Safety in the Machine Shop

Machine shop safety can be divided into two areas of concern:

1. Protection against personal injury
2. Prevention of damage to tools, machines, and equipment.

Personal Safety

Hot, sharp metal chips produced in cutting operations can burn and cut the worker. Grinding wheels can throw abrasive particles into unprotected eyes. Rotating tools and workpieces can catch loose clothing and hair. Workers who think safety and work safety can avoid hazards. They must dress properly, follow correct work procedures, and work harmoniously with fellow workers, Figure 1.

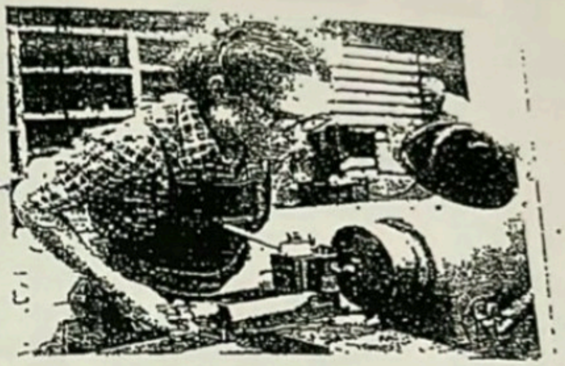


Figure 1: Worker in a machine shop

How to Dress Safely

1. For eye protection, wear clean proper goggles.
2. Wear close fitted clothing. Long sleeves should be close fitted. Wear a close fitting apron or shop coat to protect clothes.
3. Protect your feet by wearing proper shoes.
4. Always remove all jewelry before working with tools and equipment.
5. Confine long hair under a close fitting cap or tie it back securely.
6. Never wear gloves while operating machines.

Safe Work Practices

1. Before starting a machine, be sure that all its safety devices are in place.
2. Be sure that the workpiece and the cutting tool are mounted securely.
3. Keep your hands away from moving machinery and tools.
4. Handle materials carefully to avoid getting cut.
5. Avoid feeling the machined surface of the workpiece while the machine is running.
6. Never leave a machine while it is running.
7. Always stop the machine to perform an operation as measuring.
8. Never use your hand to stop a machine or a moving part.
9. If you want to change speed, wait until a complete stop of moving parts.

10. When working with another person on a machine, agree beforehand on who wi operate the switches and controls.
11. Make it a habit to stop, look, and think in unfamiliar or possibly dangerou situations.
12. Always try to be alert, patient, and willing to help.
13. Ask for help in lifting and handling heavy weights. Remember to lift with you legs, not your back. (See Figure 2)

Figure 2: Lifting heavy objects

Safety with Hand Tools

1. Use the right tool for the job.
2. Keep hands and tools wiped clean and free of dirt, oil, and grease.
3. Keep tools sharp.
4. Carry sharp-edged tools with the edges or points down
5. When handling a tool to another worker, be sure to offer its handle first.
6. The heads of chisels should be properly dressed.
7. Use the right wrench for the job.
8. Check for secure tool handle.
9. Do not use damaged tools

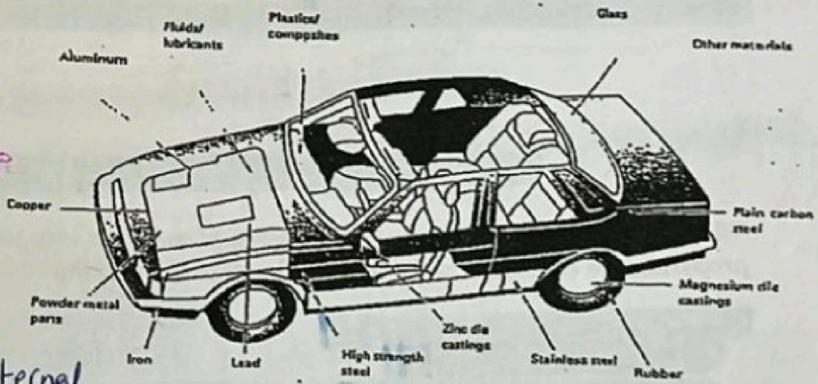
First Aid

1. Always notify the instructor immediately when injured.
2. Always get first aid treatment for cuts promptly.
3. Always treat burns promptly.
4. If you are concerned about either injury or an illness, get professional help as soon as possible.

Engineering Materials

The wealth of a community is measured by the variety and quantity of the articles it possesses for its use and consumption. All the material things we possess are made from substances, which in the first place are won from the earth, or from nature.

Engineers are concerned with the materials available to them. Consider the variety of materials used in the manufacturing of an automobile: Iron, steel, glass, plastics, rubber, and nickel.



The general classification of materials is shown below:

- Materials
  - Metals
    - Ferrous
      - steel
      - cast iron
    - Non ferrous
      - copper
      - aluminum
  - Non-metals
    - Natural Materials
      - glass
      - rubber
    - Synthetic Materials
      - thermoplastic
      - silicon

Pure metals: They are called elements, such as iron or copper. Pure state metals are not used very often.

Metal alloys: Combination of two or more metals or metals and nonmetals. Some of the common known alloys are:

- Bronze = Tin + Copper
- Steel or Cast iron = Iron + Carbon
- Steel: Up to 2% Carbon + Impurities (manganese, silicon, phosphorus).
- Cast iron: 2 to 2.5% Carbon + Impurities.
- Stainless steel: Iron + one or more of (chromium, nickel, tungsten, titanium)

Plastics: Hydrocarbons (paraffin's) linked together to form very large molecules.

