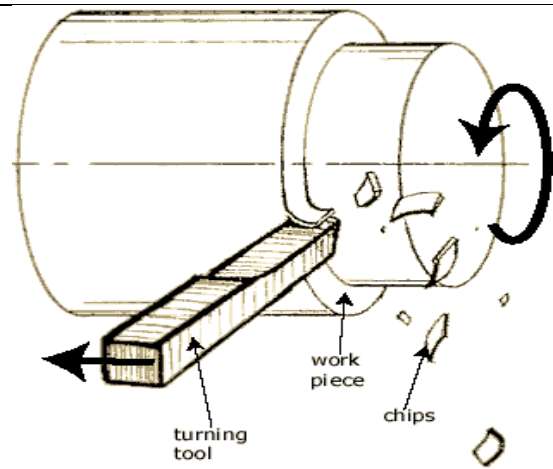


Theory of metal cutting

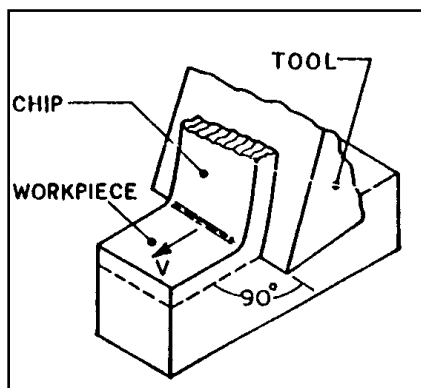
Production or manufacturing of any object is a value addition process by which raw material of low utility and value due to its irregular size, shape and finish is converted into a high utility and valued product with definite size, shape and finish imparting some desired function ability.



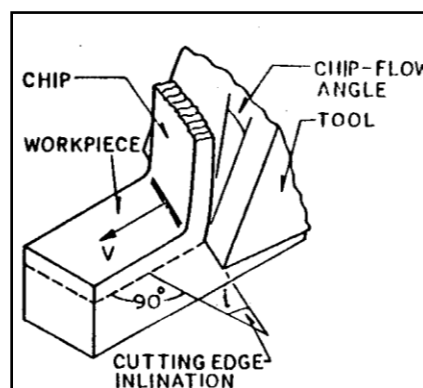
Machining is an essential process of semi-finishing and often finishing by which jobs of desired shape and dimensions are produced by removing extra material from the preformed blanks in the form of chips with the help of cutting tools moved past the work surfaces in machine tools. The chips are separated from the workpiece by means of a cutting tool that possesses a very high hardness compared with that of the workpiece, as well as certain geometrical characteristics that depend upon the conditions of the cutting operation. Among all of the manufacturing methods, metal cutting, commonly called machining; is perhaps the most important. Forgings and castings are subjected to subsequent machining operations to acquire the precise dimensions and surface finish required. Also, products can sometimes be manufactured by machining stock materials like bars, plates, or structural sections.

In the metal cutting operation, the tool is wedge-shaped and has a straight cutting edge. Basically, there are two methods of metal cutting, depending upon the arrangement of the cutting edge with respect to the direction of relative work-tool motion:

- Orthogonal cutting or two dimensional cutting
- Oblique cutting or three dimensioning cutting.



(a)



(b)

Fig 3.1 (a) Orthogonal Machining (b) Oblique Machining

Orthogonal Cutting

- The cutting edge of the tool remains at 90° to the direction of feed (of the tool or the work).
- The chip flows in a direction normal to the cutting edge of the tool.
- The cutting edge of the tool has zero inclination with the normal to the feed.
- The chip flows in the plane of the tool face. Therefore, it makes no angle with the normal (in the plane of the tool face) to the cutting.
- The shear force acts on a smaller area, so shear force per unit area is more.
- The tool life is smaller than obtained in oblique cutting (for same conditions of cutting).
- There are only two mutually perpendicular components of cutting forces on the tool.
- The cutting edge is bigger than the width of cut.

Oblique Cutting

- The cutting edge of the tool remains inclined at an acute angle to the direction of feed (of the work or tool).
- The direction of the chip flow is not normal to the cutting edge. Rather it is at an angle β to the normal to the cutting edge.
- The cutting edge is inclined at an angle λ to the normal to the feed. This angle is called **inclination angle**.
- The chip flows at an angle β to the normal to the cutting edge. This angle is called **chip flow angle**.
- The chip flows at an angle β to the normal to the cutting edge. This angle is called chip flow angle.
- The shear force acts on a larger area, hence the shear force per area is smaller.
- The tool life is higher than obtained in orthogonal cutting.
- There are only three mutually perpendicular components of cutting forces on the tool.
- The cutting edge is smaller than the width of cut.

