<table>
<tr><th>Chapter</th><th>Name of the Topic</th><th>Marks</th></tr>
<tr><td>04</td><td>4 FUNDAMENTALS OF MACHINING
Specific Objectives:
➢ Study of different types of machining tools and parameters
4.1 Chip formation
• Mechanism of chip formation.
• Types of chips
• Orthogonal and Oblique cutting
4.2 Cutting tools and fluids
• Types of cutting tools: single and multi-point
• Cutting tool materials: Selection, Properties and types
• Single point cutting Tool nomenclature and tool signature.
• Cutting fluids: Properties, types</td><td>12</td></tr>
</table>

Q. What is metal cutting?

Metal cutting or machining is process of producing workpiece by removing unwanted material from a block of metal, in the form of chips.

4.1 Chip formation

- **Mechanics of cutting and chip formation**

In Fig.4.1 the tool is considered stationary, and the work piece moves to the right. 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.

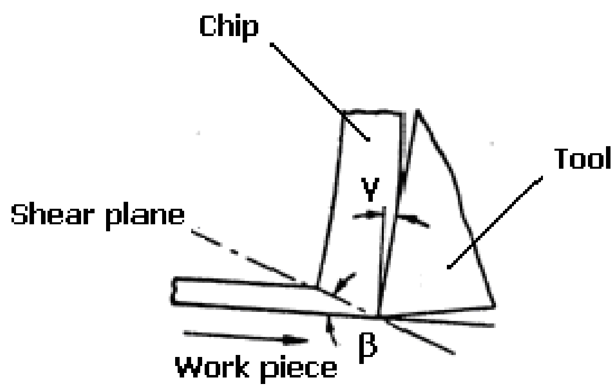


Fig 4.1 Shear plane in metal cutting

When the stress in the work piece 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 metal cutting continuous chip is formed having a highly compressed and burnished underside, and a minutely serrated top side caused by the shearing action. The place along which the element shears is called the shear plane.

Actually, the deformation does not occur sharply across the shear plane, but rather it occurs along a narrow band. The structure begins elongating along the line AB below the shear plane and continues to do so until it is completely deformed along the line CD above the shear plane in Fig.4.2. The region between the lower surface AB, where elongation of the grain structure begins, and the upper surface CD, where it is completed and the chip is born, is called the shear zone or primary deformation zone. In Fig.4.2 the shear zone is included between two parallel lines AB and CD. Actually, however, these two lines may not be parallel but may produce a wedge-shaped zone which is thicker near the tool face at the right than at the left. This is one of the causes of curling of chips in metal cutting.

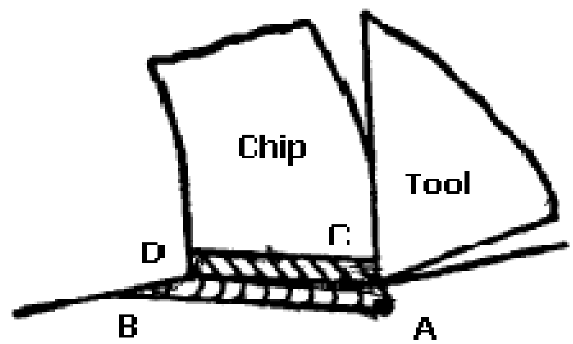


Fig 4.2 Shear zone during metal cutting

In addition, owing to the non-uniform distribution of forces at the chip-tool interface and on the shear plane the shear plane must be slightly curved concave downward. This also causes the chip to curl away from the cutting face of the tool.

- **Types of chips.**

1. The discontinuous or segmental form.
2. The continuous or ribbon type.
3. The continuous with built-up edge.

Discontinuous or segmental chips

- Machining of brittle materials produce these types of chips.
- Small fragments are produced because of lack in ductility of material.
- Friction between tool and chip reduces, resulting in better surface finish.

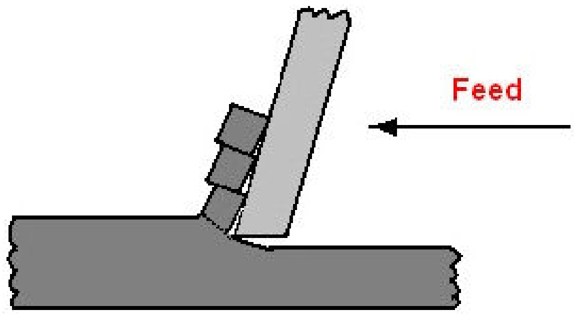


Fig 4.3 Segmental chips

Continuous chips

- Machining of ductile materials produce these types of chips.
- Continuous fragments are produced because of high ductility of material.
- Chips are difficult to handle.

