHEME

USN

BME402

Fourth Semester B.E./B.Tech. Degree Examination, June/July 2025

Machining Science and Metrology

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	**M**	**L**	**C**
Q.1	**a.**	Distinguish between orthogonal cutting and oblique cutting with neat sketches. Also justify which type of cutting method is preferred, why?	**06**	**L2**	**CO1**
	b.	With a neat sketch, explain single point cutting tool nomenclature.	**06**	**L2**	**CO1**
	c.	The following data are obtained during a turning operation on a Lathe, cutting Force = 120 kg, Feed force = 30 kg, Rake angle = 15°, Feed rate = 0.2 mm/rev, chip thickness = 0.3 mm, cutting speed = 100 m/min, work piece diameter = 120 mm, Depth of cut = 0.4 mm. calculate, a) Chip thickness ratio b) Shear angle c) Co-efficient of friction d) Friction angle e) Shear stress	**08**	**L3**	**CO1**
		OR			
Q.2	**a.**	Mention the assumption of merchant circle model, draw the neat sketch of merchant circle with all the notation.	**06**	**L2**	**CO1**
	b.	Derive the relation between Rake angle, shear angle and Frictional angle.	**08**	**L2**	**CO1**
	c.	With a neat sketch explain the principle of Lathe machine. Also distinguish between Turret Lathe and Capstan Lathe.	**06**	**L2**	**CO1**
		Module – 2			
Q.3	**a.**	Explain the constructional feature of column and knee type milling machine with a neat sketch.	**06**	**L2**	**CO2**
	b.	What is Indexing? Mention the different method, also write the steps for Indexing 69 divisions.	**08**	**L3**	**CO2**
	c.	Distinguish between Up milling and Down milling with sketches.	**06**	**L2**	**CO2**
		OR			
Q.4	**a.**	Explain the constructional feature of radial drilling machine with a neat sketch.	**06**	**L2**	**CO2**
	b.	A 12 mm hole is to be drilled through a 20 mm thick plate. The cutting speed is 12 m/min and the feed rate is 0.12 mm/rev. Estimate the machining time. Take the over travel plus the clearance of the tool as 5 mm.	**08**	**L3**	**CO2**
	c.	Distinguish between shaping and planning machine.	**06**	**L2**	**CO2**
		Module – 3			
Q.5	**a.**	With a neat sketch Explain the different temperature zones during metal cutting process.	**06**	**L2**	**CO3**
	b.	Determine the percentage change in the cutting speed required to give 60% reduction in tool life. The speed /life of the tool relationship is given by $VT^n = G$. Take $n = 0.2$.	**08**	**L3**	**CO3**
	c.	What are the functions of coolants in metal cutting process. Mention some of the coolants used during metal cutting.	**06**	**L2**	**CO3**

		OR			
Q.6	**a.**	Explain the desirable properties of cutting tool materials.	**07**	**L2**	**CO3**
	b.	Explain the salient features of cutting tool materials listed below: (i) CBN (ii) HSS (iii) Diamond	**06**	**L2**	**CO3**
	c.	What are the properties of a good cutting fluid? Explain.	**07**	**L2**	**CO3**
		Module – 4			
Q.7	**a.**	Define metrology. What are the objectives of metrology?	**06**	**L2**	**CO4**
	b.	With a neat sketch, explain the imperial standard yard.	**07**	**L2**	**CO4**
	c.	A calibrated metre end bar has an actual length of 1000.0003 mm. It is to be used in the calibration of two bars A and B, each having basic length of 500 mm. When compared with the metre bar $L_A + L_B$ was found to be shorter by 0.0002 mm. On comparing A with B it was found that A was 0.0004 mm longer than B. Find the actual length of A and B.	**07**	**L3**	**CO4**
		OR			
Q.8	**a.**	What is Line and End standard? Explain the wringing phenomena of slip gauges.	**07**	**L2**	**CO4**
	b.	Build the dimension 35.4875 mm using M112 set of gauges. Use two protector slips of 2.5 mm each.	**06**	**L3**	**CO4**
	c.	Differentiate between interchangeability and selective assembly.	**07**	**L2**	**CO4**
		Module – 5			
Q.9	**a.**	State and explain Taylor's principle of gauge design.	**06**	**L2**	**CO5**
	b.	With a neat sketch, explain a snap gauge.	**06**	**L2**	**CO5**
	c.	Calculate the dimensions of plug and ring gauges to control the production of 50 mm shaft and hole pair of H_7d_8 as per IS specification. The following assumptions may be made: 50 mm lies in diameter step of 30 and 50 mm and the upper deviation for "d" shaft is given by $-16D^{0.44}$ and lower deviation for hole H is zero. Tolerance unit i(microns) $= 0.45\sqrt[3]{D} + 0.001D$ and IT6 = 10i and above. IT6 grade the tolerance magnitude is multiplied by 10 at each fifth step.	**08**	**L3**	**CO5**
		OR			
Q.10	**a.**	Sketch and explain the working of Sigma Comparator.	**07**	**L2**	**CO5**
	b.	Select the sizes of angle gauges required to build: (i) 37°9'18" (ii) 33°16'42"	**06**	**L3**	**CO5**
	c.	With a neat sketch, explain sine bar. List the limitations of sine bar.	**07**	**L2**	**CO5**

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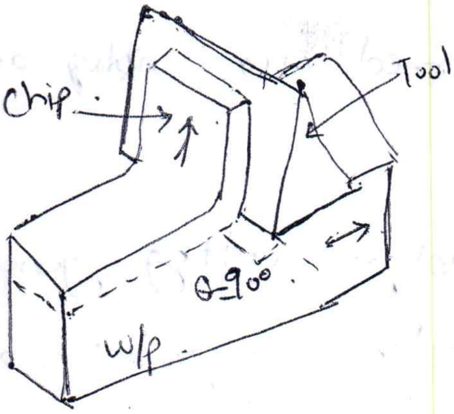
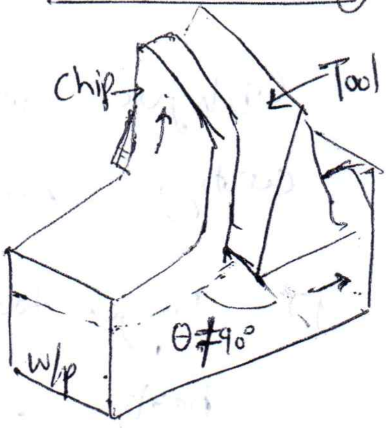
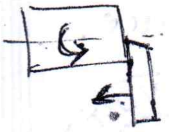
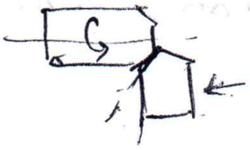
Q1. a.

Orthogonal cutting	Oblique cutting.
	
→ cutting edge of tool is inclined @ 90° to velocity vector	→ Cutting edge of tool is incline at other than 90° to velocity ve
→ 2 dimensional system	→ 3 dimensional system.
→ Chipflow is @ 90° to cutting edge	→ Chip flow is @ other than 90° to cutting
- Ex: End turning/facing with a tool - side cutting edge ∠le =0°.	Ex: Practically most of operations involve oblique cutting.
	

- Orthogonal cutting is less complicated system (forces resolved in 2 axes) and is usually used for study & research purpose. Oblique cutting is a 3 dimensional system and comparatively complex process for study and analysis. But for all practical applications oblique cutting is preferred over orthogonal cutting.

P.T.O.

Oblique cutting is preferred over ~~obliq~~ orthogonal cutting because:

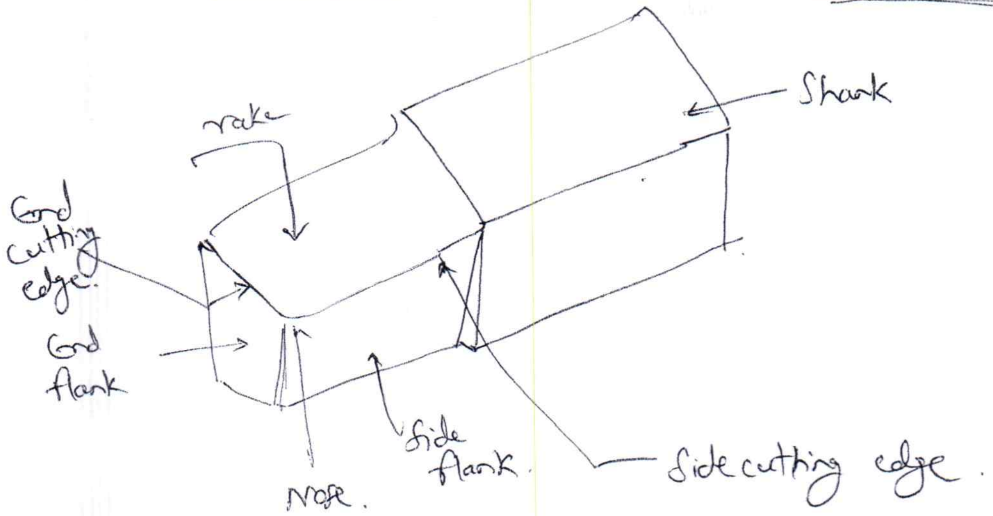
1) Logger tool life - Oblique cutting generates less heat & low temperature concentration on tool

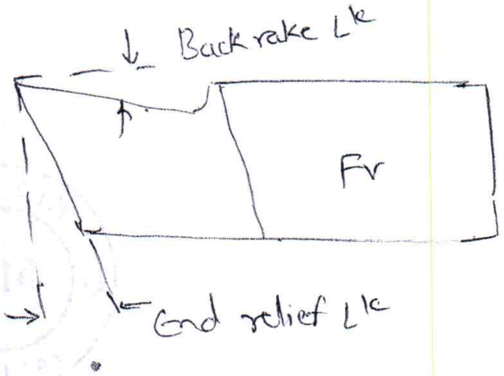
2) Better surface finish

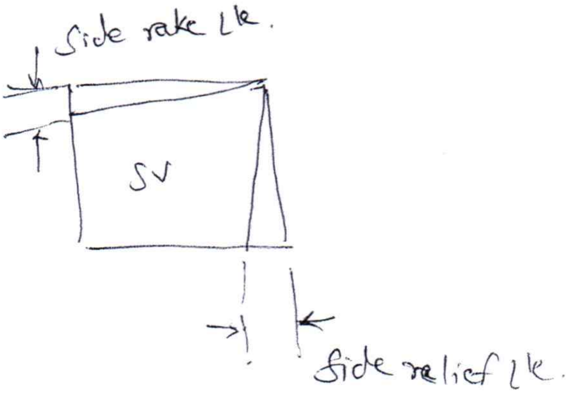
3) Lower cutting forces - The tool edge is inclined to the direction of motion, reducing the force required to remove material.

