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Internal Assesment Test - II

Sub:	METAL CUTTING & FORMING							Code:	18ME35A
Date:	12/10/2019	Duration:	90 mins	Max Marks:	50	Sem:	III	Branch:	MECH (A&B)

Answer Any FIVE full Questions

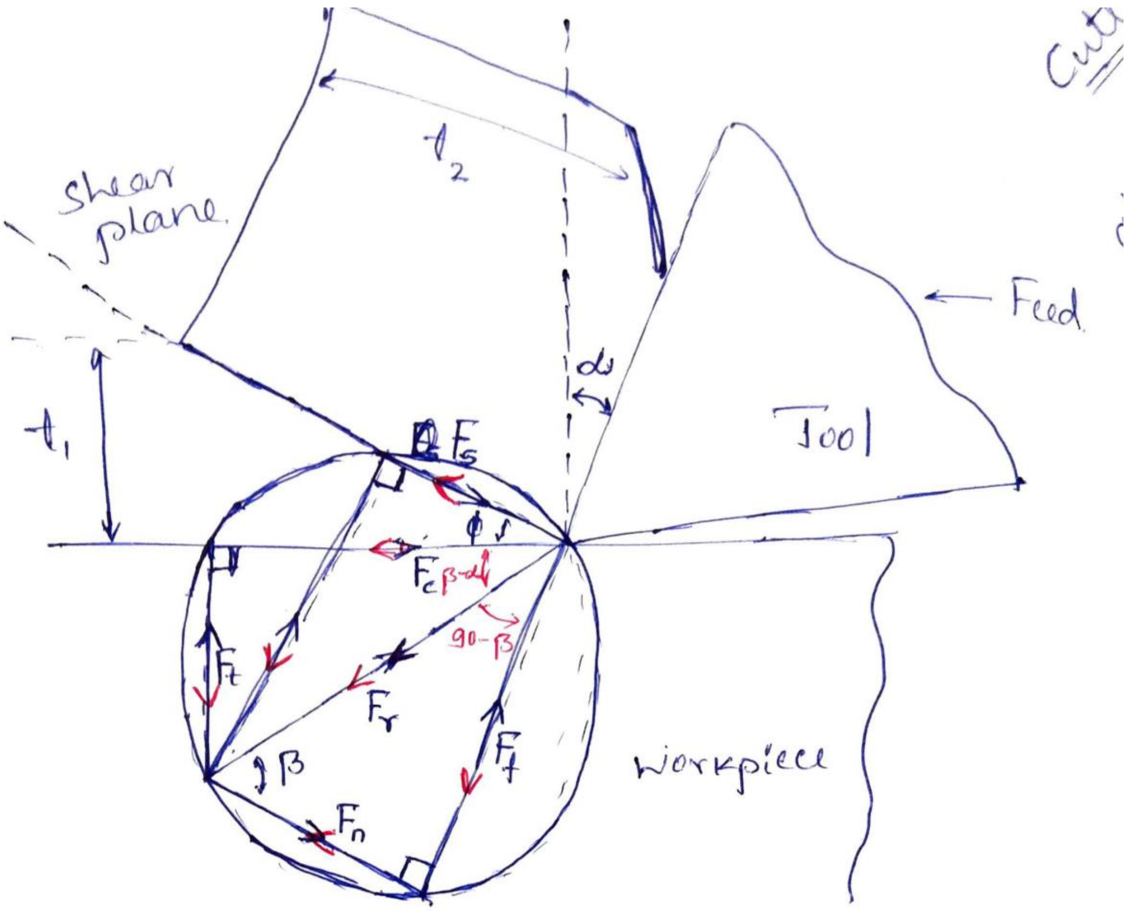
		Marks	OBE	
			CO	RBT
1	Draw Merchants force diagram and analyze the $2\emptyset+\beta-\alpha=\frac{\pi}{2}$ solution	[10]	CO3	L4
2	Describe with a neat sketch the construction & working of double house planner	[10]	CO1	L2
3	Explain in brief the following cutting tool materials (i) HSS (ii) Carbide tool (iii) Coated carbides	[10]	CO2	L2
4	Derive an expression for shear angle in terms of rake angle and chip thickness ratio	[10]	CO3	L3
5	In an orthogonal cutting process, the following data were observed: depth of cut = 0.25 mm, horizontal force = 1135 N, force component normal to horizontal force = 110 N, chip thickness ratio = 0.47, width of cut = 4 mm, cutting velocity = 30 m/min, and rake angle = 30°. Calculate the friction angle, shear plane angle, resultant cutting force, and power.	[10]	CO3	L3
6	Describe with a neat sketch the different cutting angles of single point cutting tool	[10]	CO2	L2

