Toppersnotes
Unleash the topper in you

IES/GATE

MECHANICAL ENGINEERING

VOLUME - 6

PRODUCTION ENGINEERING - 2

SIERRA INNOVATIONS

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Production Engineering – 2

PRODUCTION ENGINEERING-II

CHAPTER :- 1 THEORY OF METAL CUTTING

Theory of Metal cutting

human air
↓
100 micron

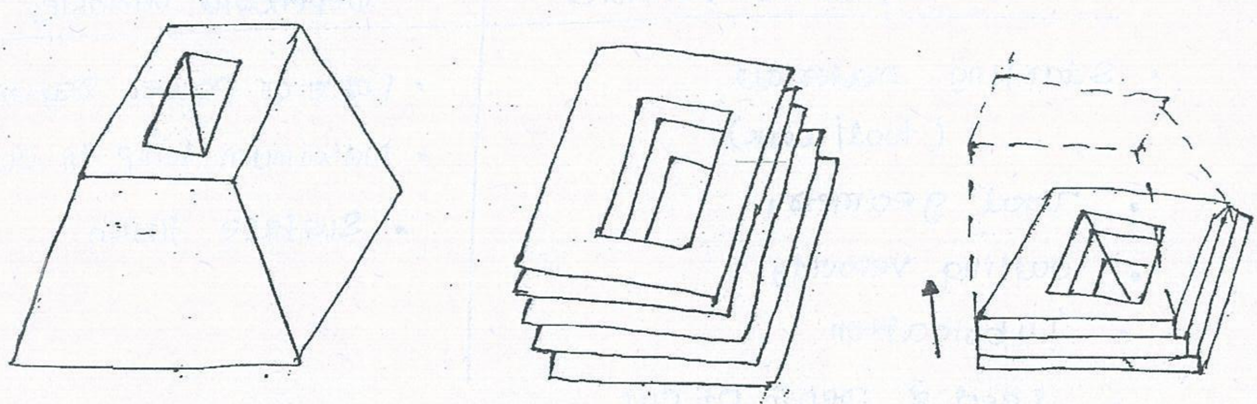
Clasification of manufacturing process

- Shaping or forming (zero process)
  ↓
  no change in mass
- Joining process (positive process)
  ↓
  mass of workpiece is more
- Removal process (Negative process)
  ↓
  Removal of mass
- Regenerative manufacturing

Regenerative manufacturing

i) Production of solid products in layer by layer from raw materials in different forms.

ii) Very rapid, accurate and used for Rapid prototyping and tooling.



Advantage:-

(workpiece)

i) Process is independent of part feature.

जो बनाना है वही लो
No material require

ii) No Blanks are Required
Pre formed shape
Shape

iii) Tooless process

iv) Easily Automation Possible.

Used In
Automobile

Machining

- Machining is an essential process of finishing by which jobs are produced to the desired dimensions and surface finish by gradually removing the excess material from the preformed blank in the form of chips with the help of cutting tools moved past the work surface.

- Machining is a removal process.

Machining aim to

i) fulfill its functional requirements.

ii) improve its performance.

iii) prolong its service.

Drawback in Machining

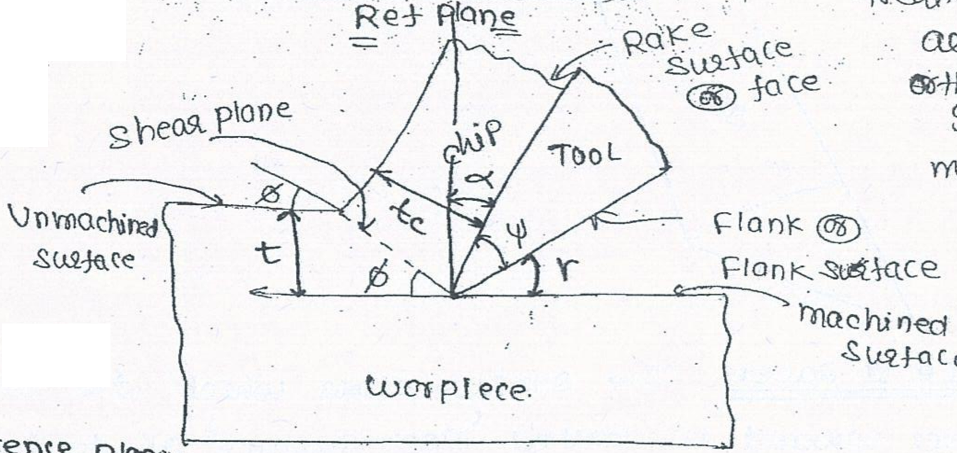
i) Loss of material in the form of chips