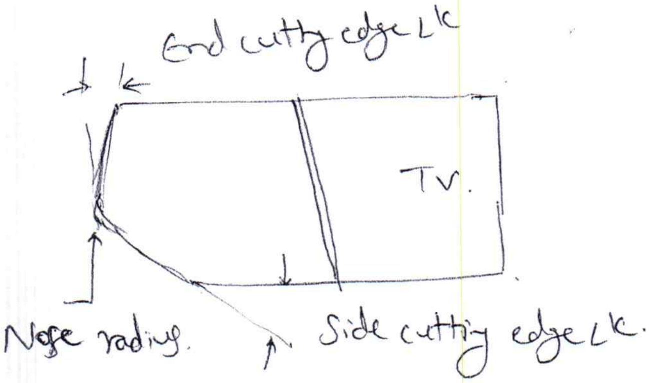
4) Chip flow - Chips flow along the tool rather than directly over the rake face.

Q1.b. Single point tool geometry – Tool Signature









Tool Signature.

1) – Back rake L^le
2) – Side " "
3) – End relief L^le
4) – Side " "
5) – End cutting edge L^le
6) – Side " " "
7) – Nose radius.

Rake ∠les -	decide the power consumption penetration inside the material Chip flow
Relief ∠les -	to avoid rubbing of tool with machined surface " " " " " " unmachined "
Cutting edge ∠les -	inclination of side & end cutting edges decide the power consumption. Controlling geometry of w/p.
Nose radius -	to enhance tool life. to enhance heat dissipation to improve surface finish.

Tool signature ex:

Tool signature is the identity or uniqueness of the tool depicting the various geometry angles and nose radius of the tool.

5, 6, 8, 7, 10, 15, 0.4.

Back rake ∠le → 5°

Side rake ∠le : 6°

End relief ∠le : 8°

Side relief ∠le : 7°

End cutting edge ∠le : 10°

Side cutting edge ∠le : 15°

Nose radius : 0.4 mm.

Q1. C. Data:

Cutting force, = 120 kg

Feed force, = 30 kg.

Rake angle, α = 15°

Feed rate = 0.2 mm/rev. (t).

Chip thickness, t_c = 0.3 mm.

Cutting speed, V = 100 m/min

Workpiece diameter, D = 120 mm.

Depth of cut, d = 0.4 mm.

a) Chip thickness ratio, $r = \frac{t}{t_c} = \frac{0.2}{0.3} = 0.667.$

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

$$= \tan^{-1}\left[\frac{0.667\cdot\cos(15^\circ)}{1-0.667(\sin 15^\circ)}\right]$$

$$= \tan^{-1}[0.779] = 37.9^\circ.$$

c) Co-efficient of friction

Friction force, $F = F_H\sin\alpha + F_V\cos\alpha$

$$= 120\times\sin(15^\circ) + 30\cos(15^\circ)$$

$$= 31.06 + 28.98$$

$$= 60.0 \text{ kgf.}$$

Normal force, $N = F_H\cos\alpha - F_V\sin\alpha$

$$= 120\cdot\cos(15^\circ) - 30\sin(15^\circ)$$

$$= 115.91 - 7.76$$

$$= 108.2 \text{ kgf.}$$

Co-efficient of friction, $\mu = \frac{F}{N}$

$= \frac{60}{108.2}$

$= 0.554$ //.

d) Friction angle (β) $= \tan^{-1}(\mu)$

$= \tan^{-1}(0.554)$

$= 29°$.

e) Shear Stress: (τ)

Shear force (F_s) $= F_H \cos\phi - F_v \cdot \sin\phi$

$= 120 \cdot \cos 37.9° - 30 \cdot \sin 37.9°$

$= 76.3$ kgf.

Shear area, $A_s = \frac{bt}{\sin\phi}$

width of chip, b = (depth of cut) = 0.4.

t, uncut chip thickness = 0.2.

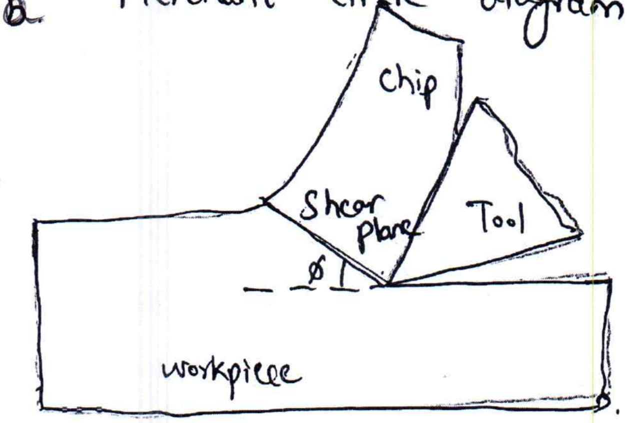
$\phi = 37.9°$.

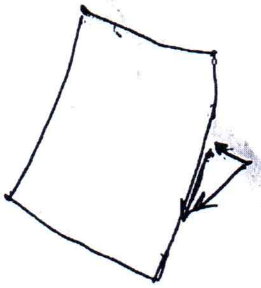
$\therefore A_s = \frac{0.4 \cdot (0.2)}{\sin(37.9)} = \frac{0.08}{0.614} = 0.130 \text{ mm}^2$.

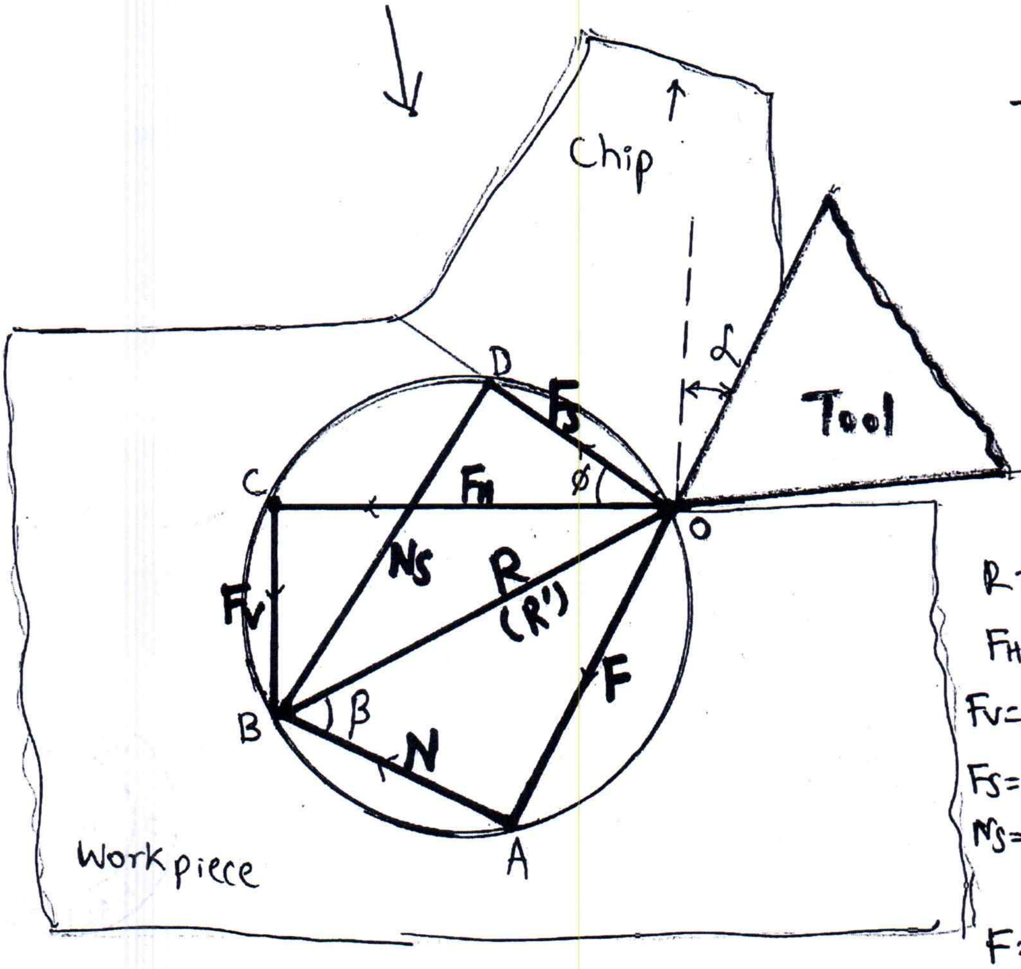
Shear stress, $\tau = \frac{F_s}{A_s} = \frac{76.3}{0.130} = 587 \text{ kgf/mm}^2$

$\tau = 587$ kgf/mm² or $587 \times 9.81 = 5760$ N/mm² or MPa.

