UNIT 2 DESIGN OF SINGLE POINT CUTTING TOOLS

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2.1 INTRODUCTION

Design of single point cutting tool is an important aspect of tool engineering. This unit deals with the design of tool shank, design of single point cutting tool, and various forces involved during machining of the workpiece. Strength and rigidity of tool is also taken into account while designing single point cutting tool.

Objectives

After studying this unit, you should be able to

- design tool shank,
- design single point cutting tool,
- select appropriate tool material, and
- calculate and analyze the forces acting on tool.

2.2 DESIGN OF TOOL SHANK

The shank of a cutting tool is generally analyzed for strength and rigidity. Tool is assumed to be loaded as a cantilever by tool forces at the cutting edge as shown in Figure 2.1.

![Figure 2.1: Forces Acting on Tool Shank](image_url)
Design of Cutting Tools and Holding Devices

The notations used in design of shank is given below:

- \( F \) = Permissible tangential force during machining, N
- \( f \) = Chatter frequency, cycle per second (c.p.s)
- \( H \) = Depth of shank, mm
- \( B \) = Width of shank, mm
- \( L_0 \) = Length of overhang, mm
- \( d \) = Deflection of shank, mm
- \( E \) = Young’s modulus of material, N/mm\(^2\)
- \( I \) = Moment of inertia, mm\(^4\)
- \( h_c \) = Height of centres, mm
- \( \sigma_{ut} \) = Ultimate tensile strength, N/mm\(^2\)
- \( \sigma_{pe} \) = Permissible stress of shank material, N/mm\(^2\)
- \( L_c \) = Length of centres, mm

The main design criterion for shank size is rigidity. The deflection at the cutting edge is limited to a certain value depending on the size of machine, cutting conditions and tool overhang. The tool overhang \((L_0)\) is related also to the shank size as well as to the end support conditions. Figure 2.2 shows graph of the amplitude and frequency of chatter for several overhang values. It is seen from Figure 2.2 that only below \( L_0/H = 2 \), the amplitude is practically zero. The recommended value of \((L_0/H)\) lies between 1.2 and 2.

For the given value of chatter frequency \( f \), the shank deflection can be calculated from the (Eq. 2.1) given as follows.

\[
 f = \frac{(15.76)}{\sqrt{d}} \text{ c.p.s.} \quad \ldots (2.1)
\]

where, \( d \) is deflection in mm.

Now as chatter frequency ranges from 80 to 160 c.p.s.,

Let \( f = 100 \) c.p.s

\[
d = \left(\frac{15.76}{100}\right)^2 \approx 0.025 \text{ mm} \quad \ldots (2.2)
\]
The permissible deflection of shanks ranges from 0.025 mm for finish cuts to 0.9 mm for rough cuts. Considering shank as a cantilever,

\[ d = \frac{FL^3}{3EI} \]

\[ d = \frac{FL^3}{3E} \left( \frac{12}{BH^3} \right) = \frac{4FL^3}{EBH^3} \]

\[ = 0.025 \text{ mm} \]

It can be noted that the same value of \( d \) has been obtained from Eq. (2.2) also.

The shank size can be estimated with respect to machine tool size by the following method:

(a) The force \( F \) for given size of lathe is given by

\[ F = f \times t \times C \]

where, \( f \) is the feed in mm,

\( t \) is the depth of cut in mm, and

\( C \) is cutting force constant.

(b) Nicolsons Manchester experiments have set a standard area of cut for lathe design given by

\[ A_c = f \times t \]

Let, \( f = h_c/180 \text{ mm} \) and \( t = h_c/25 \text{ mm} \)

\[ A_c = \frac{h_c}{180} \times \frac{h_c}{25} \]

\[ = \frac{h_c^2}{4500} \text{ mm}^2 \]

where, \( h_c \) is height of centre in mm,

Let, \( \sigma_{ut} = 440 \text{ N/mm}^2 \)

\[ C = 4\sigma_{ut} \]

\[ = 4 \times 400 = 1760 \text{ N/mm}^2 \]

