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THEORY OF METAL CUTTING

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III B.TECH I SEM

Metal Cutting

Metal cutting or Machining operation is to produce a desired shape, size and finish of a component by removing excess material in the form of chips.

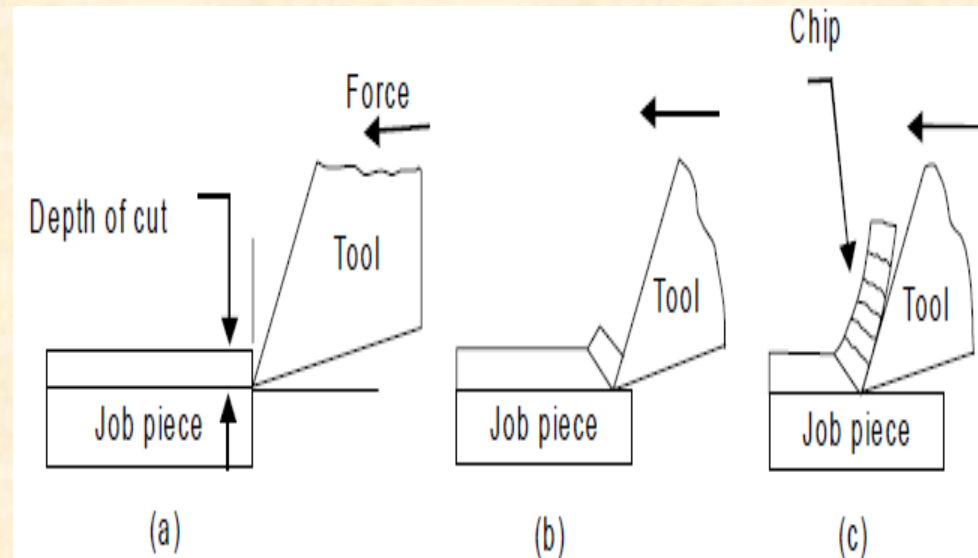
Chips may constitute more than 50% of initial work piece.

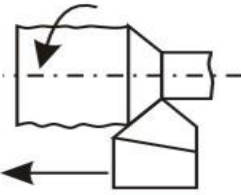
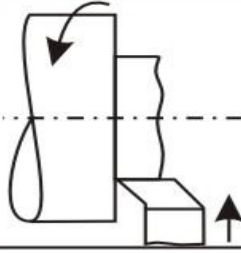
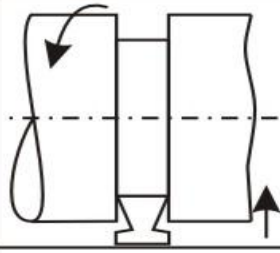
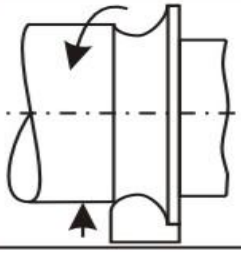
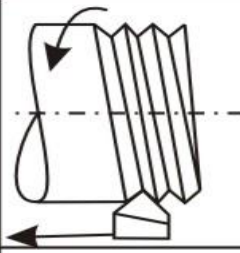
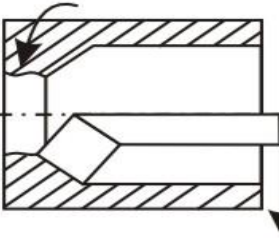
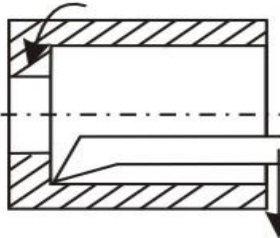
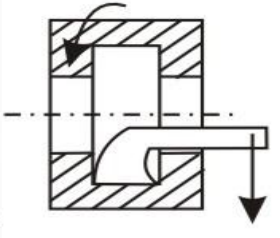
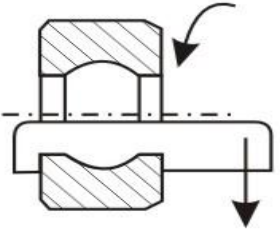
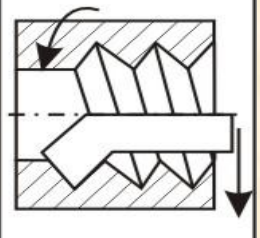
Machining processes are performed on metal cutting machines, using various types of cutting tools

Metal cutting process in general should be carried out at high speeds and feeds with least cutting effort at minimum cost.

Factors affecting metal cutting

1. Properties of Work material
2. Properties & geometry of cutting tool
3. Interaction between tool and work



	turning	facing	grooving	forming	threading
External					
Internal					

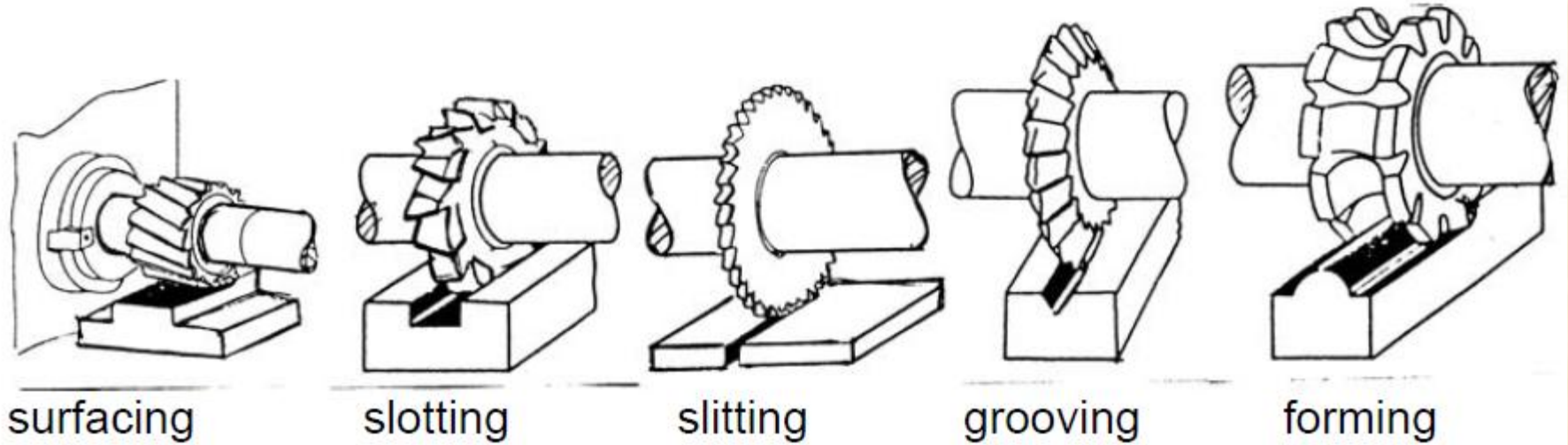


Fig. 2.15 Some common milling operation

Mechanics of Metal Cutting

A cutting tool exerts compressive force on the workpiece which stresses the work material beyond the yield point and therefore metal deforms plastically and shears off.

