SECTIONA (ANS- 1)

i)	Mechanical & strain gauge dynamometer	**ii)**	Flank
iii)	Heel	**iv)**	Feed
v)	Lower cutting speed & smaller feed	**vi)**	More rapid
vii)	Higher cutting speed & fine feed	**viii)**	Cutting force & cutting speed
ix)	Dressing	**x)**	Correct
xi)	brazing	**xii)**	Correct
xiii)	Slow speeds	**xiv)**	Decreases
xv)	Stellite	**xvi)**	VT^n = Constant
xvii)	Sulphurised mineral oil	**xviii)**	All of the below
xix)	Increases	**xx)**	Larger

UNIT I (a)

A **cutting tool** (or **cutter**) is any tool that is used to remove material from the workpiece by means of shear deformation. Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process. Also, the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the workpiece without the rest of the tool dragging on the workpiece surface. The angle of the cutting face is also important, as is the flute width, number of flutes or teeth, and margin size. In order to have a long working life, all of the above must be optimized, plus the speeds and feeds at which the tool is run.

Depending upon the no. of cutting edges the cutting tools used in metal cutting are classified as follows:

① Single Point cutting Tool.

② Multi point " "

<u>Single point cutting Tool</u> :- This type of tool has an effective cutting edge and removes excess materials from the workpiece along the cutting edge.

Single point cutting tool is of the following types:

① <u>Ground type</u> :- In ground type the cutting edge is formed by grinding the end of a piece of tool steel stock.

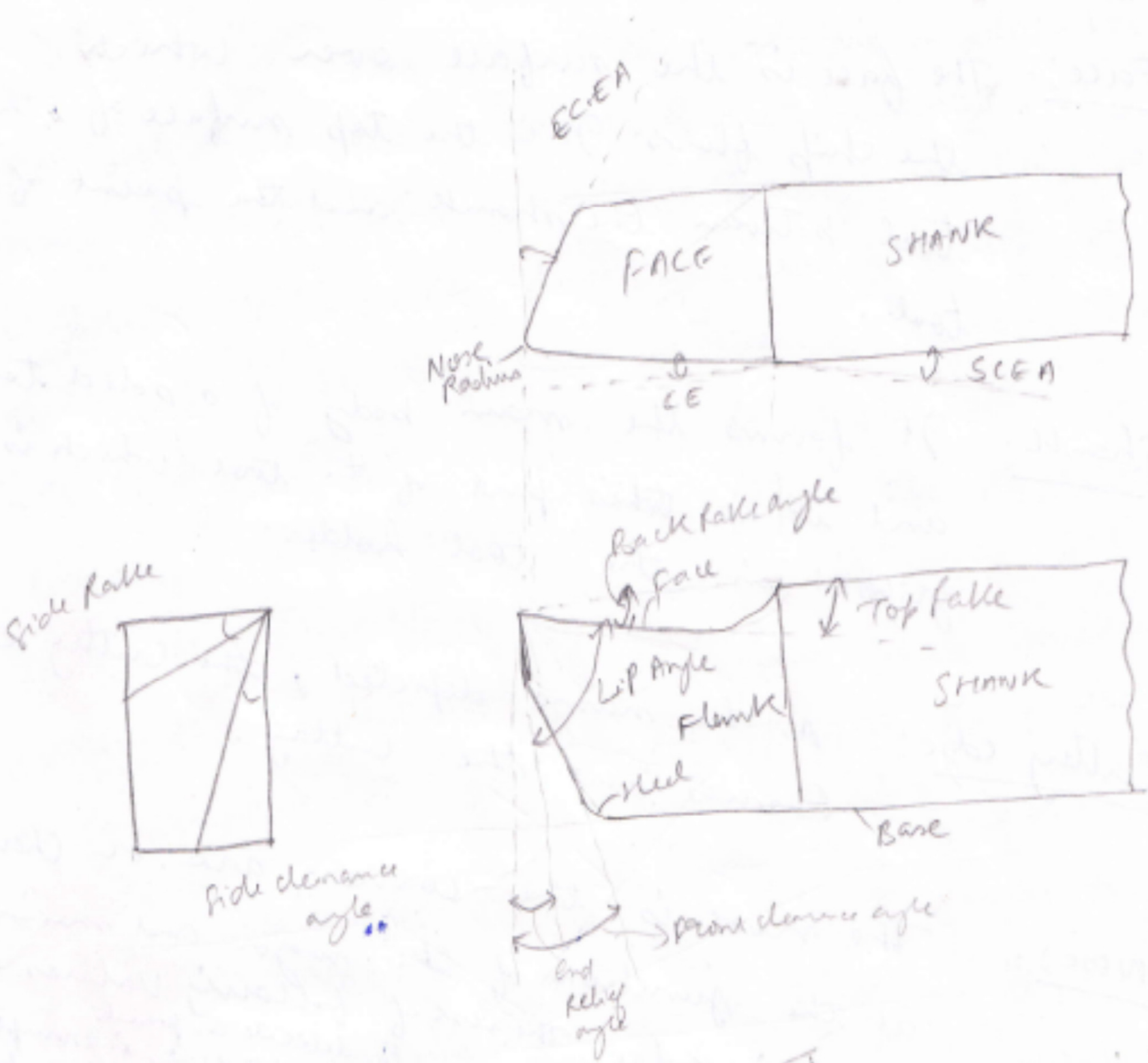
② <u>Forged type</u> :- In forged type the cutting edge is formed by Rough forging before hardening and grinding.

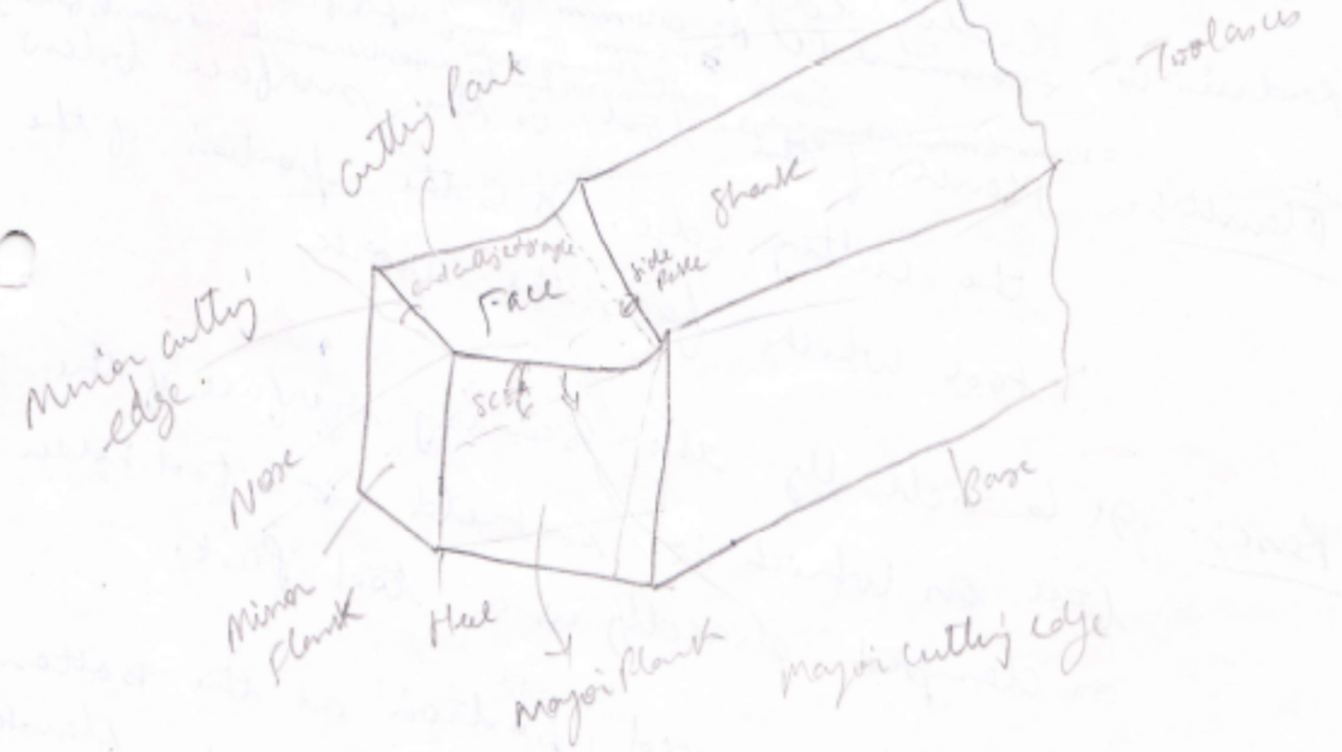
③ <u>Tipped type</u> :- In tipped type cutting tool the cutting edge in the form of a small tip made of high grade material which is welded to the shank made up of low grade mlt.

④ <u>Bit type</u> :- In Bit type, a high grade material of a square, rectangular or some other shape is held mechanically in a tool holder.

Single point cutting tools are commonly used in lathes, shapers, planners, boring mills and slotters.

drills, reamers


ECEA
FACE
SHANK
Nose Radius
CE
SCEA
Side Rake
Back Rake angle
Face
Top Rake
Lip Angle
Flank
SHANK
Heel
Base
Side clearance angle
Front clearance angle
End Relief angle


Tool axis
Cutting Point
Shank
end cutting edge angle
Side Rake
FACE
Minor cutting edge
SCEA
Nose
Base
Minor Flank
Heel
Major Flank
Major cutting edge

UNIT I (b)

Merchant circle:

It is clear from the below fig that a number of forces act on the chip during metal cutting. The relationships among these forces were established by Merchant with the following assumptions:-

① cutting velocity always remains constant.

② Cutting edge of the tool remains sharp throughout cutting and there is not contact between the workpiece and the tool flank

③ There is no sideways flow of chip.

④ only continuous chips is produced.

⑤ There is no built up edge.

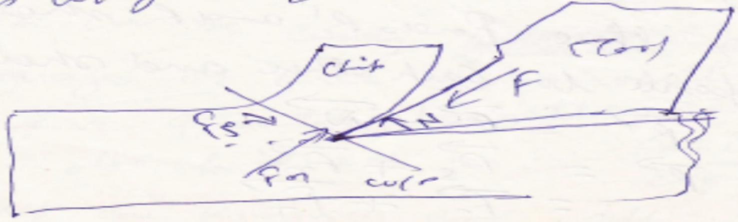
⑥ No Consideration is made of the inertia force of the chip.

⑦ The behaviour of the chip is like that of a free body which is ~~like that of a~~ in the state of a stable equilibrium due to the action of two resultant forces which are equal, opposite and collinear.

were a no. of flaws

are equal, oppo

However there were a no. of bla
and practical difficulties in these assumptions a
that is why they were modified later.



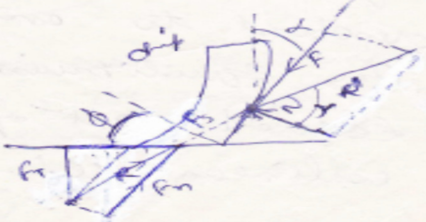


Fig represents the forces acting on a chip in orthogonal Cutting. The forces represented are the following:-

F_s = Metal resistance to shear in chip formation, acting along the shear Plane or shear force.

