Measurements and Metrology

Lec.1

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Second semester

Manufacturing Processes(1)

What is Metrology?

Metrology is defined as the science of measurement. It encompasses the study of measurement units, techniques, systems, and tools used to ensure the accuracy and precision of measurements.

The ultimate goal of metrology is to ensure reliable measurement results, allowing industries to develop quality products and maintain consistent manufacturing standards.

Metrology involves experimental and theoretical determinations, ensuring measurements are traceable to recognized international standards

Technical Terms

Range : It represents the highest possible value that can be measured by an instrument.

Accuracy :It is defined as the closeness with which the reading approaches an accepted standard value or true value.
it is also defined as the lowest reading that a device or instrument can read.

Precision :It is the degree of reproducibility among several independent measurements of the same true value under specified conditions. It is usually expressed in terms of deviation in measurement.

Calibration: is the process of determining and adjusting instruments accuracy to make sure its accuracy is within the manufacturer's specifications.

What is Measurement?

Measurement is the process of assigning a number to a physical property such as length, weight, temperature, or time-based on a standard unit using appropriate tools.
It’s a fundamental concept in both science and daily life
For example:

- A ruler measures length in centimeters or inches
- A scale measures weight in grams or kilograms
- A thermometer measures temperature in Celsius or Fahrenheit

Measurement is the technique of determining the value of a physical quantity by comparing it to a known standard using measuring instruments.

Measurement Types and Common Units

Measurement Type	Common Units
Length	mm, cm, m, km
Weight	g, kg, ton
Time	sec, min, hr, day, year
Temperature	°C, °F, K
Volume	ml, l, cm^3, m^3

Conversion between units is often required and can be done using simple mathematical formulas or conversion calculators.

Methods of Measurements

l. Direct method
2. Indirect method
3.Comparative method

1. **Direct method of measurement:** This is a simple method of measurement, in which the value of the quantity to be measured is obtained directly without any calculations. For example, measurements by using scales, vernier callipers, micrometers, bevel protector etc.

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2. Indirect method of measurement: In indirect method the value of quantity to be measured is obtained by measuring other quantities which are functionally related to the required value. E.g. Angle measurement by sine bar, measurement of screw pitch diameter by three wire method etc

3.Comparative method: In this method the value of the quantity to be measured is compared with known value of the same quantity or other quantity practically related to it. So, in this method only the deviations from a master gauge are determined, e.g., dial indicators, or other comparators.

Accuracy of Measurements

The purpose of measurement is to determine the true dimensions of a part. But no measurement can be made absolutely accurate. There is always some error. The amount of error depends upon the following factors:

• The accuracy and design of the measuring instrument • The skill of the operator
• Method adopted for measurement
• Temperature variations
• Elastic deformation of the part or instrument etc.

If the measurement of dimensions of a part approximates very closely to the true value of that dimension, it is said to be accurate.

Errors in Measurements

The error in measurement is the difference between the measured value and the true value of the measured dimension.

Error in measurement = Measured value - True value

The error in measurement may be expressed or evaluated either as an absolute error or as a relative error.

The accuracy of measurement, and hence the error depends upon so many factors, such as:

- calibration standard
- Work piece
- Instrument
- Person
- Environment.

LINEAR MEASURING INSTRUMENTS

Linear measurement applies to measurement of lengths, diameter, heights and thickness including external and internal measurements.

The instruments used for linear measurements can be classified as:

1. Direct measuring instruments
2. Indirect measuring instruments

The Direct measuring instruments are of two types:

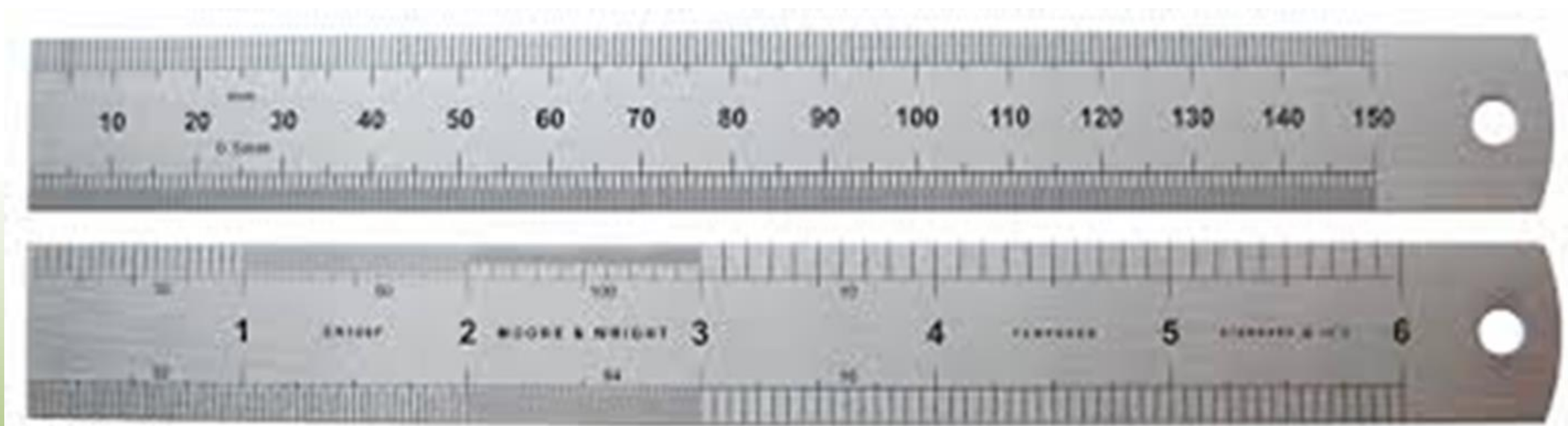
1. Graduated
2. Non Graduated

Graduated measuring devices include a set of markings (graduations) on a linear or angular scale to which the object's feature of interest can be compared for measurement include rules, vernier calipers, micrometers, dial indicators etc.

Non-graduated measuring devices are used to make comparisons between dimensions or to transfer a dimension for measurement by a graduated device include calipers, surface gauges, straight edges, screw pitch gauges, slip gauges etc.

The most basic of the graduated measuring devices is **the rule** (made of steel, and called **a steel rule**), used to measure linear dimensions.

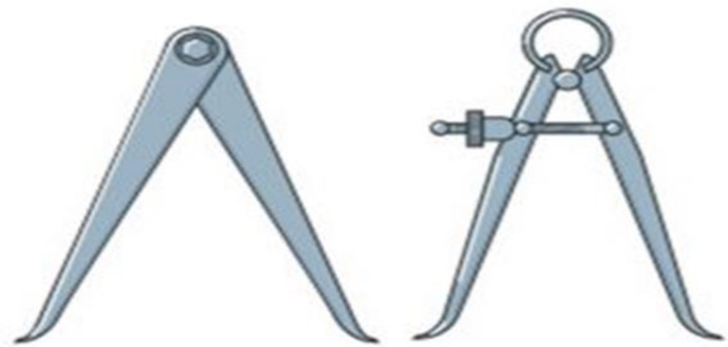
Rules are available in Metric rule lengths include 150, 300, 600, and 1000 mm, with graduations of 1 or 0.5 mm.



A tape measure or measuring tape is a long, flexible ruler used to measure length or distance.
It usually consists of a ribbon of cloth, plastic, fibreglass, or metal (usually - hard steel alloy) strip with linear measurement markings

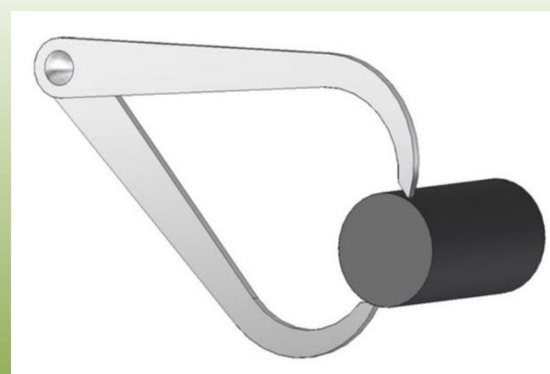
Calipers

Caliper measuring tools are comparators, used for transferring a dimension from one place to another.



The instruments are:

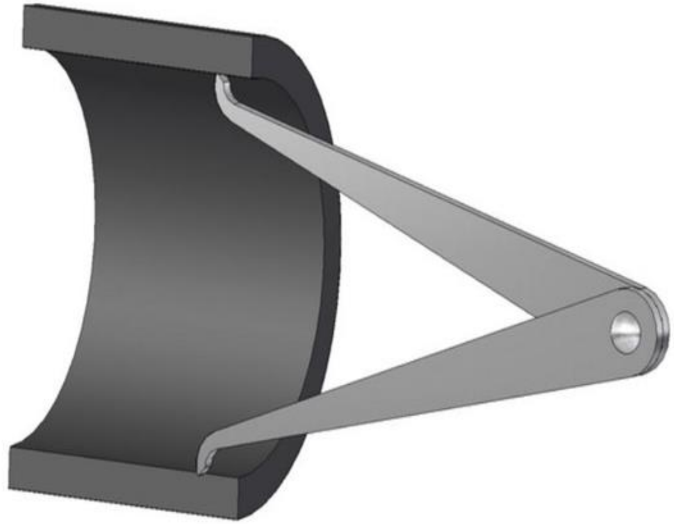
- Outside caliper, when they point inward, and is used for measuring outside dimensions such as a diameter, as in image

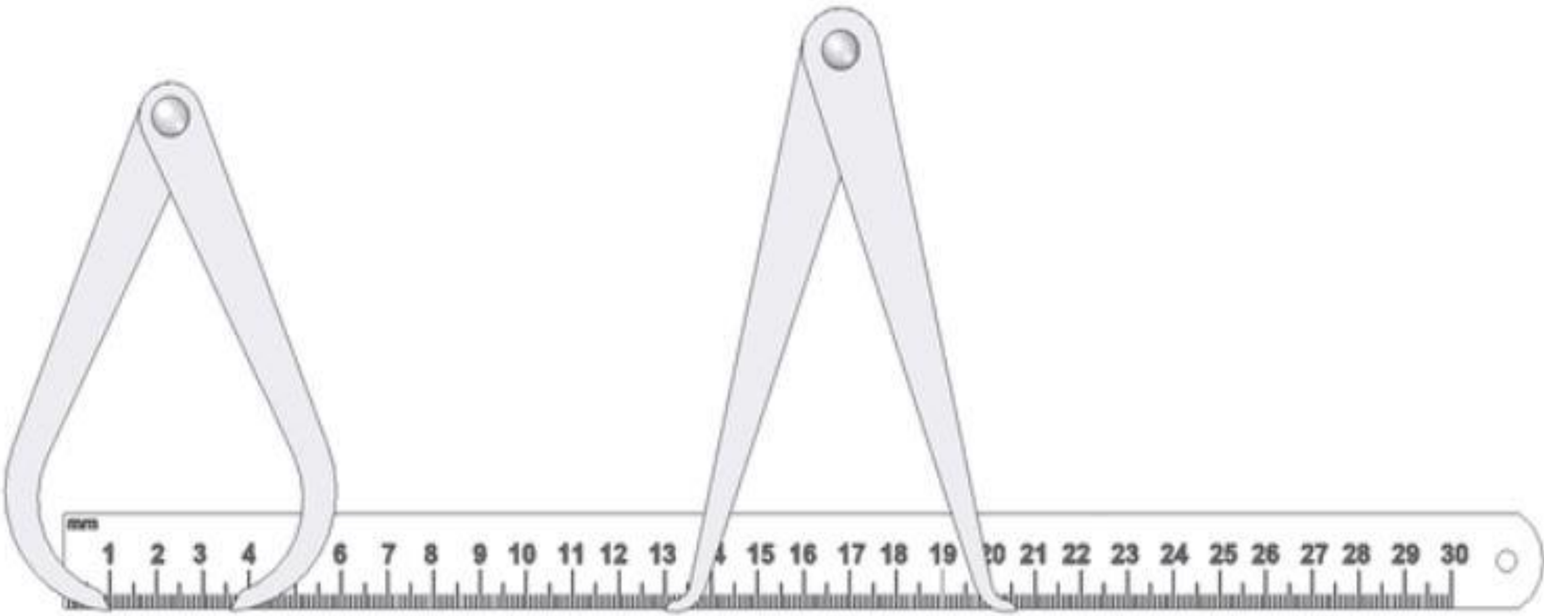


- Inside caliper, when the contacts point out ward, which is used to measure the distance between two internal surfaces.

- Divider is a similar to the caliper, except that both legs are straight and terminate in hard, sharply pointed contacts.

Dividers are used for scaling distances between two points or lines on a surface, and for scribing يخدش circles or arcs onto a surface




mm
1 2 3 4 6 7 8 9 10 11 12 13 15 16 17 18 19 21 22 23 24 25 26 27 28 29 30

Thank you

CALIPERS

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Manufacturing Processes(1)

SIMPLE CALIPERS

A variety of graduated calipers are available for various measurement purposes; The simplest is **the slide caliper**, which consists of a steel rule to which two jaws are added, one fixed at the end of the rule and the other movable, shown in Fig. 1.1.

- An improvement of the slide caliper is the vernier caliper قدمة ذات الورنية, shown in Figure 1.2. The vernier provides graduations of 0.01mm in the SI (and 0.001 inch in the U.S. customary scale.

Fig. 1.1 Slide caliper, opposite sides of instrument shown

A vernier caliper

A vernier caliper is used to measure internal or external dimensions or to measure depths.

Parts of a Vernier Caliper

1.Main Scale

The main scale is a metal strip marked in centimeters on one side and inches on the other, and it carries the inner and outer jaws. When the jaws are closed, the zero of the main scale should align with the zero of the Vernier scale; otherwise, a positive or negative zero error occurs.

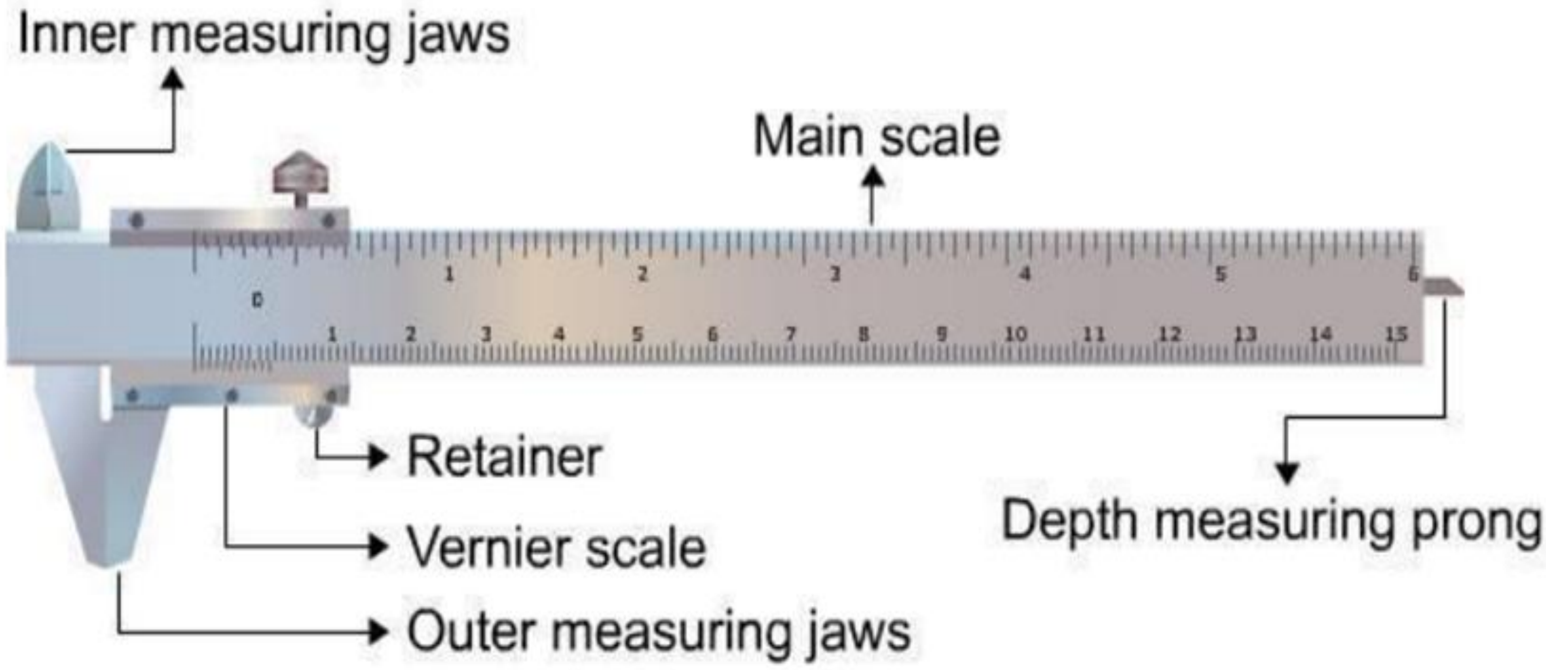


Figure 1.2 : the vernier caliper

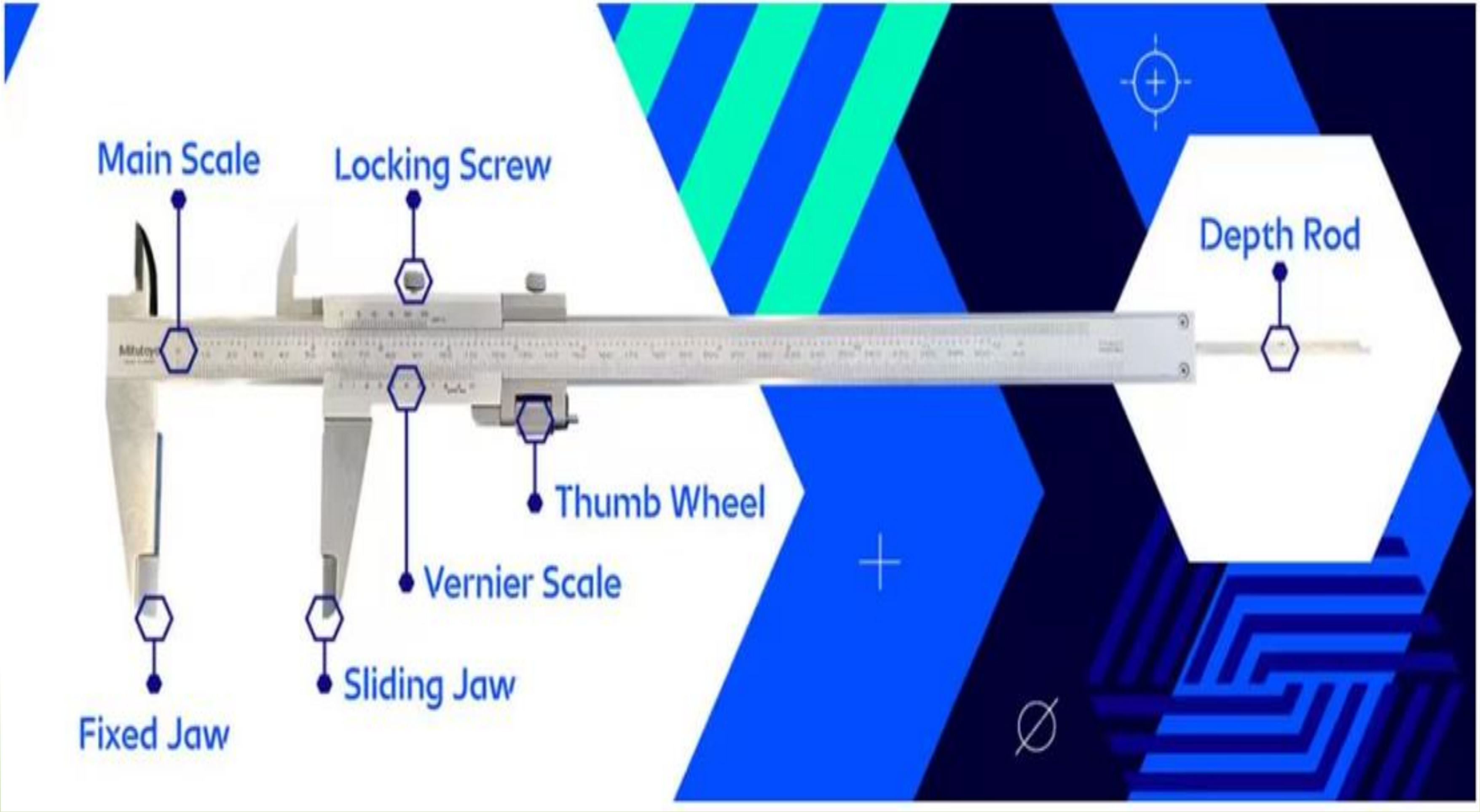
2. Vernier Scale

A vernier scale slides on the strip. It can be fixed in any position by the retainer. On the Vernier scale, 0.9 cm is divided into ten equal parts.

3. Outer Measuring Jaws The outer measuring jaws helps to take the outer dimension of an object

- Fixed Jaw : The fixed jaw is attached to the caliper's body and serves as the stationary reference point for both external and internal measurements. It's meticulously machined to ensure flatness and precision.

- Sliding Jaw : The sliding jaw, attached to the vernier scale, works in tandem with the fixed jaw to provide the measuring area. It can clamp around an object's exterior for external measurements or expand into an object for internal measurements.



4. Inner Measuring Jaws

The inner measuring jaws helps to take the inner dimension of an object.

5. Retainer

The retainer helps to retain the object within the jaws of the Vernier calipers.

6. Depth

Measuring Prong The depth measuring prong helps to measure the depth of an object.

Calipers also differ in their **measuring range**.
The measuring range of a caliper refers to the maximum length a caliper can measure.

Measuring range = Length of the caliper's shaft - Length of the vernier scale

Example 1: A measuring caliper, the length of the graduated stem is (150) mm, and the length of the vernier scale is (9) mm divided into (10) divisions. What is its accuracy? And what is its measurement range?

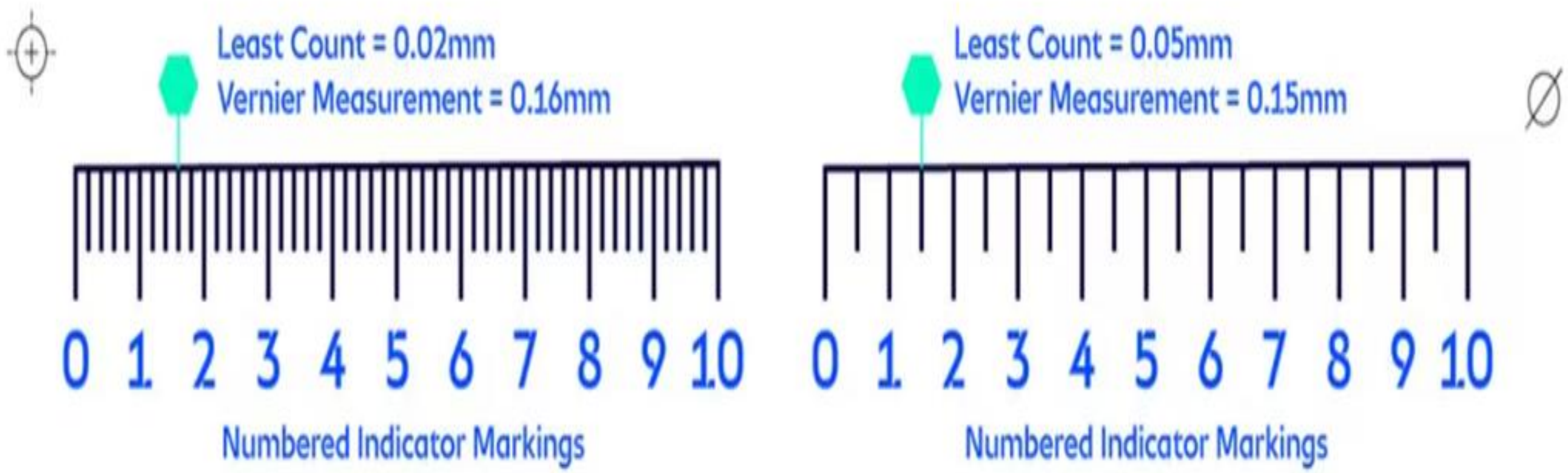
<u>Least Count</u>

the least count refers to the smallest measurement that can be obtained with the caliper, often known **<u>as its accuracy.</u>**

$$\text{Least Count} = \frac{\text{One Main scale(MS) division}}{\text{Number of divisions in Vernier Scale}}$$

For example, if the units on the main scale are measured down to millimetres and there are 50 markings on the vernier scale, that would be 1mm divided by 50.

So, the least count would be **0.02mm** meaning each individual mark on the vernier scale measures 0.02mm.



The Formula for Reading the Vernier Caliper

Total Measurement = Main Scale Reading + (Sequential Vernier Scale Marking × Least Count)

Find the marking on the vernier scale that aligns vertically with the main scale and count up to it, making a note of its numerical order value.

How To Read A Vernier Caliper In MM

To better help understand the formula, let's go step by step through an example of how to read a vernier caliper in mm

n this example, the last visible mark on the main scale is 7mm, and the vernier scale line that aligns perfectly with a main scale line is the one just after the 1 numbered indicator marking.