Plastic flow takes place in a localized region called the **shear plane**.

Sheared material begins to flow along the cutting **tool face** in the form of chips.

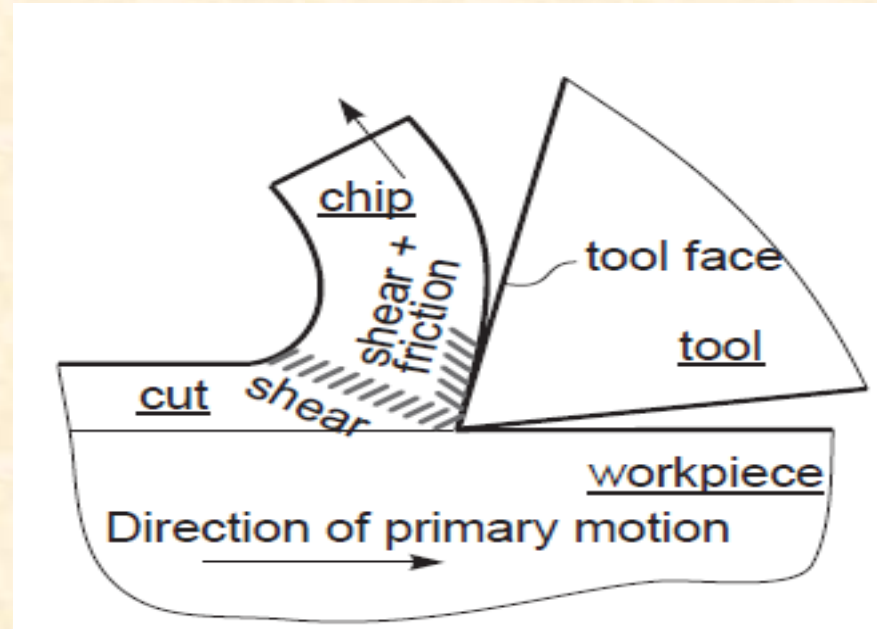
Flowing chips cause tool wear.

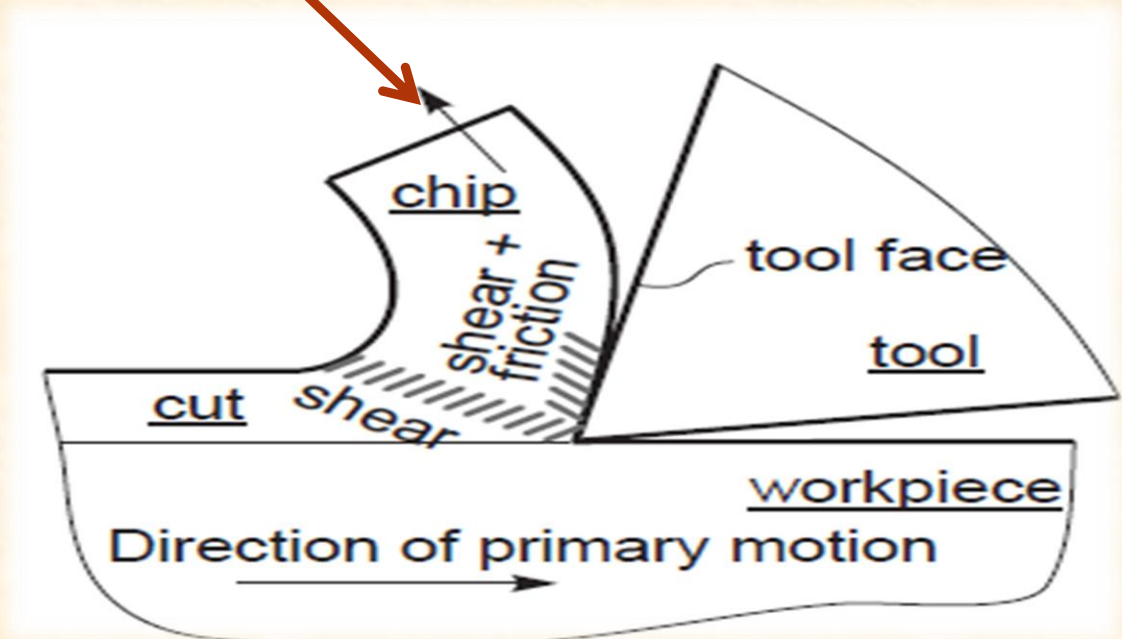
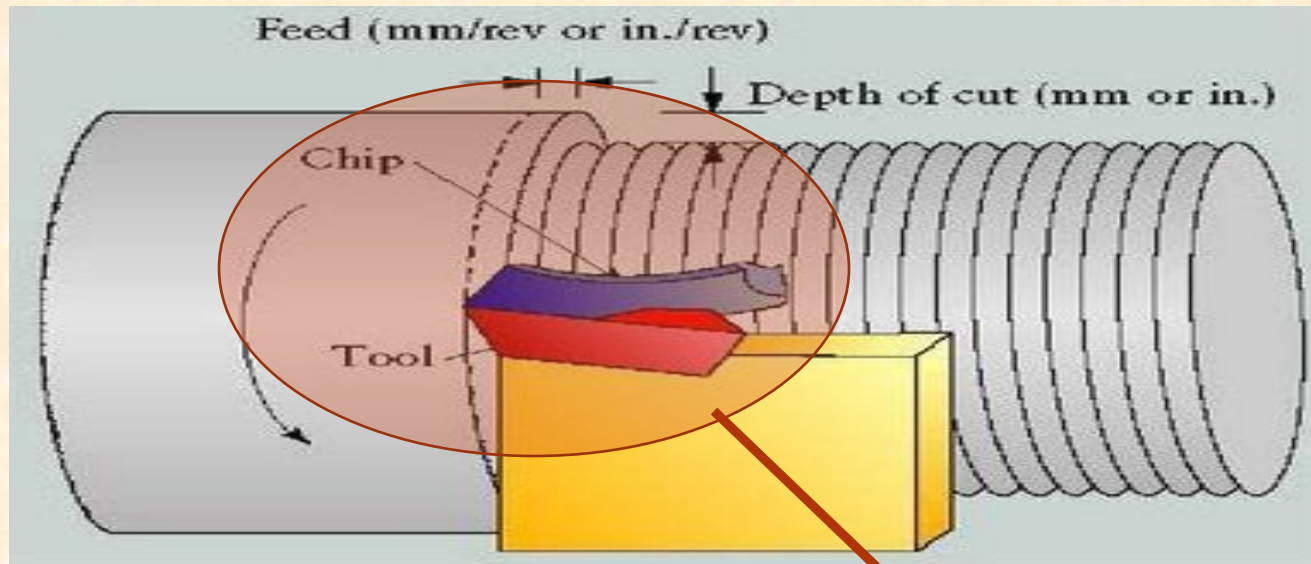
Applied compressive force which leads to formation of chips is called **cutting force**.

