Module 2 – Machining Processes

ENGINEERING LABORATORY EE-100

Lahore University of Management Sciences
Electrical Engineering Department, SSE

Module Contents

- Introduction to Workshop Facilities
- Introduction to engineering materials and their properties
- Workshop Technologies
  - **Conventional:** Casting, Forging, Welding, Molding, Machining, Fitting
  - **Non –Conventional:** 3D Printing
- Basic Measurement Tools
- Introduction to Machining
  - Lathe and Milling Machine Operations
  - Demonstration of Machine Operations

Introduction to Workshop Facilities

- **Lathe Machine -** a machine which rotates the workpiece on its axis to perform various operations such as cutting, knurling, drilling, facing and turning with tools that are applied to the workpiece to create an object which has symmetry about an axis of rotation.
- **Drilling Machine –** also called a drill press, is used to cut holes into or through metal, wood, or other materials.
- **CNC Milling Machine -** also called machining centers, is a computer controlled cutting process that uses a milling cutter to remove material from the surface of a workpiece. The milling cutter is a rotary cutting tool, often with multiple cutting points.
- **CNC PCB Milling Machine -** a process of removing areas of copper from a sheet of PCB material to recreate the signal traces and structures according to patterns from a layout file.
- **3D Printer -** a process of making three dimensional solid objects from a digital file. An object is created by laying down successive layers of material until the entire object is created.

Manufacturing Process

Manufacturing Process

Manufacturing is the process of converting raw materials into products. Manufacturing is generally a complex activity involving a wide variety of resources and activities, such as:

It consist of:

- Product design.
- Selection of materials.
- Process planning.
- Measurements.
- Selection of machinery and tools.
- Machining

Product Design

- The first step in manufacturing process is the mechanical design of the required product. The product is designed on software Creo Parametric 2.0.
- Before manufacturing of product, its mechanical design is crucial as it determines the tolerances that it must meet in order to be considered acceptable.

Selection of Materials

Material is selected in accordance with the final product. A general division of materials is

- Ferrous metals:
  - Carbon, Carbon alloy
  - Stainless Steel
- Non - Ferrous metals
  - Aluminum
  - Magnesium
  - Copper
  - Nickel
  - Titanium etc.
- Plastics:
  - Thermoplastic
  - Thermosets
  - Elastomers
- Ceramics, Glass, Graphite, Diamond
- Composite materials are engineered materials

Selection of Materials

- Properties:
  - **Metals**:
    - Hard.
    - Malleable - capable of being shaped.
    - High Strength.
    - When polished it has a lustrous appearance
    - Opaque.
    - Good conductors of electricity and heat.

Selection of Materials

- **Plastics**:
  - Soft.
  - Not as strong as metals or ceramics.
  - More flexible than metals.
  - Low density.
  - Insulated to electricity.

Selection of Materials

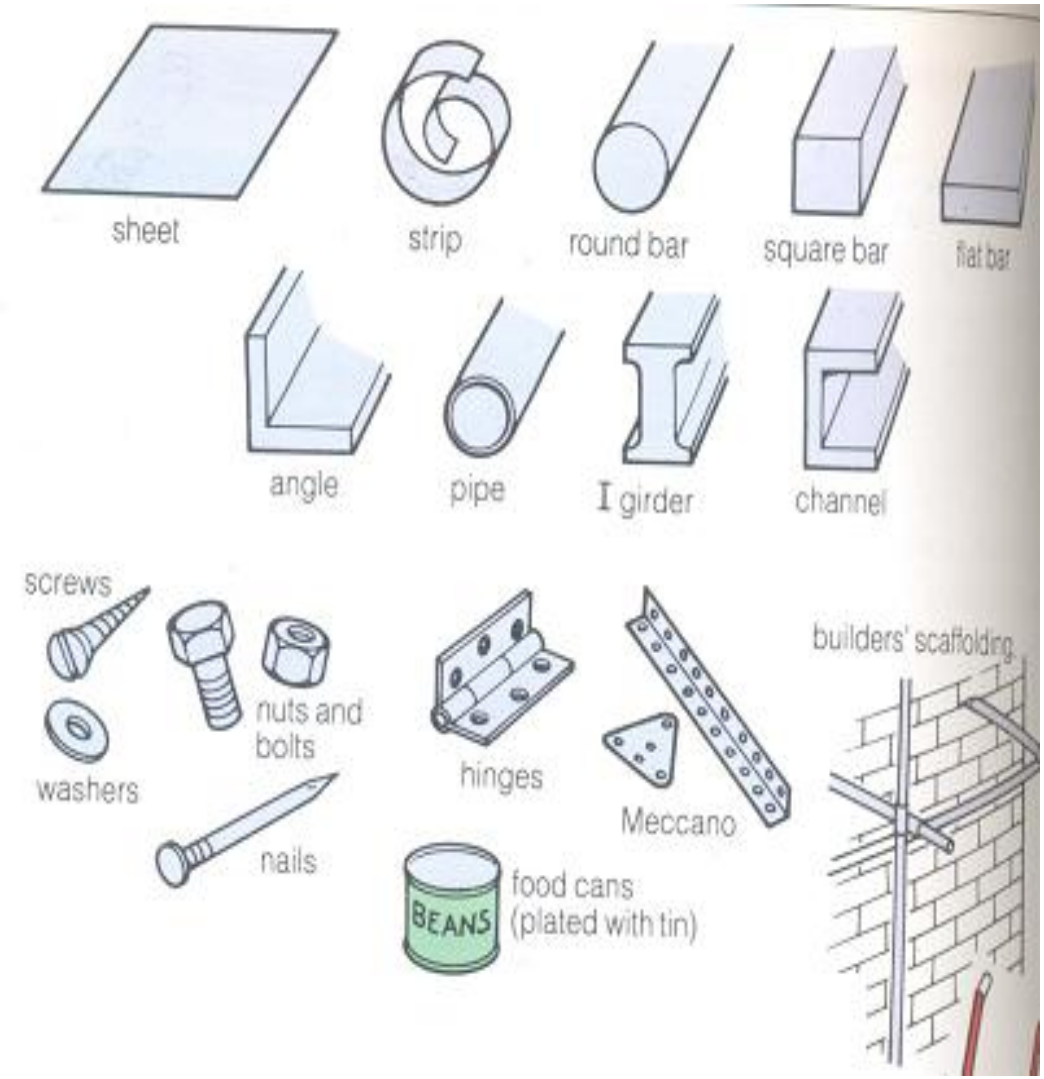
– **Ceramics**:
  - Hard and strong
  - Brittle.
  - Resistant to high temperatures and chemicals.
  - Can withstand more brutal environments than metals or plastics.
  - Not good conductors of electricity or heat.

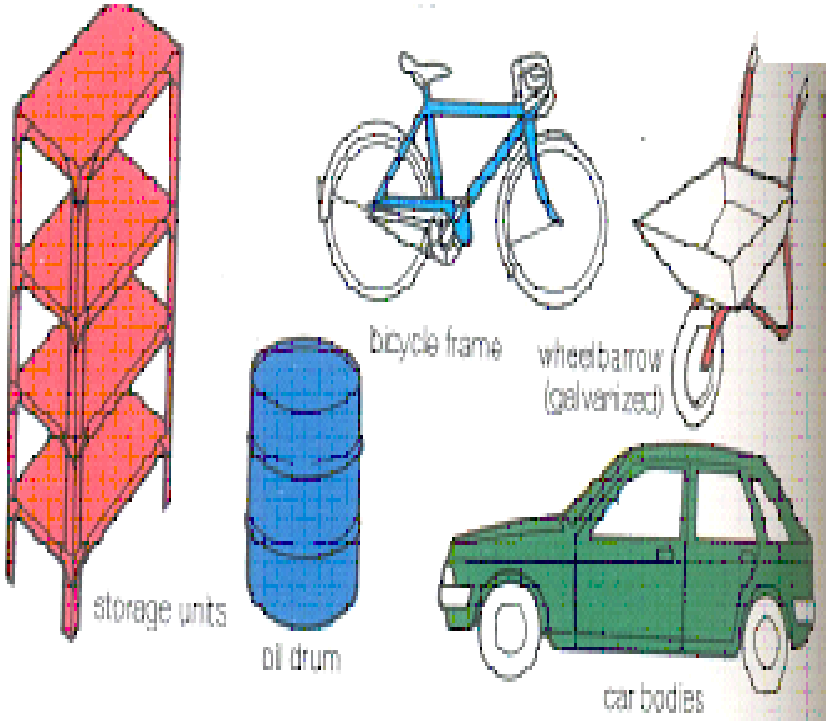
Ferrous Metals

Pure iron is of little use as an engineering material because it is too soft and ductile. It may have small amounts of other metals or other elements added, to give the required properties.

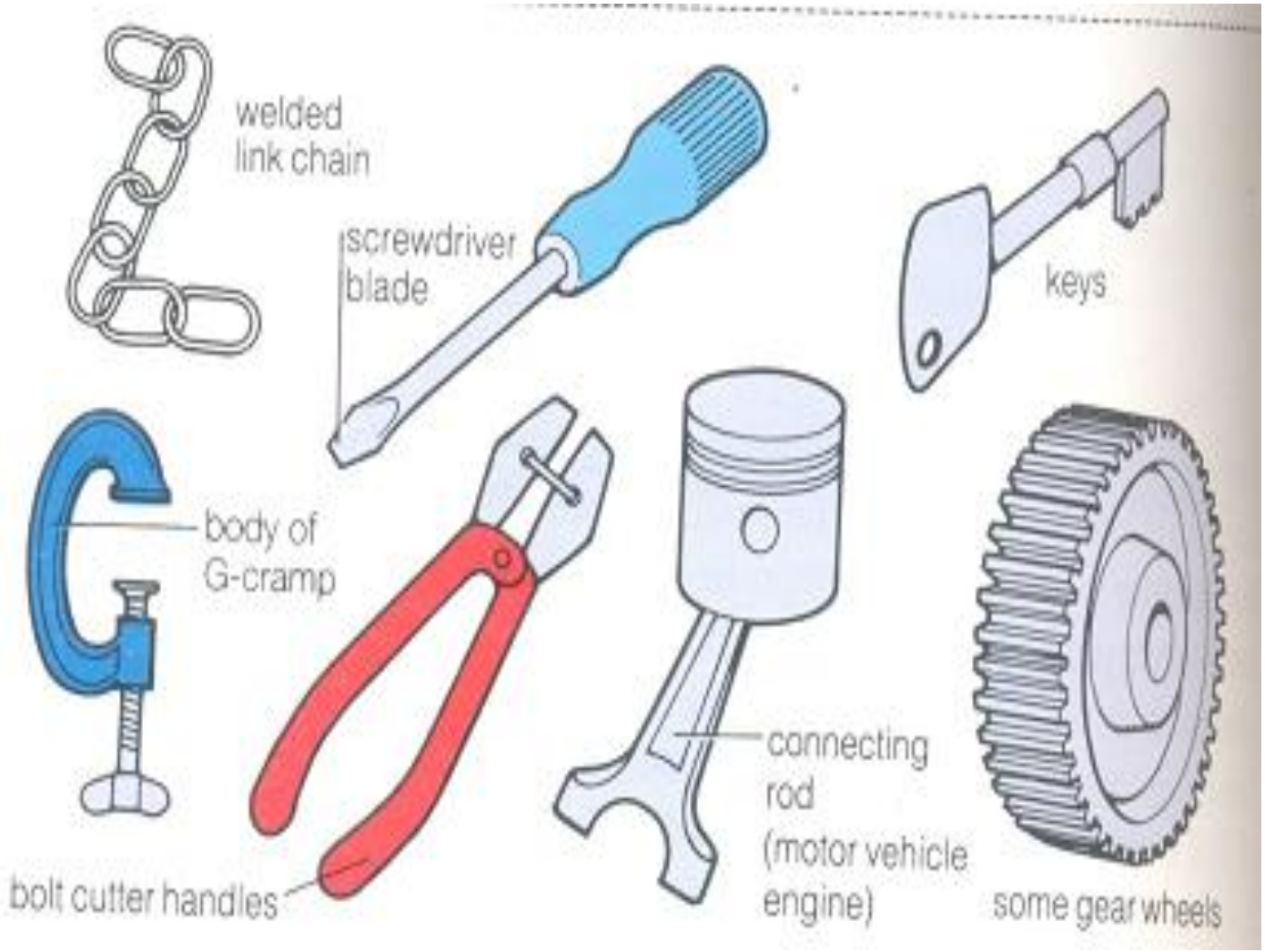
- **Mild Steel -** carbon contents between 0.1% and 0.3%.
- **Medium Carbon Steel –** carbon contents between 0.3% to 0.7%.
- **High Carbon Steel -** carbon contents between 0.7% to 1.3%.
- **Stainless Steel -** chromium contents between 13% to 27%.

