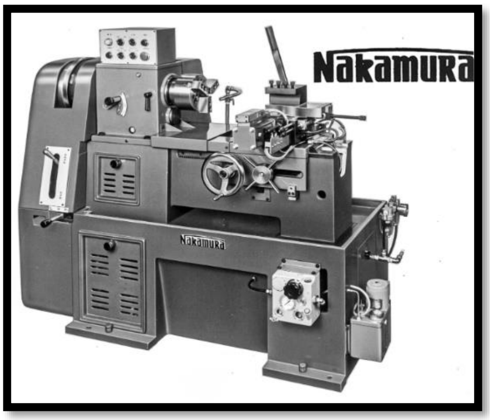
ACS College of Engineering
Approved by AICTE New Delhi, Affiliated to VTU, Belagavi
(A Unit of RajaRajeswari Group of Institutions)
CET Code : E186 COMED-K : E003 PGCET : T918

DEPARTMENT
OF
AERONAUTICAL ENGINEERING

MANUAL
FOR
AIRCRAFT MATERIAL TESTING & PROCESSING LABORAOTRY [BAEL404 - 22 SCHEME]



Vision

To be at the focus of the Aerospace orbit with Global at the Apogee and Nation at the Perigee

Mission

- Lift the Knowledge of students beyond the sky of syllabus to become Engineering leaders
- Dragging the national and global resources for making the student as skilled managers
- Thrusting the students to propel beyond the atmosphere of Employment to Entrepreneurship
- Weightage to shape the students from I to PI to excel as an ethical and responsible citizens

Program Educational Objectives (PEOs)

PEO-1 PROFESSIONAL KNOWLEDGE Aeronautical Graduates will have the global awareness to apply their knowledge across interdisciplinary areas in nationally and globally emerging domains of Aeronautical Engineering for higher studies, Research, Employment, Entrepreneurship lifelong learning and product development.

PEO-2 LEADERSHIP SKILLS Graduates will have multi-tasking skills like software, Hardware, interpersonal skills and management qualities like critical thinking, decision making to implement their knowledge in the Aeronautical domain

PEO-3 ATTITUDE DEVELOPMENT Graduates will possess the suitable attitude to recognize the need of the society and will be a citizen with strong ethics to protect the Environment and with better commitment to serve the society.

Program Specific Outcomes (PSOs)

Engineering Graduates will be able to:

PSO-1: AEROMODELLING Apply their Engineering knowledge of all the fundamental core subjects and the Hardware & Software skills in the development (Design, Fabrication, Analysis, Testing and Flying) of aero models (RC, UAV & DRONES)

PSO-2: AEROSPACE EXPOSURE Students will be given additional exposure in advanced development in the fields like Aerospace and helicopter designs

PSO-3: CAREER IMPROVEMENT THROUGH NETWORK Graduates will get quality Industrial exposure and carrier opportunity in the field of Aeronautics and Aerospace from eminent scientists of ISRO, NAL and DRDO taking advantage from the department strong network

Program Outcomes (Pos)

PO1 – Engineering Knowledge: Apply knowledge of mathematics and science, with fundamentals of Aeronautical Engineering to be able to solve complex engineering problems related to Aeronautical Engineering.

PO2 – Problem Analysis: Identify, Formulate, review research literature and analyse complex engineering problems related to Aeronautical Engineering and reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.

PO3 – Design/Development of solutions: Design solutions for complex aircraft problems related to Aeronautical Engineering and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety and the cultural societal and environmental considerations

PO4 – Conduct Investigations of Complex problems: Use research–based knowledge and research methods including design of aircraft structure experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5 – Modern Tool Usage: Create, Select and apply appropriate techniques, resources and modern engineering and IT tools including prediction and modeling to Aeronautical Engineering related complex engineering activities with an understanding of the limitations.

PO6 – The Engineer and Society: Apply Reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the Aeronautical professional engineering practice.

PO7 – Environment and Sustainability: Understand the impact of the Aeronautical professional engineering solutions in societal and environmental contexts and demonstrate the knowledge of, and need for sustainable development

PO8 – Ethics: Apply Ethical Principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9 – Individual and Team Work: Function effectively as an individual and as a member or leader in diverse teams and in multidisciplinary Settings.

PO10 – Communication: Communicate effectively on complex engineering activities with the engineering community and with High society and with write effective reports and design documentation, make effective presentations and give and receive clear instructions.

PO11 – Project Management and Finance: Demonstrate knowledge and understanding of the engineering management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multi-disciplinary environments.

PO12 – Life-Long Learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning the broadest content of technological change.

AIRCRAFT MATERIAL TESTING & PROCESSING LAB		Semester	4
Course Code	**BAEL404**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	0:0:2	SEE Marks	50
Credits	01	Exam Hours	100
Examination type (SEE)	Practical		

Course objectives:

1. Understand the formation, properties and significance of the alloys through different experiments.
2. Understand the types, advantages and applications of various NDT methods.
3. Prepare physical models using different manufacturing processes.

List of Experiments:

1. Tensile, shear and compression tests of metallic and non-metallic specimens using Universal Testing Machine.
2. Izod and Charpy Tests on M.S, C.I Specimen.
3. Brinell, Rockwell and Vickers's Hardness test.
4. Torsion Testing
5. Dye penetration testing. To study the defects of Cast and Welded specimens
6. Machining by plain turning, taper turning, step turning, eccentric turning & knurling
7. Machining by internal and external thread cutting
8. Machining by drilling and boring operation

Demonstration Experiments (For CIE)

1. Ultrasonic flaw detection
2. Heat treatment: Annealing, normalizing, hardening and tempering of steel.
3. Magnetic crack detection
4. Additive Manufacturing

Course outcomes (Course Skill Set):

At the end of the course the student will be able to:

CO1: Differentiate the formation, properties and significance of the alloys through different experiments.

CO2: Differentiate the types, advantages and applications of various NDT methods.

CO3: Demonstrate practical and working knowledge of Machine Tools and operations. Also, Demonstrate machining skills with appropriate selection of tools.

COs	POs and PSOs Mapping														
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	1	3	1	2	1	3	3	2	2	2	2	2
CO2	3	3	2	1	3	1	2	1	3	3	2	2	2	2	2
CO3	3	3	2	1	3	1	2	1	3	3	2	2	2	2	2

Assessment Details (both CIE and SEE):

- The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks).
- A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation (CIE):

- CIE marks for the practical course are50 Marks.
- The split-up of CIE marks for record/ journal and test are in the ratio 60:40.
- Each experiment is to be evaluated for conduction with an observation sheet and record write-up. Rubrics for the evaluation of the journal/write-up for hardware/software experiments are designed by the faculty who is handling the laboratory session and are made known to students at the beginning of the practical session.
- Record should contain all the specified experiments in the syllabus and each experiment write-up will be evaluated for 10 marks.
- Total marks scored by the students are scaled down to 30 marks (60% of maximum marks).
- Weightage to be given for neatness and submission of record/write-up on time.
- Department shall conduct a test of 100 marks after the completion of all the experiments listed in the syllabus.
- In a test, test write-up, conduction of experiment, acceptable result, and procedural knowledge will carry a weightage of 60% and the rest 40% for viva-voce.
- The suitable rubrics can be designed to evaluate each student’s performance and learning ability.

- The marks scored shall be scaled down to 20 marks (40% of the maximum marks). The Sum of scaled-down marks scored in the report write-up/journal and marks of a test is the total CIE marks scored by the student.

Semester End Evaluation (SEE):

- SEE marks for the practical course are 50 Marks.
- SEE shall be conducted jointly by the two examiners of the same institute; examiners are appointed by the Head of the Institute.
- The examination schedule and names of examiners are informed to the university before the conduction of the examination. These practical examinations are to be conducted between the schedule mentioned in the academic calendar of the University.
- All laboratory experiments are to be included for practical examination.
- (Rubrics) Breakup of marks and the instructions printed on the cover page of the answer script to be strictly adhered to by the examiners. OR based on the course requirement evaluation rubrics shall be decided jointly by examiners.
- Students can pick one question (experiment) from the questions lot prepared by the examiners jointly.
- Evaluation of test write-up/ conduction procedure and result/viva will be conducted jointly by examiners.
- General rubrics suggested for SEE are mentioned here, writeup-20%, Conduction procedure and result in -60%, Viva-voce 20% of maximum marks. SEE for practical shall be evaluated for 100 marks and scored marks shall be scaled down to 50 marks (however, based on course type, rubrics shall be decided by the examiners).
- Change of experiment is allowed only once and 15% of Marks allotted to the procedure part are to be made zero. The minimum duration of SEE is 02 hours.

DO’s

- Students must wear the prescribed uniform and shoes before entering the lab.
- Maintain proper conduct and adhere to ethical guidelines while in the lab.
- Keep windows and doors open to ensure adequate ventilation and air circulation.
- Record the specifications of the experimental setup before starting the experiment.
- Inspect electrical connections and report any discrepancies to the lecturer or lab instructor.
- Conduct experiments only under the supervision or guidance of a lecturer or lab instructor.
- Switch off electrical connections after completing and recording observations.
- In case of fire, use the fire extinguisher or sand provided in the lab.
- For physical injuries or emergencies, use the first aid box available.
- Report any unsafe conditions in the lab to the lab in charge.

DONT’s

- Do not operate any experimental setup at its maximum value.
- Do not touch or handle experimental setups or test rigs without prior authorization.
- Avoid overcrowding around the experimental setup or test rig; ensure there is enough space for the operator to work safely.
- Do not rest your hands on the equipment or display board, as it contains delicate measuring instruments such as thermometers and manometers.

MATERIAL TESTING:

INTRODUCTION:

Materials have played a crucial role in the advancement of human civilization, to the extent that historians have named entire eras after the predominant materials in use—such as the Stone Age and Bronze Age. This naming reflects the deep impact materials have had on shaping human progress and activities over thousands of years.

Since engineering materials form the backbone of technology, understanding how and why materials behave as they do is essential. This understanding is rooted in atomic-level knowledge, made possible by quantum mechanics, which began explaining the nature of atoms and solids in the 1930s. The interdisciplinary field that combines principles of physics and chemistry while focusing on the link between a material's properties and its internal structure is known as Materials Science. This field has not only enabled the design of new materials but has also provided the scientific foundation for engineering applications, often referred to as Materials Engineering.

Materials Science revolves around four key components: structure, properties, processing, and performance. These elements are closely interconnected, as illustrated schematically in Figure 1.

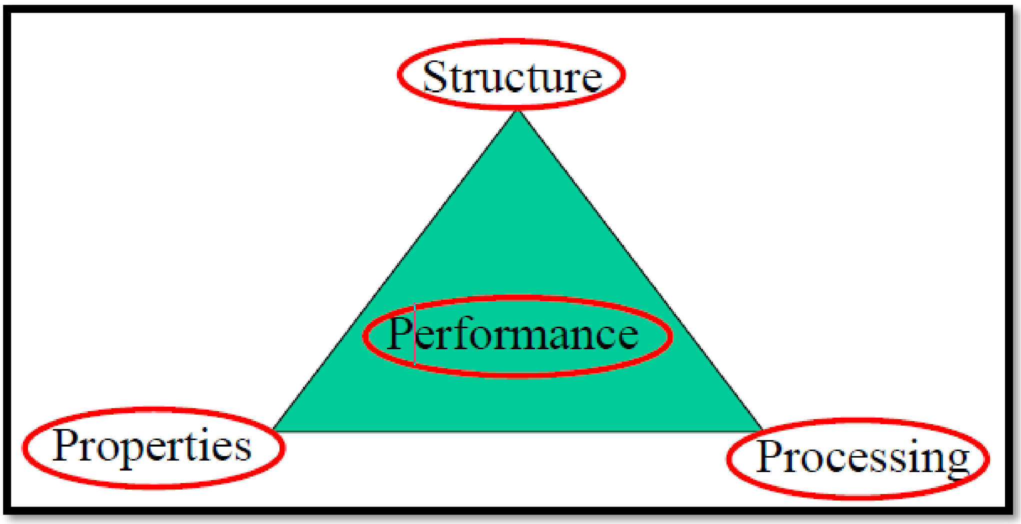


Figure 1: Interrelation between four components of Materials Science.

Why Study Materials Science and Engineering?

Studying Materials Science and Engineering is essential because materials form the foundation of all technological advancements. Every device, structure, or tool relies on specific materials to function effectively and efficiently. By understanding the relationship between a material's structure, properties, processing, and performance, engineers can innovate, improve existing technologies, and develop new ones. This field enables the creation of materials with tailored properties for specific applications—whether it's stronger construction materials, more efficient semiconductors, or biocompatible implants. As a result, Materials Science and Engineering is a critical discipline driving progress across industries including aerospace, electronics, energy, healthcare, and more.

Classification of Materials

Materials are generally classified into four main categories based on their properties and uses:

1. **Metals** – These are typically strong, ductile, and good conductors of heat and electricity. They are widely used in construction, transportation, and manufacturing.
2. **Ceramics** – Usually hard and brittle, ceramics are resistant to high temperatures and corrosion. They find applications in insulation, cutting tools, and medical devices.
3. **Polymers** – Lightweight and flexible, polymers are made of long molecular chains. They are used in packaging, textiles, electronics, and biomedical devices.
4. **Composites** – These are combinations of two or more materials designed to achieve properties superior to those of the individual components. Examples include fiberglass and carbon-fiber-reinforced plastics.

Additionally, a fifth emerging category includes **advanced materials**, such as nanomaterials, biomaterials, and smart materials, which are engineered for high-performance and specialized applications.

Mechanical Properties of Metals

Mechanical properties describe how a metal behaves when subjected to external forces or loads. These properties determine a material's ability to resist failure and deformation under such conditions. Understanding mechanical properties is essential in selecting suitable materials for various engineering and industrial applications.

Below are some key mechanical properties of metals:

1. Elasticity

Elasticity is the ability of a material to return to its original shape after the removal of an external force that caused deformation. This property is crucial for materials used in tools, machines, and structural components.

Examples: Steel and rubber. Although rubber deforms more, steel is considered more elastic because it returns to its original shape with less permanent deformation.

2. Plasticity

Plasticity is the property that allows a material to undergo permanent deformation without breaking when a force is applied. It is essentially the opposite of elasticity.

This property is important in processes like forging, stamping, and forming. Examples: Gold and lead are among the most plastic materials.

3. Stiffness

Stiffness is the ability of a material to resist deformation under stress. It is quantitatively measured by the modulus of elasticity (Young's modulus).

Stiff materials are used in machine parts, beams, columns, and tools where rigidity is essential.

4. Ductility

Ductility is the capacity of a material to be drawn out into thin wires under tensile stress. It's often measured by the percentage of elongation or reduction in cross-sectional area before fracture.

Ductility is higher in cold materials than in hot ones, which is why wire drawing is usually done at room temperature.

Order of ductility (high to low):

Gold > Platinum > Silver > Iron > Copper > Aluminum > Nickel > Zinc > Tin > Lead.

5. Malleability

Malleability is a specific form of plasticity that allows a material to be compressed, hammered, or rolled into thin sheets without breaking. It is essential in shaping processes like rolling, flattening, and hammering.

Malleability tends to increase with temperature.

Examples: Gold, silver, lead, tin, copper, soft steel, wrought iron, and aluminum.

6. Brittleness

Brittleness is the tendency of a material to fracture without significant deformation when subjected to stress. Brittle materials break suddenly and cleanly under tensile loads. Example: Cast iron.

- Materials with >15% elongation are considered ductile.
- <5% elongation indicates brittle behavior.
- Between 5%–15% is intermediate ductility. Brittleness is an important consideration in parts exposed to sudden or severe impacts.

7. Hardness

Hardness is the resistance of a material to wear, abrasion, scratching, indentation, and machining. It reflects the ability of one material to cut or scratch another and often decreases with increasing temperature.

Because hardness is a complex property, it is generally assessed by comparing with standard materials using tests like Brinell, Rockwell, or Vickers.

Example: Diamond is the hardest known material.

These mechanical properties guide engineers in selecting the appropriate metal for various applications based on the required strength, durability, formability, and resistance to environmental factors.

Toughness

Toughness is the ability of a material to absorb energy and resist fracture when subjected to sudden or high-impact loads, such as hammer blows. It indicates how much energy a material can absorb before it breaks. Toughness is measured by the amount of energy absorbed per unit volume up to the point of fracture. This property is essential for materials used in applications where shock and impact loading are common. Notably, the toughness of most materials decreases with an increase in temperature.

Creep

Creep is the tendency of a material to undergo slow, permanent deformation when subjected to constant stress over an extended period, especially at elevated temperatures. Although creep can occur at any temperature, it becomes significant at temperatures much higher than room temperature. This property is critical in the design of components like internal combustion engine parts, boilers, and turbines that operate under prolonged heat and stress.

Fatigue

Fatigue refers to the weakening or failure of a material caused by repeated or fluctuating loads over time. Unlike static loading, fatigue occurs when a material is subjected to cyclic stresses—such as alternating tensile and compressive forces. Even if these stresses are lower than the material's ultimate tensile strength, they can lead to the initiation and propagation of cracks, eventually causing failure. This phenomenon is especially important in designing machine components that endure variable or cyclic loading conditions.

Strength

Strength is the capacity of a material to withstand external forces or loads without failure or rupture. It reflects how much stress a material can resist before deforming or breaking.
Types of strength can be broadly classified as:

a) **Based on deformation behavior:**

- *Elastic strength* – resistance before permanent deformation begins.
- *Plastic strength* – resistance during permanent deformation.

b) **Based on type of applied stress:**

- *Tensile strength* – resistance to pulling forces.
- *Compressive strength* – resistance to pushing forces.
- *Shear strength* – resistance to sliding forces.
- *Bending strength* – resistance to bending forces.
- *Torsional strength* – resistance to twisting forces.

Resilience

Resilience is the property of a material that enables it to absorb energy when deformed elastically and to release that energy upon unloading. It reflects the ability to resist shock and impact loads without permanent deformation.

- **Proof Resilience** is the maximum energy stored in a material without causing permanent deformation, i.e., up to the elastic limit.
- **Modulus of Resilience** is the proof resilience per unit volume of the material and is a measure of energy absorption capacity under elastic conditions.

EXPERIMENT No: 1 Tensile, shear and compression tests of metallic and non-metallic specimens using Universal Testing Machine.

Aim: To study the **stress-strain behavior** of a **mild steel specimen** under gradually increasing tensile load and to determine the following mechanical properties:

- **Young's Modulus of Elasticity (E)**
- **Yield Stress**
- **Ultimate Tensile Strength (UTS)**
- **Percentage Elongation**
- **Percentage Reduction in Cross-sectional Area**

Theory:

The **tensile test** is a fundamental mechanical test where a material is subjected to uniaxial tension until failure. It provides important information about a material's strength and ductility.

When a mild steel specimen is subjected to a tensile force, it initially deforms **elastically**—meaning it returns to its original shape upon removal of the load. Beyond the **elastic limit**, the material deforms **plastically**, undergoing permanent deformation.

A **universal testing machine (UTM)** is typically used for this test. As the load increases:

- The **stress-strain curve** is plotted.
- The **slope of the linear portion** of the curve gives the **Young's modulus (E)**.
- The point at which the material yields is the **yield strength**.
- The maximum point on the curve indicates the **ultimate tensile strength**.
- After necking, the specimen fractures, allowing us to calculate **percentage elongation** and **percentage reduction in area**, which are indicators of **ductility**.

Apparatus Required:

- Universal Testing Machine (UTM)
- Mild Steel specimen (standard dimensions)
- Vernier caliper / Micrometer screw gauge
- Ruler or extensometer
- Graph sheet or digital software for plotting stress-strain curve

Procedure:

1. **Measure and record** the original dimensions of the specimen: gauge length and diameter/cross-sectional area.
2. **Fix the specimen** into the jaws of the Universal Testing Machine.
3. **Attach the extensometer** across the gauge length to record elongation during the test.
4. **Apply the tensile load gradually** by starting the UTM. Monitor the load and elongation.
5. Record the **load and corresponding elongation** at regular intervals.