F_n = Backing up force exerted by the workpiece on the chip, acting normal to shear Plane.

N = Force exerted by the tool on the chip, acting normal to the tool face.

$F = \mu N$ = Frictional resistance of the tool against the chip flow, acting along the tool face, μ being the coefficient of friction between the tool face and the chip.

$\mu = \frac{F}{N}$.

These forces are vectorially represented in a free body diagram as shown in Right hand side. It will be observed that the forces F_s and F_n Can be easily be replaced by their resultant R and forces F and N by their resultant R'. Thus all these forces are resolved to only two forces R and R'. For equilibrium, these forces R' and R should be

to each other and should be

equal, act opposite to each other and collinear. i.e. $\vec{R'} = \vec{F} + \vec{N}$

$\vec{R} = \vec{F_s} + \vec{F_n}$

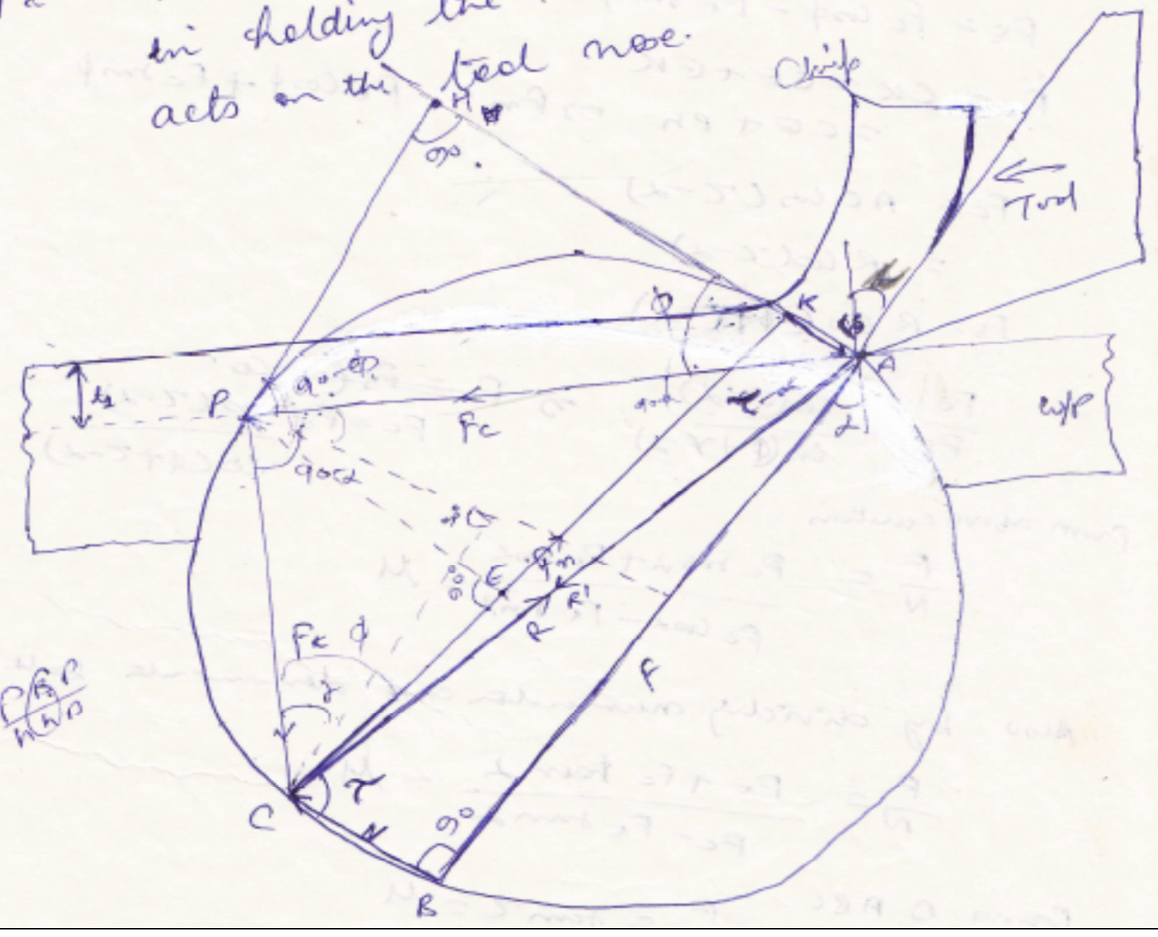
$= \vec{F_c} + \vec{F_T}$

or $\vec{R} = \vec{R}$

For the convenience in studying further relationship the two triangles of forces of the above free body diagram have been combined together in below diagram for figure called the Merchant's circle diagram for cutting forces, in which the following new components figure:.

F_c = Horizontal cutting force exerted by the tool on the workpiece.

F_t = Vertical or tangential force which helps in holding the tool in position and acts on the tool nose.



F_c and F_t can be easily found out with the help of strain guages or force dynamometers. The angle α is a known quantity, being the rake angle of the tool. ϕ can be also find out by $r = \frac{\sin\phi}{\cos(\phi-\alpha)}$. Hence F_c, F_t, α and ϕ are known and all the other forces

can be easily calculated with the help of geometry.

$$F = AQ + QB$$
$$= AQ + DC$$
$$F = F_c \sin\alpha + F_t \cos\alpha$$

nd $N = QD = PQ - PD$

$$N = F_c \cos\alpha - F_t \sin\alpha$$

$$F_s = AH - HK$$
$$= AH - PE$$
$$F_s = F_c \cos\phi - F_t \sin\phi$$

$$F_n = CK = CE + EK$$
$$= CE + PH \Rightarrow F_n = F_t \cos\phi + F_c \sin\phi$$

$$F_c = AC\cos(\tau-\alpha)$$
$$= R\cos(\tau-\alpha)$$
$$F_s = R\cos(\phi+\tau-\alpha)$$

$$\frac{F_c}{F_s} = \frac{\cos(\tau-\alpha)}{\cos(\phi+\tau-\alpha)} \Rightarrow$$ ~~$F_c = F_s ($ co~~ $$F_c = F_s \frac{\cos(\tau-\alpha)}{\cos(\phi+\tau-\alpha)}$$

From above equations

$$\frac{F}{N} = \frac{F_c \sin\alpha + F_t \cos\alpha}{F_c \cos\alpha - F_t \sin\alpha} = \mu$$

Also by dividing numerator and denominator both by $\cos\alpha$

$$\frac{F}{N} = \frac{F_t + F_c \tan\alpha}{F_c - F_t \tan\alpha} = \mu$$

From Δ ABC $\frac{F}{N} = \tan \tau = \mu$

$$\mu = \tan^{-1}\left(\frac{F}{N}\right)$$

$$\frac{CP}{AP} = \tan PAC$$

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

UNIT I (c)

Thermal aspects of Chip formation:-

work is done during the process of chip formation, which results in the generation of heat. The work also is done in the plastic deformation of the layer being Cut and the layers adjoining machined surface and the surface of the cut and in overcoming friction on the tool - face and flank.

The heat Balance in chip formation can be written as.

Total Amount of heat generated

= Amount of heat carried away in chips +
Amount of heat remaining in the cutting tool +
Amount of heat passing into the workpiece +
Amount of heat Radiated into the surrounding air.

Note:- ⇒ on an average for a lathe operation, the above heat dissipation percentage are : 50 to 86%, 10-40%, 3 to 9% and 1% respectively of the total amount of heat generated.

⇒ In finish operations, more heat (in percent) passes into the work than in Rough operations. Heat passing into tool, reduces its hardness and makes it less wear - resistant.

the chip formation zone and
and the chip

reduces its

resistant.

⇒ Heat evolved in the chip formation zone and at the interface between the tool and the chip and at the tool-work interface strongly affects the condition of rubbing surfaces (by changing their coefficient of friction) machining accuracy and the whole cutting process, and the related phenomenon that is deformation, tool wear, built up edge formation and work hardening etc.

› The important aspect in first area (A1) is the plastic deformation characteristics of the material cut.

› In (A2) the friction and wear characteristics of the tool w/p combination

› In (A3) is the surface roughness produced and the residual stresses involved in the surface constituting the area.

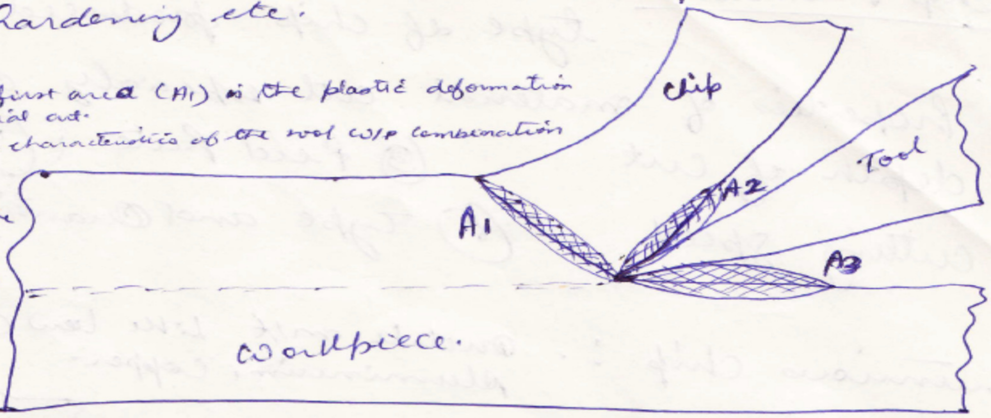


Fig: The Regions where heat is mainly generated:

› The distribution of heat both in the chip and the tool, is non uniform. Hence they are heated to non uniform temperatures. The temperature in layers of the chip nearer to the tool face will be higher than in those farther away.

› The highest temperature in the work piece is observed at the point of contact of the tool with the work.

Factors affecting Cutting Temperature:

① Work material: If w/p m/t offer more resistance, then more power requires, more work done and more heat generation and higher cutting temp.

② Cutting Variables Heat Generated ∝ Cutting force ∝ cutting speed.

) Tool Geometry $\text{Rake} \propto \frac{1}{\text{cutting angle}} \propto \frac{1}{\text{work done}} \propto \text{heat generation}$ etc.

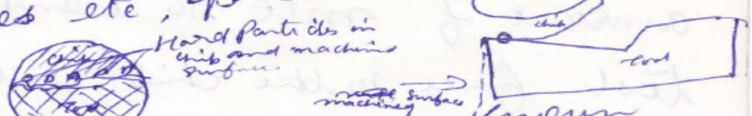
(4) Cutting fluid. helps in reducing cutting temperature by reducing friction, facilitating chip formation, absorbing and carrying away a part of the generated heat. The cooling effect of the cutting fluid gets increased with their higher specific heat and thermal conductivity.