Q2. a Merchant circle diagram







— 5M

ϕ – Shear plane $\angle^{le}$

α = rake $\angle^{le}$ of tool

β = friction $\angle^{le}$

R = Resultant

F_H = Horizontal component

F_V = Vertical component

F_S = Force along shear plane

N_S = Force normal to shear plane

F = Friction force

N = Normal force to tool

Q2a) contd.

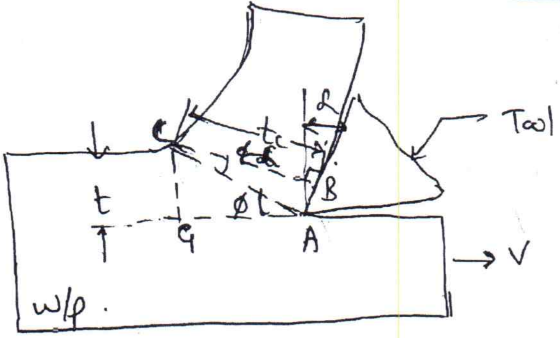
Assumptions made in establishing the relationship among the various forces :

– 3M.

- Inertia forces of chip are neglected
- The tool is perfectly sharp and there is no contact along the clearance face.
- Only continuous type of chip is formed
- The chip doesnot flow to either side, that is chip width is constant
- The depth of cut remains constant
- Width of tool is greater than that of the work.
- Work moves with uniform velocity relative to chip.
- No built up edge is formed.

[Merchant circle diagram – 5M
Assumptions – 3M.]

Q2.b. Determination of Shear plane $\angle^{le}$.



V : Cutting velocity

ϕ : Shear plane $\angle^{le}$

α : rake $\angle^{le}$ of the tool

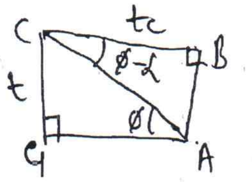
AC : Shear plane

t : Uncut chip thickness (CG)

t_c : Chip thickness (BC)

Consider an orthogonal cutting operation. work(tool) is moving with velocity V. Deformation takes place along Shear plane AC.

2 right $\angle^{le}$ Δ^{les}, ACG & ABC.



In Δ^{le} ACG,

$$\sin\phi = \frac{CG}{AC}.$$

$$\therefore AC = \frac{CG}{\sin\phi} = \frac{t}{\sin\phi} \quad — ①.$$

In Δ^{le} ABC,

$$\cos(\phi-\alpha) = \frac{BC}{AC}.$$

$$AC = \frac{BC}{\cos(\phi-\alpha)} = \frac{t_c}{\cos(\phi-\alpha)} \quad — ②$$

equating ① & ②

$$AC = \frac{t}{\sin\phi} = \frac{t_c}{\cos(\phi-\alpha)}.$$

$$\frac{t}{t_c} = \frac{\sin\phi}{\cos(\phi-\alpha)} \qquad \frac{t}{t_c} = r \text{ chip thickness ratio}$$

$$r = \frac{\sin\phi}{\cos(\phi-\alpha)}.$$

$$r\left\{\cos\phi\cos\alpha + \sin\phi\sin\alpha\right] = \sin\phi \quad — ③$$

divide ③ by $\cos\phi$.

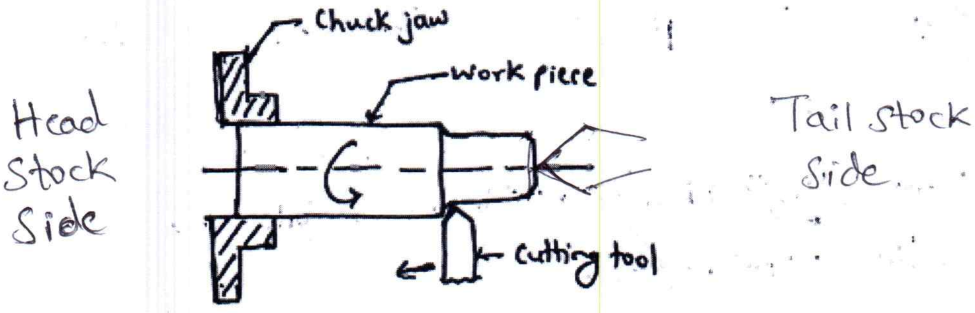
$$r\left[\frac{\cos\phi\cdot\cos\alpha}{\cos\phi} + \frac{\sin\phi}{\cos\phi}\cdot\sin\alpha\right] = \frac{\sin\phi}{\cos\phi}.$$

$$r\cos\alpha + r\tan\phi\cdot\sin\alpha = \tan\phi.$$

$$\tan\phi - r\tan\phi\sin\alpha = r\cos\alpha \longrightarrow \tan\phi\left[1-r\sin\alpha\right] = r\cos\alpha.$$

$$\therefore \tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha}. \qquad \boxed{\phi = \tan^{-1}\left[\frac{r\cos\alpha}{1-r\sin\alpha}\right]} \quad — ④$$

Q 2.c **Principle of working of lathe**



- workpiece is rigidly held / clamped in chuck (work holding device) & rotated at high speeds
- Cutting tool is fed against the rotating direction.
- Tool is moved along the axis of workpiece @ uniform rate to remove the material.
- Unwanted material is removed in the form of chips.
- Relative movement between workpiece (rotating) & tool (linear movement) results in material removal.
- Primary movement (cutting speed) – workpiece rotation
- Secondary movement (feed & depth of cut) – tool movement.

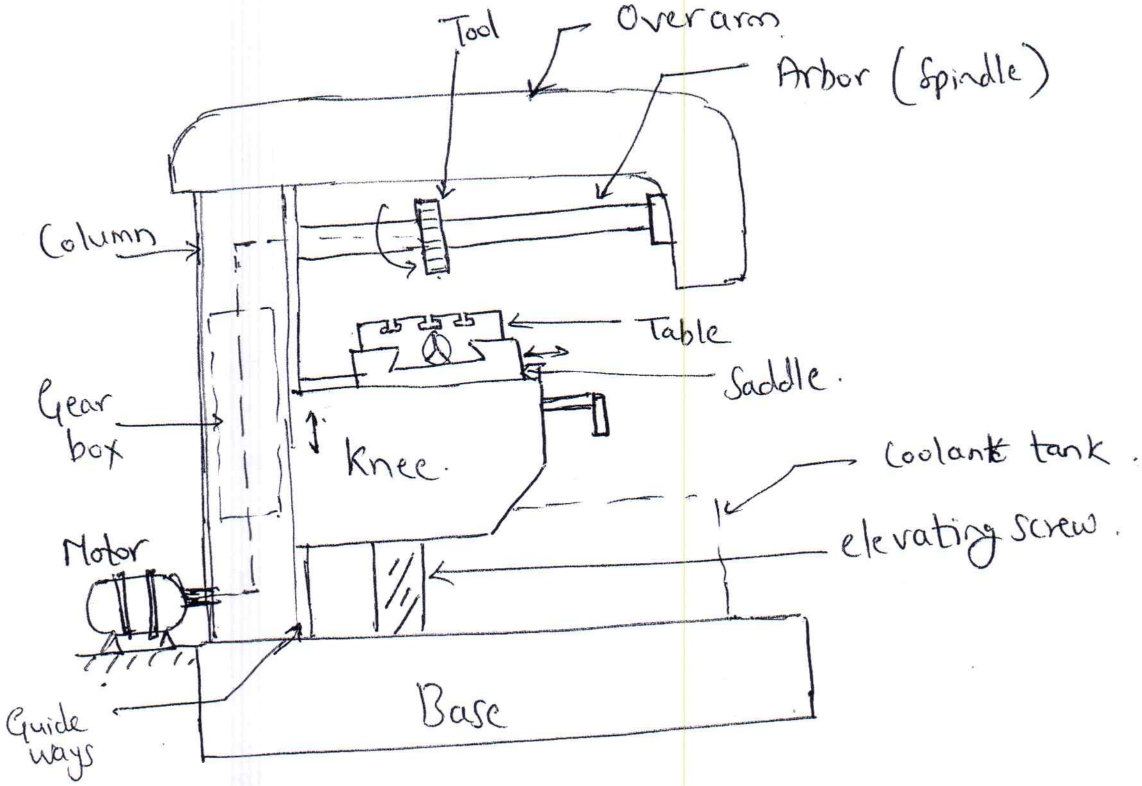
Q2 C. Contd. Differences between Turret lathe & Capstan lathe.

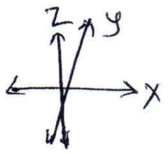
Turret lathe	Capstan lathe
1) Turret is mounted directly on the saddle	Turret is mounted on auxiliary slide which moves & which inturn is mounted on saddle.
2) For feeding the tool, entire saddle is moved	Saddle is fixed at certain distance & only auxiliary slide is moved.
3) Very high rigidity & usually of larger size.	Turret & slide will have cantilever effect, subjected to deflection. m/c is usually smaller in size.
4) can handle large & heavy workpieces.	Confined to smaller workpieces.
5) Rate of tool feeding is slower.	Rate of tool feeding is faster.
6) Tool travel is almost to full length of bed.	Tool travel is limited.

(Minimum 4 differences → 6M)

Q3.a.

Horizontal Milling Machine.- Column & knee type





Principal parts of horizontal milling m/c. :
(Column & Knee type)

- Base
- Column
- Overarm
- Knee
- Saddle
- Table
- elevating screw
- Motor
- Gearbox.

→ This machine is called so, because it consists of column (where spindle is fixed) and Knee which holds the work table.

