Cutting tools

Cutting tool

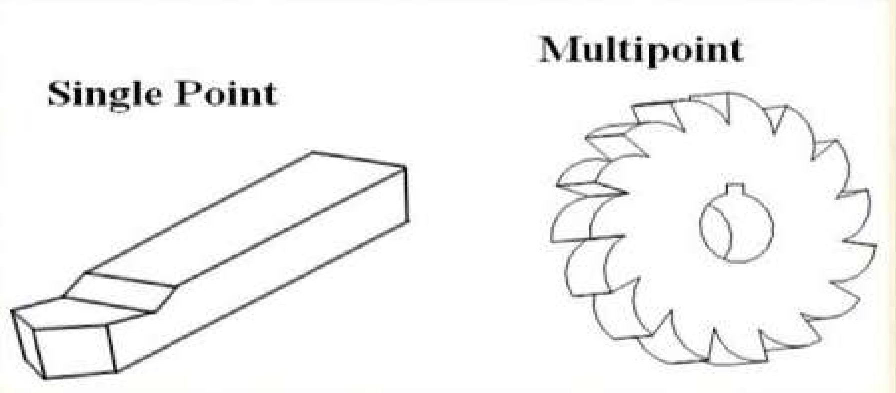
- It is any tool that is used to remove material from the work piece by means of shear deformation.
- It frequently refers to as a tool bit.
- They must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal cutting process.

Different types of cutting tools

According to the number of cutting edge the cutting tools broadly classified into

i) Single point cutting tool

ii) Multi point cutting tool



- **Single point cutting tool**

This type of tools has only one cutting edge to remove excess material from the workpiece. They may be left/ right handed according to the side of cutting edge when viewing from the end point.

Example: tools used in lathes, planers, shapers and boring machines

- **Multi-point cutting tool**

. They have more than one cutting edge to remove excess material. It considered as a series of single point cutting edge on the periphery and during operation each cutting edge independently cut the workpiece.

Example: Milling cutters, grinding wheels, drills, reamer, broaches

Types of cutting tool

- According to the construction of cutting tool :

1.**Solid type tools**: Ground type and forged type tools

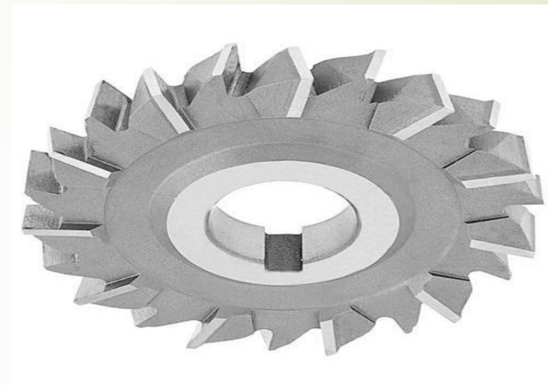
i) **Ground type -** Cutting edge is formed by grinding the end of tool
ii) **Forged type –** Rough forging is used before hardening and grinding to form a cutting edge.

2.**Tipped type tools**: Tipped type and insert type

i) **Tipped type** – High-grade material tools are usually provided by this method. The cutting edge is formed in the form of the small tip, which is brazed to the shank of lower grade material.

ii) **Insert or bit type** - A tool bit of high-grade material is formed in the form of polygonal shape, and then it is mechanically held by the cutting tool holder. Inserts cannot reshape, so it is discarded when all cutting edges wear out. Then new bits are inserted into the tool holder.

- Tipped type cutting tool



- Insert or bit type cutting tool

Types of cutting tool

- According to the quality of machining operation

I)**Roughing tools**: This type of tools used for removing a large amount of material in the form of a thick layer of chips.

ii)**Surface Finishing tools**: This type of tools used for metal removal in the form of a small section of the chip with high cutting speed to achieve good finishing.

With help of single broaching tool , roughing & surface finishing both operation can be done

Types of cutting tool

- According to the motion of cutting tool

1. Linear motion tools:

   Lathe tools, Boring tools, Broaching tools, Planing tools, Shaping tools, etc.

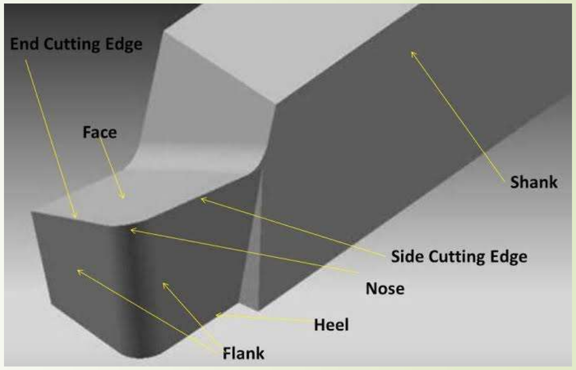
2. Rotary motion tools :

.   Milling cutters, Grinding wheels, etc.

3. Linear and Rotary tools :

   Drills, Honing tools, etc.