6. Note the following key points from the test:
    - **Proportional limit** (end of linear region)
    - **Elastic limit**
    - **Yield point** (where permanent deformation begins)
    - **Ultimate tensile strength** (maximum load before necking)
    - **Breaking point**
7. After fracture, remove the two pieces of the specimen.
8. **Measure the final gauge length** and **diameter at the neck** (minimum diameter after fracture).
9. **Plot the stress-strain curve** and calculate:
    - **Young's modulus (E)** = Stress / Strain (in the linear region)
    - **Yield stress** = Load at yield point / Original area
    - **Ultimate Tensile strength** = Maximum load / Original area
    - **% Elongation** = ((Final length - Original length) / Original length) × 100
    - **% Reduction in Area** = ((Original area - Neck area) / Original area) × 100

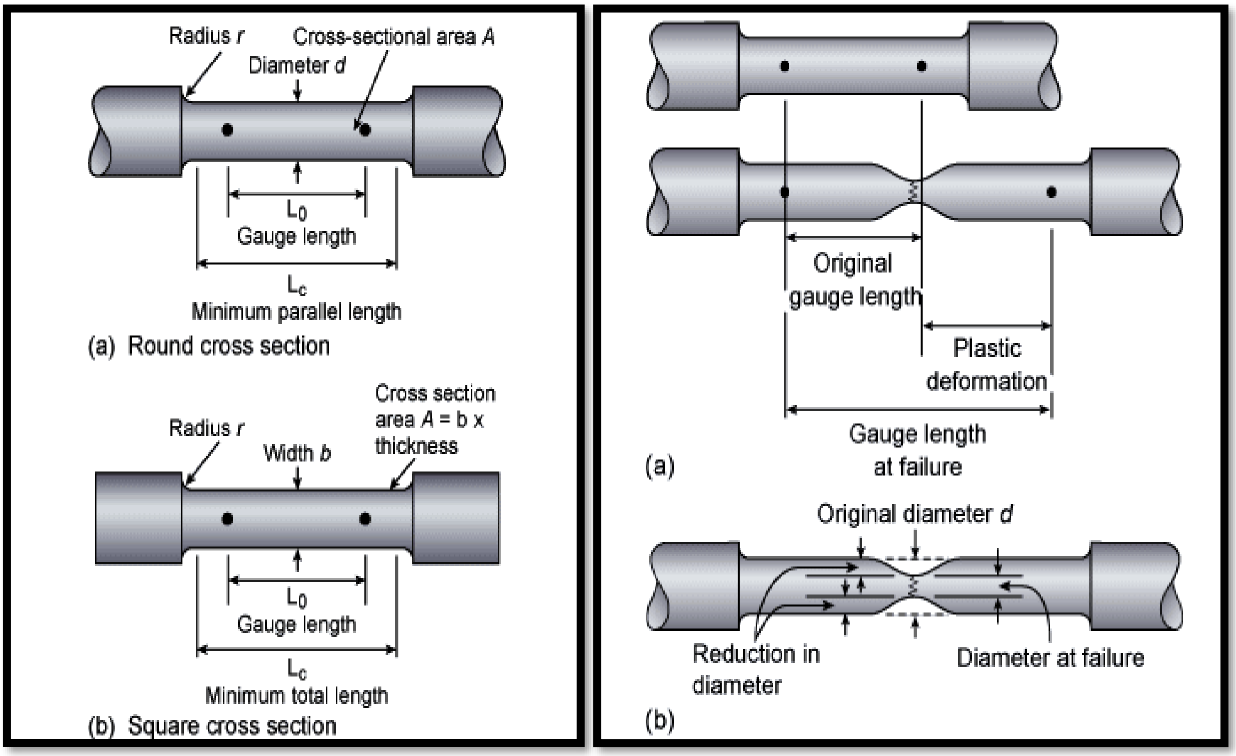


Figure 2: Specimen standard for tensile test indicating the gauge length

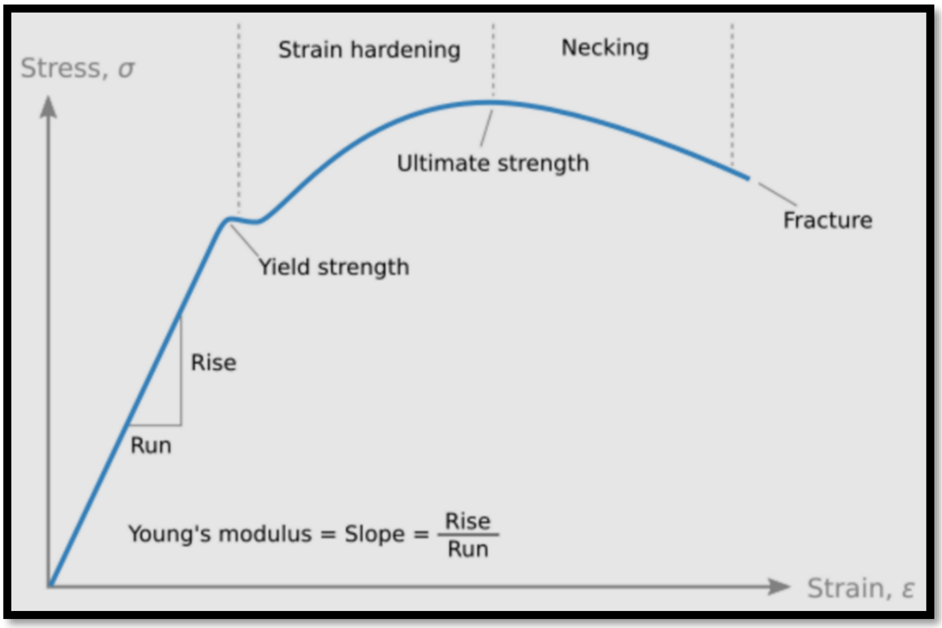


Figure 3: Stress-Strain Curve

Observation and tabulation:

Material:

Initial gauge length L_o (mm) =

Initial diameter d_o (mm) =

Original area A_o (mm^2) = $(\pi\ d_o^2)/4$

Load at Yield point F_y (N) =

Maximum load F_{max} (N) =

Load at fracture F_b (N) =

Final gauge length L_f, (mm) =

Final diameter d_f (mm) =

Final area A_f (mm^2) = $(\pi d_f^2)/4$

Yield stress, σ_y (N/mm^2) = F_y / A_o =

Ultimate Tensile strength σu (N/mm^2) = F_{max} / A_o =

Slope of straight-line portion of the graph E (N/mm^2) =

Breaking stress σb (N/mm^2) = F_b / A_o =

% Elongation D_e = $(L_f - L_o) / L_o$ X 100 =

% Reduction in area D_a = $(A_f - A_o) / A_o$ X 100 =

The stress-strain behavior of the mild steel specimen was studied and the following properties were determined:

- Young's Modulus = ______ N/mm^2
- Yield Stress = ______ N/mm^2

- UTS = ______ N/mm²
- % Elongation = ______ %
- % Reduction in Area = ______ %

Result:

Compression Test

Aim: To study the behavior of the given materials under compressive loading and to determine the following properties.

1. Proportional limit,
2. Modulus of elasticity
3. Compressive strength
4. Percentage contraction
5. Percentage increase in area

Test Set Up:

Universal Testing Machine (UTM) Dial gauge to measure the axial compression of the specimen. Slide callipers / Micrometer, Scale.

Theory:

In a compression test, a material specimen is subjected to end loading that produces a crushing action, causing the specimen to shorten. For ductile materials, compressive mechanical properties in the plastic range are difficult to determine because ultimate and breaking loads are not clearly defined. However, elastic properties such as strength, stiffness, and resilience can still be measured, similar to a tension test. The modulus of elasticity and yield strength for many metals and alloys are nearly the same in both tension and compression.

Obtaining an accurate stress-strain diagram in compression is more challenging than in tension due to several factors:

1. Misalignment during loading, which becomes more pronounced at higher loads, causing lateral deflection and bending stresses.
2. Lateral restraining forces introduced by friction between the specimen ends and the bearing plates.
3. The potential for lateral buckling if the specimen is too long.

The engineering stress-strain curves for both brittle and ductile materials under compression are shown in Figure.

Specimen:

For uniform stress distribution during compression testing, a circular cross-section is generally preferred over other shapes. To minimize the risk of failure due to bending, a common length-to-diameter ratio of 2 is used. However, the height-to-diameter ratio may vary depending on the type of material being tested.

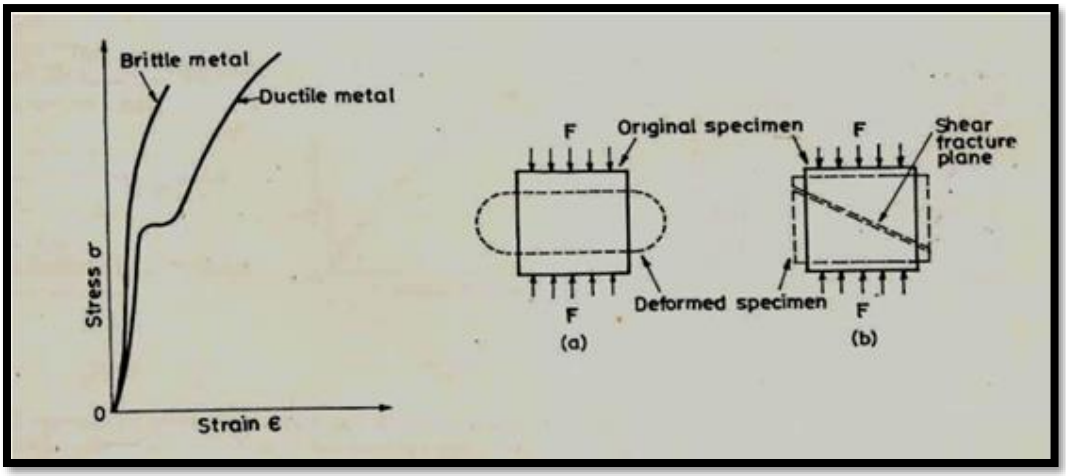


Figure 4: Stress-Strain Curve

Procedure:

1. Measure and record the original dimensions of the specimen.
2. Place the specimen between the fixed and movable jaws of the Universal Testing Machine (UTM).
3. Set the machine's load range to its maximum capacity.
4. Attach the dial gauge at the appropriate positions on the machine.
5. Switch on the machine and apply the compressive load gradually.
6. For every 0.5 kN increment in load, record the corresponding dial gauge readings and tabulate them.
7. Continue loading until the specimen either flattens (for ductile materials) or fractures (for brittle materials).
8. Remove the specimen and record its final dimensions.

Observation and tabulation:

Load [kN]	Deformation in mm

Calculation:

Specimen prepared as per IS standards

Material:

1) Initial length: $L_1 =$ mm

2) Initial diameter: $D_o =$ mm

3) Original C/IS Area: $A_I = (\pi D_o^2/ 4) =$ mm2

4) Maximum load: $P_{max} =$ KN

5) Final length: $L_F =$ mm

6) Final diameter: $D_F =$ mm

7) Final Area: $A_F = (\pi D_F /4) =$ mm^2

8) Percentage decrease in Length: $[(L_I - L_F / L_I] =$ %

9) Percentage increase in area: $[(AF - A_I)/ A_I] =$ %

10) Compressive strength = $(P_{max} / A_I) =$ kN/mm^2

Result:

1. Ultimate Compressive Strength= KN/mm^2
2. % Reduction in length= %
3. % increase in Area= %

SHEAR TEST:

AIM: To determine the ultimate shear strength in single shear for ductile material

EQUIPMENTS REQUIRED: -

1. Universal testing machine
2. Shear shackles for single shear
3. Slide calipers and screw gauge
4. Single shear specimen of mild steel of height 25 mm.

THEORY:

A shearing stress acts parallel to a plane, whereas tensile and compressive stresses act normal to a plane. There are two main types of shear stresses used in laboratories. One is called direct or transverse shear stress and corresponds to the type of stress encountered in rivets, bolts and beams. The other type of shear stress is called pure or torsional shear and represents the kind of shear stress encountered in a shaft subjected to pure torsion. Direct Shear tests are usually employed to obtain a measure of shear strength and torsion test are usually employed to evaluate the basic shear properties of the material.

PROCEDURE: -

1. The diameter of the specimen is measured using slide calipers or screw gauge; the area of the specimen is calculated.
2. The specimen as shown in Figure 4 is then inserted inside the shear shackle and the specimen with the shackles is placed inside the shear center plate.
3. The entire assembly is then placed on the lower cross head of the universal listing machine as shown in figure 4.
4. The adjustable or intermediate cross head is they moved down till it makes control with the top of the center plate. Note that the load is applied on the specimen through the center plate
5. Load the specimen at steps of 25 kg
6. The load of which the specimen in the single shear test
7. The experimental loading and the finally calcite the ultimate shear strength in N/mm2

Figure 4: specimen for shear test

FOR SINGLE SHEAR:

Material	Diameter of the specimen d in mm	Fracture load F in		Area $A = \frac{\pi d^2}{4} (mm^2)$	Ultimate shear strength F/A in N/mm2
		Kg	N		

Shear Stress = Failure load / Area of C/s of specimen N/mm^2

RESULT: - Ultimate shear strength __________

EXPERIMENT No: 2 Izod and Charpy Tests on M.S, C.I Specimen

IMPACT TESTING MACHINE

Impact test is done in a single blow pendulum impact machine. It consists of (a) moving mass whose kinetic energy is great enough to cause rupture on the test specimen, (b) An anvil with support on which the specimen is placed to receive the blow, (c) A dial with pointer for measuring the absorbed energy of moving mass after the specimen has been broken. The dial has two scales marked on it. One for Charpy and other for Izod. A sketch of the setup is shown in Figure 5.

Figure 5: Impact Testing Setup

Charpy Impact Test:

Aim:

To perform the Charpy impact test on a standard steel specimen in order to determine:

1. The energy absorbed during fracture
2. The impact strength of the specimen with a U-notch

Apparatus: Pendulum impact machine, specimens with V –groove, centerpiece, Allan key.

Theory:

The impact test is used to evaluate a material’s ability to withstand shock or sudden loading. Specifically, the notched-bar impact test is employed to determine a material's tendency to exhibit brittle behavior. This test can reveal differences between materials that may not be apparent in a standard tensile test.

The impact test is typically conducted using a pendulum-type machine. The main components of such a machine include:

1. A moving mass (pendulum) with sufficient kinetic energy to fracture the specimen,

2. An anvil and support system to securely hold the specimen in place during impact, and
3. A mechanism to measure the remaining energy of the pendulum after the specimen breaks.

During the test, the specimen is placed horizontally on the anvil, and the pendulum (with weight **W**) is raised to an initial height **a** (point A). At this position, the pendulum has potential energy equal to **Wa**. When released, this potential energy is converted into kinetic energy as the pendulum swings down. Just before impact (point B), all the potential energy is transformed into kinetic energy.

At the moment of impact, a portion of the pendulum's energy is used to fracture the specimen. The remaining energy allows the pendulum to continue its swing, eventually reaching a height **b** (point C), where the energy is again entirely potential, equal to **Wb**.

Assuming negligible energy losses due to air resistance and bearing friction, the energy absorbed by the specimen during fracture, denoted by **U**, is calculated as:

$$U = W (a - b)$$

This value is referred to as the *fracture energy* or *impact toughness*. On most impact testing machines, it is indicated directly by a pointer on a calibrated scale.

Charpy and Izod Impact Tests:

Two standardized specimen types are used for notched impact testing: the **Charpy** and **Izod** specimens. The main difference between the two lies in the method of loading, as illustrated in Figure 6.

While the Izod test has traditionally been the standard method for evaluating the brittleness of metallic materials, the Charpy test is more suitable for conducting impact tests at elevated or sub-zero temperatures. This is because the Charpy specimen does not require clamping and can be quickly positioned, minimizing any change in temperature during the setup.

The notched-bar impact test is especially useful when performed across a range of temperatures, allowing for the identification of the **ductile-to-brittle transition temperature**—the point at which a material changes from ductile to brittle behavior.

For materials that absorb less than 100 J of energy during fracture, the values obtained from Charpy and Izod tests are generally comparable. However, for materials absorbing more than 100 J, Charpy test results tend to be higher than those from the Izod test.

The primary purpose of the impact test is **not** to compare different materials, but rather to evaluate the effect of various treatments (e.g., heat treatment) on the same material. It's important to note that the fracture energy obtained from these tests is **relative** and should not be used directly in design calculations.

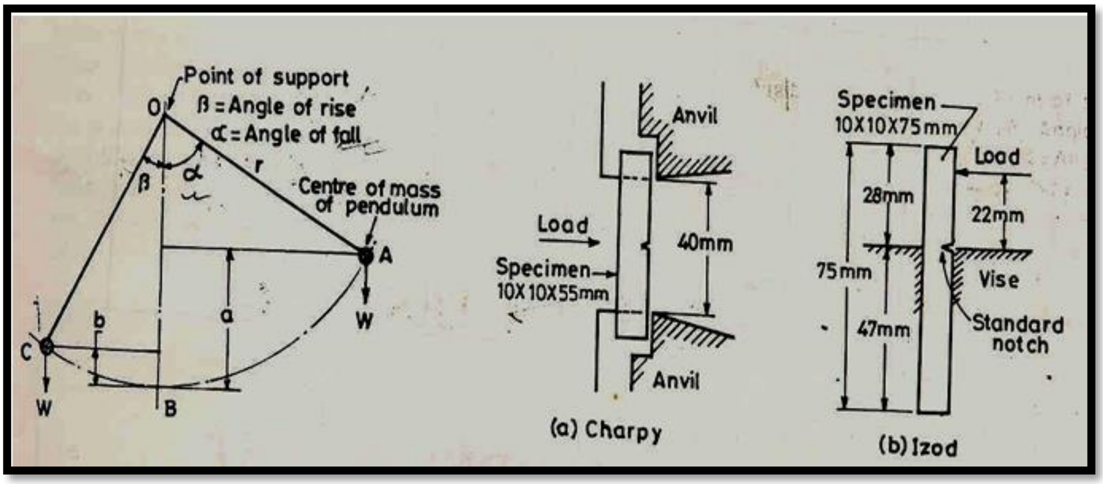


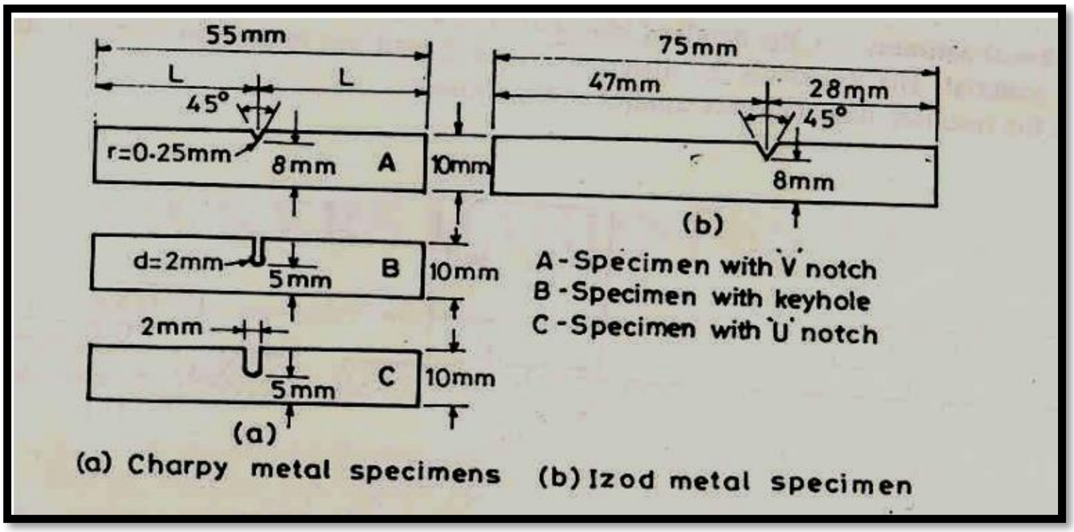
Figure 6: Charpy and Izod specimen - method of loading

Specimens:

The standard specimen for the **Charpy impact test** is a square prism with a notch, as illustrated in Figure 7. During the test, the specimen is positioned horizontally like a simple beam, with the notch placed on the tension side (as shown in Figure 7a).

For the **Izod impact test**, the specimen can be either prismatic or cylindrical and is also notched as shown in Figure 7. In this case, the specimen is clamped vertically to act as a cantilever, with the notch again located on the tension side (as shown in Figure 7b).

The notch plays a critical role in both tests—it increases the severity of the test by creating a point of **stress concentration**, ensuring that fracture occurs at a predictable location. This setup helps in consistently evaluating the material's toughness under impact loading.



Procedure:

1. Take a standard Charpy/Izod test specimen of given length and 10 mm × 10 mm square cross-section, with a central V/U-notch (2 mm deep, 45° angle for Charpy).
2. Place the specimen horizontally in the Charpy impact testing machine, resting it as a simply supported beam with the notch on the tension side as shown in figure 6a. (facing away from

the impact) & for Izod test, the specimen notch should be facing the strike edge as shown in figure 6b.

3. Raise the pendulum hammer to a specific height to attain an initial potential energy.
4. Release the hammer gently, allowing it to strike the specimen without applying any additional force.
5. Observe and record the energy absorbed by the specimen during fracture, as indicated by the pointer on the scale.

Observation Table: [Charpy Impact Test]

S. No.	Material Type	Specimen dimensions	Energy Absorbed k (J)	Impact strength I (J/mm^2)

Observation Table: [Izod Impact Test]

S. No.	Material Type	Specimen dimensions	Energy Absorbed K (J)	Impact strength I (J/mm^2)

Calculations:

1. Area of c/s of the specimen below the notch, a = bxd mm^2

Width of the specimen, b & Depth of. The specimen below the Notch, d

2. Energy absorbed by the specimen for failure, K = Joules

3. Impact strength, I =K/a = $Joules/mm^2$

EXPERIMENT No: 3 Rockwell, Brinell and Vickers's Hardness test.

Rockwell Hardness Test

Aim: To determine the Rockwell Hardness Number (RHN) of various materials. [on B and C scales]

Apparatus: Rockwell Hardness Testing Machine, Ball Indenter, Diamond Cone Indenter, Test Specimens of Different Materials.

Test Setup:

Figure 7: Rockwell Hardness Tester

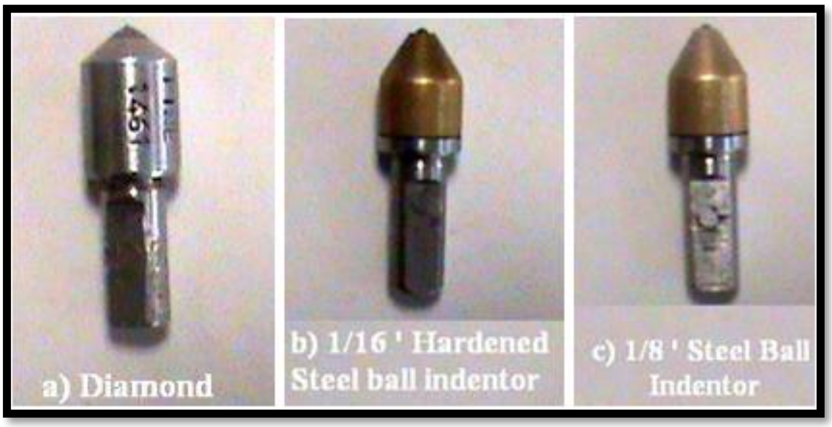


Figure 8: Indentor used namely mild steel, Brass, Aluminum as shown in Figure a, b & c

Theory: The Rockwell Hardness Number (RHN) is determined based on the depth of indentation made on a test specimen by an indenter under a specified static load as shown in figure 7. The combination of different loads and indenters varies depending on the material and the Rockwell scale being used. The test begins by applying a **minor load of 10 kg**, which creates an initial indentation depth, denoted as **‘d_1’**. This minor load helps to seat the indenter properly and compensates for any surface irregularities of the material. While maintaining the minor load, a **major load** is then applied according to the selected Rockwell scale. This additional load increases the depth of indentation, resulting in a total penetration depth, denoted as **‘d_2’**.

The Rockwell Hardness Number is calculated based on the difference between these two depths. Specific formulas are used for different scales (such as B and C), taking into account the type of indenter and the magnitude of the applied load.

Principle:

Hardness, in the context of metals, is commonly evaluated based on their resistance to indentation. The greater the resistance a metal offers to indentation, the harder the material is considered to be. Therefore, harder metals produce smaller indentations, while softer metals result in larger ones. This means that the depth of penetration is inversely proportional to the hardness of the material. The instrument used to perform this type of hardness evaluation is called the Rockwell Hardness Testing Machine.

Indentors and Scales:

The Rockwell Hardness Test utilizes different types of indenters and loads depending on the material being tested and the scale selected.

- For softer materials, a **1/16-inch hardened steel ball** as shown in figure 8 is used as the indenter. In this case, **a major load of 100 kgf** is applied, and the hardness is measured on the **B-scale**, which ranges from 0 to 100.
- For harder materials, a **diamond cone indenter** as shown in figure 8 is used. This indenter has a **120° conical shape with a spherical tip of 0.2 mm diameter**. The major load applied in this case is **150 kgf**, and the hardness value is recorded on the **C-scale**.