Cutting Tool Geometry

Cutting tool is device with which a material could be cut to the desired size, shape or finish. So a cutting tool must have at least a sharp edge. There are two types of cutting tool. The tool having only one cutting edge is called single point cutting tools. For example shaper tools, lathe tools, planer tools, etc. The tool having more than one cutting edge is called multipoint cutting tools. For example drills, milling cutters, broaches, grinding wheel honing tool etc.

A single point cutting tool may be either right or left hand cut tool depending on the direction of feed.

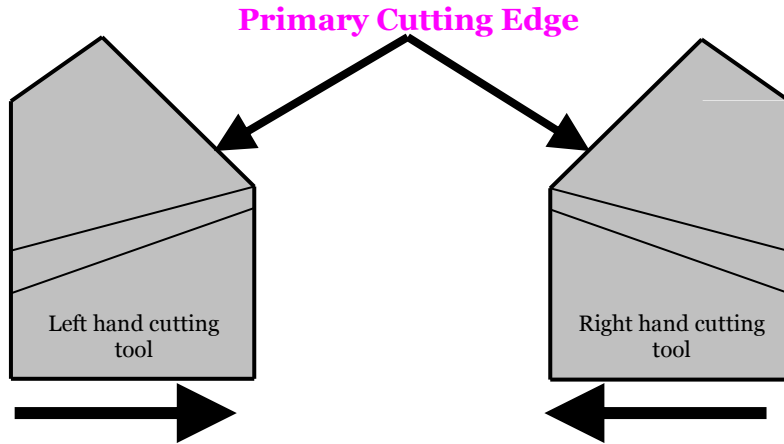


Fig 3.2 (a) Left hand (b) Right hand cutting tool

Tool-in-hand Nomenclature

The geometry of a cutting tool consists of the following elements: face or rake surface, flank, cutting edges and the corner. Face or rake is the surface of the cutting tool along which the chips flow out. Flank surfaces are those facing the work piece. There are two flank surfaces, principal and auxiliary flank surfaces. Principal cutting edge performs the major portion of cutting and is formed by the intersecting line of the face with the principal flank surface. Auxiliary cutting edge (often called end cutting edge) is formed by the intersection of the rake surface with the auxiliary flank surface. Corner or cutting point is the meeting point of the principal cutting edge with the auxiliary cutting edge.

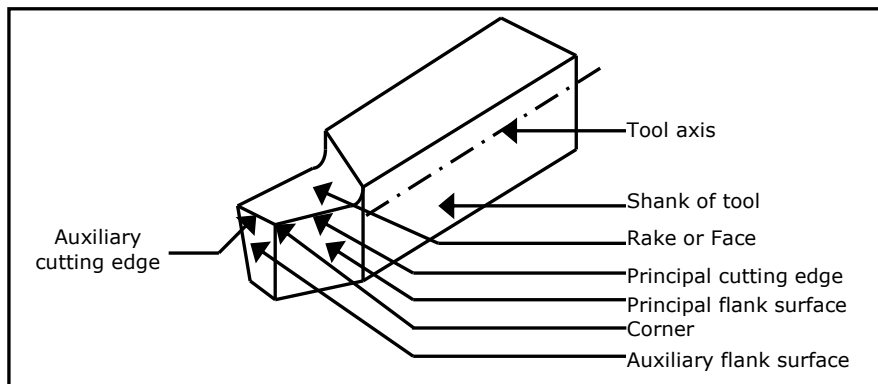
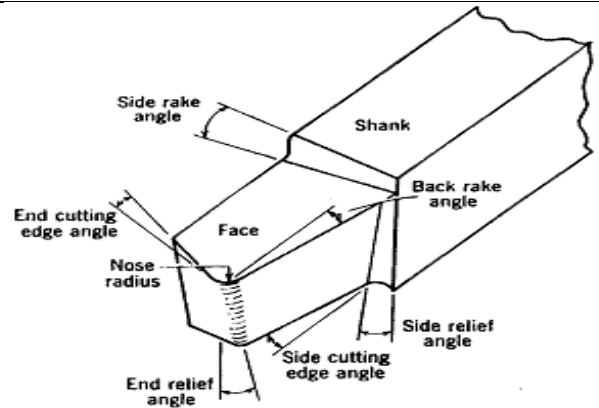