When

\[ F = \frac{h_c^2}{4500} \text{ mm}^2 \times 1760 \text{ N/mm}^2 \]

\[ = 0.4 h_c^2 \text{ N} \]

On substituting the value of \( F = 0.4 h_c^2 \) in Eq. (2.3), we get

\[ d = \frac{4(0.4 h_c^2) L_0^3}{EBH^3} \]

\[ 0.025 = \frac{4(0.4 h_c^2) L_0^3}{EBH^3} \]

As, \( d = 0.025 \) from Eq. (2.2). Thus,

\[ = \frac{(1.6 h_c^2) L_0^3}{EBH^3} \]

\( B = 0.6 \text{ H} \) for rectangular shanks
Then, \( \frac{h_c^2}{H^4} = 0.6 \frac{ED}{L_0^3} \)

Let \( L_0 = 3 \text{ mm}, E = 200 \text{ kN/mm}^2 \)
and \( d = 0.025 \text{ mm}, \) (From Eq. (2.2))

On substituting these values in above equation, i.e. \( \frac{h_c^2}{H^4} = 0.6 \frac{ED}{L_0^3} \), we get

\[ \frac{h_c^2}{H^4} = 1000 \text{ mm}^{-2} \]

Table 2.1 shows the standard shank size according to this rule.

<table>
<thead>
<tr>
<th>Height of Centres ( h_c ) (mm)</th>
<th>Shank Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( H ) (mm)</td>
</tr>
<tr>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>300</td>
<td>30</td>
</tr>
<tr>
<td>350</td>
<td>40</td>
</tr>
</tbody>
</table>

Usually the shank size is also checked for strength.

Noting, \( FL_0 = \frac{1}{6} BH^2 \sigma_1 \)

\[ \therefore \sigma_1 = \frac{6FL_0}{BH^2} \]

When the effect of \( F_x \) included,

\[ \sigma = \sigma_1 + \sigma_2 = \frac{6FL_0}{BH^2} + 6 F_x \frac{L_0}{HB^2} \quad \ldots (2.4) \]

\( F_x \) = Component of force \( F \) acting in \( x \) direction (in Newton)

\( F_x = 0.3 \) to 0.40 F

Hence,

\[ \sigma = \frac{6FL_0}{BH} \left( \frac{0.4}{B} \right) + \left( \frac{1}{H} \right) < \sigma_{\text{per}} \quad \ldots (2.5) \]

This can be expressed as

\[ F = \left\{ \frac{BH}{0.4} + \left( \frac{1}{H} \right) \right\} \sigma_{\text{per}} \left( \frac{6L_0}{B} \right) \quad \ldots (2.6) \]

where, \( F \) is permissible tangential force during machining.

The maximum depth of shank \( (H_{\text{max}}) \) must be less than the value \( h_k \) as shown in Table 2.2.
SAQ 1

(a) Which parameters are considered for designing tool shank?
(b) How one can design tool shank?

2.3 DESIGN OF TOOL GEOMETRY

2.3.1 Basic Elements

The basic elements of tool are shown in Figure 2.3.

Error!

Symbol used in figure are:

\( \alpha_b \) – Back rake angle
\( \alpha_s \) – Side rake angle
\( \theta_e \) – End relief angle
\( \theta_s \) – Side relief angle
\( C_c \) – End cutting edge angle
\( C_s \) – Side cutting edge angle

Size

It is determined by the width of shank, height of shank and overall length.

Shank

Shank is main body of a tool. It is held in a holder.
Flank

Flank is the surface or surfaces below and adjacent to cutting edge.

Heel

Heel is intersection of the flank and base of the tool.

Base

Base is the bottom part of the shank. It takes the tangential force of cutting.

Face

Face is surface of tool on which chip impinges when separated from workpiece.

Cutting Edge

Cutting edge is the edge of that face which separates chip from the workpiece. The total cutting edge consists of side cutting edge, the nose and end cutting edge.

Tool Point

That part of tool, which is shaped to produce the cutting edge and the face.

The Nose

It is the intersection of side cutting edge and end cutting edge.

Neck

Neck is the small cross section behind the point.