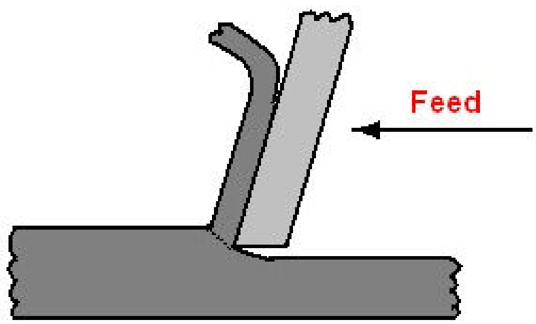


Fig 4.4 Continuous chips

Continuous chips with built-up edge (BUE)

- When machining ductile material, conditions of high local temperature and extreme pressure in the cutting zone and also high friction in the tool-chip interface, may cause the work material to adhere or weld to the cutting edge of the tool forming BUE
- BUE changes its size during cutting operation.
- It protects the cutting edge but it changes the geometry of the tool.

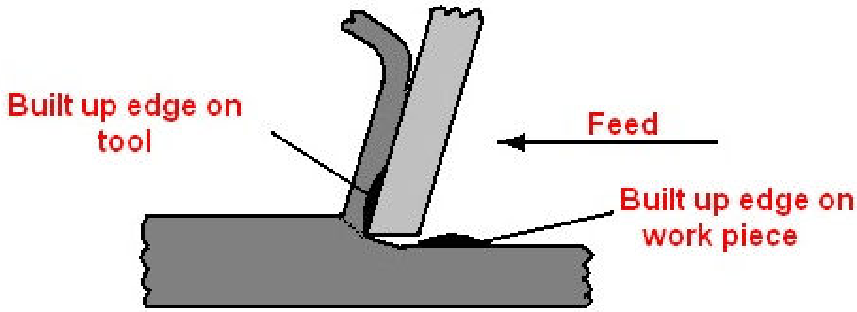


Fig 4.5 Built up chips

Conditions tending to promote the formation of built-up edges include: low cutting speed, low rake angle, high feed, and lack of cutting fluid and large depth of cut.

- **Types of cutting tools used for machining.**

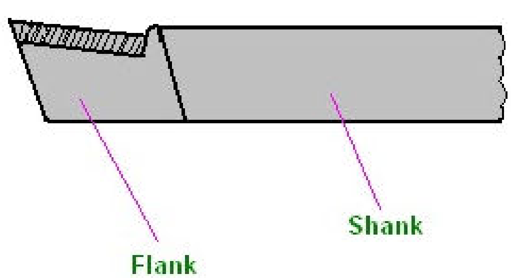
A cutting tool may be used for cutting apart, as with a knife, or for removing chips. Parts are produced by removing metal mostly in the form of small chips.

Chip removal in the metal-cutting process may be performed either by cutting tools having distinct cutting edges or by abrasives used in grinding wheels, abrasive sticks, abrasive cloth, etc. These abrasives have a very large number of hard grains with sharp edges which remove metal from the workpiece surface in such operations as grinding.

All cutting tools can be divided into two groups. These are:

1. Single-point tools. 2. Multi-point tools.

Single-point cutting tools: They having a wedge-like action find a wide application on lathes, and slotting machines. The simplest form of cutting tool is the single-point tool.



Multipoint tools: Multi-point cutting tools are merely two or more single-point tools arranged together as a unit. Cutters like twist drills, reamers, taps, milling cutters have two or more tool points each. They differ in overall appearance and purposes, but each cutting blade acts as and has the basic features of a single-point tool. The milling cutter, and drill like a single point tool, has various angles of importance. A milling cutter has clearance; it often has both a secondary and a primary clearance. A land also exists on a milling cutter and a drill. This is the narrow surface resulting from providing a primary clearance. They may have different rakes depending on the intended use.

