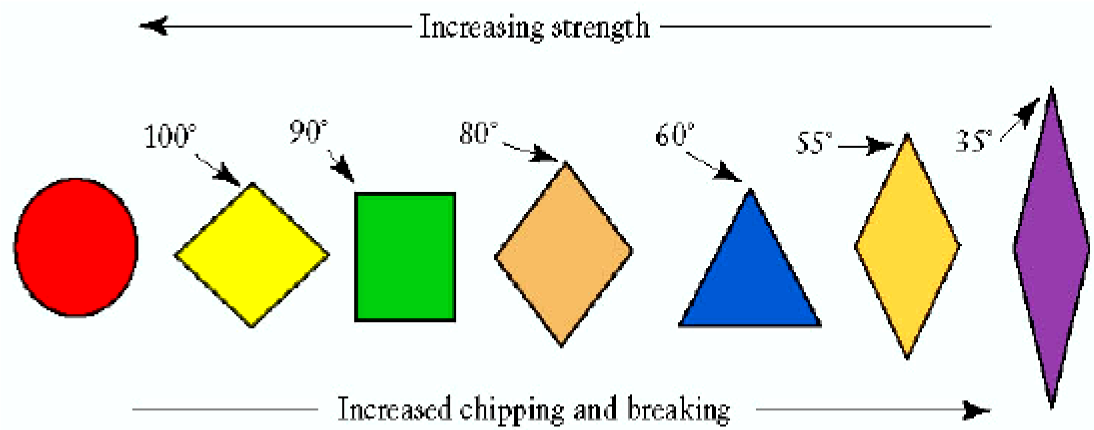
Cutting Parameters

Cutting Speed: Cutting speed is the distance traveled by the work surface in unit time with reference to the cutting edge of the tool.
The cutting speed, ***v*** is simply referred to as speed and usually expressed in m/min.

Feed: The feed is the distance advanced by the tool into or along the workpiece each time the tool point passes a certain position in its travel over the surface.
In case of turning, feed is the distance that the tool advances in one revolution of the workpiece.
Feed ***f*** is usually expressed in mm/rev. Sometimes it is also expressed in mm/min and is called feed rate.

Depth of cut : It is the distance through which the cutting tool is plunged into the workpiece surface.
Thus it is the distance measured perpendicularly between the machined surface and the unmachined (uncut) surface or the previously machined surface of the workpiece.
The depth of cut ***d*** is expressed in mm.

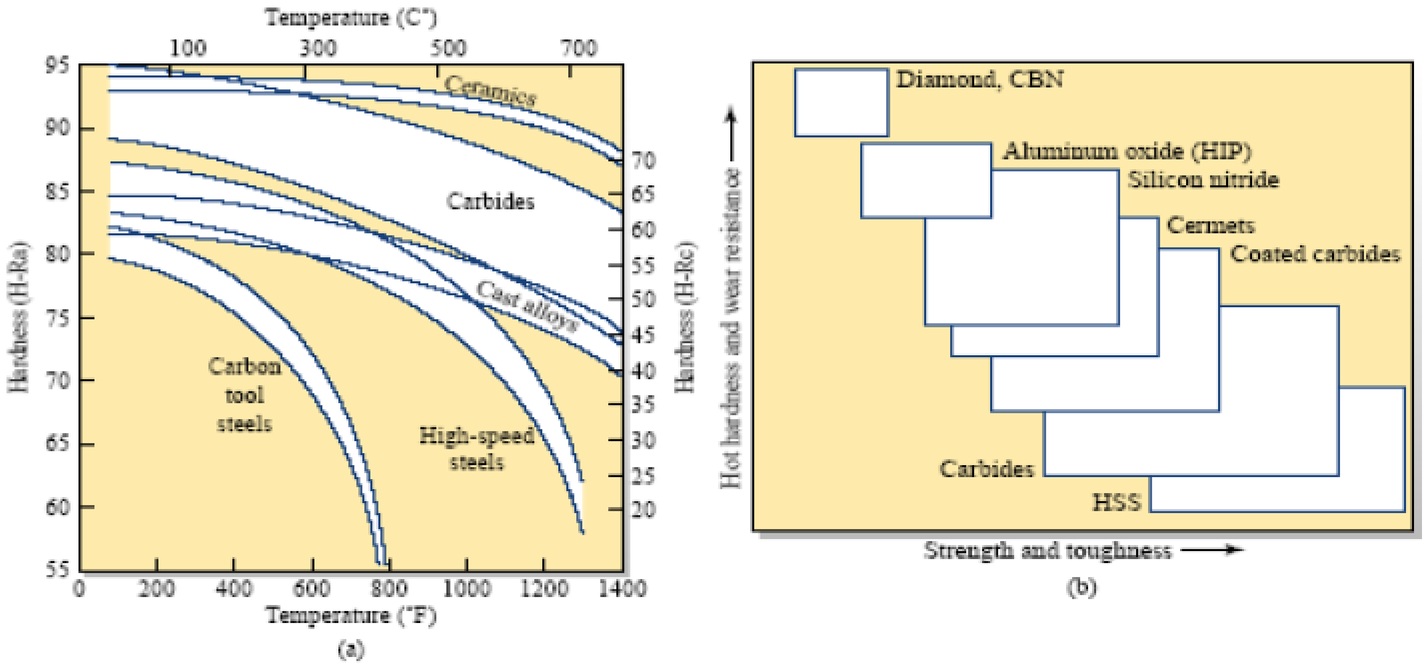
Cutting tools Angle



Factors affecting choice of insert shape	R	90	80	80	60	55	35
Roughing (strength)	●	●	●	○	○		
Light roughing/Semi-finishing (No. of edges)		○	●	●	●	●	
Finishing (No. of edges)			○	○	●	●	●
Turning and Facing (feed directions)			●	○	○	●	●
Profiling (Accessability)			○	○	○	●	●
Operational versatility	○		●	○	○	●	○
Limited machine power			○	○	●	●	●
Vibration tendencies (reduction)				○	●	●	●
Hard material	●	●					
Intermittent Machining	●	●	○	○	○		
Large entering angle			●	●	●	●	●
Small entering angle	●	●		●	●		

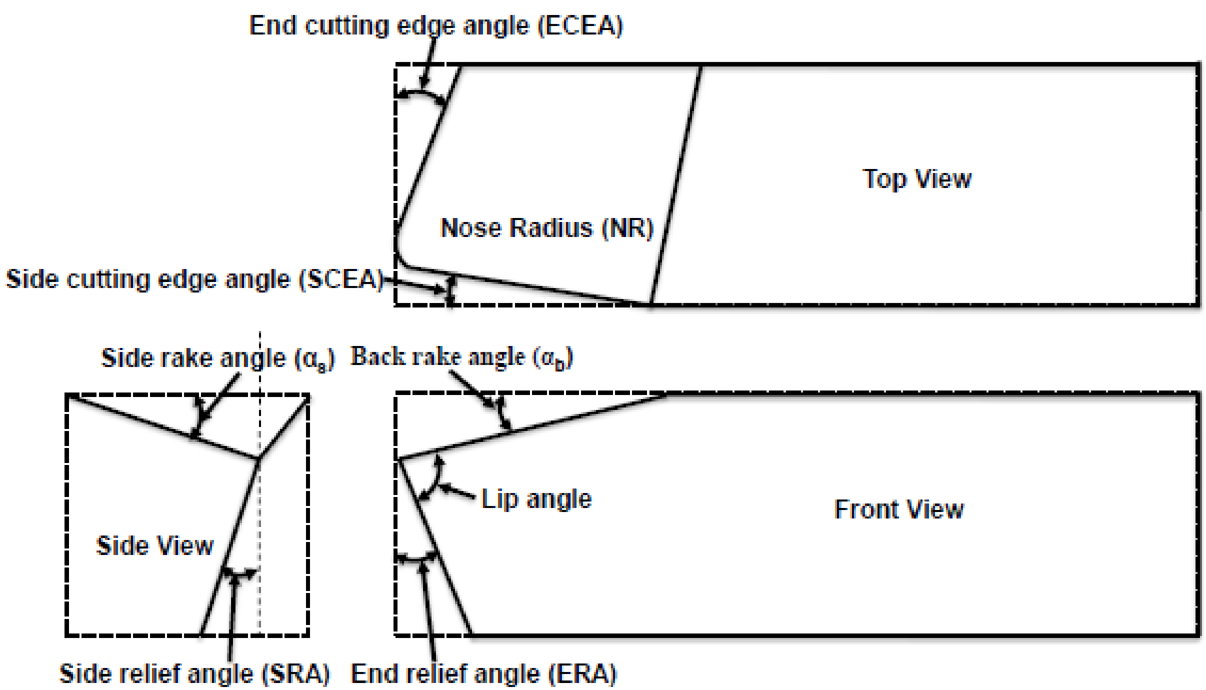
● Most suitable ○ Suitable

Cutting tool material hardness and strength



Cutting tool geometry

Geometry of negative rake single point cutting tool



Cutting Tool Angles

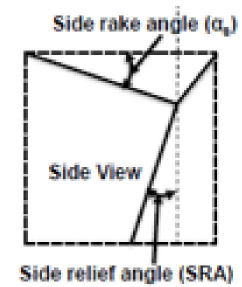
Back rake angle:

•The back rake angle is the angle between the face of the tool and a line parallel to the base of the shank in a plane parallel to the side cutting edge.