Side Cutting Edge Angle

The angle between side cutting edge and side of the tool shank is called side cutting edge angle. It is also called as lead angle or principle cutting angle.

End Cutting Edge Angle

The angle between the end cutting edge and a line perpendicular to the shank of tool is called end cutting edge angle.

Side Relief Angle

The angle between the portion of the side flank immediately below the side cutting edge and line perpendicular to the base of tool measured at right angles to the side flank is known as side relief angle. It is the angle that prevents interference, as the tool enters the work material.

End Relief Angle

End relief angle is the angle between the portion of the end flank immediately below the end cutting edge and the line perpendicular to the base of tool, measured at right angles to end flank. It is the angle that allows the tool to cut without rubbing on the workpiece.

Back Rake Angle

The angle between face of the tool and a line parallel with the base of the tool, measured in a perpendicular plane through the side cutting edge is called back rake angle. It is the angle which measures the slope of the face of the tool from the nose toward the rear. If the slope is downward toward the nose, it is negative back rake angle. And if the slope is downward from the nose, it is positive back rake angle. If there is not any slope, back rake angle is zero.

Side Rake Angle
The angle between the face of the tool and a line parallel with the base of the tool, measured in a plane perpendicular to the base and side cutting edge is called side rake angle. It is the angle that measures the slope of the tool face from cutting edge. If the slope is towards the cutting edge, it is negative side rake angle. If the slope is away from the cutting edge, it is positive side rake angle.

All the tool angles are taken with reference to the cutting edge and are, therefore, normal to the cutting edge. A convenient way to specify tool angle is by use of a standardized abbreviated system called tool signature. Sometimes it is also called as tool character. Tool signature also describes how the tool is positioned in relation to the workpiece.

The **signature for single point tool** is listed in the order as rake angles (back and side), relief angles (end and side), cutting edge angles (end and side) and nose radius.

**Example 2.1**

Tool signature of High speed steel tool: 0-7-7-15-15-0.5

**Solution**

This implies that HSS tool has

- Back rake angle = 0°,
- Side rake angle = 7°,
- End relief angle = 7°,
- Side relief angle = 7°,
- End cutting edge angle = 15°,
- Side cutting edge angle = 15°, and
- Nose radius = 0.5 mm.

**2.3.2 Influence of Various Angles on Tool Design**

**Back Rake Angle**

The rake angle of single point cutting tool is useful in determining the direction of chip flow across the face of the tool.

(a) A positive back rake angle is responsible to move the chip away from the machined workpiece surface.

(b) The tool penetrates the workpiece easily and tends to shear the material off rather than compressing. So the cutting efficiency is best with positive back rake angle.

(c) Forces and power consumption reduces with increase in positive back rake angle.

(d) If positive back rake angle increases, resisting area of tool decreases.

Generally, for softer workpiece, back rake angle of 25° to 30° is preferable and for harder workpiece back rake angle of 7° to 10° is preferable. Negative back rake angle is preferable for carbide tool. Carbide tools are very brittle in nature, so deformation occurs if we provide positive back rake angle. To avoid deformation, negative back rake angle is provided.

Positive back rake angle is used for machining low tensile strength and non ferrous materials. They are also used during machining of long/small diameter shafts or material that is work hardened during machining. Negative back rake angles are used for machining high tensile strength material, heavy feed and interrupted cuts.

**Side Rake Angle**
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Side rake angle should be positive. The significance of side rake angle is that it is used to avoid rubbing action between tool and workpiece.

Relief Angle

The main significance of relief angle is that it prevents rubbing action below cutting edge. Small relief angle gives maximum support below the cutting edge and is necessary while machining hard and strong workpiece. Too much relief angle weakens the cutting edge and failure of tool may takes place. Relief angles generally lie between 5° to 15°.

Side Cutting Edge Angle

It may vary from 0 to 90°. On increasing side cutting edge angle, the full length of cutting edge is not in contact with workpiece when the tool enters the cut. The tool takes a little shock load and gradually reaches the full depth of cut without any impact.