UNIT II (a)

Mechanism of wear:- The wear mechanism of cutting tools is a very complex phenomenon. However the common mechanisms supposed to be responsible for causing wear are the following:-

(1) Abrasion:- It is a type of mechanical wear. Under this mechanism, hard particles on the underside of the sliding chip, which are harder than the tool material, plough into the relatively softer m/t of the tool face and remove metal particles by mechanical action. The material of the tool face is softened due to the high temperature. The hard particles present on the underside of the chip may be:-

(a) Fragments of hard tool material.
(b) Broken pieces of built up edges which are strain hardened.
(c) Extremely hard constituents, like carbides, oxides, scales etc, present in the work m/t.



(2) Adhesion wear:- It should be known that due to the excessive pressure a lot of friction occur between the sliding surface of the chip and the tool face. This gives rise to extremely high localised temperature,

Causing metallic bond between of the tool face and the chip. But an important point to be notes here is

is that the surfaces of both the chip underside and tool face, although appear to be smooth apparently, are microscopically rough. Therefore the contact between these surfaces is not truly a surface contact but a point contact. Due to excessive high temperature at the chip tool interface a metallic bond takes place between the chip material and tool m/t at the contact point, in the form of small spot welds. when the chip slides, these small welds are broken. But this separation is not along the line of contact. A small portion of the weldtool contact is also carried away by the sliding chip. thus small particles from the tool face continue to be separted through this phenomeon and carried away by the chip by adhesion to its underside. The amount of m/t so transferred from the tool face to the chip will depend upon the contact area and relative hardness of the chip and tool m/ts.

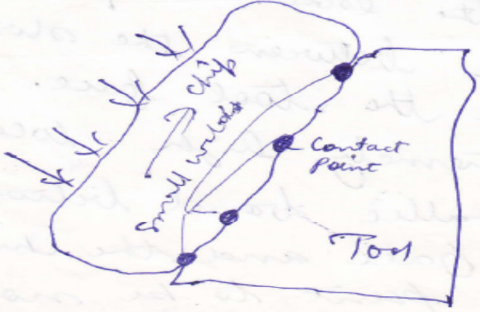


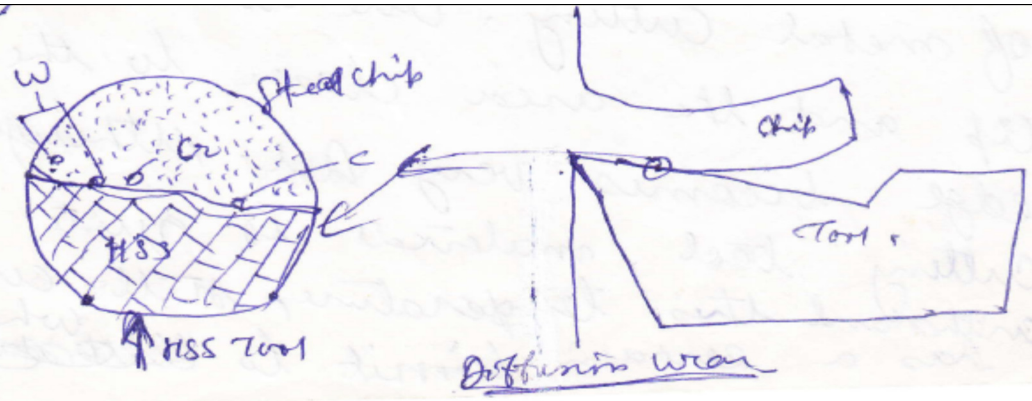
Fig:- Point contacts and metallic bonds (welds) formed between mating surfaces.

③ <u>Diffusion</u>:- Solid state diffusion which consists of transfer of atoms in a metal crystal ~~td~~ lattice, is another cause of wear. This transfer of atoms takes place at elevated temperatures from the area of high concentration to that of low concentration. The favourable condition for diffusion is provided by the use in localised temp. over the actual contact area between the chip underside and the tool face. In such a condition, the metal atoms are transferred from the tool m/t to the chip m/t at the points of contact. This weakens the surface structure of the cutting tool and may ultimately lead to tool failure. The amount of diffusion depends upon:-

(a) Temperature at the contact area between the tool face and the chip

(b) The period of contact ~~[illegible]~~ between the tool face and the chip

(c) The bonding affinity between the m/ts of the tool and the chip.



Diffusion wear

Chemical wear:- This type of wear occurs when such a cutting fluid is used in the process of metal cutting which is chemically active to the material of the tool. This is clearly the result of the chemical reaction taking place between the cutting fluid and the tool m/t, leading to change in the chemical composition of the surface m/t of the tool.

① Crater wear:- The major tendency for wear is due to the abrasion between the chip and the face of the tool, a short distance from the cutting edge. This results in the crater being formed in the tool face. The crater is formed on the surface of the tool by the action of chip particles flowing over it because of very high temperature. When cratering becomes excessive, the cutting edge may break from the tool. Cratering is commonly observed while m/cing ductile m/ts, which produce continuous chips. The maximum depth of crater usually a measure of the amount of the crater wear and can be determined by a surface measuring instruments.

Flank wear:- The area in which wear takes place is on the flank below the cutting edge resulting from the abrasive contact with the machined surface. Brittle m/ts tend to cause excessive flank wear because tool cutting edge tends to scrap over the m/ced surface and due to low abrasive action of loose fractured chips on the tool face while the flank is in constant contact with the work.

The worn region at the flank is called wear land. The criterions wear land meas-

UNIT II (b)

Selection of cutting speed is based on making the best use of the particular cutting tool, which normally means choosing a speed that provides a high metal removal rate yet suitably long tool life. Mathematical formulas have been derived to determine optimal cutting speed for a machining operation, given that the various time and cost components of the operation are known. The original derivation of these ***machining economics*** equations is credited to W. Gilbert [10]. The formulas allow the optimal cutting speed to be calculated for two objectives: (1) maximum production rate, or (2) minimum unit cost. Both objectives seek to achieve a balance between material removal rate and tool life. The formulas are based on a known Taylor tool life equation for the tool used in the operation. Accordingly, feed, depth of cut, and work material have already been set. The derivation will be illustrated for a turning operation. Similar derivations can be developed for other types of machining operations [2].

Maximizing Production Rate For maximum production rate, the speed that minimizes machining time per production unit is determined. Minimizing cutting time per unit is equivalent to maximizing production rate. This objective is important in cases when the production order must be completed as quickly as possible.

In turning, there are three time elements that contribute to the total production cycle time for one part:

1. ***Part handling time*** T_h. This is the time the operator spends loading the part into the machine tool at the beginning of the production cycle and unloading the part after machining is completed.
2. ***Machining time*** T_m. This is the time the tool is actually engaged in machining during the cycle.
3. ***Tool change time*** T_t. At the end of the tool life, the tool must be changed, which takes time. This time must be apportioned over the number of parts cut during the tool life. Let n_p = the number of pieces cut in one tool life (the number of pieces cut with one cutting edge until the tool is changed); thus, the tool change time per part = T_t/n_p.

The sum of these three time elements gives the total time per unit product for the operation cycle:

$$T_c = T_h + T_m + \frac{T_t}{n_p} \qquad (24.4)$$

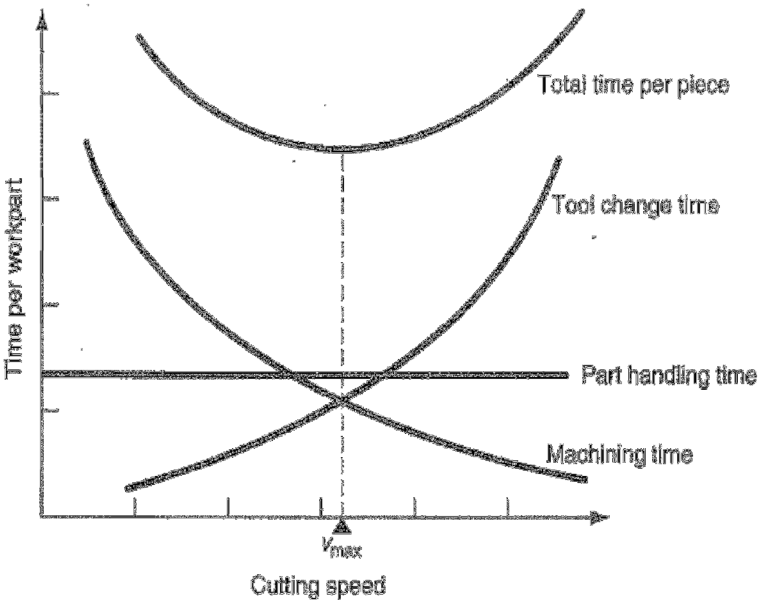


FIGURE 24.3 Time elements in a machining cycle plotted as a function of cutting speed. Total cycle time per piece is minimized at a certain value of cutting speed. This is the speed for maximum production rate.

where T_c = production cycle time per piece, min; and the other terms are defined above.

The cycle time T_c is a function of cutting speed. As cutting speed is increased, T_m decreases and T_t/n_p increases; T_h is unaffected by speed. These relationships are shown in Figure 24.3.

The total time per part is minimized at a certain value of cutting speed. This optimal speed can be identified by recasting Eq. (24.4) as a function of speed. It can be shown that the machining time in a straight turning operation is given by

$$T_m = \frac{\pi DL}{vf} \tag{24.5}$$

where T_m = machining time, min; D = workpart diameter, mm (in); L = workpart length, mm (in); f = feed, mm/rev (in/rev); and v = cutting speed, mm/min for consistency of units (in/min for consistency of units).

The number of pieces per tool n_p is also a function of speed. It can be shown that

$$n_p = \frac{T}{T_m} \tag{24.6}$$

where T = tool life, min/tool; and T_m = machining time per part, min/pc. Both T and T_m are functions of speed; hence, the ratio is a function of speed:

$$n_p = \frac{fC^{1/n}}{\pi DLv^{1/n-1}} \tag{24.7}$$

The effect of this relation is to cause T_t/n_p in Eq. (24.4) to increase as cutting speed increases. Substituting Eqs. (24.5) and (24.7) into Eq. (24.4) for T_c, we have

$$T_c = T_h + \frac{\pi DL}{fv} + \frac{T_t(\pi DLv^{1/n-1})}{fC^{1/n}} \tag{24.8}$$

The cycle time per piece is a minimum at the cutting speed at which the derivative of Eq. (24.8) is zero:

$$\frac{dT_c}{dv} = 0$$

Solving this equation yields the cutting speed for maximum production rate in the operation:

$$v_{\max} = \frac{C}{\left[\left(\frac{1}{n} - 1\right) T_t\right]^n} \tag{24.9}$$

where $v_{\max}$ is expressed in m/min (ft/min). The corresponding tool life for maximum production rate is

$$T_{\max} = \left(\frac{1}{n} - 1\right) T_t \tag{24.10}$$

Minimizing Cost per Unit For minimum cost per unit, the speed that minimizes production cost per unit product for the operation is determined. To derive the equations for this case, we begin with the four cost components that determine total cost of producing one part during a turning operation:

1. ***Cost of part handling time.*** This is the cost of the time the operator spends loading and unloading the part. Let C_o = the cost rate (e.g., \$/min) for the operator and machine. Thus the cost of part handling time $= C_o T_h$.
2. ***Cost of machining time.*** This is the cost of the time the tool is engaged in machining. Using C_o again to represent the cost per minute of the operator and machine tool, the cutting time cost $= C_o T_m$.
3. ***Cost of tool change time.*** The cost of tool change time $= C_o T_t / n_p$.
4. ***Tooling cost.*** In addition to the tool change time, the tool itself has a cost that must be added to the total operation cost. This cost is the cost per cutting edge C_t, divided by the number of pieces machined with that cutting edge n_p. Thus, tool cost per unit of product is given by C_t/n_p.