➤ Heat produced during shearing action raises the temperature of the workpiece, cutting tool and chips.

➤ Temperature rise in cutting tool softens and causes loss of keenness in cutting edge.

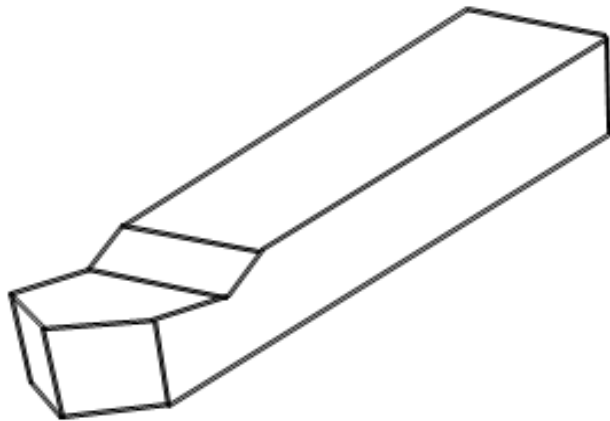
➤ Cutting force, heat and abrasive wear are important features in metal cutting.



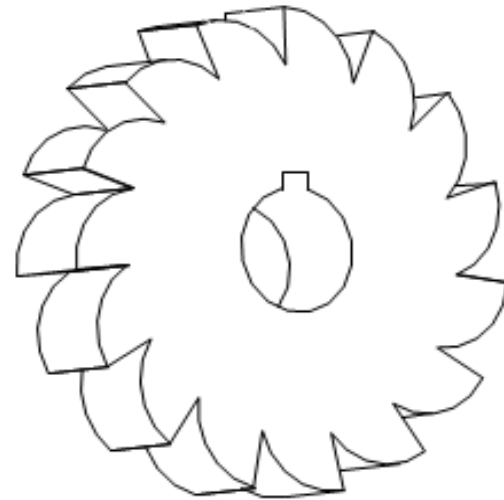


Types of Cutting Tools

Single Point

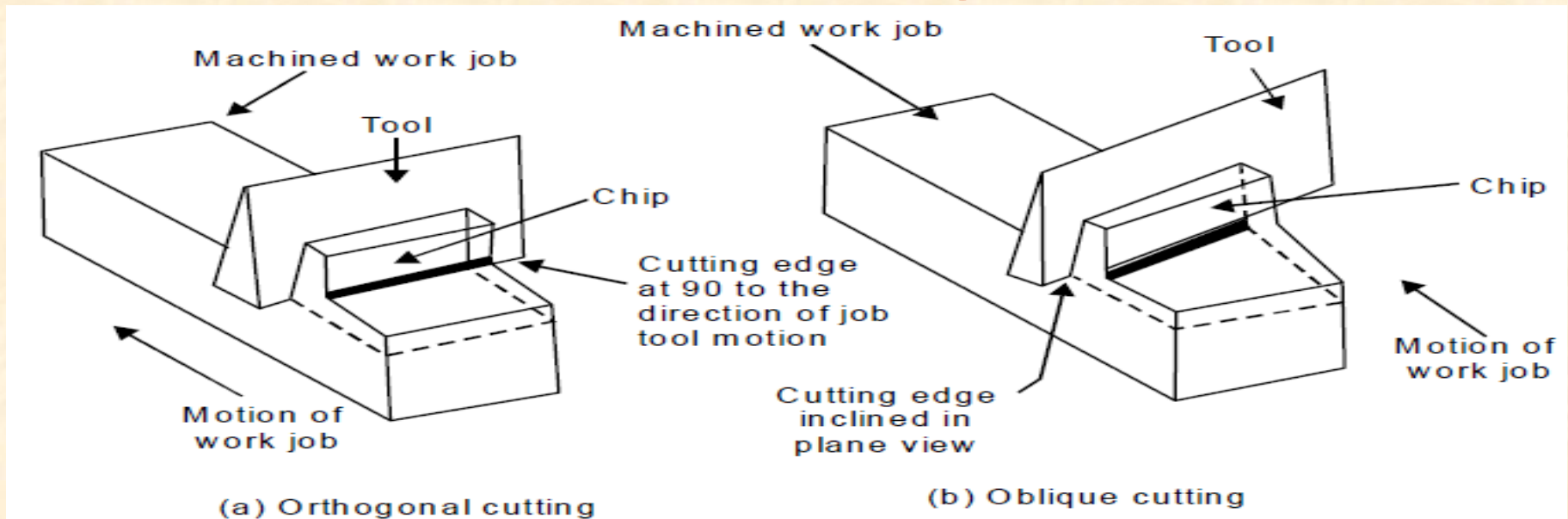


Multipoint



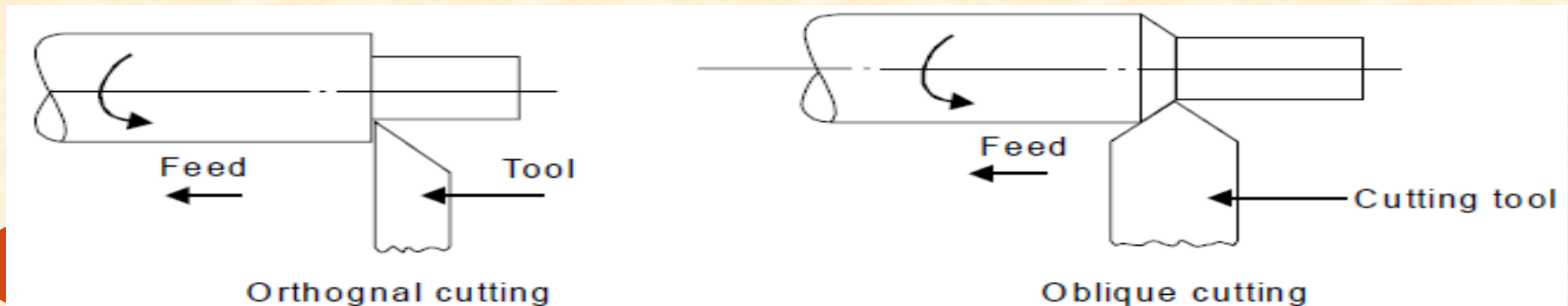
- Cutting tools perform the main machining operation.
- It is a body having teeth or cutting edges on it.
- They comprise of single point cutting tool or multipoint cutting tools.

Types of Metal Cutting Process



Orthogonal cutting is also known as two dimensional metal cutting in which the cutting edge is normal to the work piece. (angle = 90deg)

Oblique cutting is also known as three dimensional cutting in which the cutting action is inclined with the job by a certain angle called the inclination angle. (angle \neq 90deg)



Single point cutting tool : This type of tool has a effective cutting edge and removes excess material from the work piece along the cutting edge.

➤ These tools may be left-handed or right-handed.