•The back rake angle affects the ability of the tool to shear the work material and form chip.

Side Rake Angles:

•It is the angle by which the face of the tool is inclined side ways.



The Rake Angle:

The rake angle is always at the topside of the tool.

The side rake angle and the back rake angle combine to form the effective rake angle. This is also called true rake angle or resultant rake angle of the tool.

The basic tool geometry is determined by the rake angle of the tool.

Rake angle has two major effects during the metal cutting process.

One major effect of rake angle is its influence on tool strength. A tool with negative rake will withstand far more loading than a tool with positive rake.

The other major effect of rake angle is its influence on cutting pressure. A tool with a positive rake angle reduces cutting forces by allowing the chips to flow more freely across the rake surface.

Cutting Tool Angles

The rake angle has the following function:

- It allows the chip to flow in convenient direction.
- It reduces the cutting force required to shear the metal and consequently helps to increase the tool life and reduce the power consumption. It provides keenness to the cutting edge.
- It improves the surface finish.

Positive Rake:

•Positive rake or increased rake angle reduces compression, the forces, and the friction, yielding a thinner, less deformed and cooler chip.

•But increased rake angle reduces the strength of the tool section, and heat conduction capacity.

•Some areas of cutting where positive rake may prove more effective are, when cutting tough, alloyed materials that tend to work-harden, such as certain stainless steels, when cutting soft or gummy metals, or when low rigidity of workpiece, tooling, machine tool, or fixture allows chatter to occur.

•The shearing action and free cutting of positive rake tools will often eliminate problems in these areas.

Cutting Tool Angles

Negative Rake:

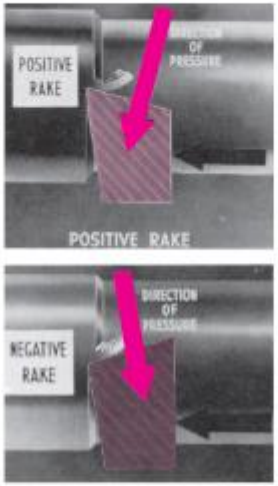
- To provide greater strength at the cutting edge and better heat conductivity, zero or negative rake angles are employed on carbide, ceramic, polycrystalline diamond, and polycrystalline cubic boron nitride cutting tools.
- These materials tend to be brittle, but their ability to hold their superior hardness at high temperature results in their selection for high speed and continuous machining operation.
- Negative rakes increases tool forces but this is necessary to provide added support to the cutting edge. This is particularly important in making intermittent cuts and in absorbing the impact during the initial engagement of the tool and work.
- Negative rakes are recommended on tool which does not possess good toughness (low transverse rupture strength).
- Thus negative rake (or small rake) causes high compression, tool force, and friction, resulting in highly deformed, hot chip.

table 31.4 Recommended angles for single-point carbide tools*

Material	End Relief (Front Clearance)	Side Relief (Side Clearance)	Side Rake	Back Rake
Aluminum	6° to 10°	6° to 10°	10° to 20°	0° to 10°
Brass, bronze	6° to 8°	6° to 8°	+8° to −5°	0° to −5°
Cast iron	5° to 8°	5° to 8°	+6° to −7°	0° to −7°
Machine steel	5° to 10°	5° to 10°	+6° to −7°	0° to −7°
Tool steel	5° to 8°	5° to 8°	+6° to −7°	0° to −7°
Stainless steel	5° to 8°	5° to 8°	+6° to −7°	0° to −7°
Titanium alloys	5° to 8°	5° to 8°	+6° to −5°	0° to −5°

table 32.2 Suggested rake and relief angles for ceramic tools*

Workpiece Material	Rake Angles (Degrees)	Relief Angles (Degrees)
Carbon and alloy steels: Annealed and heat-treated	Neg. 2 to 7	2 to 7
Cast iron: Hard or chilled Gray or ductile	0 to Neg. 7	2 to 7
Nonferrous: Hard or soft	0 to Neg. 7	2 to 7
Nonmetallics: Wood, paper, green ceramics, fiber, asbestos, rubber, carbon, graphite	0 to 10	6 to 18



(a)
(b)

Rack angle depends on

- **Type of material being cut**: A harder material like cast iron may be machined by smaller rake angle than that required by soft material like mid steel or aluminum.
- **Type of tool material**: Tool material like cemented carbide permits turning at very high speed. At high speeds rake angle has little influence on cutting pressure. Under such condition the rake angle can minimum or even negative rake angle is provided to increase the tool strength.
- **Depth of cut**: In rough turning, high depth of cut is given to remove maximum amount of material. This means that the tool has to withstand severe cutting pressure. So the rake angle should be decreased to increase the lip angle that provides the strength to the cutting edge.
- **Rigidity of the tool holder and machine**: An improperly supported tool on old or worn out machine cannot take up high cutting pressure. So while machining under the above condition, the tool used should have larger rake angle.

Relief Angle

- Relief angles are provided to minimize physical interference or rubbing contact with machined surface and the work piece.
- Relief angles are for the purpose of helping to eliminate tool breakage and to increase tool life.
- If the relief angle is too large, the cutting tool may chip or break. If the angle is too small, the tool will rub against the workpiece and generate excessive heat and this will in turn, cause premature dulling of the cutting tool.
- Small relief angles are essential when machining hard and strong materials and they should be increased for the weaker and softer materials.
- A smaller angle should be used for interrupted cuts or heavy feeds, and a larger angle for semi-finish and finish cuts.

Side relief angle: The Side relief angle prevents the side flank of the tool from rubbing against the work when longitudinal feed is given. Larger feed will require greater side relief angle.

End relief angle: The End relief angle prevents the side flank of the tool from rubbing against the work. A minimum relief angle is given to provide maximum support to the tool cutting edge by increasing the lip angle. The front clearance angle should be increased for large diameter works.

Cutting Tool Angles and their Significance

Side cutting edge angle:

The following are the advantages of increasing this angle:

- It increases tool life as, for the same depth of cut; the cutting force is distributed on a wider surface.
- It diminishes the chip thickness for the same amount of feed and permits greater cutting speed.
- It dissipates heat quickly for having wider cutting edge.

- The side cutting edge angle of the tool has practically no effect on the value of the cutting force or power consumed for a given depth of cut and feed.
- Large side cutting edge angles are lightly to cause the tool to chatter.

End cutting edge angle:

The function of end cutting edge angle is to prevent the trailing front cutting edge of the tool from rubbing against the work. A large end cutting edge angle unnecessarily weakens the tool.

It varies from 8 to 15 degrees.

Nose Radius

Nose radius:

The nose of a tool is slightly rounded in all turning tools.

The function of nose radius is as follows:

- Greater nose radius clears up the feed marks caused by the previous shearing action and provides better surface finish.
- All finish turning tool have greater nose radius than rough turning tools.
- It increases the strength of the cutting edge, tends to minimize the wear taking place in a sharp pointed tool with consequent increase in tool life.
- Accumulation heat is less than that in a pointed tool which permits higher cutting speeds.

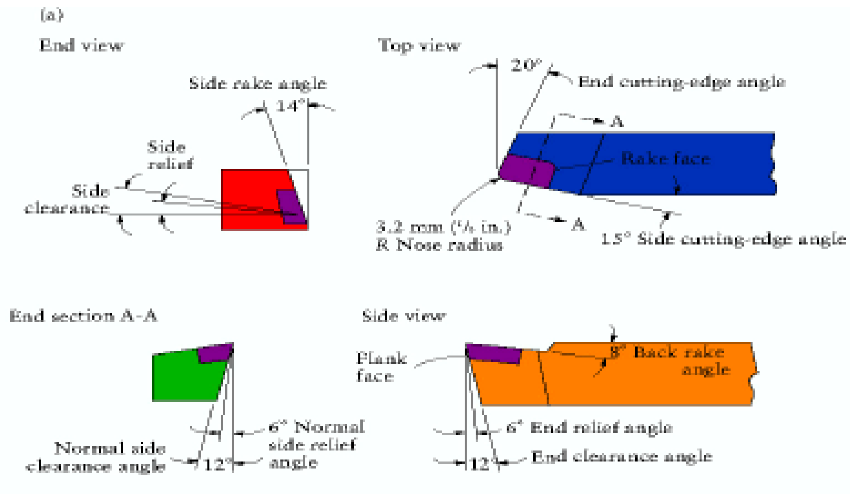
Tool Signature

8-14-6-6-6-15-1

1. Bake rake angle is 8
2. Side rake angle is 14
3. End relief angle is 6
4. Side relief angle is 6
5. End cutting Edge angle is 6
6. Side cutting Edge angle is 15
7. Nose radius is 1 mm

Tool Signature

(a)



Tool Signature	Dimensions	Abbreviation
8	Back rake angle	BR
14	Side rake angle	SR
6	End relief angle	ER
12	End clearance angle	. . .
6	Side relief angle	SRF
12	Side clearance angle	. . .
20	End cutting-edge angle	ECEA
15	Side cutting-edge angle	SCEA
1/8	Nose radius	NR