These scales and indentors ensure accurate and consistent hardness measurements across a wide range of materials.

The "B" scale is suitable to test plane carbon steels, copper, brass & bronze etc.

Scale	Indenter used	Total Load (Kgf)	Material Used
B (Red)	1/16″ Steel Ball	100	All Non-ferrous metals and ferrous metals within 100 HRB
C (Black)	120° Diamond Cone	150	All hardened and Tempered steel and material Harder than 100 HRB

Diamond cone penetrator is used to test heat treated high carbon steels, high speed steels & other alloys of steel.

Observation & Tabular Column

Sl. No	Material	Scale and Indenter used	Total Load in Kgf	RHN			Rockwell Hardness Number (RHN) AVG
				Tr-1	Tr-2	Tr-3	
1	Mild Steel	‘B’ and 1/16″ Steel Ball	100				
2	Brass	‘B’ and 1/16″ Steel Ball	100				
3	Copper	‘B’ and 1/16″ Steel Ball	100				
4	Aluminum	‘B’ and 1/16″ Steel Ball	100				

Procedure:

- Smoothen the surface of the test specimen and ensure it is clean and free from any dirt, oil, or debris.
- Attach the appropriate indenter (either steel ball or diamond cone) to the thrust member of the Rockwell hardness testing machine.
- Based on the type of indenter and the material of the specimen, **select the required load stage** and ensure the **load lever is set to position “A”.**
- Place the specimen on the test table and slowly turn the main handwheel clockwise to bring the specimen into contact with the indenter. Continue turning until the small pointer on the dial gauge reaches the red spot and the long pointer aligns with the “0” mark. This indicates that the minor load of 10 kg has been applied.
- Move the **load lever from position “A” to position “B”** to apply the major load to the specimen.
- Wait for the **long needle on the dial gauge** to settle at a steady position.
- Slowly return the **load lever from position “B” back to position “A”** to release the major load.
- **Record the reading** indicated by the long pointer on the dial:
    - Use the **red scale** for **Rockwell B test**
    - Use the **black scale** for **Rockwell C test**
- Turn the handwheel counter-clockwise to lower the table and remove the specimen.

Note:

a) Each division on the Rockwell B or C scale corresponds to an indentation depth of **2 microns.**

b) Rockwell hardness values are represented as HR followed by the numerical value and the scale letter.

- Example: **60 HRC** indicates a Rockwell hardness of 60 on the **C scale.**

Result:

Vickers Hardness Test

Aim: To determine the Vickers Hardness Number (V.H.N.) of the given specimen.

Apparatus: Vickers Hardness Testing Machine, Diamond Pyramid Indenter.

Test Set Up:

- Brinell Hardness Testing machine.
- Indenters. Steel ball indenters of diameters 5 mm and 2.5 mm.
- Test specimens of different materials: Mild steel, Cast iron, Brass, Gun metal and Aluminum. Travelling microscope.

Theory:

The Vickers hardness test as shown in figure 9, is similar in principle to the Brinell hardness test, but it uses a different type of indenter. In the Vickers test, the indenter is a square-based diamond pyramid with an apex angle of 136° between opposite faces. The applied load typically ranges from 5 kg to 50 kg, depending on the thickness and nature of the specimen being tested. The small and precise indentation produced by the pyramid-shaped indenter allows for accurate hardness measurements, even on very thin materials or surface-hardened layers.

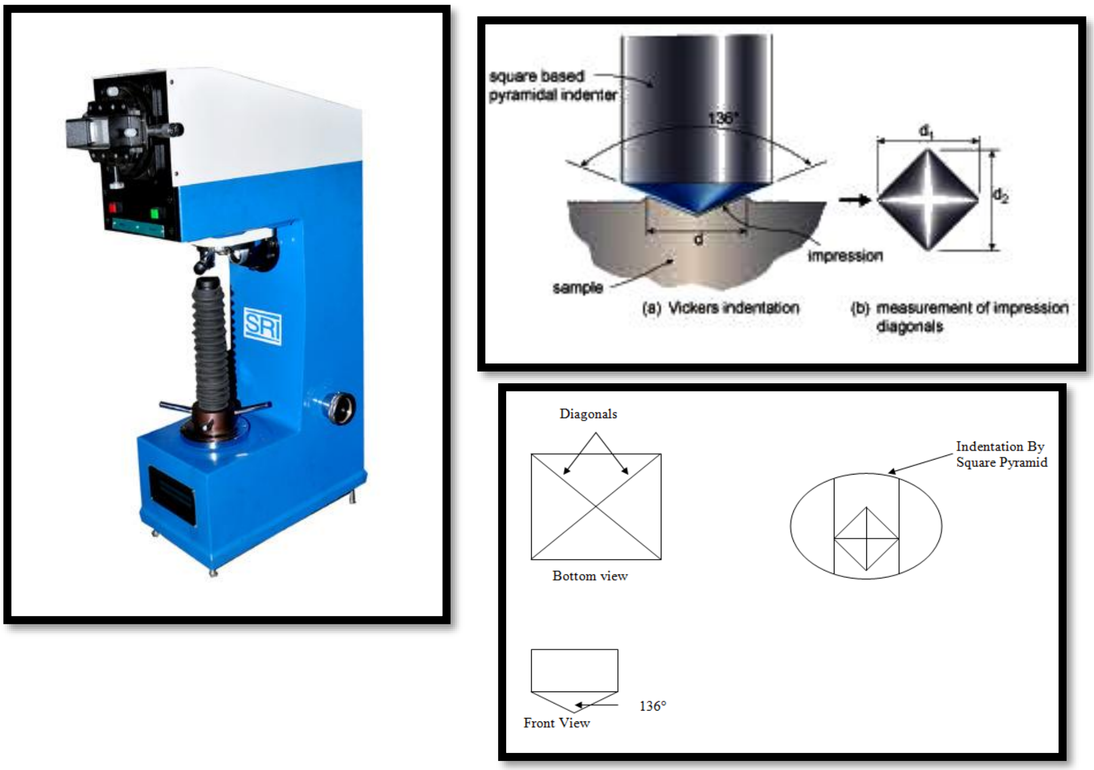


Figure 9: Vickers Hardness Tester

Procedure:

1. Clean the surface of the specimen thoroughly to remove any oil, dust, or debris.
2. Place the specimen securely on the testing table and attach the appropriate diamond pyramid indenter.

3. Adjust the optical system using the focus knob to clearly view the specimen on the screen.
4. Rotate the indexing disc to position the indenter directly above the area of the specimen to be tested.
5. Press and hold the 'START' button until the 'Dwell' light illuminates, indicating that the specified load is being applied to the specimen through the indenter.
6. Wait briefly; the machine will automatically release the load after the dwell time has elapsed.
7. Rotate the indenter head to bring the optical objective into position directly over the indentation.
8. View the indentation on the front focusing screen and measure the lengths of both diagonals of the impression.
9. Use the measured diagonal lengths to calculate the Vickers Hardness Number (V.H.N.) using the standard formula.

Observation

Sl No	Material	Load in Kgf	Length of diagonal (mm)		Mean d= $(d_1+d_2)/2$ (mm)	Vickers Hardness Number (VHN) (kgf/mm2)
			d_1	d_2		
1	Mild Steel	30				
2	Brass	20				
3	Copper	20				
4	Aluminum	10				

VHN = $\frac{2P\sin\frac{\theta}{2}}{d^2}$ where $\theta=136^0$

VHN= 1.854 P/d^2.

Where, P= load in kgf

d= Diagonal length in mm.

Result:

Brinell Hardness Test

Aim: To determine the hardness number for a given metallic specimen by Brinell Test (HB).

Apparatus: Test specimens of different materials: Mild steel, Cast iron, Brass, Gun metal and Aluminum. Indenters. Steel ball indenters of diameters 5 mm and 2.5 mm, Brinell hardness tester, and micrometer microscope.

Theory:

Hardness is typically defined as a material’s resistance to permanent indentation. Hardness testing involves evaluating how well a metal resists plastic deformation near its surface. During a hardness test, a special indenter—such as a steel ball—is pressed into the metal. Initially, the indenter must overcome the metal’s resistance to elastic deformation, followed by a small amount of plastic deformation. As the indentation deepens, greater plastic deformation occurs. Because of this, hardness tests assess material properties similar to those measured in other mechanical tests, allowing for a correlation between hardness and the ultimate tensile strength in ductile metals.

The Brinell hardness test is one of the oldest and most commonly used methods. It is a static indentation test that employs relatively large indenters. A typical Brinell testing machine is hydraulically operated as shown in figure 10. The test specimen is placed on a hardened steel anvil, which is adjusted vertically using a screw mechanism controlled by a hand wheel. The steel ball indenter is brought into contact with the specimen by turning this hand wheel. A hydraulic system then pumps oil into the main cylinder, pushing the piston downward and pressing the ball into the specimen. When the desired load is reached, a counterweight on top of the machine is lifted by a small piston to prevent any overload on the indenter. After the load is applied for a specific duration, it is removed, and the diameter of the resulting indentation is measured using a micrometer microscope. The Brinell Hardness Number (BHN) is calculated by dividing the applied load (in kilograms) by the surface area of the indentation (in square millimetres).

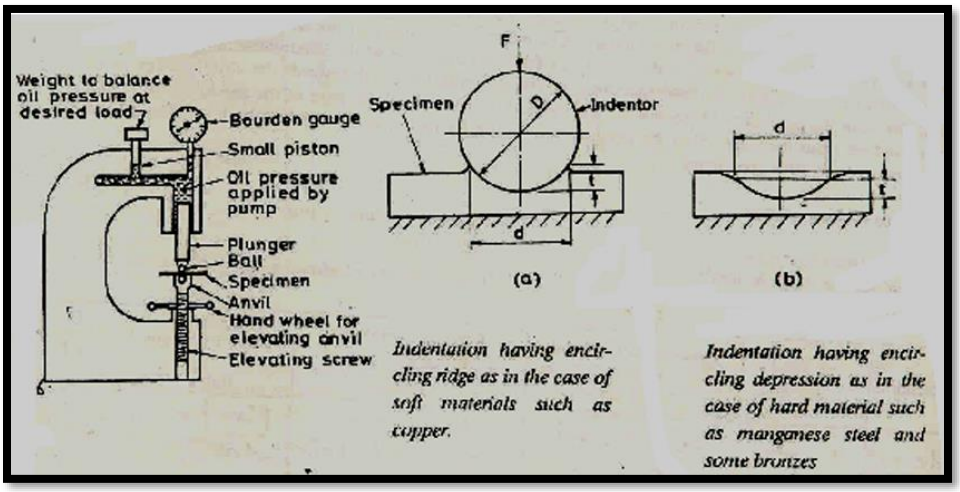


Figure 10: Brinell Hardness Tester

Specimens:

Careful selection of specimens is essential to obtain accurate and reliable results in Brinell hardness testing. This method is not suitable for extremely hard materials, as the steel ball indenter may deform under the high resistance. Similarly, it is not appropriate for testing thin specimens, since the indentation depth may exceed the material's thickness.

Brinell testing is also unsuitable for case-hardened surfaces; the indentation may penetrate beyond the hardened layer into the softer core, causing inaccurate results due to the core's yielding. Additionally, the specimen surface should be flat and reasonably well-polished to ensure precise measurement and consistent indentation.

Procedure:

1. **Clean the Specimen:** Ensure the surface to be tested is free from dirt, oil, and debris.
2. **Prepare the Surface:** Polish the test area using an emery sheet. The top and bottom surfaces of the specimen should be flat and parallel.
3. **Install the Indenter:** Attach the appropriate ball indenter and its holder to the thrust member (penetrator).
4. **Set the Load:** Based on the material and indenter size, arrange the required load on the weight shaft. The base system provides 500 kg; additional 250 kg weights can be added as needed.
5. **Power On:** Turn on the toggle switch to activate the machine.
6. **Activate Hydraulic System:** Press the green button on the side of the machine to start the hydraulic loading system.
7. **Switch On Lighting:** Turn on the indicator lamp for visibility.
8. **Position the Specimen:** Place the standard specimen on the test table. Rotate the main nut (hand wheel) clockwise until the specimen’s surface appears sharply on the measuring device’s focusing screen.
9. **Apply Load:** Move the load lever to the “Load” position to apply the test force.
10. **Wait for Indicator:** When the red indicator near the optical device lights up, the load has been properly applied.
11. **Release Load:** Move the load lever to the “Unload” position. At this point, the objective lens (14x magnification) automatically shifts above the indentation, and a clear image appears on the screen.
12. **Measure Indentation:** Use the micrometer scale on the screen to measure the diameter of the indentation accurately.

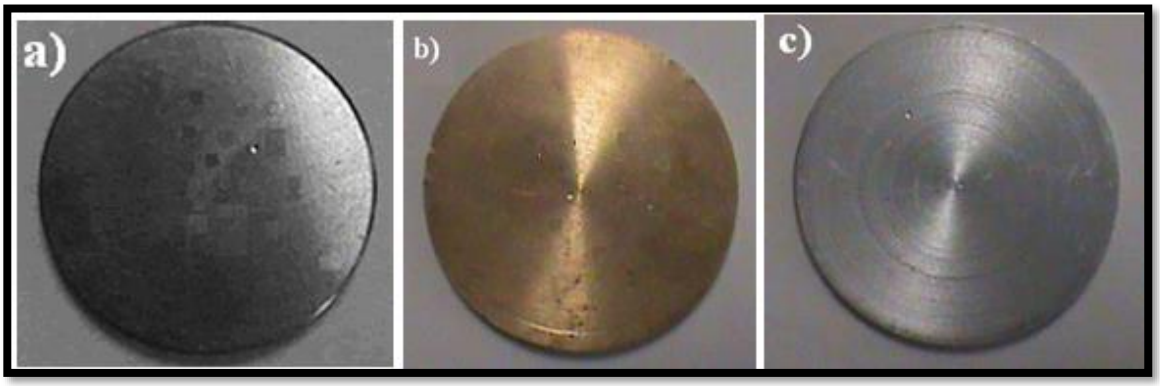


Figure 11: a) Mild Steel b) Brass c) Aluminum

There are three materials used namely mild steel, Brass, Aluminum as shown in Figure 10 a, b & c respectively.

Observations and tabulation:

Material	Thickness of specimen h (mm)	Ball diameter D (mm)	Load F (Kgf)	Time of load application T (sec)	Diameter of indentation d (mm)	HB

<u>Calculation</u>:

BHN or $\boxed{HB = \frac{2P}{\pi D\ (D-\sqrt{D^2-d^2}}}$ Kgf/mm^2

P=Test load in Kgf;

D= Diameter of ball in mm; (D=10mm for all materials);

d= Diameter of indentation in mm

Result:

EXPERIMENT No: 4 Torsion Testing

Aim: To determine the Behavior of ductile steel when subjected to torsion and obtain the following torsional properties:

a. Modulus of rigidity
b. Elastic shear strength
c. Resilience
d. Ultimate shear strength
e. Toughness
f. Ductility

APPARATUS: Torsion testing machine, graduated scale, test specimen, vernier caliper.

Theory: They are carried out on specially designed torsion tasting machines as shown in Figure 11, to determine modulus of elasticity in shear, yield strength and modulus of rupture. Torsion testing machine consists of a rigid frame with two clutches for gripping the ends of the specimen and weighing head, which grips the other end of the specimen. The clutches must be perfectly aligned to prevent bending. The load is applied by rotating one chuck about the axis while the other measures the amount of twisting moment or torque being applied on the test specimen. The chuck is rotated either by motor or by hand crank through a system of gears. A twist-measuring device called TROPTOMETER measures the deformation of the test specimen. Thin-walled tubular specimens are used in torsion test both in elastic and in-elastic range to minimize variation of stress. Further longer specimens are preferred to enable measuring of the angle of twist accurately. Material is homogenous, isotropic and elastic and also it is assumed that the plane sections before torsion remain plane after torsion.

$$\boxed{\text{Torsion Equation, } \frac{M_t}{J} = \frac{G\theta}{L} = \frac{\tau}{r}}$$

Where,

M_t = Applied torque in N –m
J = Polar moment of Inertia = ∏d4/ 32 cm4
G = Modulus of rigidity = N/ m2
θ = Angle of twist in radians
L = Gauge length of specimen in mm
r = Radius of the specimen in mm

PROCEDURE:

1. Place the specimen as shown in Figure 12, inside the shackles of the torsion-testing machine. One end is rigidly fixed.

2. The indicator of the torque scale and the indicator of graduated wheel is kept on the initial reading zero.
3. Now the handle is slowly turned so that the graduated wheel moves. Record the torque on the torque scale for every 10 deg up to 100 deg and for 20 deg beyond 100 deg. The Expt is continued till the specimen fractures.
4. The values are recorded in tabular form.
5. Draw a graph of torque on y – axis and angle of twist θ (in rad) on x-axis.

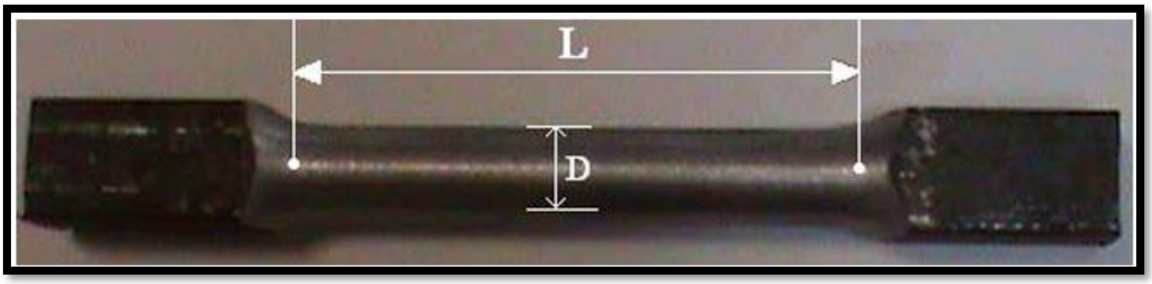


Figure 12: Torsion Test specimen

TABULAR COLUMN:

Angle of Twist $\theta°$	Torque M_t in		Shear Stress $\tau=(M_t d)/(2J)$	Shear Strain $\Phi=(d\theta/2L) \times (\Pi/180)$	Modulus of Rigidity $G=\tau/\Phi$
	Kg-m	N-m			

OBSERVATIONS:

Diameter of specimen d in mm =

Gauge Length of the specimen L in mm =

Yield Torque M_{ty} in N– mm =

Maximum Torque M_{tu} in N– mm =

Angle of Twist at fracture $\theta_f°$ =

Area of the specimen $A = d^2 \pi /4$ in mm^2 =

Polar Moment of Inertia $J = d^4 \pi /32$in mm^4 =

Yield Shear Strength $\tau_y=(M_{ty}\, d)/(2J)$ in N/mm2 =

Final fiber length $L_f = \sqrt{L^2 + (r\theta_f)^2}$ in mm =

Ductility $D = \frac{L_f - L}{L} \times 100$ =

Modulus of resilience U = $\tau_y^2/4G$ in N – mm/mm^3 =

Plastic Shear Strength τ_u= (M_{tu} d)/(2J) in N/mm^2 =

Modulus of toughness $T_0 = \frac{M_{tu}\theta_f \pi}{180AL}$ in N – mm/mm3 =

Modulus of Rigidity:

G (N/mm^2) = L / J * (Slope of the straight-line portion of the graph)

FORMULAE:

Modulus of Rigidity = c = 1/J x Slope

Ultimate shear stress = f_{sy} = Tu /J x R

Resilience = U = fsy2 /4 L

Toughness = To = Tu x θf/ A. L

RESULTS:

Modulus of Rigidity:

Toughness:

Ultimate Shear Stress:

Resilience:

EXPERIMENT No: 5 Dye penetration testing. To study the defects of Cast and Welded specimens

NON- DESTRUCTIVE TEST

DYE PENTRANTION TEST [Liquid Penetrant Test]

Aim: To detect surface defects in a test specimen using the Liquid Penetrant Testing (LPT) method.

Apparatus: Penetrate, developer, and ultraviolet light source.

The **Liquid Penetrant Test (LPT)** is a non-destructive testing method used to detect surface-breaking defects such as cracks, porosity, seams, and laps in non-porous materials. The technique relies on the ability of a liquid to penetrate into surface discontinuities through **capillary action as shown in figure 14**.

There are two primary types of penetrants:

- **Fluorescent penetrants** – which fluoresce under **ultraviolet (UV) light**, used for high-sensitivity inspections.
- **Visible dye penetrants** – typically **red-colored** and visible under normal lighting conditions.

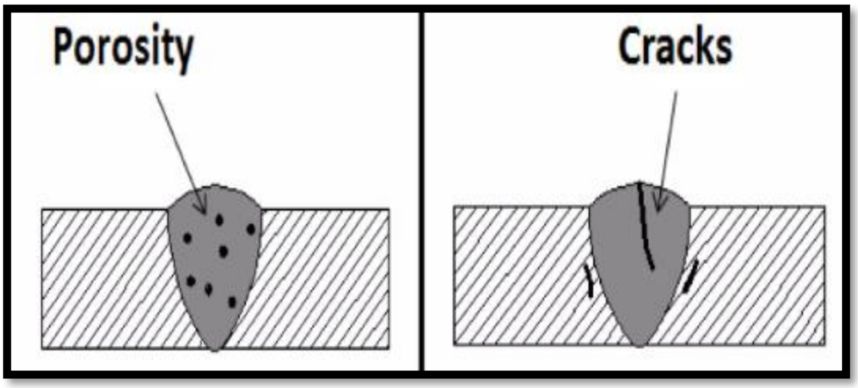


Figure 13: To detect defects in casting, welding and forging.

The basic process involves the following steps as shown in figure 15:

1. Application of penetrant to the cleaned surface.
2. Allowing time for the penetrant to seep into any defects.
3. Removing excess penetrant from the surface.
4. Applying a **developer**, which draws the penetrant out of the flaws, revealing visible indications as shown in figure 13 and figure 16 respectively.
5. Inspecting the surface for defect indications using visible light or UV light, depending on the penetrant type.