IAS-2009 main

Q. Name four independent variables and three dependent variables in metal cutting.

Independent variables	Dependent variables
• Starting materials (tool/work)	• Force or power requirements
• Tool geometry	• maximum temp in cutting
• cutting velocity	• Surface finish
• Lubrication	
• Feed & Depth of cut	

Orthogonal machining



treatment as orthogonal machining

Shaping & machine
Broaching
↓
cutting Force ⊥r to cutting velocity

Reference plane:-

- it is ⊥r to machined surface at the cutting edge.

α = Rake angle

γ = Clearance angle or relief angle. (American system)

ϕ = Shear angle

ψ = Lip angle or cutting angle or knife angle or wedge angle

t_c = chip thickness

t = Uncut chip thickness or undeformed chip thickness.

$t_c > t$

$$\boxed{r = \frac{t}{t_c} < 1}$$

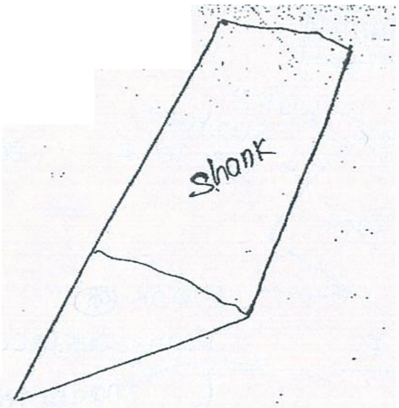
For Brittle material (no shear failure, no shear flow, no chip flow)

$t \simeq t_c$

and $r = \frac{t}{t_c} \simeq 1$

****

$t = d$ (depth of cut) orthogonal cutting
$t = f \sin\lambda$ (for Turning)



Rack surface or Face:- The surface along which the chip moves upward is called 'Rack surface' of tool.

Flank or Relief surface:- the other surface which is relieved to avoid rubbing with the machined surface is called 'Flank' or flank surface.

Rake angle (α):- angle of inclination of rake surface from reference plane i.e normal to horizontal machined surface.

Clearance angle or Relief angle (γ):- angle of inclination of clearance or flank surface from the finished surface.

Turning

Speed, feed and depth of cut

No feed in orthogonal cutting

Peripheral velocity

$$V = r \cdot \omega$$

$$= \frac{D}{2} \times \frac{2\pi N}{60} = \frac{\pi \overset{m}{D} N}{60} \text{ m/sec.}$$

$$V = \pi \overset{m}{D} N \text{ m/min}$$

$$V = \frac{\pi \overset{mm}{D} N}{1000} \text{ m/min.}$$

feed:- f (mm/rev)

$$V_f = fN \text{ mm/min}$$

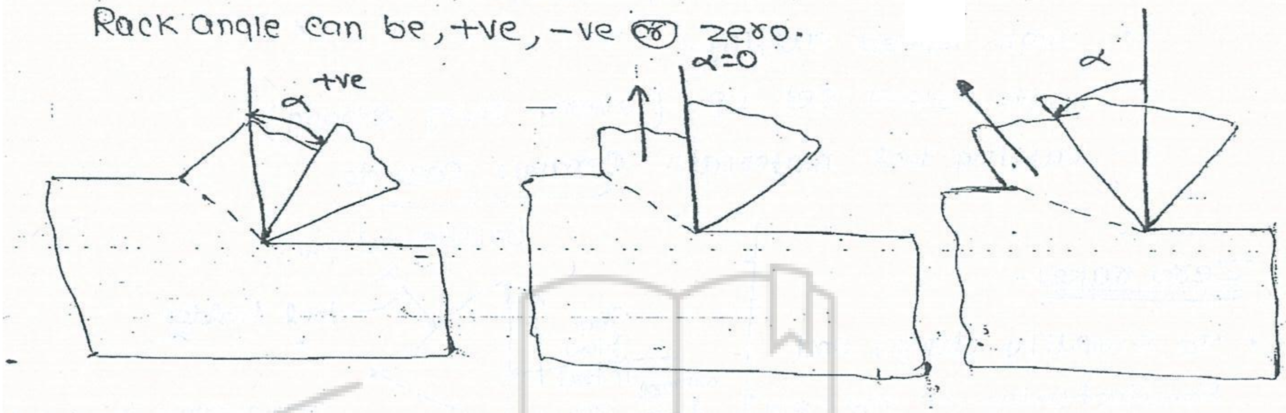
$$= \frac{fN}{60{,}000} \text{ m/sec.}$$