Mechanical Properties of Metals and Alloys

When selecting a material, a primary concern of engineers is to assure that the *material properties* are consistent with the operating conditions of the component.

Material properties are classified as:

1. Mechanical properties
2. Physical properties (weight, density, electrical conductivity)

Some of the important **Mechanical Properties** are:

Strength: The ability to resist the application of force without rupture (N/m^2).

- Tension
- Compression
- Torsion
- Shear
- Bending

Elasticity: The power of returning to the original shape after deformation by force.

Ductility: The property of being deformed plastically under load without rupture.

Brittleness: The property of breaking without being plastically deformed.

Hardness: The resistance to indentation by harder bodies.

Toughness: The amount of energy a material can absorb before it fractures.

Production of Iron and Steel

Iron is the fourth most plentiful element in the earth and for centuries has been the most important of the basic engineering materials.

The raw materials required for the production of steel are:

- 2 t Iron ore
- 1 t Coke
- ½ t Limestone
- 3½ t Air

→ Blast Furnace → 1 t Pig iron

Iron Ores as: Fe_3O_4 (Magnetite), and Fe_2O_3 (Hematite)

Pig iron is converted to steel by taking out some of its impurities through one of the following processes:

- Bessemer Process
- Open Hearth Process
- Electric Furnace Process
- Basic Oxygen Process

Heat Treatment of Steel:

Heat treatment is a variety of heating and cooling operations by which the characteristics of metals are changed. Some of these operations are:

Annealing: To soften the steel for better machinability. To relieve internal stresses.

Normalizing: To refine the structure after forging, welding, casting, cold working.

Hardening: To harden the steel to resist wear. To enable the steel to cut other materials.

Tempering: To reduce brittleness and increase toughness.

Case hardening: To harden the outer surface.

Measurement

Measurement, the act of measuring or being measured, is the process of comparing the value to be measured with an accepted standard. Precision measurement is the key to producing interchangeable parts and mass production consumer goods

Basic Standard measurements:

1. Length
2. Angle
3. Weight
4. Time
5. Temperature
6. Optical or electrical standards

Commercial standards have the disadvantage that there is a limit to the accuracy which the instrument can read. To insure accuracy, engineer must know the principle measurement. They also must know how to use the common hand tools, meas instruments, and gages.

Measuring instruments are *checked* and *calibrated* periodically to ensure their accuracy

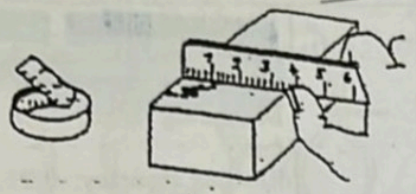
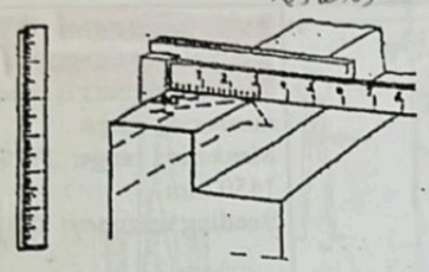
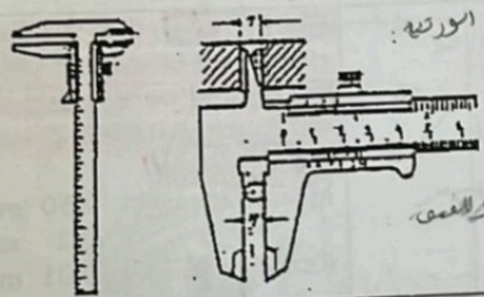
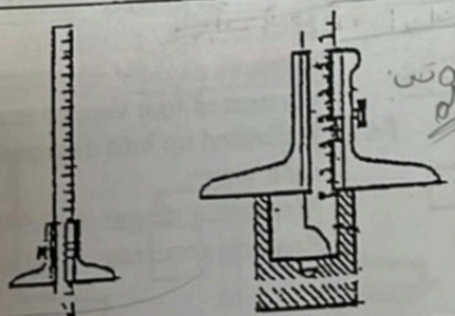
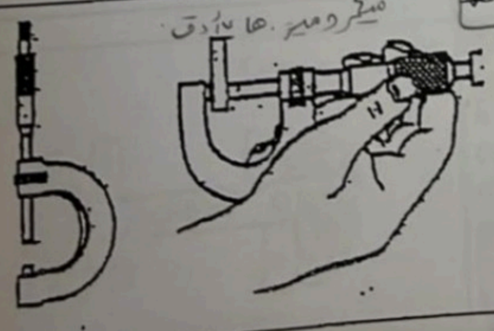
The accuracy of measurements depends on:

1. Least count of the subdivision on the instrument.
2. Line matching.
3. Parallax in reading the instrument.
4. Elastic deformation of the instrument and workpiece.
5. Temperature effect.
6. Operator skill

Types of Measuring Tools:

1. Gradual measuring tools (Figure 1).
2. Checking tools (Figure 2).

Figure 1: Graduated Measuring Tools

	Steel-tape rule. A flexible rule that when extended will support itself, but may also be used to measure curved or irregular surfaces. Measuring range: 2000 mm Reading accuracy: 1 mm
	Steel rule. A flexible rule used for taking linear measurements. Measuring range: 150, 300, 500, 1000 mm Reading accuracy: 0.5 mm
	Vernier caliper. A measuring tool for taking inside and outside measurements. The vernier caliper gives an end measurement. Measuring range: 100, 125, 150, 200, ... 2000 mm Reading accuracy: 0, 1, 0.05, 0.02 mm
	Vernier depth gauge. A tool used to measure the depth of blind holes, grooves, slots, and similar dimensions. Measuring range: 100, 125, 150, 200, ... 500 mm Reading accuracy: 0, 1, 0.05, 0.02 mm
	Micrometer caliper. A tool for taking outside measurements. The micrometer gives an end measurement. Measuring range: 0-25, 25-50, 50-75, ... 500-600 mm Reading accuracy: 0.01 mm

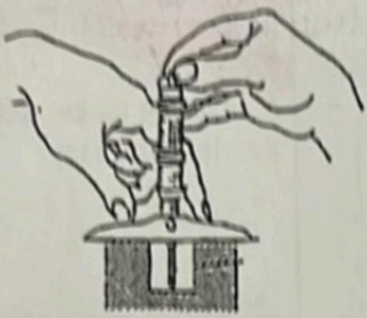
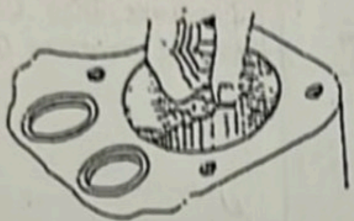
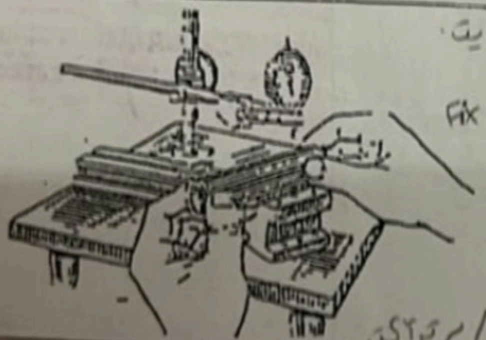
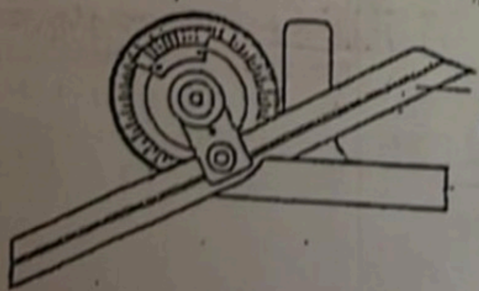
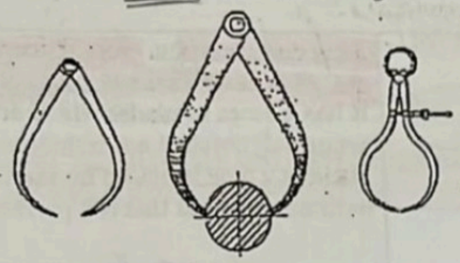
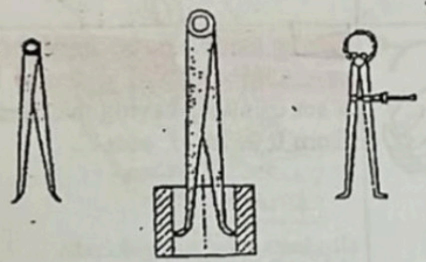
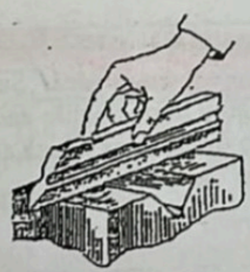
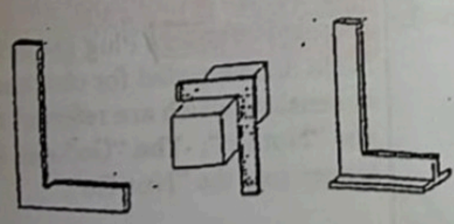
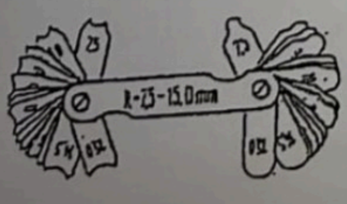
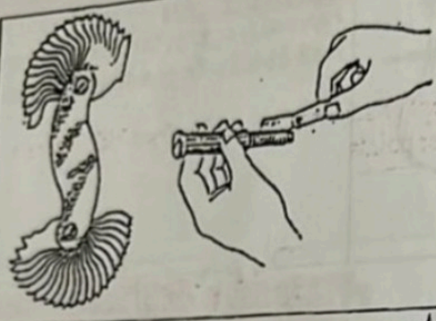
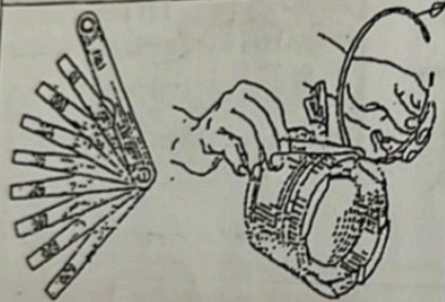
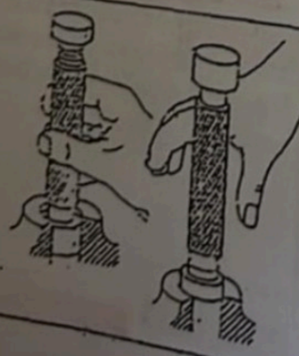
	**Depth micrometer**. A tool used to measure the depth of blind holes, grooves, slots, and similar dimensions. Measuring range: 0-75, 0-150, ... 0-300 mm Reading accuracy: 0.01 mm
	**Inside micrometer**. A tool used for taking internal measurements. A set of lengthening bars is used to increase the measuring range. Measuring range: 35-50, 50-75 ....., 50-1450 mm Reading accuracy: 0.01 mm
	**Dial indicator**. A tool which is like a small clock, used to true and align machine tools, fixtures and work; to test and inspect size and trueness of finished work; to compare measurements. Measuring range: 0-50 mm to 0-2 mm Reading accuracy: 0.01 mm or 0.001 mm
	**Vernier bevel protractor**. A tool used to measure angles. ~~The sliding blade is~~ connected to a vernier scale, the main scale is divided up into degrees from 0 to 90 each way. Measuring range: 4x0-90 Reading accuracy: 5' (minutes)