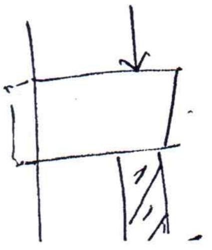
→ The base supports all the other parts and may also act as reservoir for cutting fluid.

→ Knee moves up & down in the guideways provided on the column and elevating screw helps for movement. A saddle is mounted on the knee, over which work ta is mounted.

→ The column houses the motor, gear arrangement required for adjustment of speeds. The spindle is mounted horizontally in the column & overarm with the help of bearings. The cutter is mounted on the spindle.

→ Although the m/c is rigid to hold the workpieces of medium to large size, extemely large components cannot be machined, ∵ of the weight limitations.

This is used for slab milling, slot milling & gear cutting operati



Q3.b.

<u>Indexing</u>: Milling operations sometimes require the accurate rotation of components for even cutting of slots & grooves on the surface. The operation of rotating the workpiece through required ∠le b/w 2 successive milling cuts is termed as indexing — (1M)

ex: machining of splines, gears, polygons etc.

<u>Different methods of indexing</u>:

- Direct indexing
- Simple indexing
- Compound indexing
- Differential indexing
- Angular indexing
- Indexing with servomotor.

— (1M)

P.T.O

Indexing for 69 divisions. ((compound indexing)

Solution:

$$4 = \cancel{2}\times\cancel{2}$$

$$69 = \cancel{23}\times\cancel{3}$$

Difference

$$40 = \cancel{2}\times\cancel{2}\times 2\times 5$$

$$23 = \cancel{23}\times 1 \xrightarrow{} \text{Product is 90.}$$

$$27 = \cancel{3}\times 3\times 3$$

2 Numbers chosen are 23 & 27 from plate no. II.

∴ Compound indexing equation is,

$$\frac{n_1}{N_1} \pm \frac{n_2}{N_2} = \frac{40}{2}.$$

$$\frac{n_1}{23} \pm \frac{n_2}{27} = \frac{40}{69}.$$

$$\frac{90}{23} \pm \frac{90}{27} = \frac{40}{69}.$$

$$3\,\frac{21}{23} \pm 3\,\frac{9}{27} = \frac{40}{69}.$$

$$\frac{21}{23} \pm \frac{9}{27} = \frac{40}{69} \;//.$$

∴ $n_1 = 21$, $N_1 = 23$

$n_2 = 9$, $N_2 = 27$. & compound indexing eqn is

$$\frac{21}{23} - \frac{9}{27} = \frac{40}{69}.$$

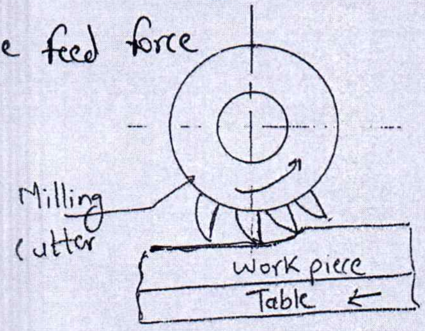
Index plate-II is used.

For each indexing, the crank is rotated by 21 holes in 23 hole pitch circle & then with the pin removed, index plate is rotated by 9 holes in 27 hole pitch circle in the reverse direction. (−ve sign)

Q3C. **Milling process: (Methods)**

*** Upmilling or Conventional milling.:** Milling process where in the Cutter rotates against the direction of feed of work piece.

F_1 = Force exerted by cutter
F_2 = Table feed force



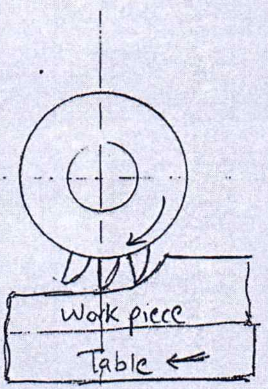
$\xrightarrow{F_1}$

$\xleftarrow{F_2}$

net force = $F_1 \sim F_2$

- In conventional milling cutter directic is just as to lift the workpiece fro fixture.
- Cutting force is higher @ the end o cut.
- Chips accummulate ahead of cuttin region.
- ◢ chip thickness – highest @ e
  ∴ Temp is high & chance of welding to

*** Down milling or clamp milling:** Milling process where in the cu rotates inline with the feed of work (climb milling)



← F_1

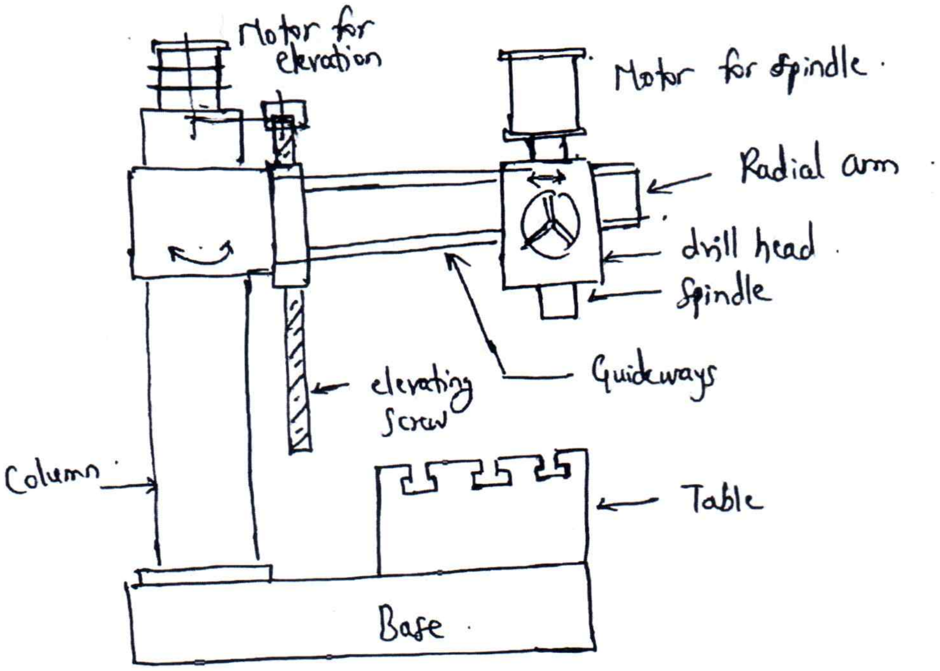
↔ F_2

net force = $F_1 + F_2$

- Cutter direction is just as to force the workpiece against fixture.
- Cutting force is high @ the begining of cut.
- ◢ - Chip thickness highest in the begining.
- Surface finish & chip disposal is better.

Upmilling is practiced on conventional machines, which are less rigid & withstand lesser forces generated in machining. ($F_1 \sim F_2$).
Down milling is practiced on CNC machines & rigid machines which can withstand higher force ($F_1 + F_2$)

Q4. a. **Radial drilling m/c :**



- Radial drilling m/c consists of base, column, table, radial arm, drill head and 2 motors.
- 1 motor for up & down movement of radial arm & 1 motor for drive spindle
- Radial arm can swing about the cylindrical column for carrying the spindle to required point
- Drill head consisting of motor, drive spindle & feed arrange--ments moves over the guideways of radial arm.
- Table is mounted on the base and the workpiece can be fixed on the table with the help of fixture / vise / clamps.
- Drilling can be done at any point within the area of reach of radial arm.

5

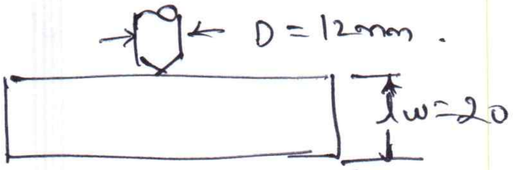
Q4 b.

Data: Drill diameter, $D = 12$ mm.

Thickness of workpiece $= 20$ mm. (l_w).

Cutting speed, $v = 12$ m/min.

feed rate, $f = 0.12$ mm/rev.



Total length of drill travel $= l_w + 0.3(D)$

$$L = 20 + 0.3(12)$$
$$= 23.6 \text{ mm}.$$

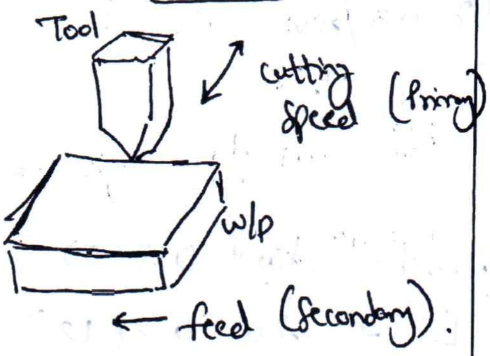
$$\text{RPM}, N = \frac{V \times 1000}{\pi \times D} = \frac{\cancel{12} \times 1000}{\pi \times \cancel{12}} = 318.31 \text{ rpm}.$$