Tooling cost requires explanation, since it is affected by different tooling situations. For disposable inserts (e.g., cemented carbide inserts), tool cost is determined as

$$C_t = \frac{P_t}{n_e} \tag{24.11}$$

where C_t = cost per cutting edge, \$/tool life; P_t = price of the insert, \$/insert; and n_e = number of cutting edges per insert. This depends on the insert type; for example, triangular inserts that can be used only one side (positive rake tooling) yield three edges/insert; if both sides of the insert can be used (negative rake tooling), there are six edges/insert; and so forth.

For regrindable tooling (e.g., high-speed steel solid shank tools, brazed carbide tools), the tool cost includes purchase price plus cost to regrind:

$$C_t = \frac{P_t}{n_g} + T_g C_g \tag{24.12}$$

where C_t = cost per tool life, \$/tool life; P_t = purchase price of the solid shank tool or brazed insert, \$/tool; n_g = number of tool lives per tool, which is the number of times the tool can be ground before it can no longer be used (5 to 10 times for roughing tools and 10 to 20 times for finishing tools); T_g = time to grind or regrind the tool, min/tool life; and C_g = grinder's rate, \$/min.

The sum of the four cost components gives the total cost per unit product C_c for the machining cycle:

$$C_c = C_o T_h + C_o T_m + \frac{C_o T_t}{n_p} + \frac{C_t}{n_p} \tag{24.13}$$

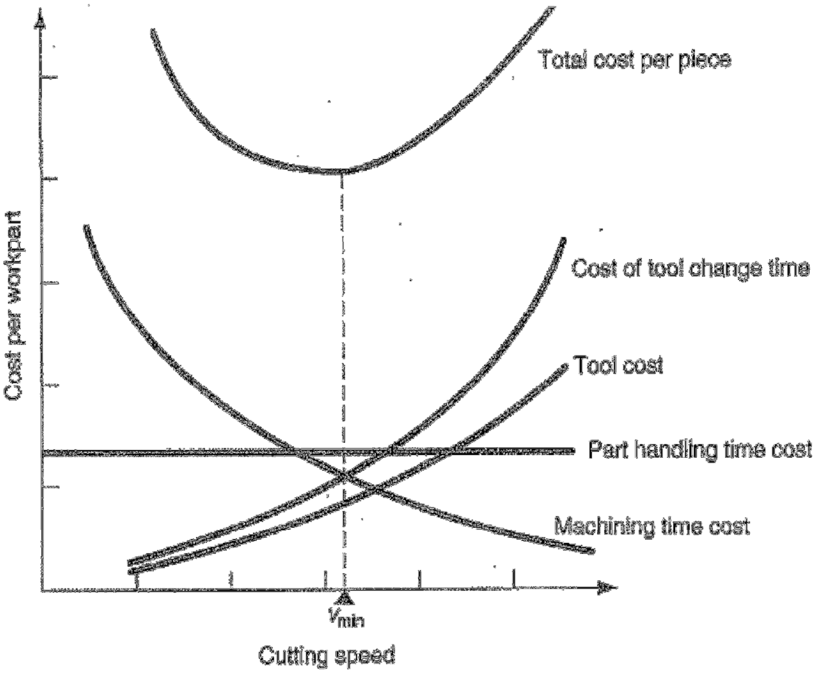


FIGURE 24.4 Cost components in a machining operation plotted as a function of cutting speed. Total cost per piece is minimized at a certain value of cutting speed. This is the speed for minimum cost per piece.

C_c is a function of cutting speed, just as T_c is a function of v. The relationships for the individual terms and total cost as a function of cutting speed are shown in Figure 24.4. Equation (24.13) can be rewritten in terms of v to yield:

$$C_c = C_o T_h + \frac{C_o \pi D L}{f v} + \frac{(C_o T_t + C_t)(\pi D L v^{1/n-1})}{f C^{1/n}} \tag{24.14}$$

The cutting speed that obtains minimum cost per piece for the operation can be determined by taking the derivative of Eq. (24.14) with respect to v, setting it to zero, and solving for $v_{\min}$:

$$v_{\min} = C\left(\frac{n}{1-n} \cdot \frac{C_o}{C_o T_t + C_t}\right)^n \tag{24.15}$$

The corresponding tool life is given by

$$T_{\min} = \left(\frac{1}{n} - 1\right)\left(\frac{C_o T_t + C_t}{C_o}\right) \tag{24.16}$$

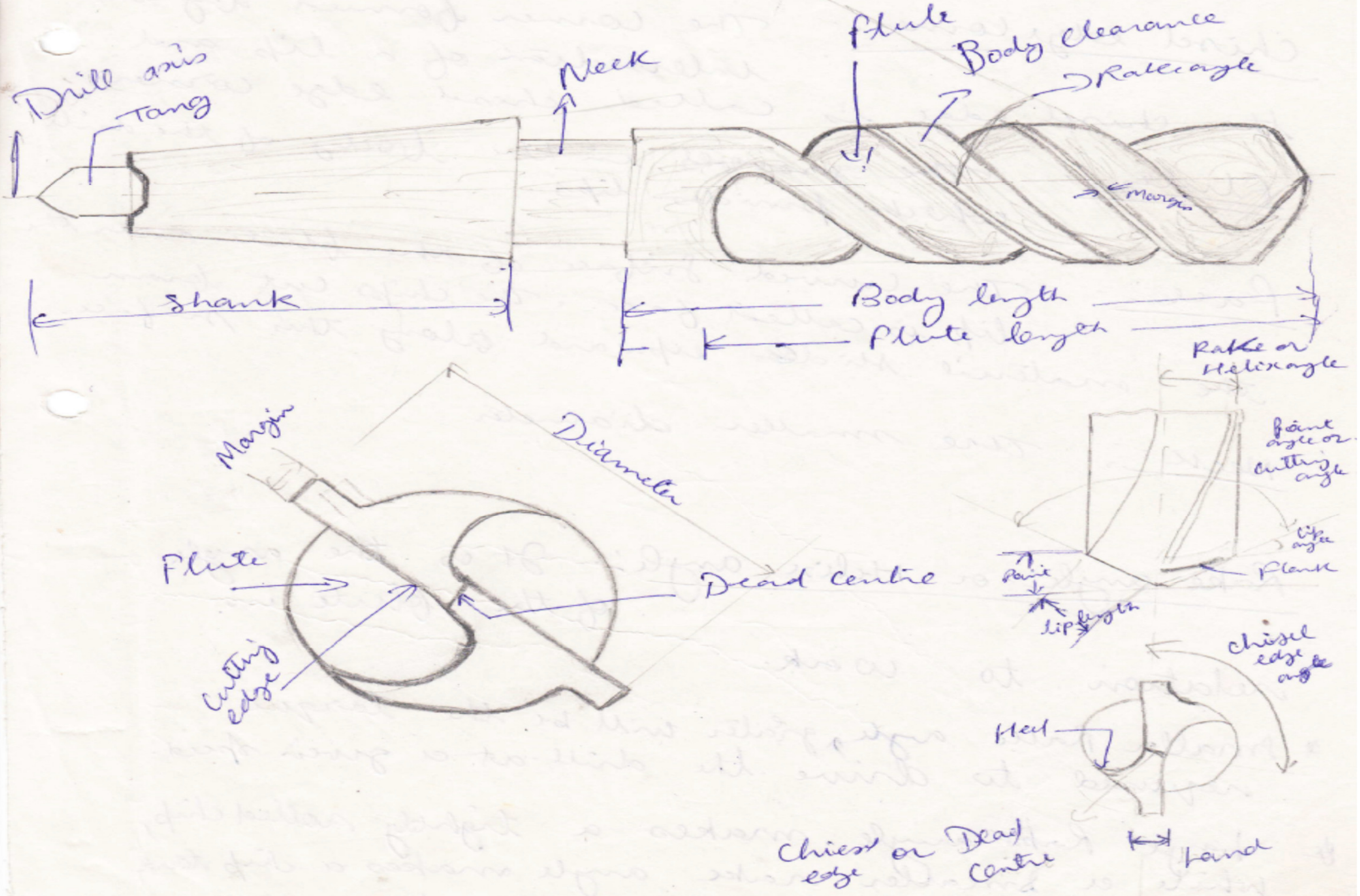
UNIT II (c)

(ii) Lip clearance angle:- It is the angle formed by the flank and a plan at right angle to the drill axis. Lip clearance is the relief that is given to the cutting edges in order to allow the drill to enter the metal without interference.

In order to provide the strength and Rigidity to the cutting edge, the clearance angle should be kept minimum.

(iii) Cutting angle or point angle:- It is the angle included between the lips projected upon a plane parallel to the drill axis and parallel to the two cutting lips. It is observed that the best point angle is 118°.

Elements of a twist drills:



Cutting Fluid :- as a result of work done. Heat is carried away from the tool and work by means of cutting fluid which at the same time reduce the friction between the tool and chip and between tool and work and also facilitates the chip formation.

If sufficient quantity of cutting fluid is properly applied, heat can be removed almost as fast as it is generated and the temperature of tool, workpiece and chip can be kept within limit.

Cutting fluid is one of the "Important Aids to improve production efficiency".

Sources of heat in Metal cutting :- The main factors likely to cause excessive heat during a metal cutting operation are as follows:-

① cutting speed too high
② Poor surface finish on the cutting face of the tool.
③ worn or incorrectly ground cutting tool.
④ Formation of a built up edge on cutting face of the tool.
⑤ Friction between tool and workpiece.

Functions of a cutting fluid :-

① To minimise the friction between mating surfaces and thus prevent rise in temperature.
② To increase tool life and prevent better surface finish by carrying away the heat generated during metal working.
③ To provide lubrication at high pressures called boundary lubrication.
④ To provide a cushioning effect between the job surface and the tool to prevent adhesion of the two, such as in stamping and extrusion, etc.
⑤ To drive away the chips, scale and dirt, etc, from between the working or mating surfaces
⑥ To prevent the work metal from a quick swelling on to the tool ~~or~~ into the die and the resulting wear on their surfaces.
⑦ To protect the finish surface from corrosion.
⑧ To avoid continuous chip means causes the chips to break up into small pieces.

Properties of cutting fluid :-

① It should have a high specific heat, high heat conductivity and high film coefficient.

② It should posses good lubricating properties to reduce frictional forces and to decrease the power consumption

should be odorles

④ It should be non corrosive

⑤ It should be non toxic to operating personnel.

⑥ It should have low viscosity to permit free flow of the liquid.

⑦ It should be stable in use and storage.

⑧ It should permit clear view of work which is specially desirable in precision work.