- Products of Mild Steel

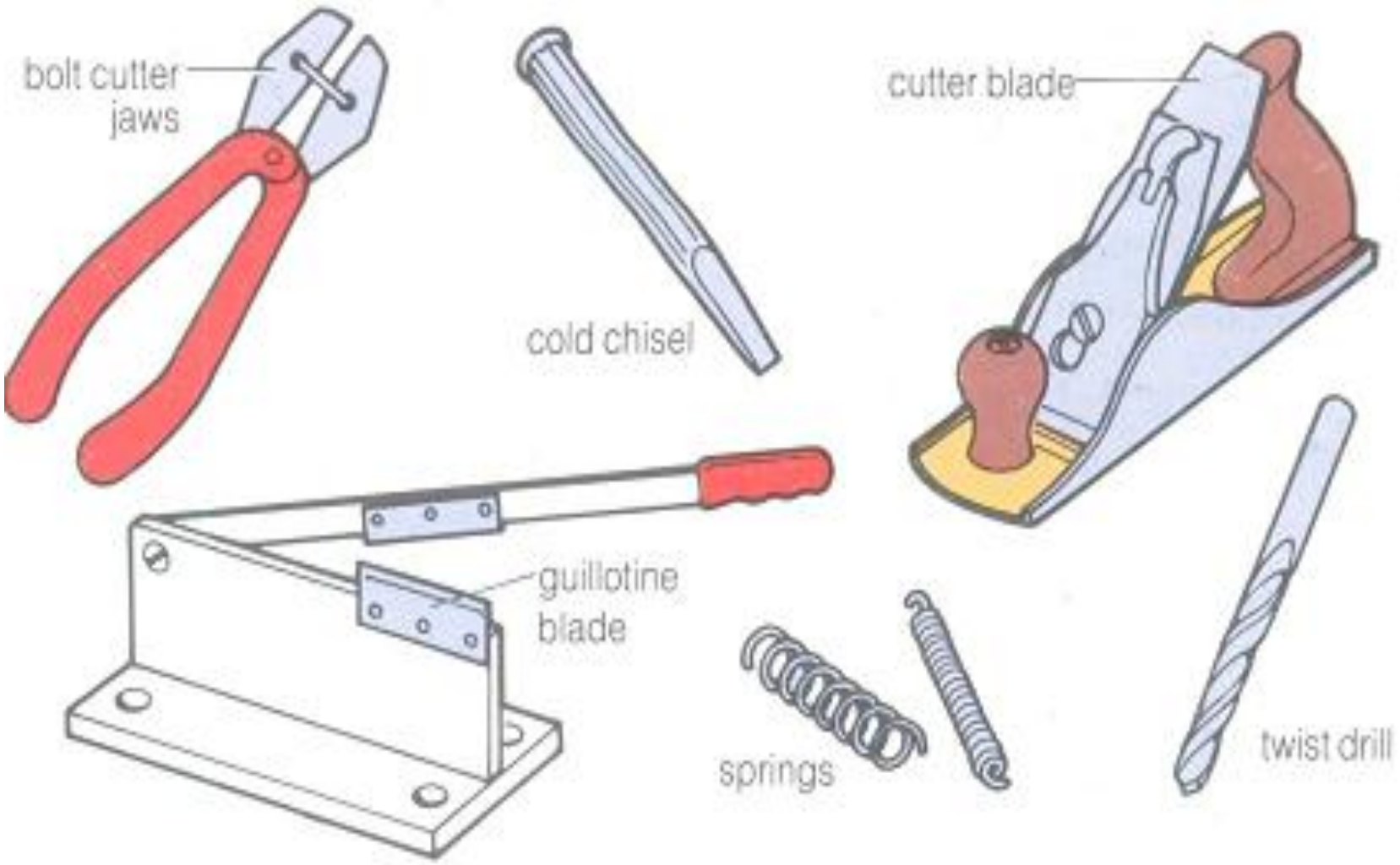




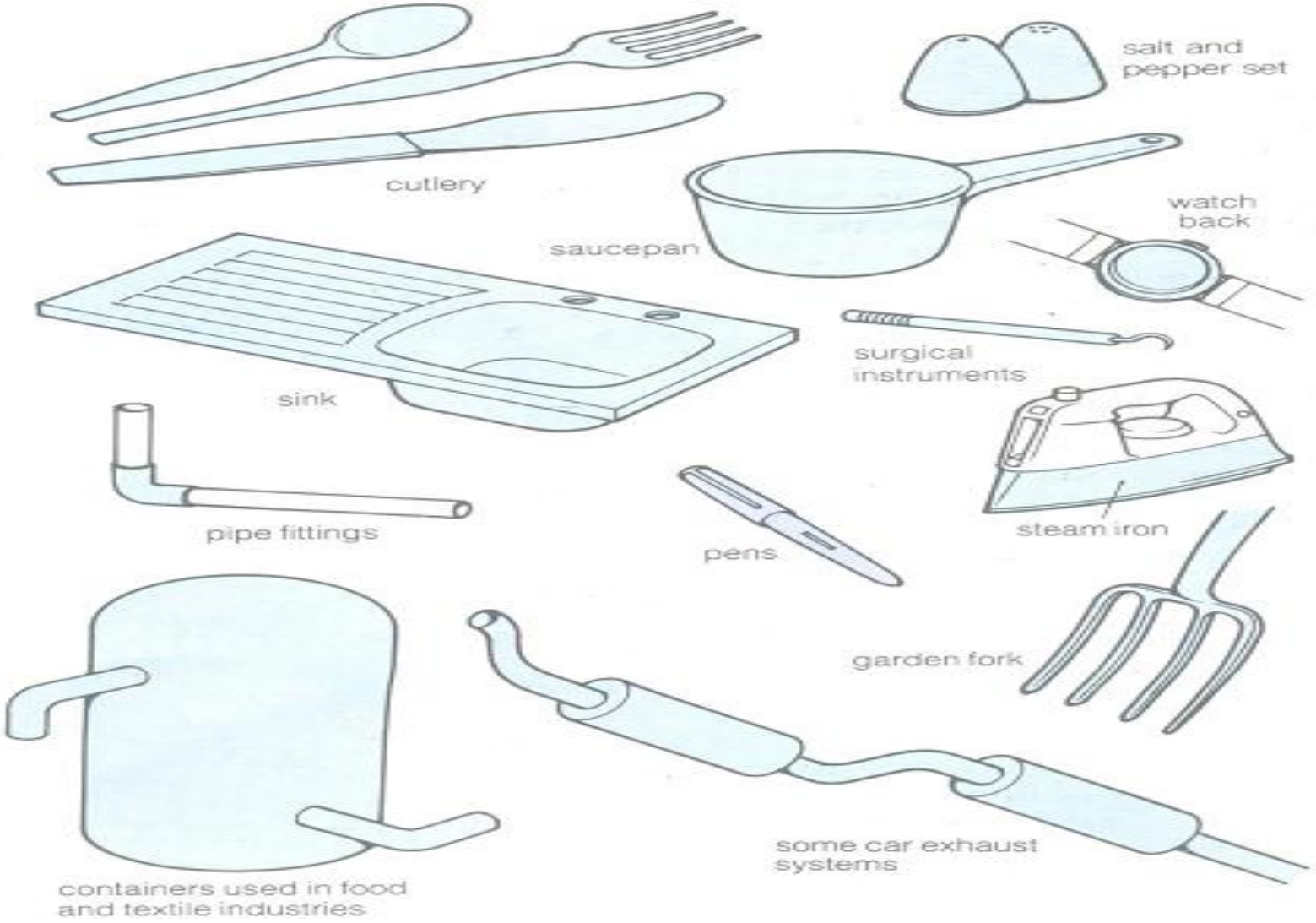
- Products of Medium Carbon Steel



- Products of High Carbon Steel



- Products of Stainless Steel

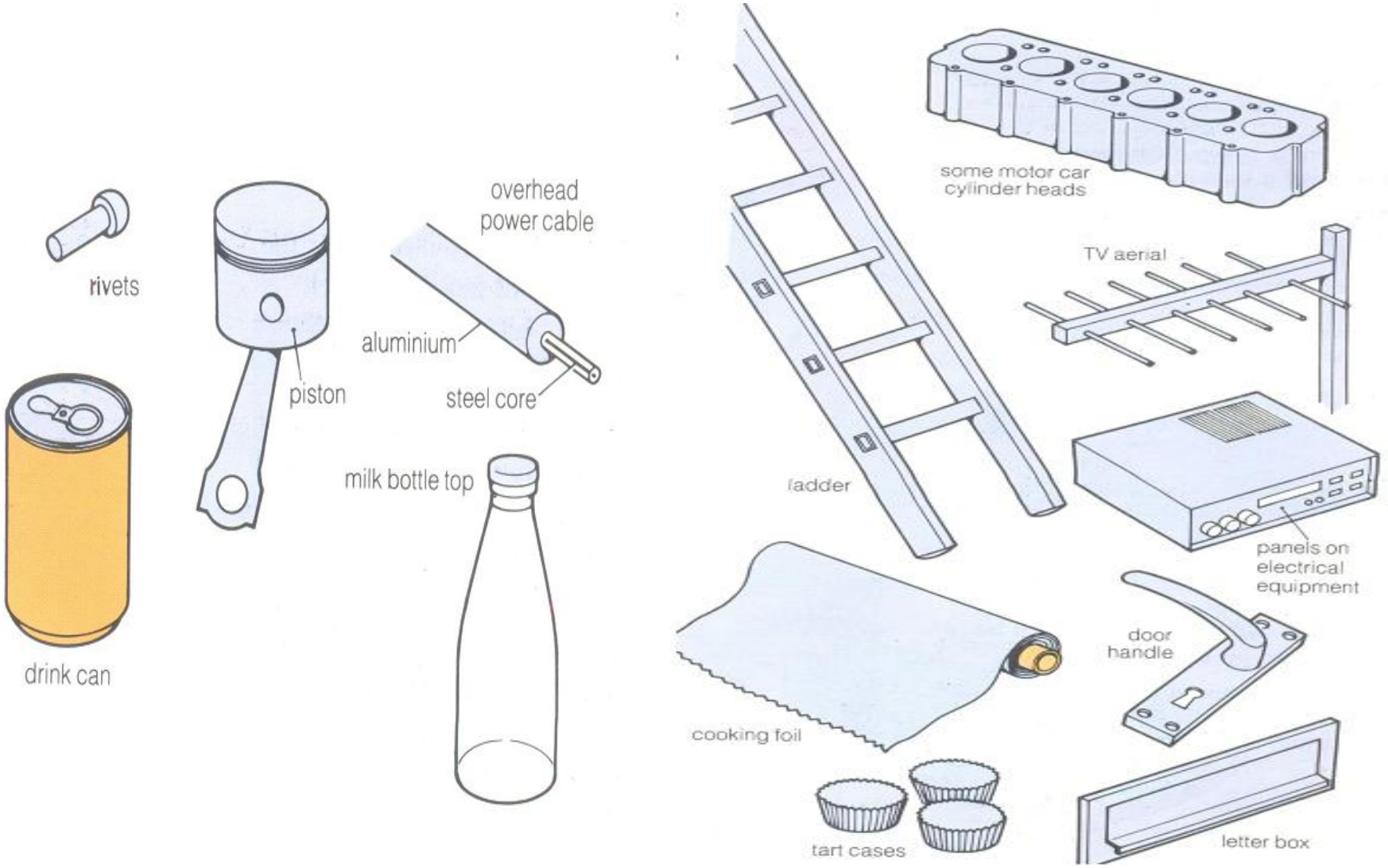


Non - Ferrous Metals

These metals do not contain any iron. They are not magnetic and are usually more resistant to corrosion than ferrous metals.

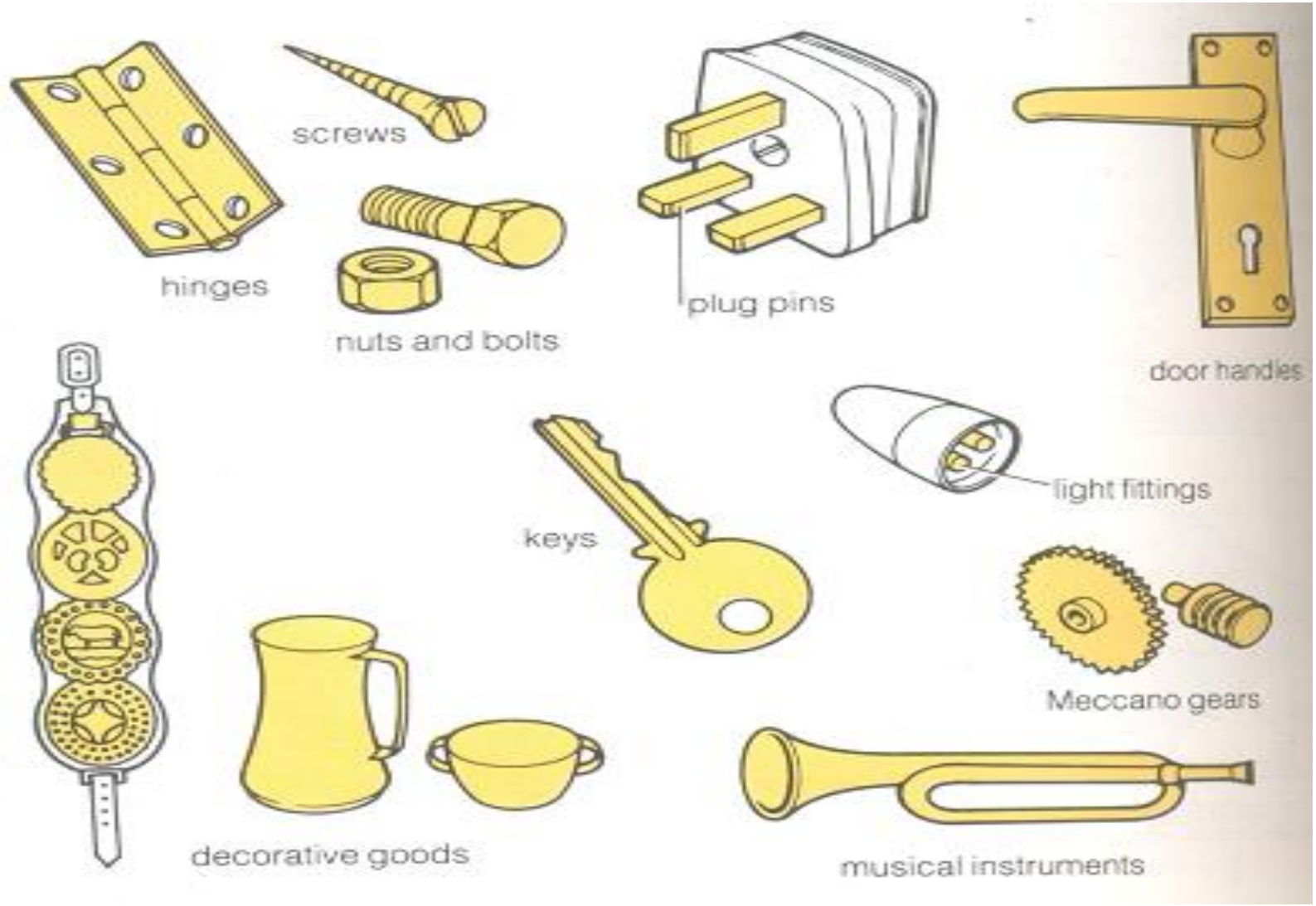
- Aluminum
- Copper
- Brass etc.

- Products of Aluminum and its alloys



- Products of Copper

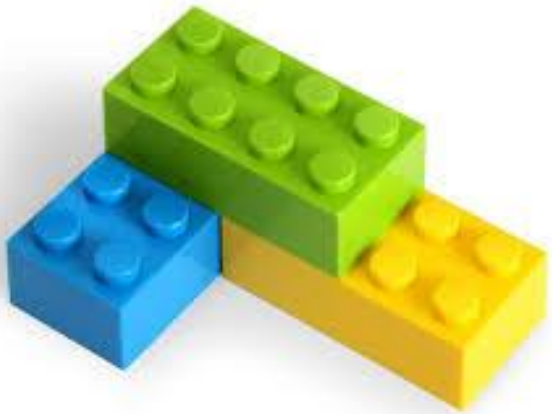
- Products of Brass



Plastics

- **Thermoplastic -** a material which becomes soft when heated and hard when cooled. Thermoplastic materials can be cooled and heated several times. They can be recycled. When thermoplastics are heated, they melt to a liquid.
- **Thermosets -** more resistant to high temperatures than thermoplastics.
- **Elastomers -** means rubber. Elastomers can be stretched to many times their original length, and can bounce back into their original shape without permanent deformation.

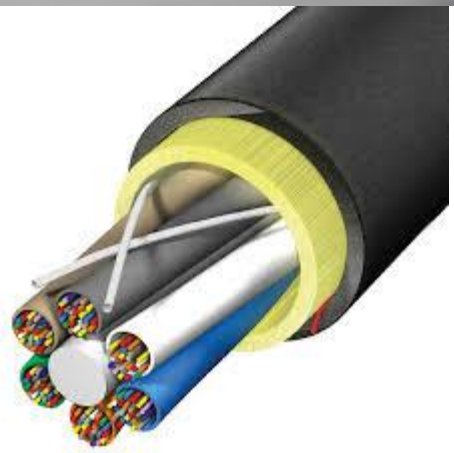
- Products of Thermoplastics



- Products of Thermosets







- Products of Elastomers

- Products of Ceramics, Glass, Graphite











Process Planning

- According to the final product and the material used, the manufacturing process is decided. Conventional manufacturing processes are:
  - Casting
  - Forging
  - Welding
  - Molding
- Non-conventional manufacturing process:
  - 3D Printing

Casting

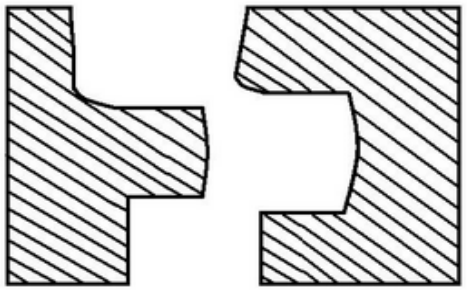
Casting is a process in which molten metal flows into a mold where it solidifies in the shape of the mold cavity. The part produced is also called casting.

- ADVANTAGES:
  - It can manufacture complex shapes
  - Large parts can be manufactured
  - Variety of metals can be used
  - Mass production
- DISADVANTAGES:
  - Poor accuracy
  - Poor surface finish
  - Internal defects

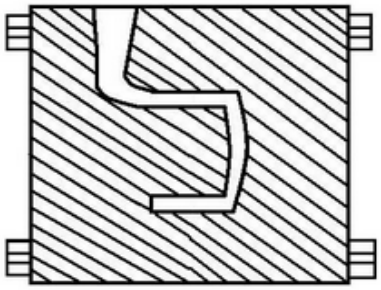
Casting

Basic factors involved in every casting technique are:

- **Mold Cavity:** A mold cavity having the desired shape and size, must be produced with due allowances for shrinkage etc. any complexity of shape desired in the finished casting must exist in the cavity.
  - **Expendable Molds** After the solidification of casting, these molds are broken to remove the casting
    - **Pattern**: Expendable molds require some sort of pattern. The interior cavities of the mold, in which the molten metal will solidify, are formed by the impression of this pattern.
  - **Permanent molds:** These molds are made of metals that maintain their strength at high temperatures. They are used repeatedly and are designed in such a way that the casting can be easily removed and mold used for next casting



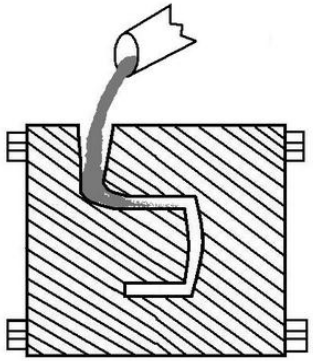
Two halves of a mold



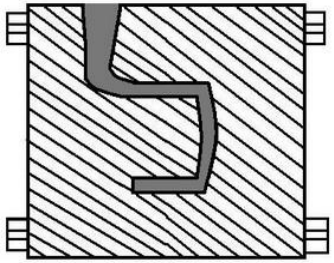
A permenant mold

- **Molten Metal:** A melting process must be capable of providing molten material at proper temperature and in the desired quantity.

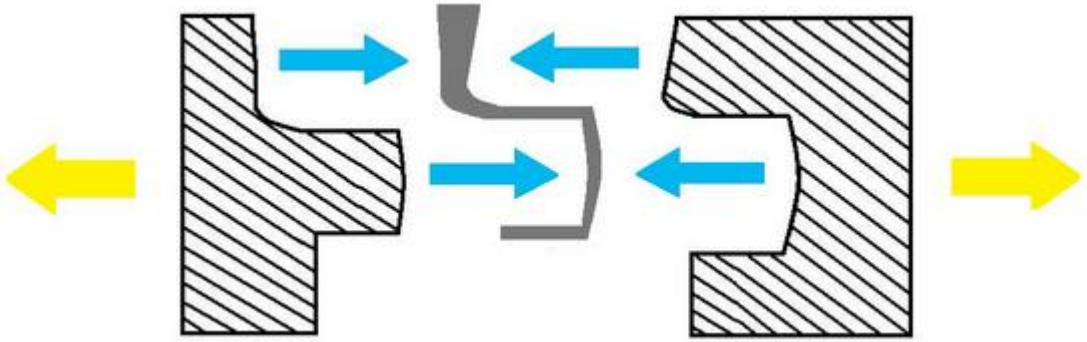
- **Pouring of Metal**: A provision for the escape of all air and gases is also required, during the pouring process.



- **Solidification:** The solidification process should be properly designed and controlled.



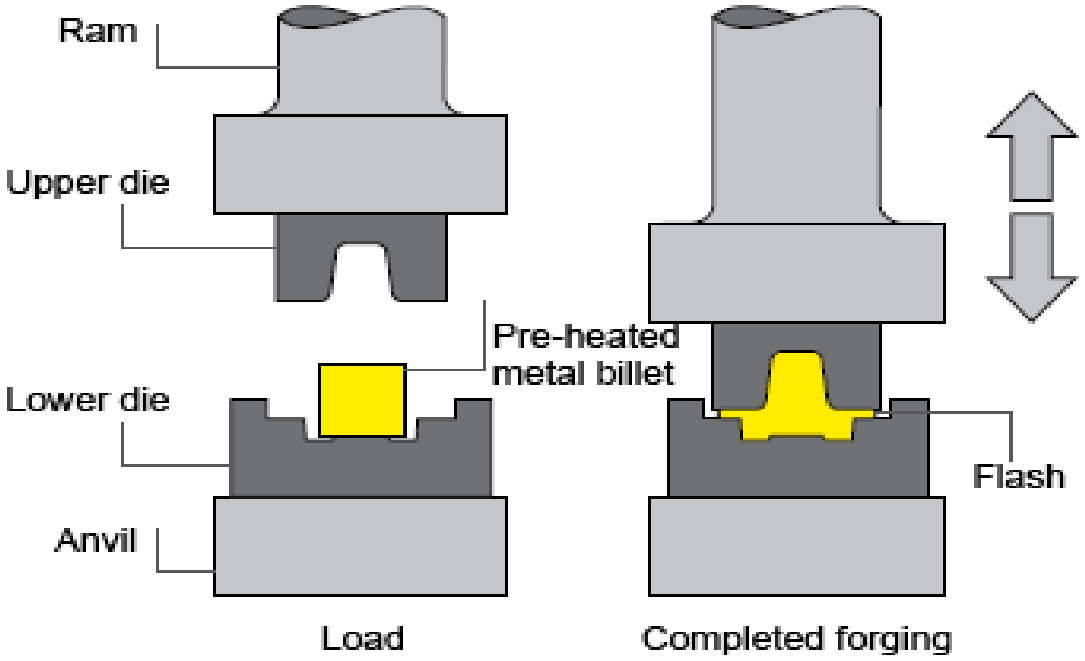
- **Mold Removal:** It must be possible to remove the casting from the mold. In single use mold, it is easy to brake the mold and recover the casting but in permanent molds, removal of mold is a major design problem.



- **Finishing:** After the casting is removed from the mold various cleaning, finishing and inspection operations may need to be performed.

Forging

- Forging is the plastic working of metal by means of localized compressive forces exerted by manual or power hammers, presses or by using special forging machines.