Geometry of cutting tool

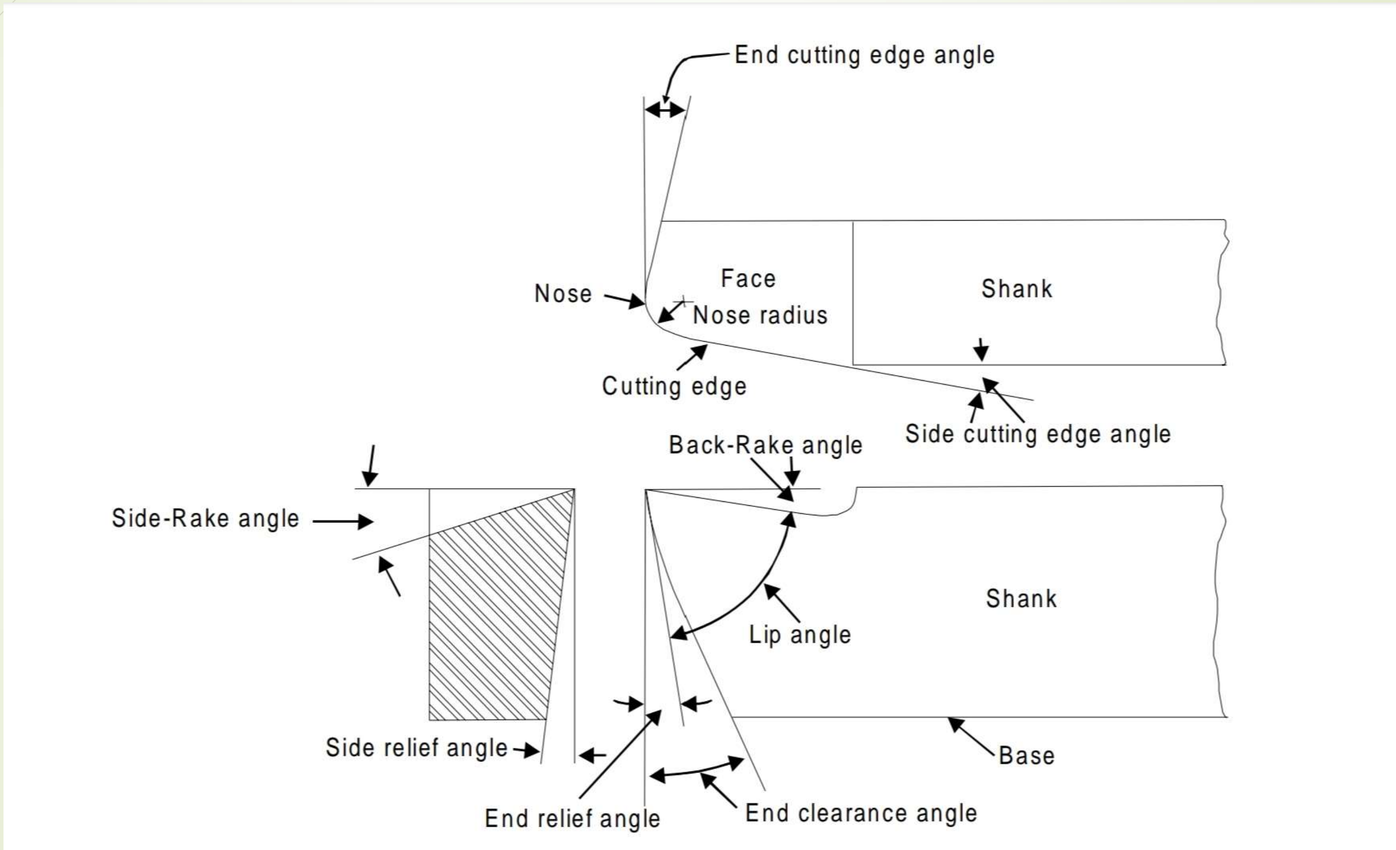


- **Shank** : Main body of tool, it is part of tool which is gripped in tool holder
- **Face** : Top surface of tool b/w shank and point of tool. Chips flow along this surface.
- **Point** : Wedge shaped portion where face and flank of tool meet.
- **Heel** : It is the intersection of the flank and the base of the tool

- **Flank** : Portion tool which faces the work. It is surface adjacent to below the cutting edge when tool lies in a horizontal position.
- **Base** : It is the portion of the flank that lies opposite to the top face of the shank
- **Nose** : The intersection point of major cutting edge and minor cutting edge is called Nose.
- **Cutting edge** : The edge on the tool which removes materials from the work piece is called cutting edges. It lies on the face of the tool.

1. end cutting edge
2. side cutting edge

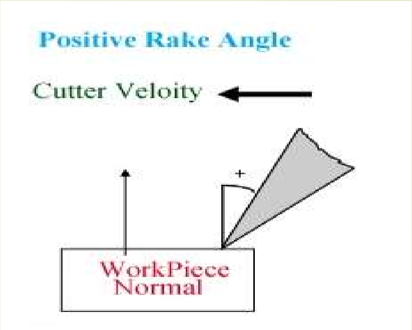
Single point cutting tool Angles



- **Lip angle**: Angle between the top face and the flank of the tool.It is also known as angle of keenness. Strength of cutting edge or point of the tool is directly affected by this angle.Larger thel lip angle stronger will be the cutting edge and vise versa. Lip angle varies inversely as the rake angle.
- **Back rake angle**: There is also known as Top rack angle. It is the angle between face of tool and a plane parallel to base of tool. The inclination is given from nose along with length of tool and towards the shank. The angle may be positive or negative .
- **side rake angle**: The angle between face of tool and line perpendicular to flank of tool. The slope is given the face (or) tool top position. The inclination is given towards the side of the tool.