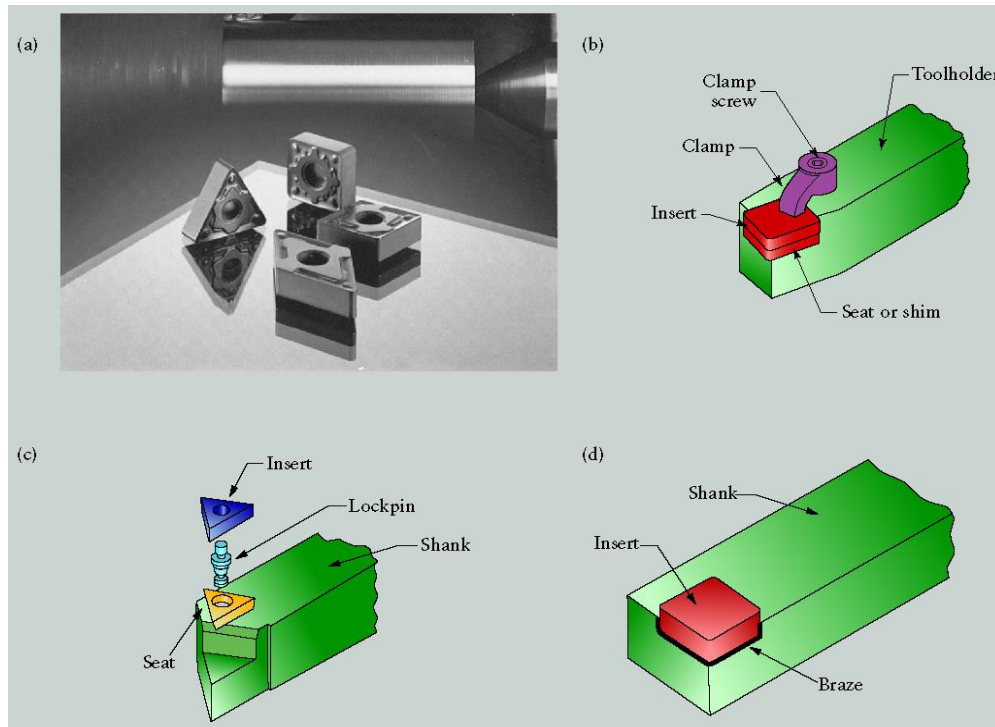
Fig 3.3 Cutting tool geometry

- 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
- Flank: Portion tool which faces the work. It is surface adjacent to & below the cutting edge when tool lies in a horizontal position.



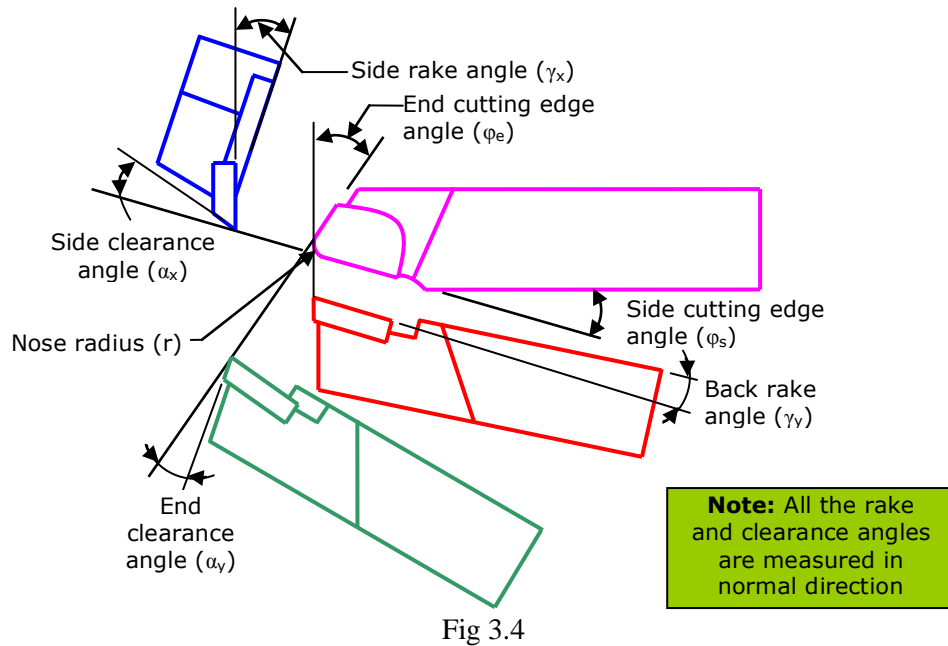
- Point: Wedge shaped portion where face & flank of tool meet.
- Base: Bearing surface of tool on which it is held in a tool holder.
- Nose radius: Cutting tip, which carries a sharp cutting point. Nose provided with radius to enable greater strength, increase tool life & surface life. Typical Value : 0.4 mm – 1.6 mm