Result:

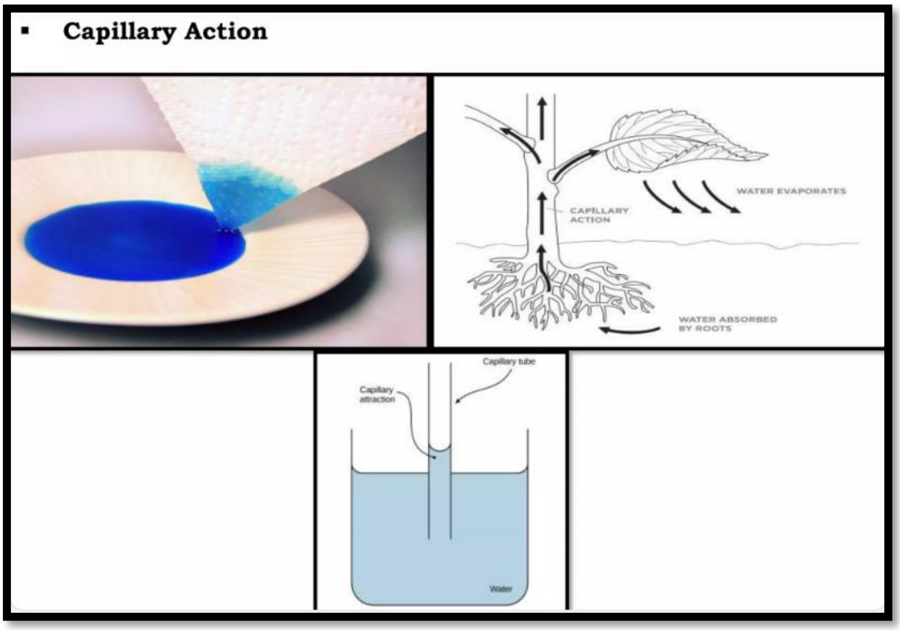


Figure 14: Principle involved – capillary action

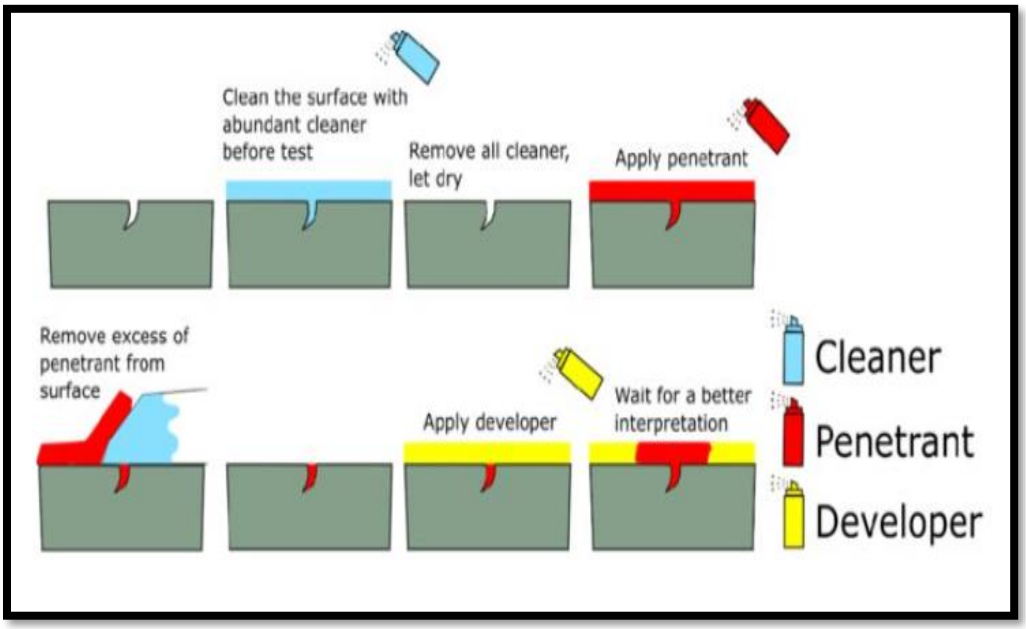


Figure 15: Basic process involved in LPT

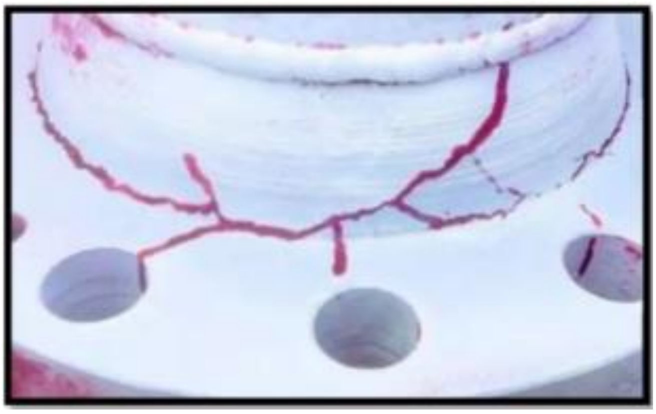


Figure 16: Dye used in penetrant should be good colour contrast against developer

MACHINE SHOP

INTRODUCTION:

In an industry, metal components are made into different shapes and dimensions by using various metal working processes.

Metal working processes are classified into two major groups. They are:

- Non-cutting shaping or chips less or metal forming process - forging, rolling, pressing, etc.
- Cutting shaping or metal cutting or chip forming process - turning, drilling, milling, etc.

BASIC METAL CUTTING THEORY:

The conventional idea of cutting involves separating a material using a thin knife or wedge. However, when cutting metal, the process differs significantly. While the cutting tool always has a wedge-shaped edge that must remain sharp, its wedge angle is much larger than that of a typical knife. As a result, instead of a simple slicing action, metal cutting primarily relies on a shearing process as the workpiece moves.

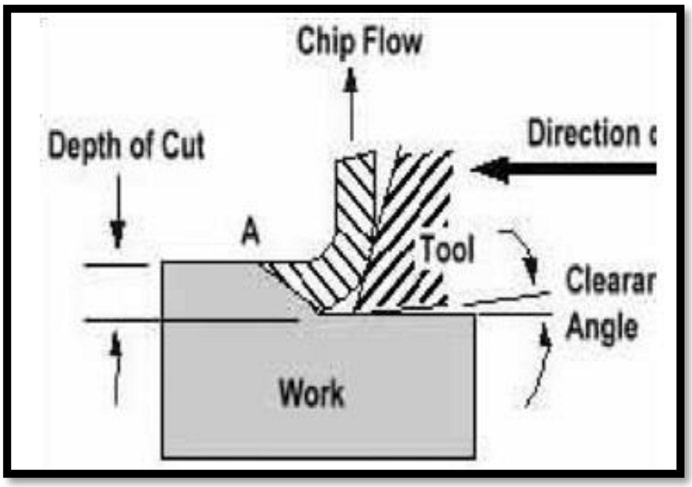


Figure 1: Basic Metal Cutting Theory against the tool.

The figure 1 illustrates a tool moving against a fixed workpiece. During the cutting process, the chip exerts significant pressure on the tool's top face, causing continuous shearing along the shear plane AB. Although the figure depicts a tool operating in the horizontal plane with a stationary workpiece, the same shearing action occurs when the workpiece rotates while the tool remains stationary.

Principle of Machining:

Figure 1 illustrates the fundamental principle of machining. A metal rod with an irregular shape, size, and surface is transformed into a finished product with the desired dimensions and surface finish. This is achieved through precise relative motion between the cutting tool and the workpiece.

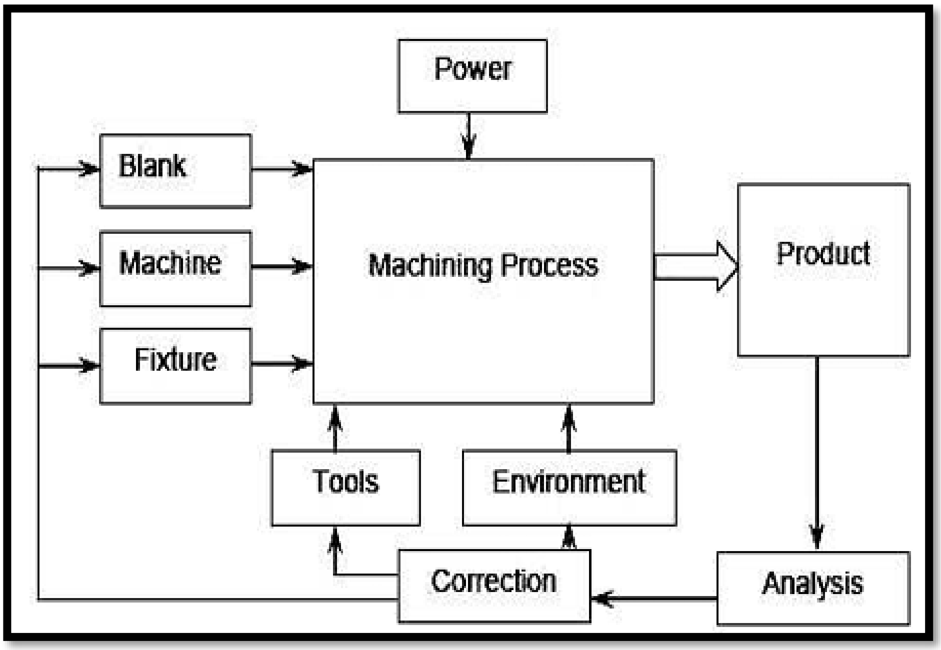


Figure 2: Requirements for machining

Purpose of machining:

Most of the engineering components such as gears, bearings, clutches, tools, screws and nuts etc. need dimensional and form accuracy and good surface finish for serving their purposes. Preforming like casting, forging etc. generally cannot provide the desired accuracy and finish. For that such preformed parts, called blanks, need semi-finishing and finishing and it is done by machining and grinding. Grinding is also basically a machining process.

Machining to high accuracy and finish essentially enables a product:

1. Fulfill its functional requirements.
2. Improve its performance.
3. Prolong its service.

Requirements of machining:

The essential basic requirements for machining a work are illustrated in Figure 2.

The blank and the cutting tool are properly mounted (in fixtures) and moved in a powerful device called machine tool enabling gradual removal of layer of material from the work surface resulting in its desired dimensions and surface finish. Additionally, some environment called cutting fluid is generally used to ease machining by cooling and lubrication.

Definition of machine tool:

A machine tool is a non-portable power operated and reasonably valued device or system of devices in which energy is expended to produce jobs of desired size, shape and surface finish by removing excess material from the preformed blanks in the form of chips with the help of cutting tools moved past the work surface(s).

Machine tools primarily shape metals through the following processes:

- Material removal by cutting chips
- Pressing, drawing, or shearing
- Controlled electrical machining

Basic functions of machine tools:

Machine tools basically produce geometrical surfaces like flat, cylindrical or any contour on the preformed blanks by machining work with the help of cutting tools.

The physical functions of a machine tool in machining are:

1. Firmly holding the blank and the tool.
2. Transmit motions to the tool and the blank.
3. Provide power to the tool-work pair for the machining action.
4. Control of the machining parameters, i.e., speed, feed and depth of cut.

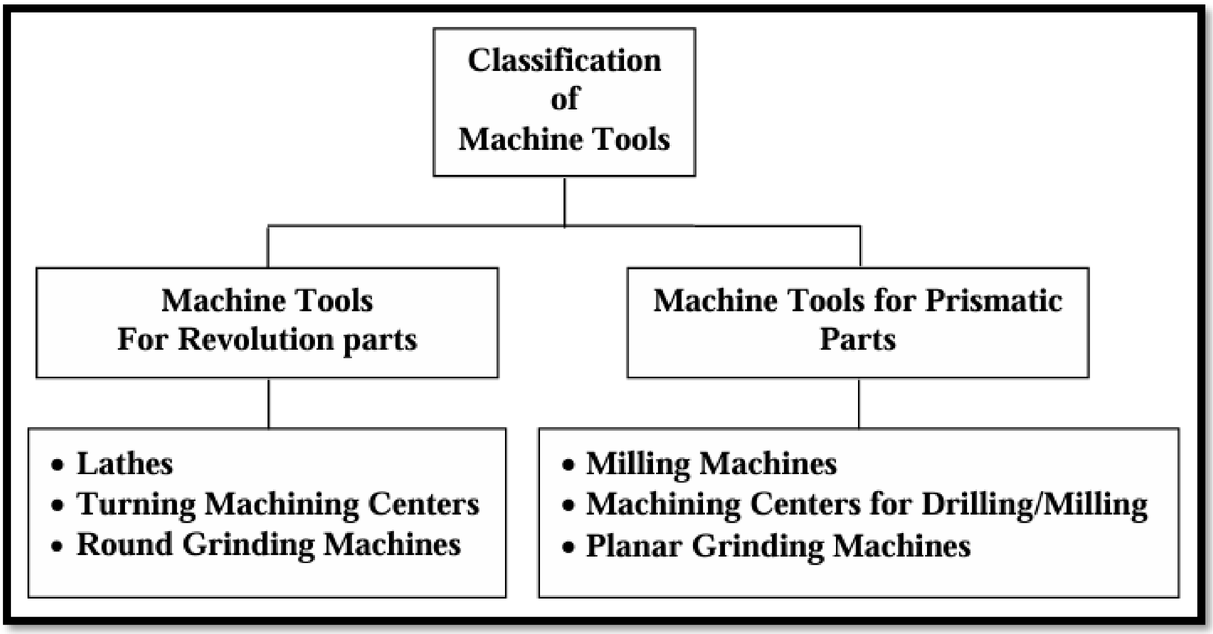


Figure 3: Classification of Machine tools

Cutting Tool:

A tool is a device or piece of equipment designed to provide a mechanical advantage in performing a physical task or to enable functions beyond natural human capability. Tools can be handheld, manually operated, or powered and portable.

There are basically two types of cutting tools:

1. Single point (e.g. turning tools).
2. Multiple point (e.g. milling tools).

Figure 4 illustrates a typical cutting tool along with the terminology used to describe its various parts:

- **Shank:** The unground portion of the tool bit that does not form cutting edges, typically rectangular in cross-section.
- **Face:** The surface of the cutting tool against which the chip slides upward during cutting.

- **Flank:** The surface of the tool that faces the workpiece.
- **Heel:** The lowest portion of the side cutting edges in a single-point cutting tool.

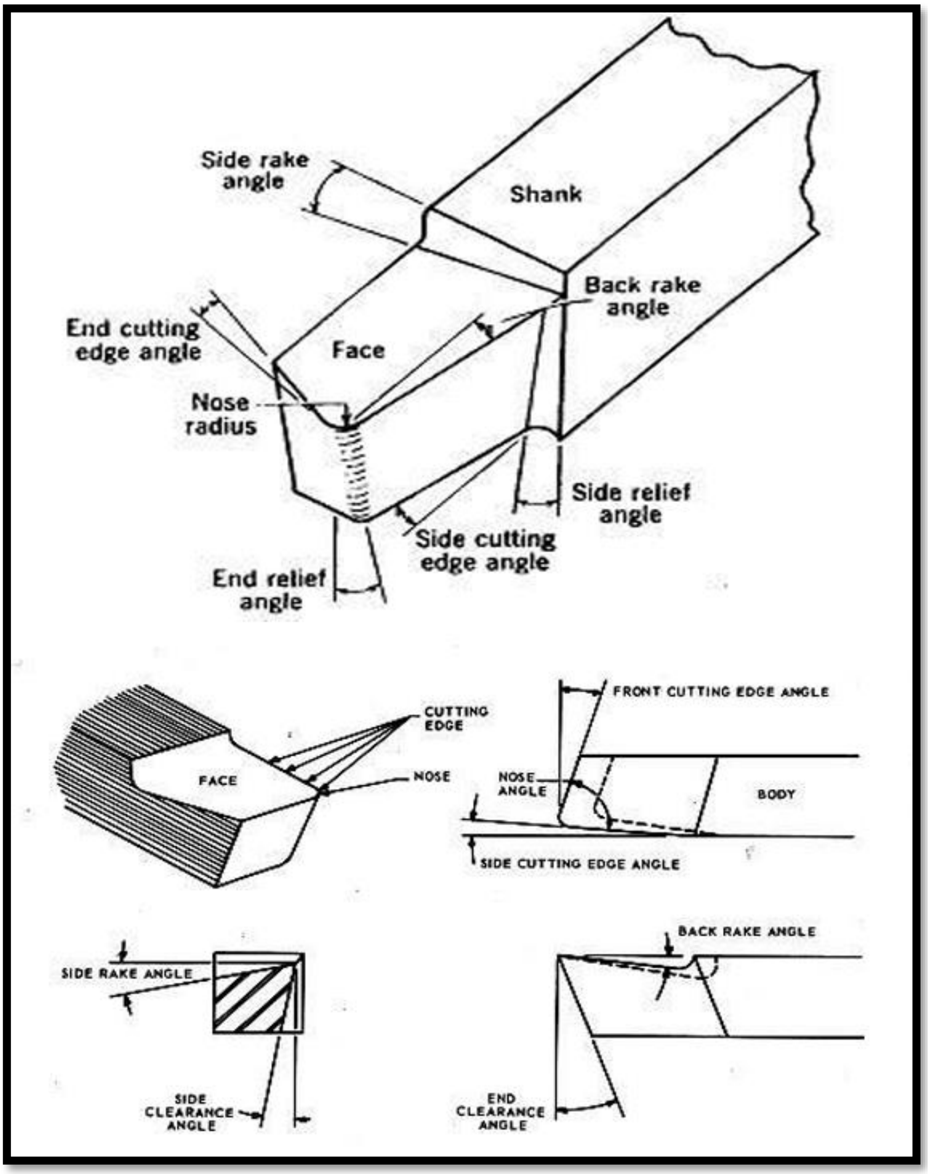
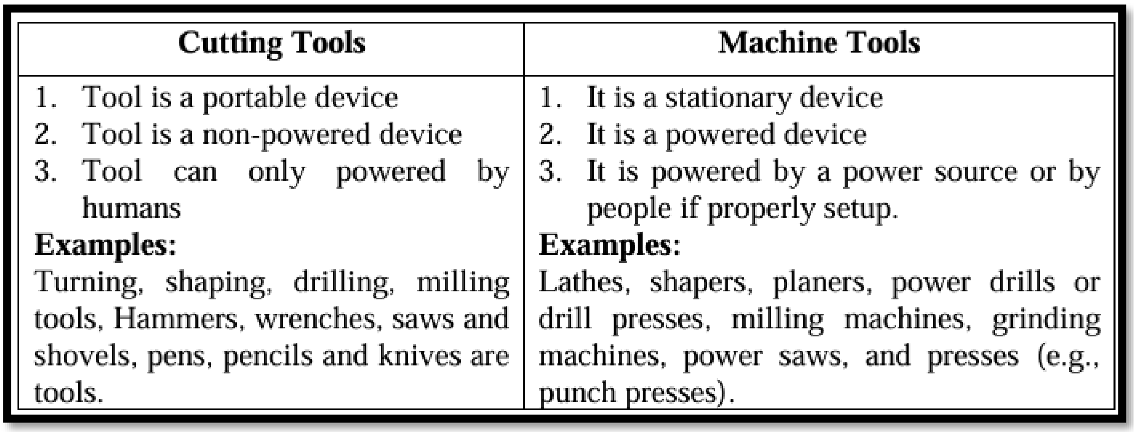


Figure 4: Cutting Tool Terminology

- **Nose:** The intersection of the side and end cutting edges. A nose radius enhances tool life and improves surface finish.
- **Base:** The underside of the tool shank.
- **Rake:** The slope of the top surface away from the cutting edge. A larger rake angle increases the shear angle, reducing cutting force and power requirements.
- **End Cutting Edge Angle:** The angle between the tool face and a plane perpendicular to the side of the shank, typically ranging from 5 to 15 degrees.



Cutting Tools	Machine Tools
1. Tool is a portable device 2. Tool is a non-powered device 3. Tool can only powered by humans **Examples:** Turning, shaping, drilling, milling tools, Hammers, wrenches, saws and shovels, pens, pencils and knives are tools.	1. It is a stationary device 2. It is a powered device 3. It is powered by a power source or by people if properly setup. **Examples:** Lathes, shapers, planers, power drills or drill presses, milling machines, grinding machines, power saws, and presses (e.g., punch presses).

Tool Signature:

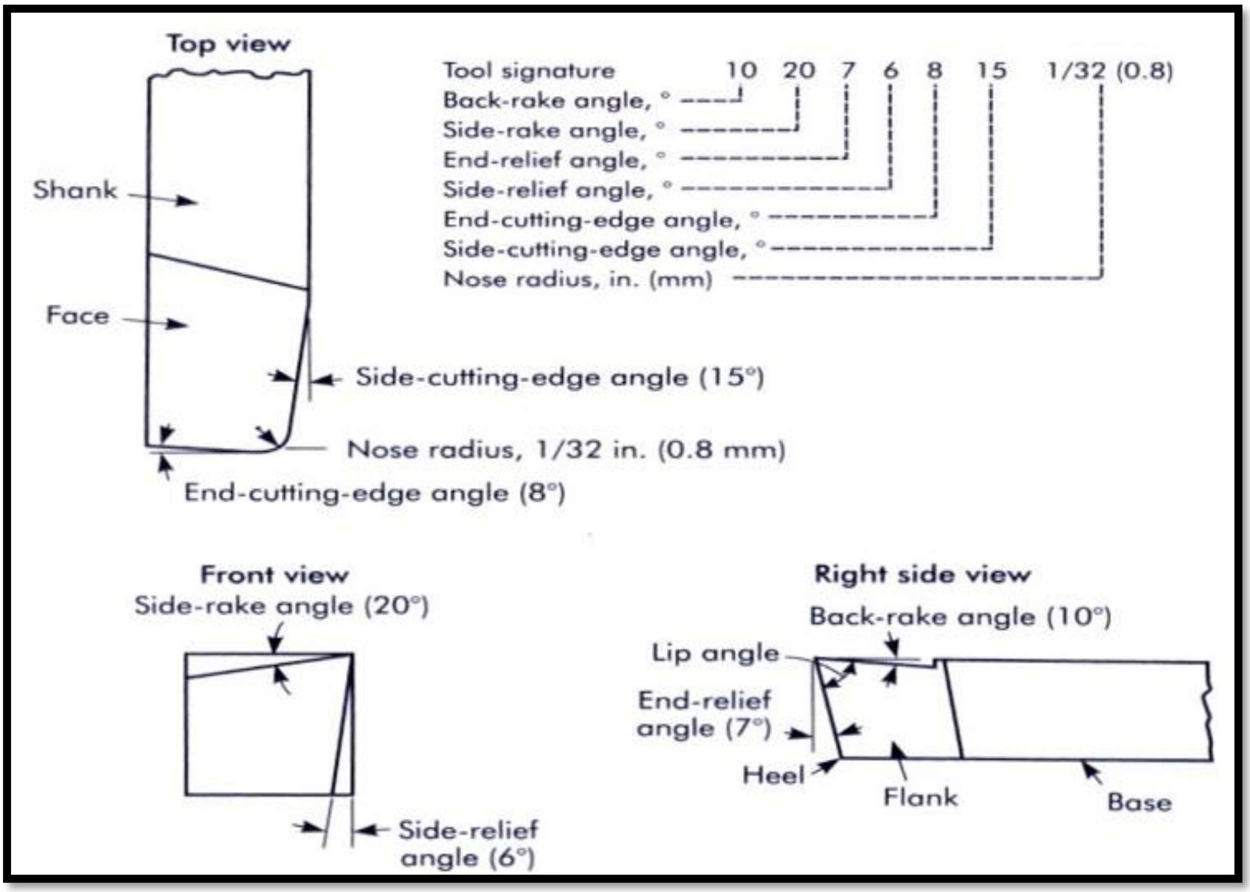


Figure 5: Tool Signature of Single Point Cutting Tool

Important angles of a Single Point Cutting Tool:

Angle	Details
Back Rake Angle	It is also called as Top Rake Angle. It is the slope given to the face or the surface of the tool. This slope is given from the nose along the length of the tool.
Side Rake Angle	It is the slope given to the face or top of the tool. This slope is given from the nose along the width of the tool. The rake angles help easy flow of chips

Relief Angle	These are the slopes ground downwards from the cutting edges. These are two clearance angles namely, side clearance angle and end clearance angle. This is given in a tool to avoid rubbing of the job on the tool.
Cutting Edge Angle	There are two cutting edge angles namely side cutting edge angle and end cutting edge angle. Side cutting edge angle is the angle, the side cutting edge makes with the axis of the tool. End cutting edge angle is the angle, the end cutting edge makes with the width of the tool.
Lip Angle	It is also called cutting angle. It is the angle between the face and end surface of the tool.
Nose Angle	It is the angle between the side cutting edge and end cutting edge.