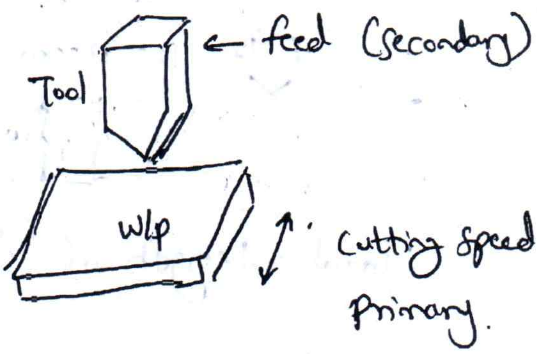
$$\text{Machining time}, t_m = \frac{L}{f \times N}$$

$$= \frac{23.6}{0.12 \times 318.31}$$

$$= 0.618 \text{ min or } 37.07 S.$$

Q4. c Differences b/w Shaper & planer





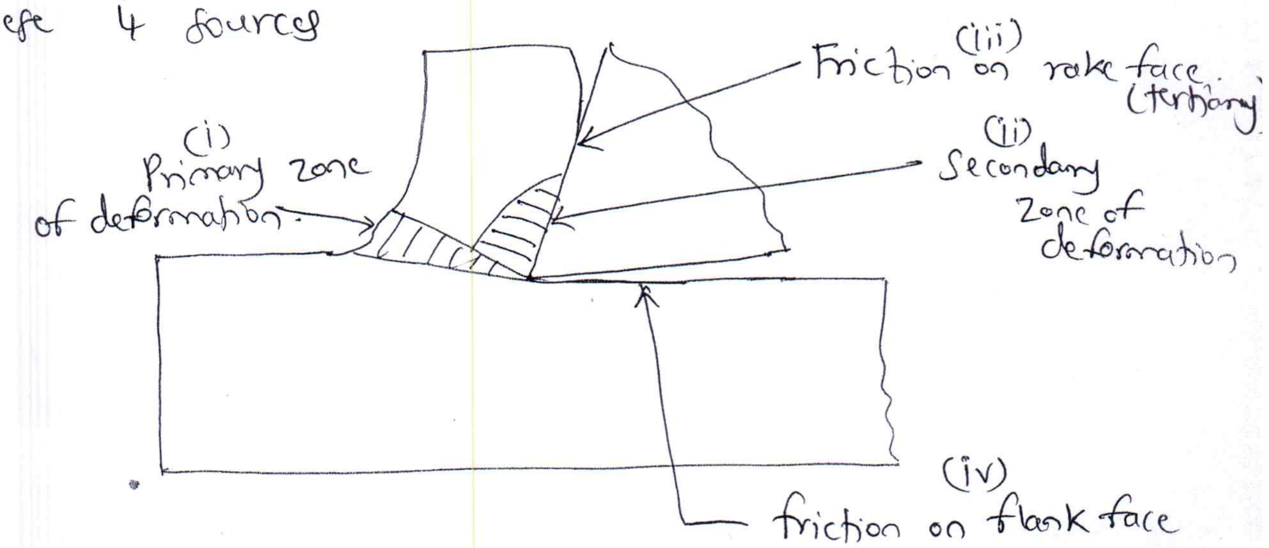
	Shaper	Planer
1.	Here the tool reciprocates and the workpiece is given the feed.	Here the workpiece reciprocates & the tool mounted on tool head is given the feed
2.	Shaper is a smaller m/c and preferred for small jobs.	Planer is a larger machine and can accommodate large & heavy jobs.
3.	Machining – light cut & fine feed.	Machining – heavy cut & coarse feed is possible.
4.	Only one tool can be used & single operation can be done at a time	Multiple tools can be accommodated and machining up to 3 faces can be done.
5.	Quick return mechanism is used.	Gear driven or hydraulic mechanism
6.	Comparatively less accurate.	High accuracy.

Different temperature zones: or

Q5a

Heat zones present during the metal cutting process

Cutting process involves severe plastic deformation in the primary & secondary zones and rubbing on tool rake & flank face. The work done in causing plastic deformation gets converted into heat. Friction of chip with tool and tool with work also produces heat. All these 4 sources



Sources of heat generation in metal cutting.

Of the total energy consumed, maximum energy (nearly 80%) is consumed in primary & secondary zones of deformation. The energy loss in friction at rake face is nearly 18% and friction loss at flank face is about 2%.

Temperature distribution in metal cutting.

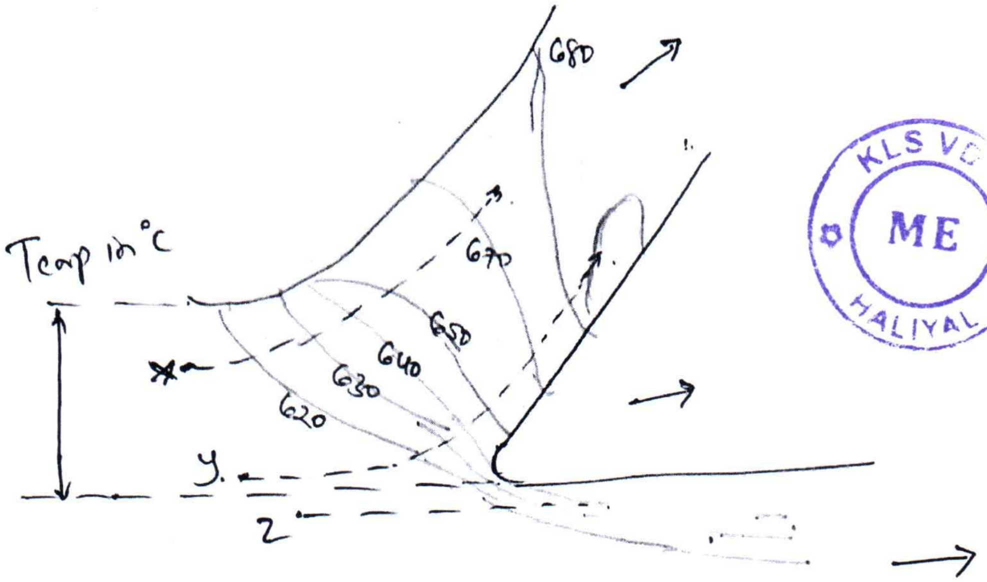


Figure shows an experimentally determined temp distribution in the workpiece & the chip during orthogonal metal cutting. This is typical temp distribution for orthogonal chip formation. As a point X in the material, which is moving toward the cutting tool, approaches & passes through the primary deformation zone, it is heated until it leaves the zone & is carried away within the chip. Point 'y' however passes through both deformation zones & is heated until it has left the region of secondary deformation.

Q5.b.

Data:

Given tool life equation: $VT^n = C$.

$n = 0.2$.

New Tool life = 60% of old tool life (0.6).

Let V_1 = Initial cutting speed

V_2 = Changed " "

T_1 = Initial Tool life (old)

T_2 = Changed Tool life (new).

$T_2 = 60\%$ of $T_1 = 0.6T_1$.

We know that, $VT^n = C$ & it can be written as

$V_1T_1^n = C = V_2T_2^n = C$.

$$V_1T_1^n = V_2T_2^n$$

$$V_1T_1^{0.2} = V_2(0.6T_1)^{0.2}$$

$$V_1\cancel{T_1^{0.2}} = V_2.(0.6)^{0.2}.\cancel{T_1^{0.2}}$$

$$V_1 = V_2(0.90)$$

$$V_2 = \frac{V_1}{0.90} = V_1(1.1075).$$

$$V_2 = V_1.(1.1075).$$

∴ Approximately 10.75% change in cutting speed is required to give 60% reduction in tool life.

Q5. C.

Functions of cutting fluids:

1) To carry away heat & improve tool life & productivity
2) Reduction of cutting force & power consumption
3) Improved surface finish & accuracy of the components
4) To break the chips into small pieces
5) Removal of chips from machining area
6) Corrosion prevention on component
7) Lubrication of machine guide ways
8) Less distortion of component due to cooling effect.
9) It should wet the surface of workpiece, i.e, it should be retained on the surface of workpiece.

P.T.O

Some of the coolants used in metal cutting:

1. Straight cutting oils (used without any mixing)
   - Mineral oils
   - fatty oils
   - combination of mineral & fatty oils

2. Oil with additives – compounds of chlorine & sulphur are added to mineral oil to improve antirust properties & reducing welding of chip to tool.

3. water based cutting fluids (mineral oil + fat mixture + emulsifier + water)

Composition of commercially available cutting fluid:

- Base oil
- Emulsifier
- Corrosion inhibitors
- Lubricating & extreme pressure [EP] additives
- biocides & fungicides
- foam inhibitors
- neutralising agents.

Q6. a.

The cutting tool is subjected to

a) high temp

b) " contact stress

c) rubbing along tool chip interface & tool - work.

The tool material should posess certain properties inorder to function satisfactorily. The requisite properties are as under.

1) hot hardness : to retain hardness at elevated temp. (∵ machining produces very high temp.).

2) Toughness :- to withstand the machining forces generated

3) Wear resistance ; wear & tare with chip & work surface.

4) Thermal & mechanical shock resistance : To withstand abrupt thermal & mechanical shock loads

5) Chemical stability - It should not react with workpiece @ high temp.

6) High thermal conductivity : to ~~maintain~~ dissipate the heat produced @ tool tip to outside atmosphere.

7) low co-efficient of thermal expansion : to maintain dimensional stability of the components machined.

8) Ease of manufacture, repair & availability : Tool material should be easy to regrind/ repair.

9) optimum cost.

Q6.b.

ii) <u>High speed steel:</u> (HSS)

∵ these were used at higher cutting speed than previous material – high carbon steel.

↳ T-Type HSS : Tungsten major alloying element.

Tungsten + Chromium + vanadium + cobalt + Iron.

↳ M-Type HSS : Molybdenum as major alloying element.

Molybdenum + Chromium + Cobalt + vanadium + Iron

ex: 18-4-1 (widely used HSS).
[W + Cr + Va] %

Cobalt – improves hot hardness

Chromium – ″ hardenability

Vanadium – ″ wear resistance

Tungsten, Molybdenum } → high hot hardness (∵ of formation of carbides).
→ tougher

Application: HSS blade, single point tool, drill, milling cutter, reamer, tap, broach, form tool, all most all types of tools.

Q6.b. Contd.

CBN & diamond :

These are extremly hard & brittle. Diamond is the hardest substance available on earth.

i) CBN – constituents : Boron nitride in cubic structure.