Carbide Inserts

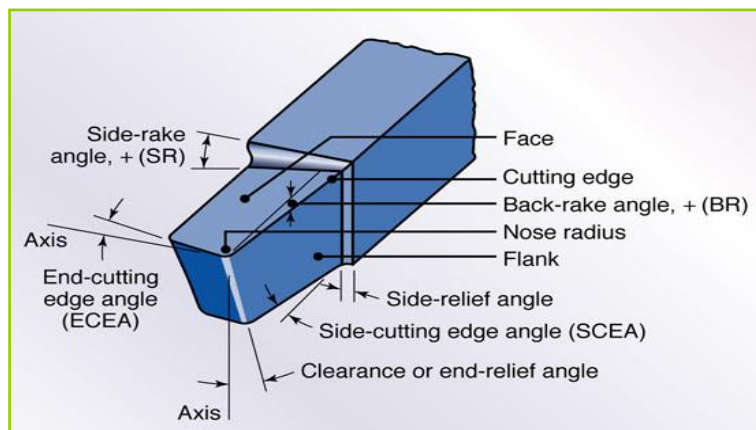


(a) Typical carbide inserts with various shapes and chip-breaker features. Round inserts are also available. The holes in the inserts are standardized for interchangeability. *Source:* Courtesy of Kyocera Engineered Ceramics, Inc., and *Manufacturing Engineering*, Society of Manufacturing Engineers. (b) Methods of attaching inserts to a tool shank by clamping, (c) with wing lockpins, and (d) with a brazed insert on a shank.

Single Point Cutting Tool



Side Cutting Edge Angle (ϕ_s): The side cutting-edge angle (SCEA) is usually referred to as the lead angle. It is the angle enclosed between the side cutting edge and the longitudinal direction of the tool. The value of this angle varies between 0° and 90° , depending upon the machinability, rigidity, and, sometimes, the shape of the workpiece. As this angle increases from 0° to 15° , the power consumption during cutting decreases. However, there is a limit for increasing the SCEA, beyond which excessive vibrations take place because of the large tool-workpiece interface. On the other hand, if the angle were taken as 0° , the full cutting edge would start to cut the workpiece at once, causing an initial shock. Usually, the recommended value for the lead angle should range between 15° and 30° .



Auxiliary or End Cutting Edge Angle (ϕ_e): The end cutting-edge angle (ECEA) serves to eliminate rubbing between the end cutting edge and the machined surface of the workpiece. Although this angle takes values in the range of 5° to 30° , commonly recommended values are 8° to 15° .

Side Clearance Angle (α_x) and End Clearance Angle (α_y): Side and end clearance (relief) angles serve to eliminate rubbing between the workpiece and the side and end flank, respectively. Usually, the value of each of these angles ranges between 5° and 15° .

Back Rake Angle (γ_y) and Side Rake Angle (γ_x): Back and side rake angles determine the direction of flow of the chips onto the face of the tool. Rake angles can be positive, negative, or zero. It is the side rake angle that has the dominant influence on cutting. Its value usually varies between 0° and 15° , whereas the back rake angle is usually taken as 0° .

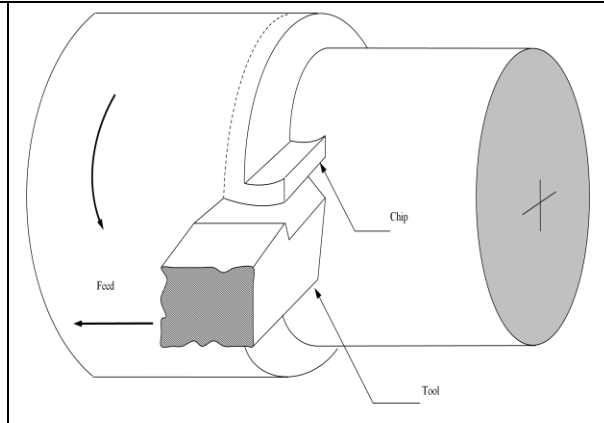
Nose radius (r): Nose radius is favorable to long tool life and good surface finish. A sharp point on the end of a tool is highly stressed, short lived and leaves a groove in the path of cut. There is an improvement in surface finish and permissible cutting speed as nose radius is increased from zero value. Too large a nose radius will induce chatter.