Multi Point Cutting Tool:

In a multi-point cutting tool, multiple cutting edges are used to remove material efficiently. These tools are commonly employed in operations such as milling, drilling, reaming, slotting, and Woodruff cutting. One crucial aspect of cutting tools is that they must be made from a material harder than the workpiece and capable of withstanding the heat generated during the metal-cutting process.

Grinding tools also function as multi-point cutting tools, where each abrasive grain acts as a microscopic single-point cutting edge.

A multi-point cutting tool consists of two or more cutting elements (chip-producing edges) attached to a common body. The terms used for single-point tools, such as face, flanks, and cutting edge, also apply to multi-point tools. Common examples of multi-point cutting tools include drills, reamers, milling cutters, broaches, and Woodruff cutters.

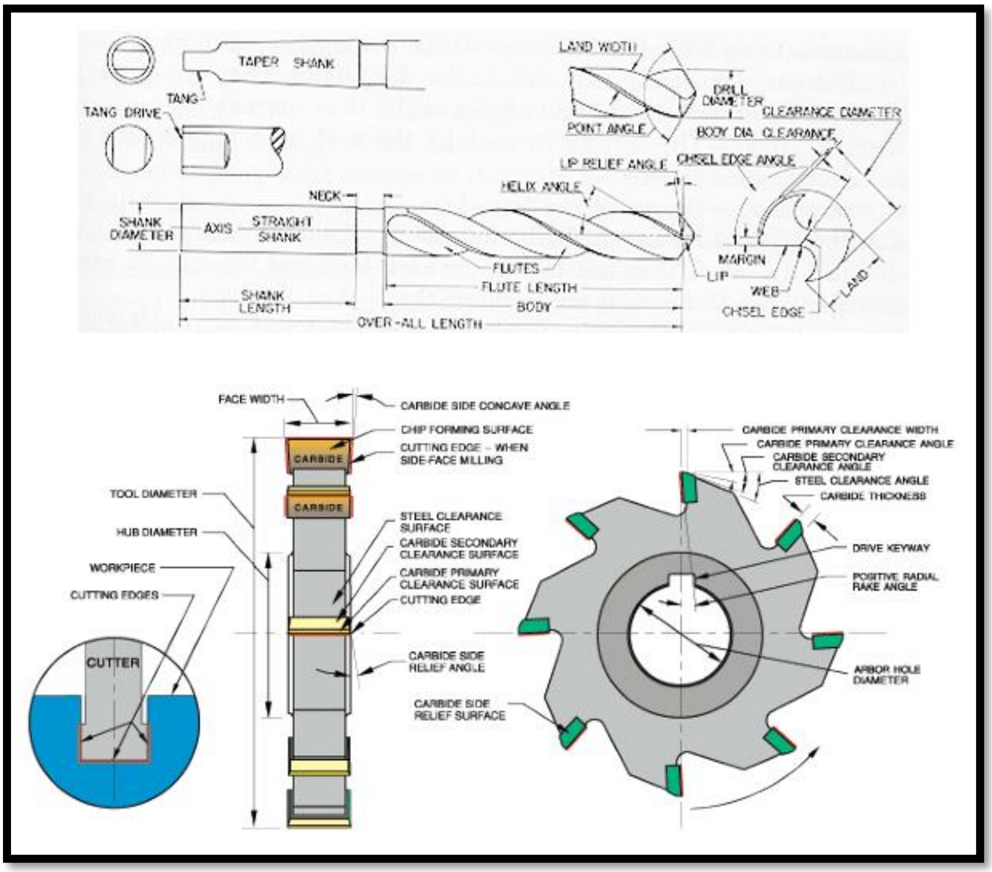


Figure 6: Tool Signature of Multi Point Cutting Tool

Basically, the metal cutting process can be classified into two main types.

- Orthogonal cutting
- Oblique cutting

ORTHOGANAL CUTTING (Two-Dimensional Cutting):

The orthogonal cutting process is a two-dimensional cutting analysis in which the tool's cutting edge is perpendicular to the direction of cutting speed. The chip is formed due to shear deformation in the shear plane. This shear deformation is a result when the force is applied to the cutting tool.

OBLIQUE CUTTING (Three-Dimensional Cutting):

The cutting edge of the tool is perpendicular to the cutting velocity in the orthogonal cutting whereas, in oblique cutting the cutting edge of the tool is inclined at a certain angle to the cutting velocity vector. It is also called a three-dimensional cutting process.

TOOL MATERIALS IN COMMON USE

The different materials used for cutting tools are:

1. High carbon steel

2. Alloy steels

3. High speed steel

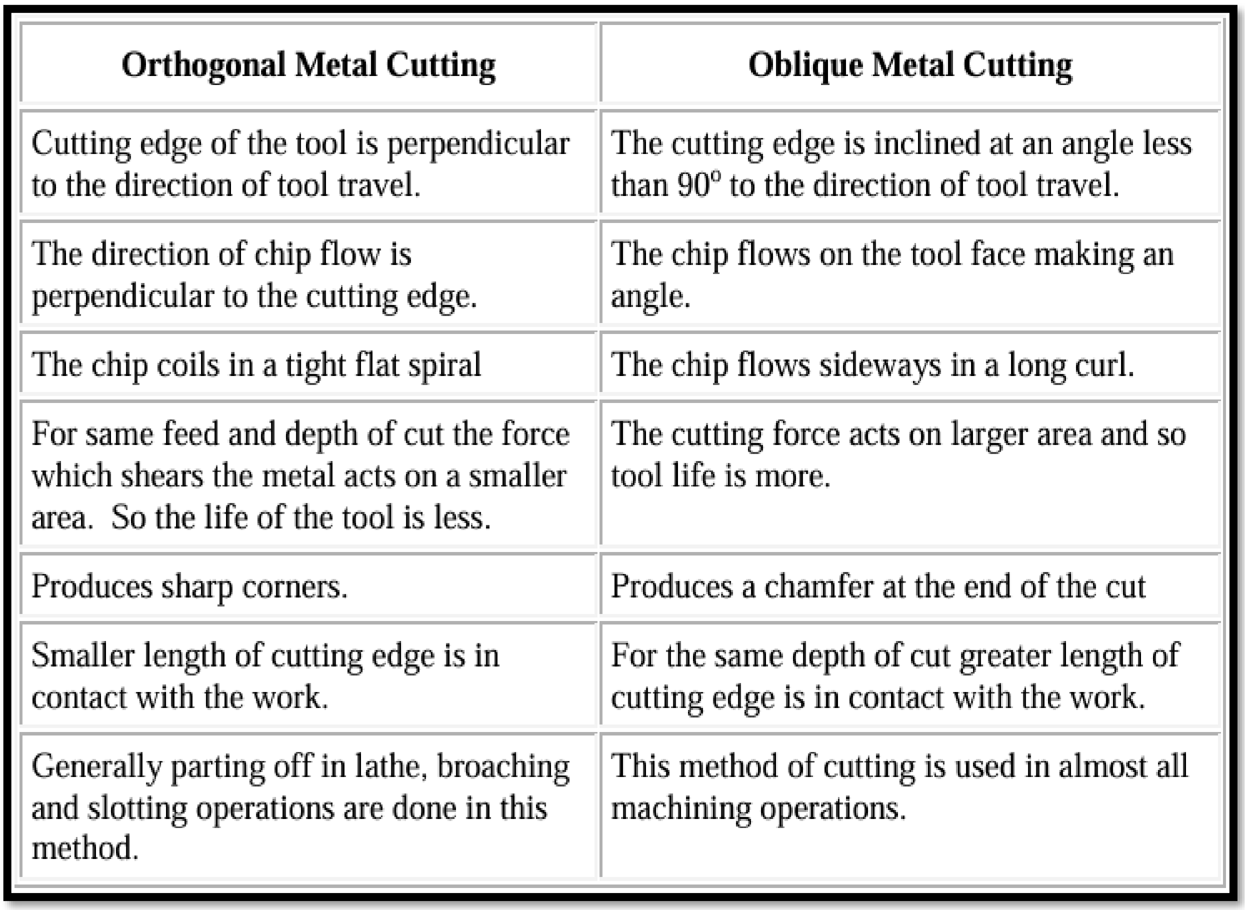
4. Stellites

5. Cemented carbides

6. Ceramics

7. Diamonds

8. Abrasives



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 area. 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.
Generally parting off in lathe, broaching and slotting operations are done in this method.	This method of cutting is used in almost all machining operations.

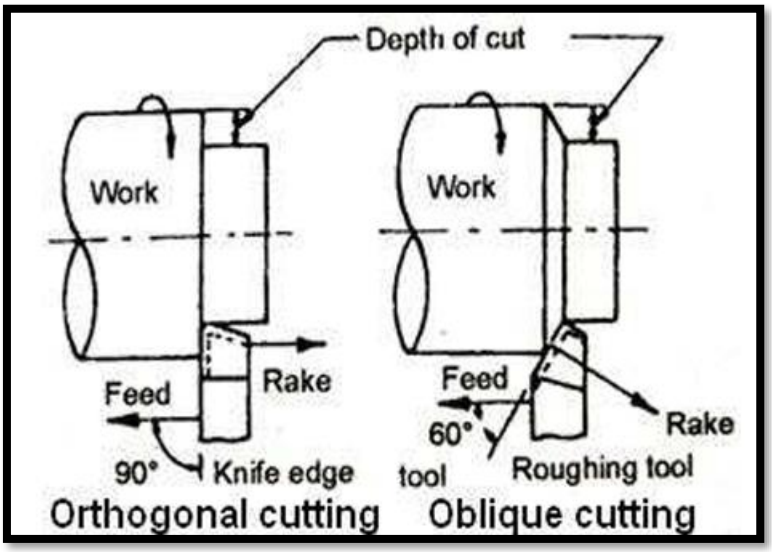


Figure 7: Setup of Orthogonal and Oblique cutting

Essential properties of cutting tool materials:

The cutting tools need to be capable to meet the growing demands for higher productivity and economy as well as to machine the exotic materials which are coming up with the rapid progress in science and technology. The cutting tool material of the day and future essentially require the following properties to resist or retard the phenomena leading to random or early tool failure:

1. High mechanical strength; compressive, tensile, and TRA.
2. Fracture toughness - high or at least adequate.
3. High hardness for abrasion resistance.
4. High hot hardness to resist plastic deformation and reduce wear rate at elevated temperature.
5. Chemical stability or inertness against work material, atmospheric gases and cutting fluids.
6. Resistance to adhesion and diffusion.
7. Thermal conductivity - low at the surface to resist incoming of heat and high at the core to quickly dissipate the heat entered.
8. High heat resistance and stiffness.
9. Manufacturability, availability and low cost.

TOOL LIFE Definition:

Tool life generally indicates the amount of satisfactory performance or service rendered by a fresh tool or a cutting point till it is declared failed.

OR

The length of time of satisfactory service or amount of acceptable output provided by a fresh tool prior to it is required to replace or recondition.

Factors affecting tool life:

The life of the cutting tool is affected by the following factors:

1. Cutting speed.
2. Feed and depth of cut.
3. Tool geometry.
4. Tool material.
5. Cutting fluid.
6. Work piece material.
7. Rigidity of work, tool and machine.

Cutting Fluids:

Purposes and application of cutting fluid:

The basic purposes of cutting fluid application are:

1. Cooling of the job and the tool to reduce the detrimental effects of cutting temperature on the job and the tool.

2. Lubrication at the chip - tool interface and the tool flanks to reduce cutting forces and friction and thus the amount of heat generation.
3. Cleaning the machining zone by washing away the chip - particles and debris which, if present, spoils the finished surface and accelerates damage of the cutting edges.
4. Protection of the nascent finished surface - a thin layer of the cutting fluid sticks to the machined surface and thus prevents its harmful contamination by the gases like SO2, O2, H2S, and NXOY present in the atmosphere.

However, the main aim of application of cutting fluid is to improve machinability through reduction of cutting forces and temperature, improvement by surface integrity and enhancement of tool life.

Desired Properties of Cutting Fluids:

An ideal cutting fluid should possess the following properties:

1. Safe for the operator
2. Non-damaging to the machine
3. Excellent heat dissipation capability
4. Low volatility
5. Non-foaming characteristics
6. Good lubrication properties & Cost-effective

Types of Cutting Fluids

Cutting fluids are generally classified into four main categories:

Air blast or compressed air only:

Machining of some materials like grey cast iron become inconvenient or difficult if any cutting fluid is employed in liquid form. In such case only air blast is recommended for cooling and cleaning.

Solid or semi-solid lubricant:

Paste, waxes, soaps, graphite, Moly-disulphide (MoS_2) may also often be used, either applied directly to the workpiece or as an impregnant in the tool to reduce friction and thus cutting forces, temperature and tool wear.

Water:

For its good wetting and spreading properties and very high specific heat, water is considered as the best coolant and hence employed where cooling is most urgent.

Soluble oil:

Water acts as the best coolant but does not lubricate. Besides, use of only water may impair the machine-fixture-tool-work system by rusting. So oil containing some emulsifying agent and additive like EPA, together called cutting compound, is mixed with water in a suitable ratio (1 ~ 2 in 20 ~ 50). This milk like white emulsion, called soluble oil, is very common and widely used in machining and grinding.

Cutting oils:

Cutting oils are generally compounds of mineral oil to which are added desired type and amount of vegetable, animal or marine oils for improving spreading, wetting and lubricating properties. As and when required some EP additive is also mixed to reduce friction, adhesion and BUE formation in heavy cuts.

Chemical fluids:

These are occasionally used fluids which are water based where some organic and or inorganic materials are dissolved in water to enable desired cutting fluid action. There are two types of such cutting fluid: Chemically inactive type - high cooling, anti-rusting and wetting but less lubricating. Active (surface) type - moderate cooling and lubricating.

Cryogenic cutting fluid:

Extremely cold (cryogenic) fluids (often in the form of gases) like liquid CO2 or N2 are used in some special cases for effective cooling without creating much environmental pollution and health hazards.

CENTRE LATHE:

Lathe is the oldest machine tool invented, starting with the Egyptian tree lathes. It is the father of all machine tools. Its main function is to remove material from a work piece to produce the required shape and size. This is accomplished by holding the work piece securely and rigidly on the machine and then turning it against the cutting tool which will remove material from the work piece in the form of chips. It is used to machine cylindrical parts.

Generally single point cutting tool is used. In the year 1797 Henry Maudslay, an Englishman, designed the first screw cutting lathe which is the forerunner of the present-day high-speed, heavy-duty production lathe.

Principal of Operations:

The lathe is a machine tool used principally for shaping articles of metal (and sometimes wood or other materials) by causing the work piece to be held and rotated by the lathe while a tool bit is advanced into the work causing the cutting action.

The basic lathe that was designed to cut cylindrical metal stock has been developed further to produce screw threads, tapered work, drilled holes, knurled surfaces, etc. The typical lathe provides a variety of rotating speeds and a means to manually and automatically move the cutting tool into the work piece.

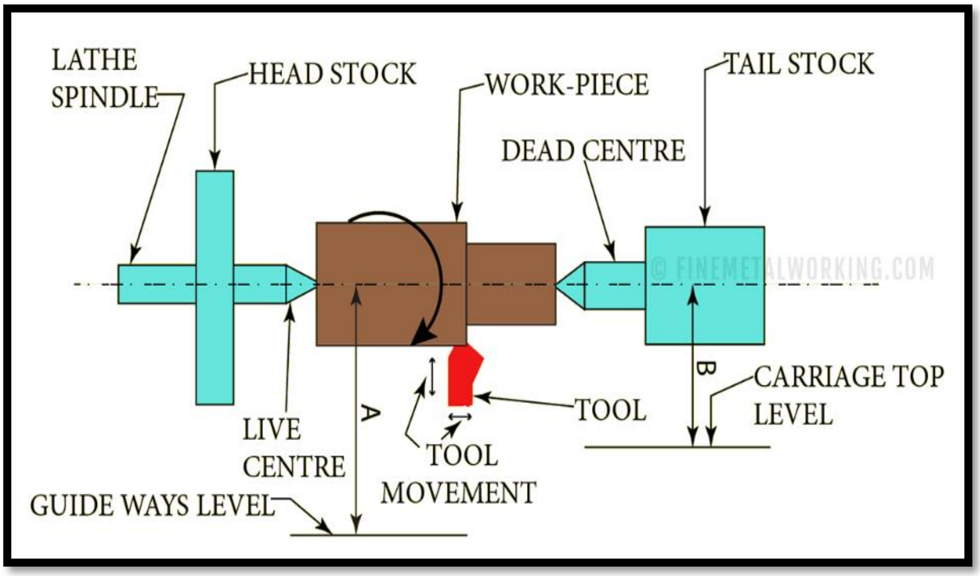


Figure 8: Principal of Operation

Types of lathes:

Lathes are manufactured in a variety of types and sizes, from very small bench lathes used for precision work to huge lathes used for turning large steel shafts. But the principle of operation and function of all types of lathes are same.

The different types of lathes are:

1. Speed lathe
2. Centre or Engine lathe
3. Bench lathe
4. Tool Room Lathe
5. Capstan and Turret lathe
6. Special purpose lathe
7. Automatic lathe

Speed Lathe:

Speed lathe is simplest of all types of lathes in construction and operation. It consists of a Bed, Headstock, Tailstock and Tool post mounted on an adjustable slide. There is no feed box, leadscrew or conventional type of carriage. The tool is mounted on the adjustable slide and is fed into the work by hand control. The speed lathe finds applications where cutting force is least such as in wood working, spinning, centering, polishing, winding etc.

Centre or Engine Lathe:

The term “engine” is associated with this lathe due to the fact that in the very early days of its development it was driven by steam engine. This lathe is the important member of the lathe family and is the most widely used. Similar to the speed lathe, the engine lathe has all the basic parts, e.g., bed, headstock, and tailstock. An engine lathe is shown in Figure. 10. Unlike the speed lathe, the engine lathe can feed the cutting tool both in cross and longitudinal direction with reference to the lathe axis with the help of a carriage, feed rod and lead screw. The power may be transmitted by means of belt, electric motor or through gears.

Bench Lathe:

This is a small lathe usually mounted on a bench. It has practically all the parts of an engine lathe or speed lathe and it performs almost all the operations. This is used for small and precision work.

Tool Room Lathe:

This lathe has features similar to an engine lathe but it is much more accurately built. It has a wide range of spindle speeds ranging from a very low to a quite high speed up to 2500 rpm. This lathe is mainly used for precision work on tools, dies, gauges and in machining work where accuracy is needed.

Capstan and Turret Lathe:

The distinguishing feature of this type of lathe is that the tailstock of an engine lathe is replaced by a hexagonal turret, on the face of which multiple tools may be fitted and fed into the work in proper sequence. Due to this arrangement, several different types of operations can be done on a job without re-setting of work or tools, and a number of identical parts can be produced in the minimum time.

Special Purpose Lathes:

These lathes are constructed for special purposes and for jobs, which cannot be accommodated or conveniently machined on a standard lathe. The wheel lathe is made for finishing the journals and turning the tread on railroad car and locomotive wheels. The gap bed lathe, in which a section of the bed adjacent to the headstock is removable, is used to swing extra-large- diameter pieces.

Automatic Lathes:

These lathes are so designed that all the working and job handling movements of the complete manufacturing process for a job are done automatically. These are high speed, heavy duty, mass production lathes with complete automatic control.

CONSTRUCTIONAL FEATURES: Major parts of a centre lathe

A simple lathe comprises of a bed made of grey cast iron on which headstock, tailstock, carriage and other components of lathe are mounted. Figure 10 shows the different parts of engine lathe or central lathe.