$D_1 = D_2 + 2d$

$$\boxed{d = \frac{D_1 - D_2}{2}} = \text{depth of cut (doc)}$$

Discussion on Rack angle

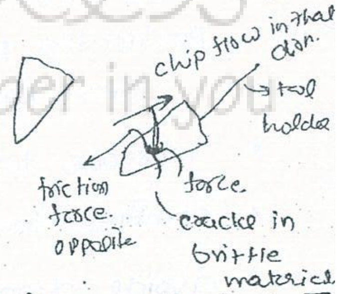
Rack angle can be, +ve, −ve or zero.



Positive rake

- Reduce cutting force
- Reduce cutting power

Positive rake angles are recommended (tool sharp)



- Machining low strength material.
- Low power machine
- Long shaft of small diameter. (due to low stiffness)
- Set-up lacks strength and rigidity.
- Low cutting speed
- cutting tool material : HSS 18-4-1
  ductile material 18% W, 4% Cr, 1% V
  Rest Fe

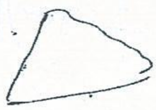
for +ve rake → materials should be ductile (HSS)

HSS tool fail temp above 600)

carbide — 150m/min
ceramic — 600m/min
brittle material.

Negative rake:- (tool dull)

- Increase edge strength (Mechanically and thermally)
- increase life of the tool.
- increase the cutting force.

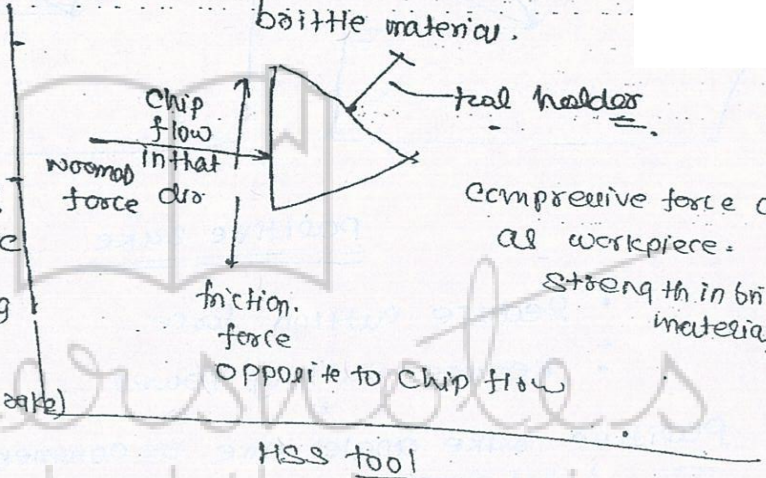


- It requires high cutting speed.
- Requires ample power.
- Heavy impact load.

Negative rake angles are recommended

- Machining high strength alloy.
- High speed cutting.
- with rigid set-up. (every thing strong)
- cutting tool material: Ceramic, carbide
  brittle material.

Zero rake:-

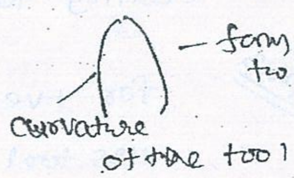


compressive force acts as workpiece.
Strength in brittle materials.

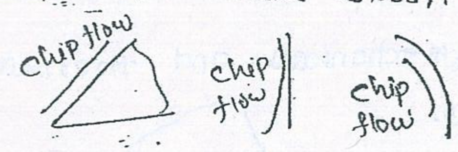
- To simplify design and manufacturing of the form tools.
  shape
- without any manufacturing to get zero rake.
- thread cutting tool (zero rake)
  particular profile cut
  gear manufacturing

HSS tool
+ve, zero rake.

- Increase tool strength.
- complex tool are formed by HSS (broaching, Hobbing)
- avoid digging of the tool into the workpiece.
  - +ve rake (digging in there) (inside digging)
  - -ve rake (outside digging)
- Brass is turned with zero rake angle.
- cast iron uses zero rake angle.
  inside Carbon Content more than 2%.
  Carbon Content forms Cementite.