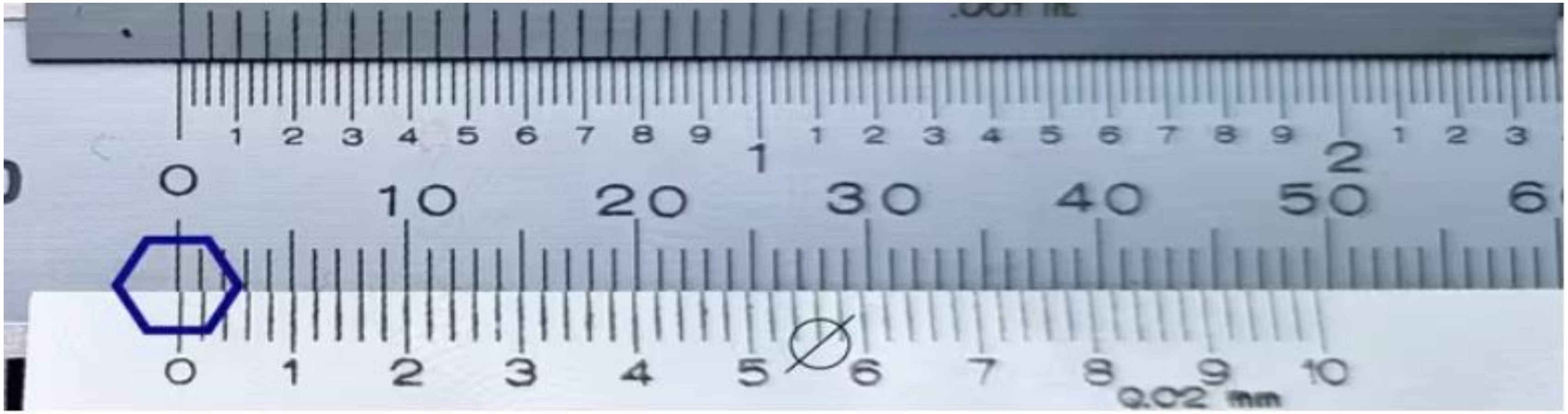
Knowing that the least count of the caliper is 0.02mm (your caliper may vary) we can safely say that the 1 marking is 0.1mm plus the one additional marking past it which is the one that lines up vertically, so, 0.12mm.

We can also calculate the reading using the formula, as we know that the marking that lines us is the 6th sequentially and the least count is 0.02mm.

$$
\begin{aligned}
\text{Total Measurement} &= 7\text{mm} + (6 \times 0.02\text{mm}) \\
&= 7\text{mm} + 0.12\text{mm} \\
&= 7.12\text{mm}
\end{aligned}
$$

Zero Error

Zero error occurs when the vernier caliper does not read zero when its jaws are fully closed. This can happen due to dirt build-up, wear and tear or improper calibration.



- To identify if you have zero error:
- Close the caliper jaws completely.
- Observe the alignment of the zero mark on the main scale with the zero mark on the vernier scale.
- If the marks do not align, there's a zero error present.
- Clean any debris from the jaws and re-measure.

- If zero error is still present:

  For a **positive zero error**, subtract the discrepancy from your measurements.

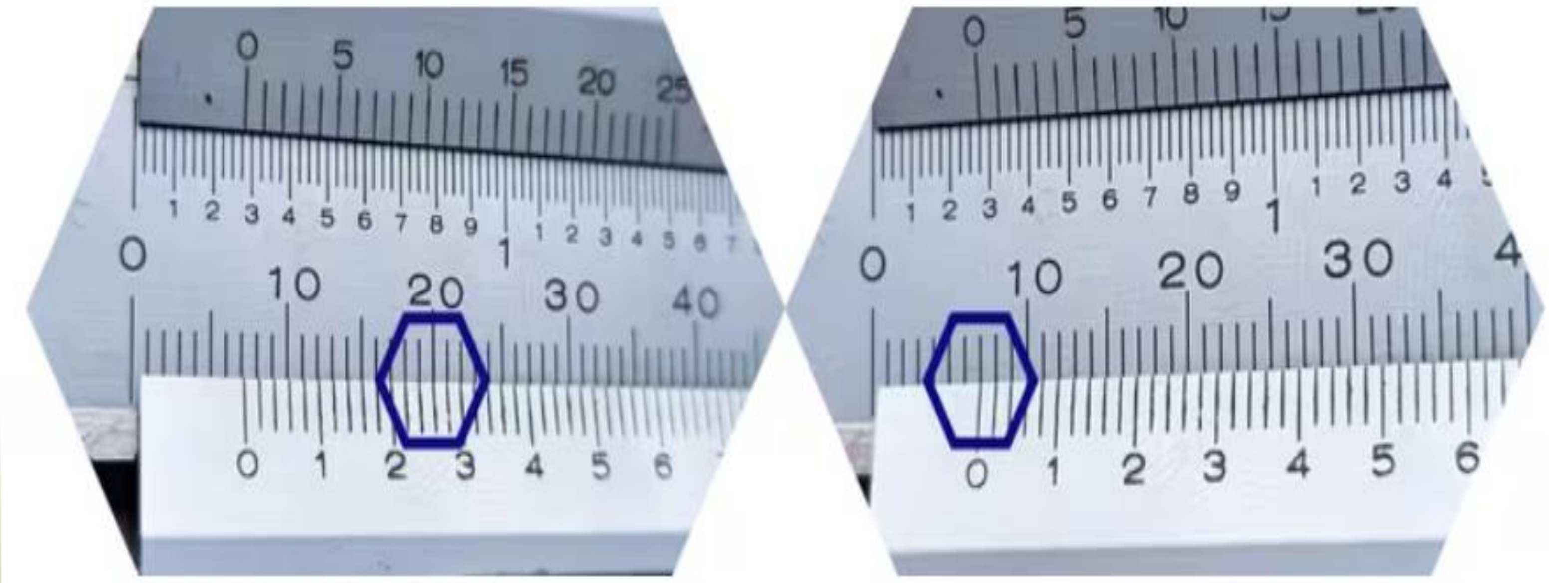
  For a **negative zero error,** add the discrepancy to your measurements.

A positive zero error occurs when the zero of the Vernier scale lies to the right of the zero of the main scale when the jaws are fully closed. This means the instrument shows a reading greater than zero even though no object is being measured.

A negative zero error occurs when the zero of the Vernier scale lies to the left of the zero of the main scale when the jaws are completely closed. This means the instrument shows a reading less than zero even though no object is being measured

Parallax Error

The parallax error arises when the scale is viewed from an angle rather than straight on. This can cause the marks on the vernier scale to appear misaligned with the main scale marks, leading to inaccurate readings



Avoiding Parallax Error:

Ensure your line of sight is perpendicular to the scales when reading measurements

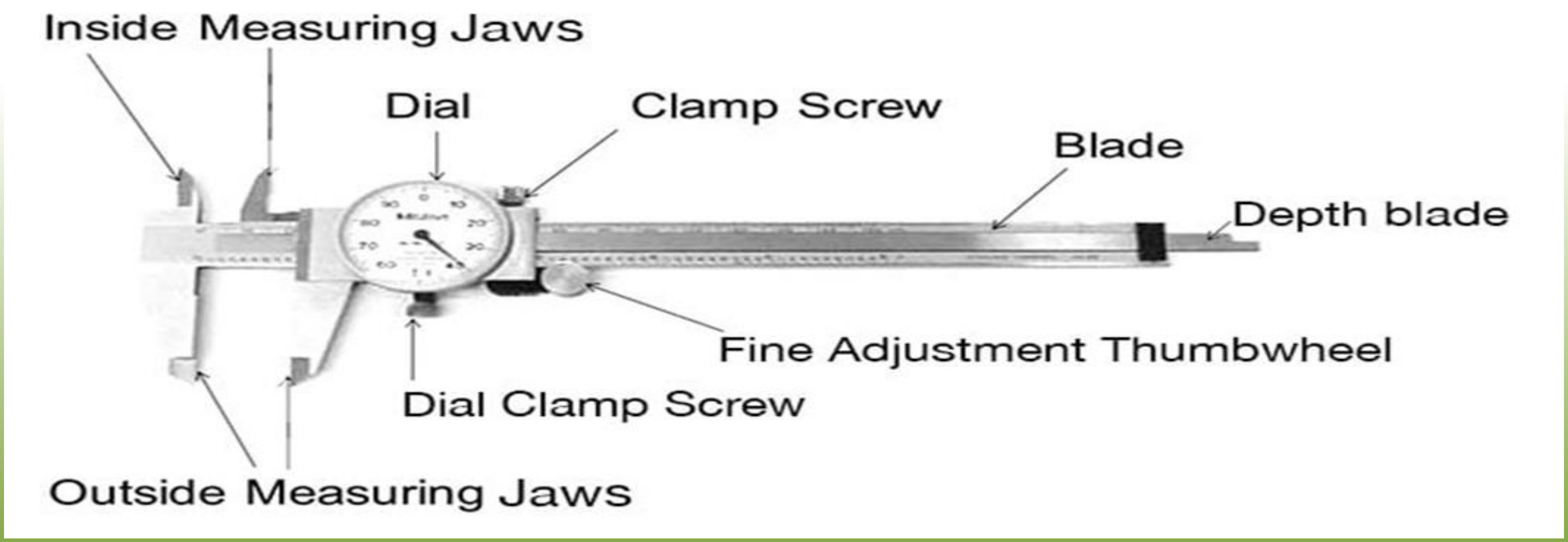
Misalignment

Misalignment errors can occur when the caliper's jaws are not correctly aligned with the faces of the object being measured.

Types of Vernier Calipers

a Dial Caliper?

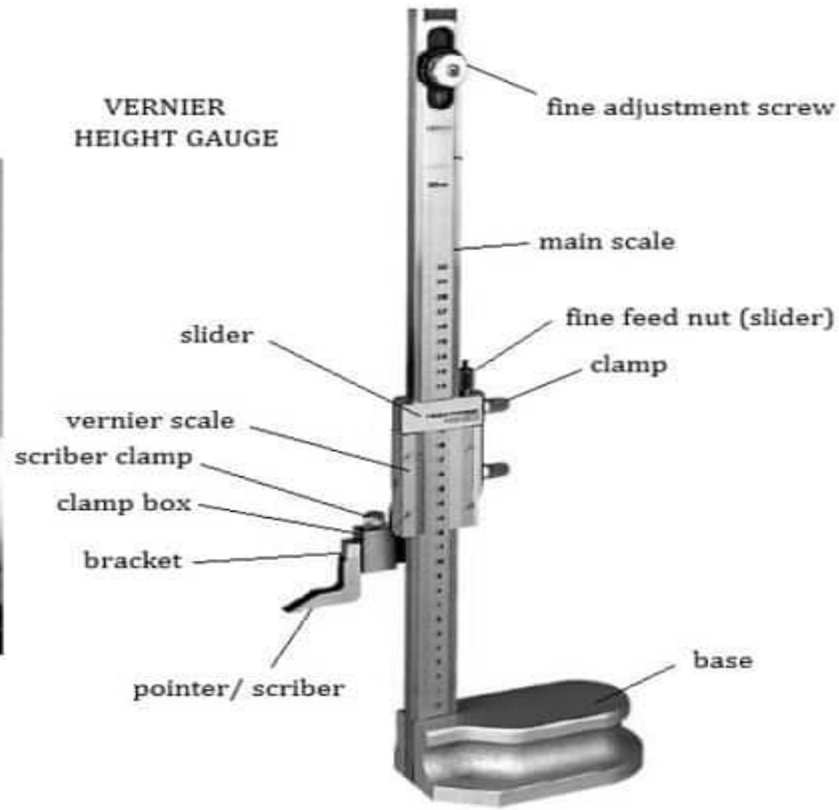
Instead of using a Vernier scale, which admittedly requires practice, dial calipers read the final fraction of a millimeter or an inch on a simple dial. The need for a Vernier scale is eliminated by the use of a miniature, precise rack and pinion that drive a pointer on a circular dial, allowing a direct readout. These dials typically rotate every inch, tenth of an inch, or a millimeter, depending on the type of caliper you bought.



Another type of Caliper is the digital Caliper.

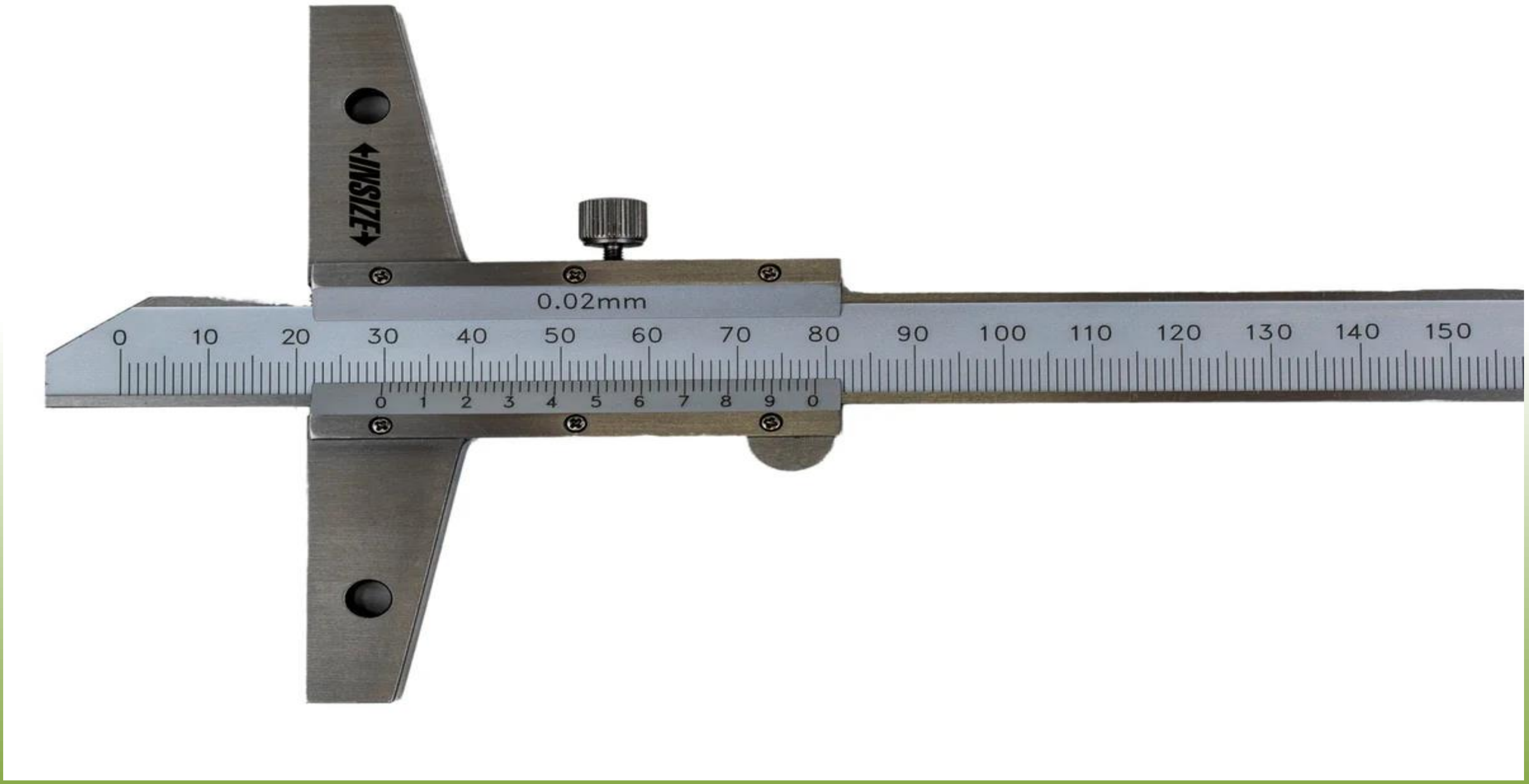
Gauge Height Vernier

This vernier is used to measure heights and differs from the ordinary vernier in that it rests on a heavy base.

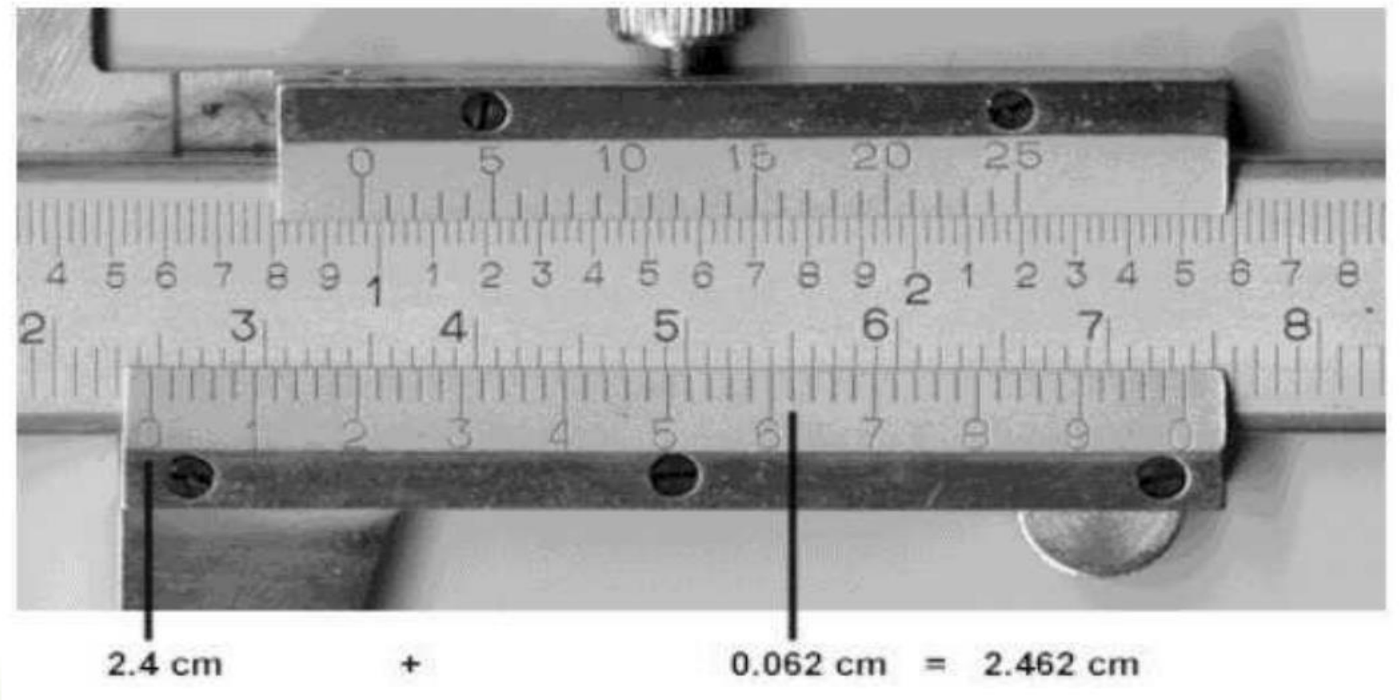


Depth gauge Vernier :

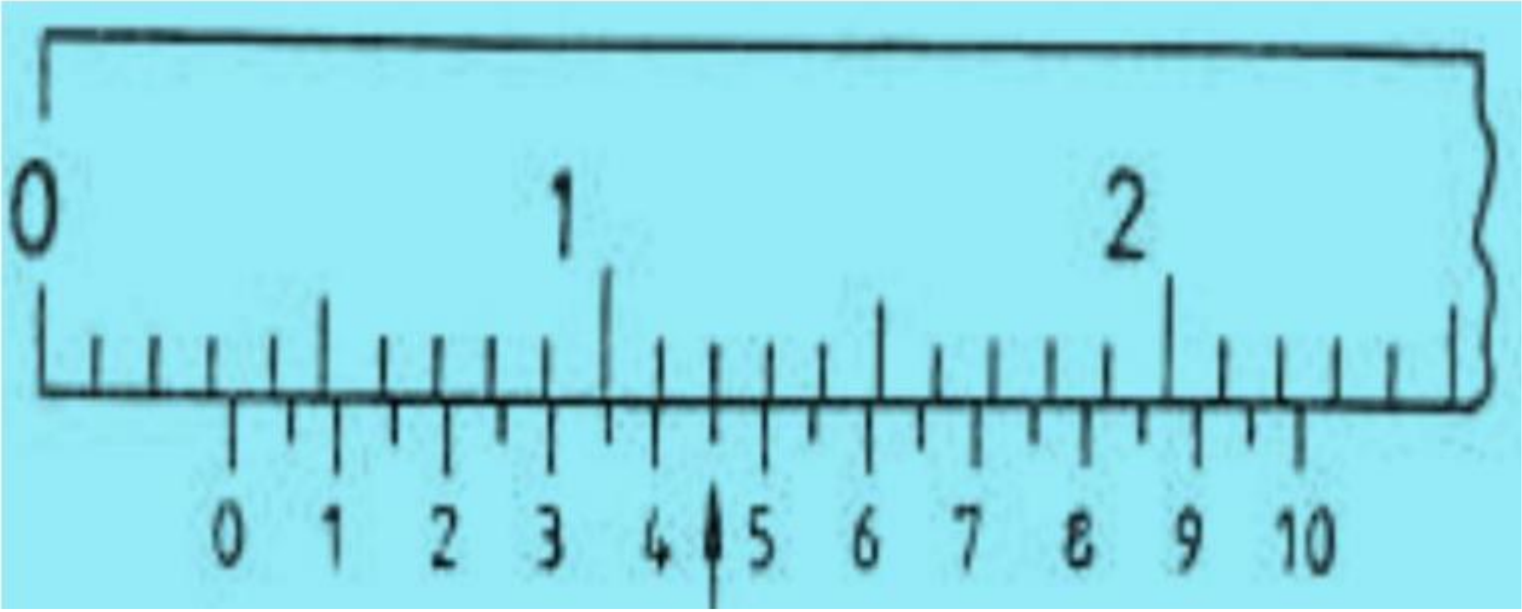
A Vernier depth gauge is a precision tool used to accurately measure the depth of holes, slots, recesses, and steps, typically ranging from 0–150mm up to 1000mm.



Example(1):Find the required measurement for the shown Verneir
Accuracy Verneir = 0.02 mm

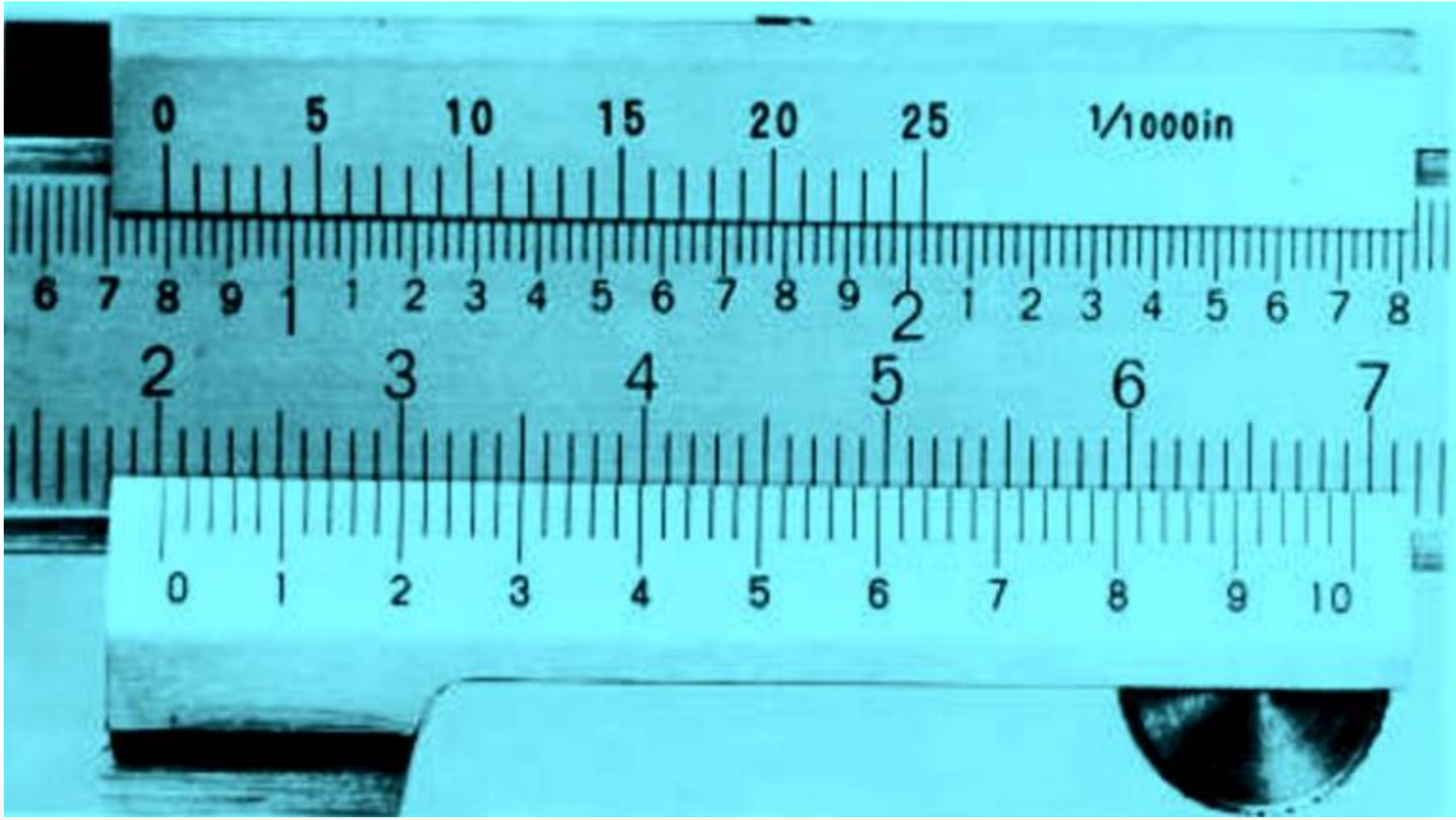


Part	Value
Main Scale	24 mm
Vernier Scale	31*0.02 mm = 0.62 mm
Final Result	24 + 0.62 = 24.62mm



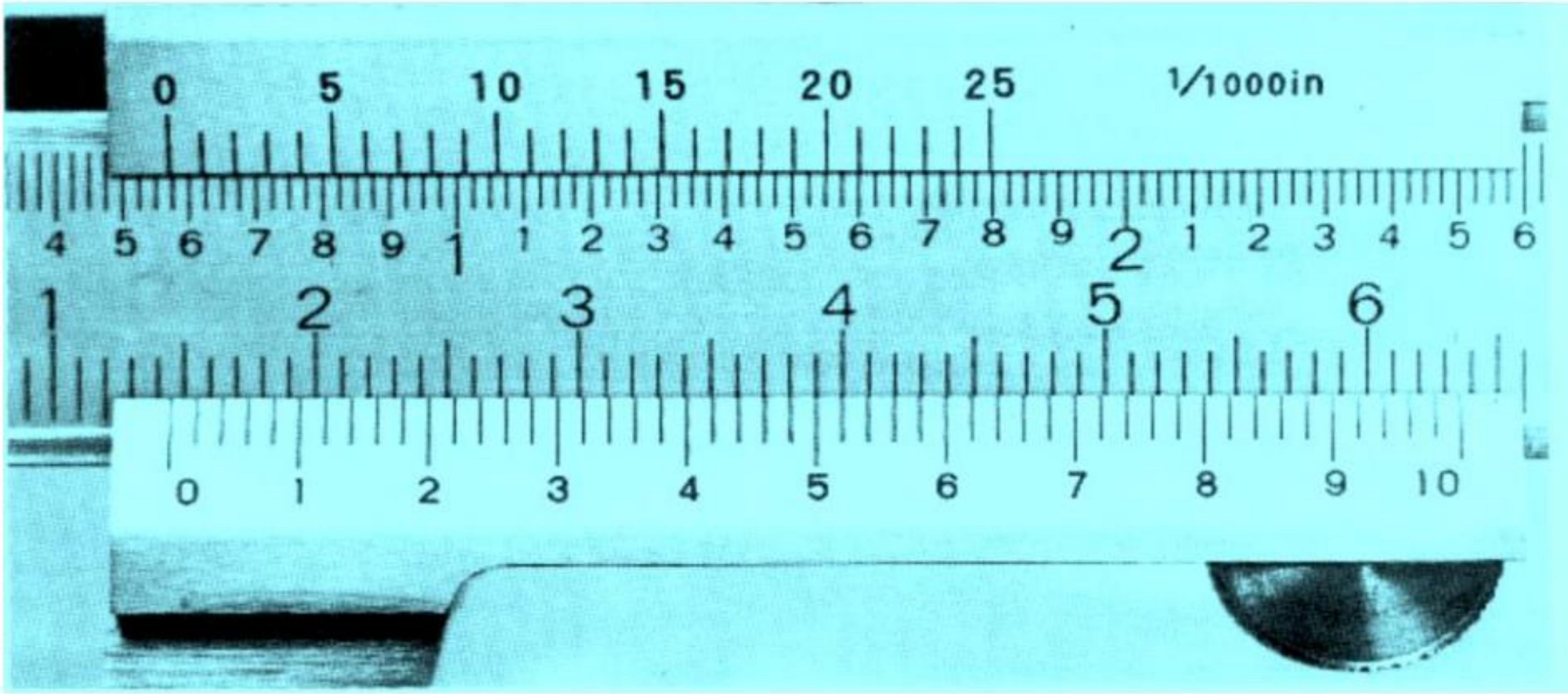
Reading the Vernier : ……………………..