Figure 2: Checking Tools:

	Outside caliper. A tool used in measuring outside diameters. When the tool has been adjusted properly, the diameter may be read from a rule or a vernier caliper.
	Inside caliper. A tool used in measuring inside diameters. The size of the opening is then read from a rule or a vernier caliper.
	Beveled straightedge. A tool used for testing the flatness of a surface. If the knife-edge is placed against a surface and then held up to the light, any small discrepancy can be detected by the appearance of light. A gap of 0,003 to 0,005 mm can be seen.
	Try square. A tool used for testing squareness. When using the square care should be taken to ensure that its blade is held perpendicular to the surface being tested.
	Radius gauge. A tool used for testing concave and convex corners. It consists of a set of steel blades that are shaped to curved surfaces of definite size. The size of the radius of the curve is stamped on each blade.

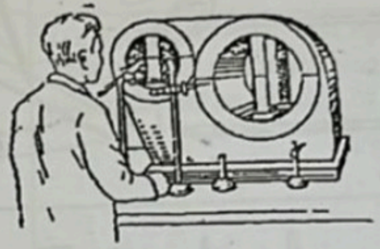
	Screw-pitch gauge. A tool used for testing the pitch of internal and external threads. It has a series of blades which are accurately notched and numbered. One blade at a time is placed on the threads until one is found that is a perfect match.
	Feeler gauge. A tool used for testing the space between two surfaces. It consists of a set of blades having thickness ranging from 0,05 to 1 mm.
	Snap-gauge. A tool used for testing external dimensions. Snap gauges are usually made double-ended for checking two dimensions which are referred to as "Go" and "Not Go".
	Plug gauge. A tool used for testing the accuracy of holes. Plug gauges are usually made double-ended for checking two dimensions which are referred to as "Go" and "Not Go". The "Go" end is made longer than the "Not Go".

Marking Out

Definition:

Marking out (laying out) is the process of scribing lines on blanks which indicate the position of finished surfaces or center points.

Marking out with steel rule

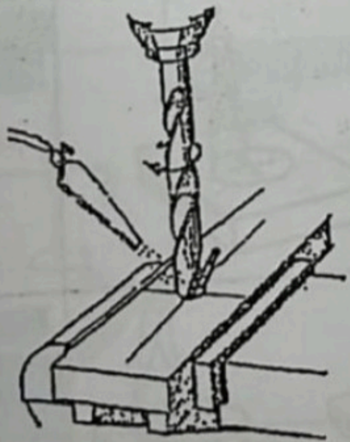


Marking out with surface gauge

Principles of Marking Out:

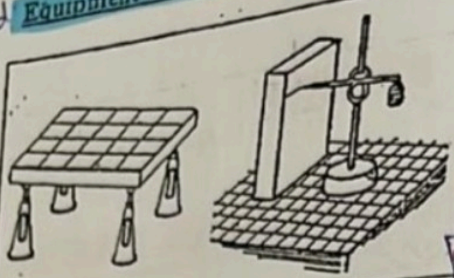
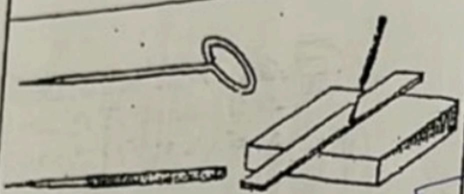
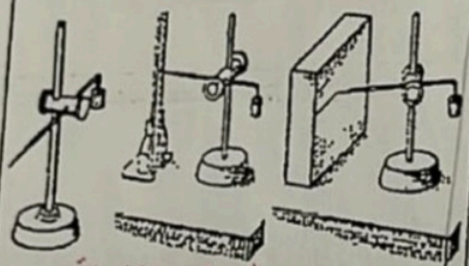
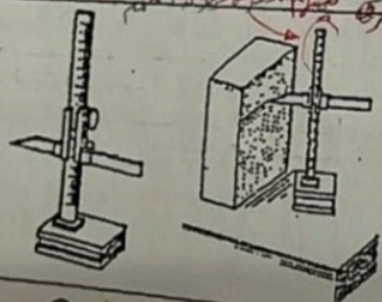
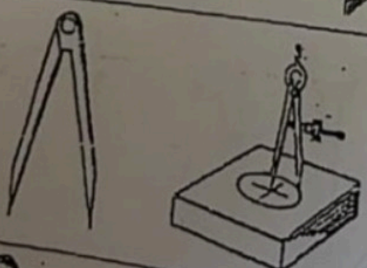
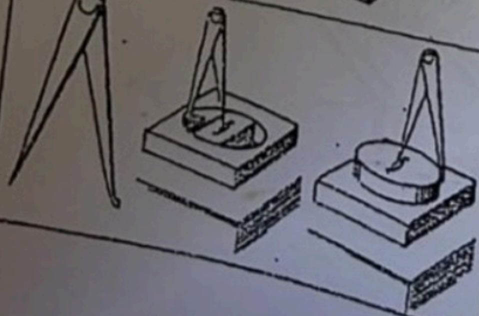
Marking out includes scribing of center points, circles, arcs or straight lines upon metal surfaces. The layout must be exactly like the drawing. These lines assist the machinist in setting up the work in his machine, and indicate to him the limit to which he may allow the cutting to proceed.