(b)

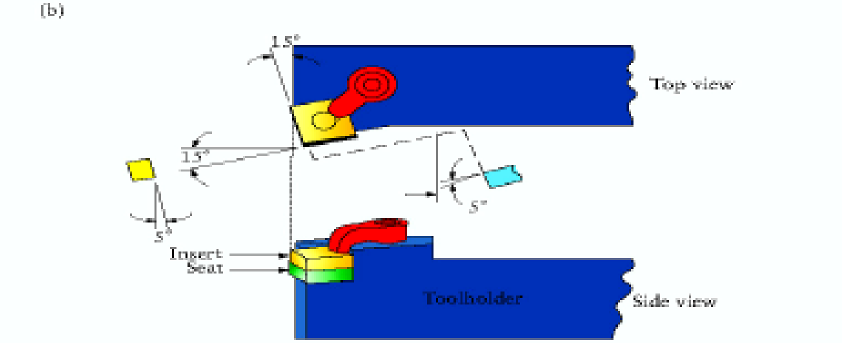
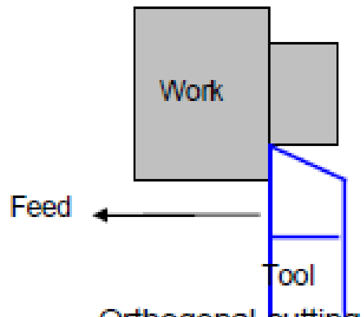


FIGURE: (a) Designations and symbols for a right-hand cutting tool; solid high-speed-steel tools have a similar designation. (b) Square insert in a right-hand toolholder for a turning operation. A wide variety of toolholder is available for holding inserts at various angles. Thus, the angles shown in (a) can be achieved easily by selecting an appropriate insert and toolholder. *Source*: Kennametal, Inc.

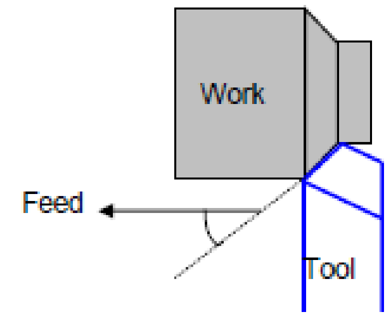
Orthogonal and Oblique cutting

The two basic methods of metal cutting using a single point tool are the orthogonal (2 D) and oblique (3D). Orthogonal cutting takes place when the cutting face of the tool is 90 degree to the line of action of the tool. If the cutting face is inclined at an angle less than 90 degree to the line of action of the tool, the cutting action is known as oblique.

Orthogonal and Oblique cutting



Orthogonal cutting



Oblique cutting

Orthogonal Cutting:

- The cutting edge of the tool remains normal to the direction of tool feed or work feed.
- The direction of the chip flow velocity is normal to the cutting edge of the tool.
- Here only two components of forces are acting: Cutting Force and Thrust Force. So the metal cutting may be considered as a two dimensional cutting.

Oblique Cutting:

- The cutting edge of the tool remains inclined at an acute angle to the direction of tool feed or work feed.
- The direction of the chip flow velocity is at an angle with the normal to the cutting edge of the tool. The angle is known as chip flow angle.
- Here three components of forces are acting: Cutting Force, Radial force and Thrust Force or feed force. So the metal cutting may be considered as a three dimensional cutting.
- The cutting edge being oblique, the shear force acts on a larger area and thus tool life is increased.

Oblique cutting

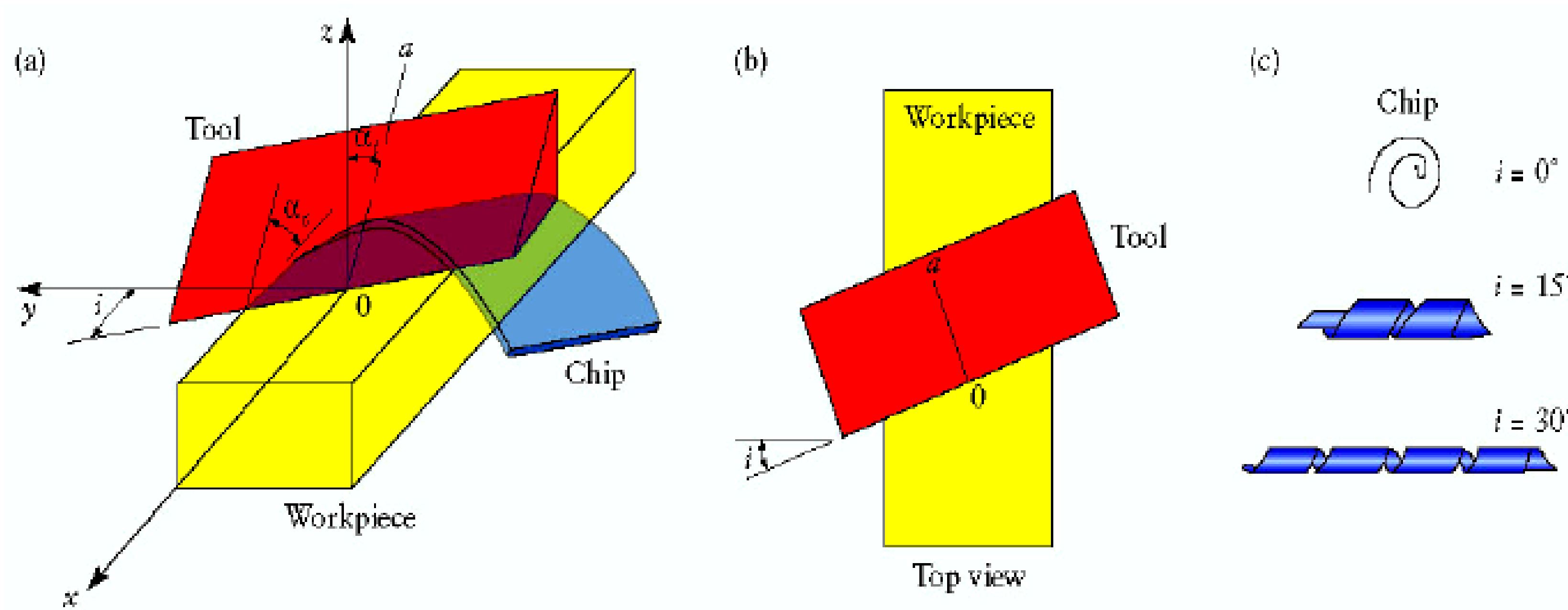


FIGURE (a) Schematic illustration of cutting with an oblique tool. (b) Top view, showing the inclination angle *i*. (c) Types of chips produced with different inclination angles

Mechanic of orthogonal metal cutting

During metal cutting, the metal is severely compressed in the area in front of the cutting tool.

This causes high temperature shear, and plastic flow if the metal is ductile.

When the stress in the workpiece just ahead of the cutting tool reaches a value exceeding the ultimate strength of the metal, particles will shear to form a chip element, which moves up along the face of the work.

The outward or shearing movement of each successive element is arrested by work hardening and the movement transferred to the next element.

The process is repetitive and a continuous chip is formed.

The plane along which the element shears, is called shear plane.

Assumptions in orthogonal Cutting

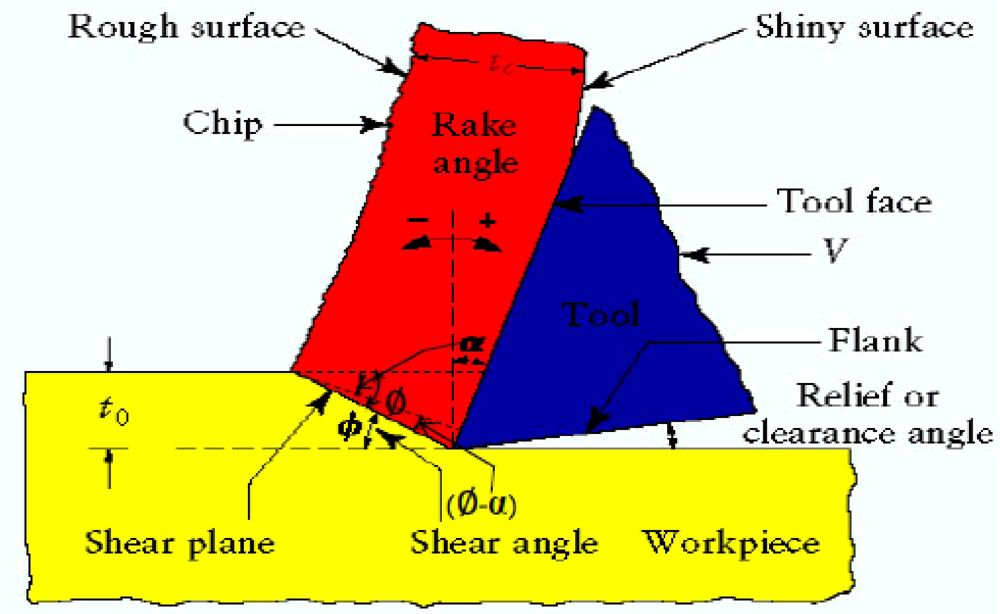
- No contact at the flank i.e. the tool is perfectly sharp.
- No side flow of chips i.e. width of the chips remains constant.
- Uniform cutting velocity.
- A continuous chip is produced with no built up edge.
- The chip is considered to be held in equilibrium by the action of the two equal and opposite resultant forces R and R/ and assume that the resultant is collinear.