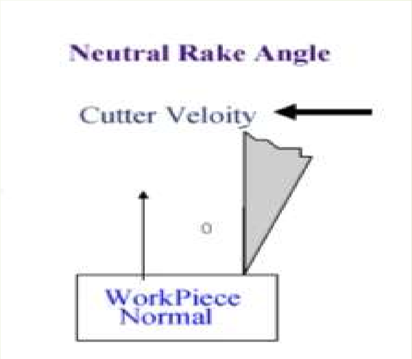
- **Positive rake angle** :

The positive rake angle tool has sharp cutting edge and the cutting force required is less in positive rake angle tool.So, the power requirement during machining is also less.This type of tool used in machining of soft material. Positive rake angle also help in achieving better machinability.



- **Zero rake angle**

Zero ranke angle is intermittent of positive and negative rake angle.It provide advantage and disadvantages of both to some extent. Zero rake angle is very easy to design and calculation for estimating machining force is very easy in zero rake angle.



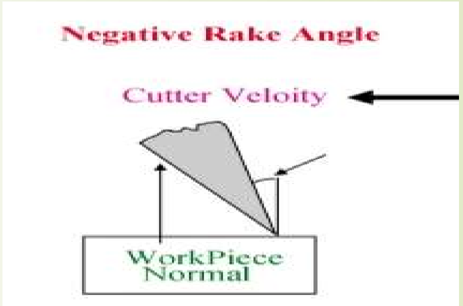
- **Negative rake Angle**

  - Used for machining hard material.

  - High cutting force required in machining.

  - Used for heavy and interrupted cuts

  - Larger lip angle, hense stronger tool.



Effects of side rake angle:-

- During the machining operation the chip curling or amount of chip bends depends upon the side rake angle. If the side rake angle is larger, cut and bending of chip and power requirement will be decreased. Hence that providing better surface finish of machining surface.

- **Side relief angle:** It is the angle that prevents the interference as the tool enters the material. It 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. It is incorporated on the tool to provide relief between its flank and the work piece surface. Some time extra side clearance is also provided on the tool that is also known as side clearance angle. It is the secondary angle directly below the side relief angle.
- **End relief angle :** It is the angle that allows the tool to cut without rubbing on the work- piece. It 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, measured at right angles to the flank. Some time extra end clearance is also provided on the tool that is also known as end clearance angle.It is the secondary angle directly below the end relief angle.

- **Nose radius**:

    It is radius at nose. It is provided to get better surface finish on the workpiece and it strengthen the cutting tip to prolonged tool life.As the value of this radius increases , a higher cutting speed can be used.But, if it is too large it may lead to chatter.

- **End cutting edge angle**:

    The angle between end flank and a plane perpendicular to the side of the shank

- **Side cutting edge angle**:

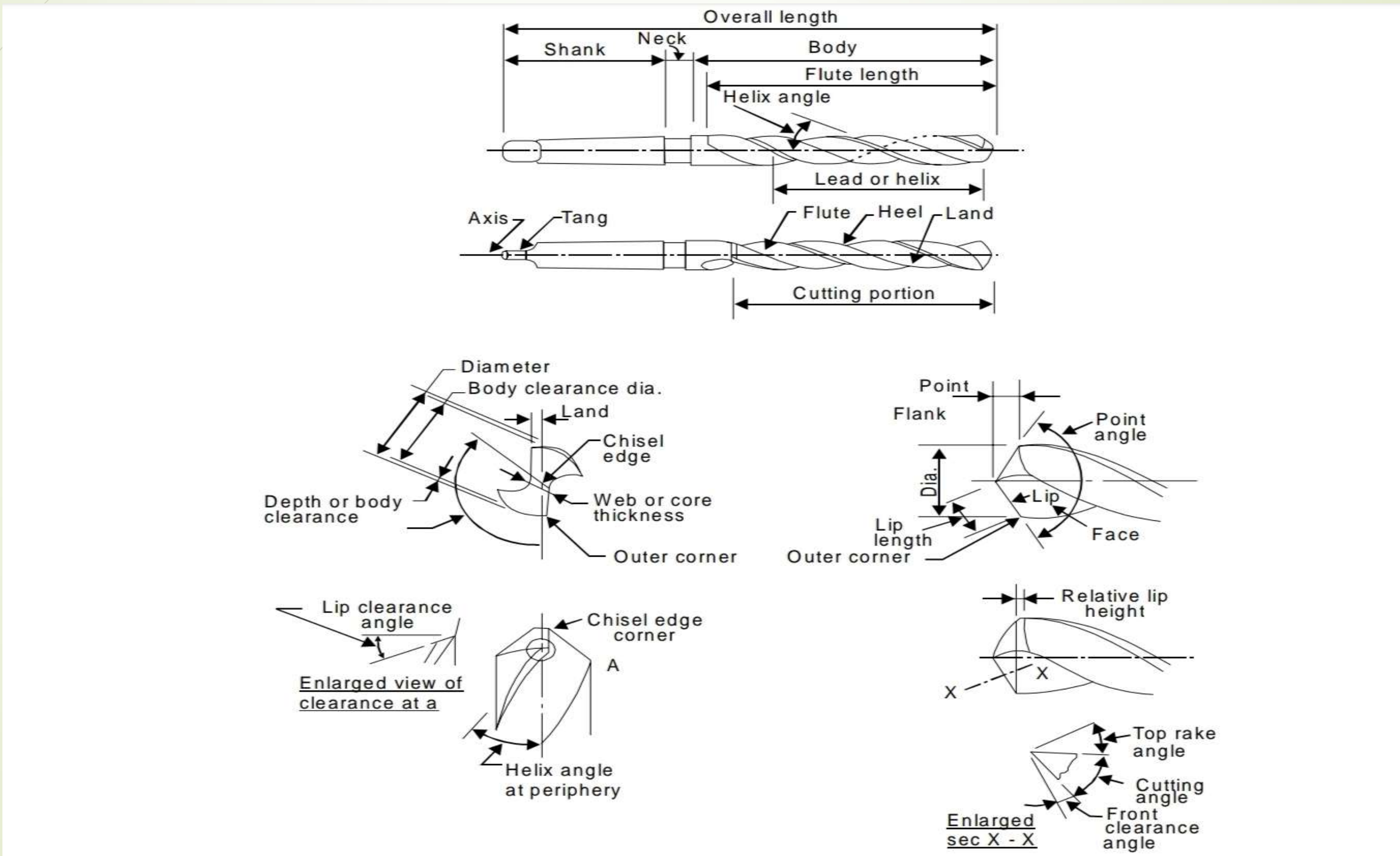
    The angle between side cutting edge and the line extending from the shank (or a line parallel to the tool axis).