If side cutting edge angle is 0°, the full length of cutting edge is in touch with workpiece at once and produces severe initial shock. If side cutting edge angle is less, forces on tool will reduce as a result of which less power consumption occur. Also with increase in side cutting edge angle, surface finish increases and vice-versa.

End Cutting Edge Angle

End cutting edge angle vary from 4° to 30°. End cutting edge angle prevents rubbing between the end of the tool and the workpiece. If end cutting edge angle is less, it will cause vibration because of excessive tool contact with workpiece. With end cutting edge angle, surface finish decreases and vice-versa.

Nose Radius

Nose radius is provided to increase strength of tip of the tool. This is done by thinning the chip where it approaches tip of tool and by enlarging the chip over a larger area of the point. It is also provided to increase the surface finish. If the radius is more, the surface finish will be good. But due to too large nose radius, contact between tool and workpiece increases, which in turn increase friction. Thus, power consumption increases, along with increase in vibration and chatter occurs.

SAQ 2

(a) Define the basic elements of tool geometry.
(b) What do you understand by tool signature? Illustrate with an example.
(c) How back rake angle influences the tool design?

2.4 SELECTION OF TOOL MATERIAL

The tool engineer is required to select material for variety of products such as cutting tools, jigs, punches, dies, special machine etc. A tool engineer must possess the knowledge of these materials and understand their properties. In addition, the various aspects of tooling, material cost, fabrication, manufacturing methods and the proper functioning of product should be considered.

2.4.1 Desirable Properties of Tool Material

The desirable properties of tool material are as follows:

Wear Resistance
Wear resistance should be as high as possible. Wear of tool is caused by abrasion, adhesion and diffusion. Wear resistance refers to the ability of tool material to retain its sharpness and shape for longer duration while machining is continued.

**Hot Hardness**

It is the measure of the ability of tool material to retain its hardness at high temperature. Hot hardness should be as high as possible especially at high temperature.

**Toughness**

It is the ability of material to absorb energy and deform plastically before failure and fracture. Tougher the material more is the ability to withstand external load, impact and intermittent cuts. Hence, toughness should be as high as possible.

**Coefficient of Thermal Expansion**

Coefficient of thermal expansion determines the influence of thermal stresses and thermal shocks on a material. It should be as low as possible so that tool does not get distorted after heat treatment, and remains easy to regrind and also easy to weld to the tool holder. Carbide have lower coefficient of thermal expansion than high speed steel and they develop lower thermal stress but are more sensitive to thermal shock because of their brittleness.

**Hardness**

It is the ability of material to resist the penetration, scratchimg, abrasion or cutting. Hardness of tool material should be as high as possible. Generally it should be higher than workpiece.

**Thermal Conductivity**

It should be as high as possible with a view to remove the heat quickly from chip tool interface.

### 2.4.2 Characteristics of Some Important Tool Material

Following are the tool materials in increasing order of their hardness:

**High Carbon Steel**

These are usually plain carbon steel containing 0.6 to 1.5% C. Method of fabrication for High Carbon Steel (HCS) is forging. HCS has hot hardness temperature of about 250°C. Also, its maximum cutting velocity is about 5 m/min. Hence, HCS is generally used for machining soft materials like aluminum, copper, magnesium etc. HCS is harder and the cheapest tool material.

**High Speed Steel**

High Speed Steel (HSS) is usually carbon steel containing 1.5 to 2% carbon, 18% tungsten, 4% chromium, 1% vanadium and rest is iron. Tungsten is added to increase hardness. Chromium is added to increase hot hardness. Vanadium is added to increase wear resistance. Method of fabrication for HSS is forging. Cutting velocity of HSS is 40-60 m/min. It gives higher speed than HCS. Hot hardness temperature of HSS is about 600°C.

Sometimes 18% molybdenum is added instead of tungsten to increase the wear resistance of tool. Then this HSS is called as molybdenum based HSS. But tungsten based HSS is commonly used. HSS has only disadvantage that during machining of pure carbon work material, diffusion of carbon atoms into iron is much more because iron has stronger affinity to attract carbon.