Chip Thickness Ratio

Chip thickness ratio

$$r = \frac{t_o}{t_c} = \frac{l_s \sin\phi}{l_s \cos(\phi - \alpha)}$$

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

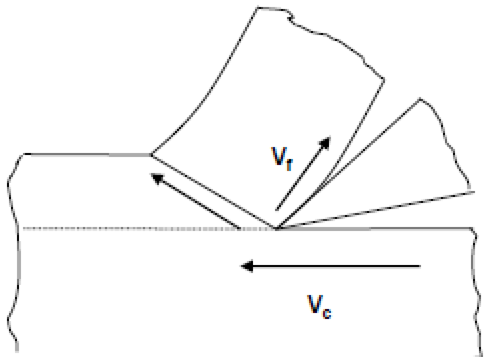


$$r = \frac{1}{r_c} = \frac{t_o}{t_c} = \frac{\sin\phi}{\cos(\phi - \alpha)}$$

Rearranging:

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

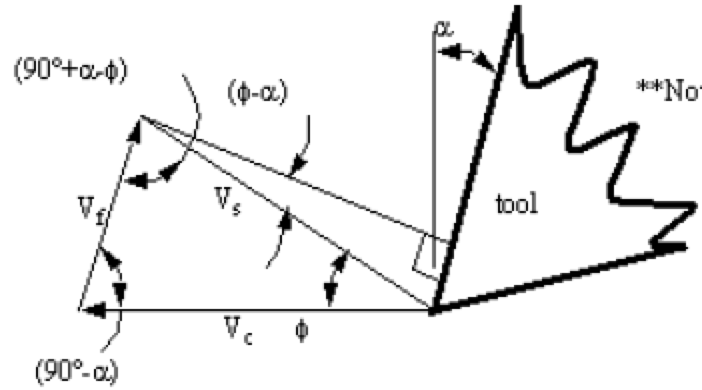
Velocity relationship



Analytically,

$$\frac{v_c}{\sin(90-(\phi-\alpha))} = \frac{v_f}{\sin\phi} = \frac{v_s}{\sin(90-\alpha)}$$

$$\frac{v_c}{\cos(\phi-\alpha)} = \frac{v_f}{\sin\phi} = \frac{v_s}{\cos\alpha}$$



where,

V_c = cutting velocity (ft./min.) - as set or measured on
V_s = shearing velocity
V_f = frictional velocity

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

$$\left[r = \frac{\sin\phi}{\cos(\phi-\alpha)} \right]$$

$$v_f = v_c \times r$$

$$\boxed{v_s = \frac{v_c \cos\alpha}{\cos(\phi-\alpha)}}$$

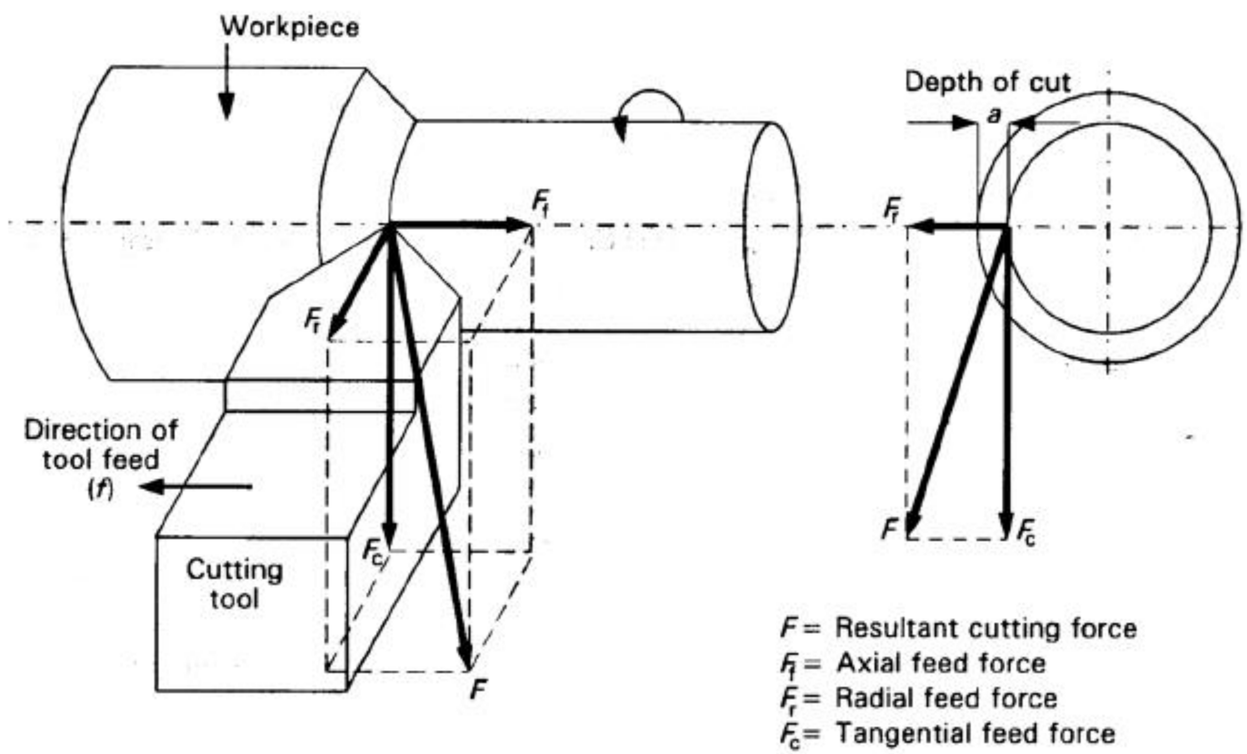
Volume of material per unit time = Volume of material flowing up the chip

$$\Rightarrow v_c \times t_0 \times w = v_f \times t_c \times w$$

$$\Rightarrow v_f = v_c \times r \quad \text{As, } r = \frac{t_0}{t_c}$$

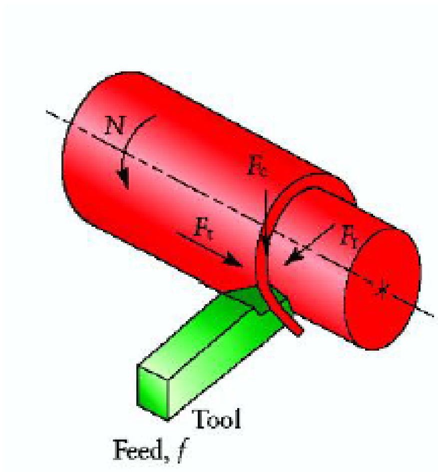
Cutting Forces

The force system in general case of conventional turning process



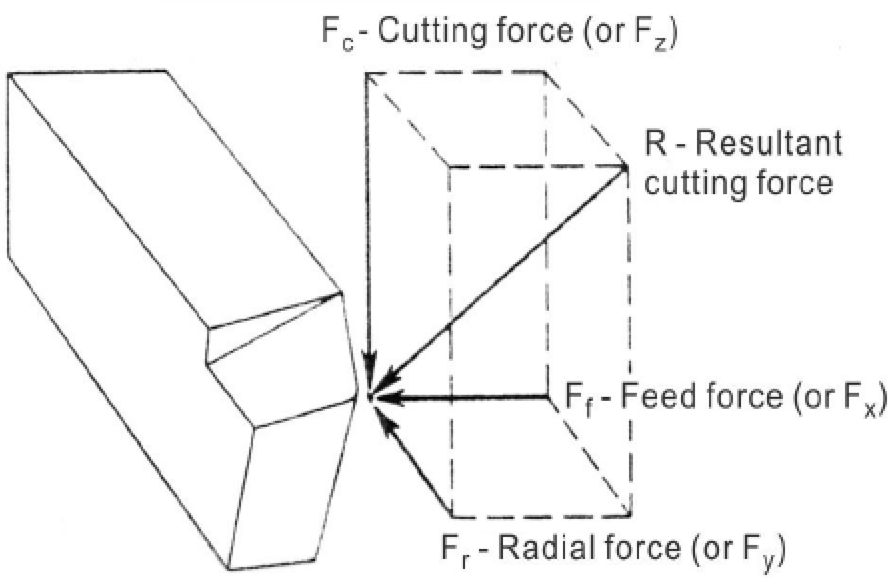
Primary forces involved in single-edge cutting. (Courtesy of Sandvik Coromant, Halesowen.)

Cutting Forces



The largest magnitude is the vertical force F_c which in turning is larger than feed force F_f, and F_f is larger than radial force F_r.