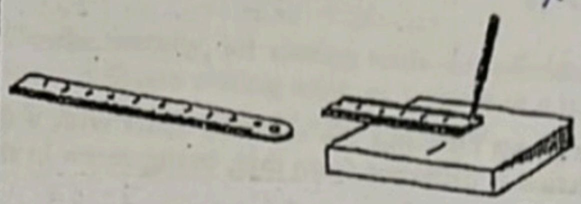
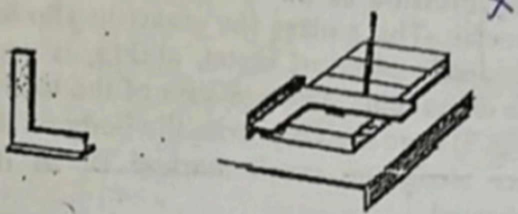
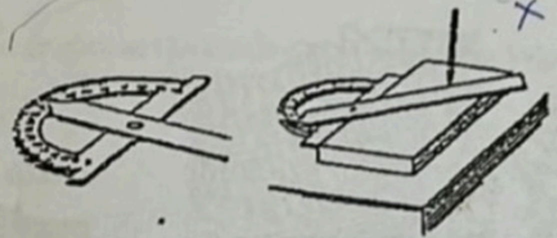
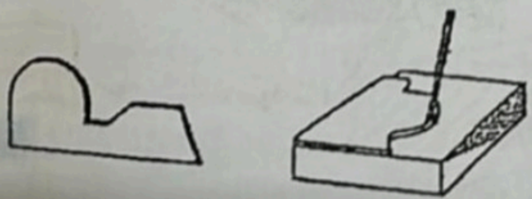
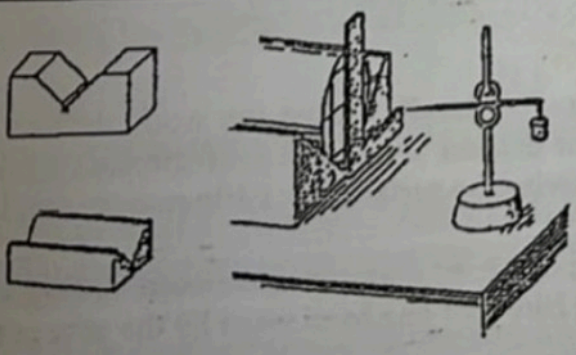
Marking out accuracy ranges from 0.25 to 0.5 mm. The process of marking out is only employed in single piece production. It is much used in drill-press work. For large quantities, marking out would be waste of time and expense. In such cases jigs or fixtures are used, which locate the work in the correct position for machining and provide some means for guiding the tool in the proper path.



Drilling according to layout

Equipment used for Marking Out:

	**Surface Plate.** A plate made of cast iron, granite, being considerably flat. Used as base upon which to rest the work, gauges and other tools when marking out.
	**Scriber.** A slender steel rod with hardened points, used to scribe lines on metal surfaces.
	**Surface gauge.** Used for scribing horizontal lines having a definite distance from the working surface of the surface plate.
	**Height gauge.** Used for scribing horizontal lines.
	**Divider.** Used for scribing circles or laying off distances.
	**Hermaphrodite caliper.** Used to locate approximate centers of work or for scribing parallel lines.

	Steel rule. Used to take measurements and for scribing straight lines.
	Try square. Used to test squareness and right angles and for scribing straight lines perpendicular to an edge of the work. يعطي زاوية 90°
	Protractor. Used for laying out angles. منقلة
	Template. The template is pressed on the work and the outline is transferred to it by means of a scriber. يتم ضغط الشبلونة على العمل ويتم نقل المخطط إليه بواسطة قلم مدبب
	V-Block. Used for supporting shafts and bushes. تستخدم لتثبيت الأعمدة والجيرات بشكل

Forming of Metals by Removing Chips

1. The Cutting of Metal:

The usual conception of cutting suggests cleaving the material apart with a thin knife wedge. When we cut metal, the action is different from this, being more in the nature a tearing than a cutting process.

Metal is made up of many grains. Pressure of the wedging action of the cutting to passes from grain to grain of the metal. This causes the grains to slip and finally brea When enough grains are thus fractured, a piece of metal, a chip, is separated from t workpiece and passes over the face of the tool. The pressure of the tool on the chip at in the direction of the arrow (see Fig. 3) tears the chip from the body of the metal, the tea being continuous and taking place along the crack marked B. In other words, th compressed element of the chip is sheared.