- **<u>Orthogonal and oblique cutting using single point cutting tool.</u>**

The two basic methods of metal cutting using a single-point tool are the orthogonal or two-dimensional, and the oblique or three-dimensional. Orthogonal cutting takes place when the cutting face of the tool is 90° to the line of action or path of the tool. If, however, the cutting face is inclined at an angle less than 90° to the path of the tool, the cutting action is known as oblique. Orthogonal and oblique cutting action are illustrated in Fig.4.6, which shows two bars receiving identical cuts. The depth of cut is the same in both cases, and so is the feed, but the force which cuts or shears the metal acts on a larger area in the case of the oblique tool. The oblique tool will, thus, have a longer life as the heat developed per unit area due to friction along the tool-workpiece interface is considerably small. Alternatively, the oblique tool will remove more metal in the same life as an orthogonal tool.

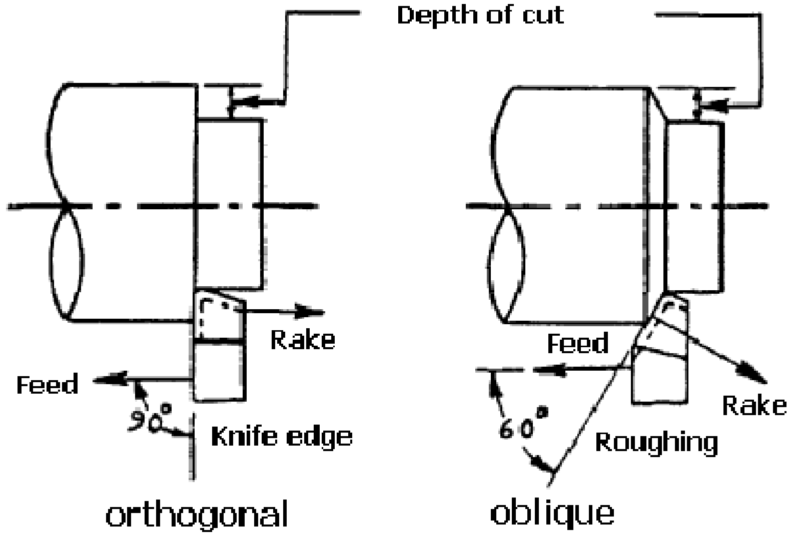


Fig 4.6 Orthogonal & oblique cutting

Fig.4.7 shows the chip flow in orthogonal and oblique cutting. In orthogonal cutting shown at (a) where the cutting edge of the tool OC is at right angles to the direction of the relative velocity V of the work, the chip coils in a tight, flat spiral. In oblique cutting as shown at (b) and at (c) where the cutting edge of the tool is inclined at the angle *i*, the chip flows sideways in a long curl. The inclination angle *i* is defined as the angle between the cutting edge and the normal to the direction of the velocity V of the work. An angle of interest in oblique cutting is the chip flow angle ῃc, which is defined as the angle measured in the plane of the cutting face between the chip flow direction and the normal to the cutting edge. In orthogonal cutting, *i* = 0, ῃc = 0.

Orthogonal cutting in the machine shop is confined mainly to such operations as knife turning, broaching and slotting, the bulk of machining being done by oblique cutting. But orthogonal cutting is the simplest type and is considered in the major part of this Chapter. The principles developed for orthogonal cutting apply generally to oblique cutting.