For orthogonal cutting system F_r is made zero by placing the face of cutting tool at 90 degree to the line of action of the tool.



$$\overline{R} = \overline{F}_x + \overline{F}_y + \overline{F}_z$$
$$= \overline{F}_c + \overline{F}_f + \overline{F}_r$$

Tangential Force (Cutting Force)

Feed Force

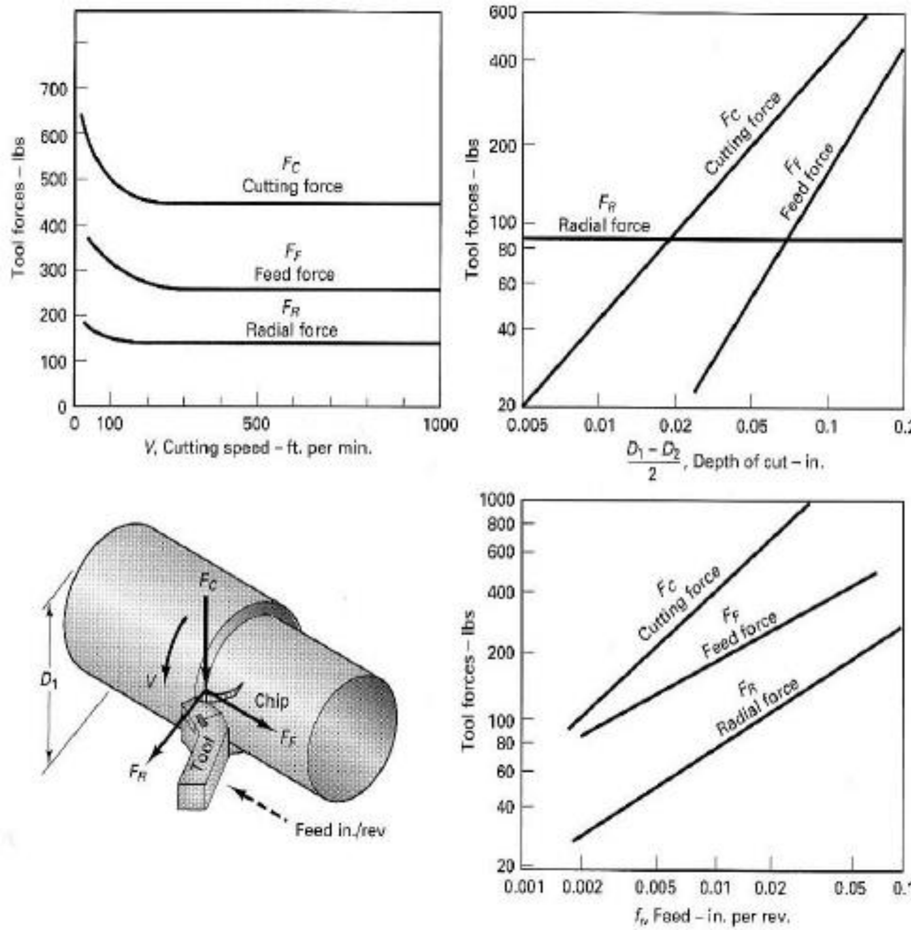
Radial Force

In orthogonal cutting

$$\overline{R} = \overline{F}_c + \overline{F}_t$$

Thrust Force

Cutting Forces(oblique cutting)



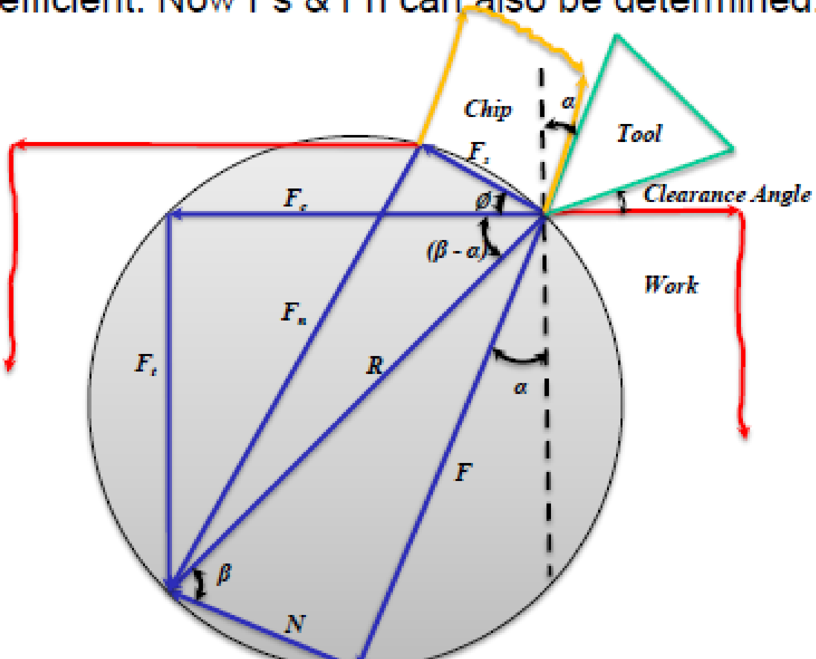
Merchant's Circle Diagram

The following is a circle diagram. Known as Merchant's circle diagram, which is convenient to determine the relation between the various forces and angles. In the diagram two force triangles have been combined and R and R/ together have been replaced by R. the force R can be resolved into two components F_c and F_t.

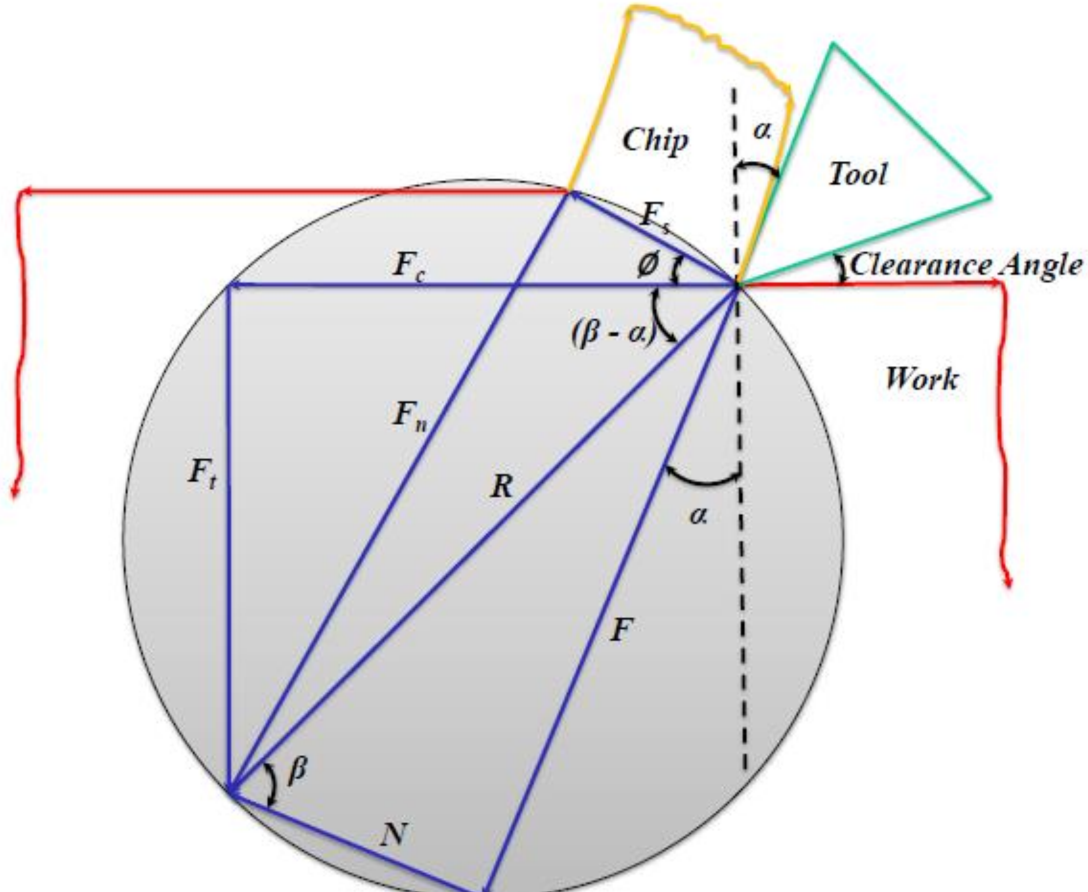
Fc and Ft can be determined by force dynamometers.

$$\vec{R} = \vec{F}_c + \vec{F}_t$$

The rake angle (α) can be measured from the tool, and forces F and N can then be determined. The shear angle (ϕ) can be obtained from it's relation with chip reduction coefficient. Now Fs & Fn can also be determined.