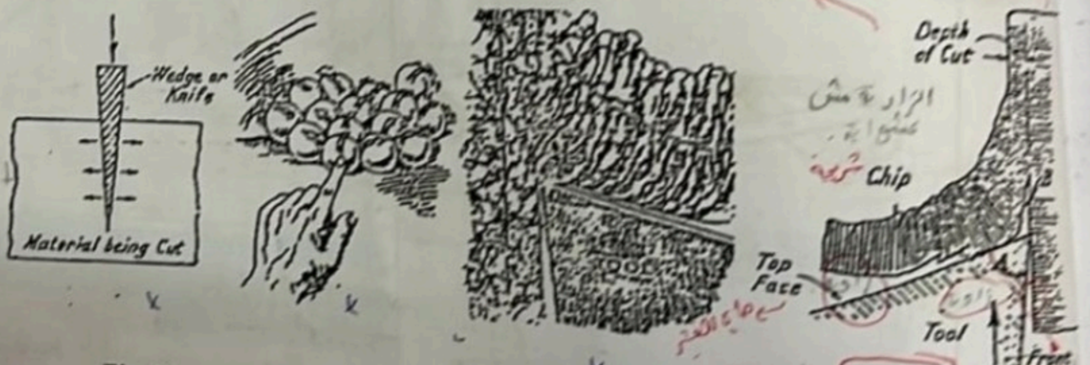


Fig. 1

Fig. 2

Fig. 3

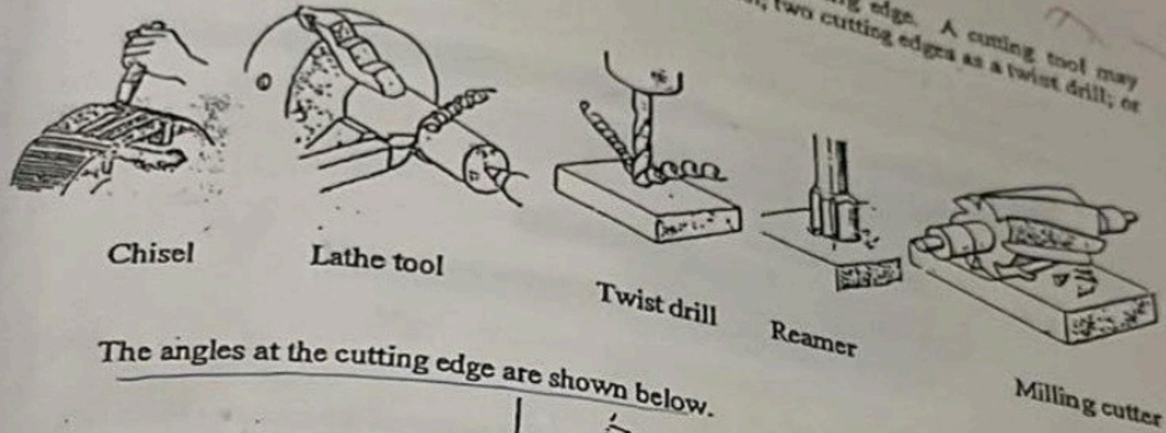
Fig. 1: cutting with a sharp edge, Fig. 2: the pressure effect of tools on metal grains is similar to that of pressure applied to one marble in a group - it is transmitted from marble to marble, Fig. 3 : cutting metal with a tool.

The tearing of the chip from the work naturally leaves the work surface in a torn and rough condition. It is at this point that the extreme tip of the tool does its work by trimming off the irregularities and leaving the surface in a fairly smooth condition.

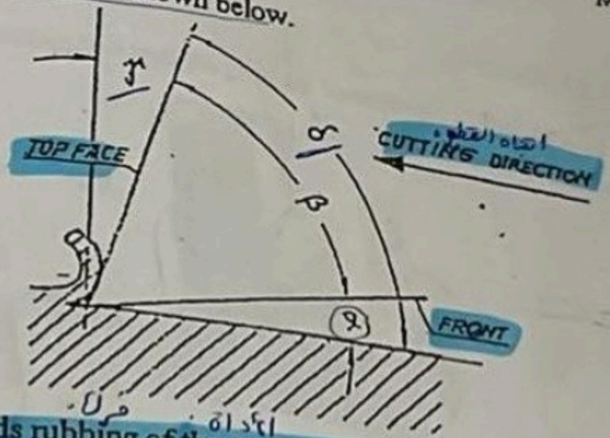
A small cavity may be observed at point A of a tool that has been cutting for a long time without having been reground. The hard tool has been worn by the severe rubbing of the chip.

2. The Cutting Edge:

Fundamentally, all cutting tools are provided with a cutting edge. A cutting tool may have a single cutting edge, as a chisel or a lathe tool; two cutting edges as a twist drill; or several, as a reamer or a milling cutter.



The angles at the cutting edge are shown below.



Clearance angle α:
The clearance angle avoids rubbing of the tool on the work surface.

Lip angle β:
The harder the material to be cut the more the cutting edge must be supported.

Rake angle γ:
The rake angle helps that the tool peals off the chip instead of pushing it off.

The operation of a cutting tool, whether it is on a lathe, on a milling machine or any other machine tool, is based upon theory, which is the same for all processes.

Tool failure may result from the wearing away of the tool's cutting edge, which changes the geometry of the tool. This geometric change may be in the nature of a dull edge, roughness, or a shift in the clearance angles.

Changes in the tool geometry will generate heat, which may cause the tool to lose hardness and soften. If the relative motion of the tool to the work is too great, the rubbing action of the tool material against the work will create even higher temperatures. The process of softening and rubbing away continues until the tool fails. Another type of tool failure results from the high stresses set up by the tool within the workpiece and within the resulting chip. The metal is said to work-harden, and as a result greater forces are needed to separate the chip from the parent metal.