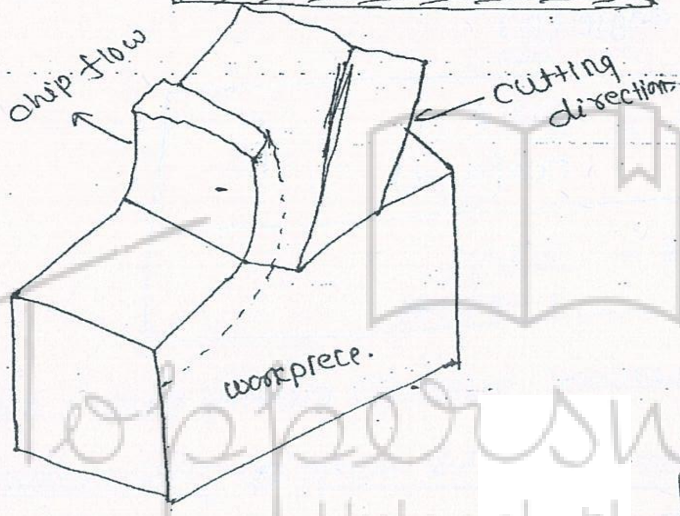
- -ve rake angle: Shear strain is more.



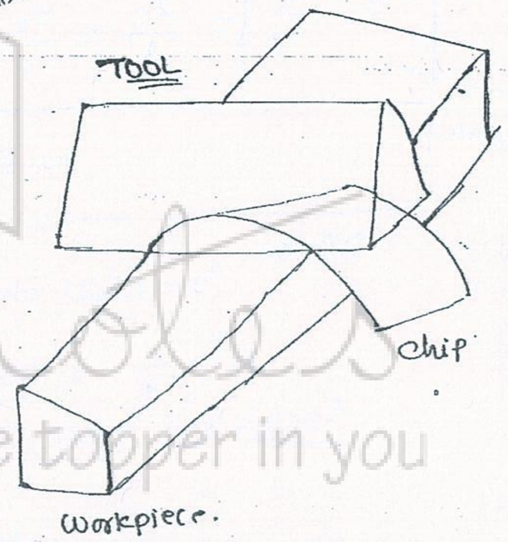
Clearance angle

- Provided to avoid rubbing of the tool (flank) with the machined surface.
- Reduce tool wear.
- Increase tool life.
- Must be +ve (3°–15°)

Types of machining



Orthogonal cutting



Oblique cutting

Orthogonal Cutting:

→ Cutting edge of the tool is perpendicular to dirⁿ of cutting velocity.

→ The Cutting edge is wider than the workpiece width and extends beyond the workpiece on either Side. Also the width of work-piece is much greater than the depth of cut.

→ The chip generated flows on the rake face of the tool with chip velocity perpendicular to cutting edge.

→ The cutting forces act along two direction only.

NOTE

During cutting of metal, an increase in cutting speed cutting force to remain unaffected and slightly reduce.

But Power, heat Production and temperature will increase.

Q. cutting speed increases it causes
→ cutting force to remain Unaffected.

Pr more. heat more ∴ temp of workpiece more.
reduce the cutting force.

Shear angle (ϕ)

$$\boxed{r = \frac{t}{t_c} = \frac{l_c}{l} = \frac{V_c}{V} = \frac{\sin\phi}{\cos(\phi-\alpha)} = \frac{1}{h}}$$

by definition.

$$\boxed{\tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha}}$$

where

r = chip thickness ratio or cutting ratio ; $r<1$

$h = \frac{1}{r}$ = inverse of chip ratio or chip reduction factor or chip compression ratio; $h>1$