**Stellite**

These are non-ferrous cast alloys. Stellite contains 40-45% cobalt, 30% chromium, 14-25% tungsten and 2% carbon. Method of fabrication for stellite is casting. Its
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hot hardness temperature is about 800°C. Its hardness is same as that of HSS. It is a substitute for HSS during machining of pure carbon work material.

**Carbide**

Carbides are either tungsten carbide or cemented carbide. It contains 85-95% tungsten carbide and 5-15% cobalt. Hot hardness temperature of carbide materials is about 1000°C, and its cutting speed is 10 times greater than HSS. Since the cost is high, hence only tip is made by carbide, and regrinding is also not possible. Fabrication for carbide is carried out by employing powder metallurgical techniques.

**Ceramics**

These are also called as cemented oxide. Its major constituent is aluminum oxide and hot hardness temperature is about 1200°C. It also has higher cutting speed of about 300 to 400 m/min. It has better resistance to abrasion than cemented carbide. It also exhibits low coefficient of friction with most of work materials. These are used for higher production rate and for continuous operation only. The disadvantages of ceramic are very low toughness and highly brittle in nature. Fabrication for ceramic is done through powder metallurgical techniques.

**Cermets**

This is combination of ceramic and metal. It is substitute for ceramics. It contains 90% ceramics and 10% nickel. The method employed for fabrication of cermet is also powder metallurgical technique. Its hot hardness temperature is about 1000°C and cutting speed is about 250 m/min. Cermet gives better toughness than ceramic. It gives very good wear resistance.

**Diamond**

Diamond possesses all the desirable characteristics but has very high cost. Diamond is made by graphitization technique. Its hot hardness temperature is about 2000°C. Its hardness is higher than any other material. It is chemically inert and has high thermal conductivity. Its cutting speed is about 500 m/min. Diamond is extensively used for machining of non-ferrous alloys such as aluminum, magnesium, copper, brass etc. Diamond is not used for machining of ferrous material because diamond is basically pure carbon and diffusion of carbon into iron takes place due to affinity of iron atoms toward carbon.

**Cubic Boron Nitride**

Cubic Boron Nitride consists of atoms of boron and nitrogen. It is hardest material next to diamond. It is substitute for diamond during machining of ferrous alloys. It has high hardness and thermal conductivity.

**UCON**

It is combination of columbium, titanium and tungsten. It contains 50% columbium, 30% titanium and 20% tungsten. Method of fabrication is rolling. Its hardness is 2500 to 3000 Vickers. The speed range for UCON is 250 to 500 m/min of steel of 200 BHN. Cost of UCON is higher than diamond and is used only for very hard material. It has excellent shock resistance, resistance to diffusion and adhesion wear.

**Sialon**

It contains silicon, aluminum, oxygen and nitrogen. It is even costlier than ucon. Sialon is used during machining of interrupted cuts. Sialon tips are used for machining of aerospace alloys.

**SAQ 3**

(a) What are the desirable properties of tool material? Discuss their effects also.
(b) State some of the important characteristics of following tool material.
2.5 CALCULATION OF FORCES AND DESIGN FOR CUTTING FORCES

The forces acting on the tool are an important aspect of machining. The knowledge of force is required for determination of power and also to design the various elements of machine tool, tool holders and fixtures.

The cutting forces vary with the tool angle and accurate measurement of forces is useful in optimizing tool design. Dynamometers are capable of measuring tool forces with increasing accuracy. The component of forces acting on the rake face of tool, normal to the cutting edge is called cutting force, i.e. in the direction of line $YO$ in Figure 2.4.

![Figure 2.4: Forces Acting on the Workpiece](image)

Cutting force $F_c$ is largest of three forces acting on workpiece and its direction is in the direction of cutting velocity.

The force component acting on tool in direction of $OX$, parallel to the direction of feed, is feed force, $F_t$. It acts tangential to main cutting force, $F_c$.

The forces involved in machining are relatively low as compared to those in other metal working operations such as forging. This is because the layer of metal being removed (i.e. the chip) is thin, so forces to be measured are less in case of machining.

Here $F_c$ is cutting force, $F_s$ is shear force, $\phi$ is shear angle, $\beta$ is frictional angle and $\alpha$ is rake angle, $t_1$ is uncut chip thickness, and $t_2$ is chip thickness.