The major parts of lathe machine are given as under:

1. Bed
2. Head stock
3. Tailstock
4. Carriage
5. Feed mechanism

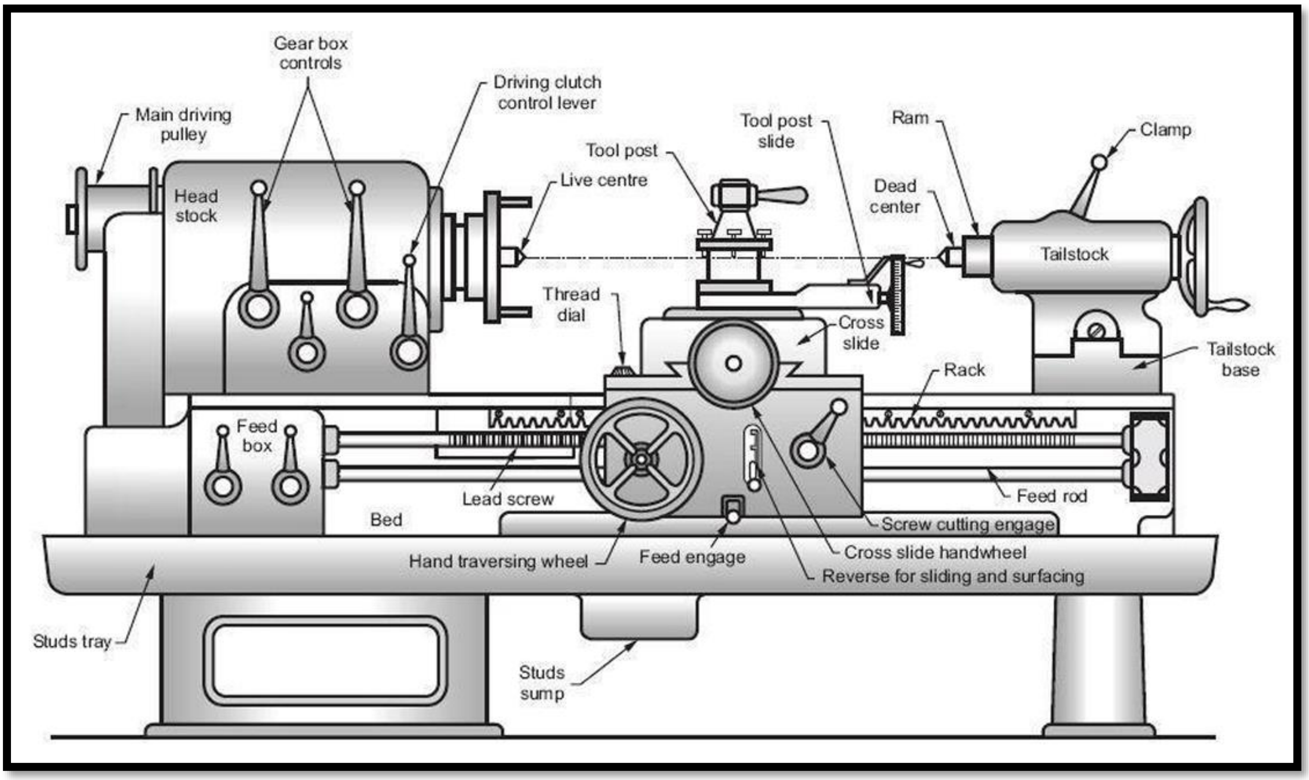


Figure 11: Different parts of engine lathe or central lathe

Bed:

The bed of a lathe machine is the base on which all other parts of lathe are mounted. It is massive and rigid single piece casting made to support other active parts of lathe. On left end of the bed, headstock of lathe machine is located while on right side tailstock is located. The carriage of the machine rests over the bed and slides on it. On the top of the bed there are two sets of guideways - innerways and outerways. The innerways provide sliding surfaces for the tailstock and the outerways for the carriage. The guideways of the lathe bed may be flat and inverted V shape. Generally, cast iron alloyed with nickel and chromium material is used for manufacturing of the lathe bed.

Head Stock:

The main function of headstock is to transmit power to the different parts of a lathe. It comprises of the headstock casting to accommodate all the parts within it including gear train arrangement. The main spindle is adjusted in it, which possesses live centre to which the work can be attached. It supports the work and revolves with the work, fitted into the main spindle of the headstock. The cone pulley is also attached with this arrangement, which is used to get various spindle speed through electric motor. The back gear arrangement is used for obtaining a wide range of slower speeds. Some gears called change wheels are used to produce different velocity ratio required for thread cutting.

Tail Stock:

Figure 12 shows the tail stock of central lathe, which is commonly used for the objective of primarily giving an outer bearing and support the circular job being turned on centers. Tail stock can be easily set or adjusted for alignment or non-alignment with respect to the spindle centre and carries a centre called dead centre for supporting one end of the work. Both live and dead centers have 60° conical points to fit centre holes in the circular job, the other end tapering to allow for good fitting into the spindles. The dead centre can be mounted in ball bearing so that it rotates with the job avoiding friction of the job with dead centre as it important to hold heavy jobs.

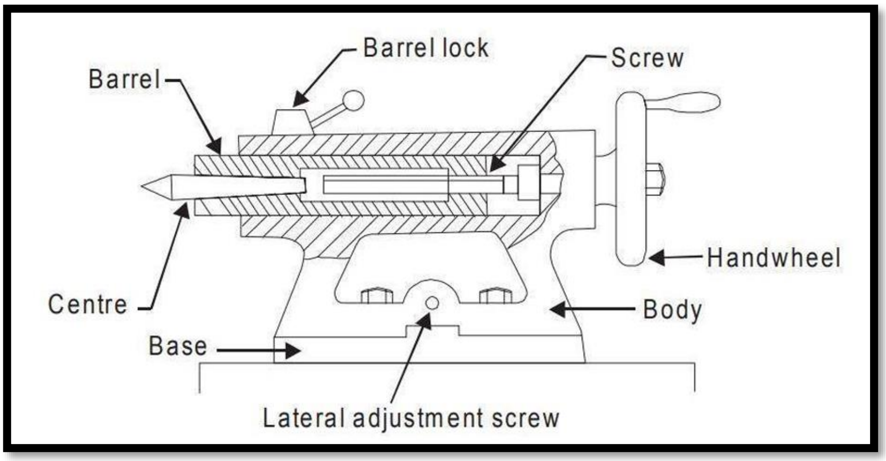


Figure 12: Tail stock of central lathe

Carriage:

Carriage is mounted on the outer guide ways of lathe bed and it can move in a direction parallel to the spindle axis. It comprises of important parts such as apron, cross-slide, saddle, compound rest, and tool post. The lower part of the carriage is termed the apron in which there are gears to constitute apron mechanism for adjusting the direction of the feed using clutch mechanism and the split half nut for automatic feed. The cross-slide is basically mounted on the carriage, which generally travels at right angles to the spindle axis. On the cross-slide, a saddle is mounted in which the compound rest is adjusted which can rotate and fix to any desired angle. The compound rest slide is actuated by a screw, which rotates in a nut fixed to the saddle. The tool post is an important part of carriage, which fits in a tee-slot in the compound rest and holds the tool holder in place by the tool post screw.

Feed Mechanism:

Feed mechanism is the combination of different units through which motion of headstock spindle is transmitted to the carriage of lathe machine. Following units play role in feed mechanism of a lathe machine.

1. End of bed gearing
2. Feed gear box
3. Lead screw and feed rod
4. Apron mechanism

The gearing at the end of bed transmits the rotary motion of headstock spindle to the feed gear box. Through the feed gear box, the motion is further transmitted either to the feed shaft or lead screw, depending on whether the lathe machine is being used for plain turning or screw cutting. The feed gear box contains a number of different sizes of gears. The feed gear box provides a means to alter the rate of feed, and the ration between revolutions of the headstock spindle and the movement of carriage for thread cutting by changing the speed of rotation of the feed rod or lead screw. The apron is fitted to the saddle. It contains gears and clutches to transmit motion from the feed rod to the carriage, and the half nut which engages with the lead screw during cutting threads.

Feed rod:

The feed rod is a long shaft, used to move the carriage or cross-slide for turning, facing, boring and all other operations except thread cutting. Power is transmitted from the lathe spindle to the apron gears through the feed rod via a large number of gears.

Lead screw:

The lead screw is long threaded shaft used as a master screw and brought into operation only when threads have to cut. In all other times the lead screw is disengaged from the gear box and remains stationary. The rotation of the lead screw is used to traverse the tool along the work to produce screw. The half nut makes the carriage to engage or disengage the lead screw.

LATHE OPERATIONS:

The machining operations generally carried out in centre lathe are:

Rough and finish turning - The operation of producing cylindrical surface.

Facing - Machining the end of the work piece to produce flat surface.

Centering - The operation of producing conical holes on both ends of the work piece.

Chamfering - The operation of beveling or turning a slope at the end of the work piece.

Shouldering - The operation of turning the shoulders of the stepped diameter work piece.

Grooving - The operation of reducing the diameter of the work piece over a narrow surface.

It is also called as recessing, undercutting or necking.

Axial drilling and reaming by holding the cutting tool in the tailstock barrel.

Taper turning by

- Offsetting the tailstock.
- Swiveling the compound slide.
- Using form tool with taper over short length.
- Using taper turning attachment if available.
- Combining longitudinal feed and cross feed, if feasible.

Boring (internal turning); straight and taper – The operation of enlarging the diameter of a hole.

Forming; external and internal.

Cutting helical threads; external and internal.

Parting off - The operation of cutting the work piece into two halves.

Knurling - The operation of producing a diamond shaped pattern or impression on the surface.

In addition to the aforesaid regular machining operations, some more operations are also occasionally done, if desired, in centre lathes by mounting suitable attachments available in the market. Some of those common operations carried out in centre lathe are shown in Figure 13.

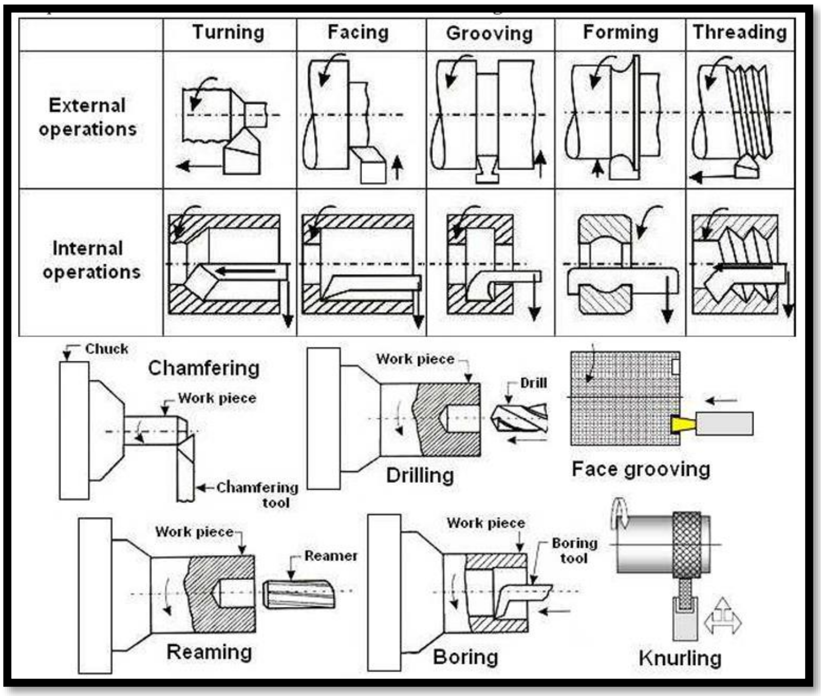


Figure 13: Some common machining operations carried out in a centre lathe

TAPER TURING METHODS:

A taper may be defined as a uniform change in the diameter of a work piece measured along its length. Taper turning is the operation of producing conical surface on the cylindrical work piece on lathe.

Taper may be expressed in two ways:

1. Ratio of difference in diameter to the length.
2. In degrees of half the included angle.

Generally, taper is specified by the term conicity. Conicity is defined as the ratio of the difference in diameters of the taper to its length.

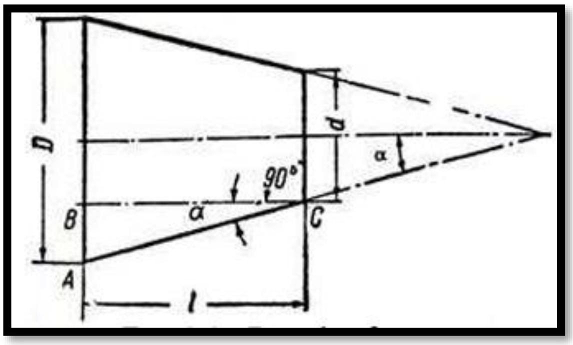


Figure 13: Details of a taper

Figure 13 shows the details of a taper.

D - Large diameter of the taper.

d - Small diameter of the taper.

l - Length of tapered part.

α - Half angle of taper.

Taper turning by a form tool:

Figure 14 illustrates the method of turning taper by a form tool. A broad nose tool having straight cutting edge is set on to the work at half taper angle, and is fed straight into the work to generate a tapered surface. In this method the tool angle should be properly checked before use. This method is limited to turn short length of taper only. This is due to the reason that the metal is removed by the entire cutting edge will require excessive cutting pressure, which may distort the work due to vibration and spoil the work surface.

Taper turning by Swiveling the compound rest:

Figure 15 illustrates the method of turning taper by Swiveling the compound rest. This method is used to produce short and steep taper. In this method, work is held in a chuck and is rotated about the lathe axis. The compound rest is swivelled to the required angle and clamped in position. The angle is determined by using the formula,

$$\boxed{\tan\alpha = \frac{D - d}{2l}}$$

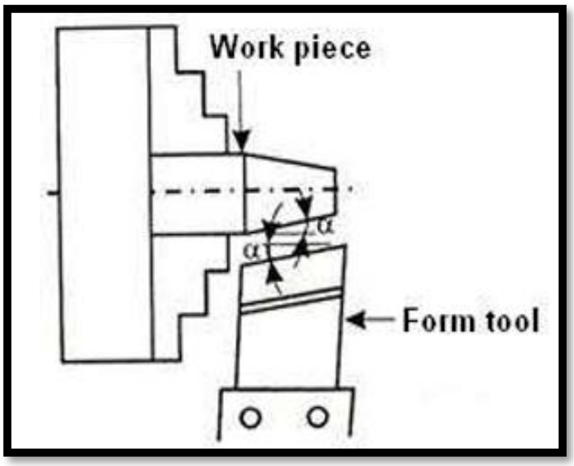


Figure 14: Taper turning by a form tool

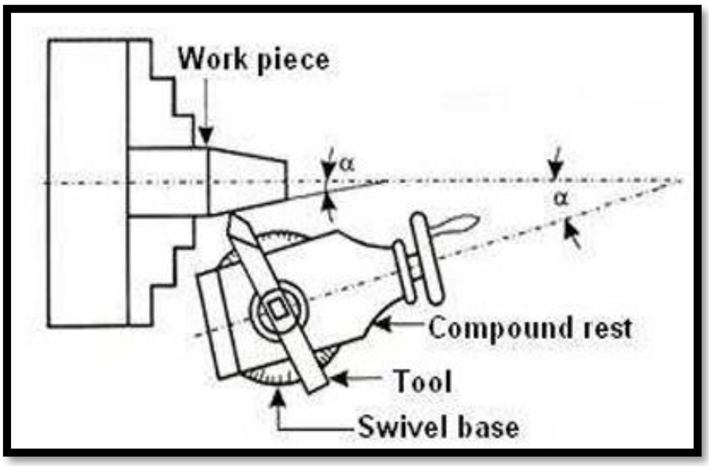


Figure 15: Taper turning by Swiveling the compound rest

Then the tool is fed by the compound rest hand wheel. This method is used for producing both internal and external taper. This method is limited to turn a short taper owing to the limited movement of the compound rest. The compound rest may be swivelled at 450 on either side of the lathe axis enabling it to turn a steep taper. The movement of the tool in this method being purely controlled by hand, this gives a low production capacity and poorer surface finish.

Taper turning by offsetting the tailstock:

Figure 16 illustrates the method of turning taper by offsetting the tailstock. The principle of turning taper by this method is to shift the axis of rotation of the work piece, at an angle to the lathe axis, which is equal to half angle of the taper, and feeding the tool parallel to the lathe axis.

This is done when the body of the tailstock is made to slide on its base towards or away from the operator by a set over screw. The amount of set over being limited, this method is suitable for turning small taper on long jobs. The main disadvantage of this method is that live and dead centres are not equally stressed and the wear is not uniform. Moreover, the lathe carrier being set at an angle, the angular velocity of the work is not constant.

The amount of set over required to machine a particular taper may be calculated as:

From the right-angle triangle ABC in Figure 16, BC =AB sinα, where BC = set over,

Set over = L sinα

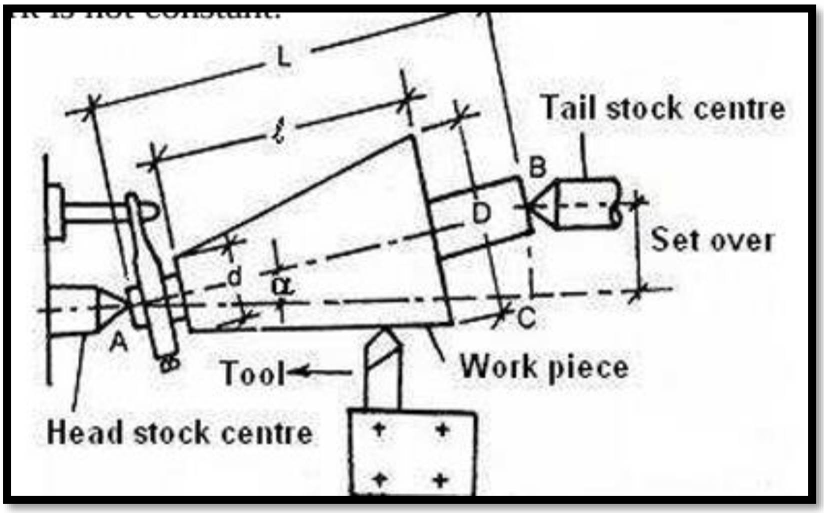


Figure 16: Taper turning by offsetting the tailstock

If the half angle of taper (α), is very small, for all practical purposes, sinα = tanα

$$\boxed{\text{Set over} = L \tan\alpha = L \times \frac{D-d}{2l} \text{ in mm.}}$$

If the taper is turned on the entire length of the work piece, then l= L, and the above equation becomes:

$$\boxed{\text{Set over} = L \times \frac{D-d}{2L} = \frac{D-d}{2}}$$

Taper turning by using taper turning attachment:

Figure 17 schematically shows a taper turning attachment. It consists of a bracket or frame which is attached to the rear end of the lathe bed and supports a guide bar pivoted at the centre. The guide bar having graduations in degrees may be swivelled on either side of the zero graduation and is set at the desired angle with the lathe axis. When this attachment is used the cross slide is delinked from the saddle by removing the binder screw. The rear end of the cross slide is then tightened with the guide block by means of a bolt. When the longitudinal feed is engaged, the tool mounted on the cross slide will follow the angular path, as the guide block will slide on the guide bar set at an angle to the lathe axis. The required depth of cut is given by the compound slide which is placed at right angles to the lathe axis. The guide bar must be set at half taper angle and the taper on the work must be converted in degrees. The maximum angle through which the guide bar may be swivelled is 100 to 120 on either side of the centre line. The angle of Swiveling the guide bar can be determined from the equation.

$$\boxed{\tan\alpha = \frac{D-d}{2l}}$$

The advantages of using a taper turning attachment are:

1. The alignment of live and dead centres being not disturbed; both straight and taper turning may be performed on a work piece in one setting without much loss of time.
2. Once the taper is set, any length of work piece may be turned taper within its limit.
3. Very steep taper on a long work piece may be turned, which cannot be done by any other method.
4. Accurate taper on a large number of work pieces may be turned.
5. Internal tapers can be turned with ease.

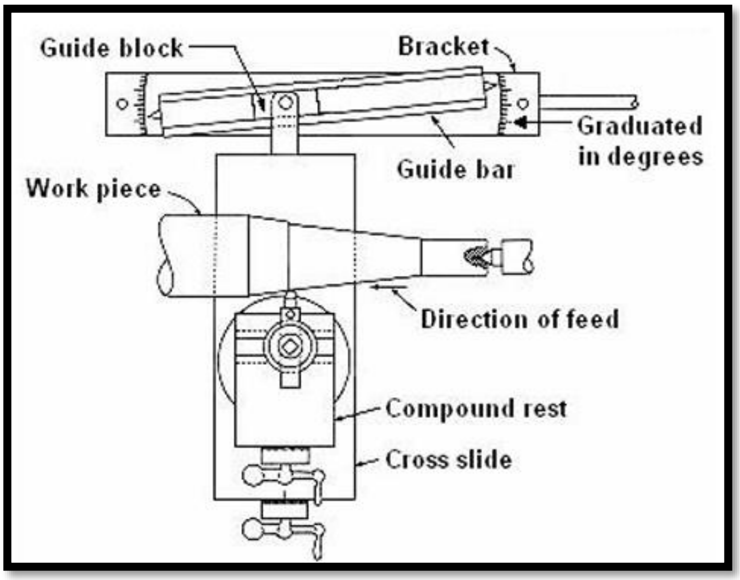


Figure 17: Taper turning attachment

THREAD CUTTING METHODS:

Thread cutting is one of the most important operations performed in a centre lathe. It is possible to cut both external and internal threads with the help of threading tools. There are a large number of thread forms that can be machined in a centre lathe such as Whitworth, ACME, ISO metric, etc. The principle of thread cutting is to produce a helical groove on a cylindrical or conical surface by feeding the tool longitudinally when the job is revolved between centres or by a chuck (for external threads) and by a chuck (for internal threads). The longitudinal feed should be equal to the pitch of the thread to be cut per revolution of the workpiece. The lead screw of the lathe has a definite pitch. The saddle receives its traversing motion through the lead screw. Therefore, a definite ratio between the longitudinal feed and rotation of the headstock spindle should be found out so that the relative speeds of rotation of the work and the lead screw will result in the cutting of a thread of the desired pitch. This is effect by change gears arranged between the spindle and the lead screw or by the change gear mechanism or feed gear box used in a modern lathe. Thread cutting on a centre lathe is a slow process, but it is the only process of producing square threads, as other methods develop interference on the helix. Figure 18 illustrates the principle of thread cutting.

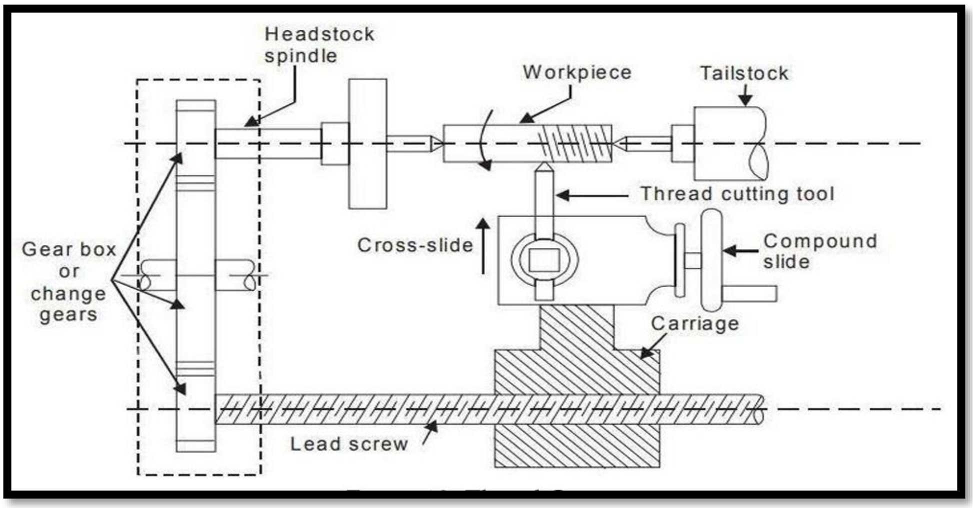


Figure 18: Principles of thread cutting

Change gear ratio:

Centre lathes are equipped with a set of change gears. A typical set contains the following change gears with number of teeth: 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 110, 120, 125 and 127. The change gear ratio (i_{cg}) must be transformed by multiplying numerator and denominator by a suitable number, to obtain gears available in the change gear set.