Merchant Analysis (Ernst - Merchant solution)

One of the earliest analyses of orthogonal cutting is due to Ernst and Merchant. The model is based on the minimization of rate of energy dissipation in the cutting process. The basic assumptions underlying the model are:

1) Tool edges is sharp.
2) The cutting edge is a straight line and moves perpendicular in the direction of feed.
3) The work material suffers deformation across a thin shear plane.
4) ~~Thickness~~ The depth of cut is constant.
5) The chip is continious, there is no side spread.
6) Width of tool is greater than width of work material.
7) There is uniform distribution of normal and shear stresses on the shear plane.
8) The work material is rigid, perfectly plastic.
9) ~~Uniform~~ The workpiece passes the tool with a uniform velocity.

Consider the chip formation process in an orthogonal cutting system as shown in figure —.



<u>Let</u>,

α = Rake angle
ϕ = Shear angle
F_f = Friction force along the tool face.
β = Friction angle
F_n = Normal force to the tool face
F_s = Shear force along the shearplane
F_{ns} = Force normal to the Shearforce.
F_c = Horizontal cutting force created by the tool on the workpiece.
F_t = Thrust force, helps to holding the tool in position
F_r = Resultant ~~force~~ tool force.

Cutting Forces in Orthogonal Cutting

Fig shows the different components of resultant cutting forces Fr.

In orthogonal cutting the component of F_r in the direction of the width 'b' is zero. Therefore, F_r may be resolved into two orthogonal components. According to the chosen directions, the components useful for analysis, ~~are as follows~~.

1) F_n & F_t in directions normal to and along the tool face
2) F_{ns} & F_s to normal to and along the shear plane.

From the geometric relation between force components given by the following equations.

$$F_c = F_s \cos\phi + F_{ns} \sin\phi \quad \text{——— (1)}$$

$$F_t = F_{ns} \cos\phi - F_s \sin\phi \quad \text{——— (2)}$$

$$F_f = F_c \sin\alpha - F_t \cos\alpha \quad \text{——— (3)}$$

$$F_n = F_c \cos\alpha - F_t \sin\alpha \quad \text{——— (4)}$$

$$F_s = F_c \cos\phi - F_t \sin\phi \quad \text{——— (5)}$$

$$F_{ns} = F_c \sin\phi - F_t \cos\phi \quad \text{——— (6)}$$

$$F_r = \frac{F_c}{\cos(\phi + \beta - \alpha)} \quad \text{——— (7)}$$

$$\therefore F_c = F_r \cos(\phi + \beta - \alpha) \quad \text{——— (8)}$$

$F_c = F_r \cos(\beta - \alpha)$ —— (9)

$F_t = F_r \sin(\beta - \alpha)$ —— (10)

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From equation (8) we can write

$F_s = F_r \cos(\phi + \beta - \alpha)$ —— (11)

$F_s = \tau_s A_s$

$F_s = \dfrac{\tau_s A_o}{\sin\phi}$ —— (12)

The coefficient of friction is given by the relation

$\mu = \dfrac{F_f}{F_n} = \dfrac{F_c \sin\alpha + F_t \cos\alpha}{F_c \sin\alpha - F_t \sin\alpha}$ —— (13)

~~Therefore~~,

From eqn (11) & (12)

$F_r = \dfrac{\tau_s A_o}{\sin\phi \cdot \cos(\phi + \beta - \alpha)}$ —— (14)

from geometry.

$F_c = F_r \cos(\beta - \alpha)$ —— (15)

from equations (14) & (15)

$F_c = \dfrac{\tau_s A_c}{\sin\phi} \dfrac{\cos(\beta - \alpha)}{\cos(\phi + \beta - \alpha)}$ —— (16).

~~Here~~ The Merchant's analysis is based on the minimization of rate of energy consumption which is equal to $F_c \cdot V$.

Let us assume that ϕ and β are not functions of V. Therefore, minimization of F_c is same as minimization of $F_c \cdot V$.