⑨ It should be safe particularly with regards to fire and accident hazards.

UNIT III (b)

Back off angle :- It is known as clearance angle and is ground on the land to provide relief. Therefore it is sometimes called a relief angle also. Its values aries ~~between~~ from .5° to 3°, value between 1.5°-2° is very mmon. However for finishing teeth, either no clearance is provided or a very small angle between 0°-1° is provided because, if at all, a very nominal cutting is done by these teeth.

Tooth or Rake angle :- It is known as face angle. It is similar to the rake angle provided on a single point cutting tool of a lathe. and purpose is also the same. Its value depends upon the material to be cut. The ductility of the material has a marked effect on the value of this angle to be adopted. Higher the ductility of the m/l to be broached the higher the value of rake angle to be provided on the broach teeth.

UNIT III (c)

5.39. TYPES OF CUTTING TOOL MATERIALS

The following materials are commonly used for manufacturing the cutting tools. Selection of a particular material will depend on the type of service it is expected to perform.

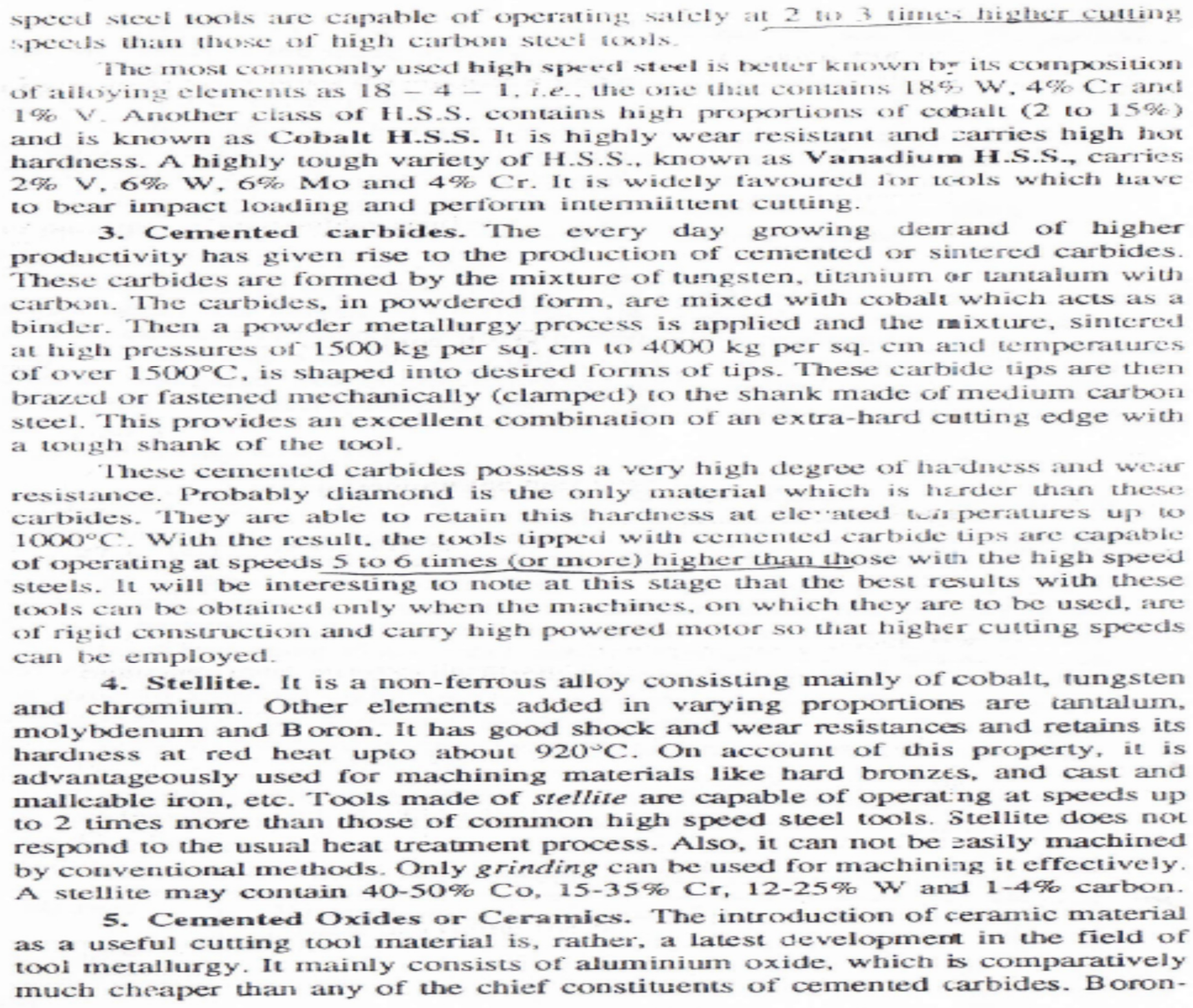
1. High Carbon Steel,
2. High Speed Steel,
3. Cemented Carbides,
4. Stellite,
5. Cemented Oxides or Ceramics, and
6. Diamond.

→ C = 0.8 to 1.3%, Si = 0.1 to 0.4%, Mn = 0.1 to 0.4%.

1. High carbon steel. Plain carbon steels having a carbon percentage as high as 1.5% are in common use as tool materials for general class of work. However, they are not considered suitable for tools used in production work on account of the fact that they are not able to withstand very high temperature. With the result, they cannot be employed at high speeds. Usually the required hardness is lost by them as soon as the temperature rises to about 200°C – 250°C. They are also not highly wear resistant. They are used mainly for hand tools. They are, however, less costly, easily forgeable and easy to heat treat. The cutting tools such as hand drills, taps, dies, reamers, hacksaw blades are made of High Carbon steel

High carbon medium alloy steels are found to be more effective than plain high carbon steels. These steels, in addition to the carbon content at par with that in the plain high carbon steels, are provided better hot hardness, higher impact resistance, higher wear resistance, etc., by adding small amounts of tungsten, chromium, molybdenum, vandium, etc., which improves their performance considerably and they are able to successfully operate upto cutting temperatures of 350°C.

2. High speed steel. It is a special alloy-steel which may contain the alloying elements like tungsten, chromium, vanadium, cobalt and molybdenum, etc. up to 25 per cent. These alloying elements increase its strength, toughness, wear resistance, cutting ability and ability to retain its hardness at elevated temperatures in the range of 550°C to 600°C. On account of these added properties the high



speed steel tools are capable of operating safely at 2 to 3 times higher cutting speeds than those of high carbon steel tools.

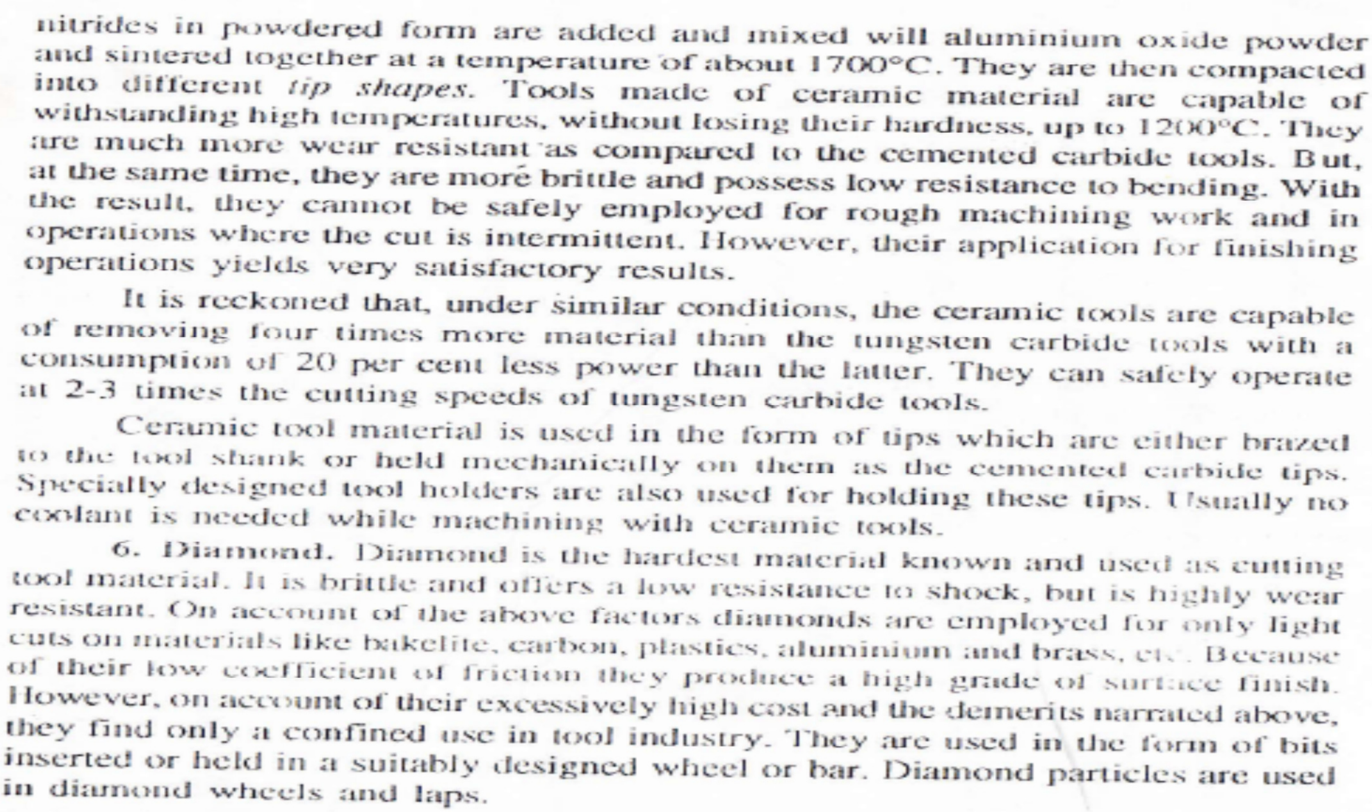
The most commonly used **high speed steel** is better known by its composition of alloying elements as 18 – 4 – 1, *i.e.*, the one that contains 18% W, 4% Cr and 1% V. Another class of H.S.S. contains high proportions of cobalt (2 to 15%) and is known as **Cobalt H.S.S.** It is highly wear resistant and carries high hot hardness. A highly tough variety of H.S.S., known as **Vanadium H.S.S.,** carries 2% V, 6% W, 6% Mo and 4% Cr. It is widely favoured for tools which have to bear impact loading and perform intermittent cutting.

3. Cemented carbides. The every day growing demand of higher productivity has given rise to the production of cemented or sintered carbides. These carbides are formed by the mixture of tungsten, titanium or tantalum with carbon. The carbides, in powdered form, are mixed with cobalt which acts as a binder. Then a powder metallurgy process is applied and the mixture, sintered at high pressures of 1500 kg per sq. cm to 4000 kg per sq. cm and temperatures of over 1500°C, is shaped into desired forms of tips. These carbide tips are then brazed or fastened mechanically (clamped) to the shank made of medium carbon steel. This provides an excellent combination of an extra-hard cutting edge with a tough shank of the tool.