The accuracy of the Vernier :………………..



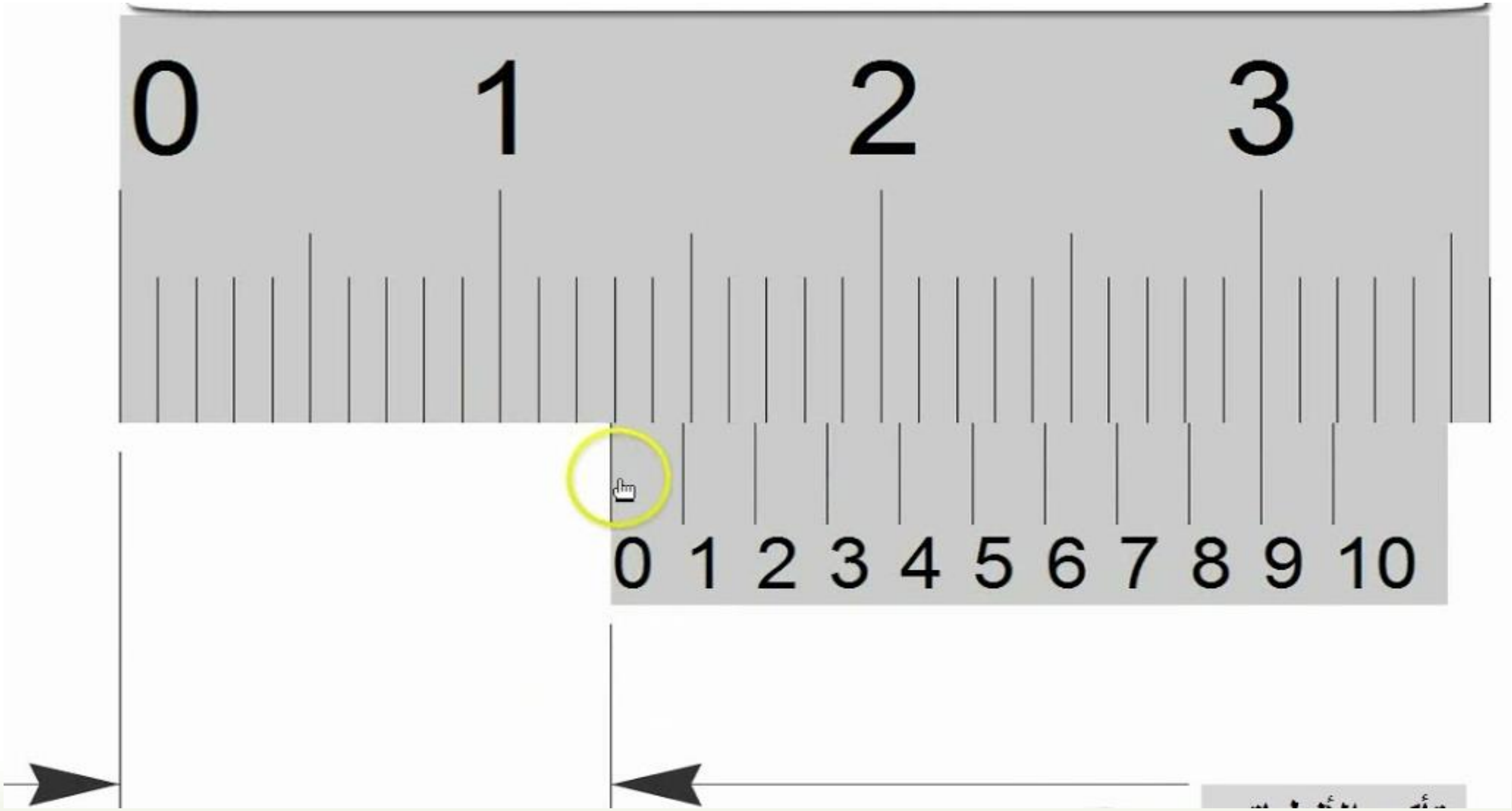
Reading the Vernier : …………………….

The accuracy of the Vernier :………………..



Reading the Vernier : …………………….

The accuracy of the Vernier :………………..



Reading the Vernier : …………………….

The accuracy of the Vernier :………………..

Micrometer

Lec.3

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Manufacturing Processes(1)

Micrometer

A micrometer is a measuring instrument that determines the distance between the sides of an object.

The ranges of micrometers are normally 0–25, 25–50, or 0–50 mm. The maximum range of micrometers is limited to 500 mm.

MICROMETER PARTS

A micrometer has a variety of parts that allow it to measure with accuracy and precision.

1. C-Frame

−It’s a **c** shaped frame as identified in the picture, is a rigid part that has both holding points for a job or object to be measured. Its size depends on micrometer measuring range so size of c frame increases as range expands to bigger see fig.3.1.

2.Anvil

The anvil is a stationary part of the micrometer on the outside jaw. It remains stationary as the inside jaw is moved closer to it.

3.Spindle

The spindle is a moveable part of the micrometer attached to the inside jaw. It is the counterpart to the anvil.

4.Sleeve

The sleeve is the part of the micrometer that contains units of measurement on it..

5.Thimble

The thimble is the part of the micrometer that is turned so the spindle can advance or retreat in comparison to the anvil.

6.Ratchet

It's knurled thumb gripe to rotate the spindle into desired direction for measuring process, provided with ratchet action to avoid over tightening of micrometer across the measuring object.

Figure 3.1. These are parts of a micrometer.

Types of micrometers

1.Inside Micrometer

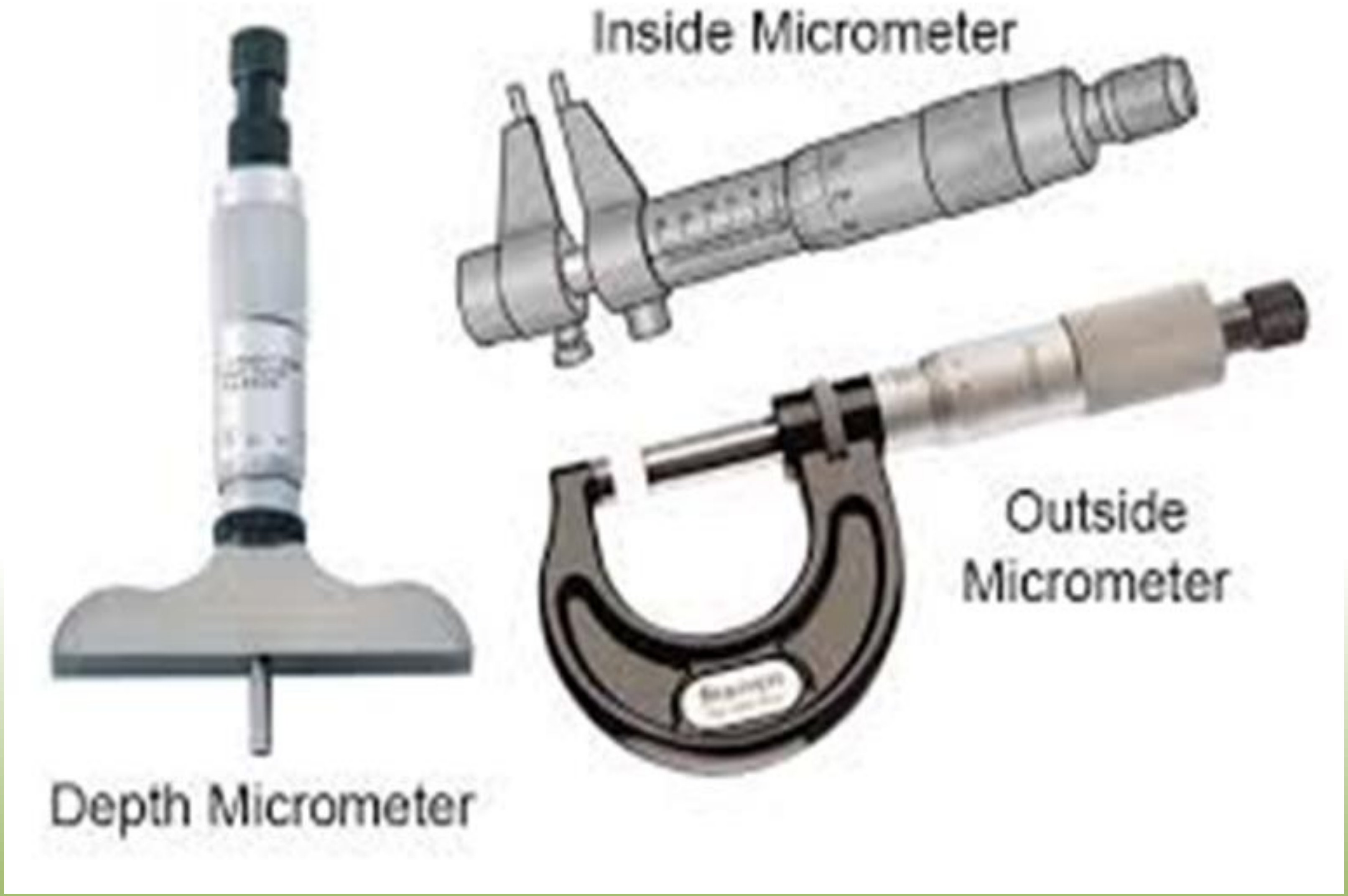
An inside micrometer is a device used primarily to measure the interior of holes or indented objects.

2.Outside Micrometer

An outside micrometer is a device used primarily to measure the outside diameter of objects.

3.Depth Micrometer

A depth micrometer is a micrometer used to determine the deepness of a hole and height.


Inside Micrometer
Outside Micrometer
Depth Micrometer

4. Outside Micrometer (Point)

For measuring the web thickness of drills, tap, small grooves, and other hard-to-reach places.

5. Outside Micrometer (Disk)

Designed to easily measure root tangent length of spur gears and helical gears.

6. Outside Micrometer (Tube)

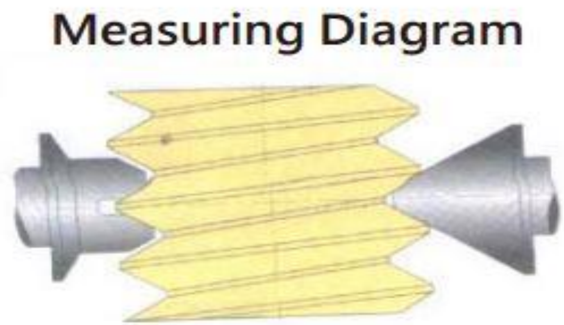
For measuring the tube wall thickness and other curved workpieces.

7. Outside Micrometer (Groove)

For measuring width, depth, and location of grooves inside/outside bores, and tubes.

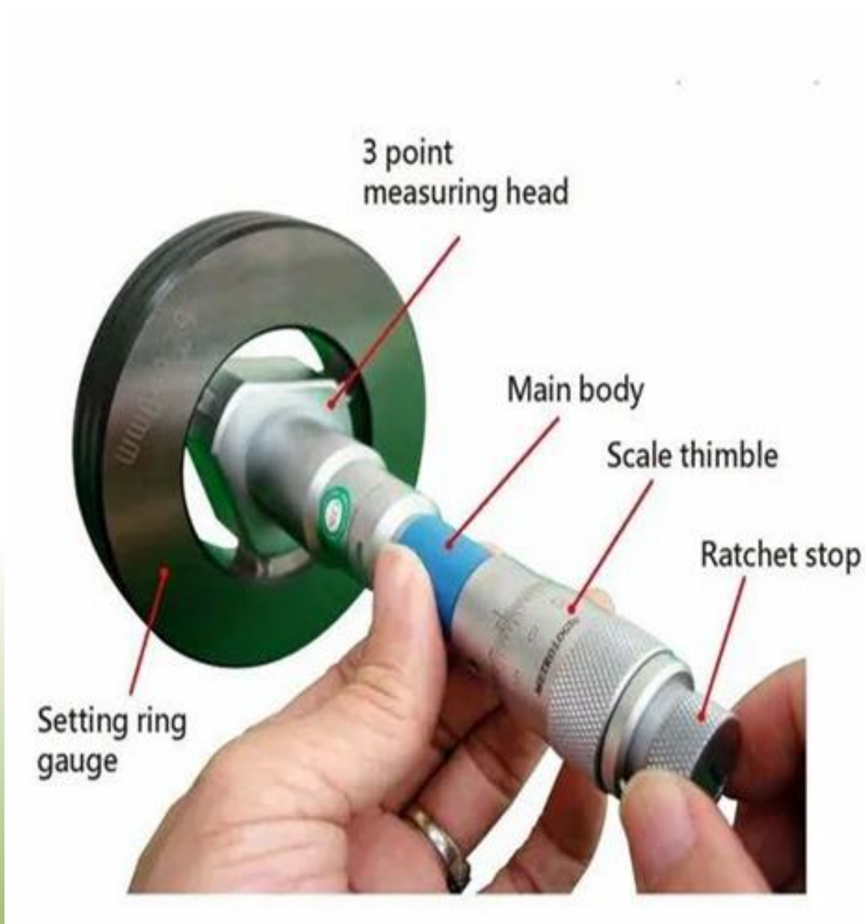
8. Outside Micrometer (Screw Thread)

For measuring pitch diameter of screw thread.



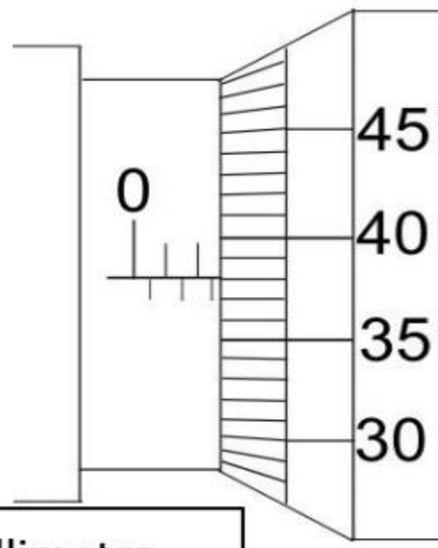
9. Three Point Inside Micrometer (Vernier)

For measuring inside diameters of lathe, grindings, boring machining.



Reading a Metric System Micrometer

a. Read off the millimetre mark to the left of the thimble.



b. Is there a half millimetre mark before the millimetre mark to the left of the thimble? If there is add 0.5 mm to your mm reading.
So in this case 2.5 mm

c. Read off the hundredths of a millimetre where the scale on the thimble meets the centre of the main scale.
In this case 0.38 mm.

d. Add the readings together, so the thickness measured here is:
2.5 + 0.38 = 2.88 mm.

Least Count of micrometer

Least Count = Pitch of the screw ÷ Number of divisions on the thimble

the pitch of the screw:

It is the distance the spindle moves when the thimble makes one complete revolution.

In a standard metric micrometer:

- Pitch = **0.5 mm**
  This means one full rotation moves the spindle 0.5 mm.

Number of divisions on the thimble

Usually :50 divisions

Least Count=0.5/50 =0.01 mm

So , **The least count of a standard micrometer is 0.01 mm.**

A micrometer has many **advantages** over other linear measurement instruments.

- It has better readability than a vernier scale and there is no parallax error.
- It is small,
- lightweight, and portable.
- It retains accuracy over a longer period than a vernier calliper and is less expensive.
- On the flip side, it has a shorter measuring range and can only be used for end measurement.

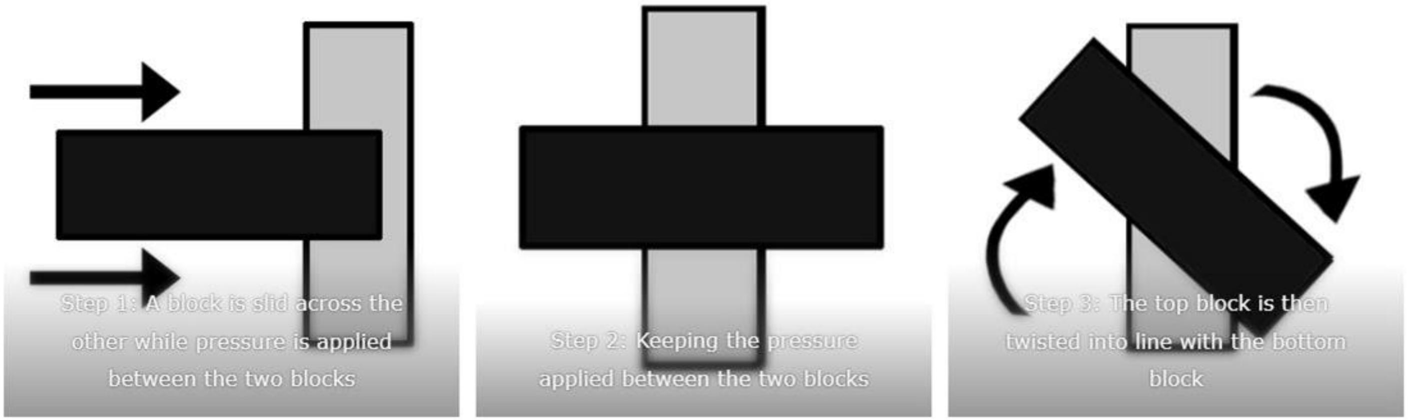
Gauge Blocks

Gauge (or Gage) blocks are precision-ground, rectangular or square blocks made from steel, tungsten carbide and ceramic designed for extreme wear resistance and dimensional stability. The process involves precision CNC machining, heat treatment for hardening, and extensive lapping to achieve sub-micron tolerances for flatness and parallelism.

Gage blocks come in various sizes, and they are used as building blocks to create precise measurement standards.

By stacking gage blocks together in various combinations, technicians can create precise lengths that can be used as references for calibrating and checking other measuring instruments, such as micrometers, calipers, and height gauges.

A step by step example of a typical wringing method is shown below.



Care should be taken when using any technique to not damage the blocks.

Step 1: A block is slid across the other while pressure is applied between the two blocks

Step 2: Keeping the pressure applied between the two blocks

Step 3: The top block is then twisted into line with the bottom block

The grades of gauge blocks(Slip gauges)

slip gauges are designated into **five grades, namely grade 2, grade 1‹grade 0, grade 00, and inspection grade.**

Grade 2 This is the workshop-grade slip gauge. Typical uses include setting up machine tools, milling cutters, etc., on the shop floor.

Grade1_ This grade is used for tool room applications for setting up sine bars, dial indicators ‹calibration of vernier, micrometer instruments, and so on.

Grade 0 This is an inspection-grade slip gauge. Limited people will have access to this slip gauge and extreme care is taken to guard it against rough usage.

Grade 00 : This set is kept in the standards room and is used for inspection/calibration of high precision only. It is also used to check the accuracy of the workshop and grade slip gauges.

Calibration grade : This is a special grade, with the actual sizes of slip gauges stated on a special chart supplied with the set of slip gauges.

Gauge blocks are manufactured in sets containing varying numbers of block of different lengths. as shown in Figure 3.2.

The number of blocks in a single set varies, containing (32, 47, 82, 88, 92, 145, and 112)blocks. Table 1 shows the measuring blocks in a set of 88 block.

Figure.3.2 : Gauge Block Set Metric Steel 88 blocks

Table 1: gauge blocks in the set with a 88 blocks

Number of Blocks	Step (mm)	Gauge Block Lengths (mm)
1	0.0005	1.0005
9	0.001	1.001 to 1.009
49	0.01	1.01 to 1.49
19	0.5	0.5 to 9.5
10	10	10 to 100
88	—	**Total**

Exercise: Arrange the blocks to create the 37.936 mm dimension using gauge blocks in the set of the 88- block ?

Sol:

37.936 mm

Start with the smallest possible block:

- **30.00 mm**
- **5.50 mm**
- **1.43 mm**
- **1.006 mm**

Verification:

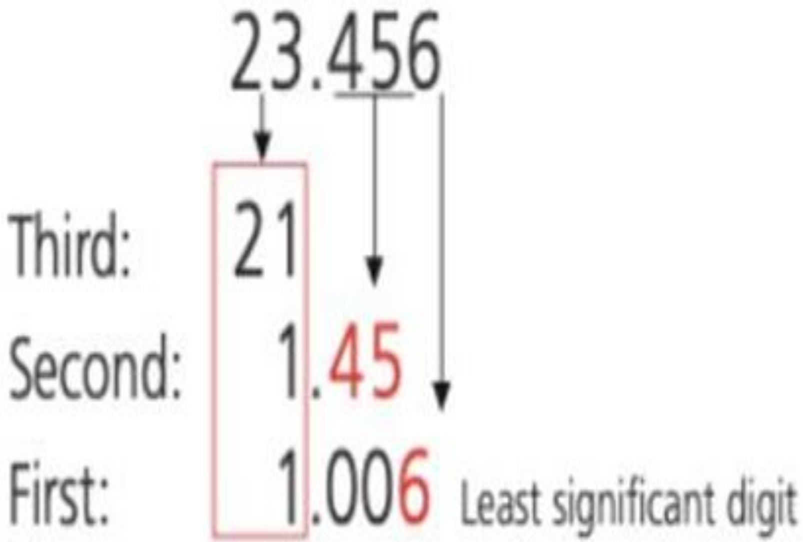
30+5.5+1.43+1.006=37.936 mm

Final Combination:

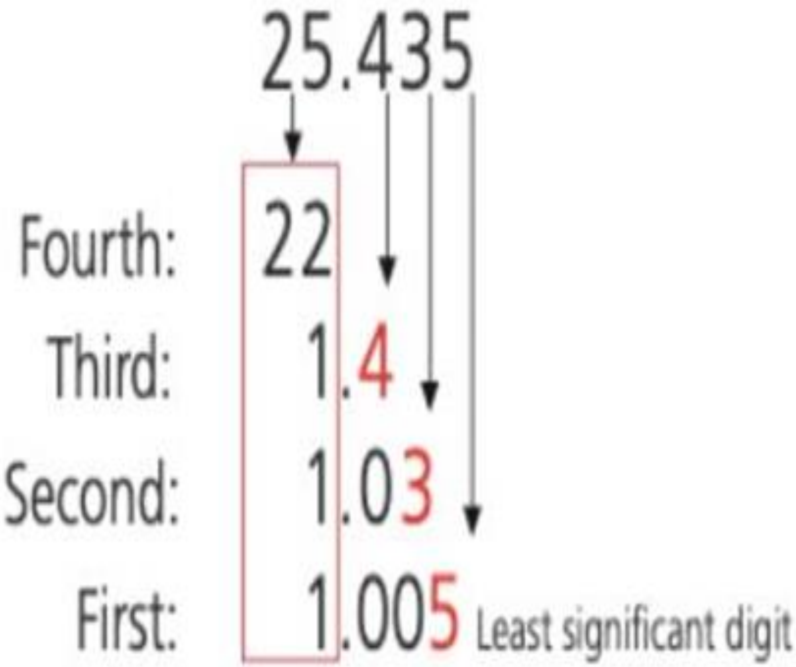
30 + 5.5 + 1.43 + 1.006 mm

(Using 4 blocks — which follows the rule of using the minimum number of blocks.)