Theory of Chip Formation

Chip Formation

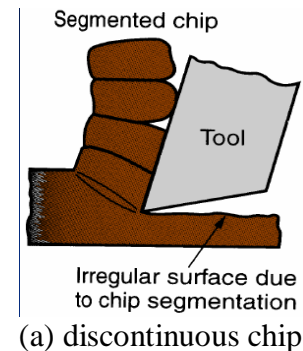
Every Machining operation involves the formation of chips. The nature of which differs from operation to operation, properties of work piece material and the cutting condition. Chips are formed due to cutting tool, which is harder and more wear-resistant than the work piece and the force and power to overcome the resistance of work material.

The chip is formed by the deformation of the metal lying ahead of the cutting edge by a process of shear. Four main categories of chips are:

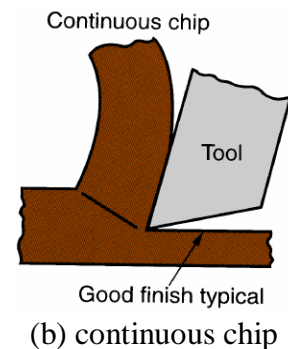


- Discontinuous Chips
- Continuous or Ribbon Type Chips
- Continuous Chip Built-up-Edge (BUE)
- Serrated Chips

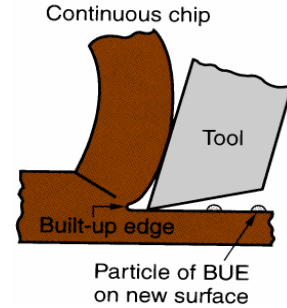
Discontinuous chips: These chips are small segments, which adhere loosely to each other. They are formed when the amount of deformation to which chips undergo is limited by repeated fracturing. Hard and brittle materials like bronze, brass and cast iron will produce such chips.



Continuous or 'ribbon' type chips: In continuous chip formation, the pressure of the work piece builds until the material fails by slip along the plane. The inside on the chip displays steps produced by the intermittent slip, but the outside is very smooth. It has its elements bonded together in the form of long coils and is formed by the continuous plastic deformation of material without fracture ahead of the cutting edge of the tool and is followed by the smooth flow of chip up the tool face.

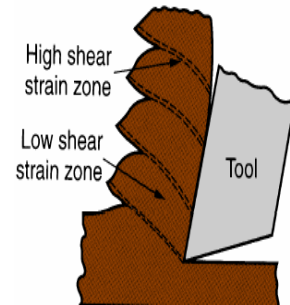


Continuous chip with built up edge: This type of chip is very similar to that of continuous type, with the difference that it is not as smooth as the previous one. This type of chip is associated with poor surface finish, but protects the cutting edge from wear due to movement of chips and the action of heat causing the increase in tool life.



(c) continuous chip with built-up edge

Serrated chips: These chips are semi continuous in the sense that they possess a saw-tooth appearance that is produced by a cyclical chip formation of alternating high shear strain followed by low shear strain. This chip is most closely associated with certain difficult-to-machine metals such as titanium alloys, nickel-base super alloys, and austenitic stainless steels when they are machined at higher cutting speeds. However, the phenomenon is also found with more common work metals (e.g., steels), when they are cut at high speeds.