- There are many different kinds of forging processes available, however they can be grouped into three main classes:
  - **Drawn out:** length increases, cross-section decreases
  - **Upset:** length decreases, cross-section increases
  - **Squeezed in closed compression dies:** produces multidirectional flow
- Common forging processes include: roll forging, swaging, cogging, open-die forging, impression-die forging, press

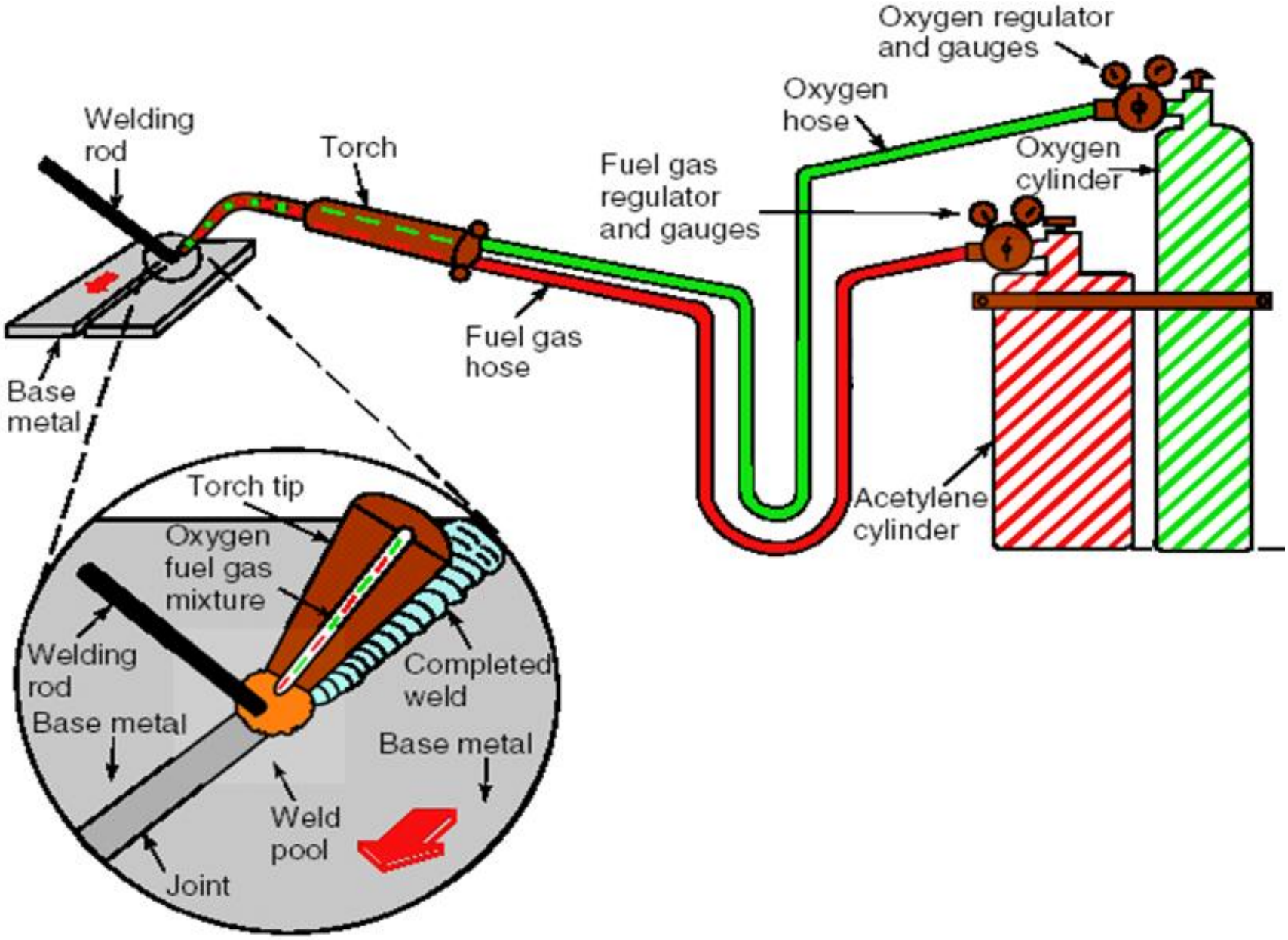
The Difference Between Casting & Forging

Casting is the process where metal is heated until molten. While in the molten or liquid state it is poured into a mold or vessel to create a desired shape.

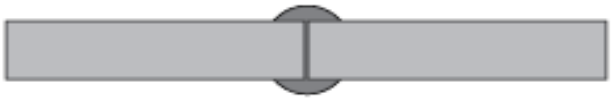
Forging is the application of thermal and mechanical energy to steel billets or ingots to cause the material to change shape while in a solid state.

Welding

- Joining two workpieces by melting the filler material between them, creating a weld seam, that cools to become a strong joint.
- Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence.
- This is often done by melting the workpieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld.
- This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the workpieces to form a bond between them, without melting the work pieces.

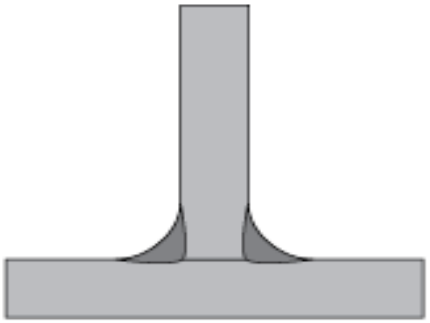

Oxygen regulator and gauges
Oxygen hose
Welding rod
Torch
Fuel gas regulator and gauges
Oxygen cylinder
Fuel gas hose
Base metal
Acetylene cylinder
Torch tip
Oxygen fuel gas mixture
Welding rod
Completed weld
Base metal
Base metal
Weld pool
Joint

The weld joints are:

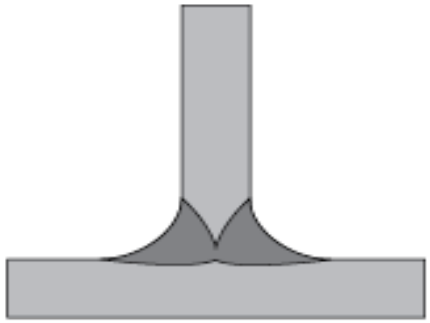


Butt Weld - Square Joint

Butt Weld - "V" Joint

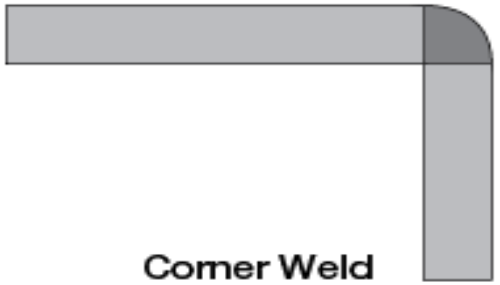


Fillet "T" Weld



Full Penetration "T" Weld

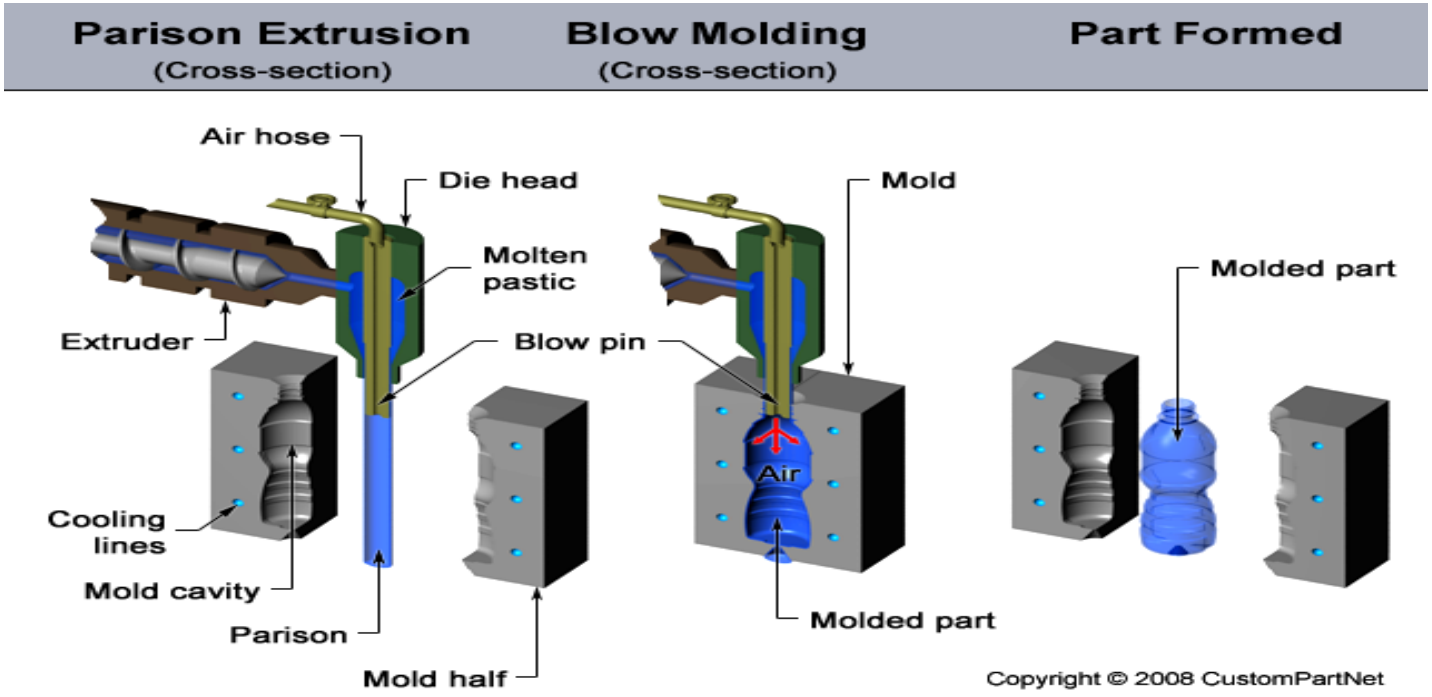
Lap Weld



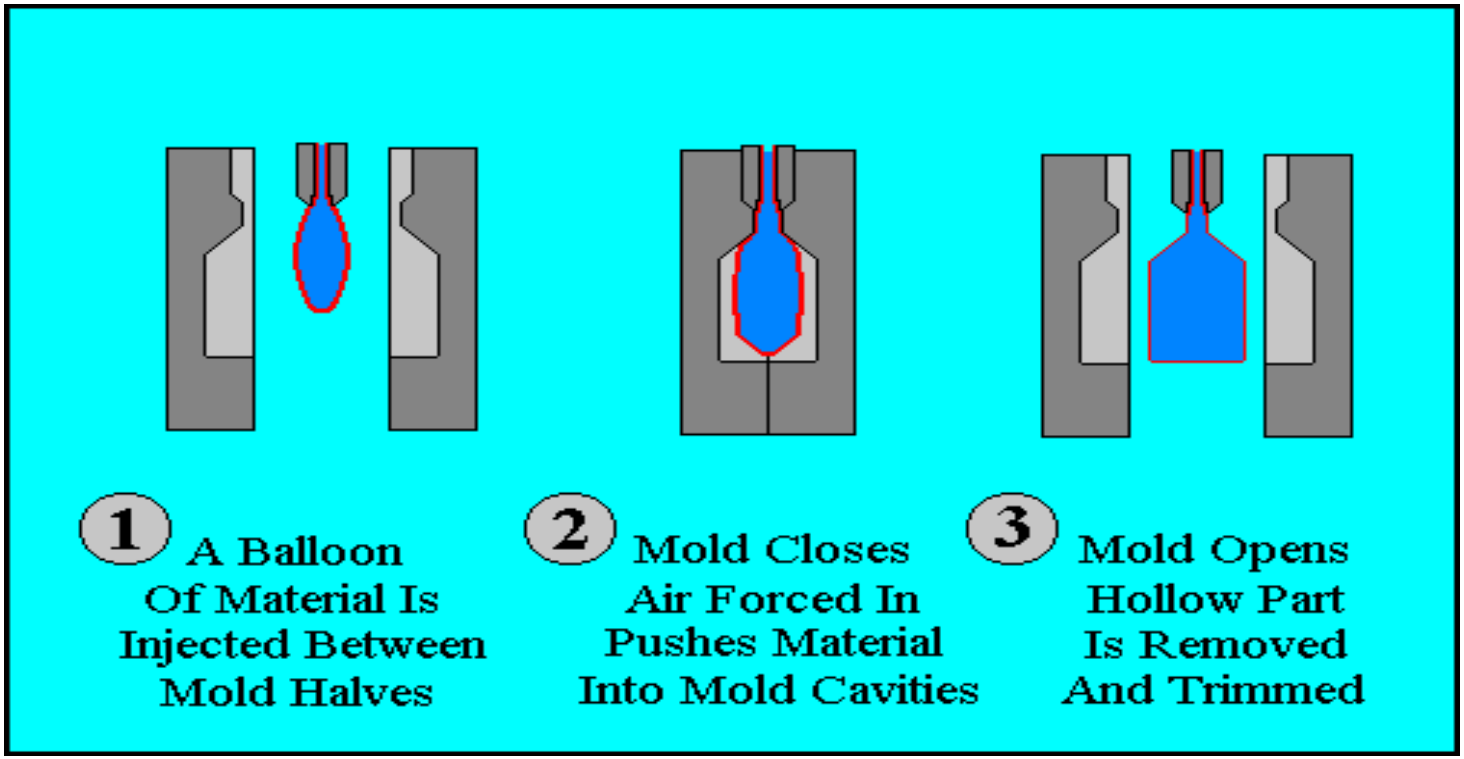
Corner Weld

Molding

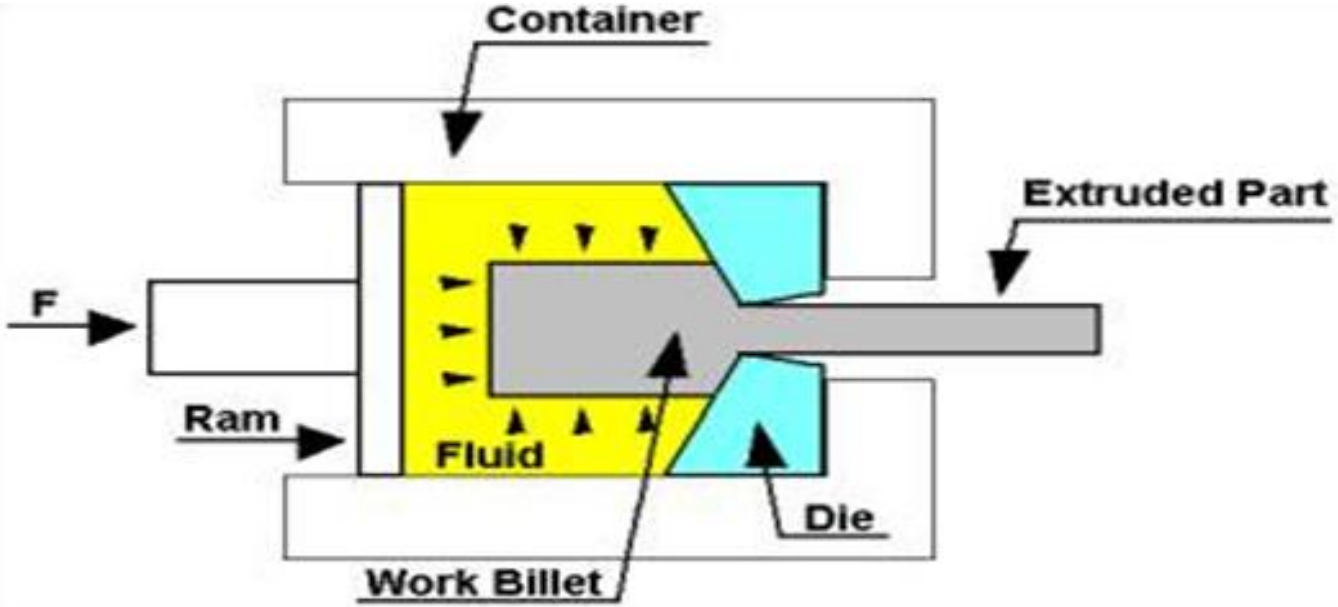
- Molding is the process of manufacturing by shaping liquid or pliable raw material using a rigid frame called a mold. This itself may have been made using a pattern or model of the final object.
- Types of molding include:
  - Blow molding
  - Extrusion molding
  - Injection molding



- **Blow Molding:**
  - The blow molding process begins with melting down the plastic and forming it into a parison.
  - The parison is a tube-like piece of plastic with a hole in one end through which compressed air can pass.
  - The parison is then clamped into a mold and air is blown into it.
  - The air pressure then pushes the plastic out to match the mold.
  - Once the plastic has cooled and hardened the mold opens up and the part is ejected.

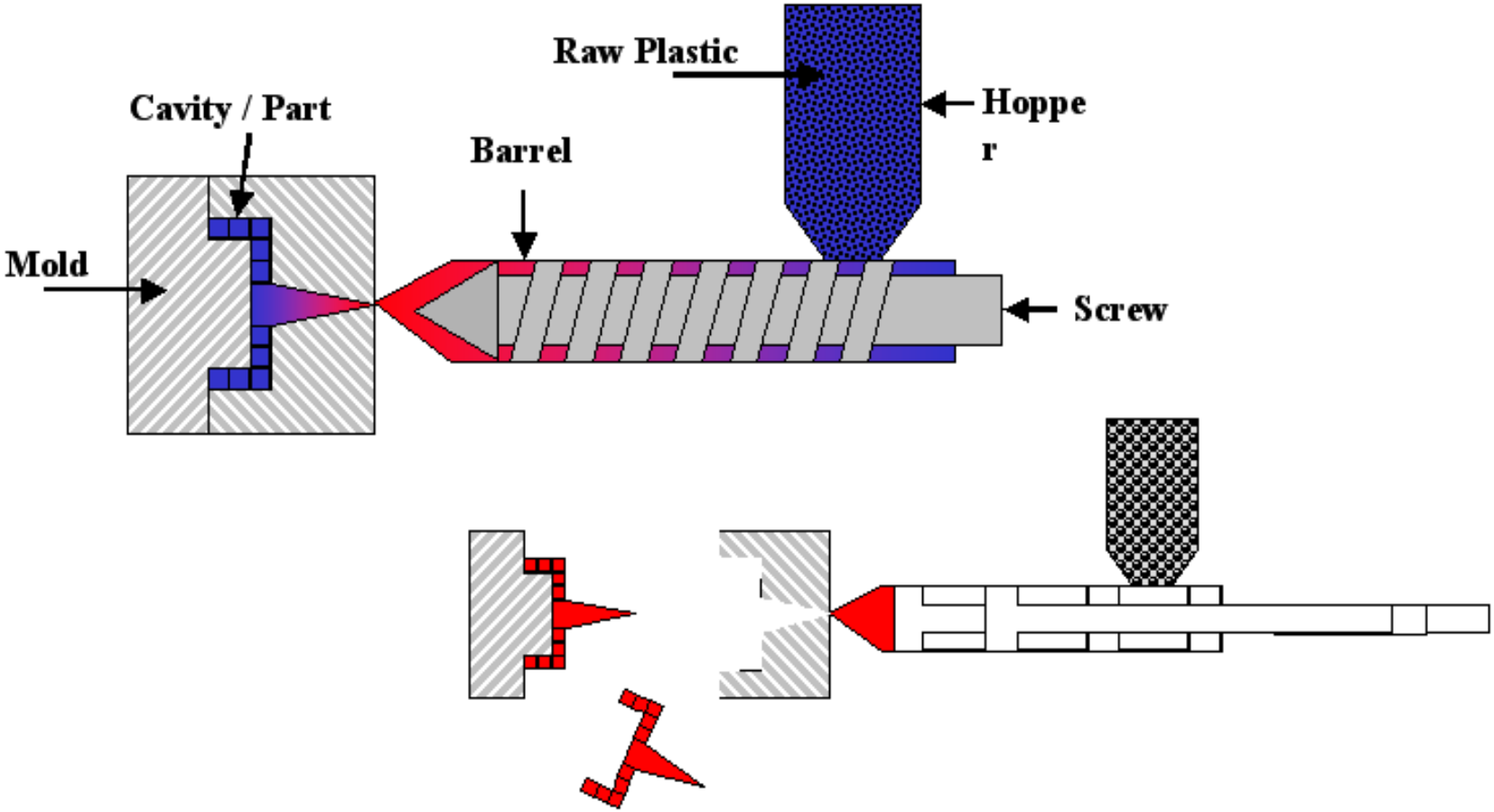


- **Extrusion Molding:**
  - a process used to create objects of a fixed cross-sectional profile. A material is pushed or pulled through a die of the desired cross-section.