Characteristic : Highly brittle & wear resistant
Higher cutting speeds

Application : Tool inserts for machining heat treated component, Ni, SS, superalloys, grinding wheel

iii) Diamond – constituents : Carbon (Polycrystalline diamond)

Characteristic : Highly brittle & wear resistant, high thermal conductivity, low co-efficient of thermal expansion
Higher cutting speeds.

Application : Tool tips for machining of Al, composites, glass, fibers, grinding wheel
[Not used for machining of ferrous materials]

Q6. C.

Desirable properties of cutting fluids:

In order to accomplish these functions, the cutting fluids should possess certain properties, These are as below:

- High heat absorption capacity : Enormous amount of heat is produced @ cutting zone, which needs to be taken away quickly.
- Chemical stability : It should not react with component, tool & machine parts.
- Low viscosity: Cutting fluid should flow easily, ofcourse some viscosity should be there that, it should wet the surface.
- Good lubrication property: It should act as lubricant between tool & workpiece & b/w tool & chip.
- High flash & fire points - It should not catch fire.
- It should not emit toxic fumes because of chemical reactions.
- It should be harmless to human beings. (Should not cause skin diseases)
- No bad smell
- Cutting fluid should be available @ optimum cost.

Q7. a. Definition: Metrology is the science of measurements, which includes all aspects of both theoretical & practical with reference to measurements, whatever their uncertainty & in whatever fields of science & technology they occur.

Metrology is mainly concerned with

i) establishing units of measurements

ii) developing methods of measurement.

iii) analysing the accuracy of methods of measurement, establishing uncertainty of measurement.

P.T.O.

The objectives of metrology :

1) Establishing the units of measurements, reproducing these units in the form of standards & ensuring the uniformity of measurements.

2) Developing methods of measurement

3) Analysing the accuracy of methods of measurement, establishing uncertainty of measurement, researching ④

4) Researching into the causes of measuring errors and eliminating these.

5) To aid industrial inspection & its various techniques.

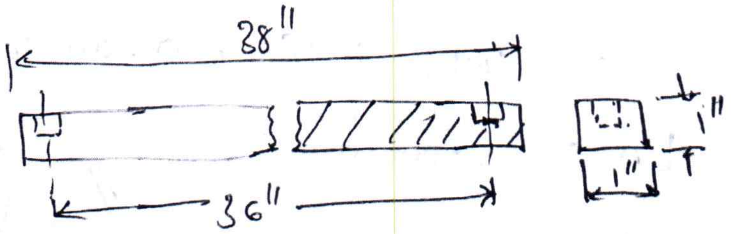
6) To design, manufacture & testing of gauges/ measuring instruments of all kinds

Gvs.

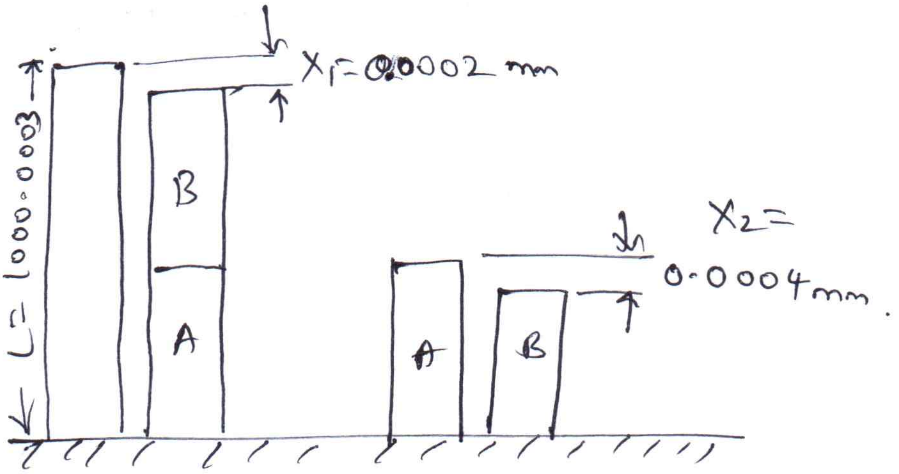
Q7b. Imperial Standard Yard :

Yard ~~or~~ ~~[illegible]~~ is defined as the distance between scribed lines on a bar of metal under certain conditions of temperature & support. These are legal standards.

Yard: The imperial standard yard is a bronze bar of 1" square c/s and 38" long. A round recess, ~~at~~ 1" away from 2 ends is cut at both ends up to central plane of bar. A gold plug $(\frac{1}{10})''$ diameter having 3 lines engraved transversely & 2 lines longitudinally is inserted into these holes ~~so~~ that the lines are in neutral plane. Yard is then defined as the distance b/w the 2 central transverse lines of the plug at ~~[illegible]~~ 62°F.



Q7.c.



Actual length of meter bar, L = 1000.0003 mm.

$$L - X_1 = L_A + L_B$$

$$L_A = L_B + X_2$$

$$\therefore \; L - X_1 = L_A + L_B + X_2 = 2L_B + X_2$$

$$2L_B = L - X_1 - X_2$$

$$L_B = \frac{1000.0003 - 0.0002 - 0.0004}{2}$$

$$L_B = \frac{999.9997}{2} = 499.99985 \text{ mm.}$$

$$L_A = L_B + X_2$$

$$= 499.99985 + 0.0004$$

$$L_A = 500.00025 \text{ mm} \,//$$

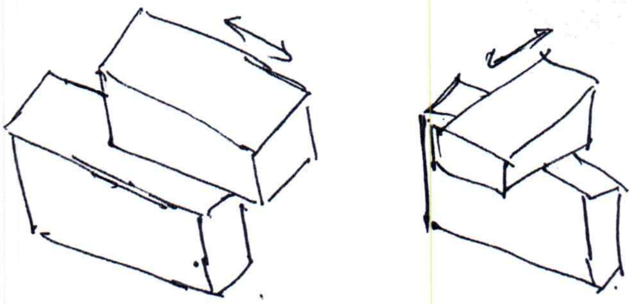
$L_A = 500.00025$ mm //

$L_B = 499.99985$ mm //.

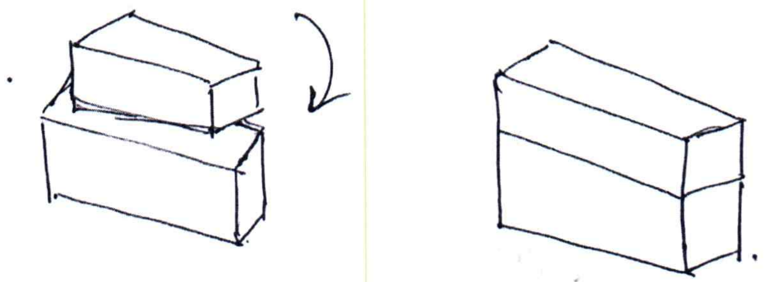
8a. Wringing phenomenon of slip gauges

The term wringing refers to the conditions of intimate & complete contact and of permanent adhesion between measuring ~~p~~ faces which is brought about by wringing together the surfaces in question without application of pressure, assuming that the surfaces have been thoroughly cleaned & exhibit a good standard of flatness & smoothness.

It is believed that the phenomenon is due to molecular adhesion between a liquid film and the mating surfaces of the flat surfaces.



Slide.



Twist.

Slip gauges are wrung together by hand through a combined blinding & twisting motion. First the gauge is oscillated slowly, with light pressure over other gauge so as to direct presence of any foreign particles b/w the surfaces. one gauge is then placed ⊥r to other & rotary motion is then applied until blocks are lined up.

8a. Contd.

Q8.a. **Line Standard:** It is the standard used to measure or calibrate by measuring the distance between 2 engraved lines. According to it, the standard length of measurement is defined as distance between 2 scribed lines on a bar of metal under certain conditions of temperature & support.

ex: international prototype meter, yard, scale, measuring tape etc.

End Standard: It is the standard used to measure or calibrate by measuring the distance between 2 end faces. The standards will be in the form of metal bar or block whose end faces are the standard distance apart.

ex: slip gauges, meter end bar, micrometer anvil, vernier calipers.

These are used to measure the distance b/w 2 parallel flat surfaces. They are used in laboratories & workshops for precision measurement.

P.T.O.

Q8b. Building the dimension 35.4875 mm using M112 set of gauges along with 2 protector slip gauges of 2.5 mm.

Dim = 35.4875.

Protector slip gauges = 2.5 mm + 2.5 mm (both sides)
= 5 mm.

35.4875 − 5 = 30.4875

Subtracting nearest available highest thickness (25 mm)

30.4875 − 25 = 5.4875 mm.

Smallest available thickness = 1.0005 mm.

5.4875 − 1.0005 = 4.487 mm.

(last digit 0.0007, ∴ selecting available gauge 1.007 mm).

4.487 − 1.007 = 3.48 mm

(last digit 0.08, but 1.48 mm gauge is available).

3.48 − 1.48 = 2 mm.

∴ To build 35.4875 mm:

2 protector slig gauges of 2.5 mm,

25 mm gauge − 1 No.

1.0005 mm " − 1 No.

1.007 mm " − 1 No.

1.48 mm " − 1 No.

2 mm " − 1 No.

Q8.c. Principle of Interchangeability & Selective Assembly

An interchangeable part is the one which can be substituted for similar part manufactured to same drawing. It becomes essential to have strict control over the dimensions of parts which have to match with other parts (in assembly). Any one component selected randomly should assemble correctly with any other mating component (selected random). This kind of system is known as interchangeable system. This increases o/p & reduced production cost.

In this system, every operator is concerned with limited portion of overall work, he can easily specialise in that work & give best results. Also this process can be achieved by automation.

Another advantage is, replacement of parts (wornout/ defective) is easy & maintenance cost will come down.