$l_c = 100mm$

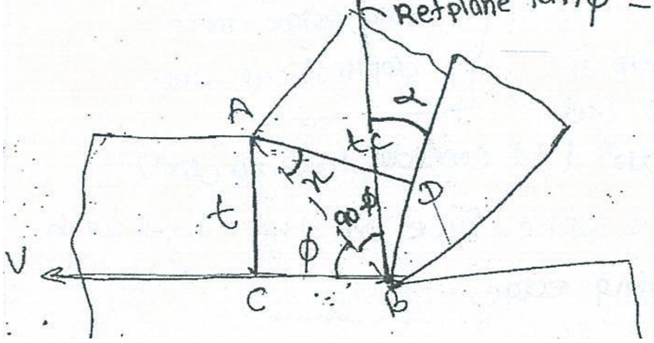
$r = \frac{l_c}{l} = \frac{100}{\pi D}$

* If $\alpha = 0$

$$\boxed{\tan\phi = \frac{r\cos 0^\circ}{1 - r\sin 0^\circ} = r}$$

IAS-2009 main

Q. Prove that $\tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha}$



$$\frac{t}{AB} = \sin\phi$$

$$\boxed{t = AB\sin\phi} \text{ —— (I)}$$

$$\frac{t_c}{AB} = \cos x$$

$$\boxed{t_c = AB\cos x} \qquad \boxed{t_c = AB\cos(\phi-\alpha)} \text{ —— (II)}$$

$$\angle B = 90 - \phi + \alpha$$

$$\angle A + \angle B + \angle D = 180^\circ$$

$$x + 90 - \phi + \alpha + 90 = 180^\circ$$

$$x = \phi - \alpha$$

$$r = \frac{t}{t_c} = \frac{\cancel{AB}\sin\phi}{\cancel{AB}\cos(\phi-\alpha)}$$

$$\sin\phi = r\cos(\phi-\alpha)$$

$$\sin\phi = r[\cos\phi\cdot\cos\alpha + \sin\phi\sin\alpha]$$

$$\sin\phi(1 - r\sin\alpha) = \cos\phi\cdot r\cos\alpha$$

$$\boxed{\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}} \quad \boxed{r = \frac{\sin\phi}{\cos(\phi-\alpha)}}$$

Q-11

$$\alpha = 12^\circ$$

$$r = \frac{0.81}{1.8} = 0.45$$

$$\phi = \tan^{-1}\left[\frac{0.45\cos 12^\circ}{1 - 0.45\sin 12^\circ}\right]$$

$$= 26^\circ$$

Cutting shear strain (ε)

$$\boxed{\varepsilon = \cot\phi + \tan(\phi-\alpha)}$$

$$\boxed{\varepsilon = \frac{\cos\alpha}{\sin\phi\cdot\cos(\phi-\alpha)}}$$

$$\varepsilon = \cot\phi + \tan(\phi-\alpha)$$

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

$$= \frac{\cos\phi\cdot\cos(\phi-\alpha) + \sin\phi\sin(\phi-\alpha)}{\sin\phi\cdot\cos(\phi-\alpha)}$$

$$\boxed{\varepsilon = \frac{\cos\alpha}{\sin\phi\cos(\phi-\alpha)}}$$

$$\varepsilon\downarrow = \cot\phi + \tan(\phi-\alpha\uparrow)$$ negative rack

chip flow
Shear strain more.

* If $\alpha = 0$

$$\varepsilon = \cot\phi + \tan\phi \geq 2$$

$$= \overset{a}{x} + \overset{b}{\frac{1}{x}} \text{ form}$$

A.M $\geq$ G.M

$$\frac{x+\frac{1}{x}}{2} \geq \sqrt{x\cdot\frac{1}{x}}$$

* $\boxed{x+\frac{1}{x} \geq 2}$

* If $\alpha = 0$, $\varepsilon \geq 2$

$\varepsilon_{min} = 2$ when $\phi = 45°$

$$\frac{d\varepsilon}{d\phi} = -\operatorname{cosec}^2\phi + \sec^2(\phi-\alpha) = 0$$

$$\phi = ?$$

GATE-1990 (PI)
Q.

$\alpha = 12°$ theoretically minimum possible shear strain to occur.

$\Rightarrow$

$$\varepsilon = \cot\phi + \tan(\phi-12)$$

$$\frac{d\varepsilon}{d\phi} = -\operatorname{cosec}^2\phi + \sec^2(\phi-12) = 0$$