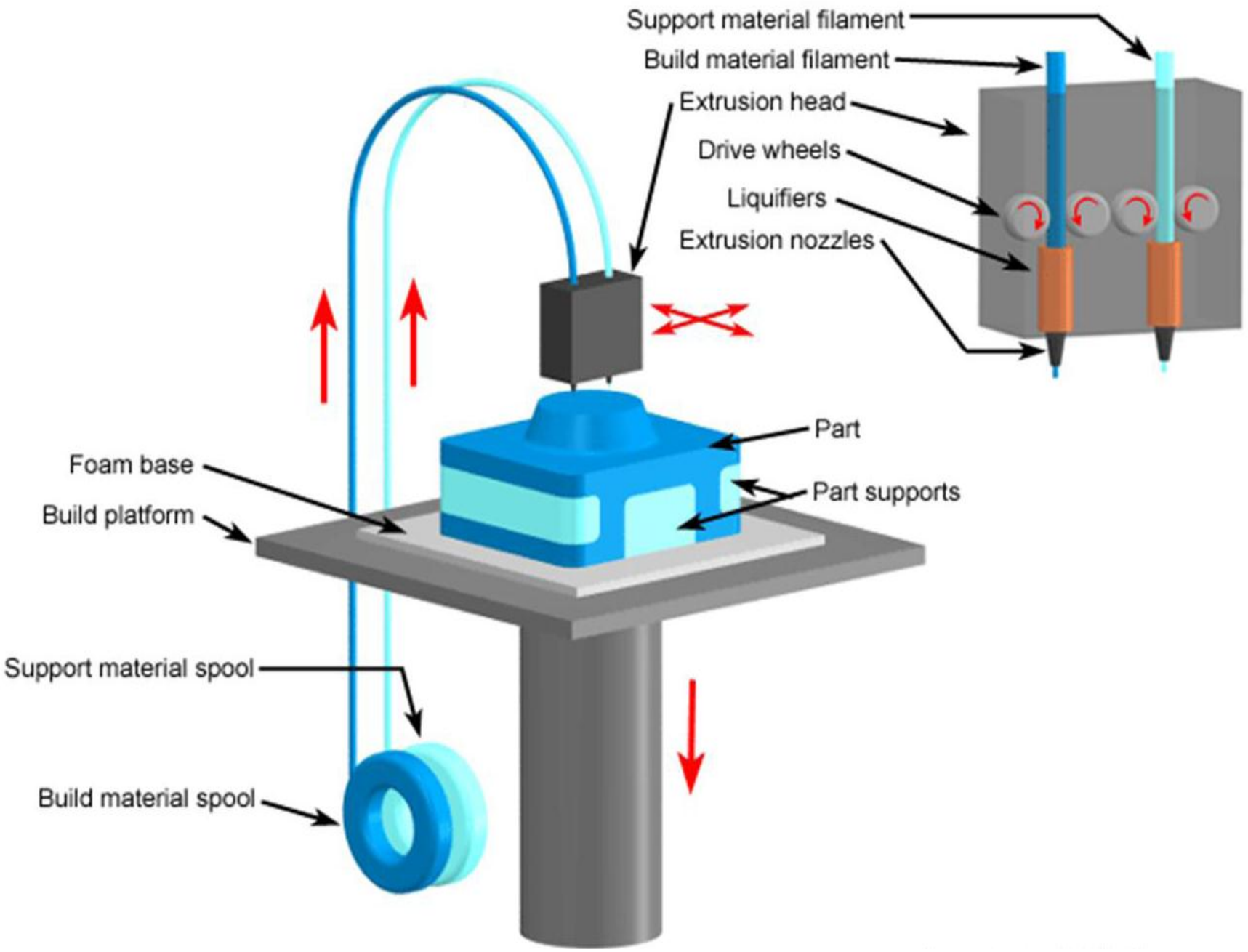
- **Injection Molding:**
  - a manufacturing process for producing parts by injecting material into a mold.

– Material for the part is fed into a heated barrel, mixed, and forced into a mold cavity, where it cools and hardens to the configuration of the cavity.



Non-conventional Manufacturing – 3D Printing

- A process of making a three-dimensional solid object of virtually any shape from a digital model.
- A 3D printer is a limited type of industrial robot that is capable of carrying out an additive process under computer control.


Support material filament
Build material filament
Extrusion head
Drive wheels
Liquifiers
Extrusion nozzles
Part
Part supports
Foam base
Build platform
Support material spool
Build material spool

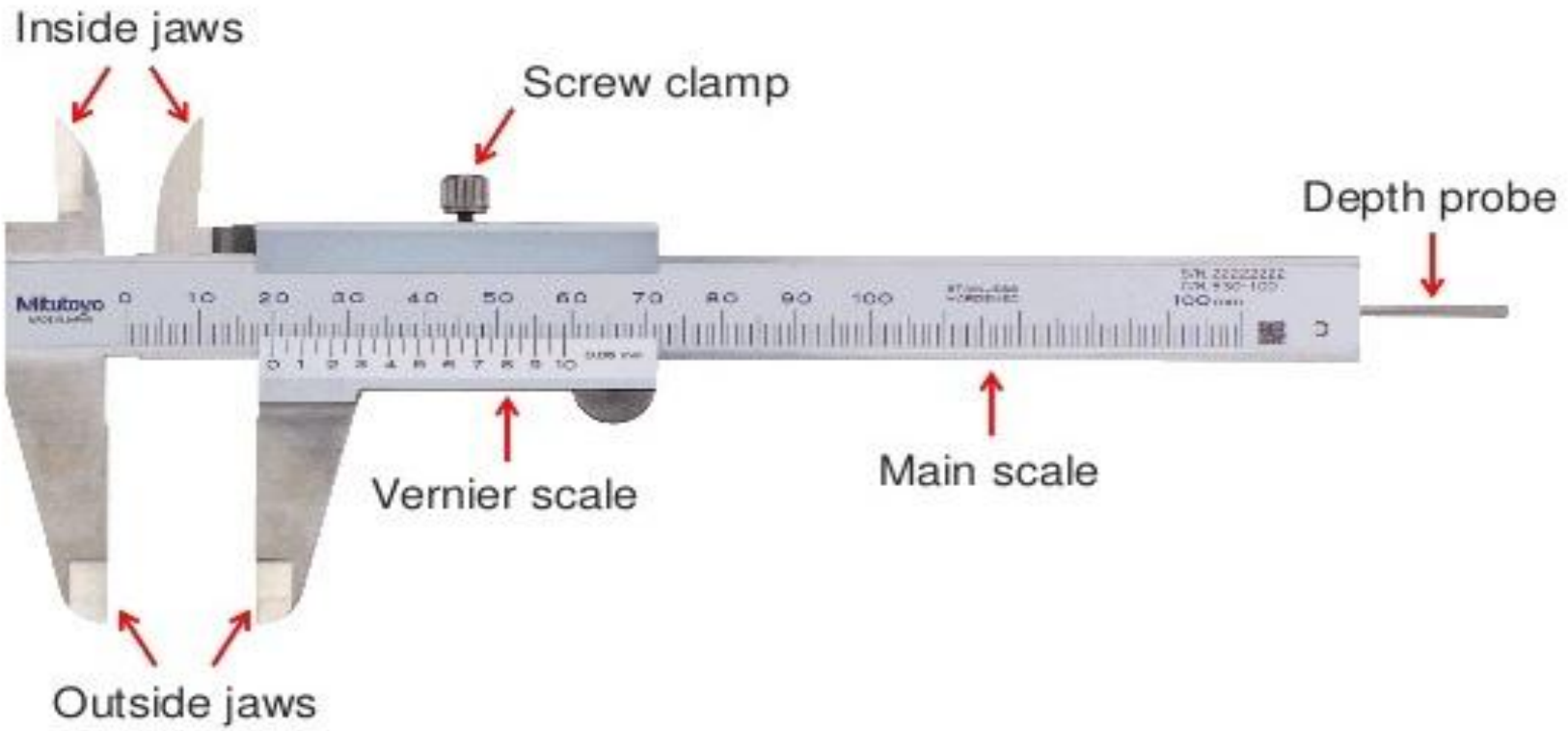
Basic Measurement Tools

- Vernier Caliper
- Micrometer Screw Gauge
- Standard Wire Gauge
- Ruler/Tape Measurement Tools
- Feeler Gauge
- Torque Wrench
- Compression Tester

Vernier Caliper

- **Function:** To measure smaller distances
- **Least Count:** 0.001 inch or 0.01mm.
- **Features:**
  - **Lower jaws** measure outer diameter
  - **Top jaws** measure inner diameter.
  - **Rod** extending from the rear of the caliper measures the depth.
  - **Main Scale** is graduated in mm.
  - **Vernier Scale** slides on the main scale. In most Vernier calipers, the vernier scale has 10 divisions

Vernier Caliper



Least Count of Vernier Caliper

- The least count (L.C.) is the finest measurement you can take. It can be calculated by dividing the least count of the main scale by the total number of divisions on the vernier scale.

  L.C. = L.C. of main scale / Number of divisions on vernier scale

- **Least count of the main scale :** There are 10 divisions in 1 cm of main scale. Divide 1 cm into 10 number of divisions; the value obtained is the least count of the main scale in cm.

  L.C.= 1/10 = 0.01 cm.

- **Number of divisions on Vernier scale :** In most Vernier calipers, the vernier scale has 10 divisions.

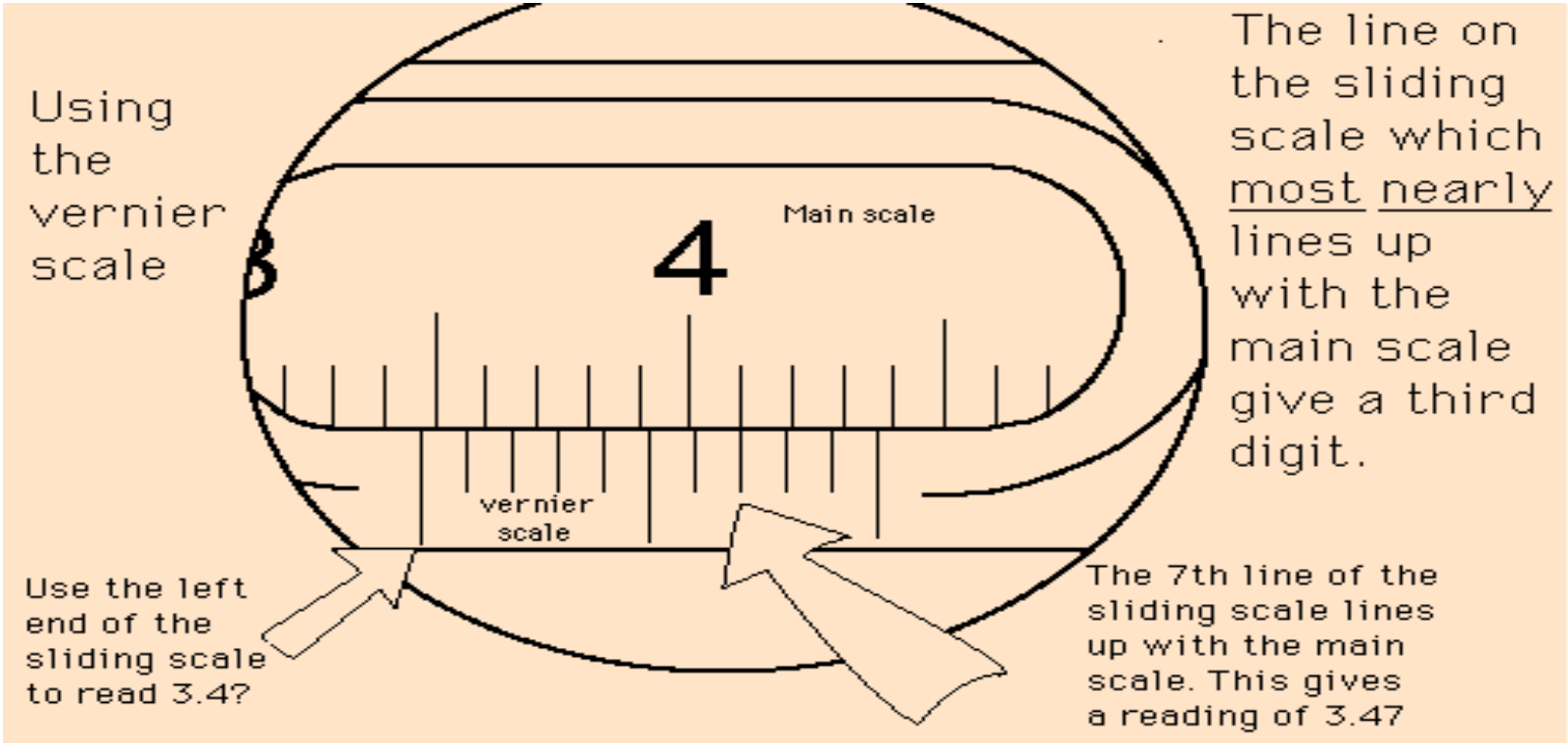
  Least count of main scale = 0.01 cm

  Number of divisions on vernier scale = 10 divisions.

  Thus,
  Least Count of vernier calipers = 0.01/10cm = 0.001 cm = 0.01 mm

How to use Vernier Caliper?

- Close the jaws.
- Calculate the least count.
- Place the object between the two jaws.
- Record the position of zero of Vernier scale on the Main scale (3.2cm).
- Notice the reading of VS which coincides with MS reading (3rd division in this case).



Reading of the instrument = Main Scale division + (coinciding Vernier Scale division x L.C)

= 3.4cm + (7 x 0.01mm)

= 3.4 + 0.07

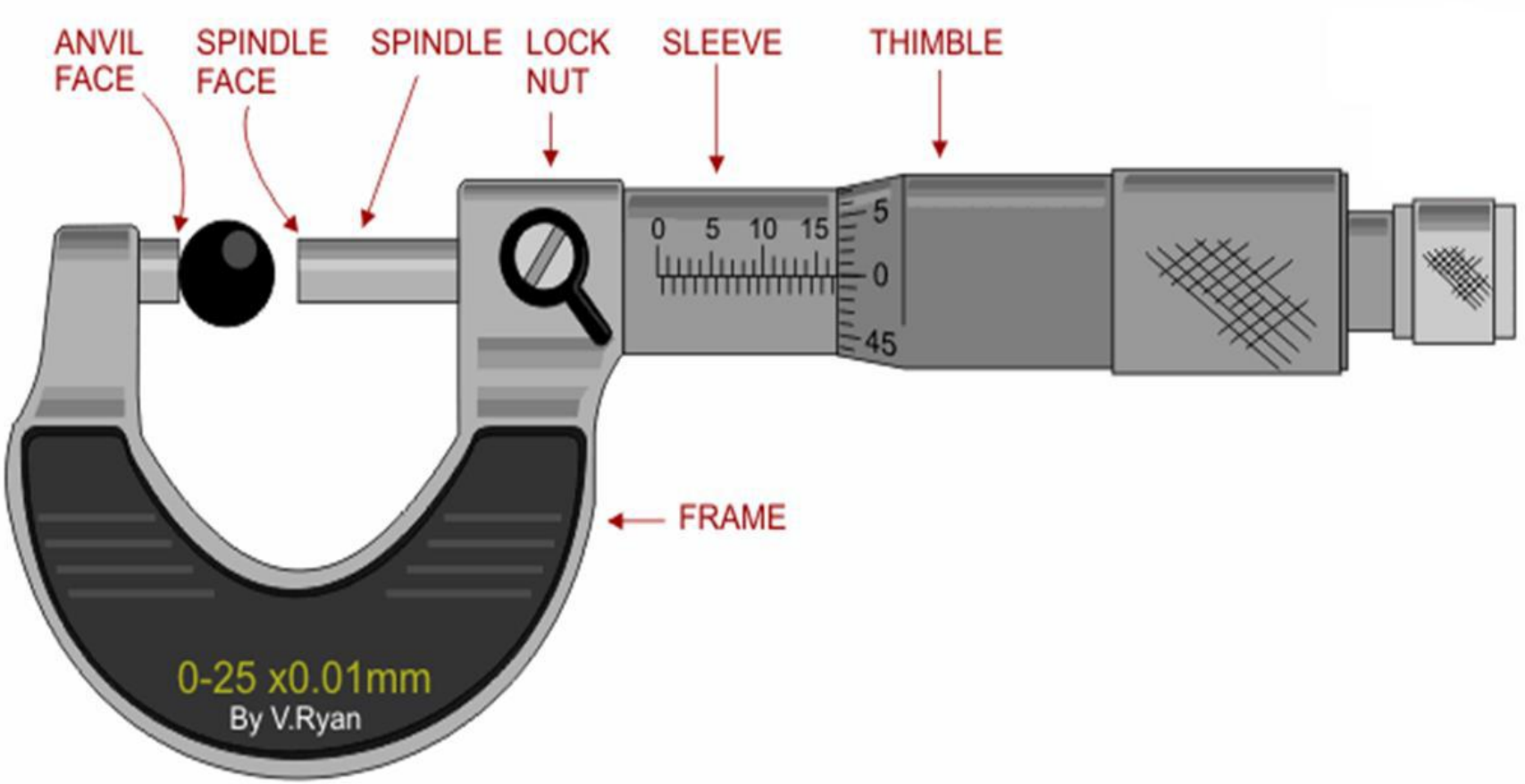
= 3.47 cm

- A rod extends from the rear of the caliper and can be used to measure the depth.
- Open the jaws of caliper and place the rod inside hole of the object, such as the rod reaches the inner most portion of the object.
- Read the vernier caliper. (same procedure as described in previous slides)

Micrometer Screw Gauge

- **Function:** allows the measurement of the size of the body i.e. thickness, depth, inner/outer diameter.
- **Features:**
  - Two jaws (one fixed, one movable)
  - Easy to use and more precise
  - Can measure up to 0.001cm
  - Circular Scale: movable jaw is attached to a screw, scale on this screw is called Circular scale. It has either 50 or 100 divisions
  - Linear Scale is the horizontal scale

- Frame: The C-shaped body that holds the anvil and sleeve in constant relation to each other.
- Anvil: The jaw which remains stationary.
- Spindle: The jaw which moves towards the anvil.
- Lock Nut: A lever, one can tighten to hold the spindle stationary.
- Sleeve: The stationary round part with the linear scale on it (Linear Scale).
- Thimble: Thimble rotates around the sleeve (Circular Scale).


ANVIL FACE
SPINDLE FACE
SPINDLE
LOCK NUT
SLEEVE
THIMBLE
0 5 10 15
5
0
45
FRAME
0-25 x0.01mm
By V.Ryan

Pitch of Micrometer Screw Gauge

- Pitch of the screw gauge is the distance moved by the spindle on linear scale per revolution of circular scale.
- The spindle moves forward or backward 1mm on the linear scale.
- Pitch of Screw Gauge = distance on linear scale / one rotation
- Pitch of Micrometer = 1/1 = 1mm

Least Count of Screw Gauge

- Least Count = Pitch of the Micrometer / Total number of circular scale division
- •Least Count = 1 / 100 = 0.01mm = 0.001cm

How to use Screw Gauge?

- Thimble rotates around a cylinder which is marked in millimeters.
- The left-hand side of the thimble has markings all around it.
- The line labeled 0 is the primary pointer.
- Close the jaws
- Calculate the least count
- Place the object between the two jaws
- Record the position of main scale where the two measuring rods met.
- Note the position of the circular scale which coincides with main scale.