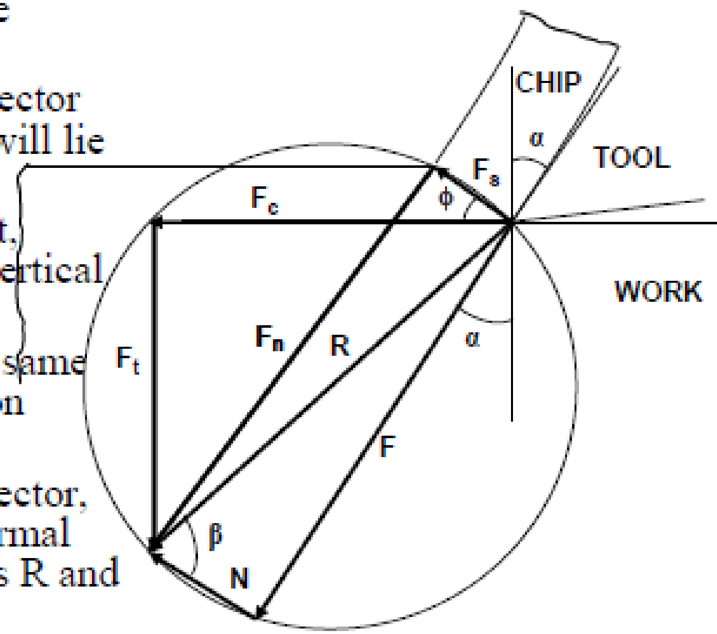


Merchant’s circle diagram

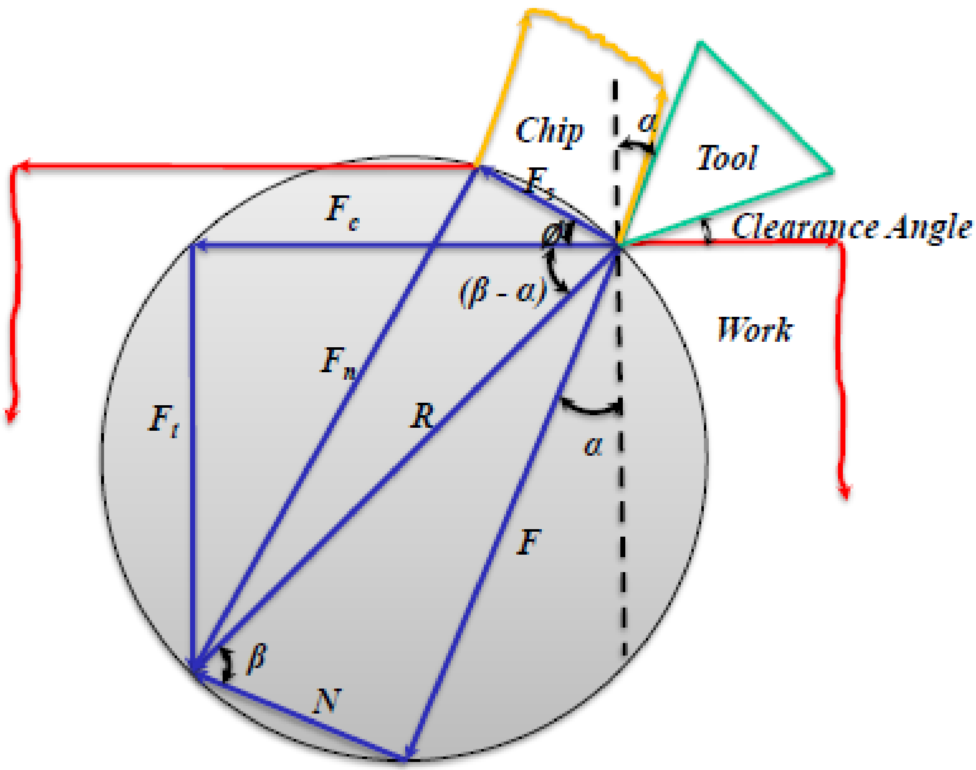


Procedure

- Set up x-y axis labeled with forces, and the origin in the centre of the page. The cutting force (Fc) is drawn horizontally, and the tangential force (Ft) is drawn vertically. (Draw in the resultant (R) of Fc and Ft.
- Locate the centre of R, and draw a circle that encloses vector R. If done correctly, the heads and tails of all 3 vectors will lie on this circle.
- Draw in the cutting tool in the upper right hand quadrant, taking care to draw the correct rake angle (α) from the vertical axis.
- Extend the line that is the cutting face of the tool (at the same rake angle) through the circle. This now gives the friction vector (F).
- A line can now be drawn from the head of the friction vector, to the head of the resultant vector (R). This gives the normal vector (N). Also add a friction angle (β) between vectors R and N. Therefore, mathematically, R = Fc + Ft = F + N.
- Draw a feed thickness line parallel to the horizontal axis. Next draw a chip thickness line parallel to the tool cutting face.
- Draw a vector from the origin (tool point) towards the intersection of the two chip lines, stopping at the circle. The result will be a shear force vector (Fs). Also measure the shear force angle between Fs and Fc.
- Finally add the shear force normal (Fn) from the head of Fs to the head of R.
- Use a scale and protractor to measure off all distances (forces) and angles.



Relationship of various forces



$$F = F_C \sin\alpha + F_t \cos\alpha$$

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

$$F_S = F_C \cos\phi - F_t \sin\phi$$

$$F_N = F_C \sin\phi + F_t \cos\phi$$

$$F_N = F_S \tan(\phi + \beta - \alpha)$$

Shear Angle

Ernest and Merchant gave the relation

$$\phi = \frac{\pi}{4} - \frac{1}{2}(\beta - \alpha)$$

M. Eugene Merchant

Assumptions of the theory:

- Tool edge is sharp.
- The work material undergoes deformation across a thin shear plane.
- There is uniform distribution of normal and shear stress on the shear plane.
- The work material is rigid and perfectly plastic.
- The shear angle Ø adjusts itself to give minimum work.
- The friction angle β remains constant and is independent of Ø.
- The chip width remains constant.

$$F_s = R\cos(\phi + \beta - \alpha)$$

$$R = F_c \sec(\beta - \alpha)$$

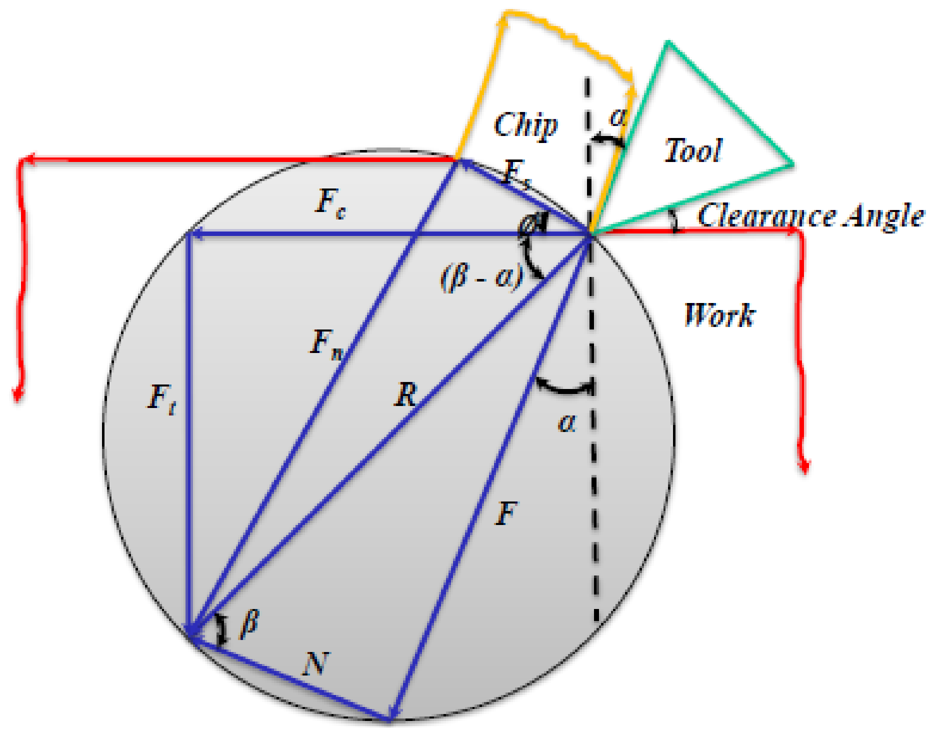
$$\Rightarrow F_s = F_c \sec(\beta - \alpha)\cos(\phi + \beta - \alpha)$$

$$\tau_s = \frac{F_s}{A_s}$$

$$where,\ A_s = \frac{wt_0}{\sin\phi}$$

$$\Rightarrow \tau_s = \frac{F_c \sec(\beta - \alpha)\cos(\phi + \beta - \alpha)}{\dfrac{wt_0}{\sin\phi}}$$

$$\Rightarrow \tau_s = \frac{F_c \sec(\beta - \alpha)\cos(\phi + \beta - \alpha)\sin\phi}{wt_0}$$



$$F_t = \frac{S_t w \sin(\beta - \alpha)}{\sin\phi\cos(\phi + \beta - \alpha)} = \frac{F_s \sin(\beta - \alpha)}{\cos(\phi + \beta - \alpha)}$$

They have assumed that ϕ adjusts itself to give minimum work. And for a given set of cutting condition, to, w and α are all constants. They also assumed that β is independent of ϕ.

$$P_c = F_c v$$

where P_c = cutting power, N-m/s or W (ft-lb/min); F_c = cutting force, N (lb); and v = cutting speed, m/s (ft/min). In U.S. customary units, power is traditionally expressed as

horsepower by dividing ft-lb/min by 33,000. Hence,

$$HP_c = \frac{F_c v}{33,000}$$

where HP_c = cutting horsepower, hp. The gross power required to operate the machine tool is greater than the power delivered to the cutting process because of mechanical losses in the motor and drive train in the machine. These losses can be accounted for by the mechanical efficiency of the machine tool:

$$P_g = \frac{P_c}{E} \quad \text{or} \quad HP_g = \frac{HP_c}{E}$$

where P_g = gross power of the machine tool motor, W; HP_g = gross horsepower; and E = mechanical efficiency of the machine tool. Typical values of E for machine tools are around 90%.