Figure 2.5 shows Merchants Circle for calculation of forces. Merchants force circle is used to determine various forces.
Coefficient of friction between chip-tool interface is given by
\[ \mu = \tan \beta \]

Now from merchants circle,
\[ R = \frac{F}{\sin \beta} = \frac{N}{\cos \beta} \quad \ldots (2.7) \]

where, \( R \) = Resultant force

Also,
\[ R = \frac{F_c}{\cos (\beta - \alpha)} = \frac{F_t}{\sin (\beta - \alpha)} \quad \ldots (2.8) \]

and,
\[ R = \frac{F_s}{\cos (\phi + \beta - \alpha)} = \frac{F_N}{\sin (\phi + \beta - \alpha)} \quad \ldots (2.9) \]

From Eqs. (2.7), (2.8), and (2.9)
\[ \frac{F_c}{\cos (\beta - \alpha)} = \frac{F_s}{\cos (\phi + \beta - \alpha)} \]
\[ F_c = F_s \frac{\cos (\beta - \alpha)}{\cos (\phi + \beta - \alpha)} \quad \ldots (2.10) \]

From Eq. (2.8), we get,
\[ \tan (\beta - \alpha) = \frac{F_t}{F_c} \]
\[ (\beta - \alpha) = \tan^{-1} \left( \frac{F_t}{F_c} \right) \]
\[ \beta = \alpha + \tan^{-1} \left( \frac{F_t}{F_c} \right) \quad \ldots (2.11) \]

Now, Shear Stress \( = \frac{F_s}{A_s} \)

From Figure 2.6(a), Shear area, \( A_s = b \times (AB) \)
AB = \frac{t_1}{\sin \phi}

A_s = \frac{t_1 b}{\sin \phi}

Shear stress,

\tau = \frac{F_s \sin \phi}{t_1 b} \quad \ldots (2.12)

If shear stress is greater than ultimate shear stress then only cutting takes place.

Figure 2.6(a) : Force Analysis

Total work done is given by

W = F_c V_c + F_t V_{Feed}

But \quad V_{Feed} = f N = very less (since linear velocity is low.)

Thus,

W = F_c V_c

But work done is equal to power.

So,

Power = F_c V_c

Now from Eq. (2.10),

\frac{F_c}{F_s} = \cos (\beta - \alpha) \quad \cos (\phi + \beta - \alpha)

Power = F_s \times V_c \frac{\cos (\beta - \alpha)}{\cos (\phi + \beta - \alpha)}

Various forces acting on orthogonal cutting when producing continuous chip is shown in Figure 2.6(b).

Figure 2.6 (b) : Force Analysis

But from Eq. (2.12),

\frac{F_s}{\sin \phi} = \frac{\tau t_1 b}{\sin \phi}
Power = \left[ \frac{\tau}{\sin \phi} \right] \times \left[ \frac{\cos (\beta - \alpha)}{\cos (\phi + \beta - \alpha)} \right] \times V_c

For minimum energy,
\[ \frac{dP}{d\phi} = 0 \]

On solving this, we get
\[ 2\phi + \beta - \alpha = 90 \]
\[ \phi = 45 - \frac{(\beta - \alpha)}{2} \quad \text{(Theoretical)} \]

If friction between chip-tool interface is 0, we get
\[ \phi = 45 + \frac{\alpha}{2} \]

Normal stress \( N \)
\[ = \frac{F_N}{A_S} \]
\[ = \frac{F_N \sin \phi}{t_i b} \]

**Example 2.1**

In an orthogonal cutting operation, the cutting velocity is 30 m/min and the chip velocity is 15 m/min. If the rake angle of the tool is 10°, calculate the shear angle and shear velocity.