Reading of the instrument = Linear Scale division + (coinciding Circular Scale division x L.C)

= 7.5mm + (22 x 0.01mm)

= 7.5mm + 0.22mm

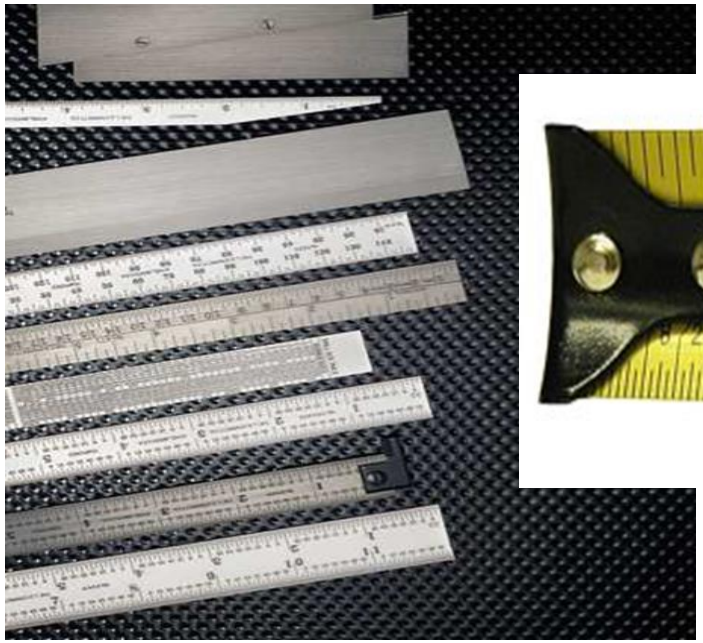
= 7.72mm = 7720µm

Standard Wire Gauge (SWG)

- A gauge for measuring the diameter of wire, usually consisting of a disk having variously sized slots in its periphery or a long graduated plate with similar slots along its edge.
- It has a standardized system of wire sizes.
- Wires are manufactured to standard sizes and labeled with their SWG.
- As the SWG increases the diameter decreases.

Ruler/Tape Measurement Tools

A tape measure or measuring tape is a flexible ruler. It consists of a ribbon of cloth, plastic, fiber glass, or metal strip with linear-measurement markings. It is a common measuring tool. Its design allows for a measure of great length to be easily carried in pocket or toolkit and permits one to measure around curves or corners.



Feeler Gauge

- A feeler gauge is a tool used to measure gap widths. Feeler gauges are mostly used in engineering to measure the clearance between two parts
- Feeler gauges are strips of hardened metal that have been ground or rolled to a precise thickness. They can be very thin and will cut through skin if not handled correctly.

Torque Wrench

- A torque wrench is a tool used to precisely apply a specific torque to a fastener such as a nut or bolt.
- A torque wrench is used where the tightness of screws and bolts is crucial. It allows the operator to measure the torque applied to the fastener so it can be matched to the specifications for a particular application.

Compression Tester

- The compression tester, also know as a compression gauge, is one of the most basic tools used for diagnosing engine problems.
- A compression test is a quick way to determine the general condition of the pistons rings and can help determine what repairs might be needed before starting to work on the engine.

Machining

Selection of Machinery and Tools

- After the workpiece is manufactured through conventional/non-conventional techniques, it can be machined to give it a finishing touch.
- Machining is a process designed to change the size, shape, and surface of a material through removal of materials.
- It offers important benefits such as
  - Excellent dimensional tolerances: Example is forged crankshaft where holes and bearing surfaces require tight tolerances.
  - External and internal geometrical features: Sharp corners, grooves, fillets, various geometry.
  - Surface finish: Example is a copper mirror by diamond turning
  - Removal of heat treat distortion: Parts such as crank and camshafts undergo distortion during heat treatment
- A machining system consists of three components:
  - machine
  - cutting tool
  - workpiece (part to be machined).

Selection of Machinery and Tools

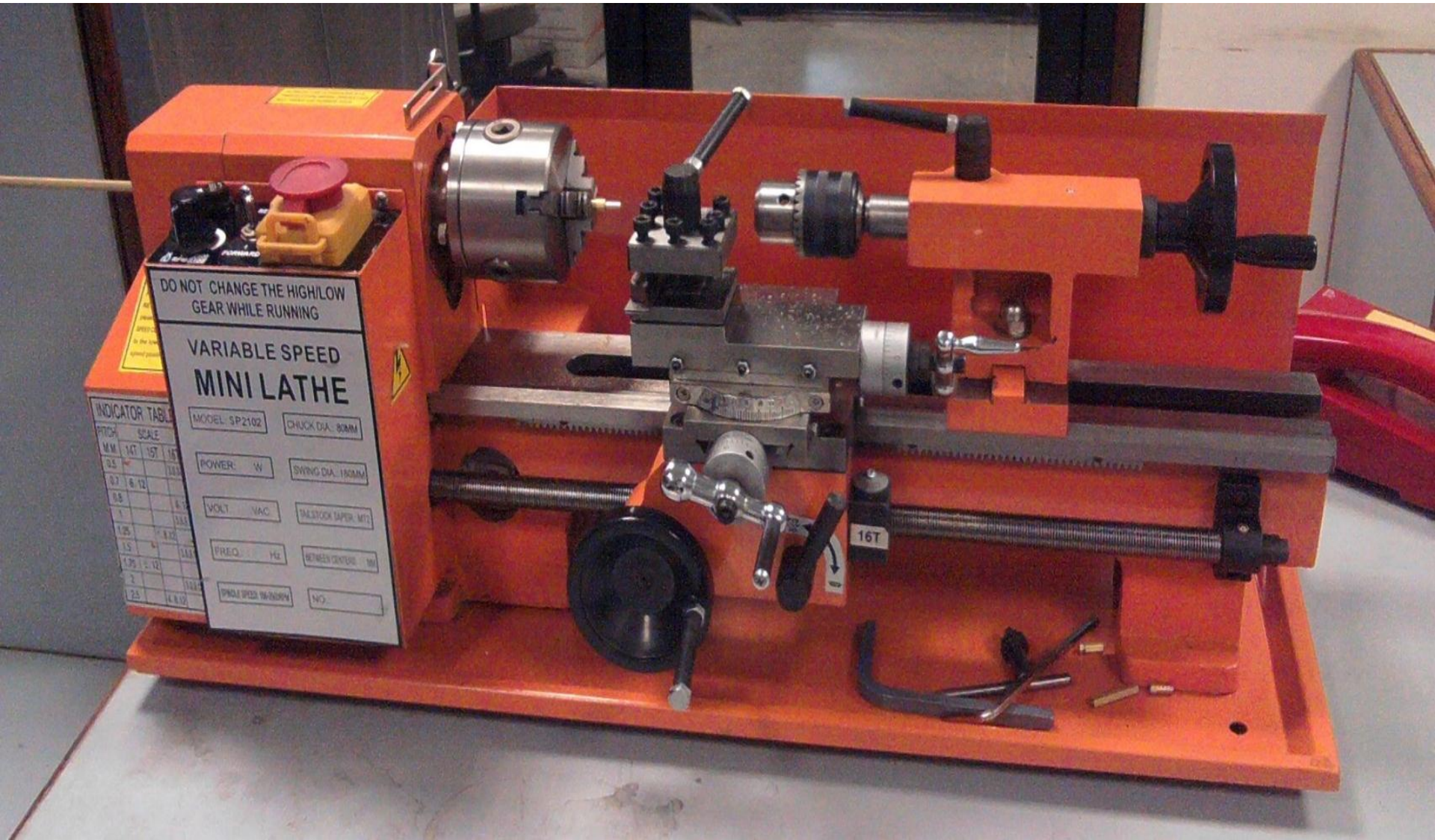
- Typical machine types are:
  - Lathe Machine
  - Milling Machine

- Machining operations are:
  - Lathe Machine
    - Turning
    - Facing
    - Drilling
    - Parting
    - Boring
    - Reaming
    - Threading
  - Milling Machine
    - Milling

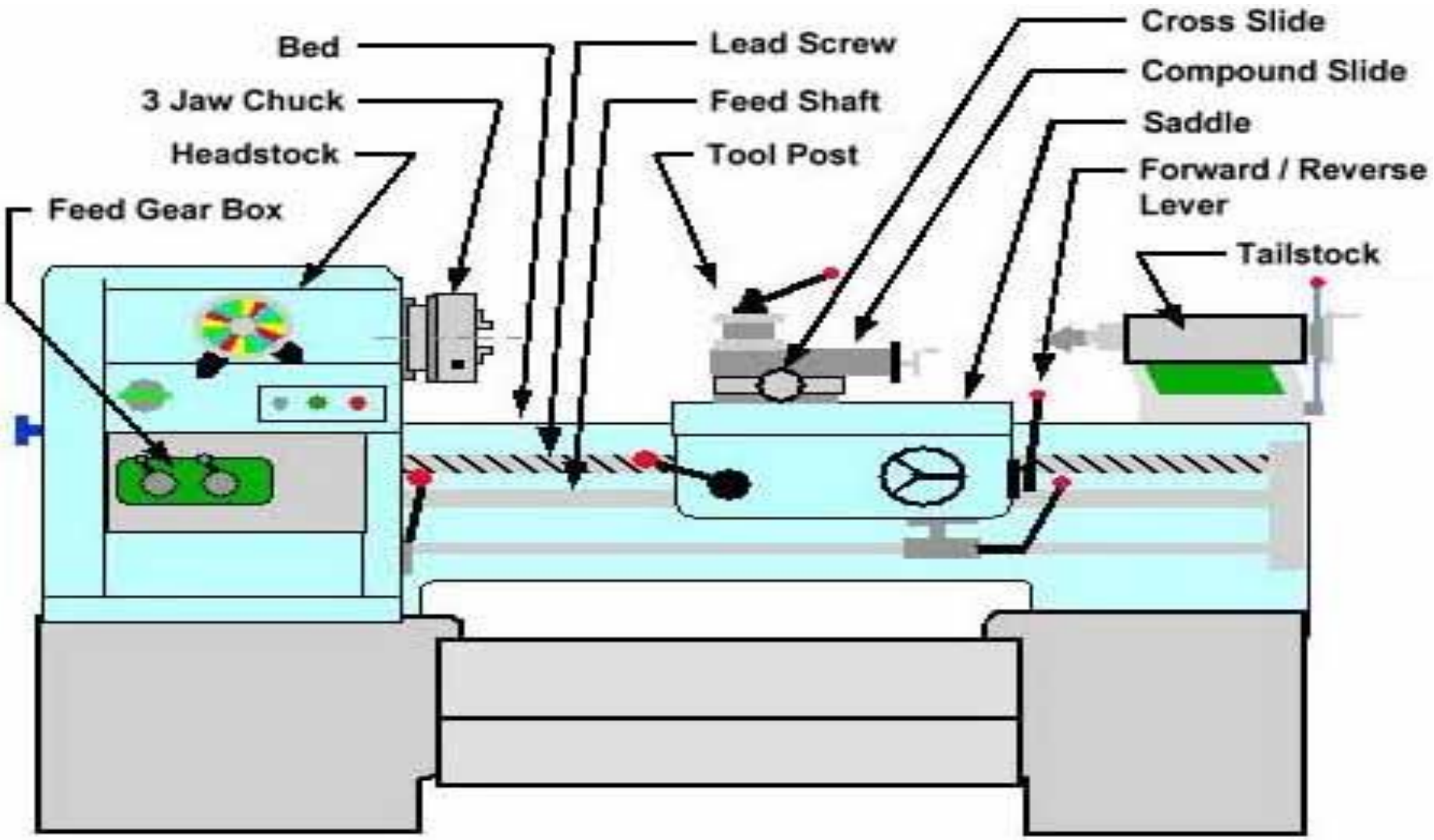
Lathe Machine

- A machine which rotates the workpiece on its axis to perform various operations such as cutting, knurling, drilling, facing and turning with tools that are applied to the workpiece to create an object which has symmetry about an axis of rotation.
- Basic Parameters:
  - Cutting Speed
  - Lathe Feed
  - Depth of Cut
    - Axial Depth of Cut
    - Radial Depth of Cut

Lathe Machine

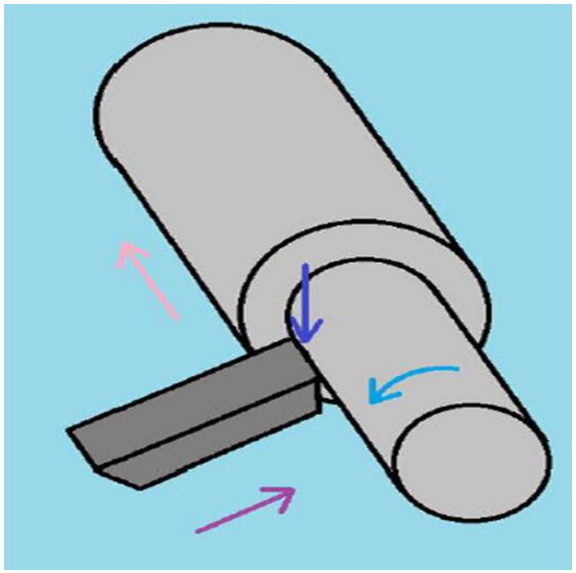


Parts of Lathe Machine

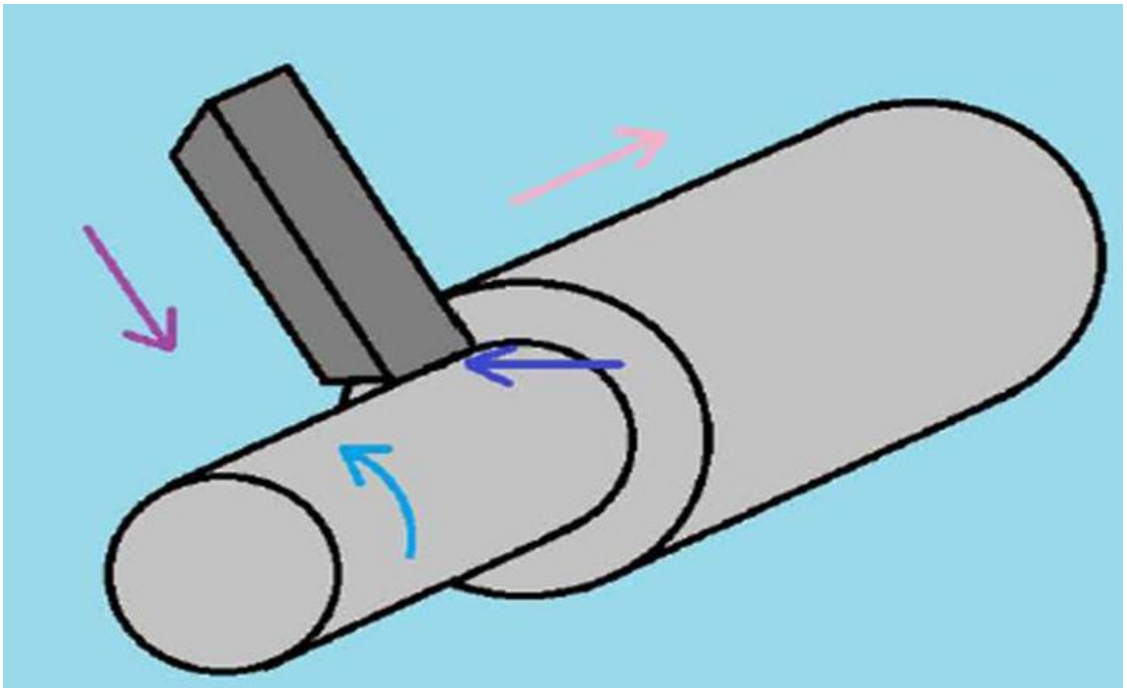


Lathe Machine

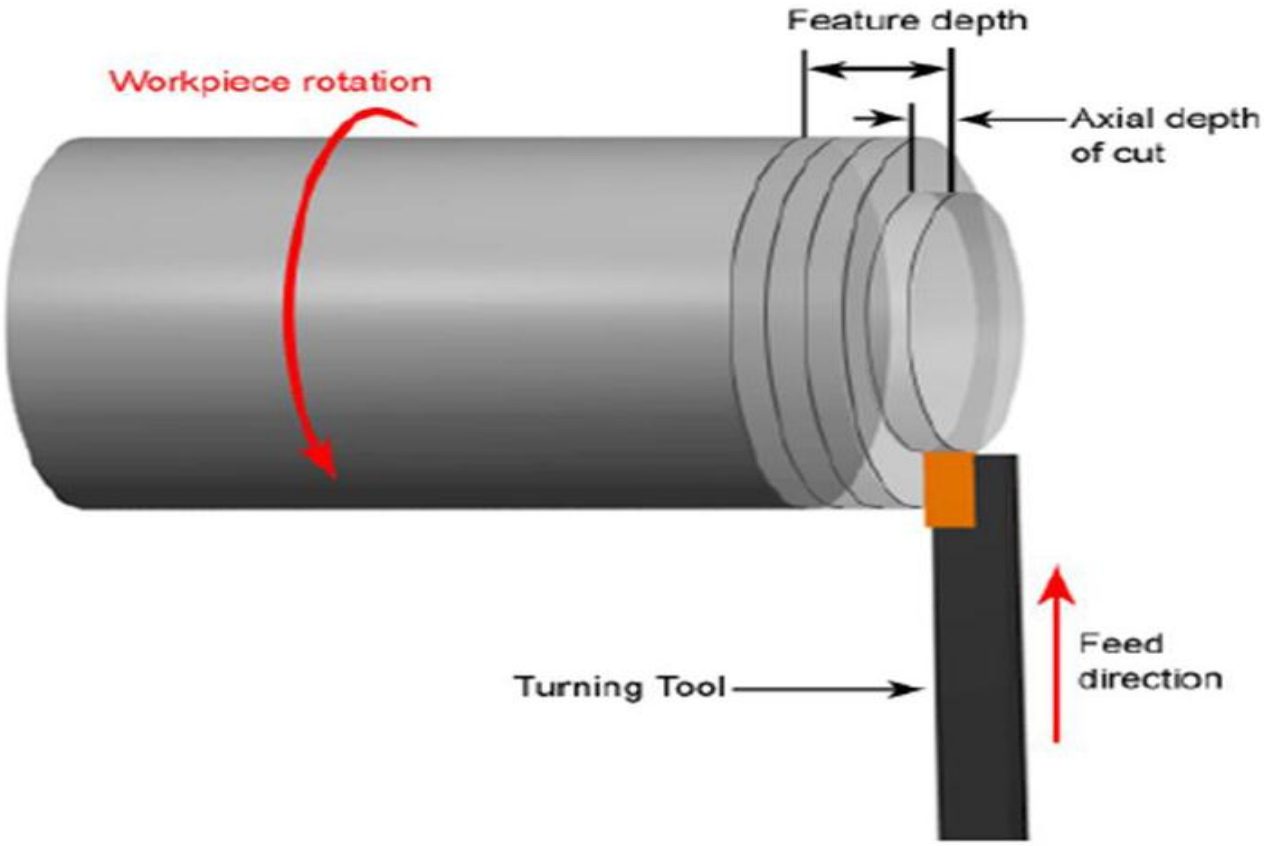
- **Cutting Speed (ft/min or m/min):** the rate at which a point on workpiece circumference travel past the cutting tool.
  - Material passing the cutting tool in one revolution is given by **RPMs**. RPMs are dependent on Cutting speed of the material.
  - Rpm = Cutting Speed / Circumference of the workpiece



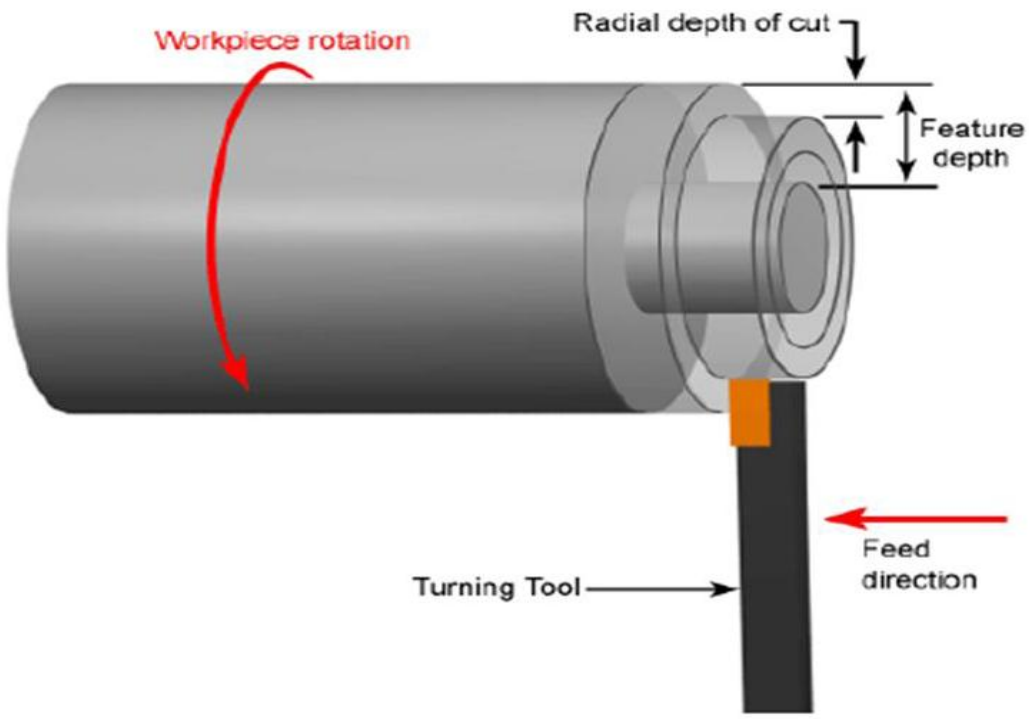
- **Feed (mm/rev or in./rev):** the distance cutting tool advances along the workpiece for every revolution of the spindle.