Example: For 23.456 mm



Example: For 25.435 mm



Example 1

Required dimension: 25.438 mm

Example 2

Required dimension: 8.254 mm

Example 3

Required dimension: 63.582 mm

Angle Measuring Instruments, Gages

Lec.4

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Introduction :

Angular measurements are used in combination with distance measurements to create positions.

Angular measurements are always based on a divided circle.

The precise measurement of angles is an important requirement in workshops and tool rooms.

Sometimes, the primary objective of angle measurement is not to measure angles .

This may sound rather strange, but this is the case in the assessment of alignment of machine parts.

Measurement of straightness, parallelism, and flatness of machine parts requires highly sensitive instruments like autocollimators. The angle reading from such an instrument is a measure of the error of alignment.

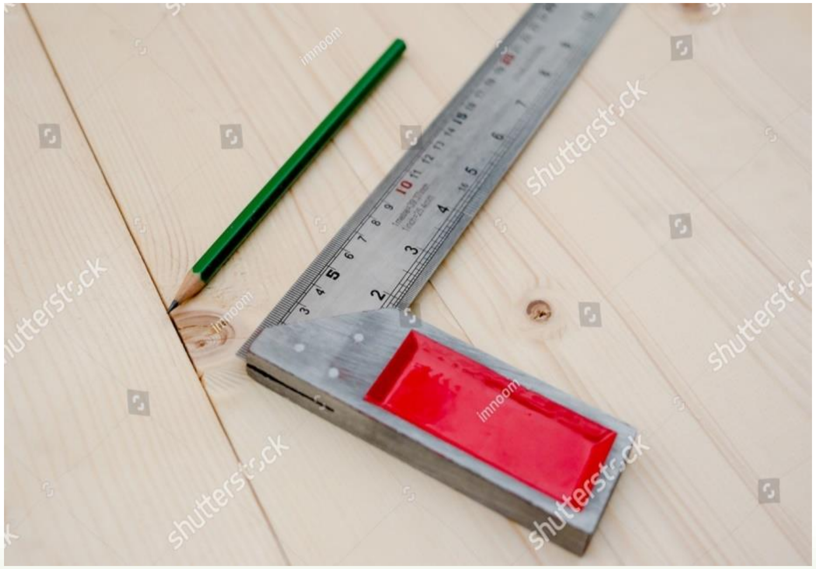
Angle units

Angle units Full turn can be divided into pieces of the same size. The most common unit of measurement is the degree (and smaller fractions of the degree).

- Degree = 1/360 of full turn. Sign of the degree is °
- Minute = 1/60 of the degree. Sign of the minute is '
- Second = 1/60 of the minute. Sign of the second is " For example: 35 degrees 5 minutes 27 seconds is written as 35° 5' 27"

Right Angle L Shape

A right angle is formed when two adjacent sides measure exactly 90 degrees and are perpendicular to each other.

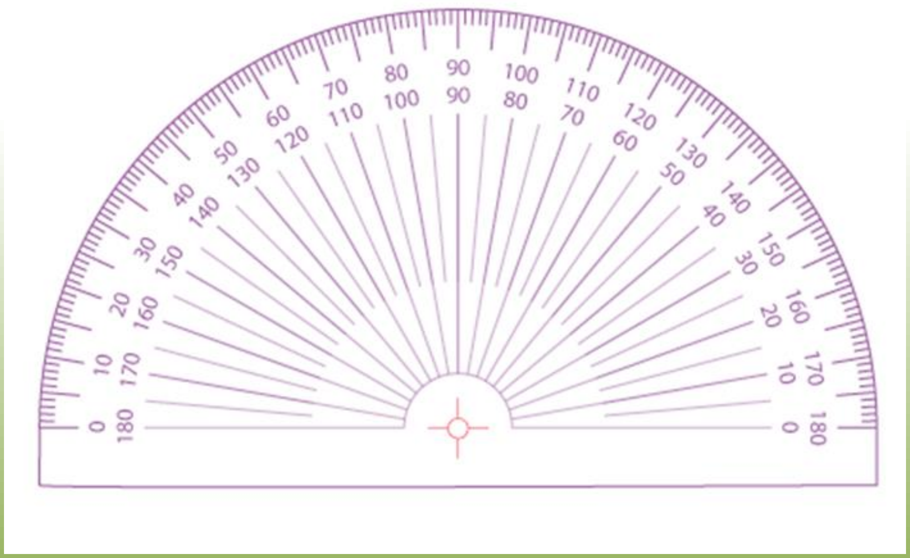


L shaped ruler is convenient for accurate cutting, trimming, slicing and measuring on almost any material. Crafted with a durable, all metal design

What is a protractor in geometry?

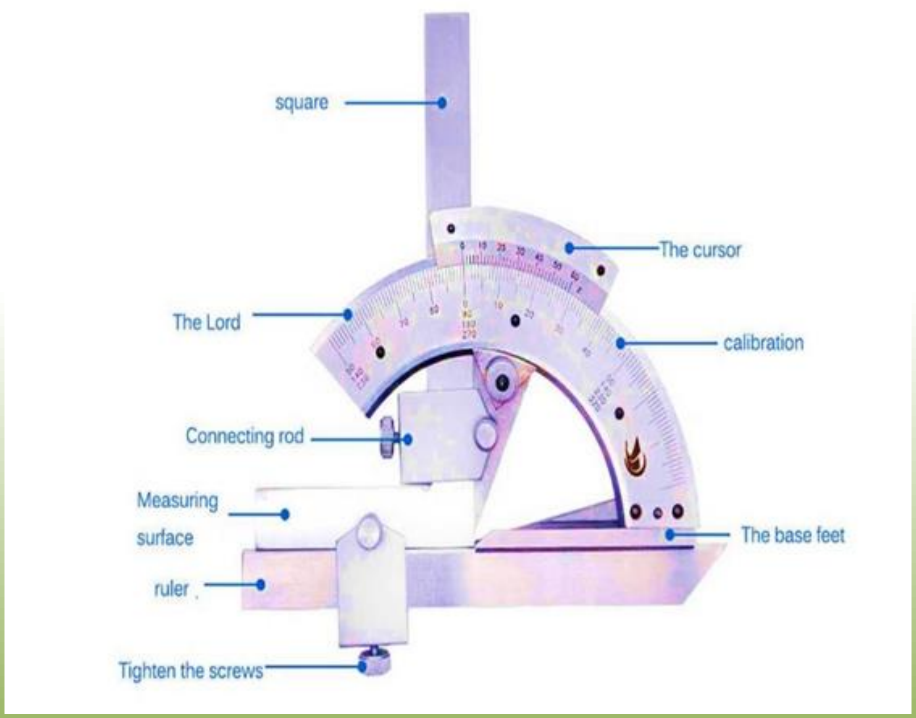
A protractor is a tool that is used to measure and draw angles in geometry. A protractor in a geometry box is in the shape of half-disc or semicircular which can measure up to 180 degrees.

A simple protractor is a basic device used for measuring angles. At best, it can provide a least count of 1° for smaller protractors and 2° for large ones.



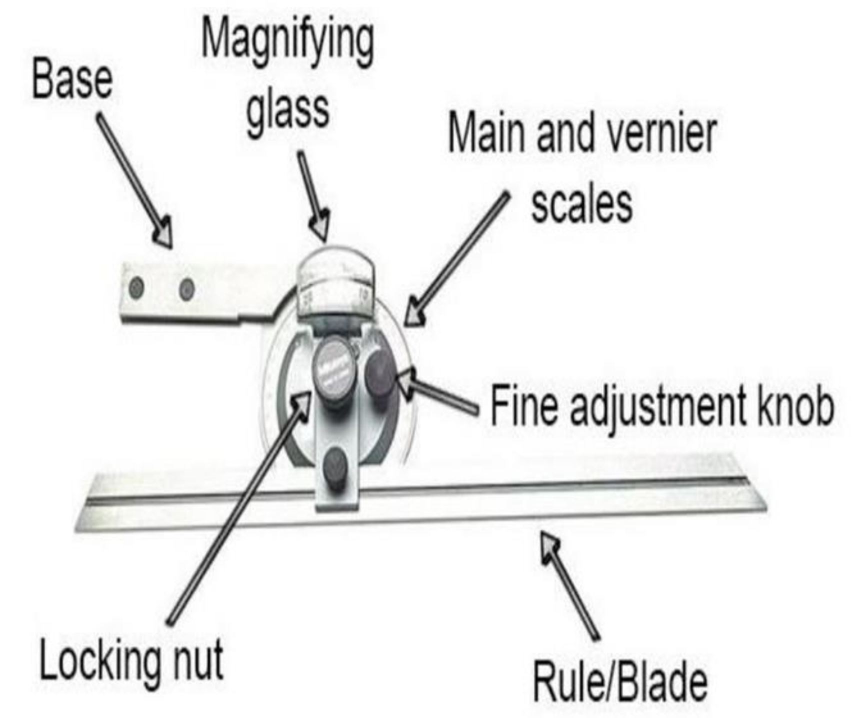
A Mechanical Bevel Protractor(Universal Bevel Protractor)

A mechanical bevel protractor is a high-precision, adjustable tool used in engineering and machining to measure or mark angles between and . Featuring a graduated dial and a vernier scale, it typically provides readings with an accuracy of 5 arcminutes (5′)



Optical bevel Protractor

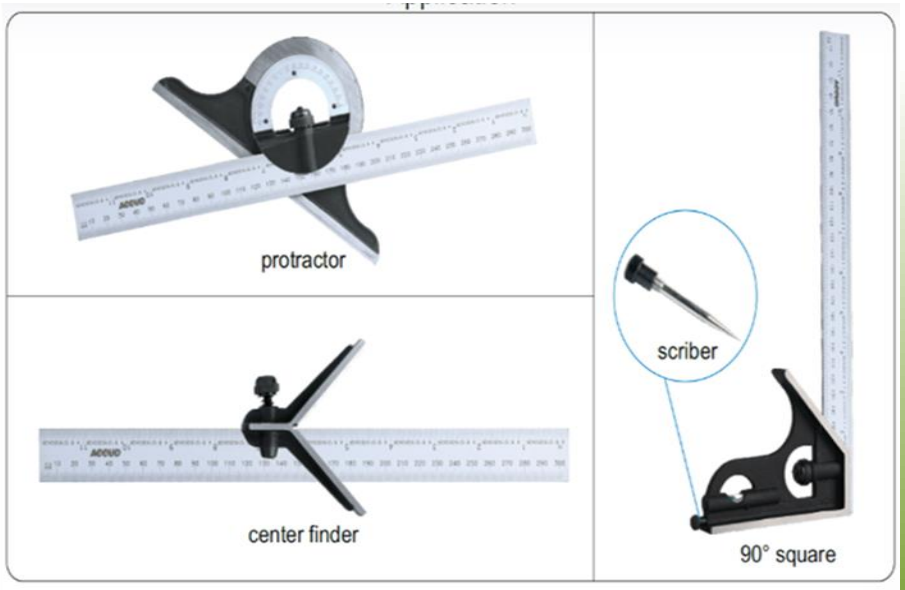
The optical bevel Protractor is a development of the Vernier Protractor with the inclusion of an optical magnifying device to achieve greater accuracy and precision in angular measurement for up to 2 minutes.



combination protractor

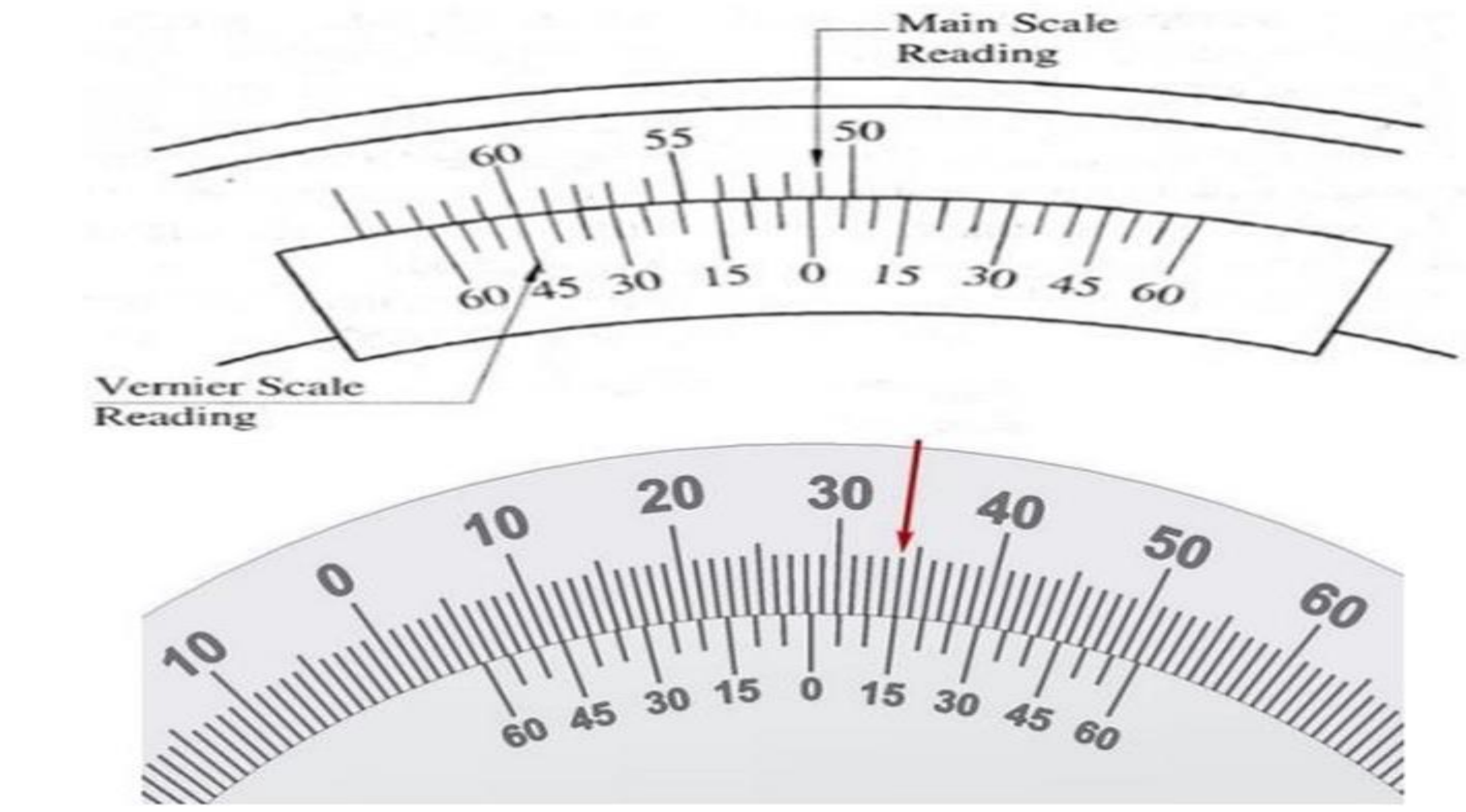
Combination Square Set, a versatile and essential tool used in various trades, including carpentry, metalworking, and engineering.

It is designed to perform multiple functions, such as measuring angles, checking for squareness, marking workpieces and To locate center of piece.The combination square set includes a ruler, a square head, a protractor head and a center head, all of which can be attached to the ruler to perform different tasks



Main Scale & Vernier Scale Reading

The figure shows on the main scale are graduated in degrees of arc. It has 12 divisions on each side of the centre zero. These are marked 0-60 mins of the arc so that each division equals 1/12 of 60 that is 5 min of arc.



These 12 divisions occupy equal space as 23° on the main scale.

Therefore each division of the vernier scale is equal to 1/12 of 23° or 1(11/12).°

Thus the reading of the vernier protractor is equal to the largest "whole" degree of the main scale + the reading on the vernier scale in line with the main scale division.

= Main scale reading, 51° + Vernier 45 mark in line with the main scale

= 51°+ 45

Sine bar

Sine bars are always used along with slip gauges as a device for the measurement of angles very precisely. They are used to

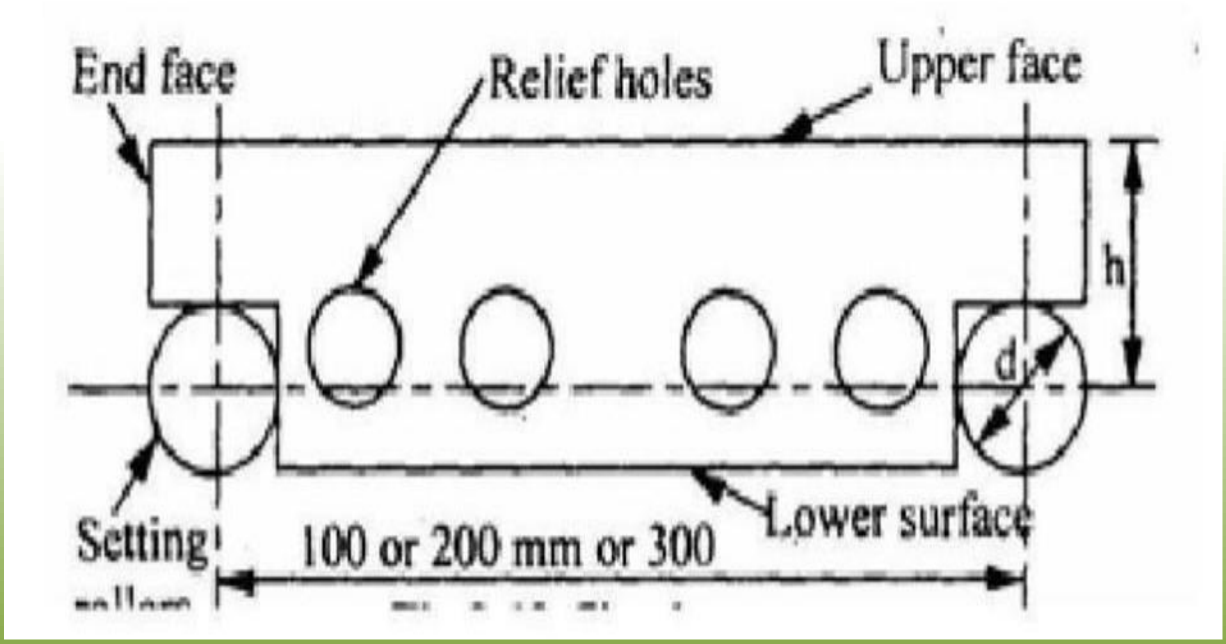
1) Measure angles very accurately.

2) Locate the work piece to a given angle with very high precision.

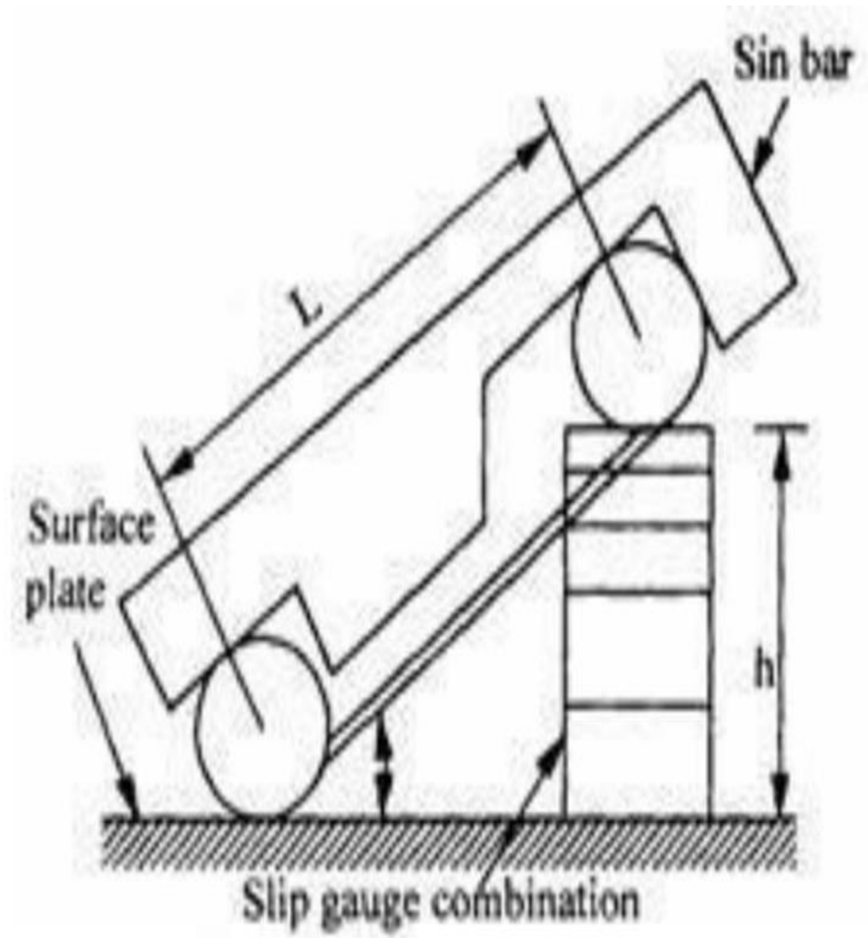
In sine bars, two cylinders of equal diameter are attached at lie ends with its axes are mutually parallel to each other.

They are also at equal distance from the upper surface of the sine bar mostly the distance between the axes of two cylinders is 100mm, 200mm or 300mm.

The cylindrical holes are provided to reduce the weight of the sine bar.



Working principle of sine bar



The working of sine bar is based on trigonometry principle.

To measure the angle of a given specimen, one roller of the sine bar is placed on the surface plate and another one roller is placed over the surface of slip gauges.

Now, ‘h is the height of the slip gauges and ‘L’ be the distance between roller centers, then the angle is calculated as

$$\mathrm{Sin}\theta = \frac{h}{L}$$

$$\therefore \theta = Sin^{-1}(h/L)$$

Limitations of sine bars

1) Sine bars are fairly reliable for angles than 15°.

2) It is physically difficult to hold in position.

3)Slight errors in sine bar cause larger angular errors.

4) A difference of deformation occurs at the point of roller contact with the surface plate and

to the gauge blocks.

5) The size of parts to be inspected by sine bar is limited

ANGLE GAUGES

Angle gauges, which are made of high-grade wear-resistant steel, work on a principle similar to slip gauges. While slip gauges can be built to give linear dimensions, angle gauges can be built to give the required angle.

The gauges come in a standard set of angle blocks that can be wrung together in a suitable combination to build an angle.

The laboratory master-grade set has an accuracy of one-fourth of a second. While the inspection-grade set has an accuracy of ½", the tool room-grade set has an accuracy of 1".

This illustration shows the way in which two gauge blocks can be used in combination to generate two different angles.

If a 5° angle block is used along with a 30° angle block, as shown in Fig. 5.14(a), the resulting angle is 35°. If the 5° angle block is reversed and combined with the 30° angle block, as shown in Fig. 5.14(b), the resulting angle is 25°. Reversal of an angle block subtracts itself from the total angle generated by combining other angle blocks

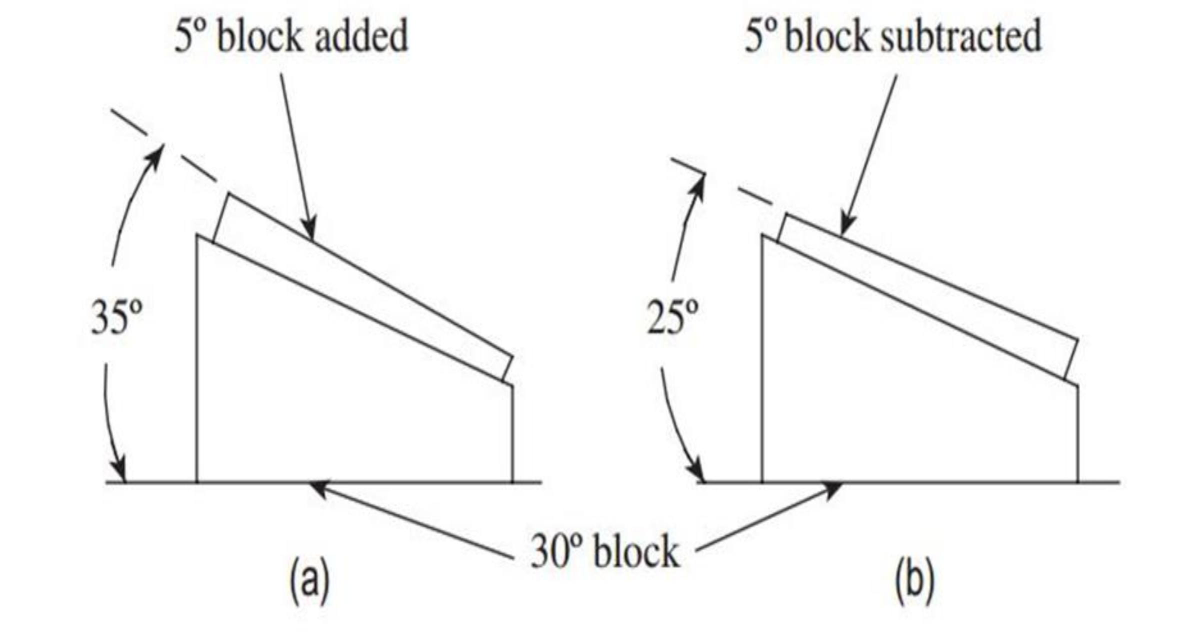


Fig. 5.14 Angle gauge block (a) Addition (b) Subtraction

Let us consider an angle 42°35′20", which is to be built using the 16-gauge set. The resulting combination is shown in Fig. 5.15.