For optimum value of ϕ we have,

$$\frac{dF_c}{d\phi} = 0$$

or $$\frac{\tau_s \cos(\beta-\alpha)\left[\cos\phi \cos(\phi+\beta-\alpha) - \sin\phi \sin(\phi+\beta-\alpha)\right]}{\sin^2\phi \cdot \cos^2(\phi+\beta-\alpha)} \quad \text{---} (17)$$

where, $\sin\phi \neq 0$, and also $\cos(\phi+\beta-\alpha) \neq 0$
Therefore, the numerator is equal to zero.
Also $\cos(\beta-\alpha)$ cannot be zero. Hence

$$\cos(2\phi+\beta-\alpha) = 0 = \cos\frac{\pi}{2} \quad (18).$$

which gives $(2\phi+\beta-\alpha) = \frac{\pi}{2}$

$$\boxed{\phi = \frac{\pi}{4} - \frac{\beta}{2} + \frac{\alpha}{2}} \quad \text{---} (19).$$

1) High Speed Steels :- (HSS)

High speed steel is an alloyed steel with 14 - 22% tungsten, as well as cobalt, molybdenum, chromium and vanadium. The tools made of such steels are popularly known as HSS tools, materials cut about four times faster than the carbon steel tools, which was once the only cutting tool available for metal cutting operations. These are the most widely used tool materials in the present day engineering industries. They can retain their hardness under high cutting speeds where temp. are as high as 650°C. and can operate satisfactorily at speeds 2 to 3 times of those of plain-carbon steels.

Types of HSS tools :- There are three classes of high speed steel tools, viz, high-tungsten (W), high molybdenum (Mo), and high cobalt (Co) steels.

Tungsten imparts higher hot hardness, molybdenum retains a sharp cutting edge and cobalt provides high wear resistance.

★ High speed steel (18-4-1) :- This is high tungsten steel also termed T-series HSS, containing 18% W, 4% Cr and 1% Va. This is the highly efficient of all high speed steel tools, since it possesses good wear resistance and high heat resistance.

★ High speed steel (6-6-4-2) :- This is high molybdenum steel also termed as M-series and contains 6% Mo, 6% W, 4% Cr and 2% Va. Such steel has high toughness (impact strength) and cutting strength. The percentage of alloying constituents can be raised to suit the requirements

super

2) Carbides :- Carbides are nonferrous, carbon base cutting tool materials with other elements. These tools have high modulus, high thermal conductivity, besides high hot hardness and low thermal expansion. These are termed as sintered or cemented carbides, since they have manufactured by powder metallurgy techniques. These are also termed uncoated carbides to distinguish them from coated tools. There are two classes of carbides depending upon the major constituent in them: WC and TiC

→ Tungsten Carbide :- Cemented tungsten Carbide, often called simple carbide is the most common material used for manufacturing cutting tools. The chief advantage of carbide versus HSS is the ability to cut at higher speeds. carbide tools cut 3-5 times faster than HSS & hence, have replaced HSS in many applications.

Cemented tungsten Carbide is produced by a powder metallurgy technique by sintering a combination of tungsten carbide powder with powdered cobalt (Co), a ductile metal that serves as a binder for the externally hard tungsten carbide particles. The material so obtained possess high strength, toughness & hardness compared to
es. high strength, toughness & hardness compared to HSS materials. Cemented tungsten carbide materials can be used to produce both inserts & solid tools. However, the high cost & low rupture strength makes them to be used in the form of tips. which are brazed or clamped on to the steel shank.

These clamped tips are used as throw away inserts. This gives the benefits of using carbides for tools in the form of inserts without the high cost of making the entire tool out of carbide.

☆ Titanium Carbide (TiC) :- TiC tools inserts are made by blending TiC particles in a nickel-molybdenum alloy matrix. These tools have a higher wear resistance than the 'WC' tools, but lower toughness because of the absence of Cobalt. These are suitable for high speed machining of hard steels and cast irons.

4) Coated Carbides :-

Cutting with carbide tools is slightly difficult because carbide is more brittle than other tool materials thereby making it susceptible to chipping and breaking. To increase the life of the carbide tools, they are coated with certain materials like titanium carbide (TiC), titanium nitride (TiN), ceramics, diamond etc, and hence are called coated carbides. Of all the coatings, Titanium carbide (TiC) is the most widely used.

Coating allows the cutting edge of the tool to clearly pass through the workpiece material without having the material stick to it. It also provides longer wear resistance and helps to decrease the temp. associated with the cutting process thereby increasing the life of the tool. Coating is usually deposited via a thermal chemical vapour deposition (CVD) technique.