- **Depth of Cut:** the distance the cutting tool penetrates into the workpiece.
  - **Axial Depth of Cut:** the depth of tool along the axis of the workpiece as it makes a cut



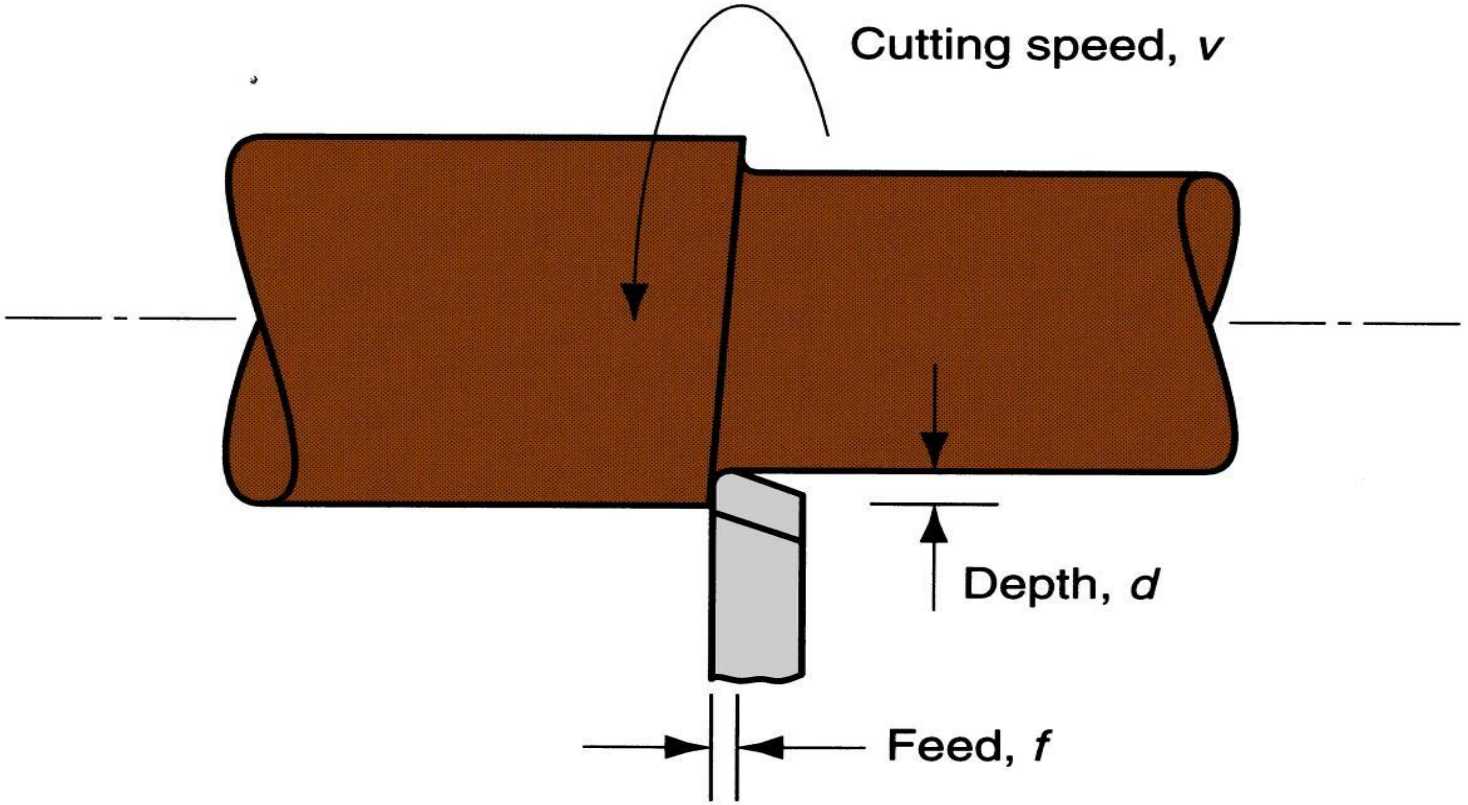
- **Radial Depth of Cut:** the depth of tool along the radius of the wokrpiece as it makes a cut



In lathe operations, first the depth of cut is applied and then the tool is given the feed until the whole material is removed. If more machining is required, again depth of cut is given and then feed is applied.

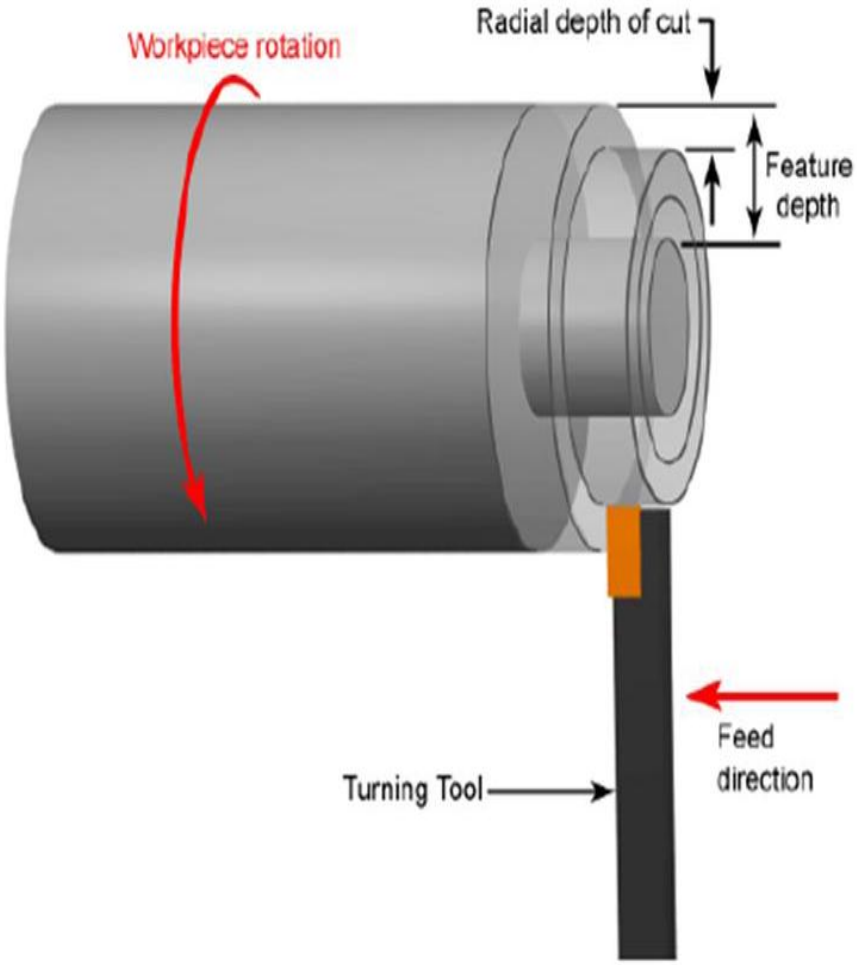
Lathe Machine

- Material Removal Rate (MRR)
- $MRR = v\ f\ d$

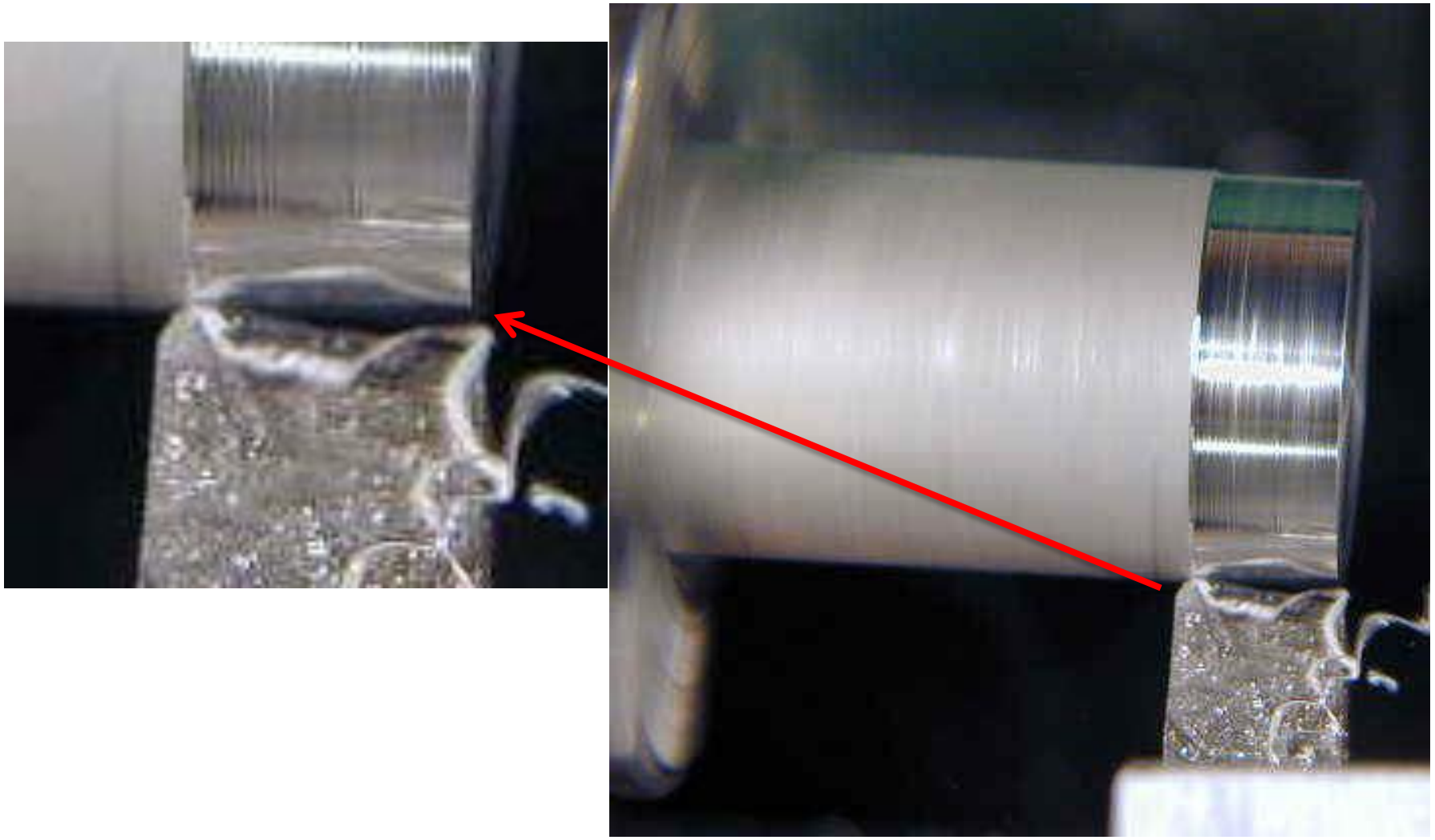


Lathe Machine Operations - Turning

- Turning is the **removal of metal from the outer diameter** of a rotating cylindrical workpiece.
- The turning process requires a lathe machine, work piece, fixture, and cutting tool
- The cutting tool is typically a single-point cutting tool that is also secured in the machine. The cutting tool feeds into the rotating workpiece and cuts away material in the form of small chips to create the desired shape.



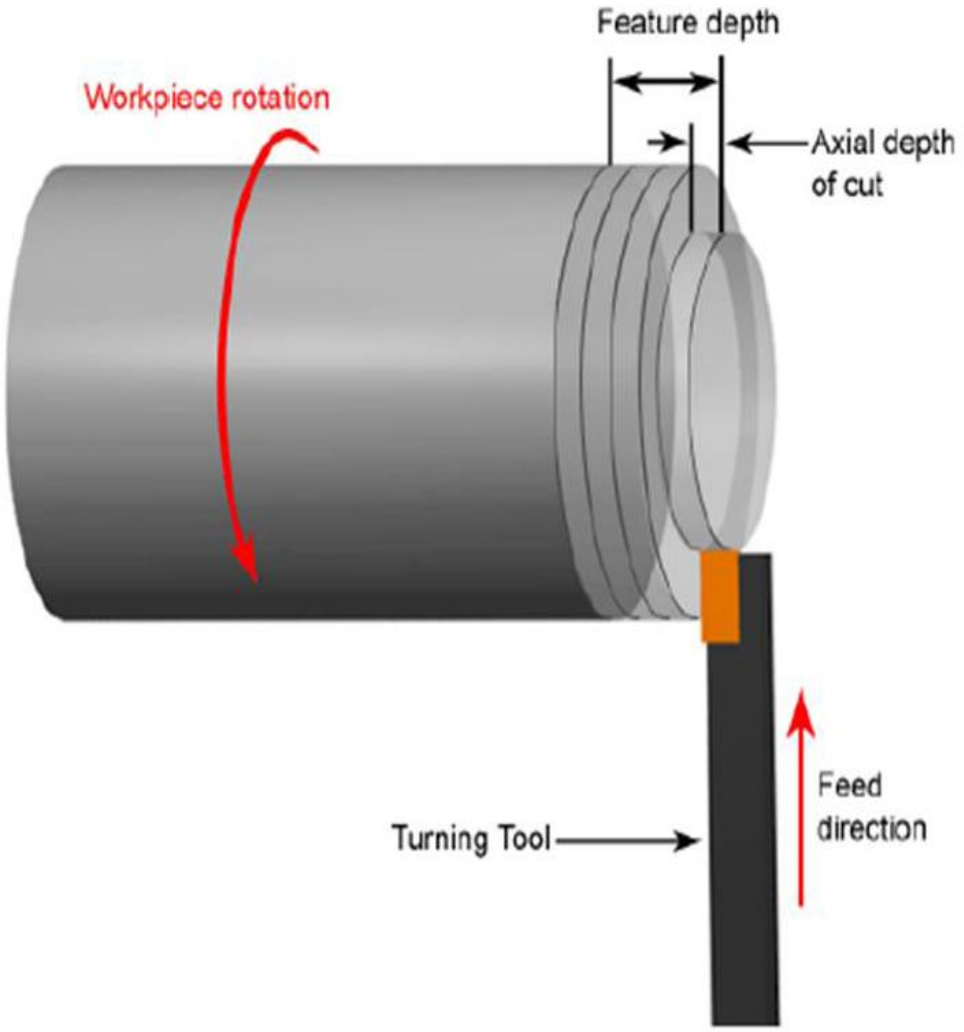
A Little More Elaboration



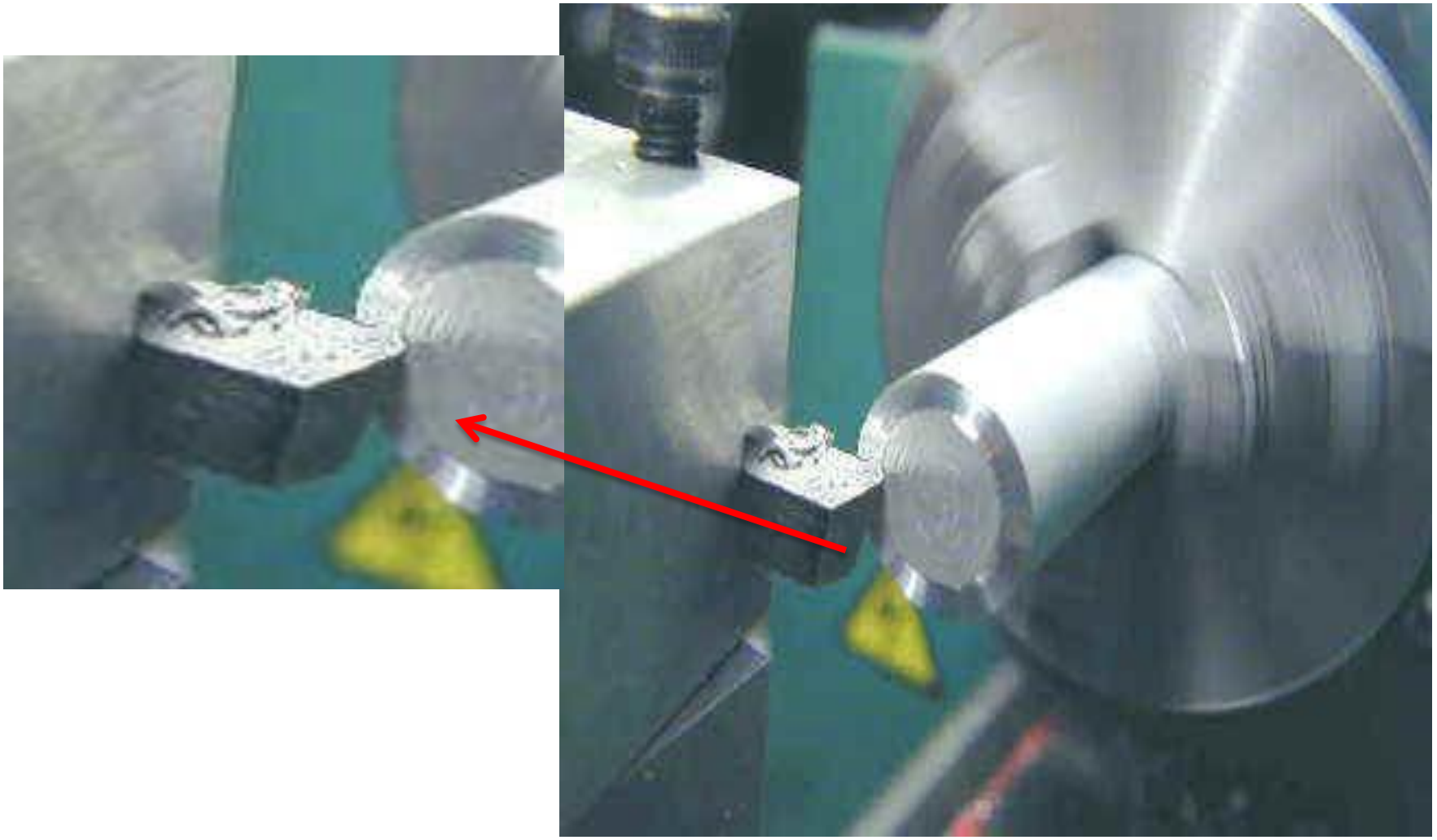
- Turning at some angle is taper turning.