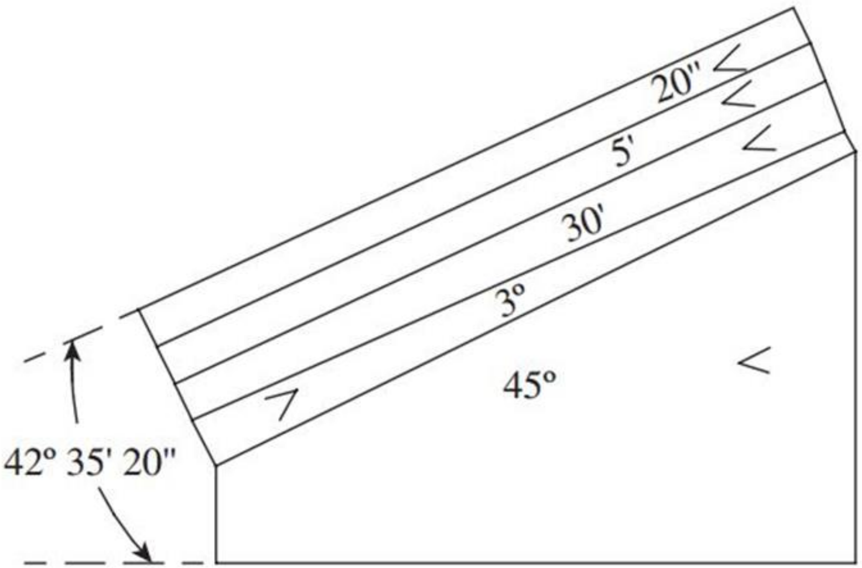


Fig. 5.15 Combination of angle gauges for 42°35'20''

Smallest increment by which any angle can be produced	Number of individual blocks contained in the set	Detailed listing of the blocks composing the set
1°	6	Six blocks of 1°, 3°, 5°, 15°, 30°, and 45°
1′	11	Six blocks of 1°, 3°, 5°, 15°, 30°, and 45° Five blocks of 1', 3', 5', 20', and 30′
1″	16	Six blocks of 1°, 3°, 5°, 15°, 30°, and 45° Five blocks of 1', 3', 5', 20', and 30' Five blocks of 1", 3", 5", 20", and 30"

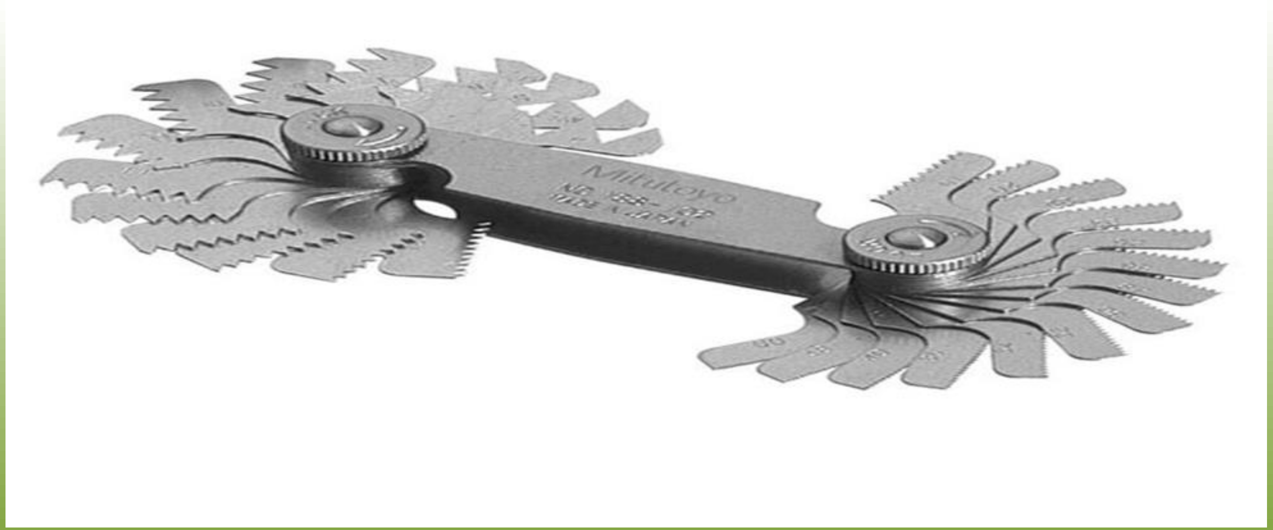
Gages

Gages are precision measurement tools used to verify the dimensions, tolerances, and quality of machined parts and components. These tools are essential for ensuring that parts meet exact specifications and standards.

Gage Types

Screw-pitch gages

Screw-pitch gages are used to determine the pitch of a screw by placement on the threaded portion. Such gages are available for the most common thread-pitch forms. However, screw-pitch gages do not check thread size and are not adequate for checking thread form for precision parts.



Plug gages (Pin gages)

Plug gages usually consist of two members: the go end and the no-go end, and can be of three types: single end, double end, and progressive.

Pin gages (also known as plug gages) are used to test hole size and it's geometry.

Shape: Cylindrical, resembling a screw or pin (plug).

Use: To check the internal thread inside holes such as nuts.

Outer surface: Contains a thread. Insert into the hole to check the thread.

Ring gages

Ring gages are fixed gages usually used in pairs of go and no-go members.

They are available in many sizes and lapped to close tolerance on the inside diameter.

It is a standard ring gauge used to check the outer diameter of smooth cylindrical parts such as shafts.

- The inner surface is smooth and without threads.
- It is used to ensure that the shaft diameter is within acceptable limits.

Go and No Go ring gauge set

Thread Ring Gauge

It is also a ring, but specifically designed for testing external threads.

- The inner surface contains a thread.
- It is used to test a screw or bolt to determine if the thread conforms to specifications.
- It also usually comes in two types:

- Go
- No-Go

Example: Testing the thread of an M10 screw after manufacturing

Thank you

Comparators

Lec.5

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Manufacturing Processes(1)

Comparators

Introduction

All measurements require the unknown quantity to be compared with a known quantity, called the standard.

we came across linear measurement instruments, such as verniers and micrometers, in which standards are in-built and calibrated.

Hence, these instruments enable us to directly measure a linear dimension up to the given degree of accuracy.

In other words, a comparator works on relative measurement. It gives only dimensional differences in relation to a basic dimension or master setting.

Comparators are generally used for linear measurements, and the various comparators currently available basically differ in their methods of amplifying and recording the variations measured

Accordingly, we can draw the following classification. With respect to the principle used for amplifying and recording measurements, comparators are classified as follows:

Mechanical comparators

Mechanical–optical comparators

Electrical and electronic comparators

Pneumatic comparators

Other types such as projection comparators and multi-check comparators

Mechanical comparator

A mechanical comparator is a measurement tool employing mechanical components such as gears, levers, pinions, and racks to achieve magnification. These components are utilized to amplify the movement of the mechanism, thereby improving the instrument's precision.

Working Principle of the Mechanical Comparator

The operational principle of a mechanical comparator involves employing mechanical mechanisms to amplify minute discrepancies.

These comparators typically offer magnifications ranging from 300 to 1000.

Additionally, the mechanical comparator, also referred to as a "microcator," is utilized for linear measurements using the relative contact method.

Types of Mechanical Comparators

There are various types of mechanical comparators, including:

- Dial Indicators
- Johanson Mikrokator
- Sigma Comparators

Dial Indicator

The dial indicator mechanical comparator is utilized for assessing geometric deviations such as roundness, taper, ovality, and others. It is instrumental in identifying errors in alignment, surface quality, squareness, parallelism, and more.

The dial indicator or the dial gauge is one of the simplest and the most widely used comparators. It is primarily used to compare workpieces against a master.

The basic features of **a dial gauge consist of** :

- a body with a circular graduated dial,
- a contact point connected to a gear train,
- and an indicating hand that directly indicates the linear displacement of the contact point see fig.5.1.

The contact point is first set against the master, and the dial scale is set to zero by rotating the bezel.

Now, the master is removed and the workpiece is set below the contact point; the difference in dimensions between the master and the workpiece can be directly read on the dial scale.

The contact point in a dial indicator is of an interchangeable type and provides versatility to the instrument. It is available as a mounting and in a variety of hard, wear-resistant materials. Heat-treated steel, boron carbide, are some of the preferred materials

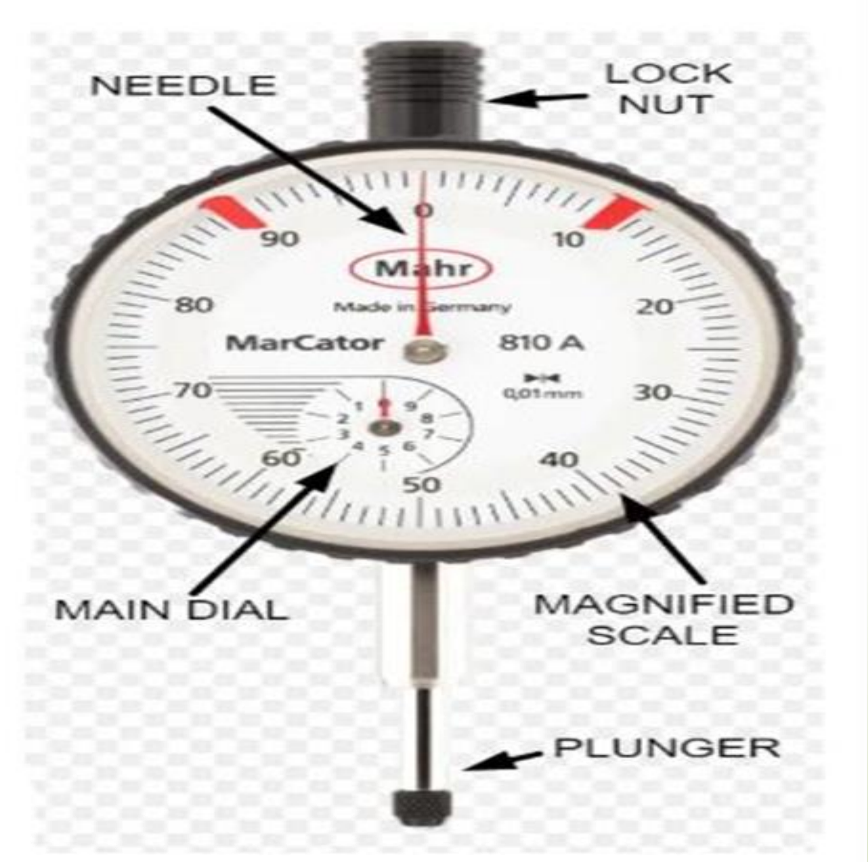


Fig. 5.1: Dial Indicator

This comparator **serves to**

- assess two heights or distances within narrow margins.
- It is employed to examine the compression and tension of materials.
- It is utilized to authenticate the precision of milling machine arbors.
- It is employed to validate the alignment of lathe machine centers using a bar placed between them.

ELECTRICAL COMPARATOR

Electrical Comparators are used as a means of detecting and amplifying small movements of a work contacting elements.

An electrical comparator consists of the following three major part such as

1)Transducer

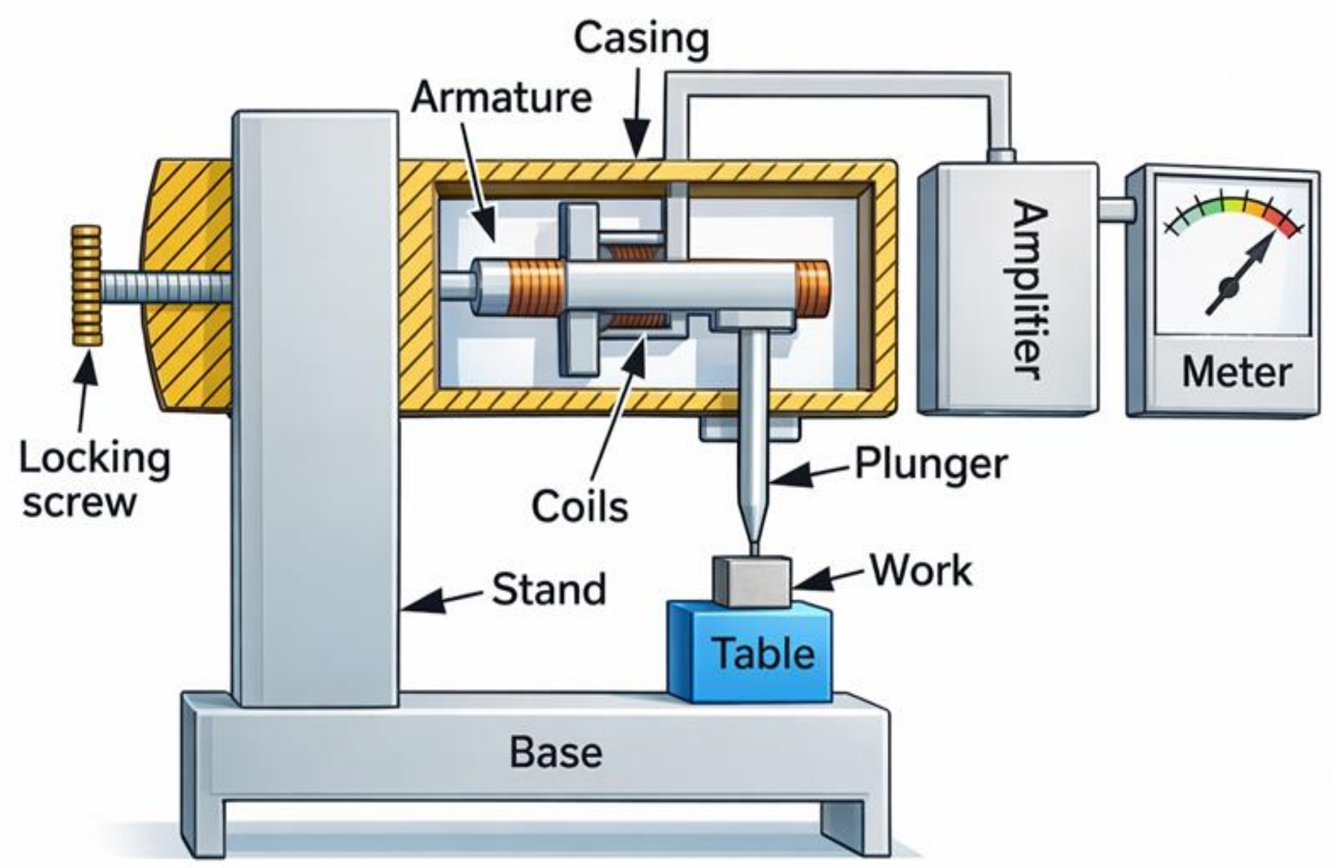
An iron armature is provided in between two coils held by a lea spring at one end. The other end is supported against a plunger. The two coils act as two arms of an A.C. wheat stone bridge circuit

2) Display device as meter

The amplified input signal is displayed on some terminal stage instruments. Here, the terminal instrument is a meter.

3) Amplifier

The amplifier is nothing but a device which amplifies the give input signal frequency into magnified output



Electrical Comparators

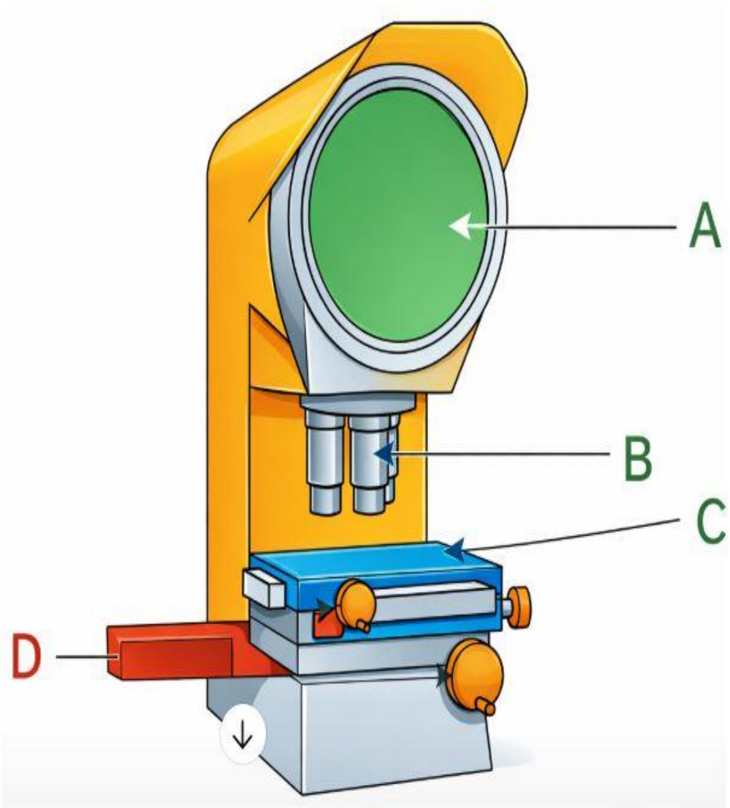
Optical comparators (profile projector)

An optical comparator, often referred to as a profile projector, is an instrument used in the inspection and measurement of manufactured components.

It operates by leveraging optical techniques to project an enlarged and precise silhouette of the examined part onto a viewing screen.

This projected image can then be compared against established reference standards or engineering drawings.

Optical comparators find wide-ranging utility in industries where precision matters, allowing for the assessment of critical attributes like dimensions, angles, and surface finishes in diverse manufacturing processes. Their ability to facilitate accurate and reliable measurements makes them valuable tools in quality control, ensuring that products meet exacting specifications and standards.



A
Projection screen
B
Projection lens
C
Movable stage
D
Stage movement handles (X and Y handles)

How to Use an Optical Comparator ?

Using our optical comparators effectively require a combination of proper setup, careful operation, and adherence to best practices. Follow these step-by-step instructions to ensure accurate and reliable measurements:

1. Prepare the workpiece: Ensure that the component or object you wish to measure is clean and free from any debris or contaminants that could obstruct the view or affect the measurements.

   Position the workpiece securely on the comparator's stage, using clamps or fixtures as needed to prevent movement during inspection.

2. Adjust the lighting: Proper illumination is crucial for obtaining a clear and well-defined silhouette.

3. Calibrate the instrument: Before taking any measurements, calibrate the optical comparator using a certified reference standard or gauge block.

4. Select the magnification: Choose the appropriate magnification level based on the size and intricacy of the workpiece's features.

5 .Align the workpiece: Carefully position and orient the workpiece on the stage, ensuring that the desired features or dimensions are clearly visible and aligned with the measurement axes or reference points on the viewing screen.

6 .Focus the image: Adjust the focus of the projector lens assembly to obtain a sharp and well-defined silhouette or profile on the viewing screen.

7 .Take measurements: Depending on the chosen measurement method (silhouette measurement, point comparison, or software analysis), follow the appropriate procedures to measure the desired dimensions, angles, radii, or other geometric characteristics.

Optical comparators offer several methods for precisely measuring angles, measure a Radius/Diameter catering to different preferences and applications

Accuracy of Optical Comparators

Optical comparators are renowned for their precision, with an accuracy of approximately 0.0005 inches. Maintaining this high level of accuracy requires understanding the key factors that influence performance.

Woodworking (Carpentry)

Lec.6

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Manufacturing Processes(1)

Definition and Types of Carpentry

Carpentry, a traditional craft known to humankind for centuries, is the technique through which a vast number of everyday items are crafted,

such as furniture, wooden objects, decorative items, and more. It is a skill acquired through observation, practice, and extensive experience.

Carpentry is classified into the following types:

1- Furniture Carpentry: This refers to the general manufacture of furniture, such as bedroom furniture, living room furniture

2- Architectural Carpentry: This encompasses all visible woodwork in architecture and construction.

3- Molding Carpentry: This involves creating a model onto which a mold is stamped for the molten metal.

Types of wood used in carpentry

First: Natural Wood: This type of wood is taken from tree trunks and is divided into two categories:

A- Hard Woods: These include beech wood and mahogany wood.

B. Softwoods: There are many of them, such as white and yellow pine.

Commonly Used Woods in Carpentry

Among the most commonly used woods in carpentry are:

1. White or Yellow Pine: This wood is white with a yellowish tinge or light brown color. It is a softwood, lightweight, closed-pore wood, durable, easy to work, relatively low in shrinkage, and free of resinous materials. This type of wood is used in the manufacture of furniture, doors, windows, and wooden models.

2. Teak Wood: Teak wood is a weather-resistant and insect-resistant wood due to its natural oils. It is brownish-yellow or dark in color, has good strength, and is relatively easy to work with. It is used for plywood, engineered wood, furniture, and cladding

3. Oak Wood: Oak wood is light brownish-yellow in color and is a good hardwood.

It has open pores and attractive colors due to the visible medullary radii. It is used for furniture, plywood, and transportation.

4. Walnut Wood: Walnut wood varies in color, weight, and grain straightness depending on its source.

It has open pores, the medullary radii are not visible, it dries easily, is relatively smooth, and stains easily.

This wood is used for making chairs, handles, and transportation equipment.

5.Mahogany wood: Its color is dark brown, golden, light brown. It is one of the finest hardwoods, with straight grain and a very attractive color. It is used in furniture making, construction, and the building of trains and airplanes

6. Ash wood: Its color is light brown, tending towards white. Its grain is tightly packed, and it has elastic properties. The medullary rays are visible. It is used in making chairs, some desks, and molds.

7. Jawi wood: Its color is dark brown to reddish. The trees are large, and their pores are open. It is greatly affected by humidity and heat and is used in construction and inexpensive furniture.

8. Basswood (Lindenwood): It is one of the softest types of hardwood and is very flexible. It is used in model making in general.

Wood Defects

Wood defects, or non-compliance with specifications, are due to climatic **conditions such as low rainfall, frost, or storms**.

The most important wood defects are:

1. Live Knots:
2. Dead Knots:
3. Cracks
4. Resin pockets
5. Fiber Peeling
6. Fungal or insect attack

Figure (4-6) shows some defects in the wood.

2. Dead Knots
1. Live Knots
4. Resin Pockets
3. Cracks in Wood
5. Fiber Peeling
6. Fungal and Insect Attack

Main tools used by carpenters

1. Measuring and drawing tools: ruler, tape measure, and level

2. Basic cutting and trimming tools: saw, circular saw, and handsaw

3. Drilling and boring tools: drill, electric drill, and electric saw

4. Shaping and finishing tools: planer, hammer, and lathe

5. Fastening and fastening tools: nails, screws, and clamps

6. Sanding and polishing tools: sandpaper, polisher, and brush

Carpentry Tools

A carpentry workshop contains a range of tools, equipment, and machinery specific to carpentry work, including:

Measuring and Marking Tools in Carpentry

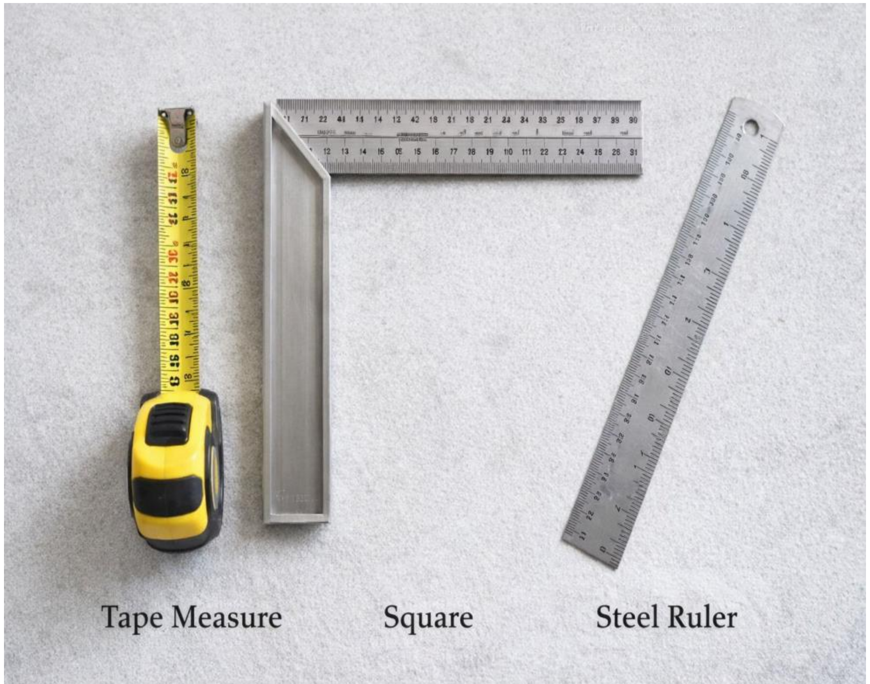
1. **Measuring tools in carpentry**

Length measuring tools, used to measure both small and large lengths, include rulers and tape measures.

Angle measuring tools, used to draw and measure angles such as right angles, angles, and inclined angles, are also used.

Vertical and horizontal alignment tools, used to adjust and define vertical lines and horizontal planes, include plumb bobs and balances.

Figure 7-7 illustrates some common measuring and alignment tools used in carpentry workshops.