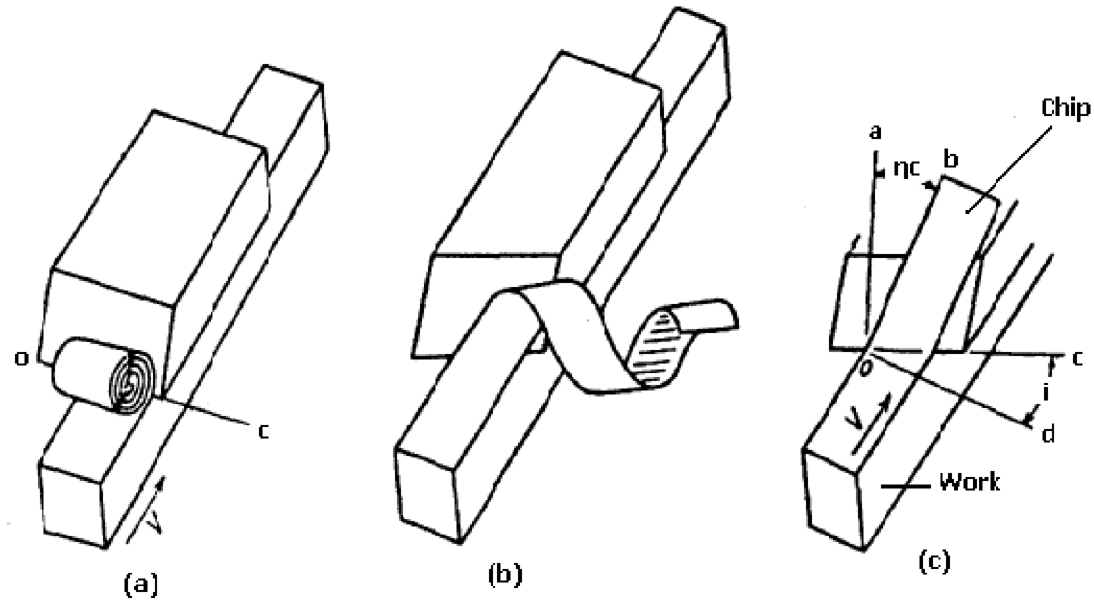


Fig 4.7 Direction of chip flow in orthogonal & oblique cutting

Orthogonal metal cutting	Oblique metal cutting
Cutting edge of the tool is perpendicular to the direction of tool travel.	The cutting edge is inclined at an angle less than 90° to the direction of tool travel.
The direction of chip flow is perpendicular to the cutting edge.	The chip flows on the tool face making an angle.
The chip coils in a tight flat spiral	The chip flows sideways in a long curl.
For same feed and depth of cut the force which shears the metal acts on a smaller areas. So the life of the tool is less.	The cutting force acts on larger area and so tool life is more.
Produces sharp corners.	Produces a chamfer at the end of the cut
Smaller length of cutting edge is in contact with the work.	For the same depth of cut greater length of cutting edge is in contact with the work.

- **Properties of tool materials**

The characteristics/ properties of the ideal material are:

1. **Hot hardness:** The material must remain harder than the work material at elevated operating temperatures.

2. **Wear resistance:** The material must withstand excessive wear even though the relative hardness of the tool-work materials changes.

3. **Toughness:** The material must have sufficient toughness to withstand shocks and vibrations and to prevent breakage.

4. **Cost and easiness in fabrication:** The cost and easiness of fabrication should have within reasonable limits.

- **Tool materials**

The selection of proper tool material depends on the type of service to which the tool will be subjected. No material is superior in all respects, but rather each has certain characteristics which limit its field of application.

The principal cutting materials are:

1. High-speed steels.
2. Stellites.
3. Cemented carbides.
4. Diamonds.

1. **High-speed steels:**

- These steels are called as HSS because these steels cut material at high speeds and retain their hardness even at high temperature.
- It consists of iron and carbon with differing amounts of alloying elements such as tungsten, chromium, vanadium and cobalt.
- 18:4:1 HSS tool is used to manufacture drills, reamers, and taps.

2. **Stellites:**

- Stellite is the trade name of a nonferrous cast alloy composed of cobalt, chromium and tungsten.
- It is shaped by casting from which it gets cutting properties.

3. **Cemented carbides:**

The basic ingredient of most cemented carbides is tungsten carbide which is extremely hard. Pure tungsten powder is mixed under high heat, at about 1500 ^{0}C, with pure carbon (lamp black) in the ratio of 94 per cent and 6 per cent by weight. The new compound, tungsten carbide, is then mixed with cobalt until the mass is entirely homogeneous.

4. **Diamond:**
   - The diamonds used for cutting tools are industrial diamonds, which are naturally occurring diamonds containing flaws and therefore of no value as gemstones. Alternatively they can be also artificial.
   - These are suitable for cutting very hard materials such as glass, plastics and ceramics.
   - **Elements of the metal cutting process**

Feed (S): it is the movement of the tool cutting edge per revolution of workpiece. In turning, feed is expressed in mm/revolution.

Speed (V): The distance travelled by the work surface per unit time in reference to the cutting edge of the tool.

Cutting speed=πDN/1000 m/min

Where, D= Diameter of workpiece in mm

N= Speed of the workpiece in rpm

Depth of cut (t): It is measured in a direction perpendicular to work axis.

$$\mathbf{t} = \frac{\mathbf{D-d}}{\mathbf{2}} \quad \text{mm}$$

Standard time (T): The time required to machine one workpiece

T= Tm+Th+Ts+Tf

Where, Tm= Machining time; Th=Handling time;

Ts= Servicing time; Tf= Fatigue time

- **Single point cutting tool nomenclature.**

Cutting tool nomenclature means systematic naming of the various parts and angles of a cutting tool. The surface on the point of a tool bears definite relationship to each other that are defined by angles. The principles underlying cutting-tool angles are the same whether the tool is a single-point tool, a multipoint tool, or a grinding wheel. Since a single-point tool is the easiest to understand, it will be discussed in greater detail. The basic angles needed on a single-point tool may be best understood by removing the unwanted surface from an oblong tool blank of square section.