➤ Again single point cutting tools classified as

A. solid type

B. tipped tool.

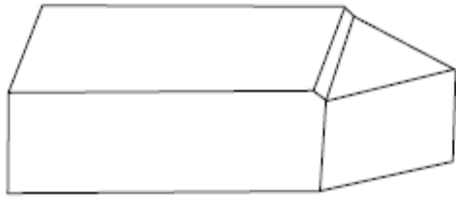
C. Brazed tools

are generally known as tool bits and are used in tool holders.

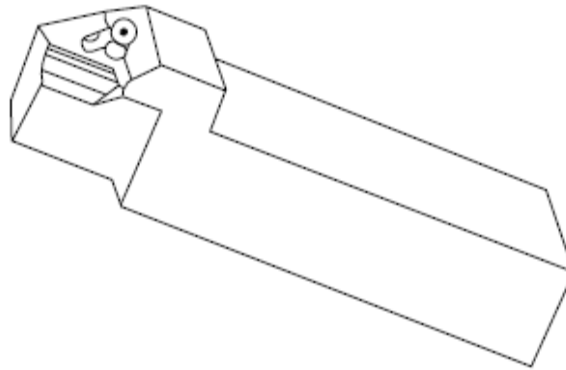
➤ The tipped type of tool is made from a good shank steel on which is mounted a tip of cutting tool material.

➤ Tip may be made of high speed steel or cemented carbide.

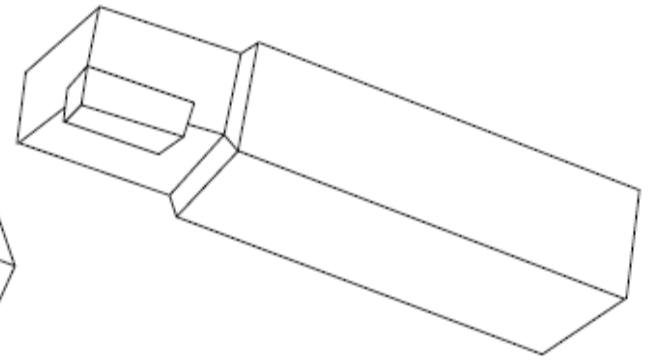
➤ Different types of carbide tips are generally used on tipped tool.



Solid type of single point cutting tool



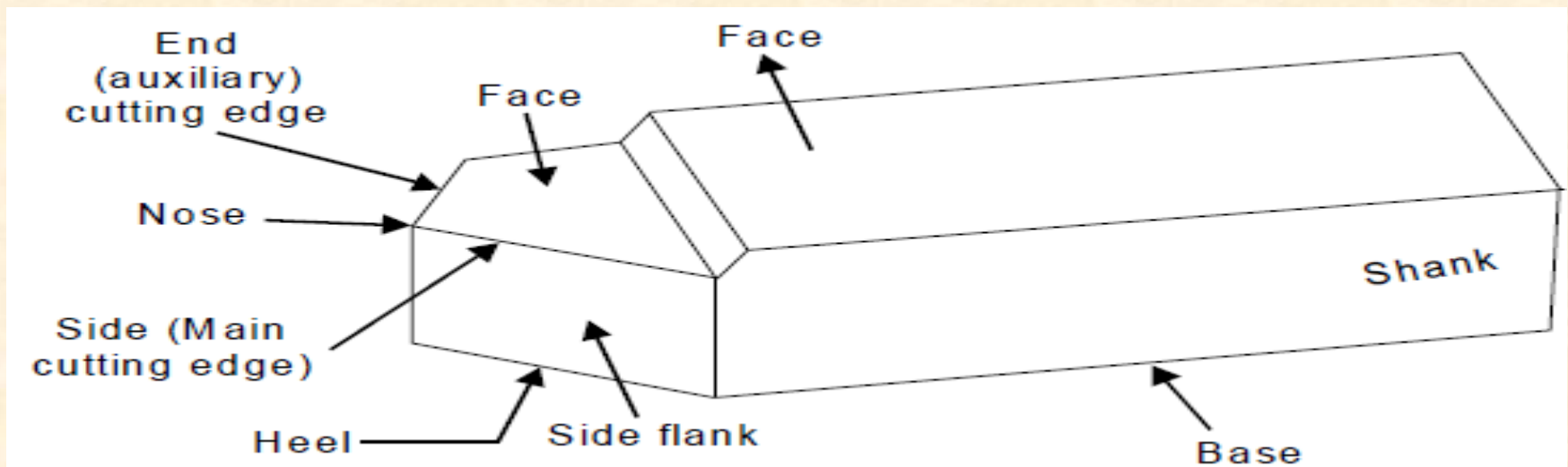
Tipped type single point cutting tool



Index-able insert type single point cutting tool

Geometry comprises mainly of nose, rake face of the tool, flank, heel and shank etc.

The nose is shaped as conical with different angles.

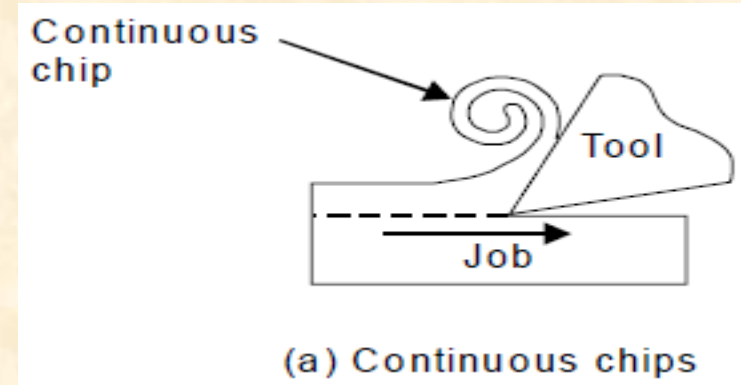


Types of Chips

Chips are separated from the workpiece to impart the required size and shape.

The chips that are formed during metal cutting operations can be classified into four types:

1. **Continuous chips**
2. **Continuous chips with built-up edge**
3. **Discontinuous or segmental chips.**
4. **Non homogenous chips**

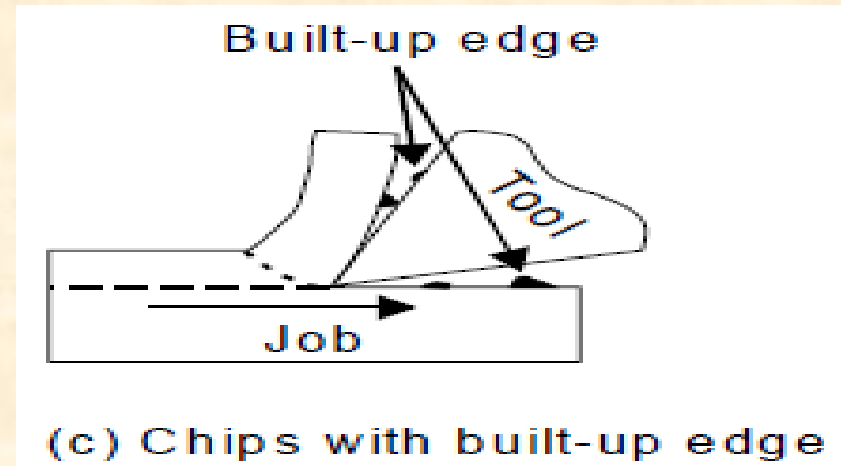


1. Continuous chips

- Chip is produced when there is low friction between the chip and tool face
- This chip has the shape of long string or curls into a tight roll
- Chip is produced when ductile materials such as Al, Cu, M.S, and wrought Iron are machined.
- Formation of very lengthy chip is hazardous to the machining process and the machine operators.