$$\operatorname{cosec}^2\phi = \sec^2(\phi-12)$$

$$=$$

$$\cos^2(\phi-12) = \sin^2\phi$$

$$\Rightarrow \sin\phi = \cos(\phi-12)$$

$$\sin\phi = \cos\phi\cdot\cos 12 + \sin\phi\cdot\sin 12^\circ$$

$$\sin\phi(1-\sin 12^\circ) = \cos\phi\cdot\cos 12$$

$$\tan\phi = \frac{\cos 12^\circ}{1-\sin 12^\circ} \qquad \phi = 51$$

$$\epsilon_{min} = \cot(51) + \tan(51-12)$$

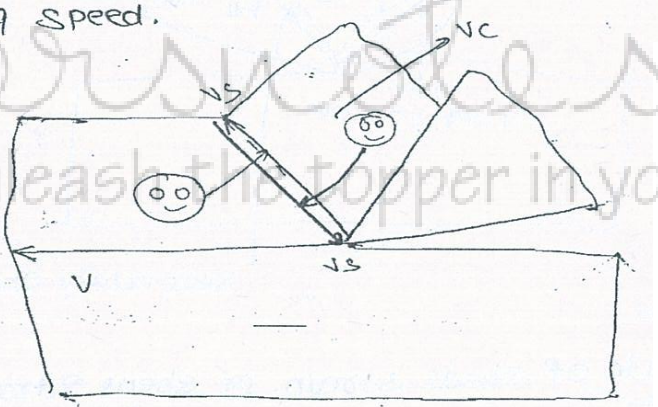
$$= 1.619$$

Velocities in metal cutting

i) The velocity of the tool relative to the work piece (V) is called the cutting speed.

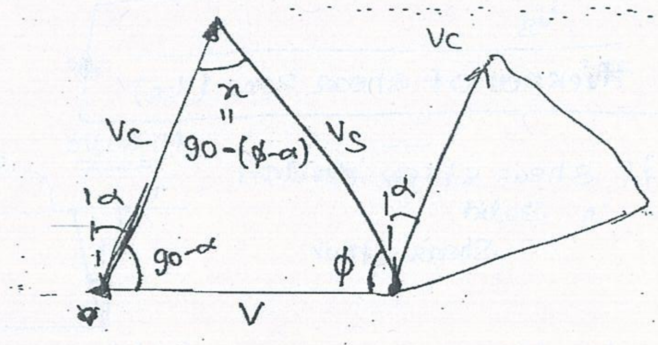
ii) The velocity of the chip relative to the work, V_s is called the shear velocity.

iii) the velocity of the chip relative to the tool, V_c is called chip velocity.



ESE-07

Q. Derive the expression for velocities in metal cutting



$$\frac{V}{\sin\{90-(\phi-\alpha)\}} = \frac{V_c}{\sin\phi} = \frac{V_s}{\sin(90-\alpha)}$$

this eq^n satisfied then net resultant is zero.

** $$\boxed{\frac{V}{\cos(\phi-\alpha)} = \frac{V_c}{\sin\phi} = \frac{V_s}{\cos\alpha}}$$

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

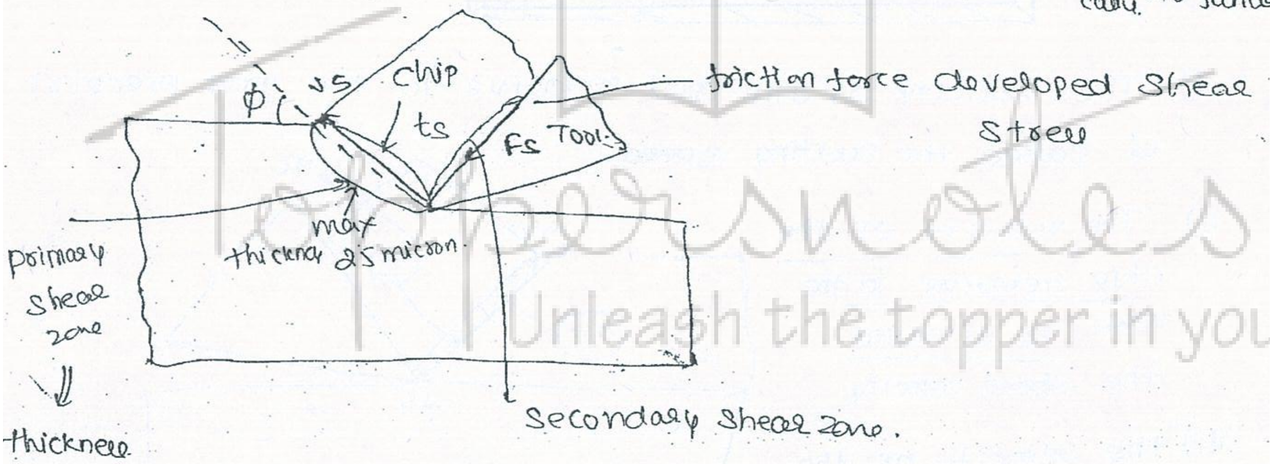
$$\frac{V_s}{V} = \frac{\cos\alpha}{\cos(\phi-\alpha)}$$

$$\tan\phi = \frac{r\cos\alpha}{1-r\sin\alpha}$$

Shear plane

thickness zero.