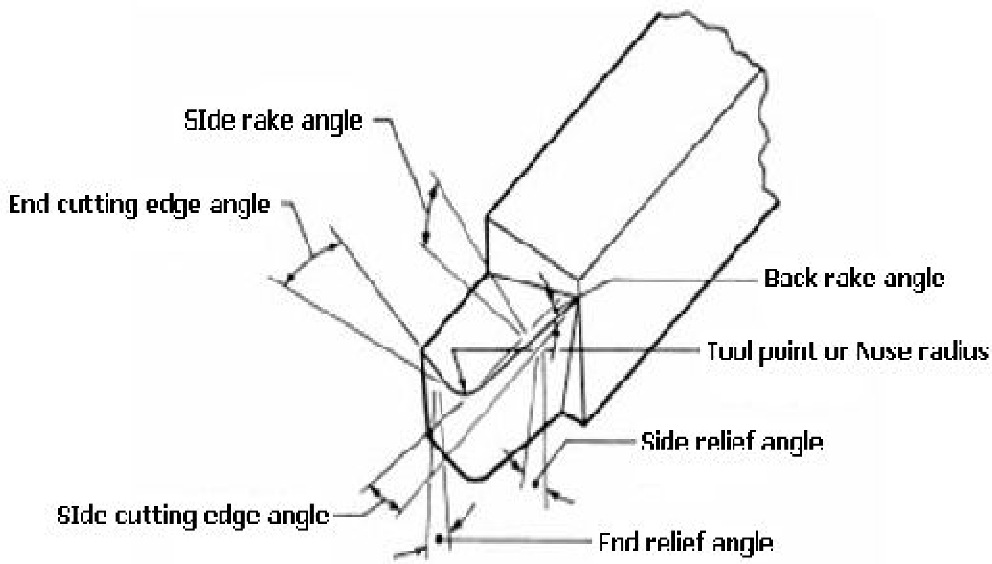
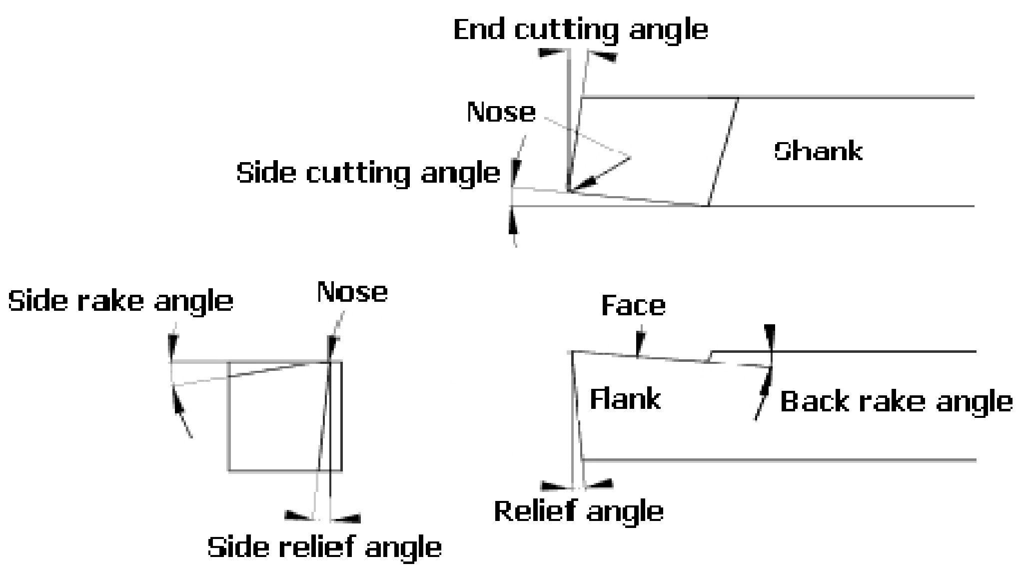


Fig 4.8 3D view of cutting tool

The **Shank** is that portion of the tool bit which is not ground to form cutting edges and is rectangular in cross-section.