- It may wrap up on the cutting tool, work piece and interrupt in the cutting operation.
- It becomes necessary to deform or break long continuous chips into small pieces.
- It is done by using chip breakers and this can be an integral part of the tool design or a separate device.

2. Continuous chips with built-up edge



- When high friction exists between chip and tool, the chip material welds itself to the tool face.
- Welded material increases friction further which in turn leads to the building up a layer upon layer of chip material.
- Build up edge grows and breaks down when it becomes unstable.
- Chips with build up edge result in higher power consumption, poor surface finish and large tool wear

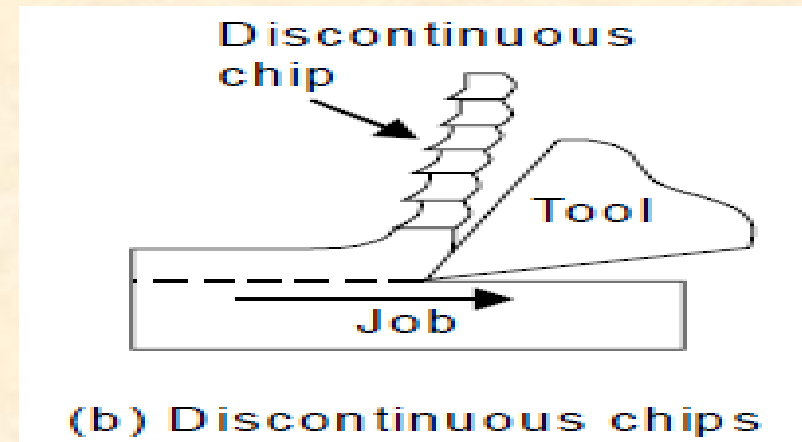
3. Discontinuous or segmental chips

Chip is produced in the form of small pieces.

These types of chips are obtained while machining brittle material like cast iron, brass and bronze at very low speeds and high feeds.

For brittle materials it is associated with fair surface finish, lower power consumption and reasonable tool life.

For ductile materials it is associated with poor surface finish excessive tool wear.



4. Non-homogeneous chips

It will be in the form of notches and formed due to non-uniform strain in material during chip formation.

Non homogenous chips are developed during machining highly hard alloys like titanium.

Chip Control and Chip Breakers

- During machining high tensile strength materials chips has to be properly controlled.
- Carbide tip tools will be used for high speeds which leads to high temperature and produce continuous chips with blue color.
- If the above mentioned chips are not broken means it will adversely effect the machining in following ways,
 - Spoiling cutting edge
 - Raising temperature
 - Poor surface finish
 - Hazardous to machine operator
- Two ways are employed to overcome all the above drawbacks.

First one is **Proper selection of cutting conditions** and second one is **chip breakers** are used to break the chips.

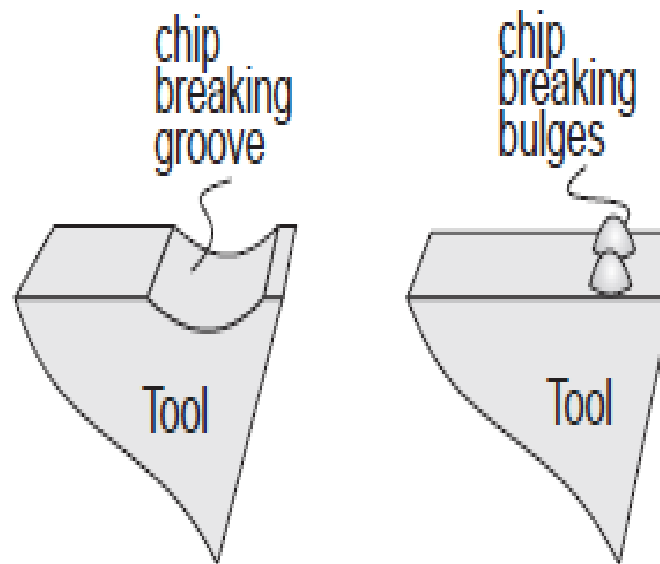
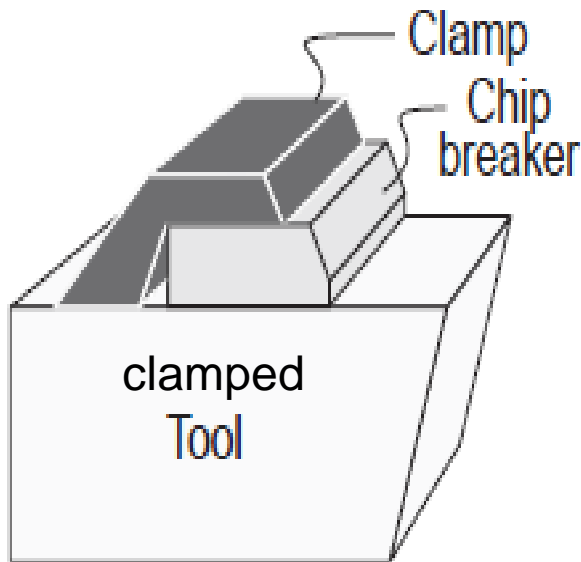
Proper selection of cutting conditions

- Since the cutting speed influences to the great extend the productivity of machining and surface finish, working at low speeds may not be desirable.
- If the cutting speed is to be kept high, changing the feed and depth of cut is a reasonable solution for chip control.