Interchangeability is possible only when certain standards are strictly followed. Universal interchangeability: i.e, parts drawn from any 2 altogether different manufacturing sources for mating purposes) is desirable and for this it is essential that common standards be followed by all. The required fit in an assembly can be obtained in 2 ways:

i) Universal or full interchangeability (mentioned above)

ii) Selective assembly.

Q9. a. **Taylor's Principle**

'Go' & 'No Go' gauges should be designed to check maximum and minimum material limits which are checked as below.

'Go' Limit. This designation is applied to that limit of the 2 limits of size which corresponds to the maximum material limit considerations, i.e, upper limit of a shaft & lower limit of a hole.

- The form of the 'Go' gauge should be such that it can check one feature of the component in one pass.

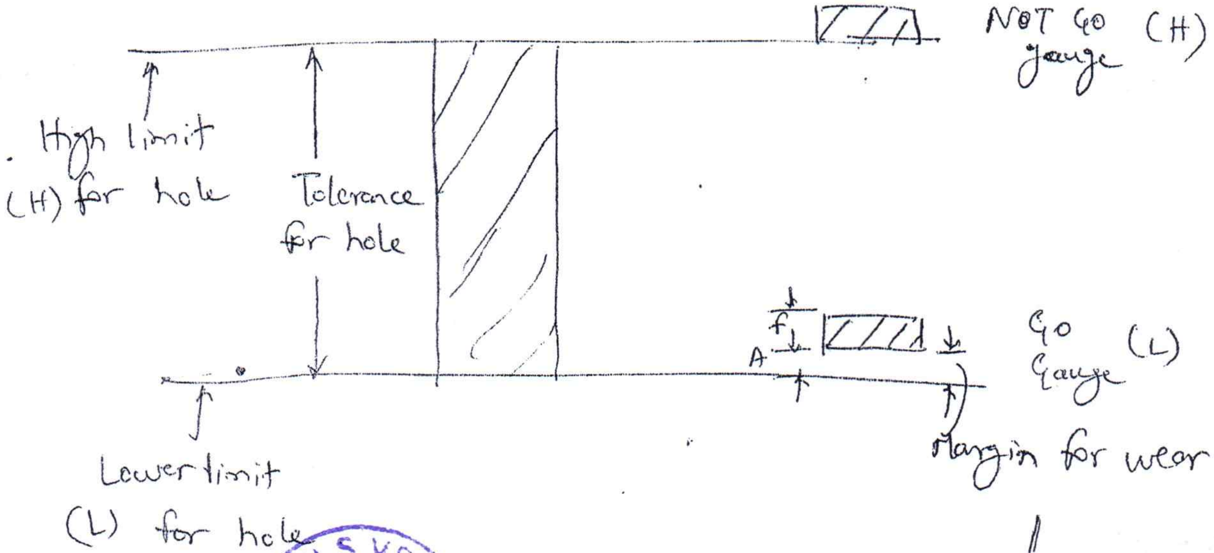
'No Go' Limit. This designation is applied to that limit of the two limits of size which corresponds to the minimum material condition, i.e, the lower limit of a shaft & upper limit of a hole.

'No Go' gauge should check only one part or feature of the component at a time, so that specific discrepancies in shape or size can be detected. Hence a separate 'No Go' gauge is required for each different individual dimension.

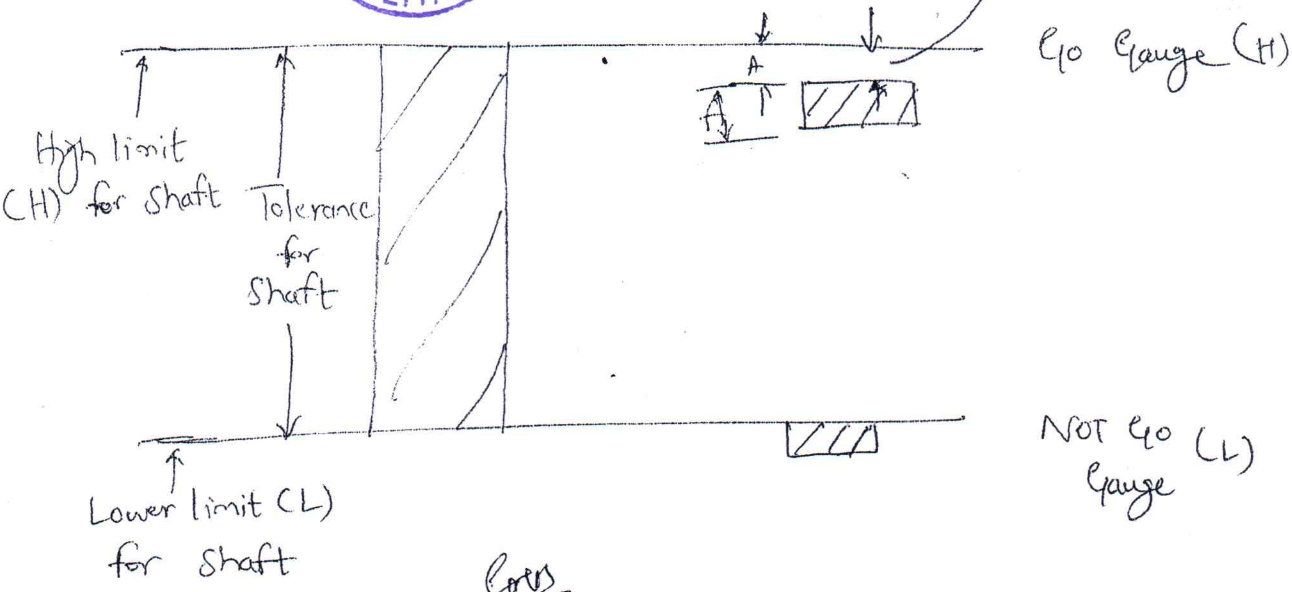
In the new system of gauge design, following principles are followed along with Taylor's principle.

1) Tolerance should be as wide as is consistent with satisfactory functioning, economical production & inspection.

2) No work should be accepted which lies outside the drawing specified limits.



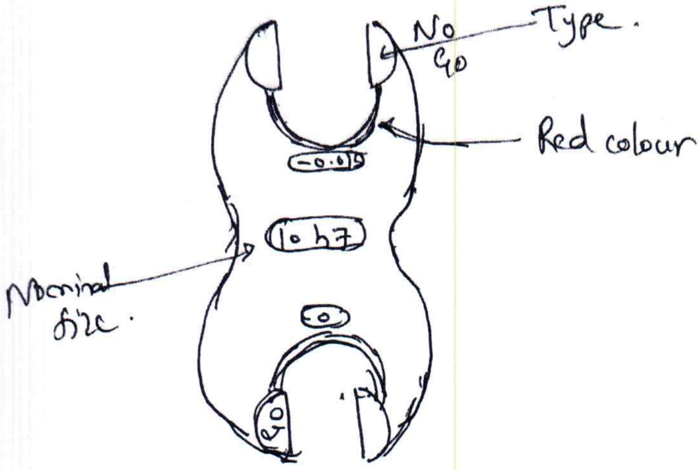
(a) Plug gauges



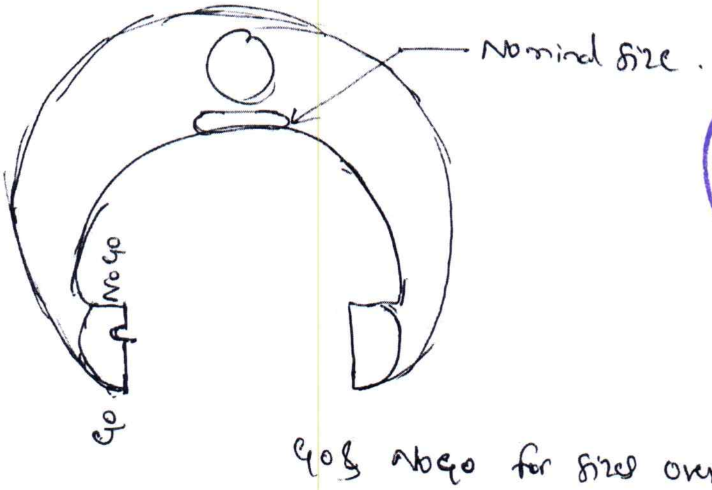
Q9b. Snap gauges:

Snap gauges are used to check external dimensions, thickness, diameters etc.

Rib types snap gauges:



Double ended snap gauges can be used for checking sizes in the range of 3mm to 100mm & single ended progressive type snap gauges are suitable for sizes 100 to 250mm. The gauging surfaces of snap gauges are hardened upto 720 to 750 HV (58-60 HRC) & are suitably stabilised, ground & lapped.



Go & No go for sizes over 100 mm & upto 250mm.

Q 9 **C**

Q 9 C

Data: Diameter of the Shaft = 50 mm

Shaft-hole pair = $H_7 d_8$

Diameter range : 30 mm to 50 mm.

Upper deviation for 'd' Shaft = $-16 D^{0.44}$

Lower " " 'H' hole = 0.

Tolerance, $i = 0.45 \sqrt[3]{D} + 0.001D$

$IT6 = 10i$

Soln: For calculation of tolerance,

$D = \sqrt{30 \times 50}$ [Geometric mean of diameter steps : 30 to 50]

$= 38.73$ mm.

Tolerance unit, $i = 0.45 \sqrt[3]{D} + 0.001D$

$= 0.45 \sqrt[3]{38.73} + 0.001 (38.73)$

$= 1.523 + 0.03873 = 1.56$ microns.

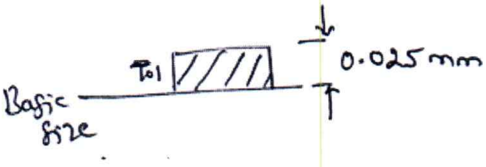
For Hole, type of hole = H7.