**Solution**

Given:
- Cutting velocity, \( V_c = 30 \text{m/min} \)
- Chip velocity, \( V_f = 15 \text{m/min} \)
- Rake angle \( \alpha = 10^\circ \)
- Shear Velocity = \( V_s \)

We know that

Chip reduction ratio, \( r = \frac{V_f}{V_c} = \frac{15}{30} \)

Shear angle, \( \phi = \tan^{-1} \left( \frac{r \cos \alpha}{1 - r \sin \alpha} \right) \)
\[ = \tan^{-1} \left( \frac{0.5 \cos 10}{1 - 0.5 \sin 10} \right) \]
\[ = \tan^{-1} \left( \frac{0.49}{0.9131} \right) \]
\[ = 28.33^\circ \]
Velocity Vector Diagram

From velocity vector diagram,

\[
\frac{V_s}{\cos \alpha} = \frac{V_f}{\sin \phi}
\]

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

\[
V_s = \cos 10 \times \frac{15}{\sin 28.33}
\]

∴ \[V_s = 31.12 \text{ m/min}\]

Example 2.2

In an orthogonal cutting operation, the depth of cut is 2 mm, width is 15 mm, cutting speed is 0.5 m/s and the rake angle is 0°. The cutting force and thrust force are 900 N and 600 N respectively. Shear angle is 30°. Calculate coefficient of friction between the chip and the tool. Calculate power required in watt. Calculate length of shear plane.

Solution

Given data:

Depth of cut, \(d = 2 \text{ mm}\)
Width \(b = 15 \text{ mm}\)
Rake angle, \(\alpha = 00\)
Cutting force, \(F_c = 900 \text{ N}\)
Thrust force, \(F_t = 600 \text{ N}\)
Cutting speed \(V_c = 0.5 \text{ m/s}\)

\[
\tan (\beta - \alpha) = \frac{F_t}{F_c}
\]

∴ \[\tan (\beta - 0) = \frac{600}{900}\]

∴ \[\tan \beta = 0.67 = \mu\]

∴ \[\mu = 0.67\]

We know that,

\[
\text{Power} = F_c \times V_c
\]

Substituting the value of \(F_c\) and \(V_c\) from given data

\[
\text{Power} = 900 \times 0.5
\]

= 450 watt

Length of shear zone:
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Length of shear zone, \( L_s = \frac{t_i}{\sin \phi} = \frac{2}{\sin 30} = 4 \text{ mm} \)

SAQ 4

(a) Discuss various forces involved in machining operation.
(b) How one can design tool shank?
(c) Derive Frictional angle, \( \beta = \alpha + \tan^{-1} \left( \frac{F_i}{F_c} \right) \).
(d) Derive expression for power required during machining.
(e) Following data obtained during machining of mild steel with single point HSS tool rake angle of tool = 10°, uncut chip thickness = 0.3 mm, width of cut = 2 mm, shear plane angle = 36°, shear strength of mild steel = 450 MPa. Using Merchants analysis find out the coefficient of friction between the chip and tool. Also calculate shear force in cutting.
(f) A 0.2% carbon steel is machined with a triple carbide cutting tool having 0-10-6-6-8-75-1mm ORS shape, a feed of 0.15 mm/min have been employed. A chip thickness of 0.36 mm has been obtained. Calculate chip thickness coefficient and shear angle.

2.6 SUMMARY

Strength and rigidity are the important parameters while designing the shank of the cutting tool. Forces and power consumption decreases with increase in positive back rake angle. A positive back rake angle is responsible to move the chip away from the machined workpiece surface. The tool material should have high wear resistance, hot hardness, hardness, toughness, thermal conductivity, and low coefficient of thermal expansion. Cutting force, feed force and shear force acts on the workpiece and cutting force is the largest of these three forces. Dynamometers are used for measuring tool forces with great accuracy.

2.7 KEY WORDS

Back Rake Angle : It is the angle between face of the tool and a line parallel with the base of the tool. It moves the chip away from the machined workpiece surface.

Cutting Force : The component of forces acting on the rake of tool, normal to the cutting edge and in the direction of cutting velocity. It is the largest of three forces of component.

Merchants Circle : Used to determine forces.

2.8 ANSWERS TO SAQs

Refer the relevant text in this unit for answer to SAQ.

SAQ 4

(e) \( \mu = 0.531 \), shear force = 460 N.
(f) Chip thickness coefficient = 2.64, shear angle = 21.76°.