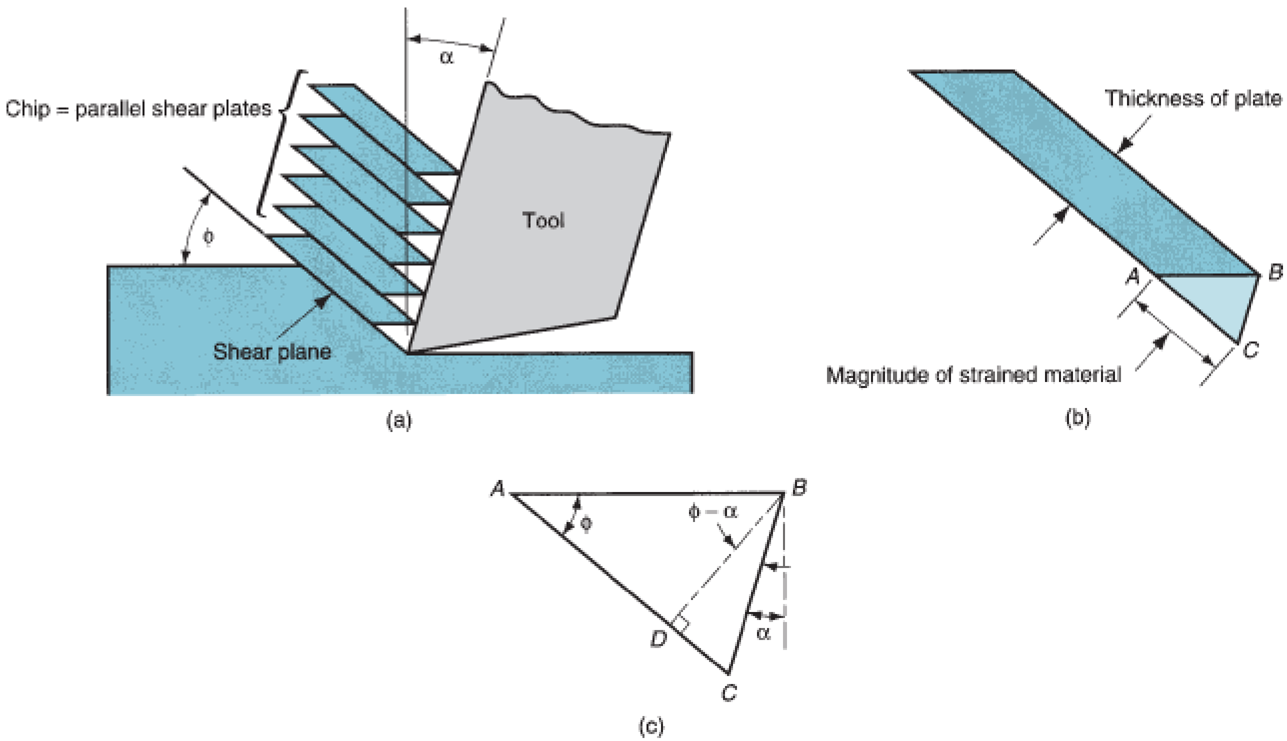
It is often useful to convert power into power per unit volume rate of metal cut. This is called the ***unit power,*** P_u (or ***unit horsepower,*** HP_u), defined:

$$P_u = \frac{P_c}{R_{MR}} \quad \text{or} \quad HP_u = \frac{HP_c}{R_{MR}}$$

where R_{MR} = material removal rate, mm^3/s (in^3/min). The material removal rate can be calculated as the product of $vt_o w$.

Unit power is also known as the ***specific energy*** U.

$$U = P_u = \frac{P_c}{R_{MR}} = \frac{F_c v}{v t_o w} = \frac{F_c}{t_o w}$$



$$\gamma = \frac{AC}{BD} = \frac{AD + DC}{BD}$$

which can be reduced to the following definition of shear strain in metal cutting:

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

Shear Stress and Strain

$$Mean\ shear\ stress\ \tau_s = \frac{F_s}{A_s}$$

$$Mean\ normal\ stress\ \sigma_s = \frac{F_n}{A_s}$$

The shear strain be γ.

Considering no loss of work during shearing

We Know,

Work done in shearing unit volume of the metal = shear stress × shear strain

$$\Rightarrow \frac{F_s \times v_s}{t_0 \times w \times v_c} = \tau_s \times \gamma$$

$$\Rightarrow \gamma = \frac{F_s \times v_s}{\tau_s \times t_0 \times w \times v_c}$$

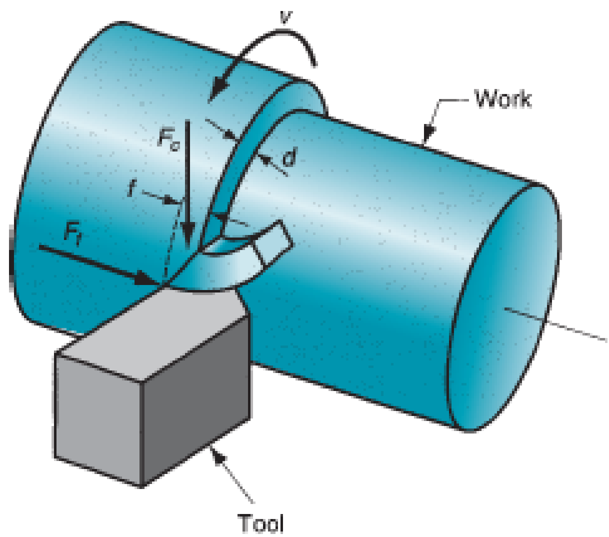
$$\Rightarrow \gamma = \frac{F_s \times v_s}{\frac{F_s}{A_s} \times t_0 \times w \times v_c}$$

$$\Rightarrow \gamma = \frac{F_s \times v_s}{\frac{F_s}{t_0 \times w / \sin\phi} \times t_0 \times w \times v_c}$$

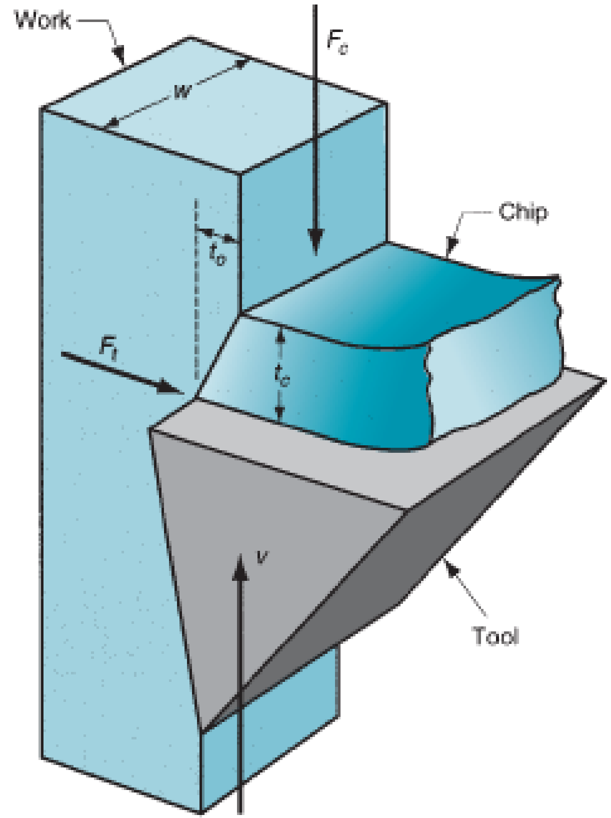
$$\Rightarrow \gamma = \frac{v_s}{v_c} \times \frac{1}{\sin\phi}$$

$$But\ \frac{v_s}{v_c} = \frac{\cos\alpha}{\cos(\phi-\alpha)},\ therefore$$

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



(a)



(b)

TABLE 21.1 Conversion key: turning operation vs. orthogonal cutting.

Turning Operation	Orthogonal Cutting Model
Feed f =	Chip thickness before cut t_o
Depth d =	Width of cut w
Cutting speed v =	Cutting speed v
Cutting force F_c =	Cutting force F_c
Feed force F_f =	Thrust force F_t

Orthogonal Cutting

Assume that in orthogonal cutting the rake angle is 15° and the coefficient of friction is 0.2. determine the percentage increase in chip thickness when friction is doubled.

Orthogonal Cutting

The following data are available from orthogonal cutting experiments. In both cases, depth of cut (feed) $t_o = 0.13$ mm, width of cut $w = 2.5$ mm, rake angle $\alpha = -5°$, and cutting speed $V = 2$ m/s.