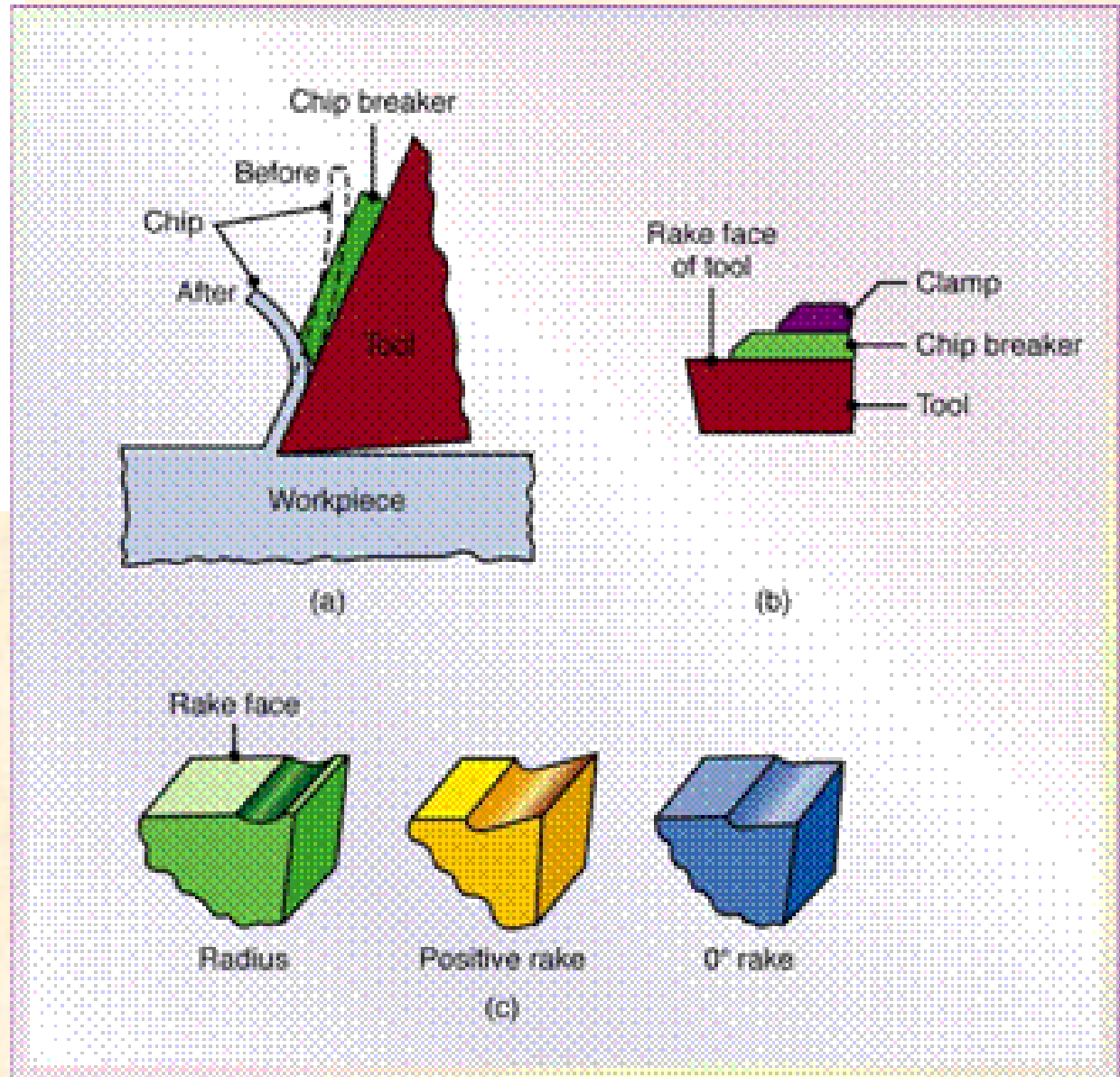
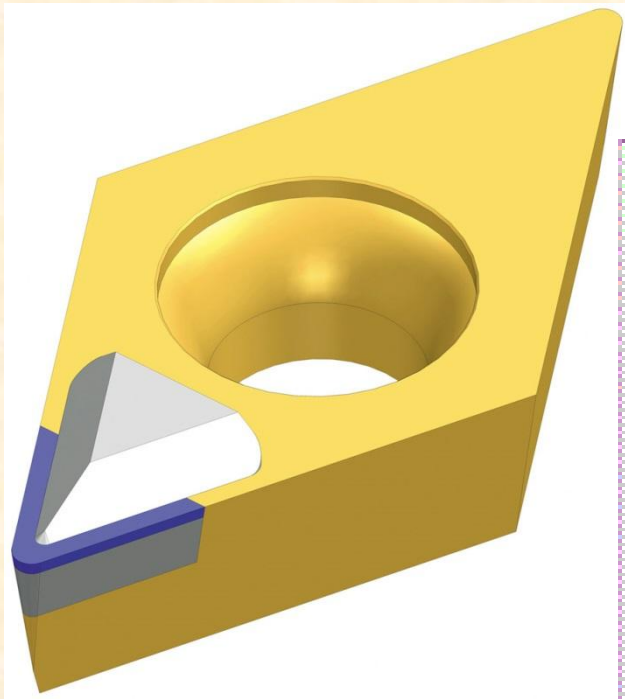
Chip breaker

There are two types of chip breakers

1. External type, an inclined obstruction clamped to the tool face
2. Integral type, a groove ground into the tool face or bulges formed onto the tool face