∴ fundamental deviation = 0. (lower deviation)

Upper deviation, $IT7 = 16i = 16(1.56) = 24.96$ microns

$\simeq 25$ microns

or 0.025 mm.



Dimensions of hole:

Upper limit: 50.025 mm

Lower limit: 50.000 mm.

For shaft: (d8)

Fundamental deviation (d-shaft) $= -16D^{0.44}$

$= -16(38.73)^{0.44}$

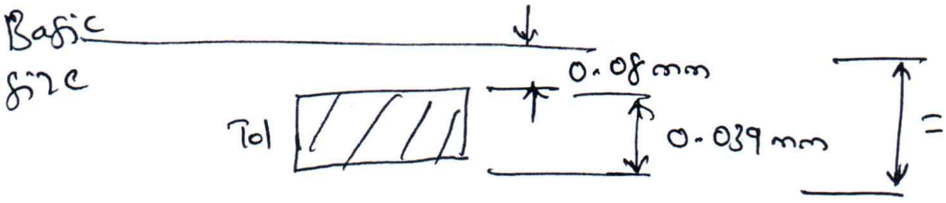
$= -79.96$ microns

$\simeq -80$ microns

or -0.08 mm.

Tolerance, $IT8 = 25i = 25(1.56) = 39$ microns

or $= 0.039$ mm



$= 0.08 + 0.039$

$= 0.119$ mm.

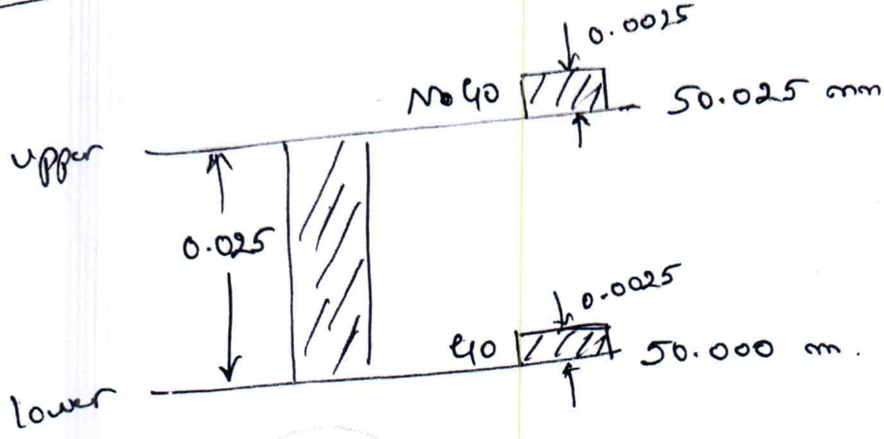
Shaft dimensions are: $50 - 0.08 = 49.92$ mm (upper limit)

&

$50 - (0.08 + 0.039) = 49.881$ mm. (lower limit).

Plug gauge dimensions:

(Wear allowance is not considered).



Gauge mfg tolerance = 10% of work tolerance

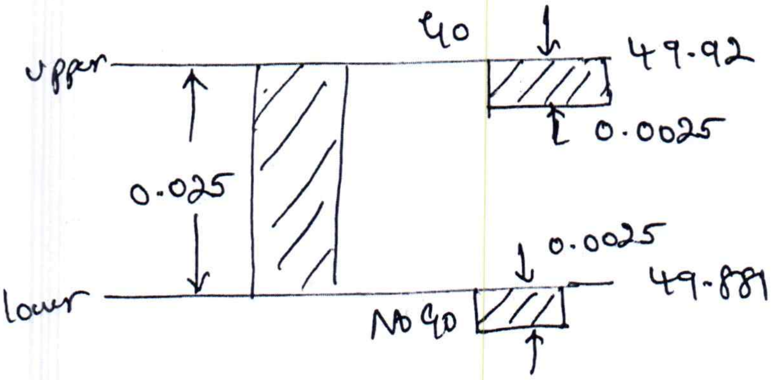
= 0.1×0.025 = 0.0025 mm.

Go gauge dimensions = 50.000 to 50.0025 mm.

No Go gauge dimensions = 50.025 to (50.025 + 0.0025)

= 50.025 to 50.0275 mm.

Ring gauge dimensions:



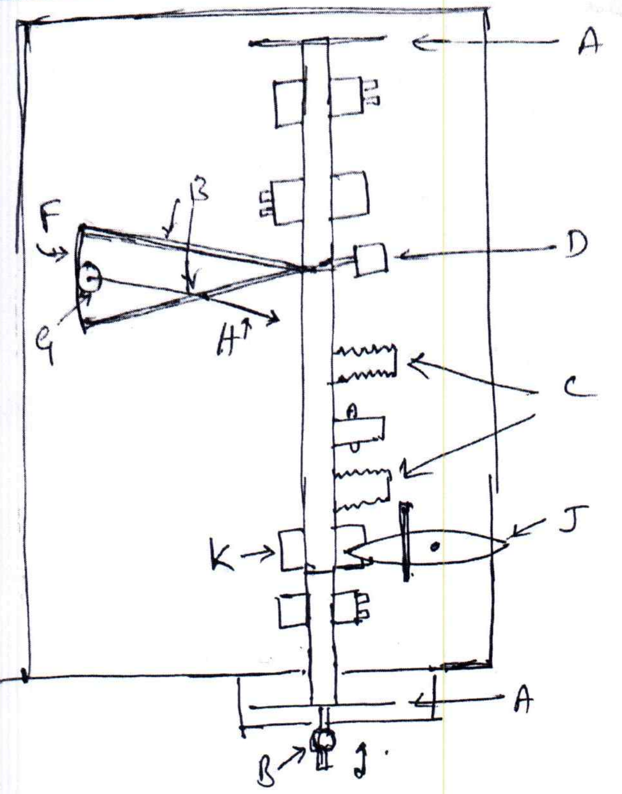
Ring – Go Gauge dimensions : 49.92 & 49.92 – 0.0025

= 49.92 & 49.9175 mm.

No Go Gauge dimensions : 49.881 & 49.881 – 0.0025

= 49.881 & 49.8785 mm

Q10 a. Sigma Comparator:



It is a mechanical comparator. Constructional details are as shown in the figure. The vertical beam is mounted on flat steel springs 'A' connected to fixed members, which inturn are screwed to back plate. The assembly provides a frictionless movement with a restraint from the springs. The shank 'B' at the base of the vertical beam is arranged to take a measuring contact, selecting from the available range. The stop 'C' is provided to restrict movement at the lower extremity of the scale.

Mounted on the fixed members, is the hinged assembly 'D' carrying the forked arms 'E'. This assembly incorporates a hardened fulcrum operative on the face of a jewelled insert on the flexible portion of the assembly.

The metal ribbon F, attached to the forked arms, passes around the spindle 'G' causing it to rotate in specially designed miniature ball bearings. The indicating pointer H is secured to boss on the disc. The trigger 'J' is used to protect the measuring contact. The instrument is available with vertical capacities (150 mm to 600 mm) & magnifications (500 to 5000).

Q10.b.

Angle gauge set available:

1°, 3°, 9°, 27° & 41°

1', 3', 9', 27'

3", 6", 18", & 30".

(i) 37° 9' 18'

∴ Gauges required to build:

27° + 9° + 1° + 9' + 18" — all in one orientation.

(ii) 33° 16' 42"

33° = 27° + 9° − 3°

16' = 27' − 9' − 3' + 1'

42" = 30" + 18" − 6"

Angle gauge combination:

+27° + 9° − 3°   +27' − 9' − 3' + 1'   +30" + 18" − 6"

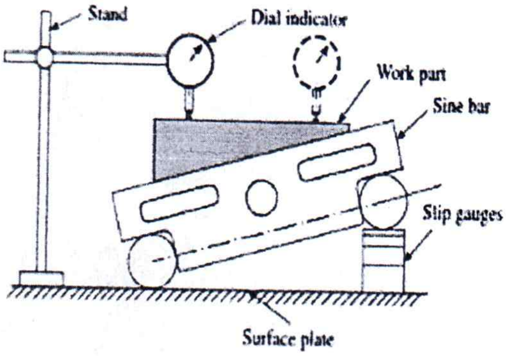
Grs.

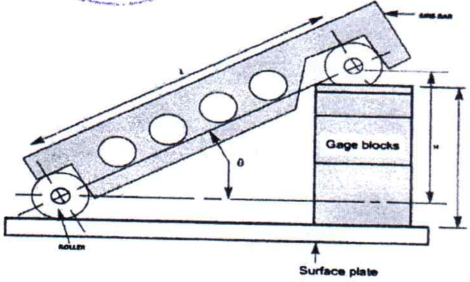
Q10. c. Sine bars:

It is an instrument, which utilizes the high degree of precision available for linear measurement in the form of slip gauges [illegible]. ~~utilised~~ for the measurement of angles with usage of slip gauges. Sine bar consists of lapped steel bar at each end of which is attached an accurate cylinder, the axes of cylinders being mutually parallel and parallel to upper surface of bar. The axes are separated by a nominal distance usually 100mm or 250mm for metric bars and 5 or 10 inches (for those in inch units)

If the cylinders or rollers are stood on a surface plate, the surface of the bar will be parallel to the plate. If pile of slip gauges is placed under one roller, the bar

Surface will lie at an angle to the surface plate and in order to set the bar at a specified Lle the slips required will have a value equal to the distance between the rollers multiplied by the sine angle.





Some limitations of sine bar:

1) reduced accuracy ii) high sensitivity to slipgauge height errors

3) requirement of additional equipment like surface plate & slip gauges.

4) time consuming 5) component size should be less than bar.

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