The change gear ratio may result either in a 'Simple gear train' or 'Compound gear train'. In modern lathes using quick change gears, the correct gear ratio for cutting a particular thread is quickly obtained by simply shifting the levers in different positions which are given in the charts or instruction plates supplied with the machine.

Calculation for change gear ratio:

Metric thread on Metric lead screw Calculation for change gear ratio for cutting metric thread on a centre lathe with a metric lead screw is as follows;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{\text{Lead screw turn}}{\text{Spindle turn}} = \frac{\text{Pitch of the thread to be cut}}{\text{Pitch of the lead screw}}$$

Example 1: The pitch of the lead screw is 12 mm, and the pitch of the thread to be cut is 3 mm. For this condition the change gear ratio is as follows;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{\text{Pitch of the thread to be cut}}{\text{Pitch of the lead screw}} = \frac{3}{12} = \frac{1}{4} = \frac{1 \times 20}{4 \times 20} = \frac{20}{80}$$

Therefore, the driver gear will have 20 teeth and the driven gear will have 80 teeth. ***This is effect by simple gear train.***

Example 2: The pitch of the lead screw is 6 mm, and the pitch of the thread to be cut is 1.25 mm. For this condition the change gear ratio is as follows;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{\text{Pitch of the thread to be cut}}{\text{Pitch of the lead screw}} = \frac{1.25}{6} = \frac{1.25 \times 4}{6 \times 4} = \frac{5}{4} \text{X} \frac{1}{6} = \frac{5 \times 10}{4 \times 10} \text{X} \frac{1 \times 20}{6 \times 20} = \frac{50 \times 20}{40 \times 120}$$

Therefore, the driver gears will have 50 teeth & 20 teeth and the driven gears will have 40 teeth & 120 teeth. ***This is effect by compound gear train.***

Thread cutting procedure:

1. The work piece should be rotated in anticlockwise direction when viewed from the tail stock end.
2. The excess material is removed from the workpiece to make its diameter equal to the major diameter of the screw thread to be generated.
3. Change gears of correct size are fitted to the end of the bed between the spindle and the lead screw.
4. The thread cutting tool is selected such that the shape or form of the cutting edge is of the same form as the thread to be generated. In a metric thread, the included angle of the cutting edge should be ground exactly 60^0.
5. Then the tool is mounted in the tool post such that the top of the tool nose is horizontal and is in line with the axis of rotation of the workpiece. This is illustrated in Figure 19.
6. The speed of the spindle is reduced by ½ to ¼ of the speed required for turning according to the type of material being machined.
7. The tool is fed inward until it first scratches the surface of the workpiece. The graduated dial on the cross slide is noted or set to zero. Then the split nut or half nut is engaged and the tool moves along helical path over the desired length.

8. At the end of tool travel, it is quickly withdrawn by means of cross slide. The split nut is disengaged and the carriage is returned to the starting position, for the next cut. These successive cuts are continued until the thread reaches its desired depth (checked on the dial of cross slide).
9. For cutting left hand threads the carriage is moved from left to right (i.e. towards tail stock) and for cutting right hand threads it is moved from right to left (i.e. towards headstock).

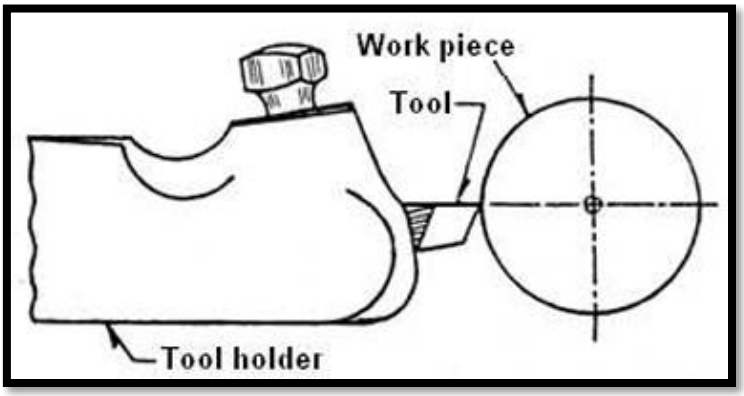


Figure 19: Mounting of the cutting tool

CUTTING PARAMETERS

Cutting speed:

Cutting speed for lathe work may be defined as the rate in meters per minute at which the surface of the job moves past the cutting tool. Machining at a correct cutting speed is highly important for good tool life and efficient cutting. Too slow cutting speeds reduce productivity and increase manufacturing costs whereas too high cutting speeds result in overheating of the tool and premature failure of the cutting edge of the tool. The following factors affect the cutting speed:

1. Kind of material being cut
2. Cutting tool material
3. Shape of cutting tool
4. Rigidity of machine tool and the job piece and
5. Type of cutting fluid being used.

Cutting speed is the speed at which metal is removed by the tool from the work.

$$\boxed{\text{cutting speed} = \frac{\pi DN}{1000}\ \text{meters/min}}$$

Where,

D is diameter of job in mm

N is speed in RPM

Feed:

It is the distance the tool advances for every revolution of the workpiece. It is expressed in mm/rev.

Depth of Cut:

It is perpendicular distance measured from the machined surface to the uncut surface of work. It is expressed in mm

$$\boxed{\text{Depth of cut} = \frac{D_1 - D_2}{2} \text{ mm}}$$

Where, D1 is diameter of work before machining,

D2 is diameter of work after machining.

Machining Time:

$$\boxed{\text{Machining time taken for one pass of cutting} = \frac{\text{Length of the tool travel in mm}}{\text{Feed in mm/ min X RPM}}}$$

Lathe Specifications (Dimensions):

Lathe size is determined by the swing and length of bed. Swing indicates the largest diameter that can be turned over the ways (flat or V-shaped bearing surface that aligns and guides moveable parts of machines). Bed length is entire length of the ways. Bed length must not be mistaken for the maximum length of the work that can be turned between centers. The longest piece that can be turned is equal to the length of the bed minus the distance taken up by the headstock and tailstock.

Maximum Length of Workpiece (A)

This measures the longest workpiece the lathe can accommodate, spanning from the headstock spindle to the tailstock center.

A greater length allows machining of longer parts, making the lathe more versatile.

Maximum Swing over Cross Slide (B)

This defines the largest workpiece diameter that can rotate above the cross slide.

A larger swing over the cross slide enhances the lathe’s ability to handle broader workpieces.

Maximum Swing over Bed (C)

This indicates the largest diameter a workpiece can have while rotating over the bed.

Swing the largest work diameter that can be swung over the lathe bed.

Manufacturers often use this value to classify lathe sizes.

Maximum Cross Slide Travel (D)

This specifies the cross slide’s movement range, affecting the tool’s ability to cut across the workpiece.

A longer travel distance enables wider cuts and increased machining flexibility.

Tailstock Quill Travel (E)

This measures the quill's extension and retraction, crucial for supporting long workpieces. Greater travel provides better stability during drilling and turning operations.

Maximum Longitudinal Travel over Tool Post (F)

This defines the carriage's movement along the bed, impacting how long a cut can be made. A longer travel range allows machining of larger workpieces.

Bed Way Shape and Motor Horsepower:

The design of bed ways influences rigidity and precision. Motor horsepower determines the cutting power and overall efficiency.

Distance Between Headstock and Tailstock Centers:

This measurement affects the maximum workpiece length the lathe can handle.

Lathe Classification by Swing and Bed Length:

Some manufacturers define lathe models based on swing diameter and bed length, making it easier to compare machines.

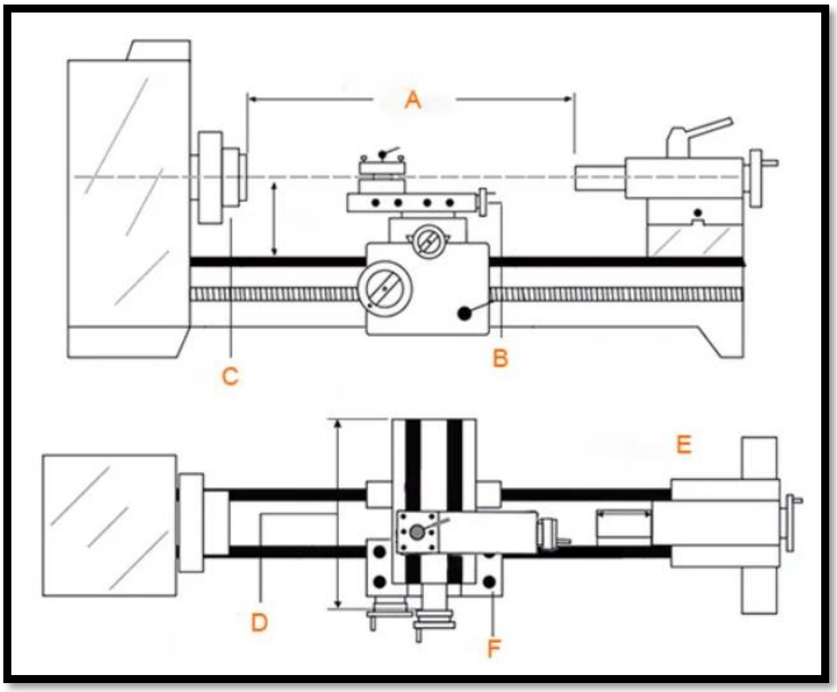


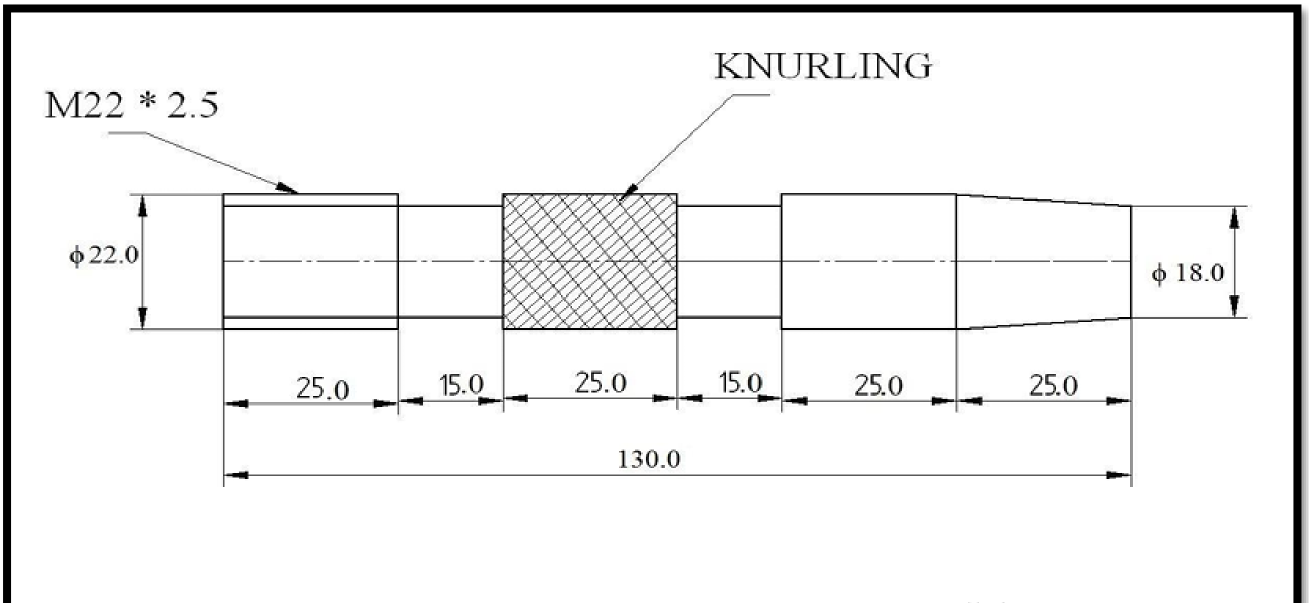
Figure 20: Specifications of a Lathe

EXPERIMENT NO. 6: Machining by plain turning, taper turning, step turning, eccentric turning & knurling

AIM: To perform machining by plain turning, taper turning, step turning, eccentric turning & knurling operation on the given work piece.

MATERIAL REQUIRED: Mild steel rod of 25 mm diameter and 150 mm long.

TOOLS REQUIRED: Vernier callipers, steel rule, spanner, chuck spanner, and H.S.S. single point cutting tool.



All dimensions are in mm

PROCEDURE:

1. Hold the job in self-centering 3 jaw chuck firmly with enough overhang to work on the job on the other side; face and counter sink one end.
2. Reverse and face to size 150mm and countersink the other end.
3. Hold the job in chuck, support the other end with revolving center fixed in tailstock; turn ϕ22×150mm long (approximately). Turn steps ϕ18×23 mm, ϕ18×23 mm.
4. To perform taper turning as per the drawing. Using the equation

$$\boxed{\tan\alpha = \frac{D-d}{2l}}$$

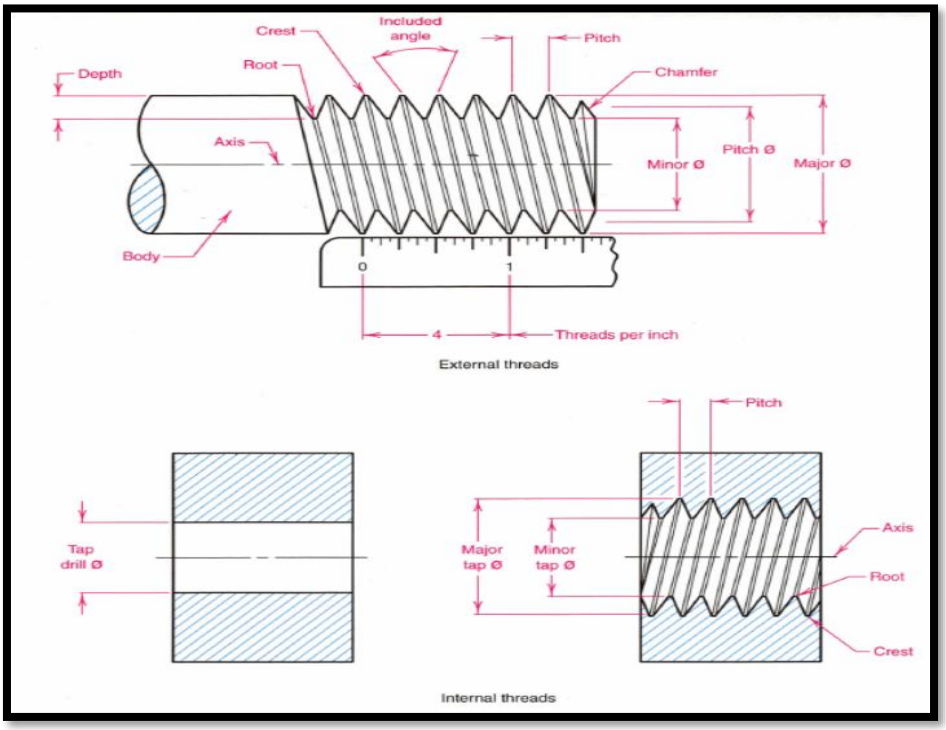
5. Step turn ϕ 17.5×15 mm and cut M22×2.5pitch×30mm thread and knurl as per the drawing.
6. Inspect the job.

EXPERIMENT NO. 7: Machining by internal and external thread cutting

AIM: To perform internal and external thread cutting operation on the given work piece.

MATERIAL REQUIRED: Mild steel rod of 25 mm diameter and 150 mm long.

TOOLS REQUIRED: Vernier callipers, steel rule, spanner, chuck spanner, Threading and tapping tool.



Procedure:

1. Workpiece: Securely mount the workpiece in the lathe chuck or between centers. Ensure the diameter is machined to the thread's major diameter.
2. Threading Tool: Select a threading tool with the correct profile for the desired thread (e.g., 60° for metric threads) and set it to the center height of the lathe.
3. Angle Setting: Set the compound rest at the correct angle (e.g., 29° for Acme threads, or half the thread angle for other types) relative to the lathe axis.
4. Gear Ratio: Set the quick-change gearbox to the correct ratio for the desired thread pitch.
5. Speed: Start with a slow speed for the initial cuts, gradually increasing it as you become more comfortable.

Cutting Process:

1. First Cut: Advance the threading tool into the workpiece until it makes a light scratch or groove, marking the start of the thread.
2. Engaging the Lead Screw: Engage the half-nut (or split-nut) lever to connect the carriage to the lead screw, allowing it to move along the workpiece as it rotates.
3. Subsequent Cuts:

4. Take light cuts with the cross-slide, advancing the tool slightly for each pass. Disengage the half-nut and return the carriage to the starting point after each cut.
5. Thread Dial: Use a thread dial to ensure accurate re-engagement of the half-nut on the correct thread groove for subsequent cuts.
6. Depth of Cut: Gradually increase the depth of cut with each pass until the desired thread depth is achieved.
7. Finishing: Take a few final light cuts to clean up the thread and ensure accuracy.

Internal Threading:

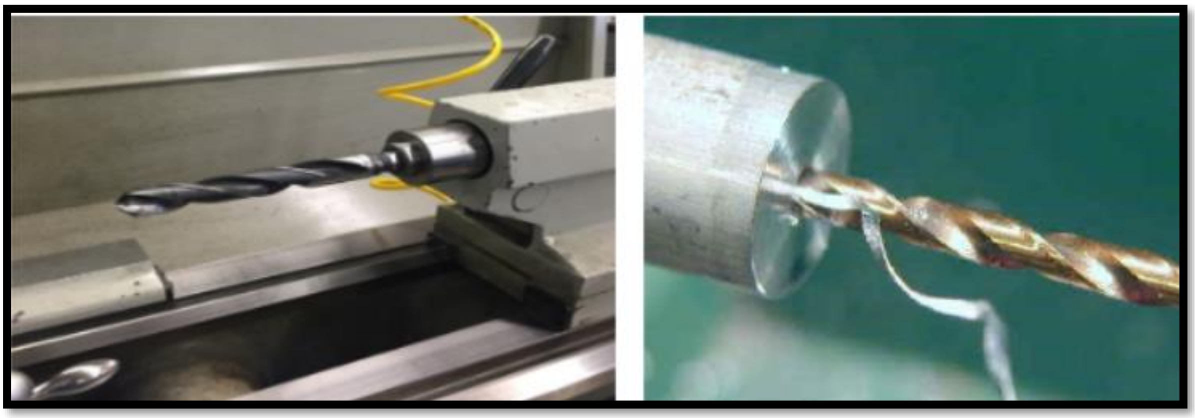
1. Follow the same general procedure as external threading, but use a boring bar with a threading insert or a ground threading tool.
2. Ensure the hole is bored to the correct diameter before threading.
3. Use a thread gauge or thread plug gauge to verify the internal thread's accuracy.

EXPERIMENT NO. 7: Machining by drilling and boring operation

AIM: To perform drilling and boring operation on the given work piece.

MATERIAL REQUIRED: Mild steel rod of 25 mm diameter and 150 mm long.

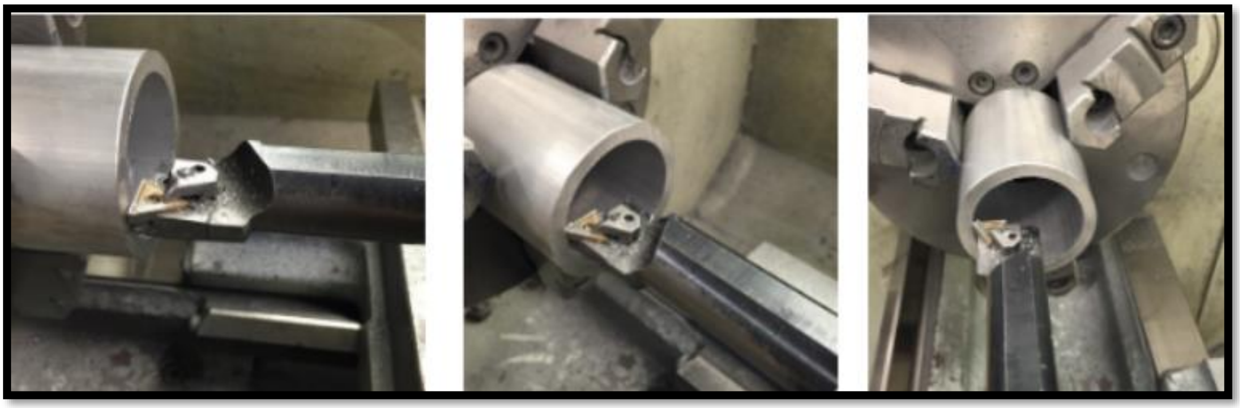
TOOLS REQUIRED: Vernier callipers, steel rule, spanner, chuck spanner, drill bit and boring tool.



Procedure:

1. Mount the drill chuck into the tailstock.
2. Mount workpiece true in a chuck.
3. Check the tool stock center and make sure it is in line.
4. Ensure that the tang of the drill chuck is properly secured in the tailstock.
5. Move and lock the tailstock to the desired position.
6. Before turning the machine on, turn the spindle by hand to make sure parts do not interfere with spindle rotation.
7. Start the hole using a spotting or center drill tool bite.
8. When using a center drill, always use cutting fluid along with it.
9. A center drill doesn't cut as easily as a drill bit would, as it has shallow flutes for added stiffness.
10. Drill past the entirety of the taper to create a funnel to guide the bit in.
11. Mount the drill in the tailstock spindle, in a drill chuck or in a drill holder.
12. Set the lathe to the proper speed the type of material to be drilled.
13. Start the lathe and drill to the desired depth according to the blueprint drawing, applying cutting fluid.
14. To gauge the depth of the hole, use the graduations on the tailstock spindle, or use a steel rule to measure the depth.
15. Use the peck drill operation to remove the chips and measure the depth of the hole.
16. When drilling, take off at most one or two drill bit diameters worth of material before backing off, clearing chips, and reapplying cutting fluid.
17. If the drill bit squeaks against the stock, apply more cutting fluid.

18. To remove the drill chuck from the tailstock, draw it back by around a quarter turn more than it will easily go.



Boring is an operation to enlarge and finish holes accurately. Truing of a hole by removing material from internal surfaces with a single point tool bit cutter. Special diameter holes, for which no drills are available, can be produced by boring.

Boring utilizes a single point cutting tool to enlarge a hole. This operation provides for more accurate and concentric hole, as opposed to drilling.