Cut-off carbide insert with an inbuilt advanced chip breaking groove



NOMENCLATURE of SINGLE POINT TOOL

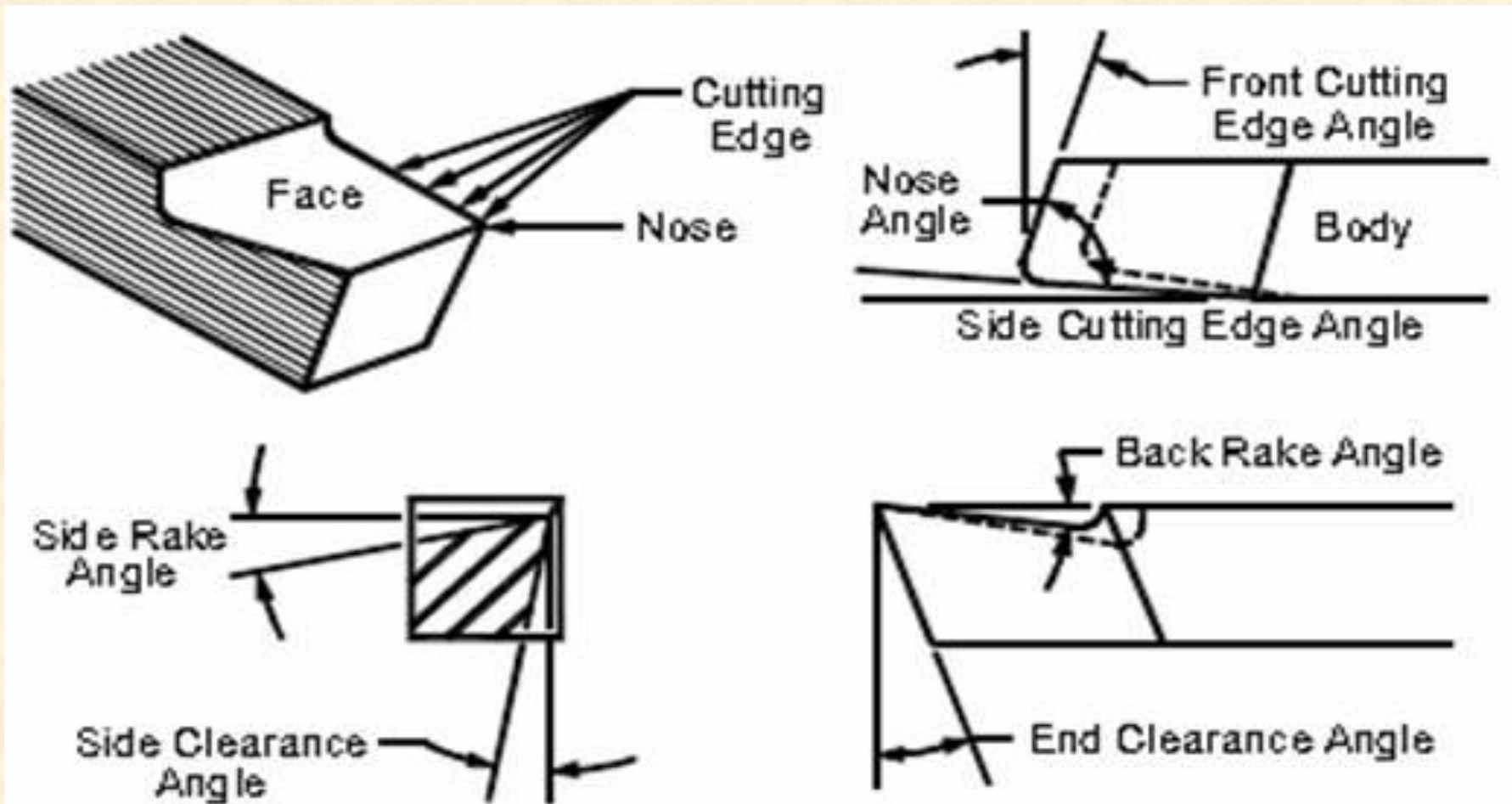
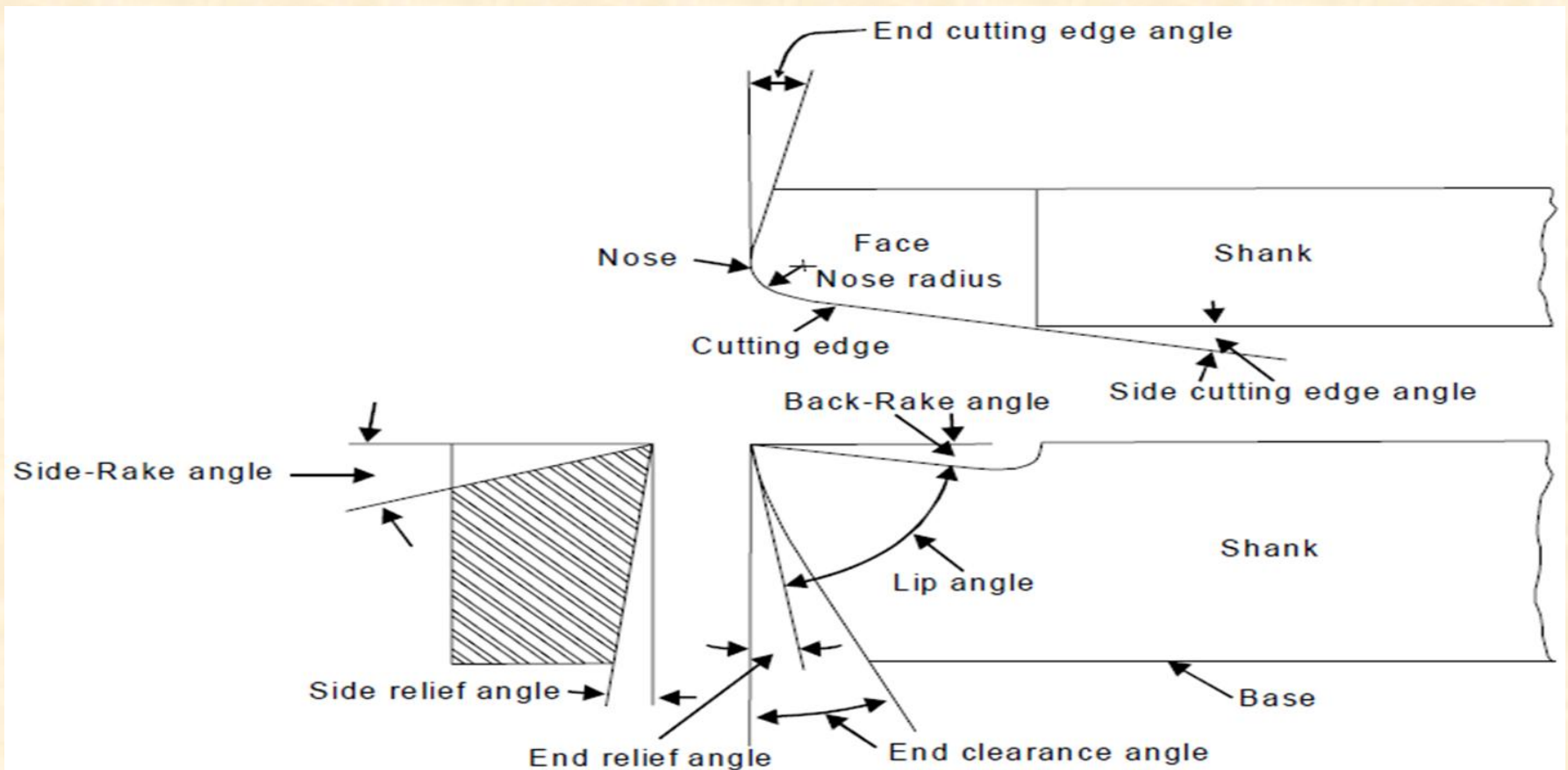
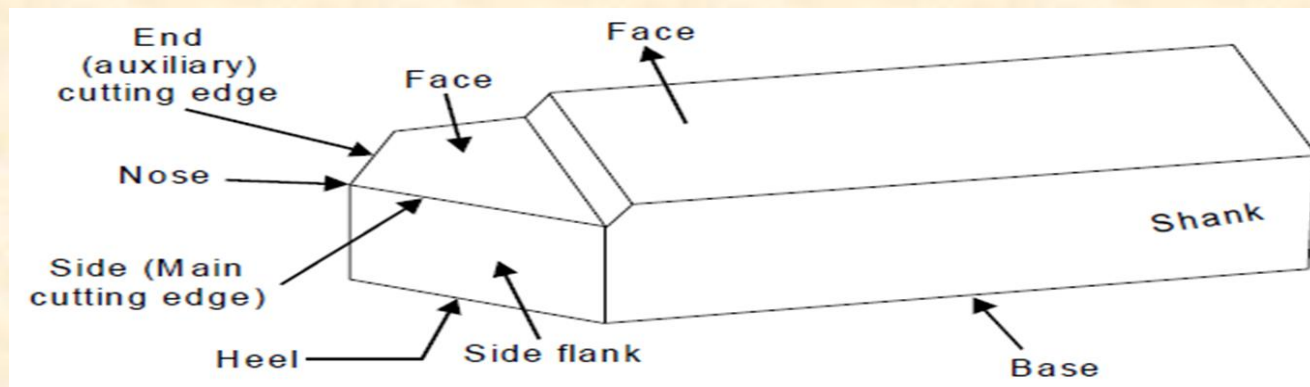
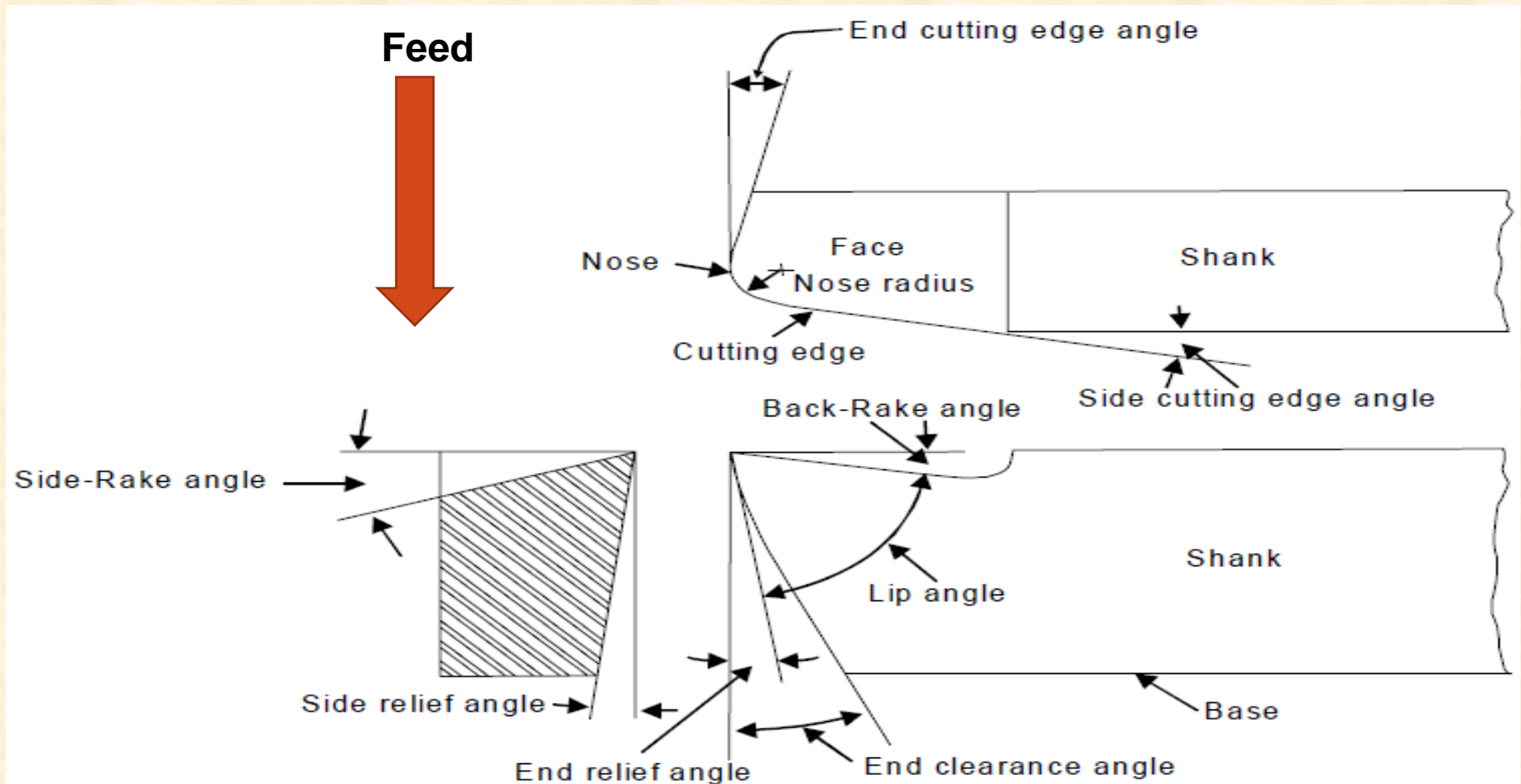