Tool signature

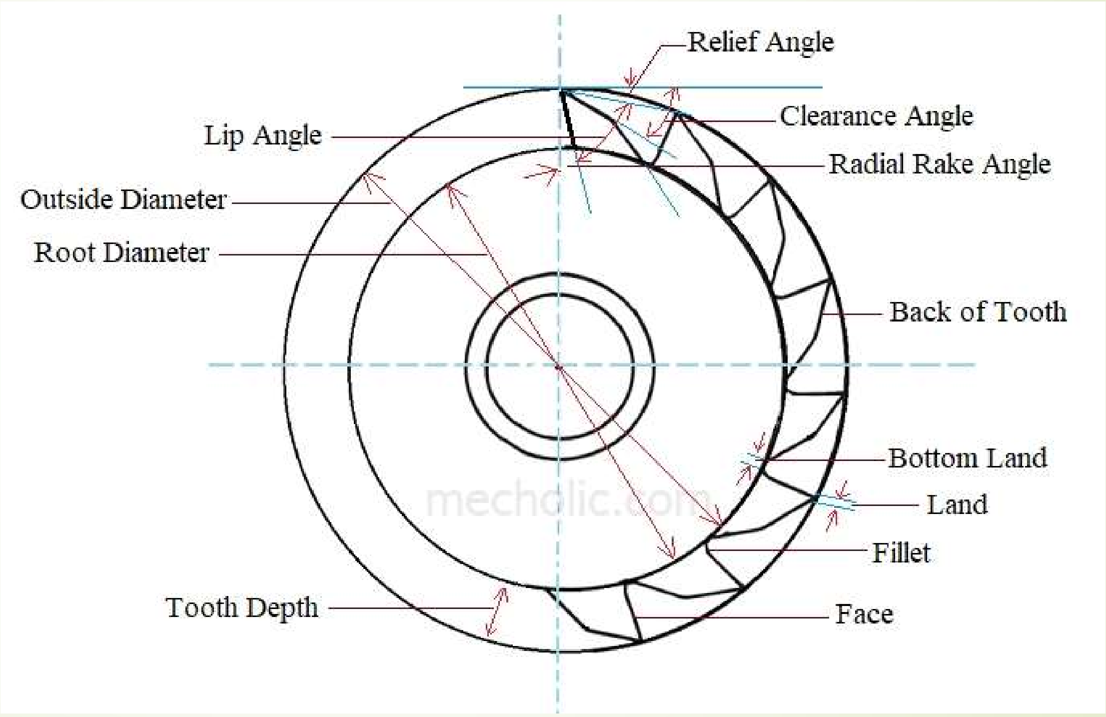
- The seven elements that comprise the signature of a single point cutting tool can be state in the following order:
- For example : Tool signature 0-7-6-8-15-16-0.8

1. Back rake angle (0°)
2. Side rake angle (7°)
3. End relief angle (6°)
4. Side relief angle (8°)
5. End cutting edge angle (15°)
6. Side cutting edge angle (16°)
7. Nose radius (0.8 mm)