Since the cutter extends from the machine from a boring bar, the tool is not as well-supported, which can result in chatter. The deeper the boring operation, the worse the chatter. To correct this:

1. Reduce the spindle speed.
2. Increase the feed.
3. Apply more cutting fluid.
4. Shorten the overhang of the boring bar.
5. Grind a smaller radius on the tool's nose.

Procedure:

1. Mount the workpiece in a chuck.
2. Face, spot and drill the hole on the workpiece.
3. Check to see if the boring bar has enough clearance.
    - If the hole is too small for the boring bar, the chips will jam while machining and move the bar off-center.
4. Make sure that the point of the boring tool is the only part of the cutter than contacts the inner surface of the workpiece.
5. If the angle does not provide sufficient end relief, replace the cutter with one that has a sharper angle.
6. Position the boring bar so the point of the cutter is positioned with the centerline of the stock.
7. A tool that is not placed in line with the center of the workpiece will drag along the surface of stock, even if there is a sufficient end relief angle.

8. Select a boring bar as large as possible and have it extended beyond the holder only enough to clear the depth of the hole to be bored.

9. Mount the holder and boring tool bar with the cutter tool bit on the left-hand side of the tool post and revolving the workpiece.

10. Set the boring tool bit to center.

- Note: Depending on the rigidity of the setup, the boring tool bit will have a tendency to spring downward as pressure is applied to the cutting edge. By setting the boring tool bit slightly above center, compensation has been made for the downward spring and the tool bit will actually be positioned on the exact center of the workpiece during machining operations.

11. Set the lathe to the proper cutting speed and feed. a. Note: For feedrate select a medium feed rate.

12. Apply lube to the hole before turning the machine on.

13. Turn the machine on and move the tool into the pre-drilled hole.

14. Start the lathe and slowly bring the boring tool until it touch the inside diameter of the hole.

15. Take a light cut (about .003 in.) and about -375 long.

16. Stop the lathe and measure the hole diameter, use a telescopic gauge or inside micrometer.

17. After measure the hole, determine the amount of material to be removed from the hole. Leave about .020 in a finish cut.

18. Start the lathe and take the roughing cut.

19. Feed the boring bar into the workpiece, taking off about .020 on each pass.

20. Bring the boring bar out once the desired depth has been reached.

21. Repeat steps 19 and 20 until the desired diameter of the inside hole has been attained.

22. After roughing cut is completed, stop the lathe and bring the boring tool bit out of the hole without moving the cross-feed handle.

23. Set the depth of the finish cut and bore the hole to size. For a good surface finish, a fine feedrate is recommended.

24. On the last pass, stop at the desired depth and bring the cutter back towards the center of the stock. This will face the back of the hole.

25. Bring the boring bar out of the machine and stop the machine.

Demonstration Experiments (For CIE):

EXPERIMENT No: 1 Ultrasonic flaw detection

Aim: To study the ultrasonic flow detector and to determine the location of the interior crack or cavity in the given specimen.

Ultrasonic Flaw Detector – Theory:

An ultrasonic flaw detector is a non-destructive testing device used to identify internal discontinuities within a material. It operates on the principle of sound wave reflection, also known as the echo or back reflection phenomenon. When ultrasonic waves are transmitted into a material, a portion of the sound is instantly reflected from the entry surface, producing a strong initial echo. The remaining sound travels deeper into the material and is partially reflected from the back surface, creating a second echo.

If there is a flaw or discontinuity inside the material, some of the sound waves will reflect from that defect and return to the receiver as an additional echo, appearing between the front and back surface echoes. These echoes are displayed on a cathode ray tube (CRT), which includes a time base to indicate the distance between the probe and the reflecting surface, based on the echo's position on the screen.

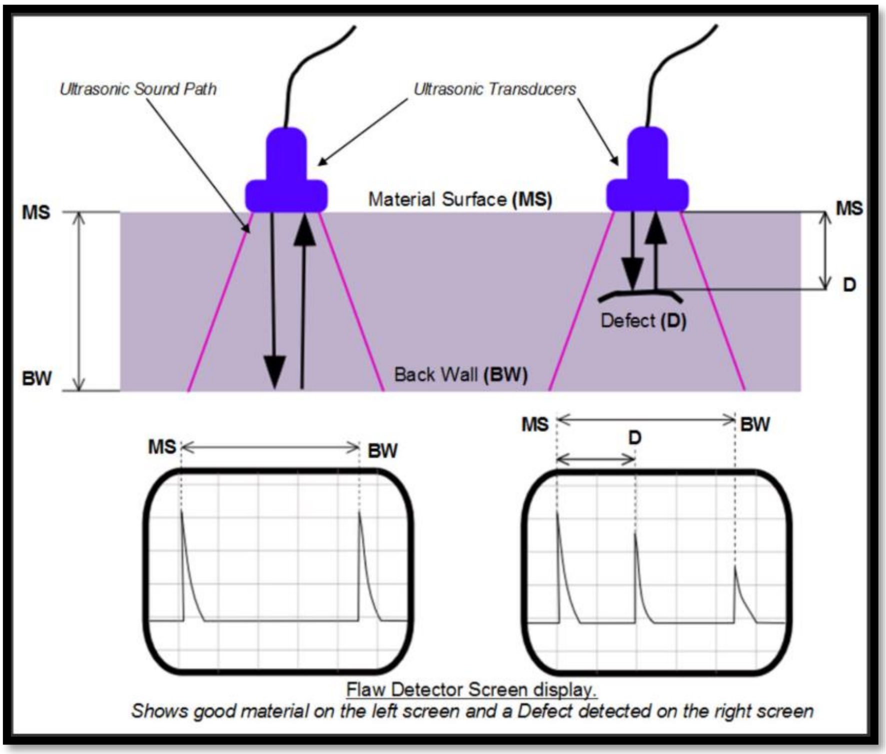


Figure: Ultrasonic Flaw Detector

Ultrasonic waves have frequencies above 20,000 cycles per second (cps), making them inaudible to the human ear. These high-frequency sound waves are generated by a piezoelectric crystal, which is electrically pulsed and vibrates at its natural frequency. To ensure proper transmission of sound from the crystal to the test material, a liquid couplant—typically a thin film of oil—is applied between the two surfaces.

A single crystal probe is used both to emit and receive the ultrasonic waves. After emitting a brief pulse, the crystal stops vibrating and listens for returning echoes. This transmit-receive cycle is repeated at a variable rate, typically between 100 and 1000 times per second.

Interpretation of CRT Display in Ultrasonic Testing:

When returning echoes are displayed on the cathode ray tube (CRT), they appear as short vertical spikes known as **pips**. These pips are aligned along the baseline and are spaced according to the time it takes for each echo to return. Since ultrasonic waves travel through the material at a constant speed, the spacing between the pips is directly related to the thickness of the material.

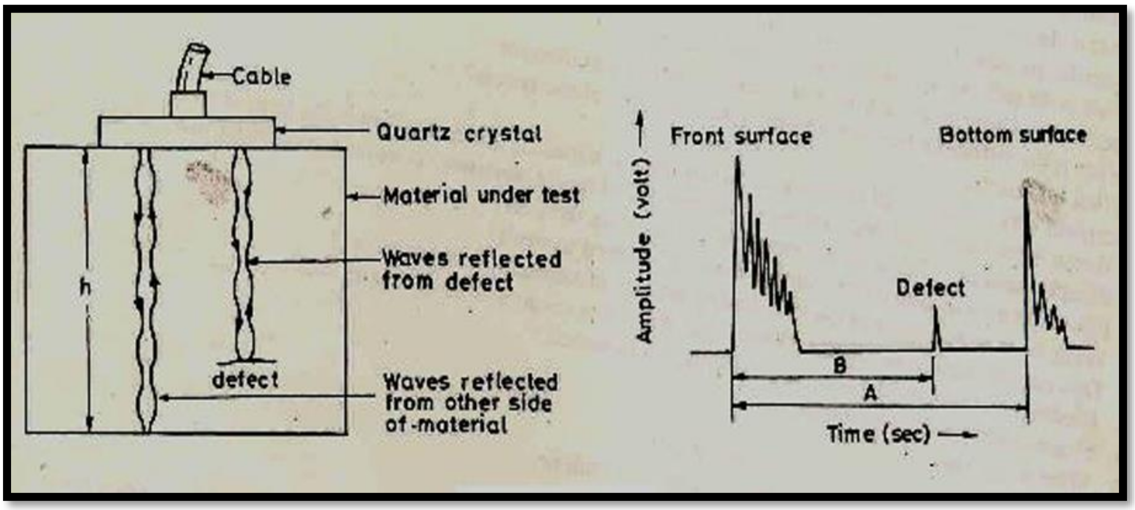
Unwanted echoes caused by internal reverberations can sometimes interfere with accurate readings. These can be minimized by adjusting the CRT settings to expand the display to full screen, which helps isolate the meaningful echoes.

To locate a flaw within the material, consider the following:

- Let **A** be the time interval between the pips from the front surface and the back surface echoes (in seconds).
- Let **B** be the time interval between the pips from the front surface and the echo from a defect or cavity (in seconds).
- Let **h** be the total thickness of the test specimen (in millimeters).

The distance **x** of the defect from the front surface is then calculated using the formula:

$$x = (B / A) \times h$$



Procedure:

1. Thoroughly clean the surface of the test specimen to ensure proper contact.
2. Apply a thin film of oil as a couplant, and place the probe firmly against the surface.
3. Turn on the power supply for the ultrasonic wave generator.

4. Set the desired frequency for transmitting and receiving the ultrasonic pulses.
5. Adjust the time base on the CRT to display the segment that contains the relevant echo pips.
6. Observe the CRT screen for echo signals, including any that indicate internal cavities or flaws, and measure the distances between pips along the time axis to analyze their positions.

EXPERIMENT No: 2 MAGNETIC CRACK DETECTION TEST

Aim: To detect the surface or subsurface crack of the given ferromagnetic material.

Apparatus: Magnetic field generator, and ferromagnetic powder.

Theory: Magnetic Particle Inspection

Magnetic particle inspection is a non-destructive testing method used to detect surface and near-surface defects in ferromagnetic materials. The process involves applying fine ferromagnetic particles to the surface of the test object. These particles can be used in dry form or suspended in a liquid carrier, such as water or kerosene.

When the object is magnetized, any discontinuity—such as a crack or flaw—disrupts the magnetic field, causing a phenomenon known as **flux leakage**. This leakage attracts the magnetic particles, which gather visibly around the defect, effectively outlining its shape and size. In this way, the defect itself behaves like a small magnet.

While the method is most effective for surface defects, it can also reveal shallow subsurface flaws. To enhance visibility, the magnetic particles are often colored with pigments, making them easier to see against the metal surface.

Magnetic fields for the test can be produced using either direct current (DC) or alternating current (AC), with devices like magnetic yokes, bars, or coils. The equipment used for this inspection can be either portable for field use or stationary for controlled environments.

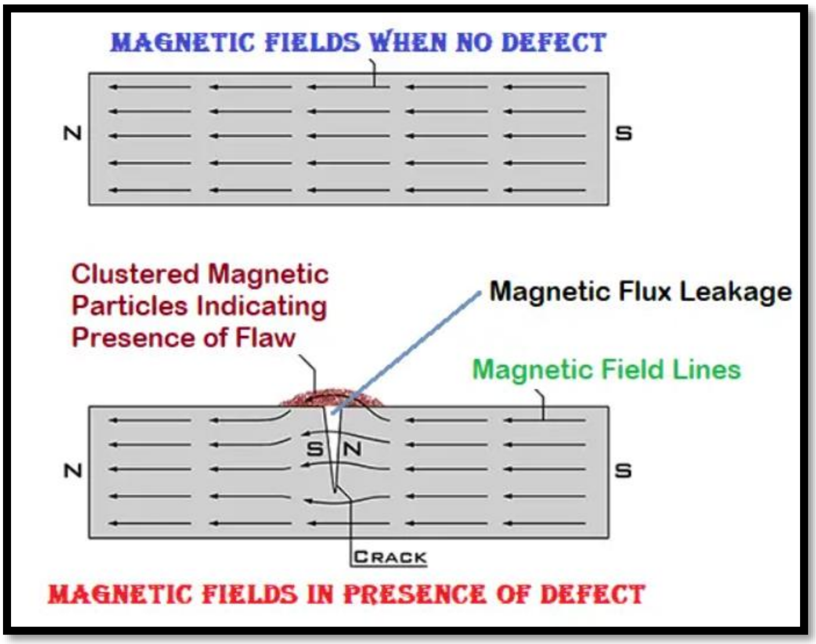


Figure: Principle of Magnetic Particle Inspection

Procedure:

1. Thoroughly clean the surface of the test specimen to remove any scale, oil, grease, or other contaminants.
2. Magnetize the test specimen using an appropriate method (e.g., yoke, coil, or bar).

3. Apply a thin, even layer of ferromagnetic particles to the area being inspected—either in dry form or suspended in a liquid carrier.
4. Observe the accumulation of magnetic particles. The pattern they form will indicate the presence, shape, and size of any surface or near-surface defects.

EXPERIMENT No: 3 Additive Manufacturing

Additive Manufacturing (AM):

Additive Manufacturing, commonly known as 3D printing, is a modern manufacturing process in which objects are built layer by layer directly from a digital model. Unlike traditional subtractive methods, which remove material from a solid block, AM adds material only where needed, making it highly efficient and versatile.

The process begins with creating a 3D model using computer-aided design (CAD) software. This model is then sliced into thin horizontal layers, and the AM machine follows these layers to deposit material—such as plastic, metal, resin, or composite—one at a time until the final object is formed.

There are several types of additive manufacturing techniques, including:

- Fused Deposition Modeling (FDM) – uses thermoplastic filaments melted and extruded layer by layer.
- Stereolithography (SLA) – uses a UV laser to cure liquid resin into solid layers.
- Selective Laser Sintering (SLS) – uses a laser to sinter powdered material.
- Direct Metal Laser Sintering (DMLS) – similar to SLS but used for metals.

Advantages of Additive Manufacturing:

- Allows for complex and customized designs.
- Reduces material waste.
- Shortens the time from design to production.
- Enables on-demand manufacturing and rapid prototyping.

Applications:

Additive manufacturing is used across various industries including aerospace, automotive, healthcare (prosthetics, implants), consumer products, and architecture. It’s especially valuable in producing low-volume, high-complexity parts that would be difficult or impossible to make with conventional methods.

As technology advances, AM continues to transform the manufacturing landscape by offering greater design freedom, reduced production costs, and new possibilities for innovation.

Detailed Steps in Additive Manufacturing (3D Printing):

Additive Manufacturing involves a systematic sequence of steps, from digital design to the final physical product. Here's a breakdown of the process in detail:

1. Conceptualization and 3D Modeling

- **Objective:** Develop a digital representation of the object.
- **Tools:** Computer-Aided Design (CAD) software such as SolidWorks, AutoCAD, or Fusion 360.

- **Details:** The part is designed in 3D, considering functionality, dimensions, tolerances, and material behavior. Complex geometries, internal structures, and optimized designs (e.g., lattice structures) can be easily incorporated.

2. Conversion to STL File

- **Objective:** Translate the 3D model into a format the printer can understand.
- **File Format:** The 3D model is exported as an STL (Stereolithography) file.
- **Details:** The STL file approximates the shape using triangles. Higher resolution models use more triangles for better detail but result in larger files.

3. Slicing the Model

- **Objective:** Convert the STL file into layers and generate printing instructions.
- **Tool:** Slicing software (e.g., Cura, PrusaSlicer, or Simplify3D).
- **Details:**
    - The model is divided into horizontal layers.
    - Parameters such as layer thickness, print speed, infill density, and support structures are set.
    - The software generates **G-code**, which provides the printer with specific movement and extrusion instructions.

4. Material Selection and Preparation

- **Objective:** Choose and load the appropriate material.
- **Materials:** Depends on the printing process – common options include:
    - **Plastics:** PLA, ABS, PETG (used in FDM)
    - **Resins:** Photopolymers (used in SLA/DLP)
    - **Metals:** Titanium, stainless steel, aluminum (used in DMLS/SLM)
    - **Composites & Ceramics**
- **Details:** Materials may come in filament spools, resin vats, or powder form. Proper handling and safety precautions are essential.

5. 3D Printing / Layer-by-Layer Fabrication

- **Objective:** Build the physical object layer by layer.
- **Process:** The 3D printer reads the G-code and starts building the object.
- **Details:**
    - Each layer is added on top of the previous one.
    - Some processes require curing (e.g., with light or laser), melting, or sintering.
    - Printing time varies based on the part size, complexity, and layer height.

6. Post-Processing

- **Objective:** Improve the appearance, functionality, or mechanical properties of the part.

- **Steps Involved:**
    - **Support Removal:** Break away or dissolve support structures.
    - **Cleaning:** Remove uncured resin, loose powder, or excess material.
    - **Curing (for resins):** Additional UV curing for strength and stability.
    - **Surface Finishing:** Sanding, polishing, or coating for a smoother finish.
    - **Heat Treatment (for metals):** Relieve stress and improve strength.

7. Inspection and Testing

- **Objective:** Ensure the final product meets design and quality specifications.
- **Methods:**
    - **Visual inspection** for defects.
    - **Dimensional accuracy** checks using calipers, CMM, or 3D scanning.
    - **Mechanical testing** (e.g., tensile, hardness tests) if required.
    - **Non-destructive testing** (e.g., ultrasonic, X-ray for metal parts).

8. Final Use or Assembly

- **Objective:** Deploy the part in its intended application.
- **Details:** The printed part may be a final product, a prototype, or a component in a larger assembly.

Additive manufacturing's flexibility and efficiency make it a powerful tool for innovation, especially where complex geometry, customization, or rapid development are required.

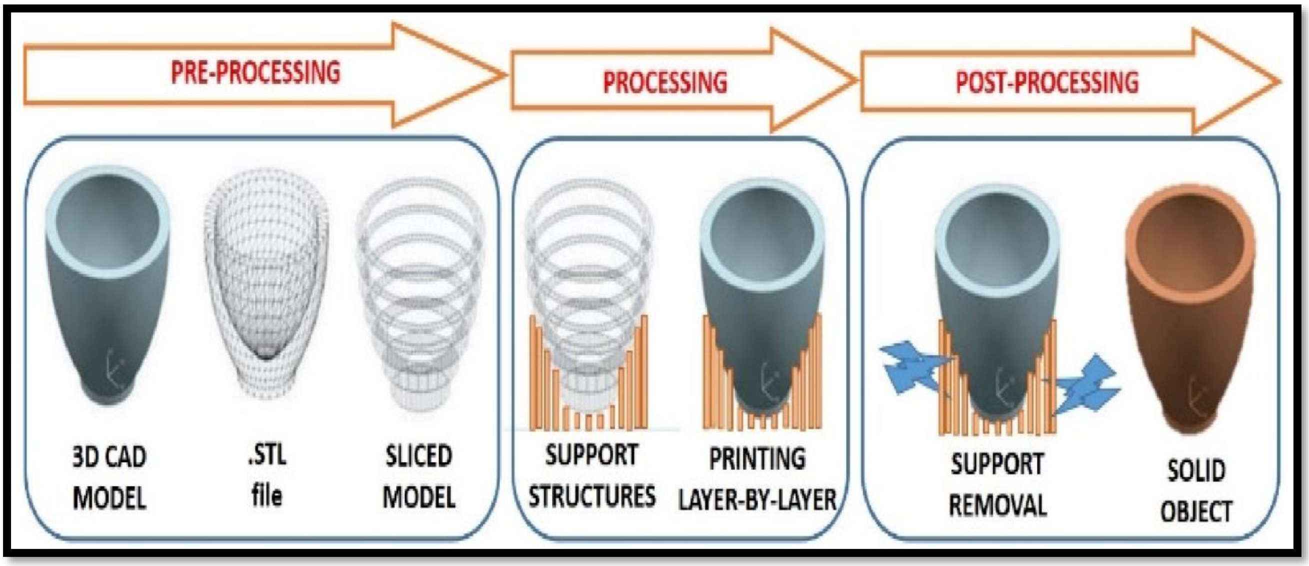


Figure: Detailed Steps in Additive Manufacturing

VIVA QUESTIONS

1. Define Metallography?
2. What are the equipments used to study of microstructure?
3. What is main objective of the Material-testing lab?
4. What is meaning of stress?
5. What is the meaning of strain?
6. Explain the tensile and compression processes in materials?
7. What is Izod Impact test?
8. Briefly explain Izod Impact test experiment?
9. Briefly explain Charpy Impact test experiment?
10. What is fracture energy, impact energy and impact strength?
11. What is angle of fall in Izod & Charpy Impact experiment?
12. What is Hardness?
13. What is meaning of Brinell's and Rockwell's hardness testing?
14. What is Indentor?
15. How many types of Indentor?
16. Define Torsion?
17. What are the parts in torsion testing machine?
18. Write Torsion equation and explain?
19. What is Modulus of toughness and modulus of rigidity?
20. What is shear strength and ultimate shear strength?
21. What is resilience and modulus of resilience?
22. What are the parts in Universal testing machine?
23. What are the equipments required for Universal testing machine to conduct tensile, compression, and shear stress?
24. Write stress verses strain graphs for mild steel, copper and aluminum?
25. What is meaning of gauge length?
26. What is Caliper and it's function?
27. How many types of caliper?
28. What are the characteristics properties of all materials?
29. Which type of powder is used for polishing of material?
30. What are the applications of Material Testing Laboratory?

I. General Machine Shop & Safety:

- What is a machine shop?
- What are the different types of machine tools found in a machine shop?
- What safety precautions should be followed in a machine shop?
- What are the different types of cutting tools used in a machine shop?
- What are the differences between instruments and tools?
- What are the uses of different types of hammers, chisels, and vices?
- What are common measuring instruments used in fitting?
- What is the function of a divider?

II. Lathe Machine:

- What is a lathe machine?
- What is the working principle of a lathe machine?
- What are the principal parts of a lathe? (e.g., headstock, tailstock, carriage)
- What are the different types of headstocks?
- What are the different types of tool posts?
- What is the function of the apron?
- What are the different operations that can be performed on a lathe? (e.g., turning, facing, knurling)
- What is conicity?
- What are the specifications of a lathe?
- What are the different types of lathes?
- What is a semi-automatic lathe?
- What are the different feed mechanisms used in a lathe?
- What are some common holding devices used on a lathe?
- What are the advantages of a capstan lathe and turret lathe?
- What is tooling in the context of a lathe?

IV. Milling Machine:

- What are the specifications of a milling machine?
- What are the different types of milling cutters?
- What are the different operations performed on a milling machine?
- What is indexing in milling?
- What is a universal dividing head?
- What is cam milling?
- How is a spur gear cut on a milling machine?
- What are cutter holding devices used in a milling machine?