These cemented carbides possess a very high degree of hardness and wear resistance. Probably diamond is the only material which is harder than these carbides. They are able to retain this hardness at elevated temperatures up to 1000°C. With the result, the tools tipped with cemented carbide tips are capable of operating at speeds 5 to 6 times (or more) higher than those with the high speed steels. It will be interesting to note at this stage that the best results with these tools can be obtained only when the machines, on which they are to be used, are of rigid construction and carry high powered motor so that higher cutting speeds can be employed.

4. Stellite. It is a non-ferrous alloy consisting mainly of cobalt, tungsten and chromium. Other elements added in varying proportions are tantalum, molybdenum and Boron. It has good shock and wear resistances and retains its hardness at red heat upto about 920°C. On account of this property, it is advantageously used for machining materials like hard bronzes, and cast and malleable iron, etc. Tools made of *stellite* are capable of operating at speeds up to 2 times more than those of common high speed steel tools. Stellite does not respond to the usual heat treatment process. Also, it can not be easily machined by conventional methods. Only *grinding* can be used for machining it effectively. A stellite may contain 40-50% Co, 15-35% Cr, 12-25% W and 1-4% carbon.

5. Cemented Oxides or Ceramics. The introduction of ceramic material as a useful cutting tool material is, rather, a latest development in the field of tool metallurgy. It mainly consists of aluminium oxide, which is comparatively much cheaper than any of the chief constituents of cemented carbides. Boron-



nitrides in powdered form are added and mixed will aluminium oxide powder and sintered together at a temperature of about 1700°C. They are then compacted into different *tip shapes*. Tools made of ceramic material are capable of withstanding high temperatures, without losing their hardness, up to 1200°C. They are much more wear resistant as compared to the cemented carbide tools. But, at the same time, they are more brittle and possess low resistance to bending. With the result, they cannot be safely employed for rough machining work and in operations where the cut is intermittent. However, their application for finishing operations yields very satisfactory results.

It is reckoned that, under similar conditions, the ceramic tools are capable of removing four times more material than the tungsten carbide tools with a consumption of 20 per cent less power than the latter. They can safely operate at 2-3 times the cutting speeds of tungsten carbide tools.

Ceramic tool material is used in the form of tips which are either brazed to the tool shank or held mechanically on them as the cemented carbide tips. Specially designed tool holders are also used for holding these tips. Usually no coolant is needed while machining with ceramic tools.

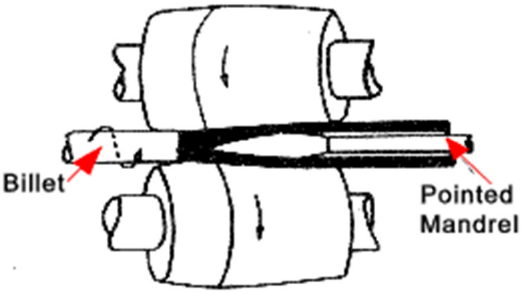
6. Diamond. Diamond is the hardest material known and used as cutting tool material. It is brittle and offers a low resistance to shock, but is highly wear resistant. On account of the above factors diamonds are employed for only light cuts on materials like bakelite, carbon, plastics, aluminium and brass, etc. Because of their low coefficient of friction they produce a high grade of surface finish. However, on account of their excessively high cost and the demerits narrated above, they find only a confined use in tool industry. They are used in the form of bits inserted or held in a suitably designed wheel or bar. Diamond particles are used in diamond wheels and laps.

UNIT IV (a)

Tube drawing is a metalworking process to size tube by shrinking a large diameter tube into a smaller one, by drawing the tube through a die. This process produces high-quality tubing with precise dimensions, good surface finish, and the added strength of cold working. Because it is so versatile, tube drawing is suitable for both large- and small-scale production.

There are five types of tube drawing: tube sinking, mandrel drawing, stationary mandrel, moving mandrel, and floating mandrel. A mandrel is used in many of the types to prevent buckling or wrinkling in the workpiece.

Most ferrous seamless tubes are first rotary forged. This process consists of two hot working processes the first of which is rotary piercing.



Tube drawing is a metalworking process used to create a tube with a smaller diameter by pulling, or drawing, a larger diameter tube through a die. There are five methods of tube drawing that are commonly used. These methods are fixed plug drawing, floating plug drawing, tethered plug drawing, rod drawing and tube sinking.

This process is a cold-working process, meaning that the metal tubing is not heated prior to being shaped in the tube drawing process. This gives the finished product added strength because the metal tubing is not affected by thermal expansion during the process. In addition, this process produces tubing with more precise measurements than other methods of production.

Fixed plug drawing is the oldest form of tube drawing. Using a mandrel that is locked in a fixed position near the die, the process of fixed plug drawing produces the best interior surface finish of any tube drawing method. Fixed plug drawing is also the slowest method in use and is extremely limited in the amount of diameter reduction possible.

Floating mandrel, or floating plug, drawing incorporates a free-floating mandrel placed inside the tube stock. The plug is forced to the throat of the die by friction and pressure, called axial force. The floating plug method is capable of producing very thin tubing diameters. This method of tube drawing is noted for producing tubing with high-quality inner and outer surface finishes.

UNIT IV (b)

Forging is one of the oldest known metalworking processes. Traditionally, forging was performed by a smith using hammer and anvil, and though the use of water power in the production and working of iron dates to the 12th century, the hammer and anvil are not obsolete. The smithy or forge has evolved over centuries to become a facility with engineered processes, production equipment, tooling, raw materials and products to meet the demands of modern industry.

In modern times, industrial forging is done either with presses or with hammers powered by compressed air, electricity, hydraulics or steam. These hammers may have reciprocating weights in the thousands of pounds. Smaller power hammers, 500 lb (230 kg) or less reciprocating weight, and hydraulic presses are common in art smithies as well. Some steam hammers remain in use, but they became obsolete with the availability of the other, more convenient, power sources.

Forging is a manufacturing process involving the shaping of metal using localized compressive forces. Forging is often classified according to the temperature at which it is performed: "cold", "warm", or "hot" forging. Forged parts can range in weight from less than a kilogram to 580 metric tons. Forged parts usually require further processing to achieve a finished part. Forging as an art form started with the desire to produce decorative objects from precious metals.

Forging can produce a piece that is stronger than an equivalent cast or machined part. As the metal is shaped during the forging process, its internal grain deforms to follow the general shape of the part. As a result, the grain is continuous throughout the part, giving rise to a piece with improved strength characteristics.

Distortion energy theory:

This theory was advanced by M.T. Huber in Poland (1904) and independently by

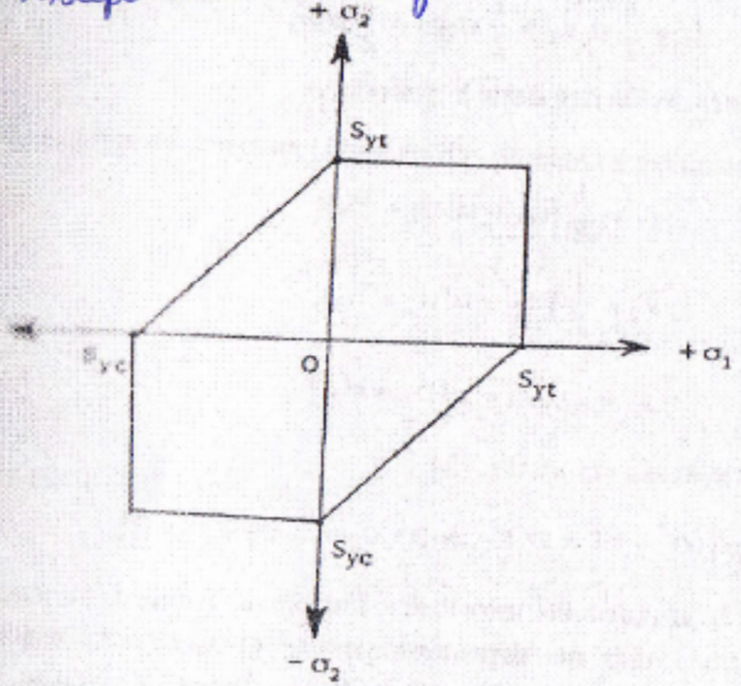
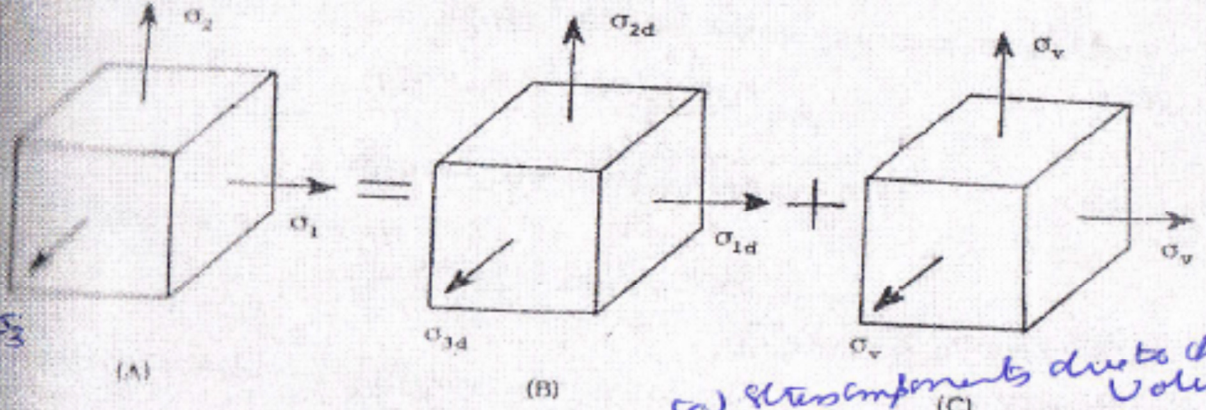


Fig. 4.19 Boundary for maximum-shear-stress theory under bi-axial stresses

R. Von Mises in Germany (1913) and H. Hencky (1925). It is known as the Huber Von Mises and Hencky's theory. The theory states that the failure of the mechanical component subjected to bi-axial or tri-axial stresses occurs when the strain energy of distortion per unit volume at any point in the component becomes equal to the strain energy of distortion per unit volume in a standard tension-test specimen when yielding starts.