Tape Measure
Square
Steel Ruler


TOP LEVEL
LJD13060B
SIZE 600mm
TOP LEVEL
LJD13030B
SIZE 300mm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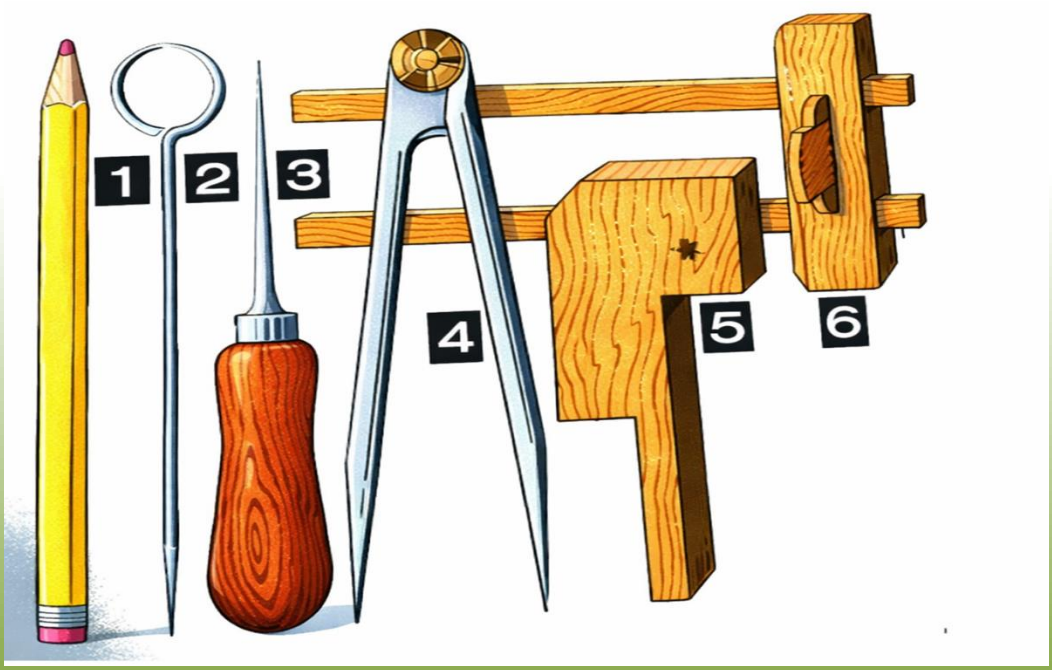
2. Marking Tools in Carpentry:

When measuring vertical, horizontal, and perpendicular lengths, drawing angles, or adjusting alignments, their dimensions must be taken from the drawings and then clearly marked on the workpiece.

In all carpentry operations, such as cutting, drilling, sawing, boring, leveling, etc., the dimensions must be marked on the workpiece using one of the following tools:

1. Pencil
2. Plank fork (planer)
3. Awl
4. Compasses
5. Dial-up tool.
6. Marking tool (slot).



Hand Woodworking Tools

These include:

1.Wood Saws (Hand Wood)
2. Carving Tools (Axes 8,9)

1.WoodworkingTools(Leveling)
2. Wood Chisel
3. Drilling Tools
4. Filing and Assembly Tools.

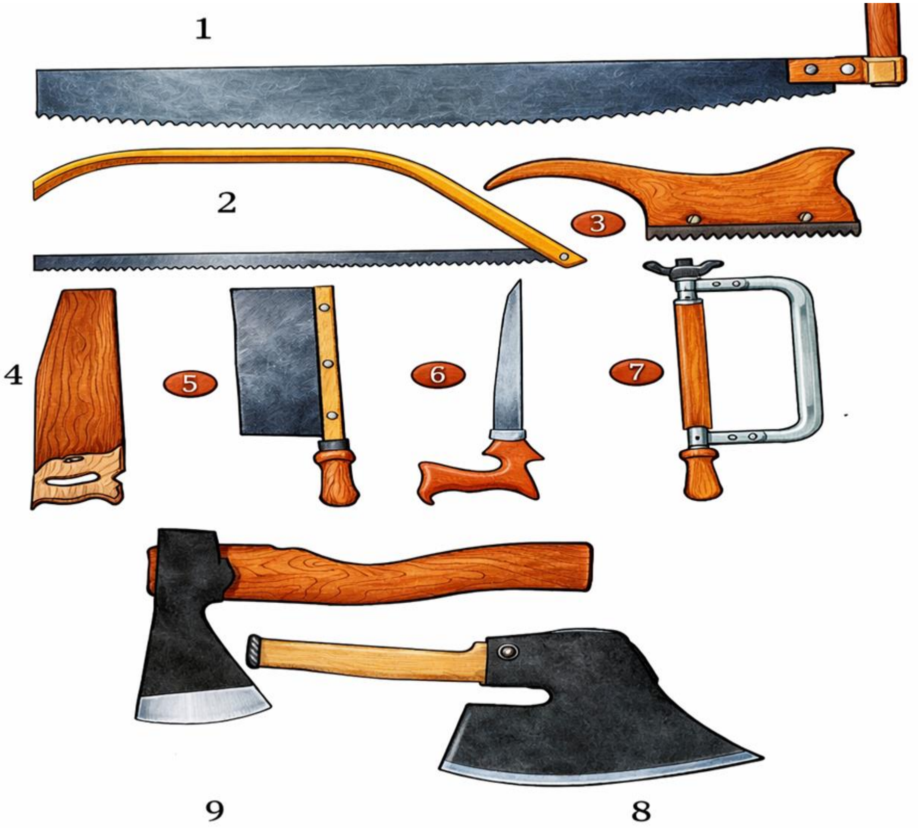


Figure 9-4
A collection of several pieces of wood and their carving and Assorted carpentry tools

Woodworking Machinery

In woodworking workshops, various types of machines are used for cutting and preparing wood and manufacturing doors and other products. Among the most important are:

1. **Band saw**

Band saws have been renowned for their capacity to cut out irregular shapes and large wooden sections easily.

This is because the saw features a continuous loop that remains straight, helping to produce cleaner cuts with minimal wastage.Band saws are cheap

Key Functions and Features:

- Ideal for making intricate, curved cuts.
- Can cut thick wood into thinner slices.
- Produces a smooth edge on the wood.
- Compatible with various blade types for different applications

2. Circular saws

Circular saws are used to make straight cuts in various materials.

They are power saws, and they use special circular blades to cut different materials using a rotary motion.

Key Functions and Features:

- Delivers straight cuts with speed and high accuracy and the ability to cut planks at the required angle or slope using a guide lever.
- Allows for varying cutting depths depending on material thickness.
- Splitting large tree trunks into planks of varying sizes.
- Splitting very hard wood.
- The ability to create tongues for the heads and posts for joining together.

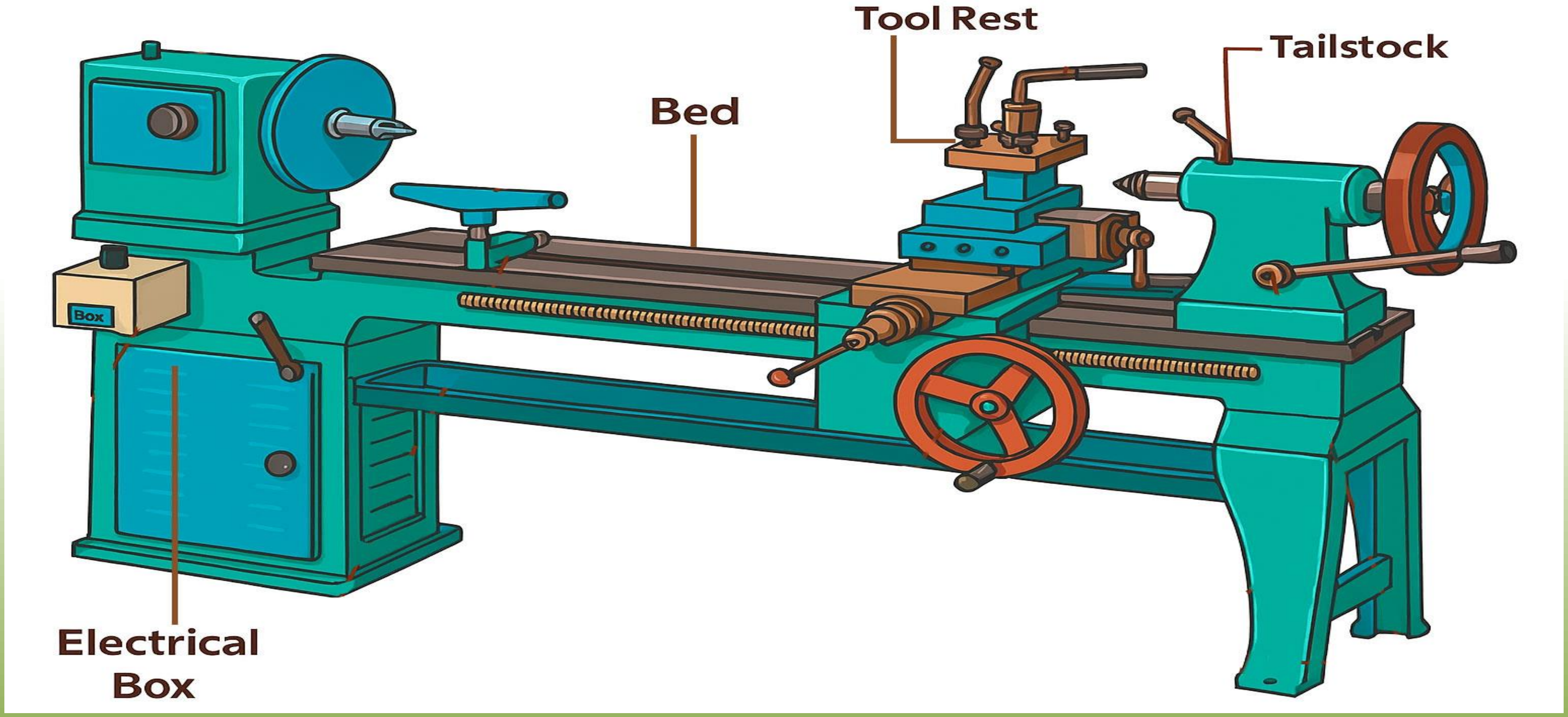
3. **A planer machine (**Thickenssing planers)

A planer machine is a heavy-duty industrial tool used to create flat, smooth surfaces on metal or wood by using linear relative motion between a stationary single-point cutting tool and a reciprocating worktable.

One important aspect when using the wood thicknessing planer is to insert the wood in the direction of the grain to prevent the fibres from fraying.

4. A Wood Turning Lathe Machine

is a type of lathe specifically designed for shaping wooden workpieces. It rotates the wood along its axis to perform various operations such as cutting, sanding, knurling, drilling, or deformation, using tools applied to the workpiece.

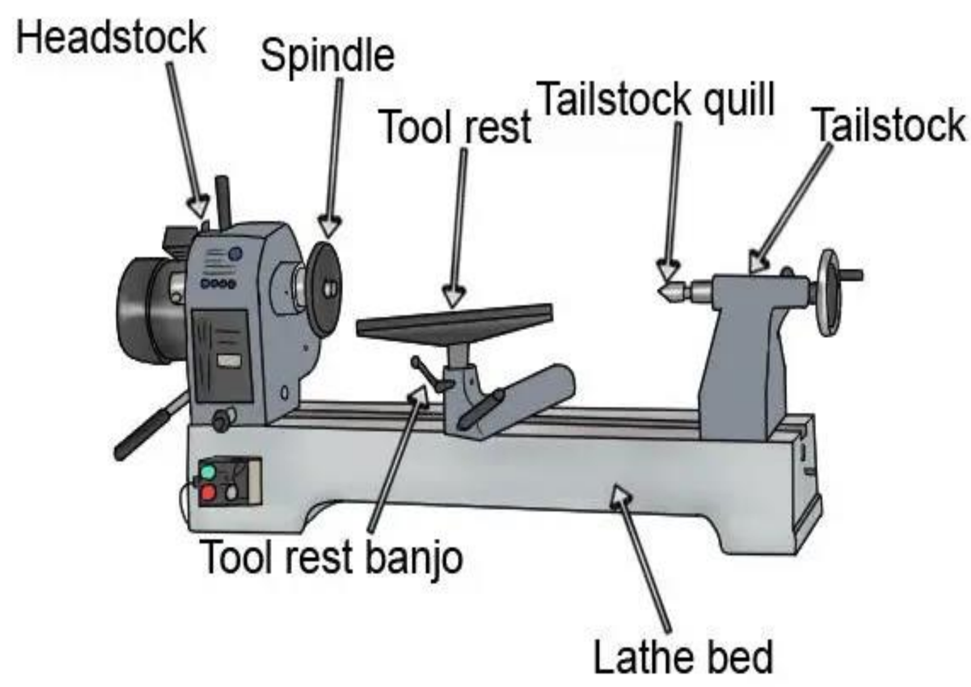


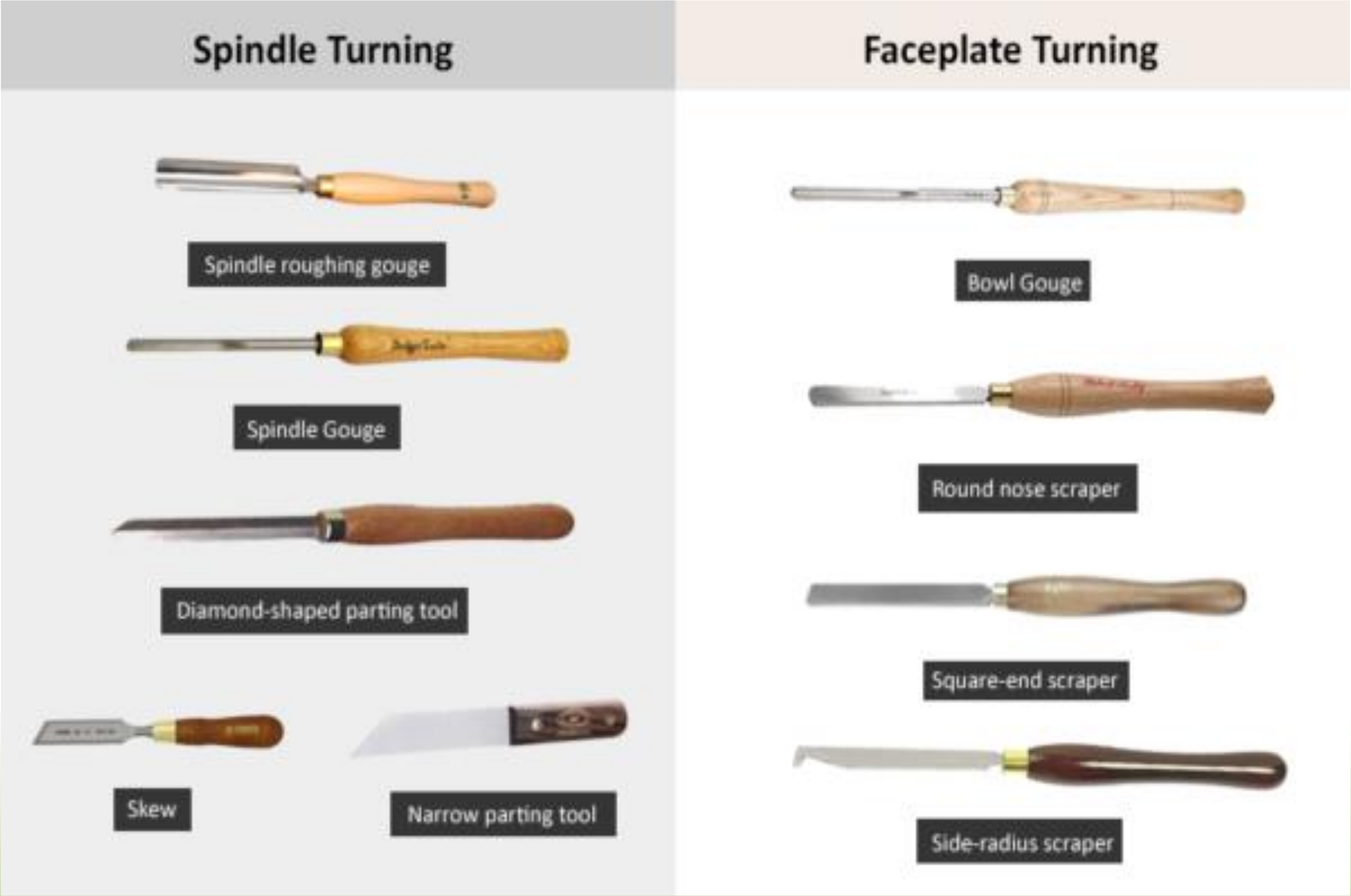
A lathe is a simple wood turning tool. It consists of a metal bed with "ways." The ways hold the headstock and tailstock. The headstock is the motorized portion of the lathe at one end of the bed.

The tailstock is at the opposite end of the bed. The workpiece is held between the headstock and tailstock.

As the motor on the headstock turns, the lathe operator uses any of a variety of tools to shape the wood.

A tool rest positions the tool in relation to the workpiece and the operator uses it to guide the tool when cutting.





Types of lathe tools

Patternmaking Patterns Types of Patterns Used in Casting, Pattern Allowances

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Manufacturing Processes(1)

PATTERN

A pattern is a model or the replica of the object (to be casted). It is embedded in molding sand and suitable ramming of molding sand around the pattern is made. The pattern is then withdrawn for generating cavity (known as mold) in molding sand.

COMMON PATTERN MATERIALS

The common materials used for making patterns are wood, metal, plastic, plaster and wax

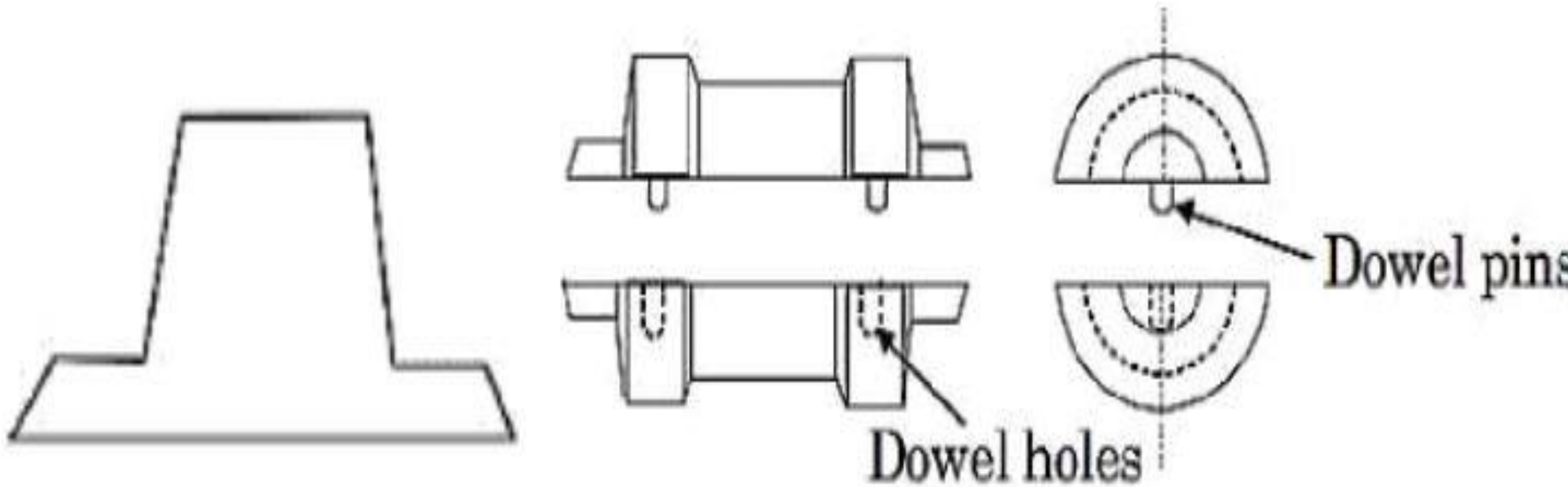
This model is usually made of wood (if the number required to be produced is less than 100 units), or of metal such as aluminum, iron and cast iron (if the number required to be produced is more than 100 units).

TYPES OF PATTERN

The types of the pattern and the description of each are given as under.

1. One piece or solid pattern
2. Two piece or split pattern
3. Cope and drag pattern
4. Three-piece or multi- piece pattern
5. Loose piece pattern
6. Match plate pattern
7. Follow board pattern
8. Gated pattern
9. Sweep pattern
10. Skeleton pattern

• Single-piece or solid pattern: Solid pattern is made of single piece without joints, partings lines or loose pieces.It is the simplest form of the pattern. Typical single piece pattern is shown in Fig.1



(a)Single piece pattern (b)Two piece pattern

Fig. 1 Types of pattern

- Two-piece or split pattern: When solid pattern is difficult for withdrawal from the mold cavity, then solid pattern is split in two parts.

Split pattern is made in two pieces which are joined at the parting line by means of dowel pins. The splitting at the parting line is done to facilitate the withdrawal of the pattern. A typical example is shown in Fig.1

A. Required allowances in the dimensions of the model

1. Shrinkage Allowances: Metals naturally expand and contract with temperature changes. Therefore, this allowance is intended to compensate for the shrinkage expected to occur during freezing and cooling to ambient temperature.

2. Machining Allowances: If further machining operations are to follow the casting process, these are added only to the dimensions that will be machined.

3. Pulling or Negative Allowances: A negative angle must be created along the sides of the model to enable its removal from the sand with minimal damage to the mold sand. The degree of this negative angle depends on the model shape and the molding method. The negative angle value ranges from 0.25 to -1 degree.

B. Model Properties

The model must be made of materials that possess the following characteristics:

1. Lightweight
2. Easily molded
3. Corrosion resistant
4. Surfaces that can be painted or polished

Casting, Advantages of Casting, Disadvantages of Casting

Lec.8

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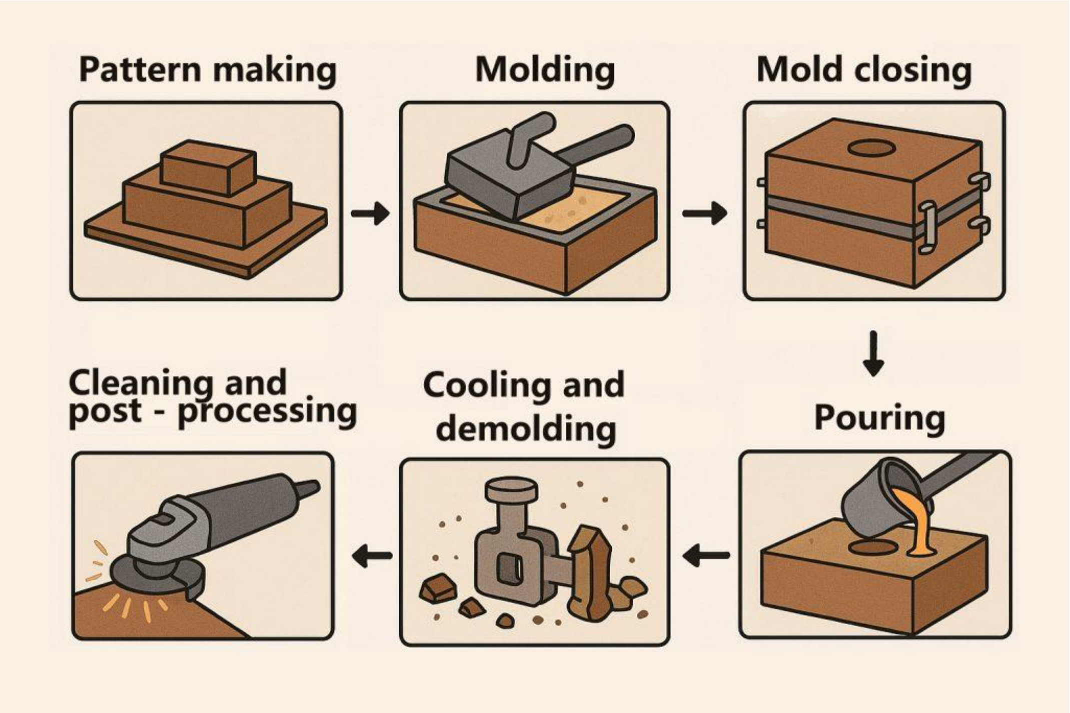
Mechanical Engineering Techniques

Introduction to Casting

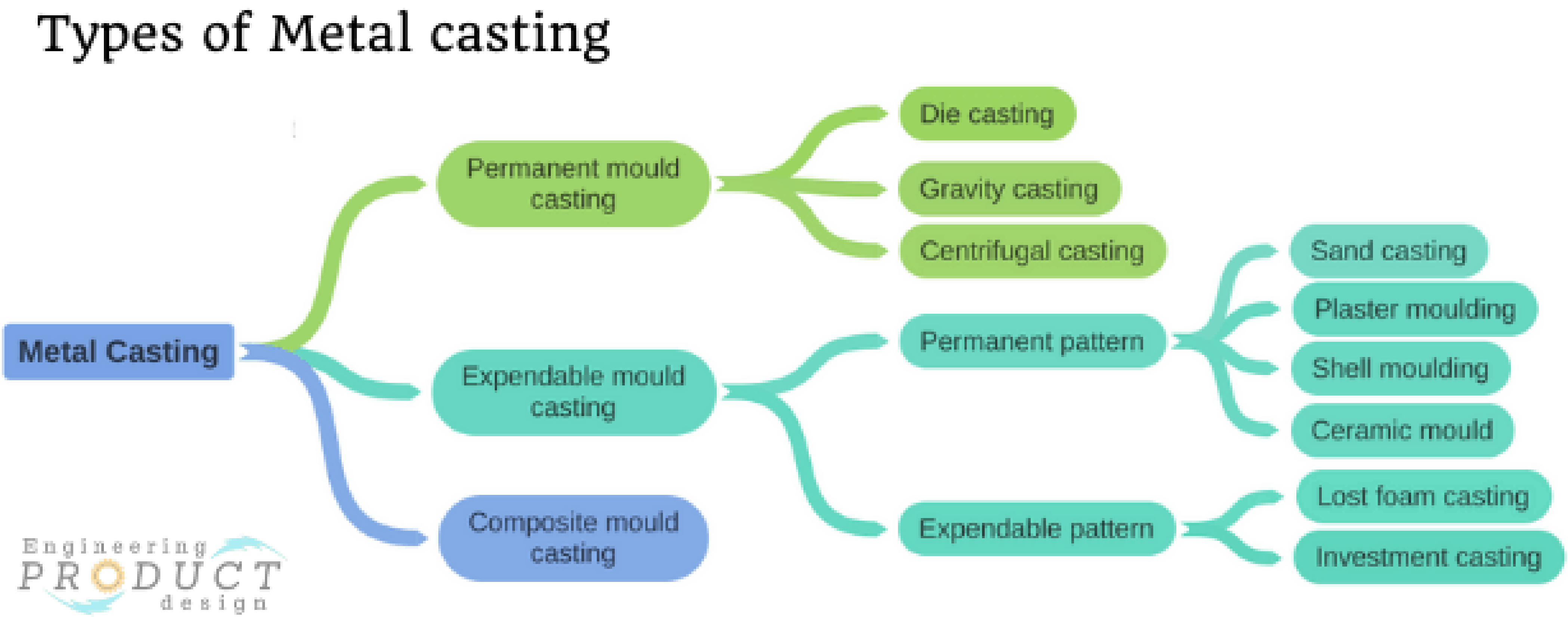
Casting is a versatile manufacturing process where molten metal is poured into a mold cavity, allowed to solidify, and then removed to create complex, near-net-shape parts. It is used for producing large, intricate components like engine blocks and gears, weighing from a few grams to over 100 tons.