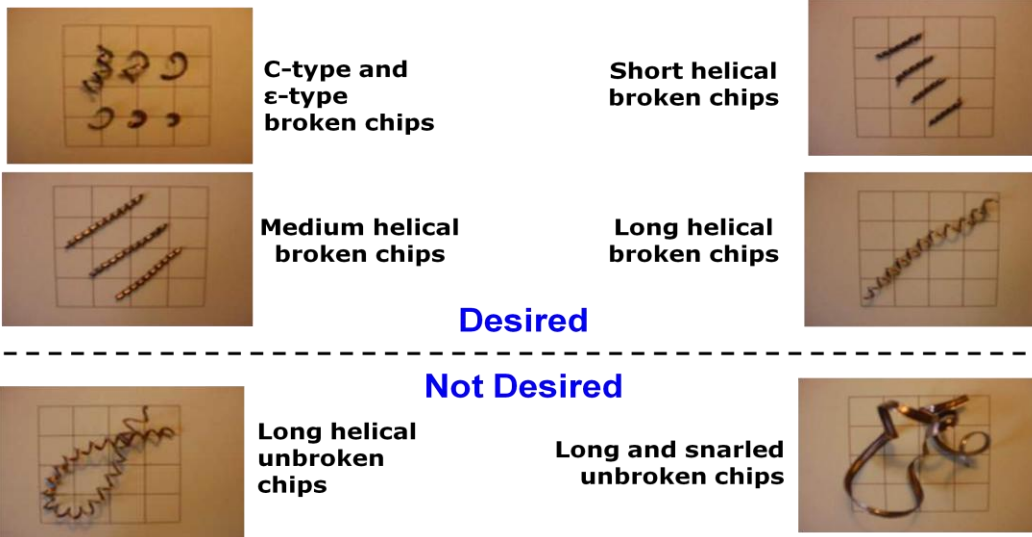


(d) serrated chip

Cutting conditions are the main causes for discontinuous chips

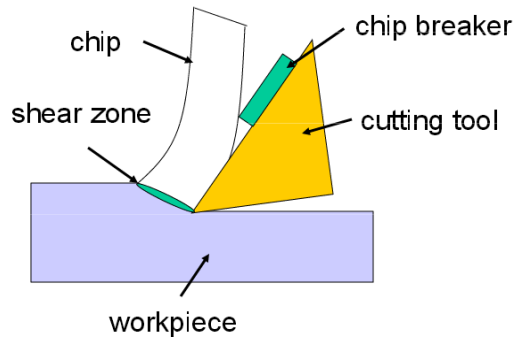
- Very low or very high cutting speed
- Large depth of cut
- Low rake angle
- Lack of cutting fluid
- Vibration on the machine tool

Actual Chip Forms and Classifications



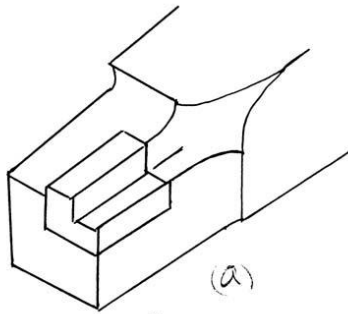
Chip Breaking

- If you decrease the radius of chip enough you can break the chip.
- Why break the chip?
 - easier to remove chips
 - chips don't nest and entangle part or machine.

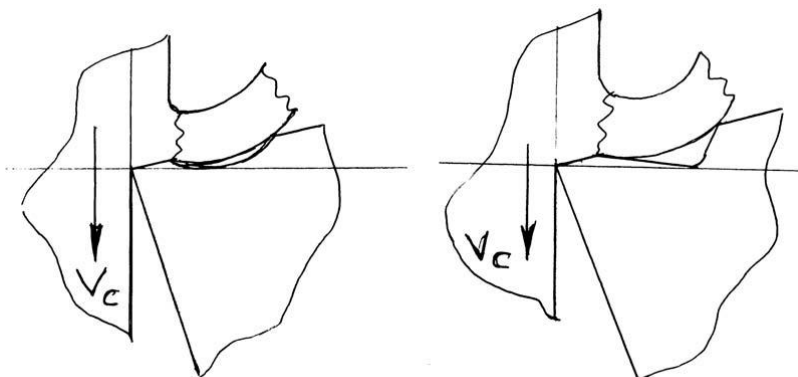
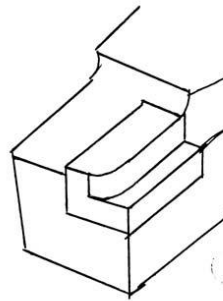


Chip breakers are basically of two types:

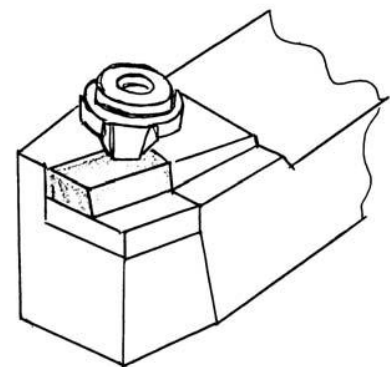
1. In-built type-
 - a. Step type in-built
 - b. Groove type in-built
2. Clamped or attached type



1. a-Step type in-built chip breaker



1. b-Groove type in-built chip breaker



2. Clamped type chip breakers