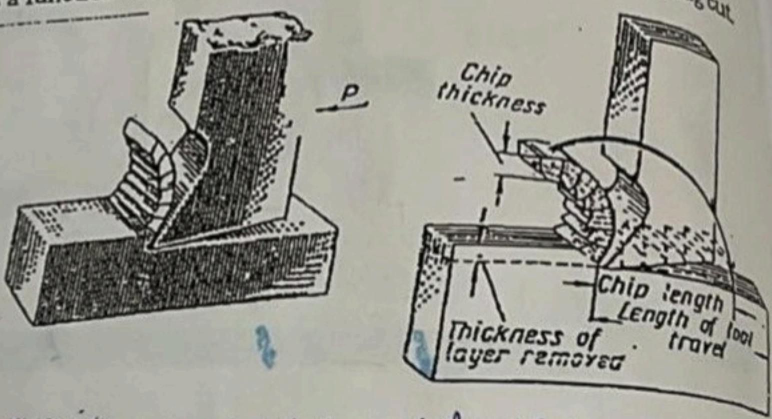
Tool life is defined as the length of time a tool will operate before failure occurs.

Tool life can be increased by:

1) Proper lubrication or cooling
2) Sharp tools
3) Proper angles
4) Careful selection of tool materials
5) Proper feeds and speeds
6) Proper setting-up of the tool relative to the work

3. Chip formation:

Chip formation is a function of the tool bit and the nature of the material being cut.



Chip types:

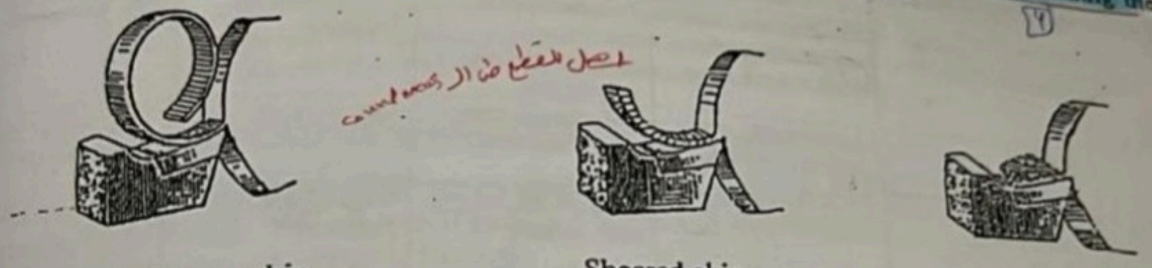
1. Continuous Chip: When ductile metals, such as lead, tin, copper, soft steel, aluminum, etc., are machined, the separate elements of the chip are bonded firmly together and form an uninterrupted chip that curls into a coil.

2. Sheared Chip: If less ductile metals such as hard steel are machined, the chip will consist of separate elements weakly bonded together.

3. Discontinuous Chip: If the metal to be machined is brittle such as cast iron or bronze, the elements of the chip will break off and will be separate from each other.

4. **Build-up Edge Chip:** The high heat generated during cutting welds a small chip to the tool. As the weld builds up, the welded chip grows and finally breaks away from the tool. A built-up edge is useful in roughing, as the cutting edge is heated less and its wear is reduced. For finishing operations a built-up edge is undesirable, since it distorts the shape of the cutting edge and effects poor surface finish. Another result of welded chips is cratering in the face of the tool. Each time the chip breaks away from the face of the tool, it takes a very small amount of material off the face of the tool. The accumulated effect of many such actions is a crater in the face of the tool.

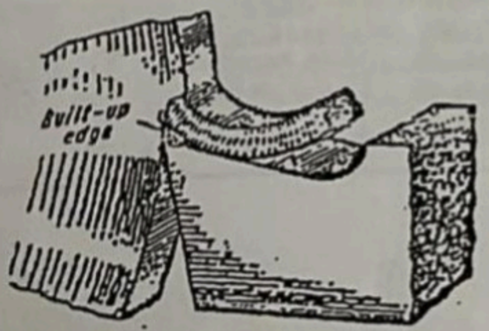
The built-up edge may be reduced by increasing the rake angle, by high quality grinding of the tool, by employing a suitable cutting fluid and by increasing the cutting-speed.

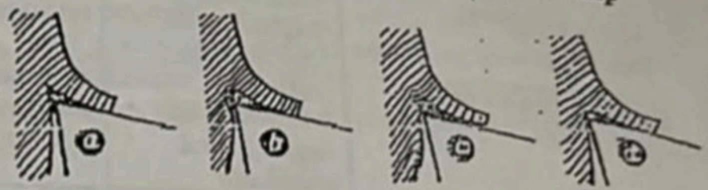


Continuous chip

Sheared chip

Discontinuous chip





Built-up edge: a = material welded on tool, b = growing of welded material, c = breaking away of particles, welded on chip and work, d = growing of welded material.

Built-up edge

4. Cutting Fluids and Coolants:

From the above discussion it can be seen that the friction must be kept as low as possible to reduce the heat generated. Using lubricants that form an oily film on the surface of the metal and thus make the shearing of the metal easier can reduce heat. This is the primary purpose of a lubricant. It may be a fatty oil, mineral oil, or sulfurized mineral.

Its secondary effect is to remove heat generated during the cutting operation.