Basic Steps in Casting

– Pattern making
– Molding.
– Mold closing.
– Pouring into mold.
– Cooling and demolding.
– Cleaning and post-processing.



Types of Casting Processes



Materials Used in Casting

- **Gray Cast Iron**: Known for its excellent vibration damping and machinability. It is widely used for engine blocks and machine bases.
- **Ductile Iron**: Features spherical graphite that provides greater toughness and impact resistance than gray iron. It is common in automotive and heavy machinery parts.
- **Carbon Steel**: Economical and strong for structural components.
- **Stainless Steel**: High in chromium for superior corrosion resistance, ideal for medical and food-grade equipment.

Materials Used in Casting

- **Aluminum Alloys**: The most popular non-ferrous choice due to its high strength-to-weight ratio and excellent thermal conductivity. Common in aerospace and automotive sectors.
- **Copper Alloys (Brass & Bronze)**: Valued for electrical and thermal conductivity. Bronze is preferred for high-wear parts like bearings, while brass is used for decorative and plumbing fittings.

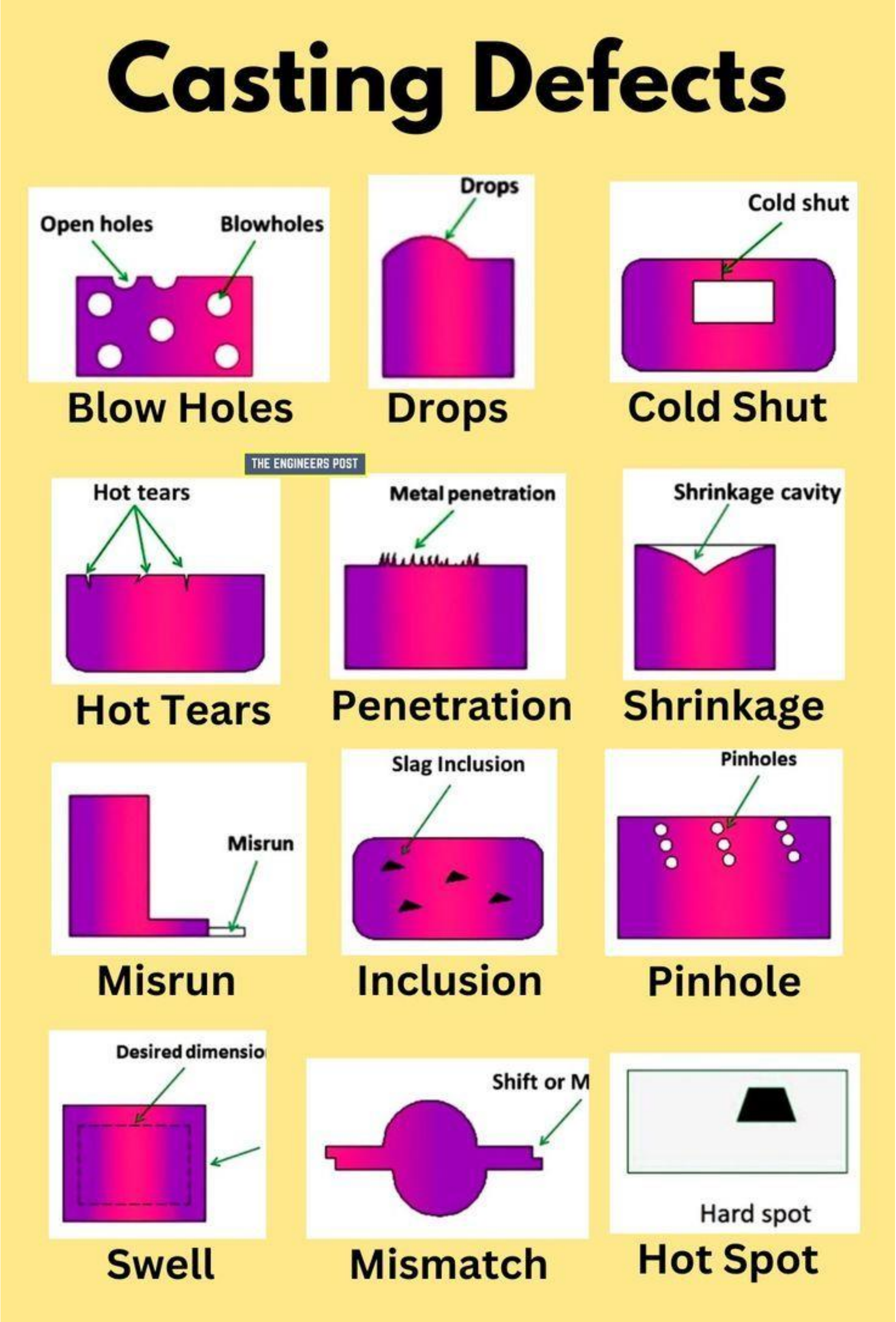
Advantages of Casting

1) Can produce complex shapes.
2) Suitable for large and small components.
3) Economical for mass production.
4) Wide range of materials can be used.
5) Minimal material waste.
6) Can produce internal cavities.
7) Low tooling cost (especially sand casting).

Disadvantages of Casting

1. Possibility of defects .
2. Surfaces may be rough.
3. Dimensional accuracy may be limited.
4. Requires finishing operations.

Common Casting Defects



Applications

1. Engine blocks.
2. Machine tool bases.
3. Pipes and fittings.
4. Automotive and industrial parts.

Metal Mold and Centrifugal Casting

Lec.9

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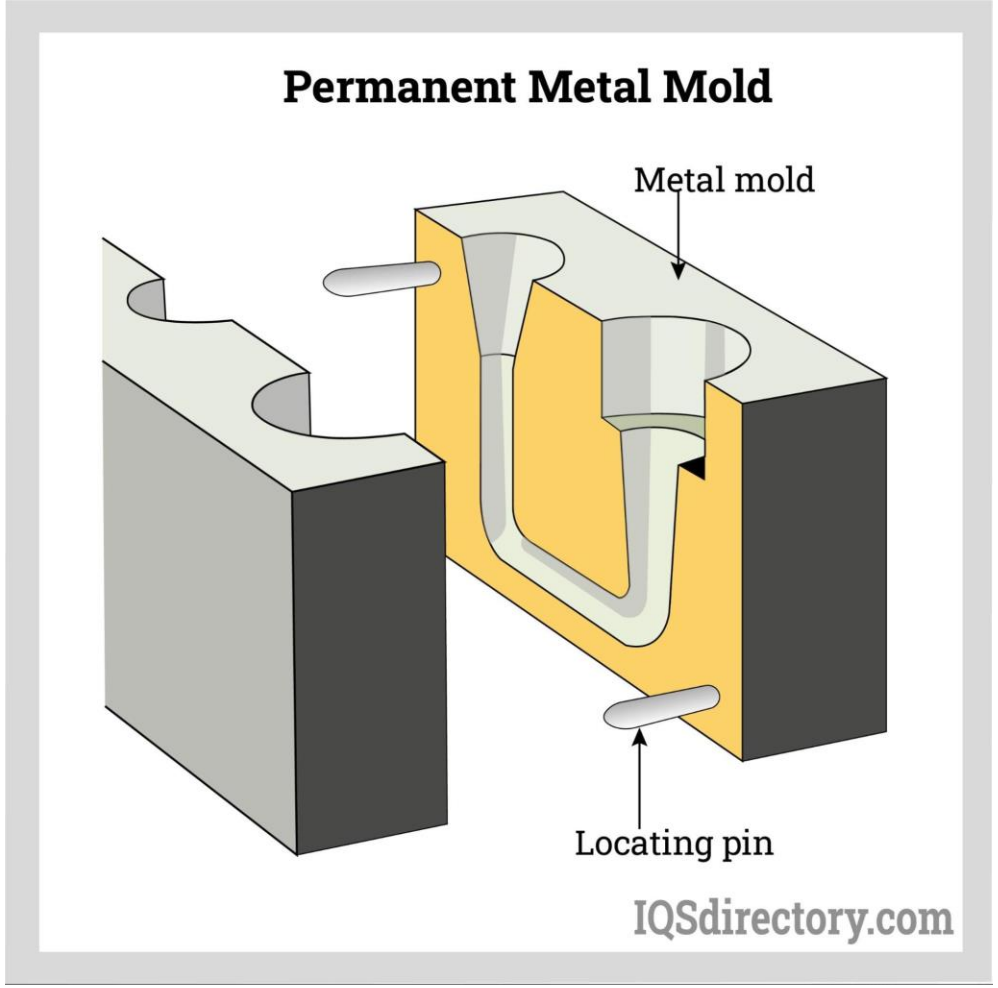
Mechanical Engineering Techniques

Metal Mold Casting (Permanent Mold Casting(

A process that uses reusable metal molds.

Molten metal is poured into a durable mold made of steel or iron.



Advantages of Metal Mold Casting

1. Good surface finish
2. High dimensional accuracy
3. Reusable molds
4. Faster production rates

Disadvantages of Metal Mold Casting

1. High initial cost of mold
2. Limited to simple shapes
3. Not suitable for very large castings

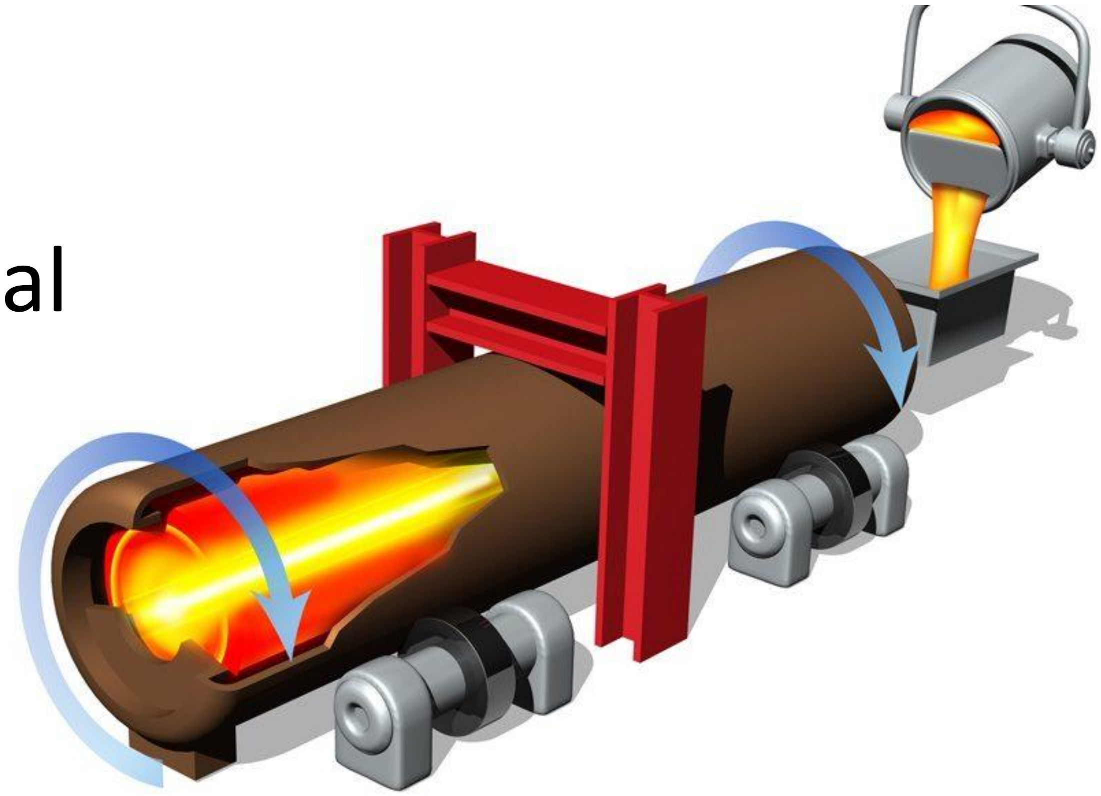
Types of Metal Mold Casting

- Gravity Die Casting
- Low-Pressure Die Casting
- High-Pressure Die Casting

Centrifugal Casting

- A casting process where molten metal is poured into a rotating mold.

- Centrifugal force distributes metal evenly.



Types of Centrifugal Casting

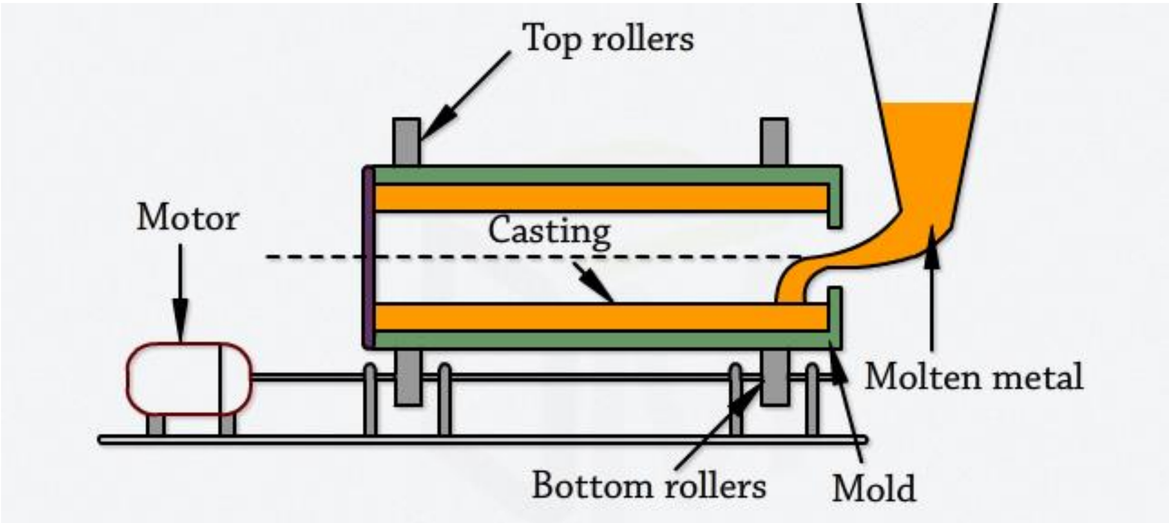
- True Centrifugal Casting
- Semi-Centrifugal Casting
- Centrifuging

Advantages of Centrifugal Casting

1. High density and strength
2. Reduced defects
3. Good mechanical properties
4. No need for cores

Disadvantages of Centrifugal Casting

1. Limited to cylindrical shapes
2. Equipment cost is high
3. Requires careful control



Centrifugal casting

Applications

- Pipes and tubes
- Engine parts
- Machine components
- Widely used in mechanical engineering industries

Sand Casting

Lec.10

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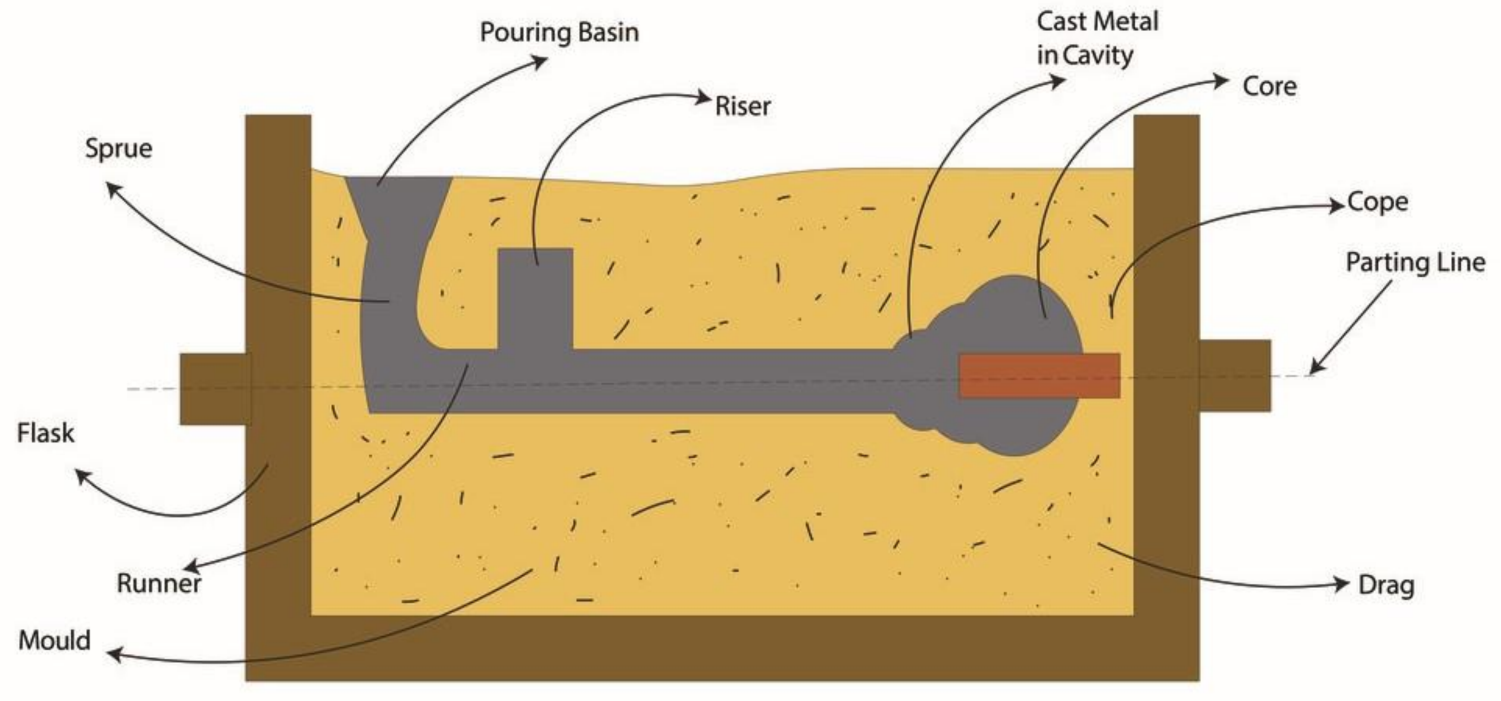
Polytechnic Karbala Collage

Mechanical Engineering Techniques

Introduction to Sand Casting

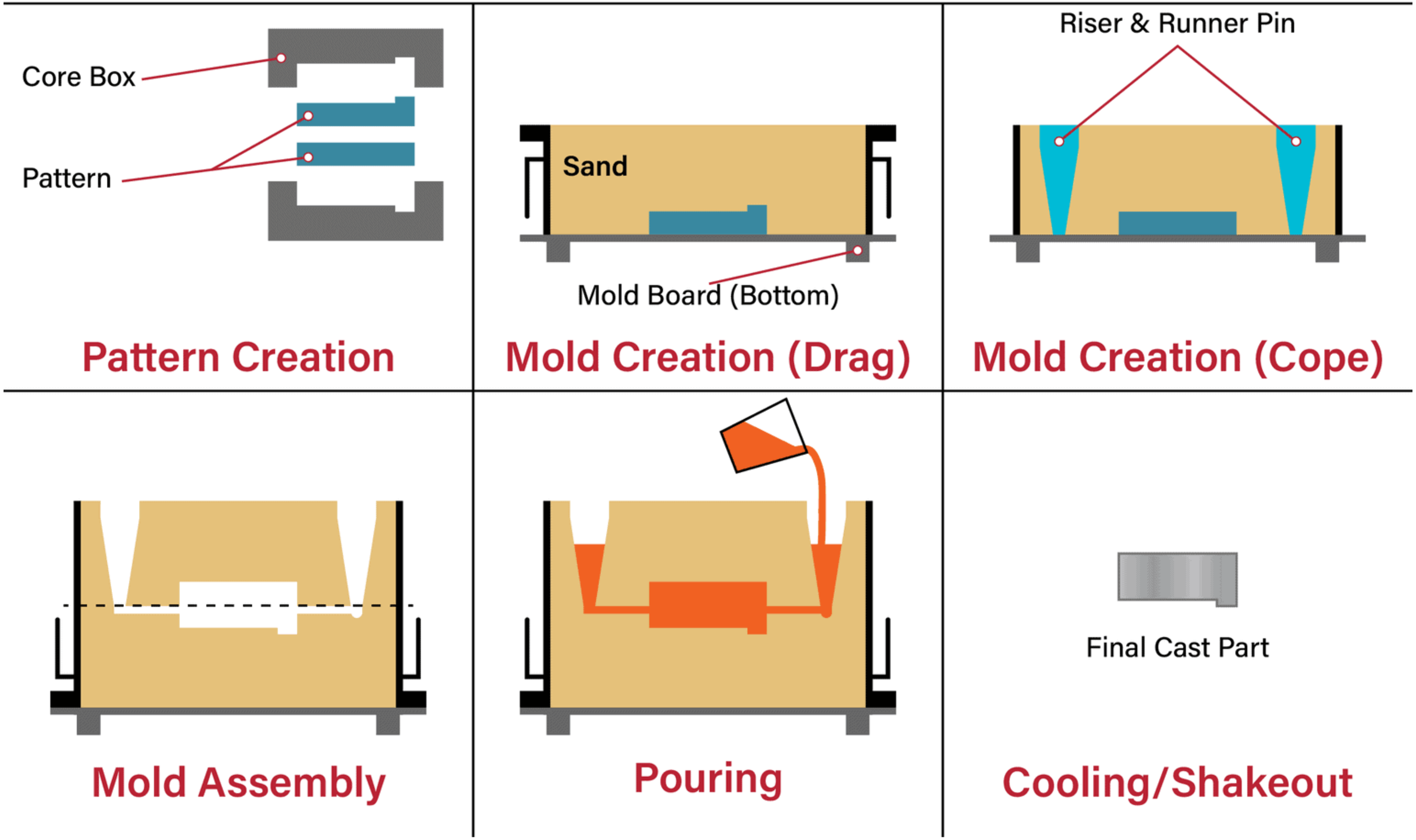
- Sand casting is a manufacturing process where molten metal is poured into a sand mold.
- It is one of the oldest and most widely used casting methods.



Steps in Sand Casting:

1. **Pattern Preparation:** A model of the desired part is made.
2. **Mold Creation:** Sand is compacted around the pattern.
3. **Core Making:** Sand cores are placed inside the mold to create internal cavities.
4. **Pouring:** Molten metal is poured into the mold.
5. **Cooling and Shakeout:** The metal solidifies and the sand is broken away.
6. **Finishing:** The casting is trimmed, cleaned, and sometimes machined.