Determination of Shear Plane and Shear Angle

In the formation of chip, the work material ahead of the tool tip suffers plastic deformation by shearing action. The work material shears across a plan and forms the chip. Plane defines, it is a narrow zone starting from cutting edge of the tool to the work surface. This plane is called Shear Plane (fig 3.5)

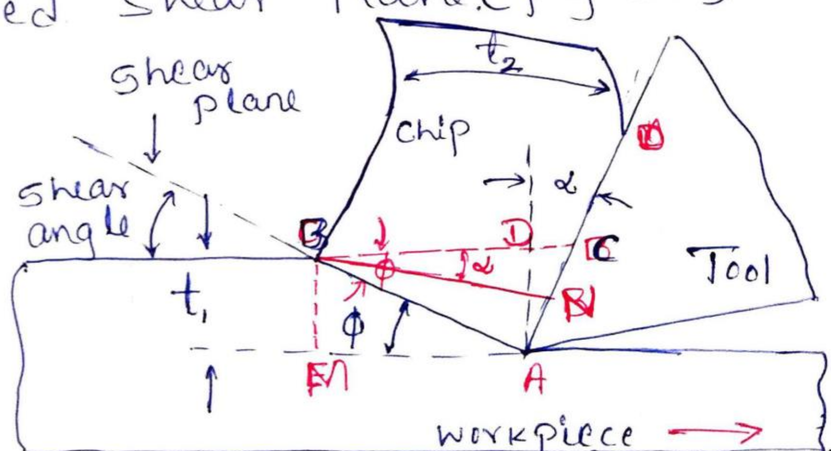


Fig 3.5 Shear Plane & Shear Angle.

The shear plane is denoted by angle Now ϕ.
The chip material comes entirely from work material and also material flow is Continious. In plastic deformation there is negligible Change in volume of work material, hence we can write.

$$t_1 b_1 V = t_2 b_2 V_c \quad \text{———} \quad (1)$$

where
t_1 = thickness of uncut chip or depth of cut
b_1 = width of uncut chip
t_2 = thickness of cut chip
b_2 = width of cut chip.
V = Cutting velocity
V_c = Chip velocity

In most cutting processes b_1 is nearly equal to b_2. Hence.

$$t_1 V = t_2 V_c \quad \text{———} \quad (2)$$

Therefore,

$$\frac{t_1}{t_2} = \frac{V_c}{V} = r_0 \quad \text{———} \quad (3)$$

where
r_c = Chip thickness ratio

$r_c < 1$.

(3)

Now draw two perpendiculars BM & BN from 'B' as shown in fig 3.5. Also extend the line BC parallel to the horizontal plane AM upto the tool surface. Mark point D, which is the intersection of SP on a normal drawn at A in the plane AM.

From, right angled triangles BNA and CDA,

$$\angle CBN = \angle CAD = \alpha$$

or $\angle NBA = \angle CBA - \angle CBN = \phi - \alpha$

we can write the length of AB as follows.

$$AB = \frac{MB}{\sin\phi} = \frac{NB}{\cos(\phi-\alpha)}$$

$$AB = \frac{t_1}{\sin\phi} = \frac{t_2}{\cos(\phi-\alpha)} \quad \text{--- (4)}$$

where α is the rake angle of the tool.

Hence

$$\boxed{\frac{t_1}{t_2} = r_c = \frac{\sin\phi}{\cos(\phi-\alpha)}} \quad \text{--- (5)}$$

The Equation (5), $r = \dfrac{\sin\phi}{\cos(\phi-\alpha)}$

or $$r = \frac{\sin\phi}{\cos\phi\cos\alpha + \sin\phi\sin\alpha}$$

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

Dividing both side by $\cos\phi$, we get

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

By rearranging, we get

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

or $\tan\phi = \dfrac{r\cos\alpha}{1 - r\sin\alpha}$.

Given

1) Depth of cut = t_1 = 0.25 mm
2) Horizontal force = F_c = 1135 N
3) Normal force = F_t = 110 N
4) Chip thickness ratio = r = 0.47
5) Width of cut = b = 4 mm
6) Cutting velocity = V = 30 m/min.
7) Rake angle = 30°

~~Calculate~~ -

1) Friction angle = β

$\beta = \tan^{-1}\mu$

where $\mu = \dfrac{F_f}{F_n} = \dfrac{F_c\sin\alpha + F_t\cos\alpha}{F_c\cos\alpha - F_t\sin\alpha}$ (1)

$= \dfrac{1135\sin 30 + 110\cos 30}{1135\cos 30 - 110\sin 30}$

$\mu = 0.71$ (1)

$\therefore \beta = \tan^{-1} 0.71$

$\boxed{\beta = 35.5^\circ}$ (1)

2) Shear plane angle = ϕ.