Lathe Machine Operations - Facing

- Facing is the process of **removing metal from the end of a workpiece** to produce a flat surface
- Need for Facing:
  - Work piece is usually not square in raw form.
  - Work piece has not been cut to specified length.
- Facing should not be done on work pieces extending more than 5 diameters out of chuck .
- The cutting tool is typically a single-point cutting tool.

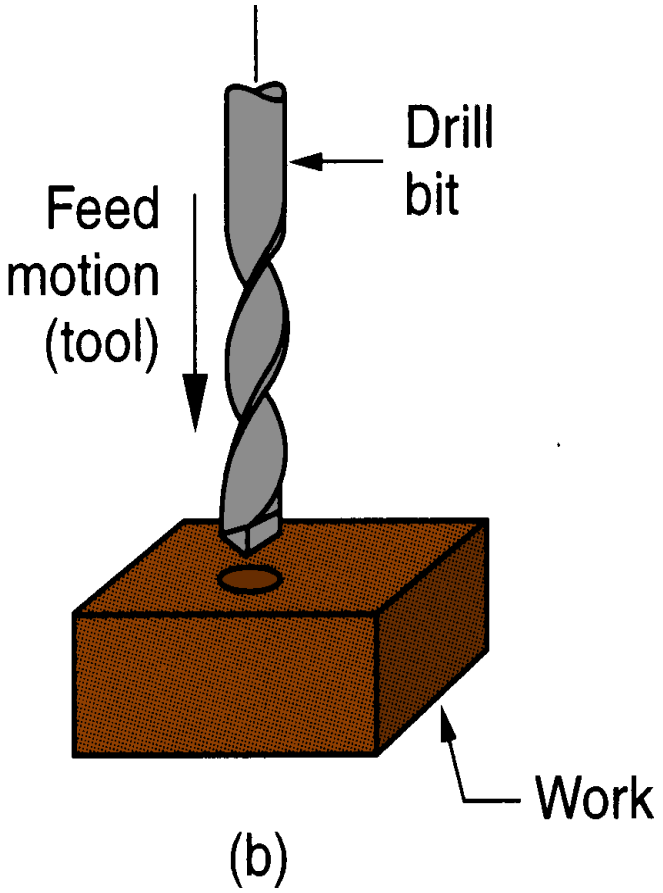


A Little More Elaboration

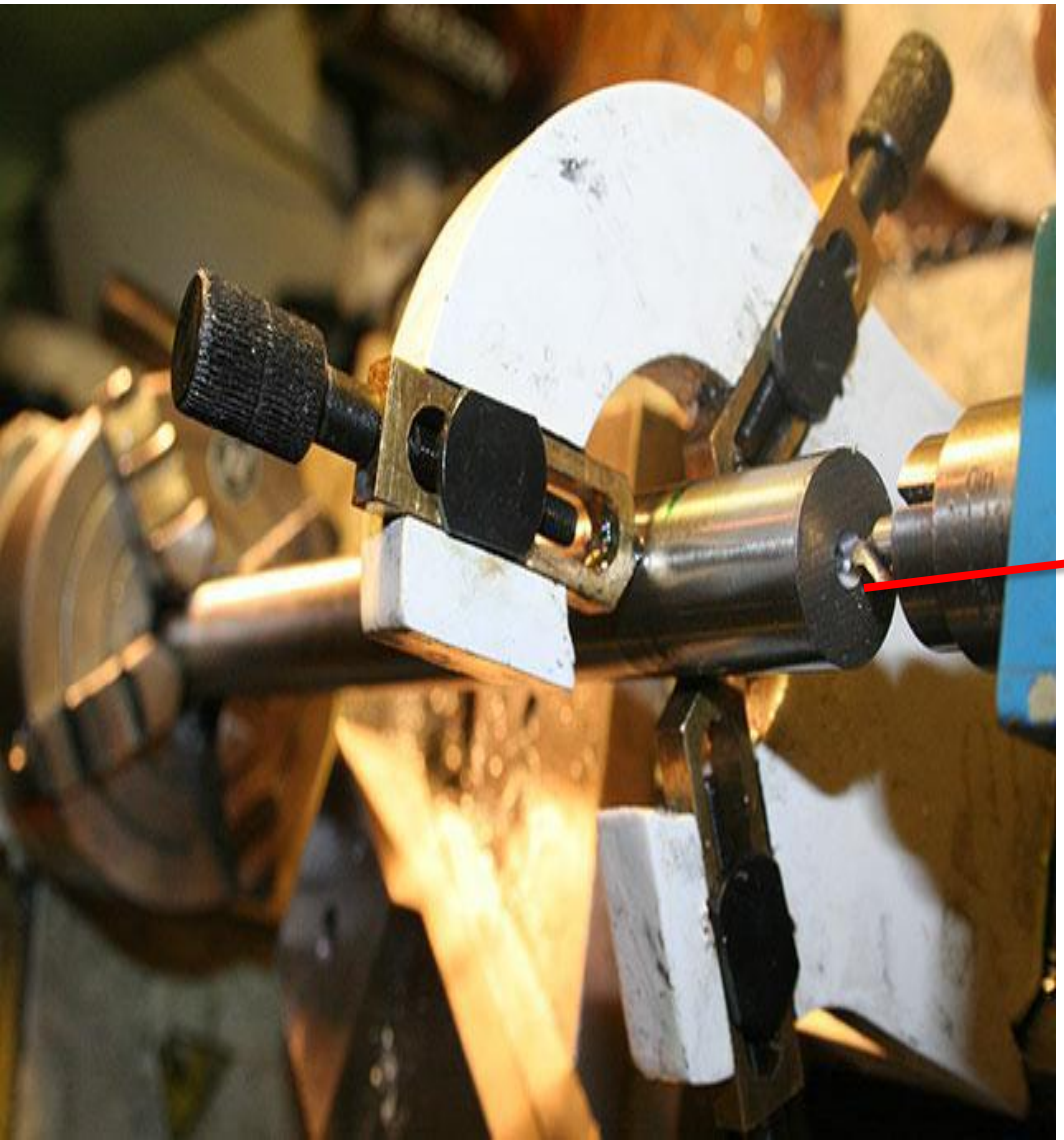


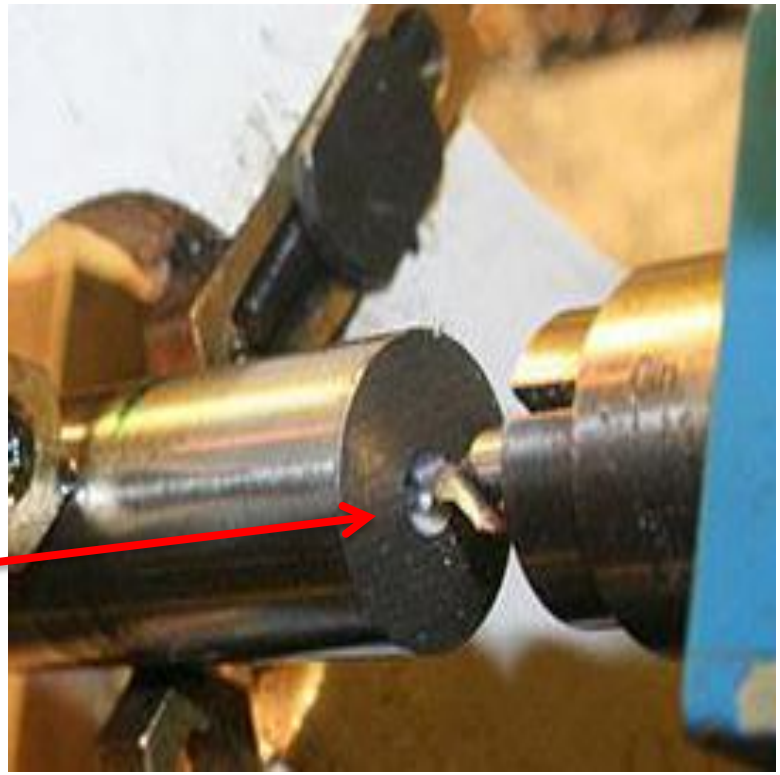
Lathe Machine Operations - Drilling

- Drilling is a cutting process that uses a drill bit to cut or enlarge a hole of circular cross-section in solid materials.
- The **drill bit** is a rotary cutting tool, often multipoint. The bit is pressed against the work piece and rotated at rates from hundreds to thousands of revolutions per minute.
- This forces the cutting edge against the work piece, cutting off chips from the hole as it is drilled.



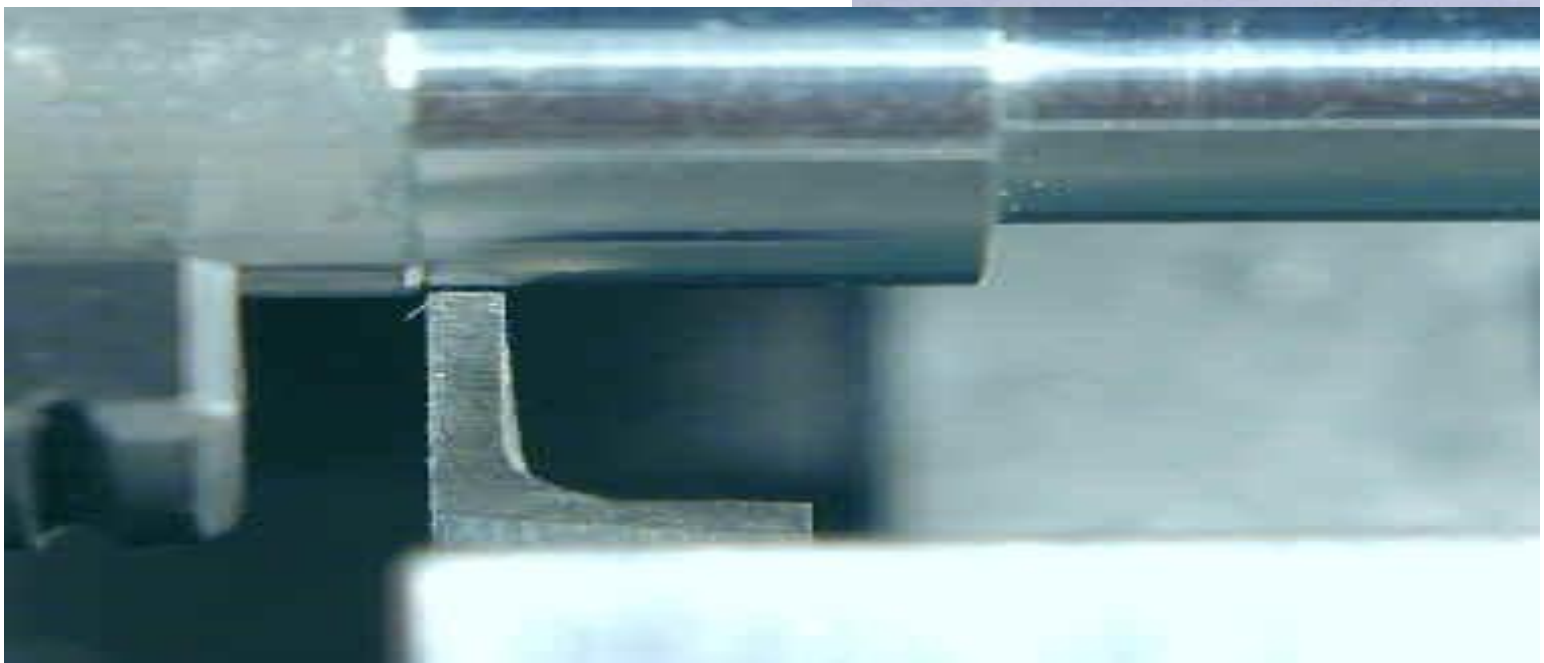
A Little More Elaboration





Lathe Machine Operations - Parting

- Parting uses a blade-like cutting tool plunged directly into the workpiece to cut off the workpiece at a specific length.

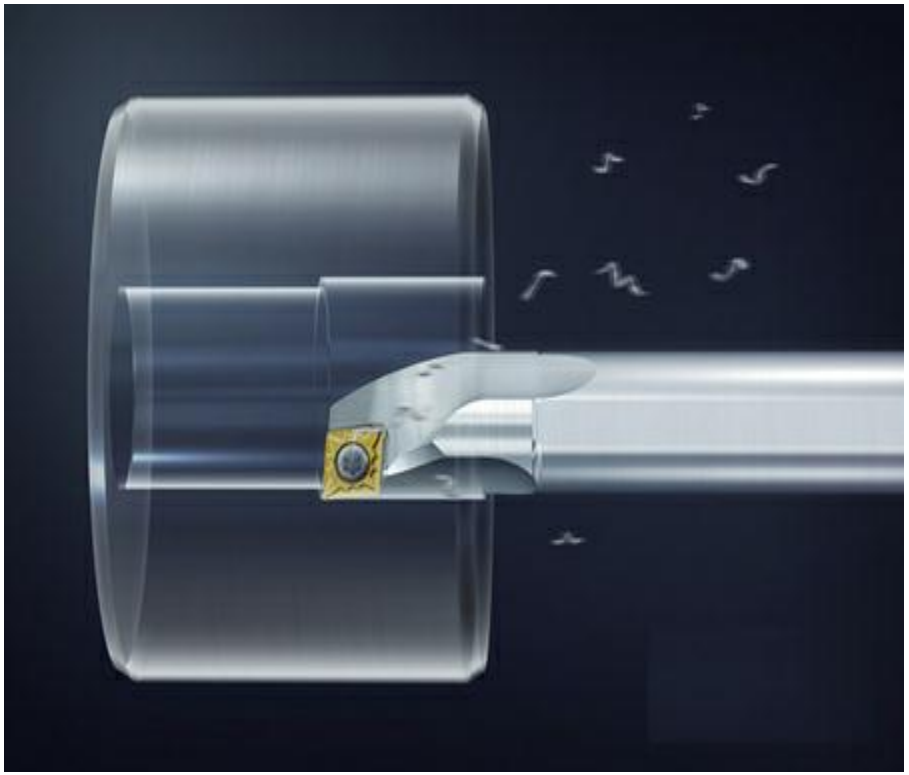


Demonstration of Lathe Operations

Group 1

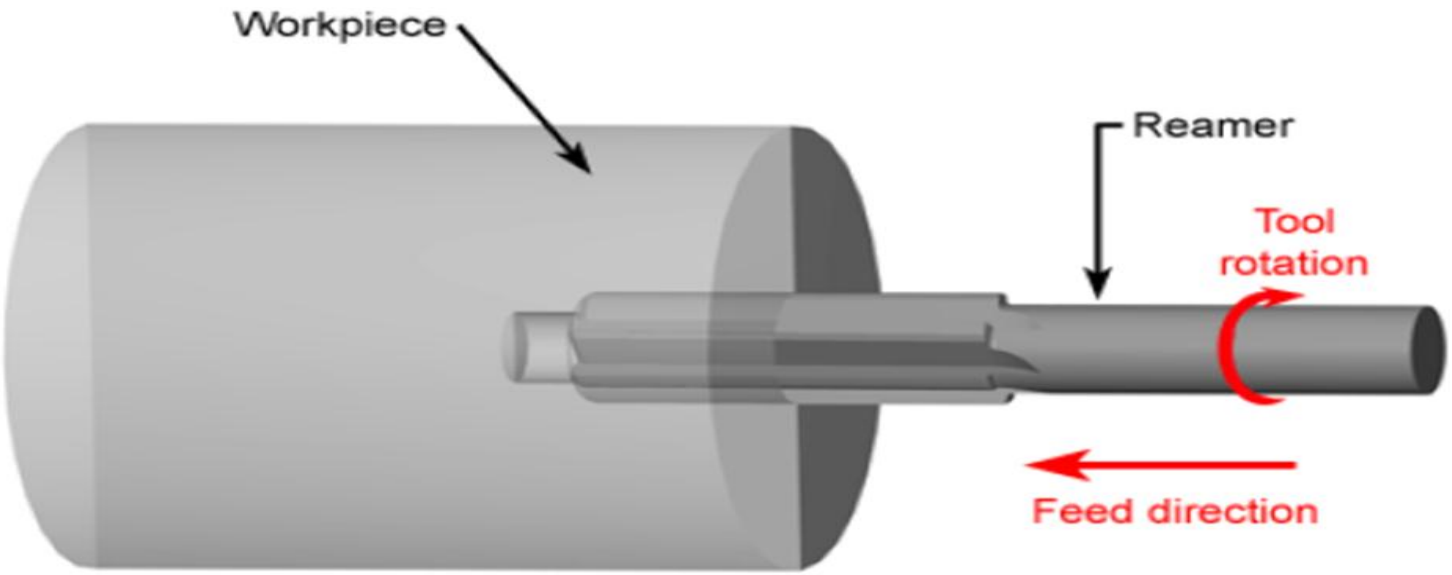
Lathe Machine Operations - Boring

- Enlarging existing or drilled hole. This operation is much like turing.
- Vernier Calipers, outside/ inside micrometers and rule are used for measurements.



Lathe Machine Operations - Reaming

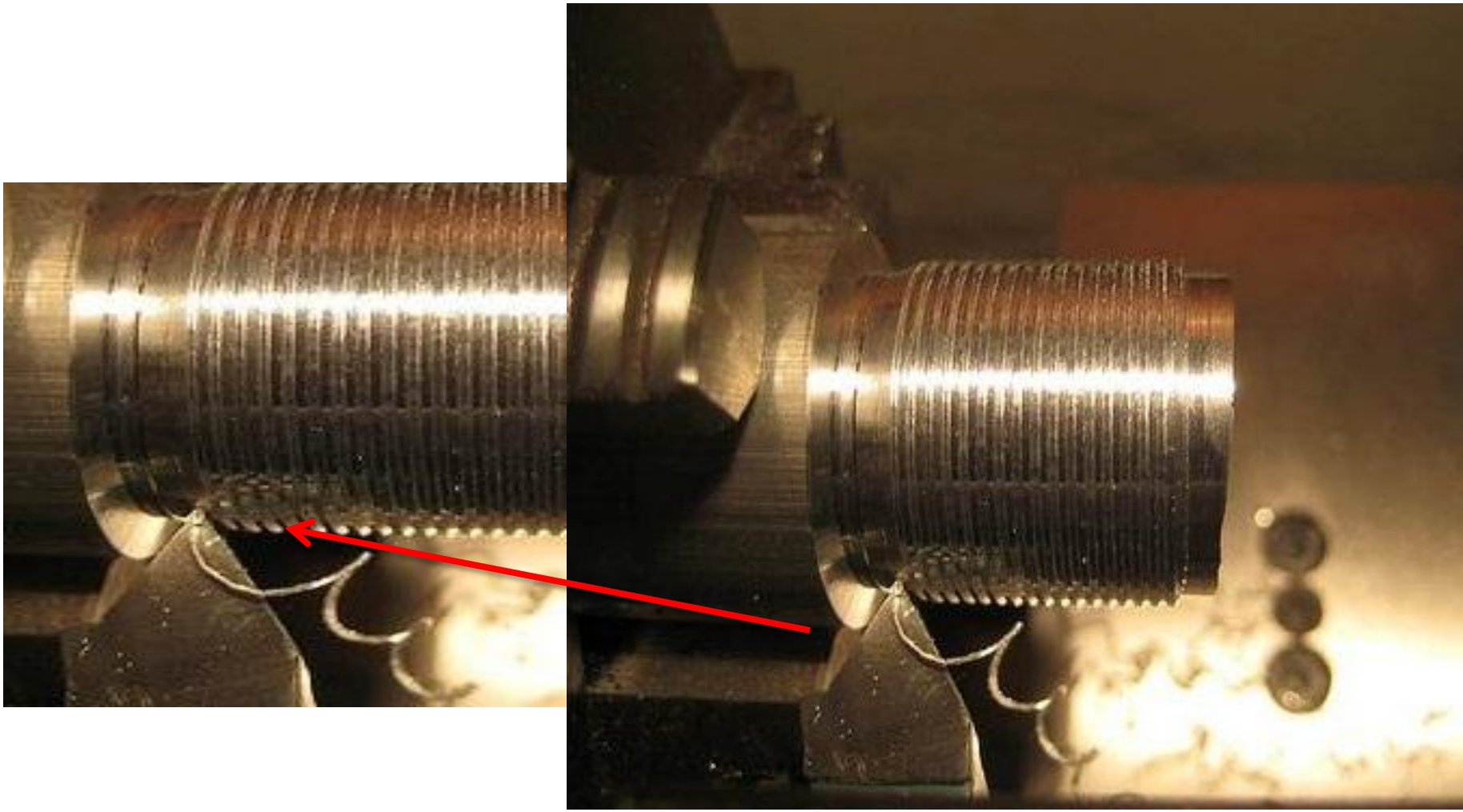
- Finishing a drilled or bored hole to size…
- Reamers are like drills.