A unit cube subjected to the three principal stresses σ_1, σ_2 and σ_3 is shown in Fig 4.20 (a). The total strain energy U of the cube is given by

4.19
the
es for σ_3
like
sults

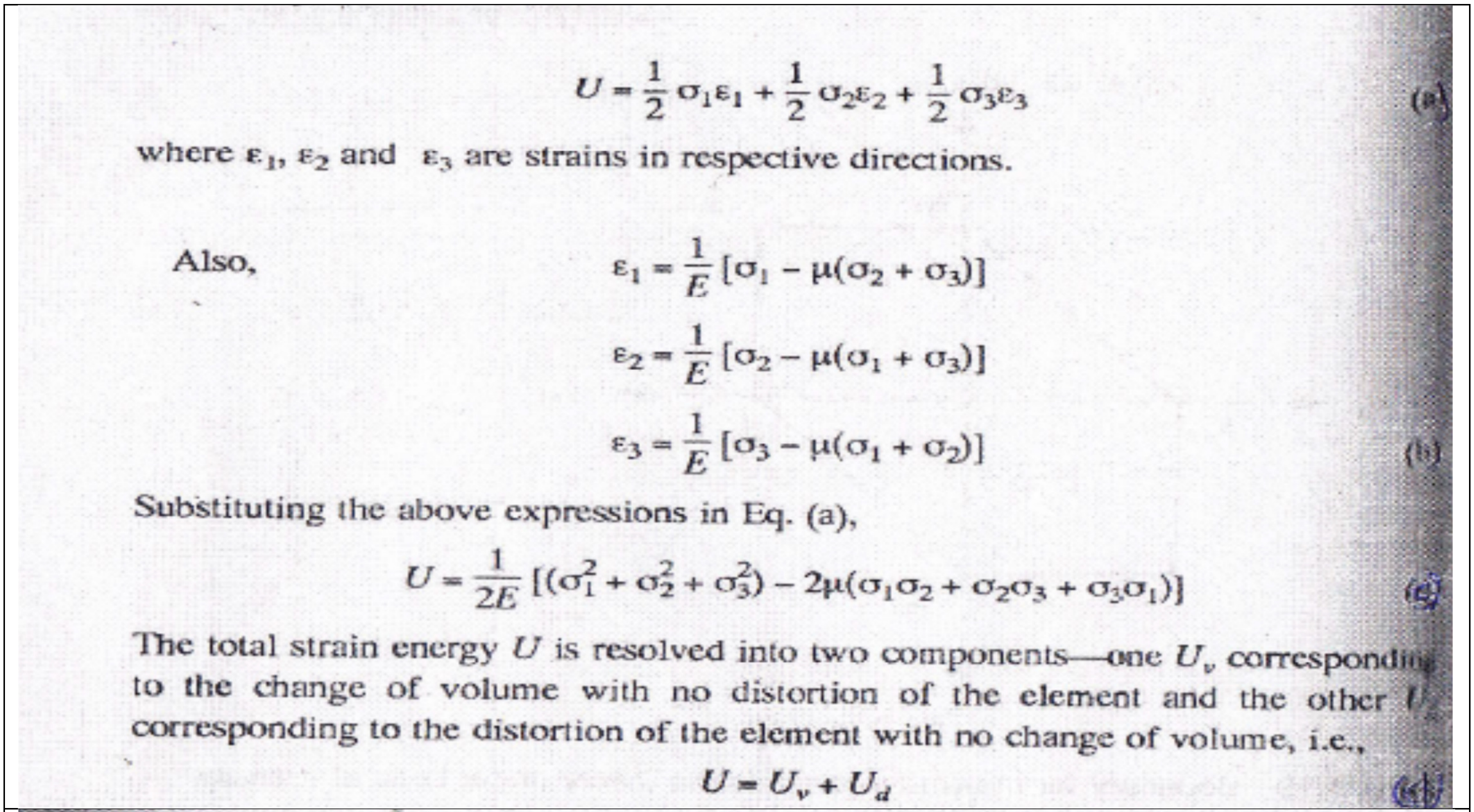


(A) (B) (C)

(c) Stress components due to change of Volume

Fig. 4.20 (a) Element with tri-axial stresses, (b) Stress components due to distortion of element

(b) Stress components due to distortion of



$$U = \frac{1}{2}\sigma_1\varepsilon_1 + \frac{1}{2}\sigma_2\varepsilon_2 + \frac{1}{2}\sigma_3\varepsilon_3 \qquad (a)$$

where ε_1, ε_2 and ε_3 are strains in respective directions.

Also,

$$\varepsilon_1 = \frac{1}{E}[\sigma_1 - \mu(\sigma_2 + \sigma_3)]$$

$$\varepsilon_2 = \frac{1}{E}[\sigma_2 - \mu(\sigma_1 + \sigma_3)]$$

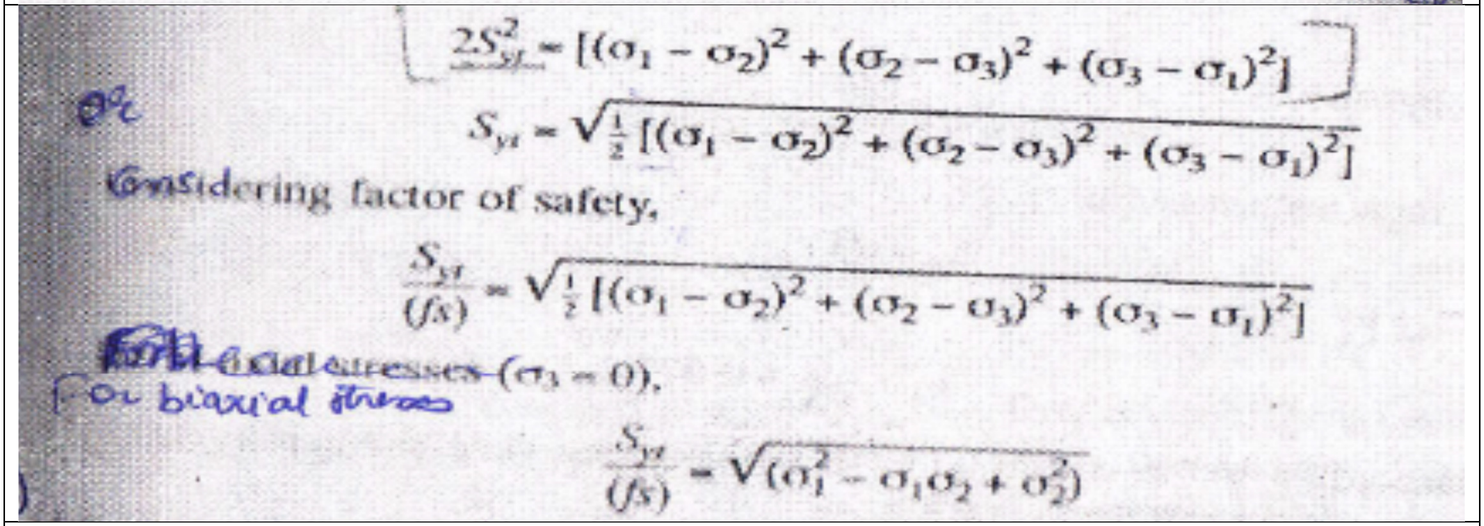
$$\varepsilon_3 = \frac{1}{E}[\sigma_3 - \mu(\sigma_1 + \sigma_2)] \qquad (b)$$

Substituting the above expressions in Eq. (a),

$$U = \frac{1}{2E}[(\sigma_1^2 + \sigma_2^2 + \sigma_3^2) - 2\mu(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1)] \qquad (c)$$

The total strain energy U is resolved into two components—one U_v correspondin to the change of volume with no distortion of the element and the other U corresponding to the distortion of the element with no change of volume, i.e.,

$$U = U_v + U_d \qquad (d)$$



$$\boxed{2S_{yt}^2 = [(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]}$$

or

$$S_{yt} = \sqrt{\tfrac{1}{2}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]}$$

Considering factor of safety,

$$\frac{S_{yt}}{(fs)} = \sqrt{\tfrac{1}{2}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]}$$

~~For bi-axial stresses~~ ($\sigma_3 = 0$),
For biaxial stress

$$\frac{S_{yt}}{(fs)} = \sqrt{(\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2)}$$

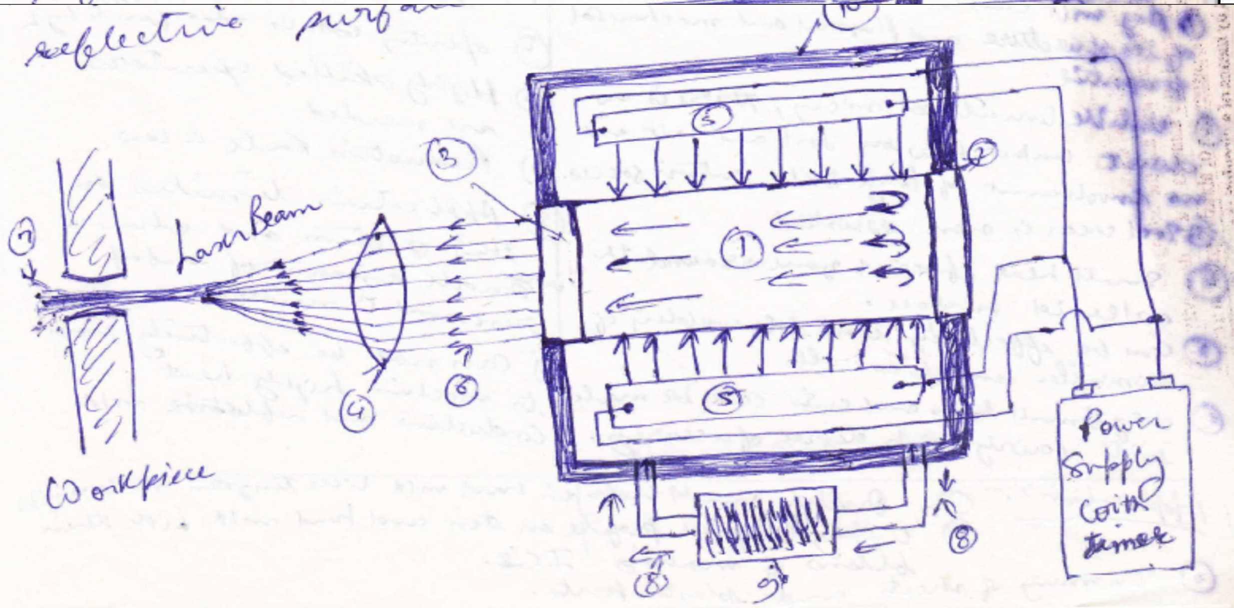
UNIT V (a)

Laser Beam Machining:-

Laser is the term used for the phenomenon of "amplification of light by stimulated emission of radiation". The set up consist of a stimulating light source (like Xenon flash lamp) and a laser rod. The light radiated from the flash lamp is focused on to the laser rod (Laser Tube), from where it is reflected and accelerated in the path. This light is emitted in the form of a slightly divergent beam. A ~~lens~~ lens is incorporated suitably in the path of this beam of light which converges and focuses the light beam on to the W/P to be machined. This concentration of laser beam on the workpiece melts the work material and vapourises it.

The figure shows the set up of LBM. It mainly consists of laser tube rod, a pair of mirrors - one at each end of the tube, a flash lamp or lamp (energy source), an amplifying source (Laser), a power supply source, a cooling system and a lens (focusing source). The main setup is fitted inside an enclosure, which carries a highly reflective surface inside.

reflective surfa



i.e. ① Ruby laser tube ③ Partially reflecting mirror ② Total reflecting mirror. ④ lens ⑤ flash tube (Xenon flash lamp) ⑥ Monochromatic light output ⑦ Vapourised particles of work material ⑧ Coolant flow ⑨ Cooling System ⑩ Enclosure.