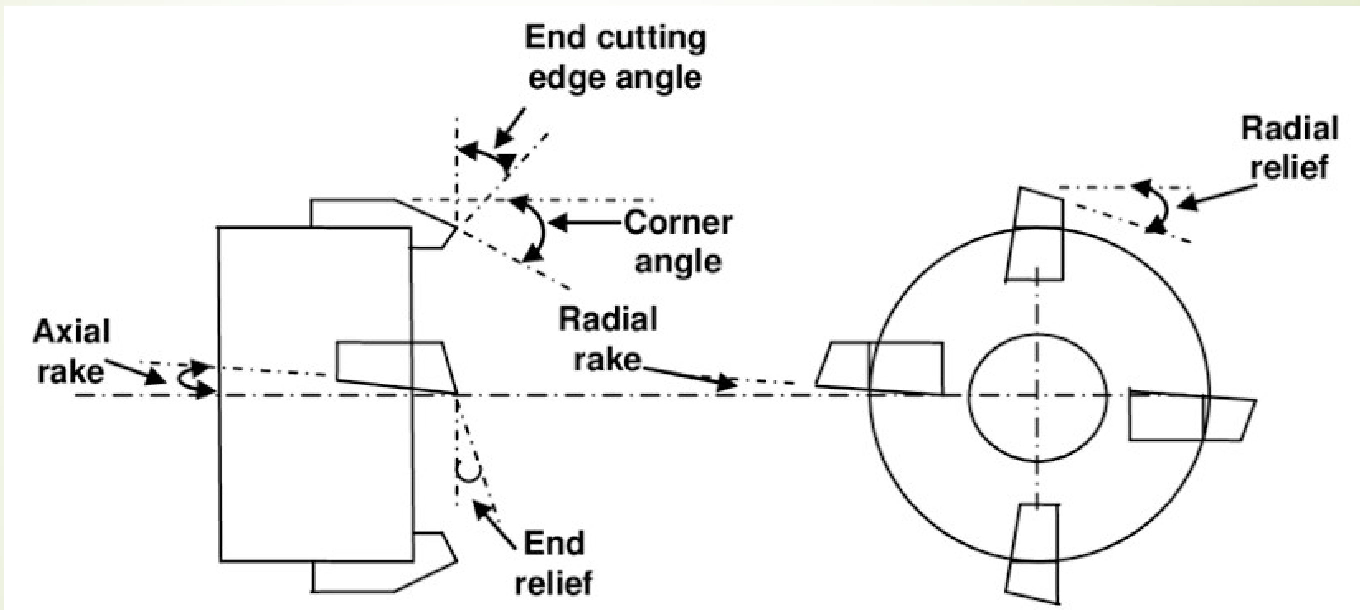
Drill tool geometry



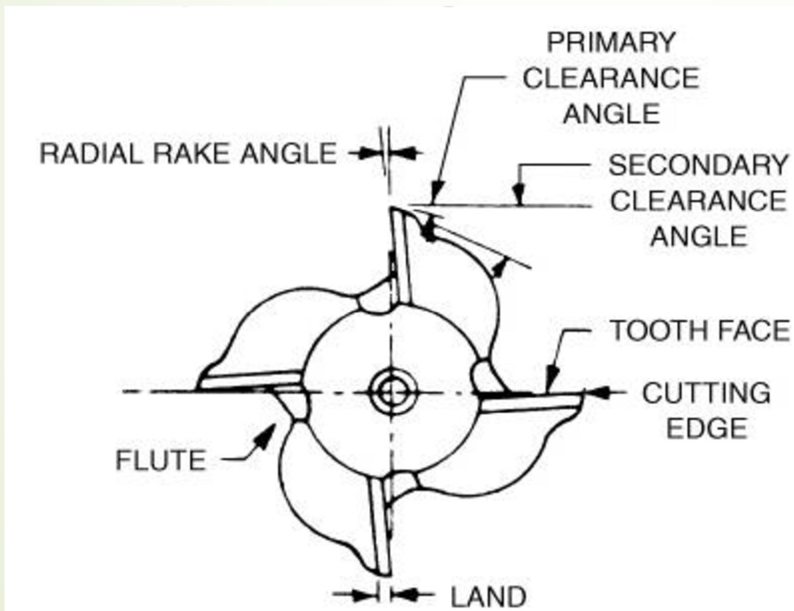
Plain milling cutter

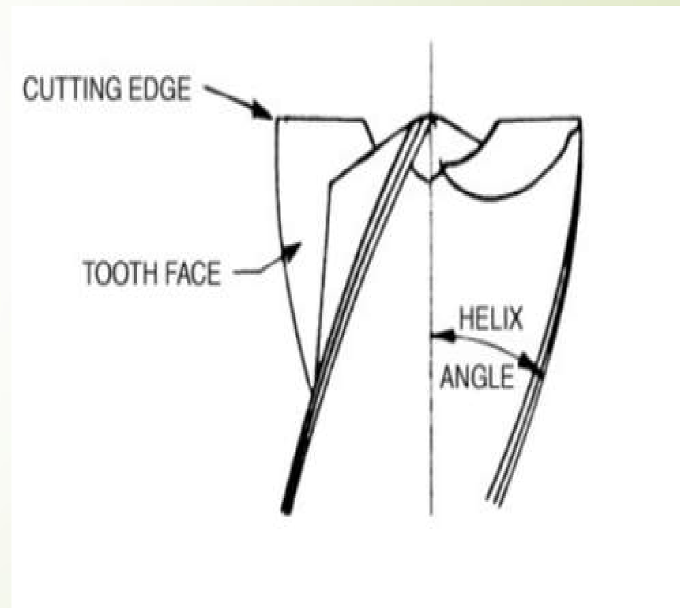


Face milling cutter geometry



Nomenclature of End mill





Cutting tool material

- **Properties of cutting tool material**

1.Red hardness or Hot Hardness: It is the ability of a material to retain its hardness at elevated temperatures.
2.Wear resistance: It enables the cutting tool to retain its shape and cutting efficiency
3.Toughness: It relates to the ability of a material to resist shock or impact loads associated with interrupted cuts .