Where the cutting operation is severe and the lubricant cannot remove the heat enough, there are water-soluble oils used. When mixed with a high concentration of water, the cooling effect is greatly increased with some lubricating properties. These mixtures do not corrode the steel parts with which they come into contact.

Thus, lubricating oils are used chiefly to reduce friction and water-soluble oils are used chiefly as coolants

Selection of Cutting Fluids for Various Types of Lathe Work

Type of lathe work	Material to be machined			
	carbon steel	~~alloy steel~~	grey cast iron and brass	aluminium and its alloys
Turning external surfaces	Soluble oil, sulphurised oil	Sulphurised soluble oil, sulphurised oil, mixed oils	Dry, soluble oil, kerosene	Dry, kerosene
Boring	Soluble oil, sulphurised oil, rape oil	Soluble oil, mixed oils, linseed oil	Dry, rape oil	Turpentine with kerosene (4:5)
Drilling and enlarging holes	Soluble oil	Soluble oil, mixed oils, linseed oil	Dry, soluble oil, kerosene	Dry, soluble oil, rape oil, mixed with kerosene
Reaming	Soluble oil, sulphurised oil, vegetable oils	Soluble oil; mixed oils, linseed oil	Dry, rape oil	Turpentine with kerosene, rape oil
Cutting thread	Soluble oil, sulphurised oil. vegetable and mixed oils	Sulphurised and plain soluble oil. rape or linseed oil	Dry, kerosene (rape on for brass)	Dry, kerosene, rape oil

5. Tool Bit Materials:

The materials used for tool bits must possess the following properties:

1) hardness, 2) strength, 3) toughness, 4) heat resistant.

High-carbon tool steel: tools are used for small-quantity production of wood parts or machining soft materials such as free cutting steels and brass. It is important that the operational temperatures be kept below 200° to 250°C. This type of material loses its hardness above this temperature. For this reason coolants should be used freely.

High-speed steel contains tungsten, chromium and vanadium. The most common type has 18% tungsten, 4% chromium, and 1% vanadium. Other alloying elements are cobalt and molybdenum. The main property of high-speed steel is its "red hardness", i.e. its ability to retain its cutting properties without decreasing the tool life when heated even to 600°C as a result of high cutting speeds.

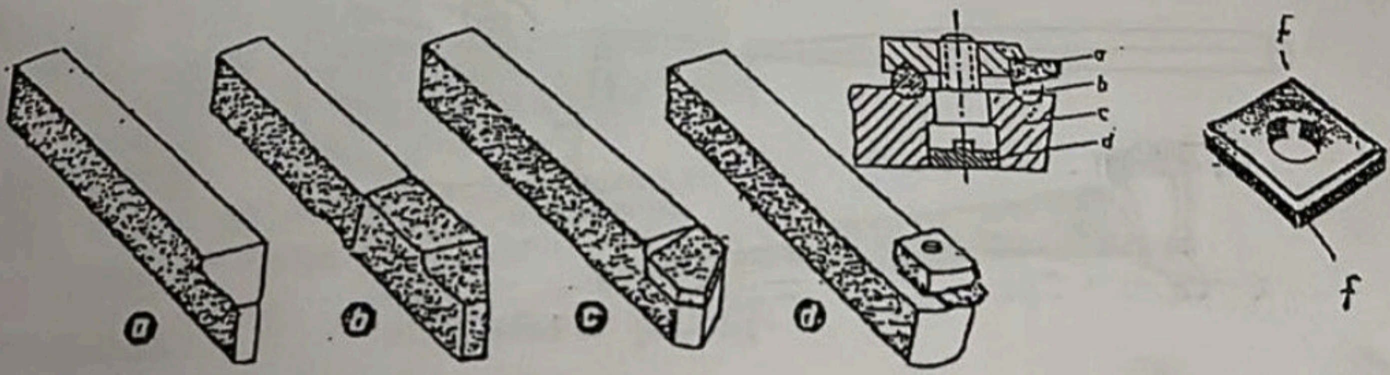
Cemented carbides: are manufactured in the form of tips from a mixture of tungsten and titanium carbides with cobalt. Tungsten and titanium carbides have a very high hardness and heat resistance.

Cemented-carbide tips are brazed to the tool shank and are the cutting element of the tool. The main advantages of cemented carbides are their excellent resistance to wear from the chip and the retention of their cutting qualities at temperatures of 900° to 1000°C. Due to these properties, tools tipped with cemented carbides are suitable for machining the very hardest metals and nonmetallic materials, such as glass, porcelain, and plastics, at speeds from 4 to 6 times higher than possible with high-speed steel tools.

The disadvantage of cemented carbides is their brittleness.

Ceramic tool materials: namely aluminum oxide or silicon carbide, are mixed with a glass binder. This mixture is hard and brittle and will withstand temperatures of 1200°C without losing hardness or strength.

Industrial diamonds: have limited use in present-day machining of metals. They may be used to machine aluminum, plastics, hard rubber, and, if used with very fine feeds and high spindle speeds, for fine finishing of bored holes in steel. They are expensive and difficult to shape into desired forms. Diamonds will withstand temperatures of 1600°C to 1800°C without losing hardness or strength.



a = cutting tool made entirely of tool steel or high-speed steel, b = high-speed cutting t welded to a shaft of structural steel, c = tip made of high-speed steel, welded, or made cemented carbide, brazed, d = diamond tip with holder (a = diamond, b = support, holder, d = seal), f = cutting edges of a tool tip made of ceramic tool material (these are clamped in holders similar to those used for diamonds).