	Aluminum
Chip thickness, t_c, mm	0.23
Cutting force, F_c, N	430
Thrust force, F_t, N	280

Determine the shear angle ϕ [do not use Eq. (8.20)], friction coefficient μ, shear stress τ and shear strain γ on the shear plane, chip velocity V_c and shear velocity V_s

Orthogonal Cutting

The following data are available from orthogonal cutting experiments. In both cases, depth of cut (feed) $t_o = 0.13$ mm, width of cut $w = 2.5$ mm, rake angle $\alpha = -5°$, and cutting speed $V = 2$ m/s.

	Workpiece material
	Steel
Chip thickness, t_c, mm	0.58
Cutting force, F_c, N	890
Thrust force, F_t, N	800

Determine the shear angle ϕ [do not use Eq. (8.20)], friction coefficient μ, shear stress τ and shear strain γ on the shear plane, chip velocity V_c and shear velocity V_s

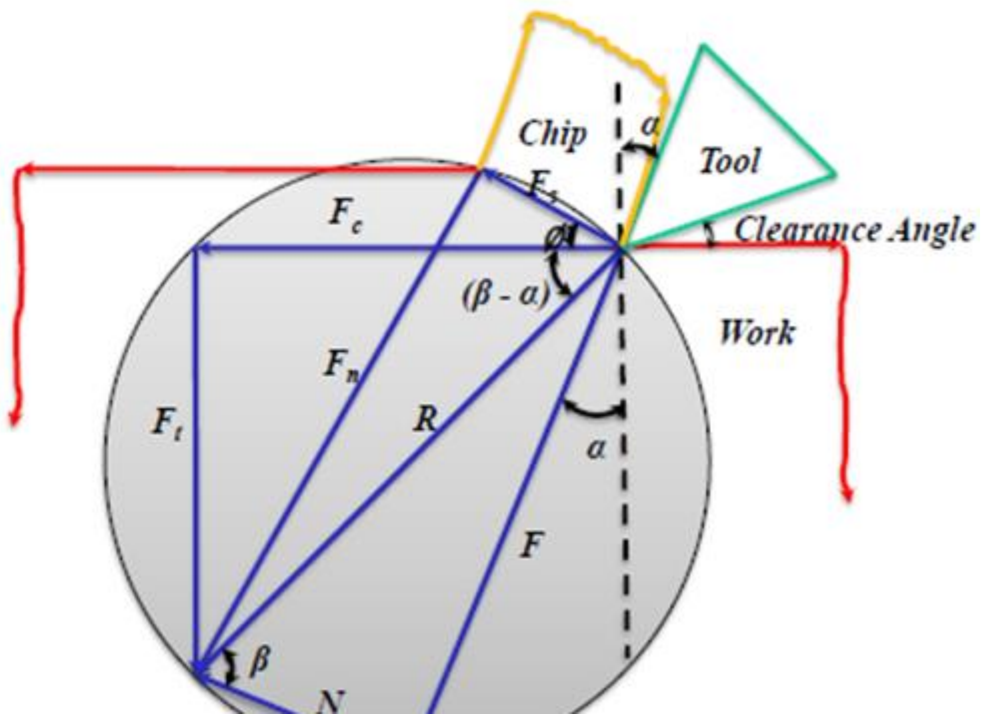
Orthogonal Cutting

In a dry cutting operation using a -5° rake angle, the measured forces were $F_c = 1330$ N and $F_t = 740$ N. When a cutting fluid was used, these forces were $F_c = 1200$ N and $F_t = 710$ N. What is the change in the friction angle resulting from the use of a cutting fluid?

Orthogonal cutting

An orthogonal cutting operation is being carried out under the following conditions: depth of cut = 0.10 mm, width of cut = 5 mm, chip thickness = 0.2 mm, cutting speed = 2 m/s, rake angle = 15°, cutting force = 500 N, and thrust force = 200 N. Calculate the percentage of the total energy that is dissipated in the shear plane during cutting.

Use the given relations in the merchant circle to find the answer



Orthogonal cutting

In an orthogonal cutting operation, the tool has a rake angle = 15°. The chip thickness before the cut = 0.30 mm and the cut yields a deformed chip thickness = 0.65 mm. Calculate (a) the shear plane angle and (b) the shear strain for the operation.

Orthogonal cutting

In an orthogonal cutting operation, the 0.250 in wide tool has a rake angle of 5°. The lathe is set so the chip thickness before the cut is 0.010 in. After the cut, the deformed chip thickness is measured to be 0.027 in. Calculate (a) the shear plane angle and (b) the shear strain for the operation.

Orthogonal cutting

The cutting force and thrust force in an orthogonal cutting operation are 1470 N and 1589 N, respectively. The rake angle = 5°, the width of the cut = 5.0 mm, the chip thickness before the cut = 0.6, and the chip thickness ratio = 0.38. Determine (a) the shear strength of the work material and (b) the coefficient of friction in the operation.

$$\tau_s = \frac{F_s}{A_s}$$

$$A_s = \frac{wt_0}{\sin\phi}$$

$$\phi = \frac{\pi}{4} - \frac{1}{2}(\beta - \alpha)$$

$$F = F_c \sin\alpha + F_t \cos\alpha$$

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

$$F_s = F_c \cos\phi - F_t \sin\phi$$

$$F_N = F_c \sin\phi + F_t \cos\phi$$

The cutting force and thrust force have been measured in an orthogonal cutting operation to be 300 lb and 291 lb, respectively. The rake angle = 10°, width of cut = 0.200 in, chip thickness before the cut = 0.015, and chip thickness ratio = 0.4. Determine (a) the shear strength of the work material and (b) the coefficient of friction in the operation.

Orthogonal cutting

The shear strength of a certain work material = 50,000 lb/in^2. An orthogonal cutting operation is performed using a tool with a rake angle = 20° at the following cutting conditions: cutting speed = 100 ft/min, chip thickness before the cut = 0.015 in, and width of cut = 0.150 in. The resulting chip thickness ratio = 0.50. Determine (a) the shear plane angle, (b) shear force, (c) cutting force and thrust force, and (d) friction force.

$$\tau_s = \frac{F_c \sec(\beta - \alpha)\cos(\phi + \beta - \alpha)}{\frac{w t_0}{\sin\phi}}$$

$$F_t = \frac{S_t w \sin(\beta - \alpha)}{\sin\phi \cos(\phi + \beta - \alpha)} = \frac{F_s \sin(\beta - \alpha)}{\cos(\phi + \beta - \alpha)}$$

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

Orthogonal cutting

A carbon steel bar with 7.64 in diameter has a tensile strength of 65,000 lb/in^2 and a shear strength of 45,000 lb/in^2. The diameter is reduced using a turning operation at a cutting speed of 400 ft/min. The feed is 0.011 in/rev and the depth of cut is 0.120 in. The rake angle on the tool in the direction of chip flow is 13°. The cutting conditions result in a chip ratio of 0.52. Using the orthogonal model as an approximation of turning, determine (a) the shear plane angle, (b) shear force, (c) cutting force and feed force, and (d) coefficient of friction between the tool and chip.

Orthogonal cutting

A turning operation is made with a rake angle of 10°, a feed of 0.010 in/rev and a depth of cut = 0.100 in. The shear strength of the work material is known to be 50,000 lb/in2, and the chip thickness ratio is measured after the cut to be 0.40. Determine the cutting force and the feed/thrust force. Use the orthogonal cutting model as an approximation of the turning process.

Approximate Energy Requirements in Cutting Operations

TABLE 20.2 Approximate Energy Requirements in Cutting Operations (at drive motor, corrected for 80% efficiency; multiply by 1.25 for dull tools).

Material	Specific energy	
	$W\text{-}s/mm^3$	$hp\text{-}min/in.^3$
Aluminum alloys	0.4–1.1	0.15–0.4
Cast irons	1.6–5.5	0.6–2.0
Copper alloys	1.4–3.3	0.5–1.2
High-temperature alloys	3.3–8.5	1.2–3.1
Magnesium alloys	0.4–0.6	0.15–0.2
Nickel alloys	4.9–6.8	1.8–2.5
Refractory alloys	3.8–9.6	1.1–3.5
Stainless steels	3.0–5.2	1.1–1.9
Steels	2.7–9.3	1.0–3.4
Titanium alloys	3.0–4.1	1.1–1.5

Approximate Energy Requirements in Cutting Operations (at drive motor, corrected for 80% efficiency; multiply by 1.25 for dull tools).

Material	Specific energy $W \cdot s/mm^3$	Specific energy $hp \cdot min/in.^3$
Aluminum alloys	0.4–1.1	0.15–0.4
Cast irons	1.6–5.5	0.6–2.0
Copper alloys	1.4–3.3	0.5–1.2
High-temperature alloys	3.3–8.5	1.2–3.1
Magnesium alloys	0.4–0.6	0.15–0.2
Nickel alloys	4.9–6.8	1.8–2.5
Refractory alloys	3.8–9.6	1.1–3.5
Stainless steels	3.0–5.2	1.1–1.9
Steels	2.7–9.3	1.0–3.4
Titanium alloys	3.0–4.1	1.1–1.5

Thank You