4.Chamical stability : Tool material must have chemical stability, so that any undesirable reactions between tool material, and work material are avoided.

5.Shock resistance : Tool material must have high resistance against thermal and mechanical shocks, specially in intermittent cutting in which tool-work engages and dis-engages at regular intervals.

6.Low friction : Tool material must have low coefficient of friction. So that the heat generated will be lower, and tool life increases.

Cutting tool material

- **Carbon-Tool Steels:**

1. 0.6-1.5% carbon + little amount of Mn, Si, Cr, V to increase hardness.
2. Low carbon varieties possess good toughness & shock resistance.
3. High carbon varieties possess good abrasion resistance
4. This material loses their hardness rapidly at a temperature about 250°C. Therefore, it can't use in high-temperature application.
5. Carbon steel tool is used in twist_drills , milling tools, turning and forming tools, used for soft material such as brass, aluminum magnesium, etc.

- **High speed steel (HSS)**

1. High carbon+ little amount Tungsten, Molybdenum, Cr, V & cobalt to increase hardness, toughness and wear résistance.
2. High operating temperatures upto 600°C

- Two types of HSS i.e, is T-type and M-Type

  I) T- type : Tungsten predominant type

  Ii)M- type : Molybdenum dominant type

- Cutting speed range - 30-50 m/min
- Vanadium increases abrasion resistance but higher percentage will decreases grindability.
- Chromium increases hardenability
- Cobalt is added to HSS to increase red hardness.

Cast alloys

- Usually contains 25% to 35% chromium, 4% to 25% tungsten and 1% to 4% carbon. Remaining is Cobalt.
- It is a non- ferrous alloy consisting mainly of Cobalt , Tungsten and other elements like Tantalum, Molybdenum and Boron.
- It has good shock and wear resistance and retais it's hardness at red heat upto 920°C.
- Tools made of this are capable of operating at speed up to 2 times more than those of common HSS tools.
- This material does not respond to the usual heat treatment process and only grinding can be used for machining it effectively.
- Cast alloys also called Stellite.

- **Cemented carbide cutting tool and cermet**

- The cemented carbide cutting tool is produced by powder metallurgy technique. It consists of tungsten, tantalum and titanium carbide with cobalt as a binder (when the binder is nickel or molybdenum, then it is called cermet).
- Cemented carbide tools are extremely hard; they can withstand very high-speed cutting operation. Carbide tool does not lose their hardness up to 1000° C.
- A high cobalt tool is used for a rough cut while low cobalt tool used for finishing operations.

Cutting speed range - 60-200m/min

- **Ceramic**
- Most common ceramic materials are aluminum oxide and silicon nitride. Powder of ceramic material Compacted in insert shape, then sintered at high temperature.
- Ceramic tools are chemically inert and possess resistance to corrosion. They have high compressive strength.
- They are stable up to temperature 1800°C. They are ten times faster than HSS. The friction between the tool face and chip are very low and possess low heat conductivity, usually no coolant is required. They provide the very excellent surface finish.
- Usually no coolant is needed while machining with ceramic tools.

  Cutting speed 300-600m/min
  Temperature - 1200°C

- **Cubic boron nitride**
- It is the second hardest material after diamond. They are generally used in hand machines. They offer high resistance to abrasion and use as an abrasive in grinding wheels. Sharp edges are not recommended.

  Speed 600-800m/min
- **Diamond**
- It is the hardest material known and it is also expensive. It possesses very high thermal conductivity and melting point. Diamond offers excellent abrasion resistance, low friction coefficient and low thermal expansion. It is used in machining very hard material such as carbides, nitrides, glass, etc. Diamond tools give a good surface finish and dimensional accuracy. They are not recommended for machining steel.

Tool failure

- Whenever the tool is not performing satisfactory, then there is a failure of cutting tool.
- Tool failure is reflected by the following adverse effects observed during the operation.

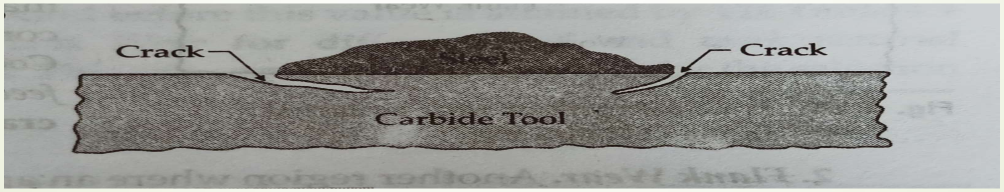
1. Extremely poor surface finish on the workpiece.
2. Higher consumption of power.
3. Work dimensions not being produced as specified.
4. Overheating of cutting tool
5. Appearance of burnishing band on the work surface.