Peach calu. no failure



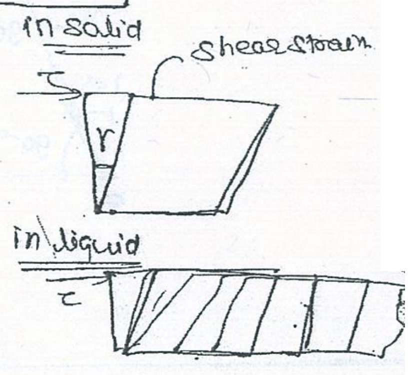
Rate of shear strain or shear strain Rate.

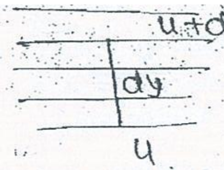
Note:- (It is not shear strain. It is rate of shear strain i.e flow)

$$\boxed{\dot{\varepsilon} = \frac{d\varepsilon}{dt} = \frac{V_s}{\text{thickness of shear zone } (t_s)}}$$

if shear stress acts
in solid
shear strain.

in liquid
rate of shear strain.





$$\frac{V_s}{t_s} = \frac{du}{dy} = \text{rate of shear strain.}$$

⇒ Thickness of shear zone can be taken as $\frac{1}{10}$th (10%) of shear plane length and its max value is 25 micron.

GATE-2012

Q.

$r = 0.4$

$\alpha = 10°$

$V_c = 2.5\ m/s$

$t_s = 25$ micron.

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$$

$$\phi = 22.944$$

$$\varepsilon = \frac{V_s}{t_s}$$

$$= \frac{2.5261}{25\times10^{-6}}$$

$$= 1.01\times10^{5}$$

$$\frac{V_c}{\cos(\phi-\alpha)} = \frac{V_s}{\cos\alpha}$$

$$\Rightarrow \frac{2.5}{\cos(22.944 - 10)} = \frac{V_s}{\cos(10)}$$

$$V_s = 2.5261$$

Geometry of Single Point turning tool

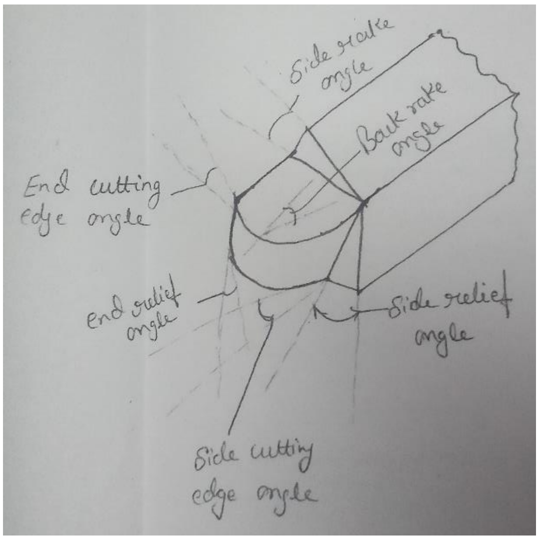
cutting edge.

classification:- (A/c to the no of major cutting edges (points) involved)

- **Single point :-** turning, shaping, planning, slotting tools, parting tools etc.
- **Drilling point:-** drilling tools
  two cutting edge
  double point
  one Second.
- **Multipoint:-** Milling, broaching, hobbing tools, Saw, grinding wheel etc.
  gear cut used

Machining: - Metal Removal Process

Single Point Cutting



Multipoint Cutting

(It is a tool with 'n' no of single Point cutting tool)

Single point cutting tool geometry

Steel → (0.1-2.1) % of 'c'

H.S.S

T- Series

w- Red hot hardness,

Absorbs ion resistance

Cr- corrosion resistance

V- Harder ability, Shock & wear resistance

M- Series

M_o→ same as 'w' creep resistance