Lathe Machine Operations - Threading

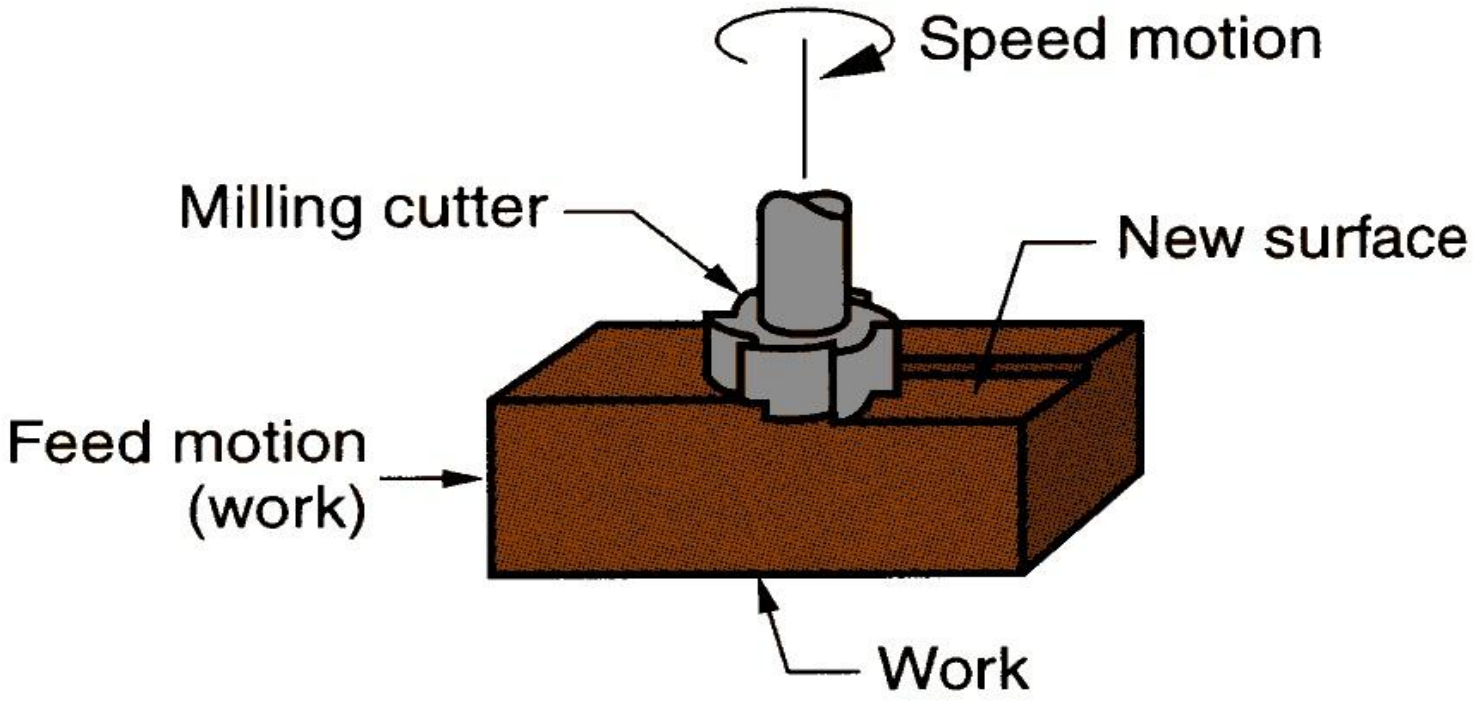
- Threads are **helical ridge of uniform cross section** carved on the **outer or inner diameter** of some work-piece so that one having external threads can meet with the one having internal threads.
- Threads can be used for
  - Fastening
  - Motion
  - Measurements

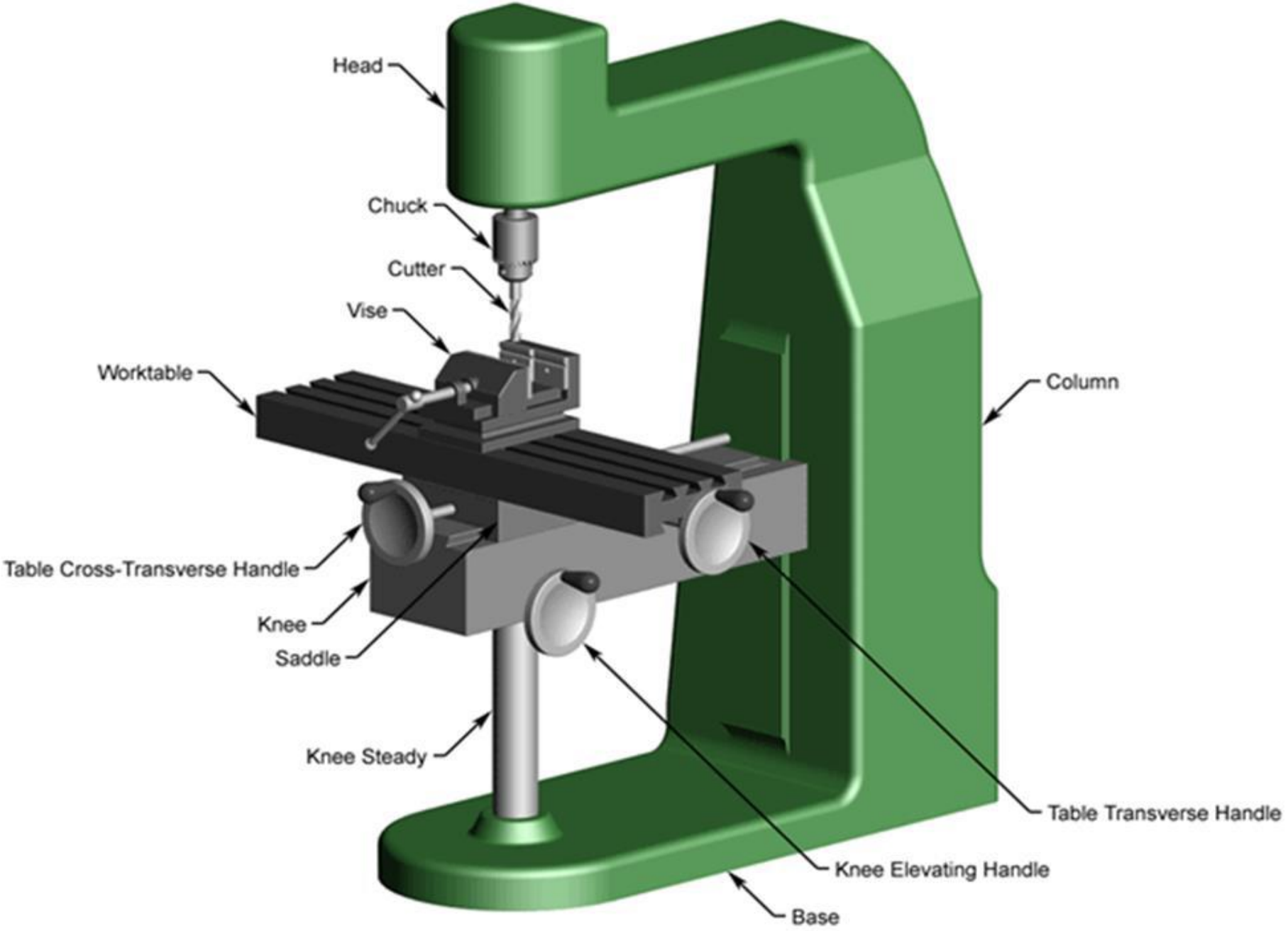
A Little More Elaboration



Milling Machine

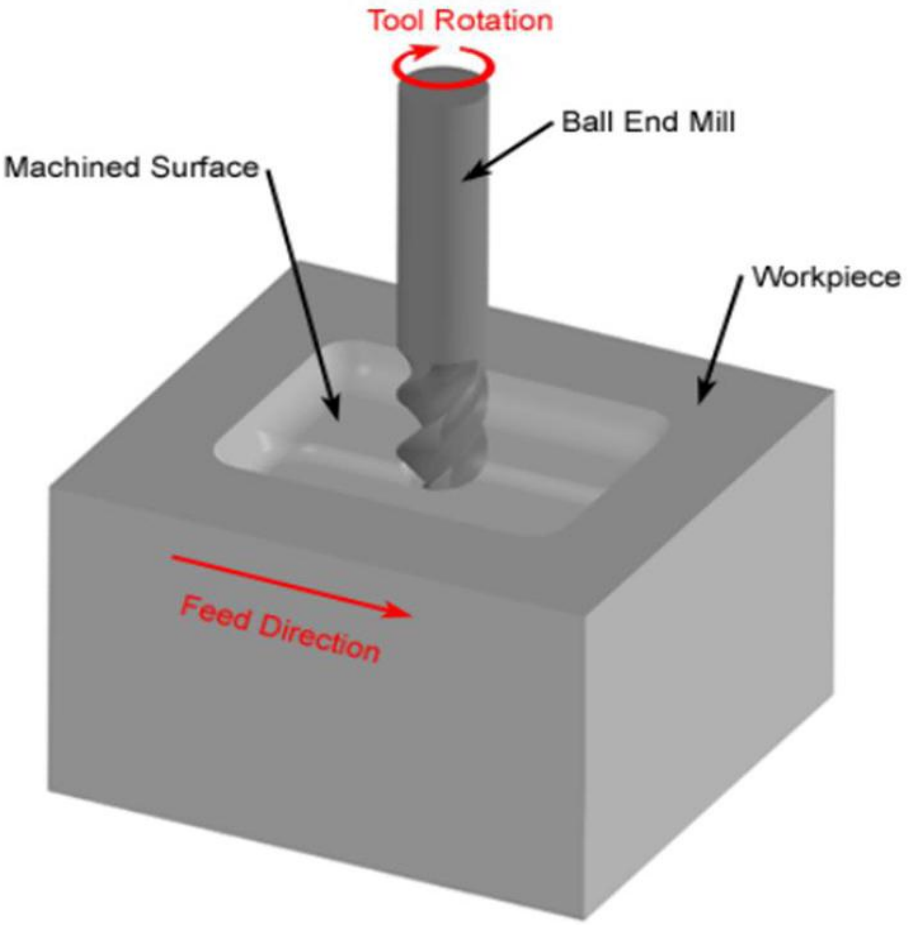
Milling is a cutting process that uses a milling cutter to remove material from the surface of a work piece.



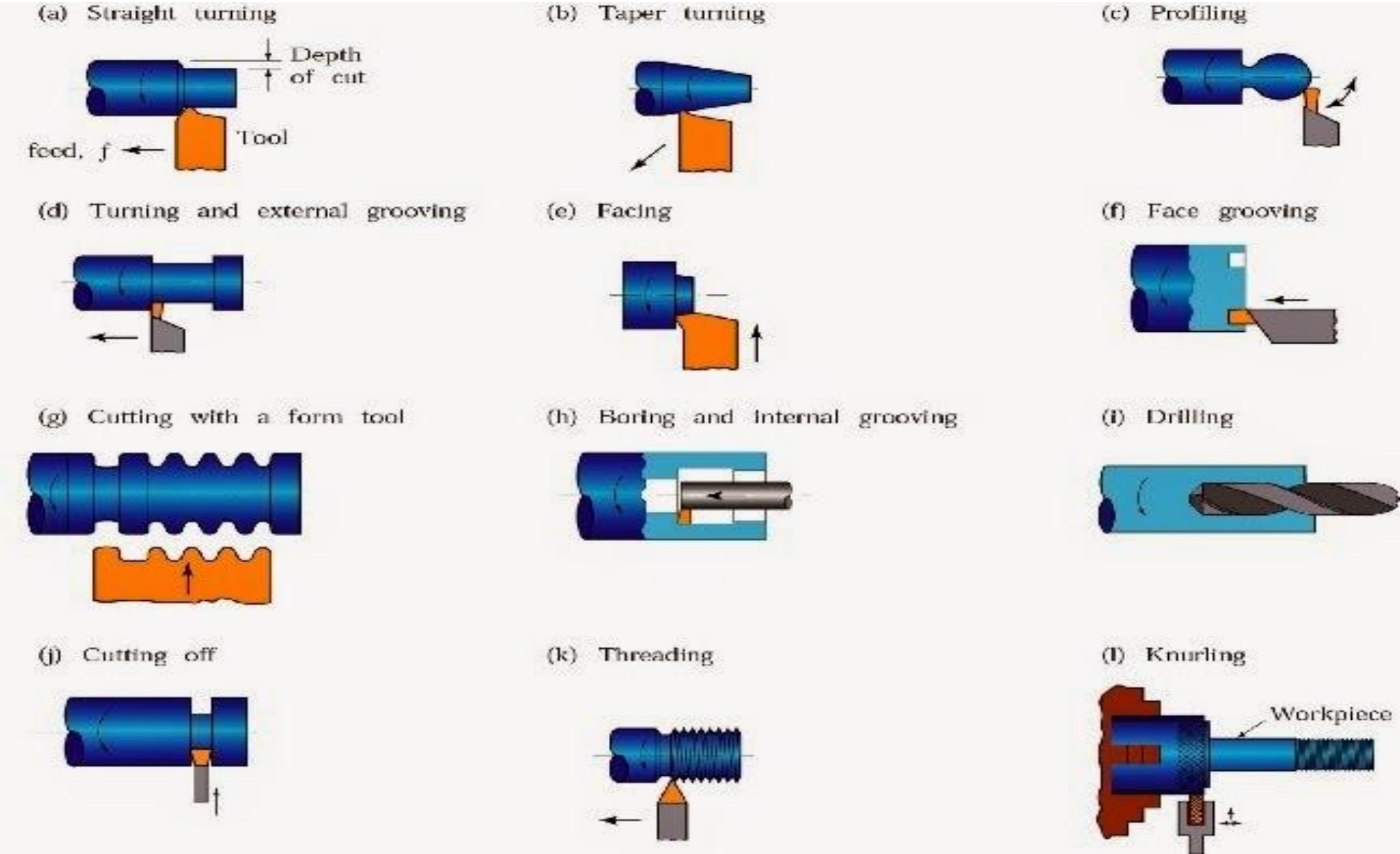

Head
Chuck
Cutter
Vise
Worktable
Column
Table Cross-Transverse Handle
Knee
Saddle
Knee Steady
Table Transverse Handle
Knee Elevating Handle
Base

Milling Operation

- The milling cutter is a rotary cutting tool, often with multiple cutting points.
- As opposed to drilling, where the tool is advanced along workpiece's rotation axis, the cutter in milling is usually moved perpendicular to its axis so that cutting occurs on the circumference of the cutter.

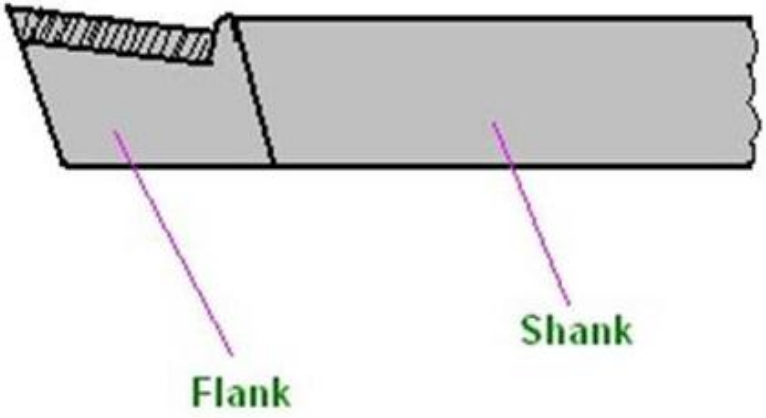


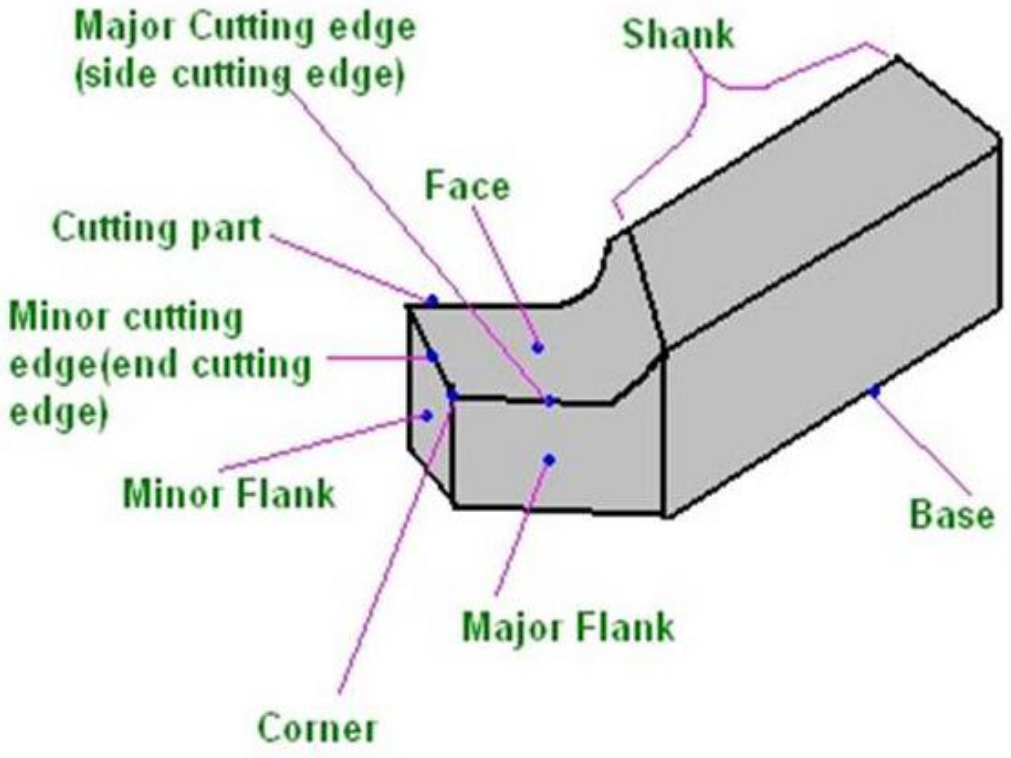
Tools with Operations



Nomenclature – Single point Cutting Tool

- Single Point Cutting Tool
  - One dominant cutting edge
  - Point is usually rounded to form a nose radius





Demonstration of Lathe Operations

Group 2