Modes of tool failure

1. Thermal cracking and softening
2. Mechanical chipping
3. Gradual wear.

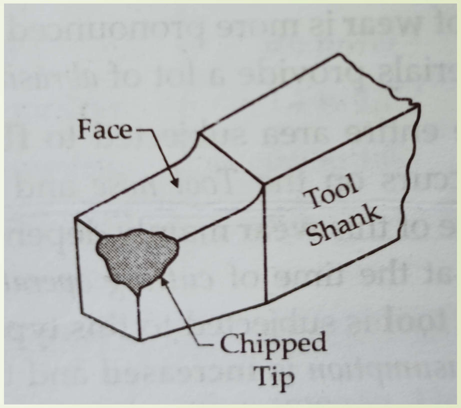
Thermal cracking and softening

- Heat generated during the process of metal cutting, the tool tip and the area closer to the cutting edge becomes very hot.
- If hot hardness limit of tool material is crossed, the material starts deforming plastically at the tip and adjacent to the cutting edge under the action of cutting pressure and the high temperature.
- factors responsible for creating such conditions of tool failure are High cutting speed, High feed rate, Excessive depth of cut, Smaller nose radius and choice of a Wrong tool material.



Mechanical chipping

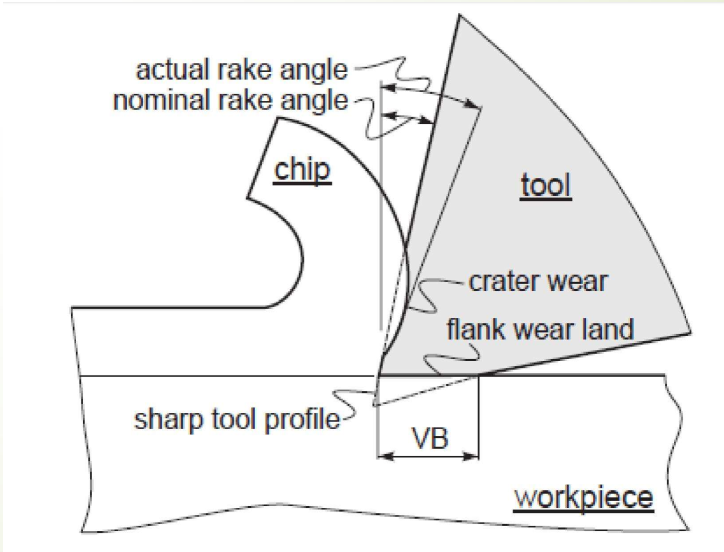
- A cutting tool gets broken due to the following factors:
- Large cutting force.
- By developing fatigue cracks under chatter conditions.
- Weak tool materials.
- High temperature and high stress
- In this also failure duration is repeatable.
- Therefore it is also considered as abnormal failure of tool



Gradual wear

- When a tool is in use for sometime it is found to have lost some weight or mass, implying that it has lost some material from it, which is due to wear.
- The following two types of wears are generally found to occur in cutting tools.

1. Crater wear
2. Flank wear



Crater wear

- The principle region where wear takes place in a cutting tool is its face, at a small distance from it's cutting edge.
- This type of wear generally take places while machining ductile materials like steel & steel alloys, in which continuous chip is produced
- The resultant feature of this type of wear of a crater at the tool chip interface
- This type of wear, or the formation of crater on the tool face is due to the pressure of the hot chip sliding up the face of the tool
- The metal from the tool face is supposed to be transferred to the sliding chip by means of the diffusion process

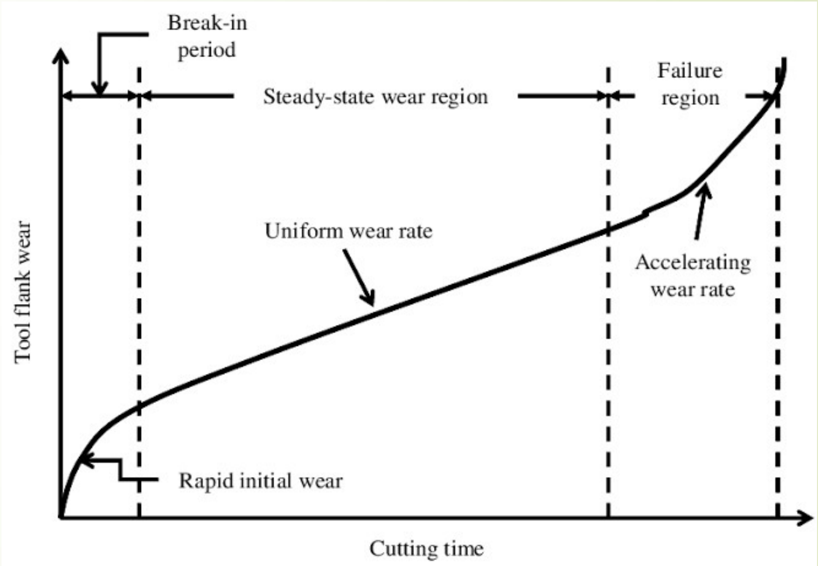
Flank wear

- It occurs due to abrasion between the tool flank & the work piece and excessive heat generated as a result of the same
- The abrasion action is aided by the hard micro constituents of the cut material provide a lot of abrasive material readily
- The entire area subjected to flank wear is known as wear land.
- This type of wear mainly occurs on the tool nose, front & side relief faces.
- The magnitude of this wear mainly depends on the relative hardness of the work piece and tool materials at the time of cutting operation.
- When the tool is subjected to this type of wear ,the work piece loses its dimensional accuracy, energy consumption is increased and the surface finish is poor.

Flank wear

- Stages tool flank wear

1. Primary stage – Rapid wear due to very high stress at tool point , exists for a small duration.
2. Secondary stage – in this stage wear process uniformity , exists for long duration.
3. Tertiary stage – wear rate increases rapidly and results in total failure of the tool.