Figure 7 29. Tool bit nomenclature.





Back rake angle (α_b)

It is the angle between the face of the tool and a line parallel with base of the tool measured in a perpendicular plane through the side cutting edge.

Side rake angle (α_s)

- It is the angle by which the face of tool is inclined side ways.
- This angle of tool determines the thickness of the tool behind the cutting edge.
- It is provided on tool to provide clearance between work piece and tool so as to prevent the rubbing of work- piece with end flank of tool.

End relief angle

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.

It is the angle that allows the tool to cut without rubbing on the work- piece.

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.

End cutting edge angle

- It 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 work piece.

Side cutting edge angle

- It is the angle between straight cutting edge on the side of tool and the side of the shank.
- It is also known as lead angle.
- It is responsible for turning the chip away from the finished surface.

Tool Signature

Convenient way to specify tool angles by use of a standardized abbreviated system is known as tool signature or tool nomenclature.

The seven elements that comprise the signature of a single point cutting tool can be stated in the following order:

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)

Properties of cutting tool materials

1. **Red hardness or Hot Hardness:** It is the ability of a material to retain its hardness at high temperature
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

Classification tool materials

1. *Carbon-Tool Steels:*

- 0.6-1.5% carbon + little amount of Mn, Si, Cr, V to increase hardness.
- Low carbon varieties possess good toughness & shock resistance.
- High carbon varieties possess good abrasion resistance

2. *High Speed Steels (HSS):*

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

- Two types of HSS i.e, is T-type and M-Type
- Vanadium increases abrasion resistance but higher percentage will decreases grindability.
- Chromium increases hardenability
- Cobalt is added to HSS to increase red hardness.

3. Cast Cobalt Base Alloys:

- It is a combination of W, Cr, carbon and Cobalt which form an alloy with red hardness, wear resistance and toughness. It is prepare by casting.
- Used for machining Cast iron, alloy steels, non-ferrous metals and super alloys

4. Cemented Carbides:

- These are carbides of W, Titanium and tantalum with small amount of cobalt produced by means of powder metallurgy route.
- Two types i.e, **Straight Tungsten Carbide Cobalt Grade** and **Alloyed Tungsten Carbide Grade**

Straight Tungsten Carbide Cobalt Grade : Cast iron, non ferrous alloys, plastics, wood, glass etc.

Alloyed Tungsten Carbide Grade: All grades of steel at 3 to 4 times more speeds than HSS

5. Ceramic Tools:

- Aluminium Oxide, Silicon Carbide, Boron Carbide, Titanium Carbide, Titanium Boride
- High speed, longer tool life, superior surface finish, No coolant is required.

6. Diamond Tools:

- More abrasion resistance
- Used for turning grinding wheels
- Used to produce mirror surface finish.
- Diamond abrasive belts are used to produce TV screens
- Poly crystalline diamond inserts are brazed into cutting edges of circular saws for cutting construction materials like concrete, refractories, stone etc.