In operation the optical energy (light) is thrown by the flash lamp on to the laser tube (Ruby rod). This excites the atoms of the inside media, which absorb the radiations of incoming light energy. This results in the to and fro travel of light between the two reflecting mirrors. But the partially reflecting mirror does not reflect the total light back and a part of it goes out in the form of a coherent stream of monochromatic light. The highly amplified stream of light is focused through a lens, which converges it to a chosen point on a workpiece. This high intensity converged laser Beam when falls on the W/P, melts the W/P material, vaporises it almost instantaneously and penetrates into it. Thus it can be called a type of thermal cutting process.

Advantages:-

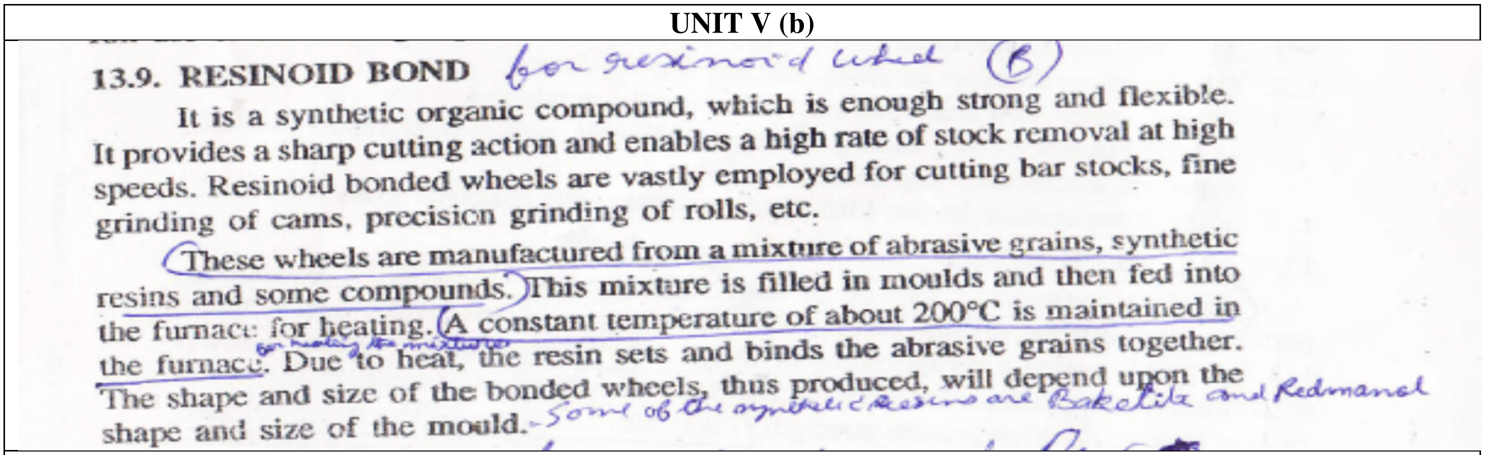
① Any mlt can be easily m/c and irrespective of its structure and physical and mechanical properties.
② Unlike conventional m/cing, there is no direct contact b/w the tool and W/P and no involvement of large scale cutting forces.
③ Tool wear is non existent
④ Small heat affected zone around the m/cined surface.
⑤ Can be effectively used for welding of dissimilar metals as well.
⑥ very small holes and cuts can be made with fairly high degree of accuracy.

Disadvantages:

① High capital investment needed
② operating cost is also quite high
③ Highly skilled operators are needed
④ Production rate is low
⑤ Application is limited to thin section and where a very small amount of metal removal is needed.
⑥ Can not be effectively used to machine highly heat conductive and reflective mlt

Applications:- ① Drilling small holes in hard m/l like tungsten and ceramics
② Cutting complex profile on thin and hard mlt like thin films of making IC's.
③ Trimming of sheets and plastic parts.

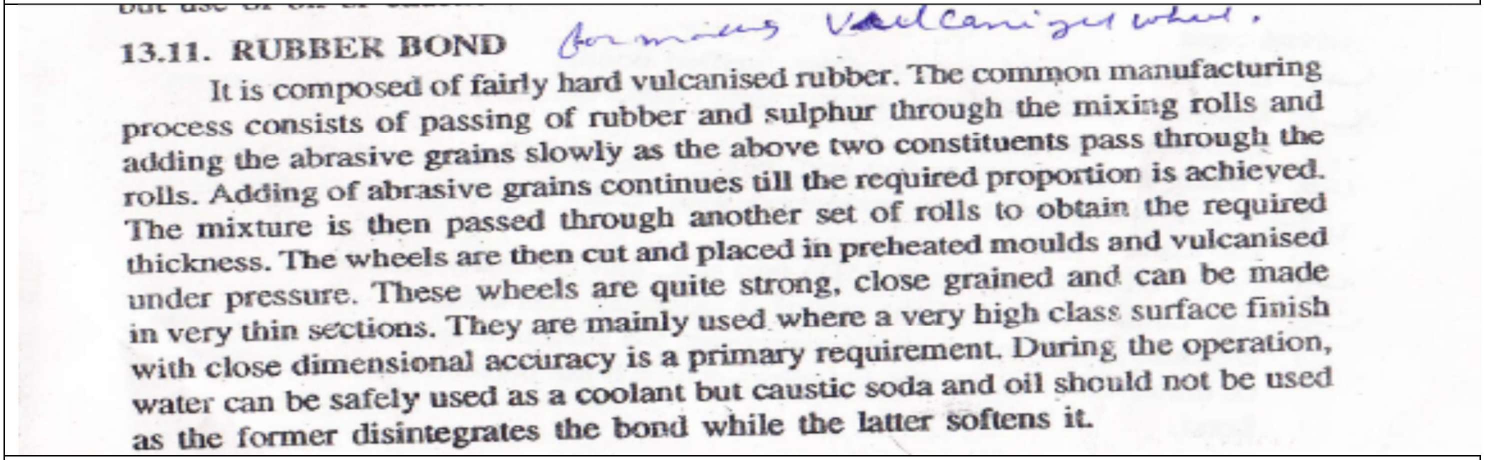
UNIT V (b)



13.9. RESINOID BOND for resinoid wheel (6)

It is a synthetic organic compound, which is enough strong and flexible. It provides a sharp cutting action and enables a high rate of stock removal at high speeds. Resinoid bonded wheels are vastly employed for cutting bar stocks, fine grinding of cams, precision grinding of rolls, etc.

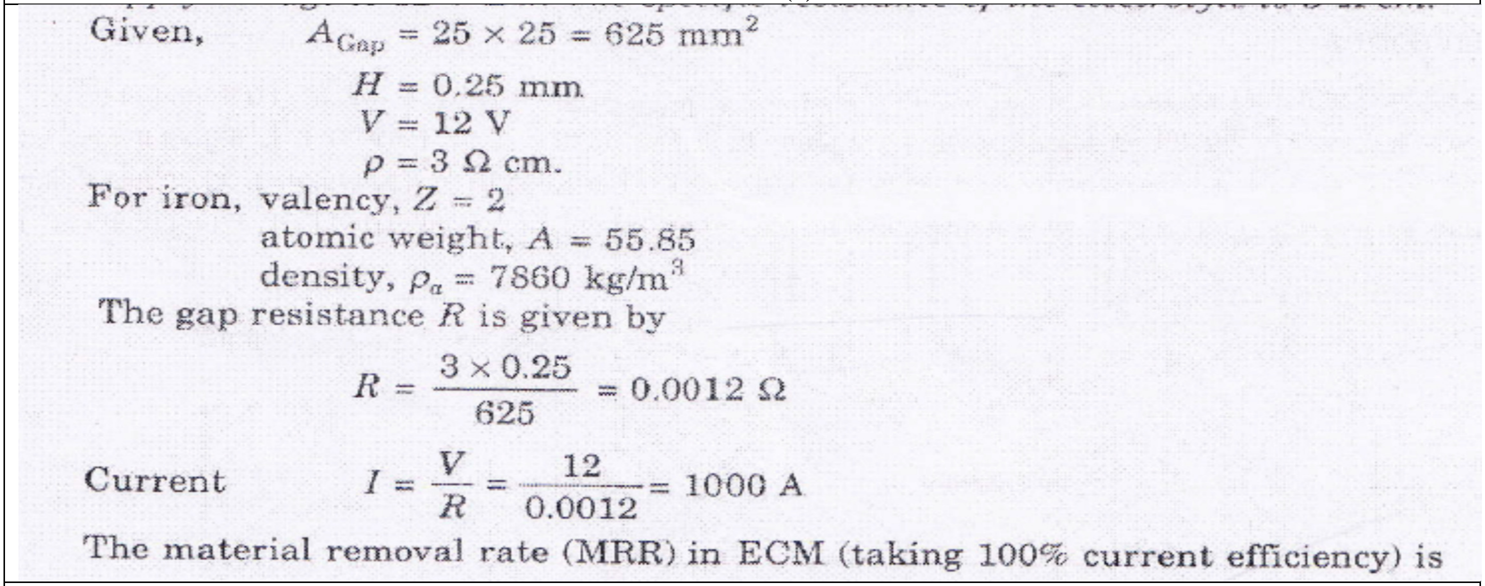
These wheels are manufactured from a mixture of abrasive grains, synthetic resins and some compounds. This mixture is filled in moulds and then fed into the furnace for heating. A constant temperature of about 200°C is maintained in the furnace. for making the mixture Due to heat, the resin sets and binds the abrasive grains together. The shape and size of the bonded wheels, thus produced, will depend upon the shape and size of the mould. - Some of the synthetic Resins are Bakelite and Redmanol



13.11. RUBBER BOND for making Vulcanised wheel.

It is composed of fairly hard vulcanised rubber. The common manufacturing process consists of passing of rubber and sulphur through the mixing rolls and adding the abrasive grains slowly as the above two constituents pass through the rolls. Adding of abrasive grains continues till the required proportion is achieved. The mixture is then passed through another set of rolls to obtain the required thickness. The wheels are then cut and placed in preheated moulds and vulcanised under pressure. These wheels are quite strong, close grained and can be made in very thin sections. They are mainly used where a very high class surface finish with close dimensional accuracy is a primary requirement. During the operation, water can be safely used as a coolant but caustic soda and oil should not be used as the former disintegrates the bond while the latter softens it.

UNITVI (c)



Given, $A_{Gap} = 25 \times 25 = 625 \text{ mm}^2$

$H = 0.25$ mm

$V = 12$ V

$\rho = 3\ \Omega$ cm.

For iron, valency, $Z = 2$

atomic weight, $A = 55.85$

density, $\rho_a = 7860 \text{ kg/m}^3$

The gap resistance R is given by

$$R = \frac{3 \times 0.25}{625} = 0.0012\ \Omega$$

Current $$I = \frac{V}{R} = \frac{12}{0.0012} = 1000 \text{ A}$$

The material removal rate (MRR) in ECM (taking 100% current efficiency) is

$$\text{MRR} = \frac{eI}{\rho F} = 3.68 \times 10^{-5} \text{ gm/s}$$