Wear Mechanism of cutting tool

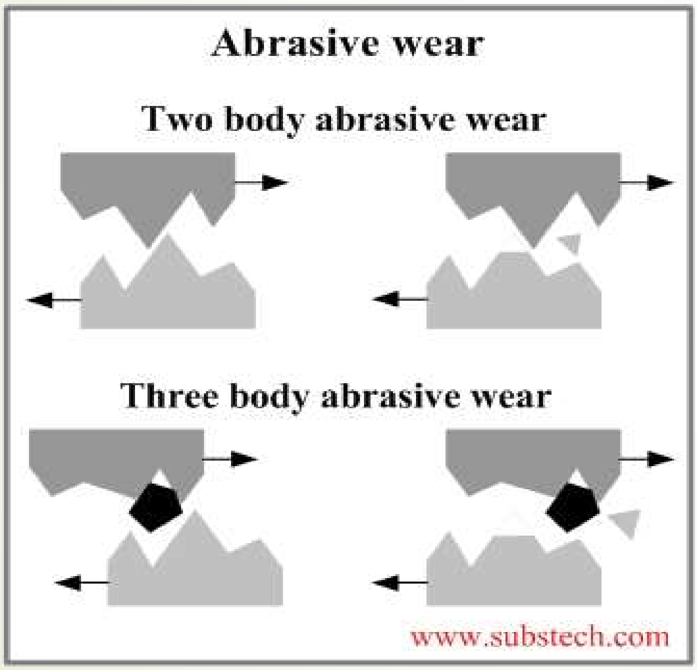
1. **Abration wear**

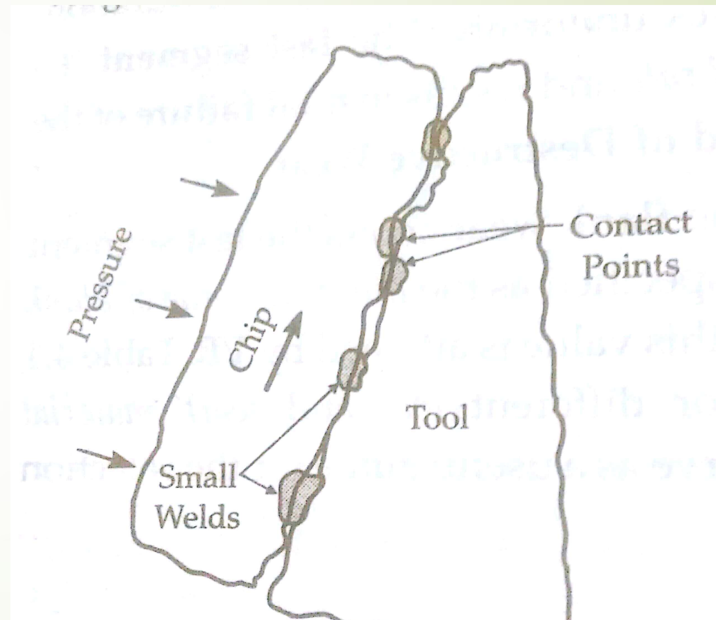
- It is a type of Mechanical Wear. Under this mechanism, hard particles on the underside of the sliding chip, which are harder than the tool material, plough into the relatively softer material of the tool face and remove metal particles by mechanical action. The material of the tool face is softened 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 edge, which are strain hardened.

(c) Extremely hard constituents, like carbides, oxides, scales, etc., present in the work material.





adhesion wear

Wear Mechanism

2. **Adhesion wear**

- During cutting operation, due to the excessive pressure a lot of friction occurs between the sliding surface of chip and the tool face. This gives rise to high localized temperature, causing mettalic bond between the chip material and tool material at the contact points, 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 welded tool contact is also carried away by the sliding chip.
- The amount of material so transferred from the tool face to the chip will depend upon the contact area and relative hardness of the chip and the tool materials.

Wear Mechanism

3. **Diffusion Wear**

- When a metal is in sliding contact with another metal the temp. at the interface is high
- The high temperature allows the atoms of hard material to diffuse into softer material matrix
- Hence the strength and abrasiveness of the softer material Increase. Atoms of the softer metal may also diffuse into harder medium, thus weakening the surface of harder material
- Diffusion phenomenon is strongly dependent on temperature

Wear Mechanism

4. **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 material, leading to a change in the chemical composition of the surface material of the tool.

Tool Life

- There are three common ways of expressing Tool Life :

1. As Time Period in minutes between two successive grindings.
2. In terms of Number of Components machined between two successive grindings. This mode is commonly used when the tool operates continuously, as in case of Automatic Machines.
3. In terms of the Volume of Material removed between two successive grindings. This mode of expression is commonly used when the tool is primarily used for heavy stock removal.

Tool Life

- Factors affecting life of Cutting tool:

1. Cutting speed
2. Feed and depth of cut
3. Tool geometry
4. Tool material
5. Work material
6. Nature of cutting
7. Rigidity of machine tool and work
8. Use of cutting fluids

Tool Life

- Out of all factor affecting tool life , the maximum effect on tool life is of cutting speed .

  $V.T^n = C$. (Taylor's tool life equation)

  Where, V= Cutting speed (m/min)

  T = tool life (min)

  n = Tool life index

  C= Machining constant