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

$$= \frac{0.47\cos 30}{1 - 0.47\sin 30}$$

$\tan\phi = 0.53$

$$\boxed{\phi = 27.92} \quad \text{——— (2)}$$

3) Resultant cutting Force = R

$$R = \sqrt{F_c^2 + F_t^2}$$

$$= \sqrt{1135^2 + 110^2}$$

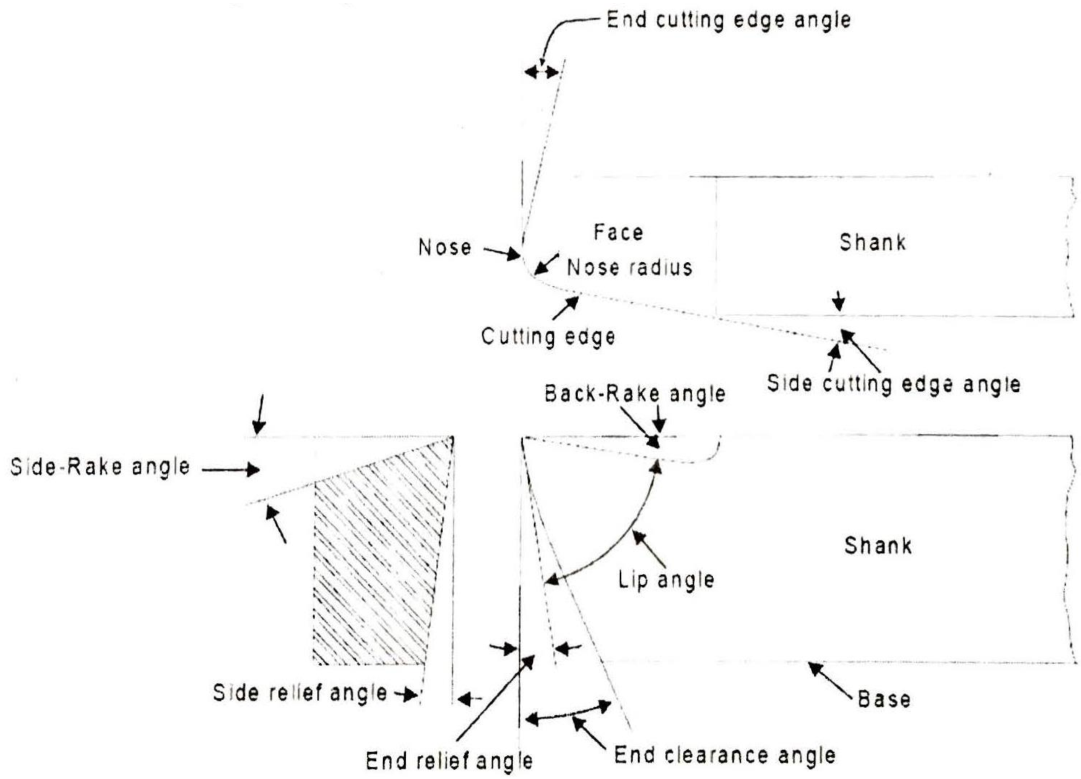
$R = 1140.3$ N.

4) Power = P

$$P = \frac{F_c \times V}{60000} \text{ kW.}$$

$$P = \frac{1135 \times 30}{60000}$$

$P = 0.56$ kW



(i) Back rake angle: Back rake angle is the angle between the face of the single point cutting tool and a line parallel with base of the tool measured in a perpendicular plane through the side cutting edge. If the slope face is downward toward the nose, it is negative back rake angle and if it is upward toward nose, it is positive back rake angle. Back rake angle helps in removing the chips away from the workpiece.

(ii) Side rake angle: Side rake angle is the angle by which the face of tool is inclined sideways. Side rake angle is the angle between the surface the flank immediately below the point and the line down from the point perpendicular to the base. Side rake angle of cutting tool determines the thickness of the tool behind the cutting edge. It is provided on tool to provide clearance between workpiece and tool so as to prevent the rubbing of workpiece with end flake of tool.

(iii) End relief angle: End relief angle is defined as the angle between the portion of the end flank immediately below the cutting edge and a line perpendicular to the base of the tool, measure it at right angles to the flank. End relief angle allows the tool to cut without rubbing on the workpiece.

(1v) Side relief angle: Side rake angle is the angle between the portion of the side flank immediately below the side edge and a line perpendicular to the base of the tool measured at right angles to the side. Side relief angle is the angle that prevents the interference as the tool enters the material. It is incorporated on the tool to provide relief between its flank and the workpiece surface.

(v) End cutting edge angle: End cutting edge angle is the angle between the end cutting edge and a line perpendicular to the shank of the tool. It provides clearance between tool cutting edge and workpiece.

(vi) Side cutting edge angle: Side cutting edge angle is the angle between straight cutting edge on the side of tool and the side of the shank. It is responsible for turning the chip away from the finished surface.

(vii) Nose radius: It is the radius provided at the tip of the cutting edge.