The **face** of the cutting-tool is that surface against which the chip slides upward.



The **flank** of a cutting-tool is that surface which faces the work piece.

The **heel** of a single point tool is the lowest portion of the side-cutting edges.

The **nose** of a tool is the conjunction of the side- and end-cutting edges. A nose radius increases the tool life and improves surface finish.

The **base** of a tool is the under-side of the shank.

The **rake** is the slope of the top away from the cutting edge. The larger the rake angle, the larger the shear angle and subsequently the cutting force and power reduce. A large rake angle is conducive to good surface finish. Each tool has a side and back rake. Back rake indicates that the plane which forms the face or top of a tool has been ground back at an angle sloping from the nose. Side rake indicates that the plane that forms the face or top of a tool has been ground back at an angle sloping from the side cutting edge. Side rake is more important than back rake for turning operations.

The **side clearance or side relief** indicates that the plane that forms the flank or side of a tool has been ground back at an angle sloping down form the side cutting edge. Likewise, the end clearance or end relief indicates that the nose or end of a tool has been ground back at an angle sloping down from the end cutting edge.

The **end cutting edge angle** indicates that the plane which forms the end of a tool has been ground back at an angle sloping form the nose to the side of the shank, whereas the side cutting edge angle indicates that the plane which forms the flank or side for a tool has been ground back at an angle to the side of the shank. In the main, chips are removed by this cutting edge.

The **lip or cutting angle** is the included angle when the tool has been ground wedged-shaped.

- **Tool signature**

Convenient way to specify tool angles by use of a standardized abbreviated system is known as tool signature or tool nomenclature. It indicates the angles that a tool utilizes during the cut. It specifies the active angles of the tool normal to the cutting edge. This will always be true as long as the tool shank is mounted at right angles to the work-piece axis.

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)

Tool signature (designation) under ASA (American Standards Association) System is given in the order

$$\alpha_b\text{-}\alpha_s\text{-}\theta_e\text{-}\theta_s\text{-}C_e\text{-}C_s\text{-}R$$

α_b = Back rake angle; α_s = Side rake angle; θ_e = End relief angle;

θ_s **=** Side relief angle; C_e = End cutting edge angle; C_s **=** Side cutting edge angle; R = Nose radius

- **Purposes, properties and types of cutting fluids**

Cutting fluids, sometimes referred to as lubricants or coolants are liquids and gases applied to the tool and work piece to assist in the cutting operations.

Purpose of Cutting Fluids

Purposes:

Cutting fluids are used for the following

1. To cool the tool: Cooling the tool is necessary to prevent metallurgical damage and to assist in decreasing friction at the tool-chip interface and at the tool-work piece interface.
2. To cool the work piece. The role of the cutting fluid in cooling the work piece is to prevent its excessive thermal distortion.
3. To lubricate and reduce friction
4. To improve surface finish

Properties of Cutting Fluids:

- High heat absorption for readily absorbing heat developed.
- Good lubricating qualities to produce low-coefficient of friction.
- High flash point so as to eliminate the hazard of fire.
- Stability so as not to oxide in the air.
- Neutral so as not to react chemically.

Type of Cutting Fluids:

Water: Water, plain or containing an alkali, salt or water-soluble additive but little or no oil or soap are sometimes used only as a coolant. But water alone is, in most cases, objectionable for its corrosiveness.

Soluble oils: Soluble oils are emulsions composed of around 80 per cent or more water, soap and mineral oil. The soap acts as an emulsifying agent which breaks the oil into minute particles to dispose them throughout water. The water increases the cooling effect and the oil proxies the best lubricating properties and ensures freedom from rust. By mixing various proportions of water with soluble oils and soaps, cutting fluids with a wide range of cooling and lubricating properties can be obtained.

Straight oils: The straight oils may be (a) straight mineral (petroleum) oils, kerosene, low-viscosity petroleum fractions, such as mineral seal, or higher-viscosity mineral oils, (b) straight fixed or fatty oils consisting animal, vegetable, or synthetic equivalent, lard oil, etc. They have both cooling and lubricating properties and are used in light machining operations.

Chemical compounds: These compounds consist mainly of a rust inhibitor, such as sodium nitrate, mixed with a high percentage of water.

Solid lubricants: Stick waxes and bar soaps are sometimes used as a convenient means of applying lubrication to the cutting tool.