Sand Casting Process

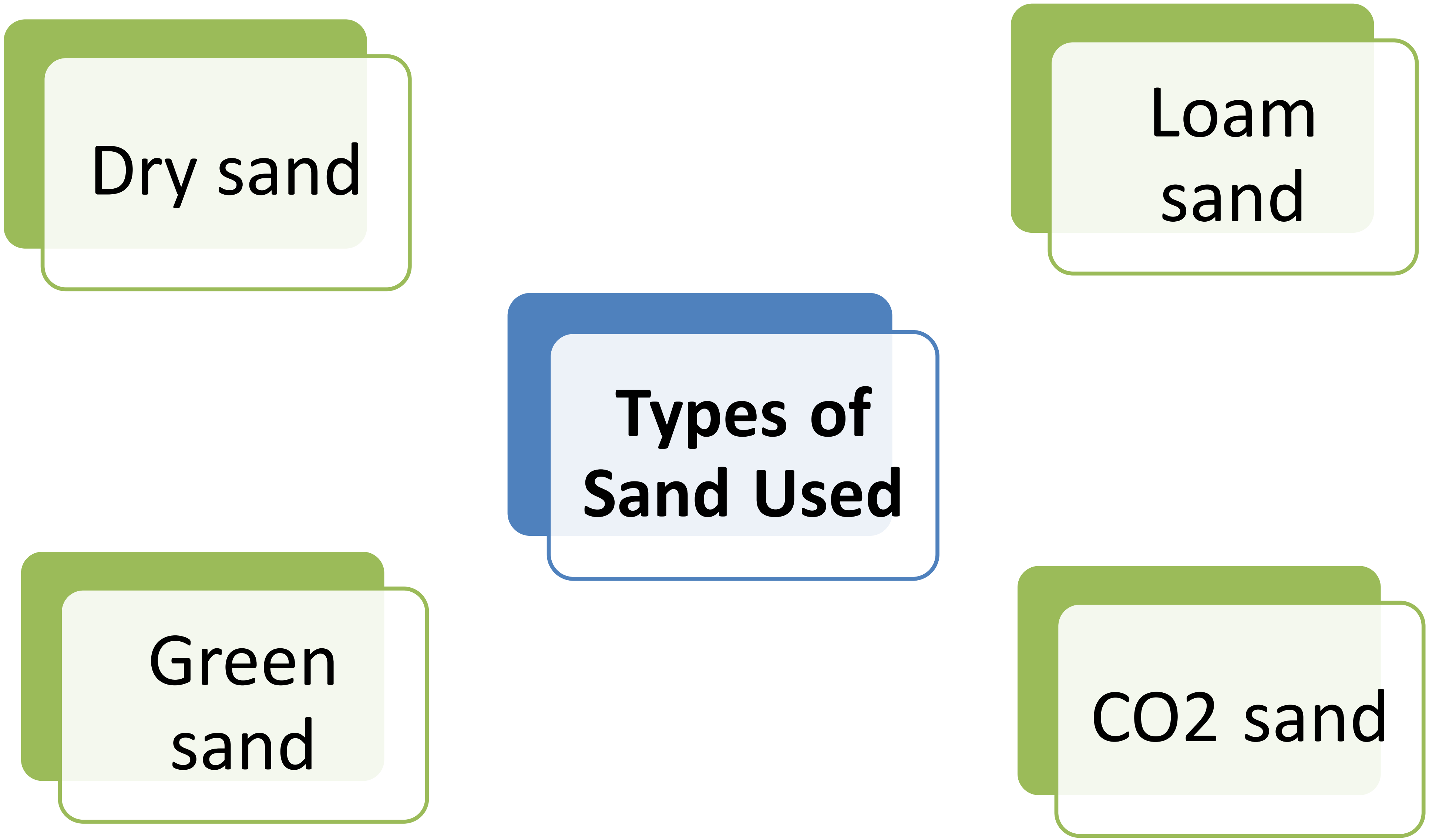


Advantages of Sand Casting

1. Low cost
2. Suitable for complex shapes
3. Can produce large components
4. Wide range of metals can be used

Disadvantages of Sand Casting

1. Poor surface finish
2. Lower dimensional accuracy
3. More finishing operations required

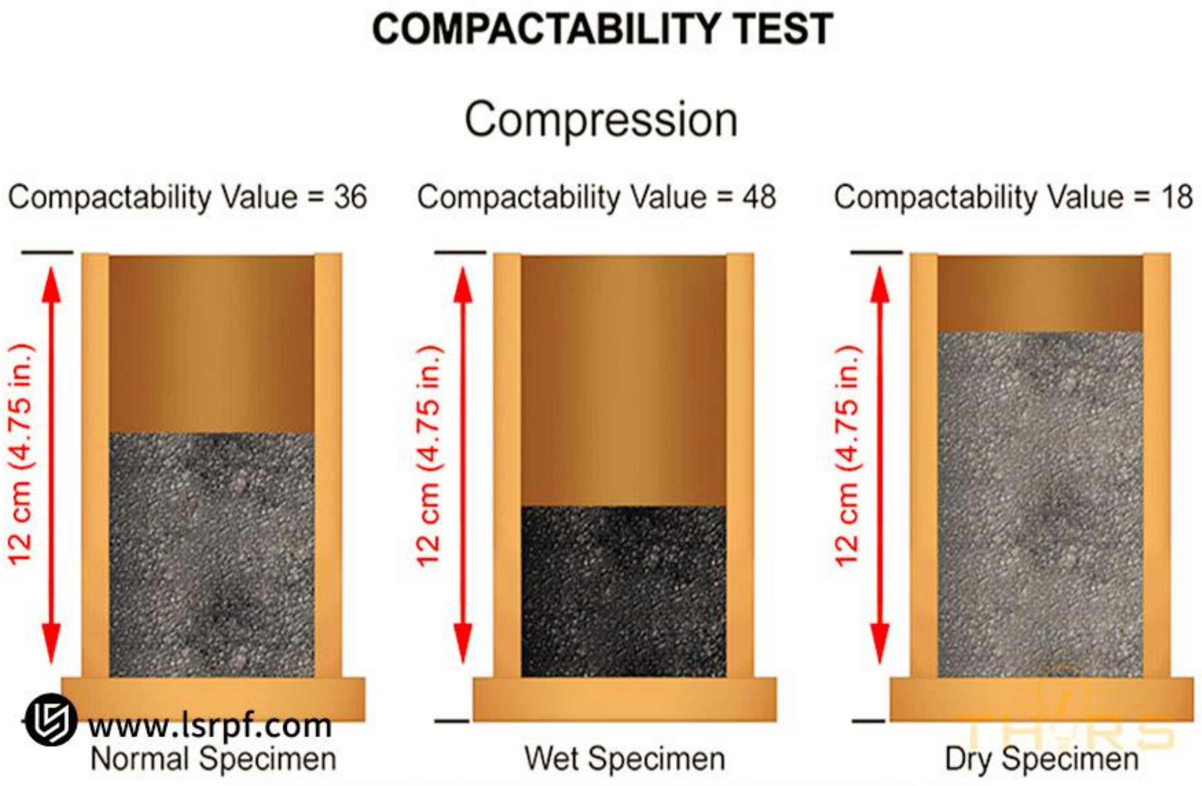

Dry sand
Loam sand
Types of Sand Used
Green sand
CO2 sand

Sand Properties

1. **Permeability:** Ability to allow gases to pass through
2. **Strength:** Ability to hold shape under stress Cohesiveness
3. **Refractoriness:** Resistance to high temperature
4. **Plasticity:** Ability to flow and take shape
5. **Adhesiveness:** Ability to stick to mold walls

Sand Testing Methods

1. Moisture content test
2. Permeability test
3. Compression strength test
4. Grain size analysis



Applications of Sand Casting

1. Engine blocks
2. Pipes
3. Machine bases
4. Automotive and heavy machinery parts

Cores in Casting

Lec.11

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Mechanical Engineering Techniques

Introduction to Cores in Casting

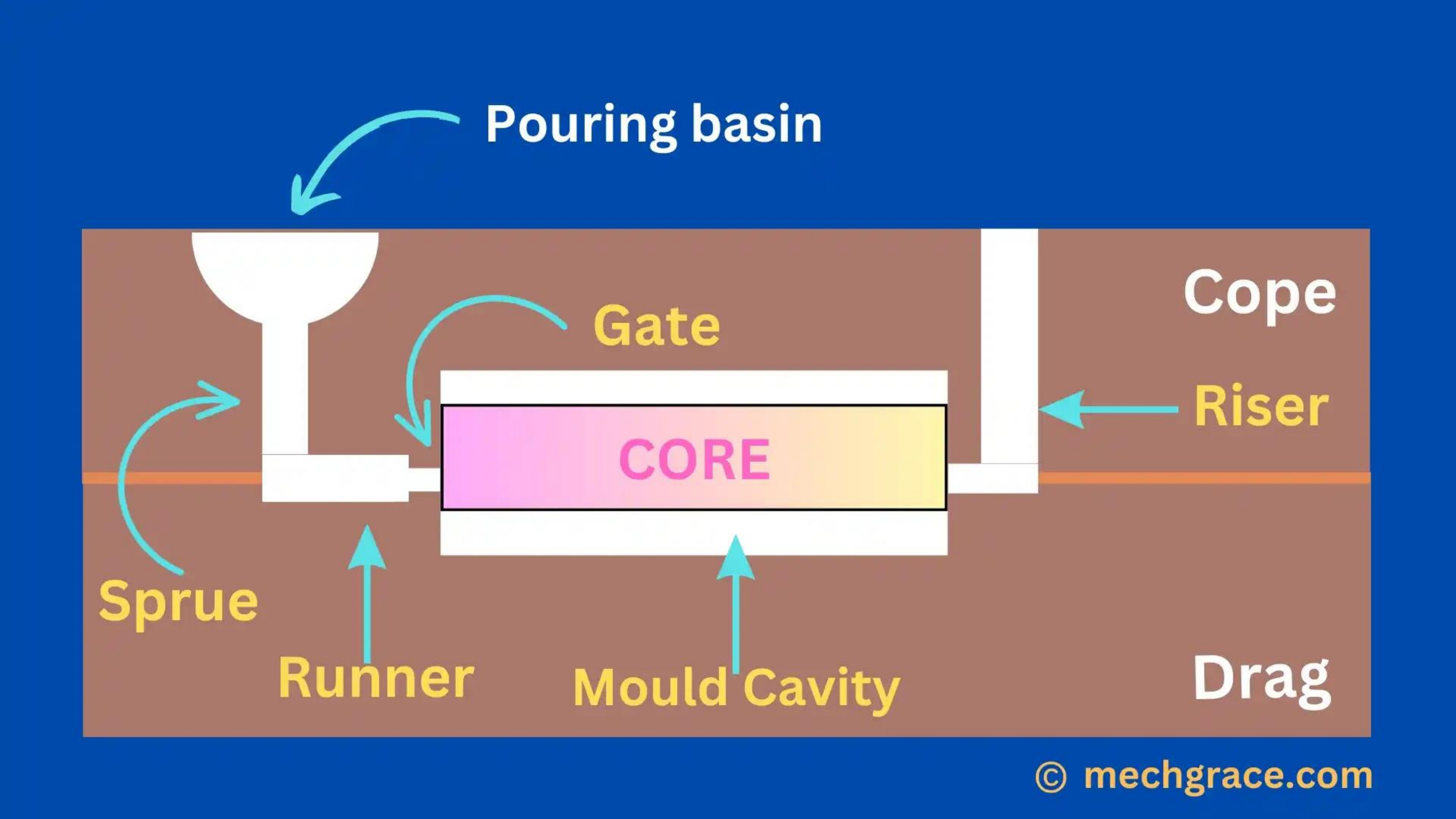
Cores are removable, pre-formed inserts placed inside a casting mold to create internal cavities, intricate shapes, or holes that a standard pattern cannot produce. Typically made of sand with binders, they are placed into the mold before pouring and are broken down and removed during the "shakeout" phase

Functions of Cores

1. Create hollow sections
2. Improve design flexibility
3. Reduce material usage

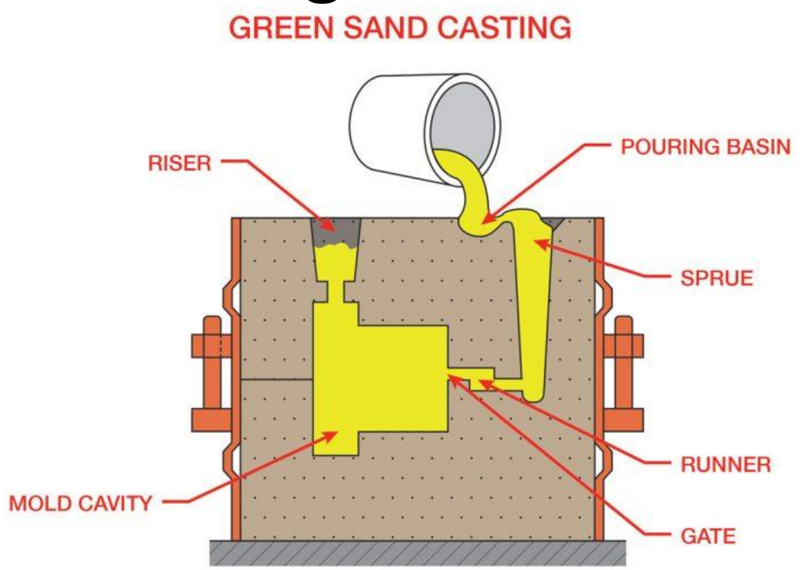
Types of Cores

1. Green sand cores
2. Dry sand cores
3. Shell cores
4. Cold box cores


Pouring basin
Cope
Gate
Riser
CORE
Sprue
Runner
Mould Cavity
Drag
© mechgrace.com

Green Sand Cores

Green sand cores are unbaked, moist mixtures of silica sand, bentonite clay, and water used in foundry casting to create internal voids or shapes. Because they are used in their "green" (wet) state and not baked, they are cost-effective, reusable, and offer excellent permeability, though they provide less strength and dimensional accuracy than hard sand cores.

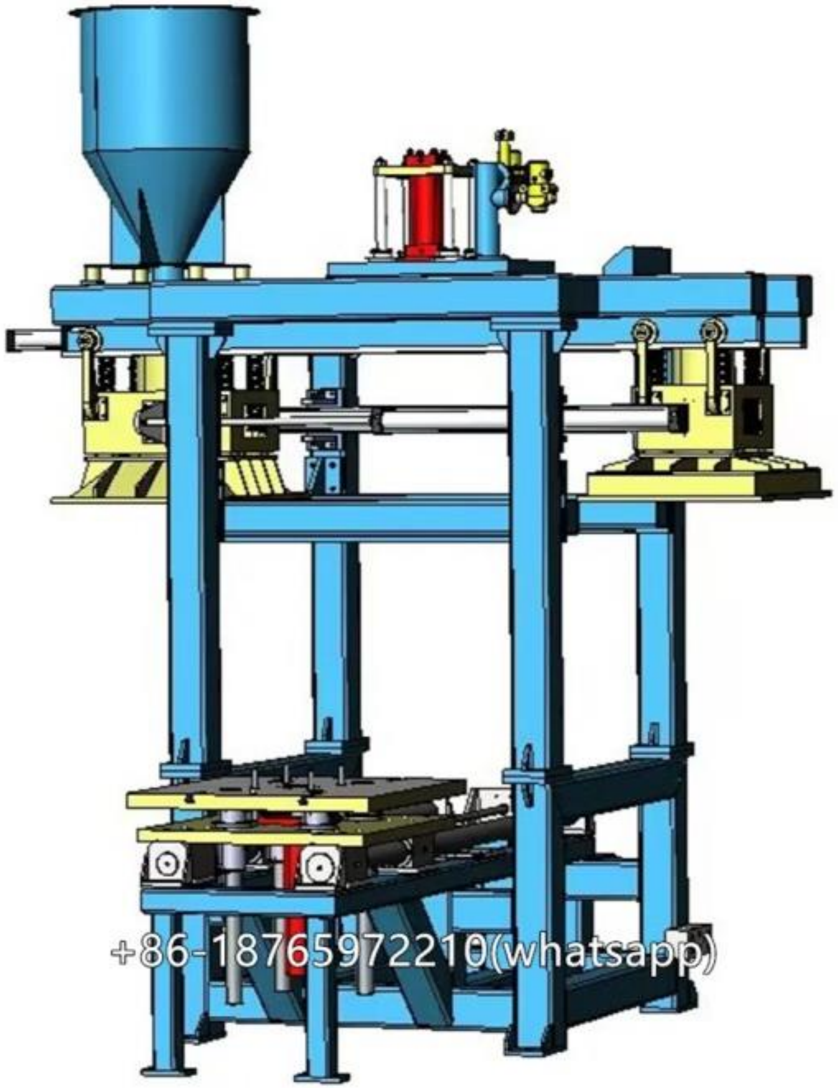


Dry Sand Cores

Dry sand cores are pre-formed sand shapes mixed with binders and hardened by baking or chemical curing to create internal cavities, hollows, or complex profiles in metal castings. They offer high strength, rigidity, and superior dimensional accuracy compared to green sand cores, resisting erosion from molten metal.

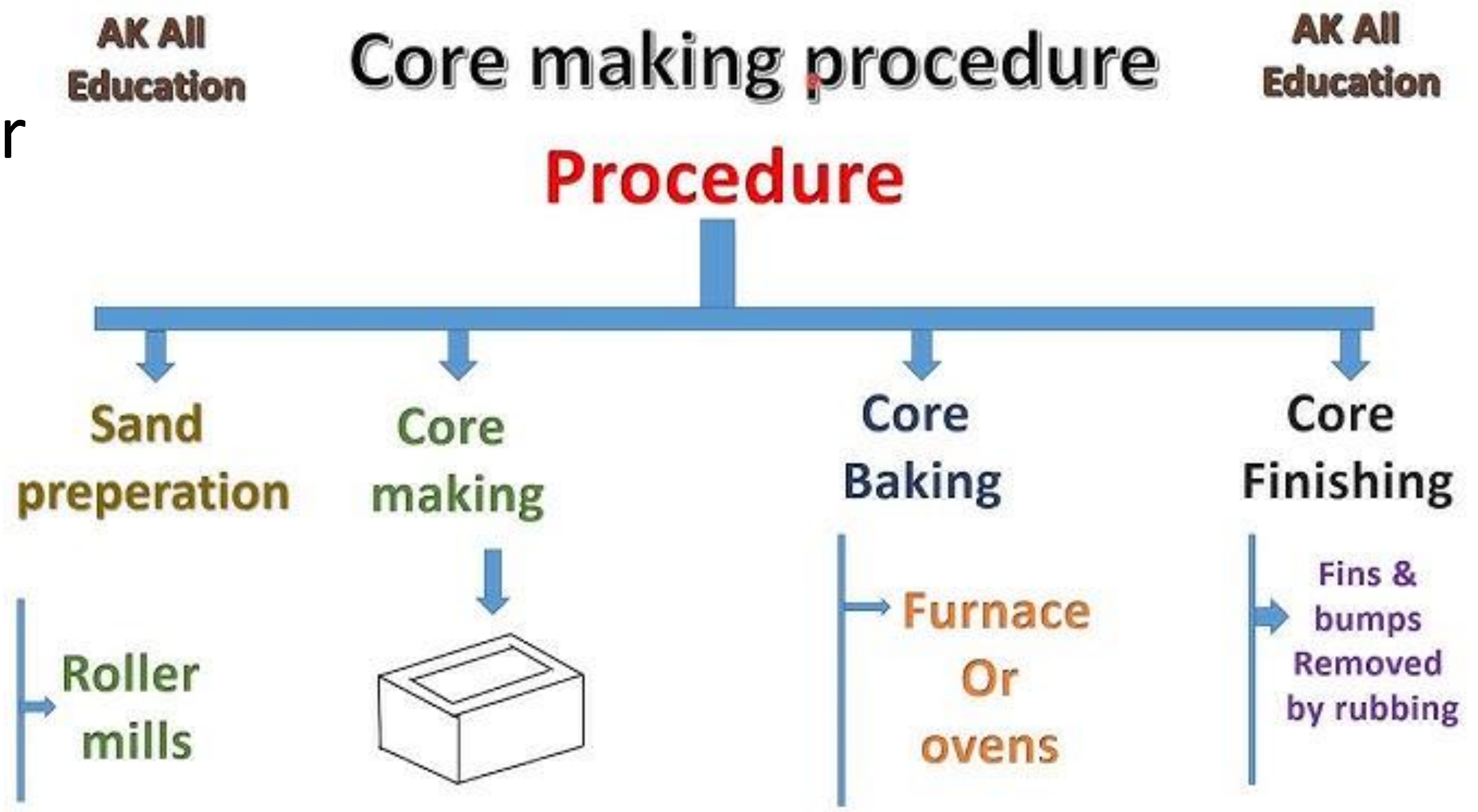
Shell and Cold Box Cores

1. Shell cores: resin-coated sand
2. Cold box: chemically hardened
3. High accuracy and strength



Core Manufacturing Process

1. Mixing sand and binder
2. Shaping in core box
3. Curing or baking
4. Inspection



Core Features

1. Core prints
2. Chaplets
3. Vents
4. Reinforcements

Tools & Techniques in Sand Mold Preparation

Lec.12

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Polytechnic Karbalaa Collage

Mechanical Engineering Techniques

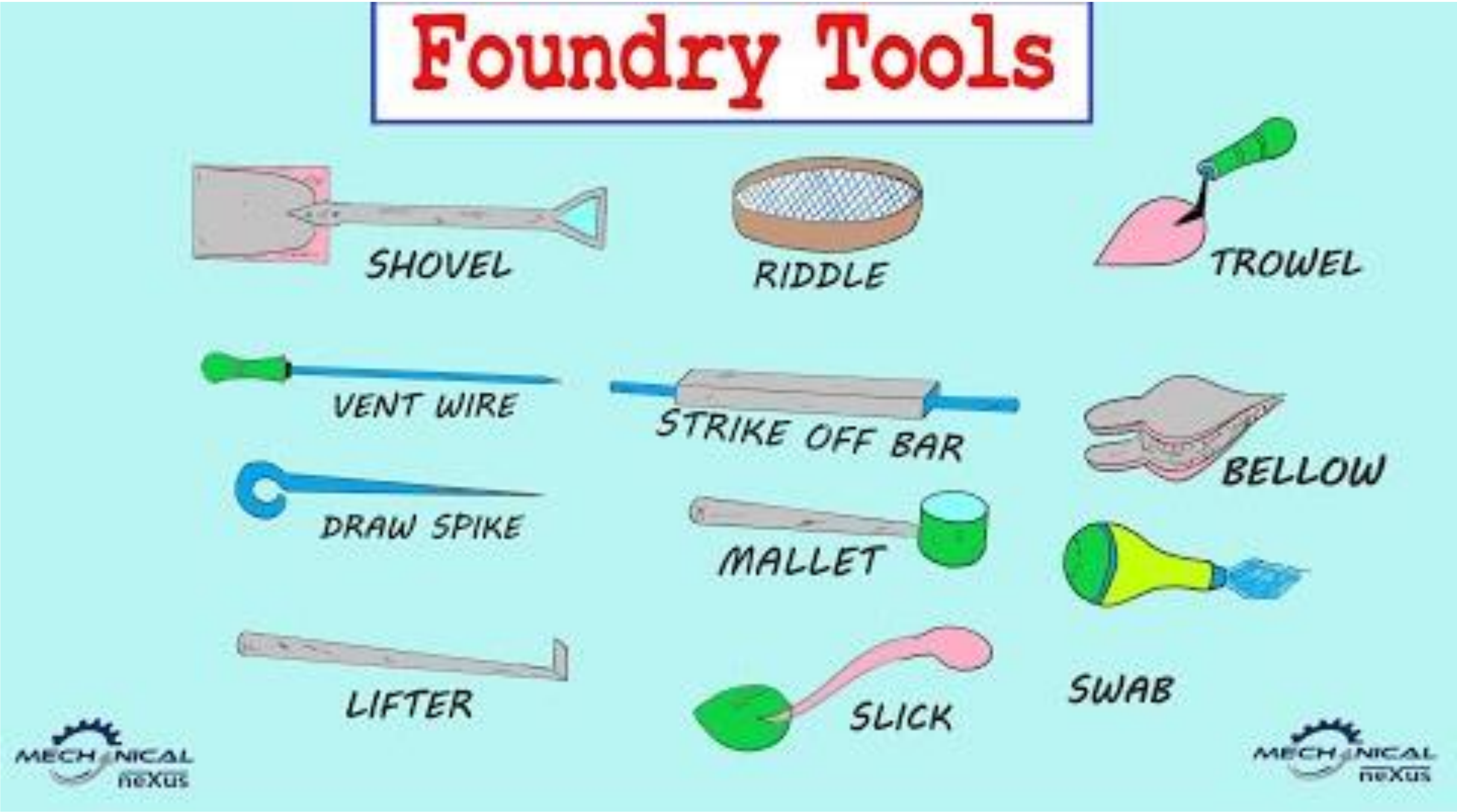
The Foundation: Flasks and Patterns

The Flask: A two-part frame (Cope for the top, Drag for the bottom) that holds the sand.

The Pattern: The "replica" of the object to be cast.

Simple Models: Solid (one-piece) patterns.

Complex Models: Split patterns or multi-piece patterns to allow for easy removal without damaging the mold.


Foundry Tools
SHOVEL
RIDDLE
TROWEL
VENT WIRE
STRIKE OFF BAR
BELLOW
DRAW SPIKE
MALLET
LIFTER
SLICK
SWAB
MECHANICAL neXus
MECHANICAL neXus

Essential Hand Tools (Part I)

To prepare a mold manually, engineers use specific hand tools:

Shovel & Riddle: Used for mixing sand and "riddling" (sieving) it over the pattern to ensure a fine surface finish.

Rammer: Used for packing (compacting) the sand. It has two ends: the "peen" (pointed) and the "butt" (flat).

Note: Proper ramming is critical.

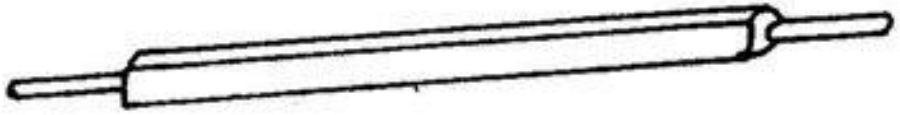
Too loose = mold collapse; too tight = gas defects.

Essential Hand Tools (Part II)

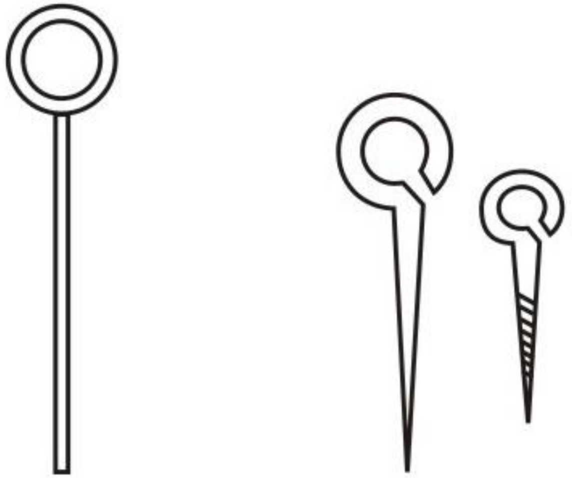
Strike-off Bar: A straight-edge metal piece used to remove excess sand from the top of the flask.

Vent Rod: A thin wire used to poke holes in the sand to allow gases to escape during pouring.

Draw Spike: A tool driven into the pattern to lift it out of the sand.



A strike off bar



(f) Vent Rod (g) Draw Spikes

Finishing Tools for the Mold Cavity

Once the pattern is removed, the cavity needs "cleaning":

Trowels: Used for smoothing flat surfaces and repairing edges.

Slicks & Lifters: Small, double-ended tools used to reach deep into the mold to remove loose sand or smooth intricate corners.

Swab: A small brush used to apply water/moisture to the edges of the pattern before removal to strengthen the sand.

Creating the Gating System

The "plumbing" of the mold is what makes or breaks a cast:

Sprue Cutter: A hollow metal tube used to cut the vertical hole (sprue) where metal enters.

Gate Cutter: A small curved tool used to cut the horizontal channels (runners/gates) connecting the sprue to the mold cavity.

Riser: A reservoir of molten metal to compensate for shrinkage as the part cools.

Sprue cutter

Techniques for Simple Models

For a basic geometry (e.g., a simple block or gear):

Placement: Place the pattern in the Drag (bottom flask).

Facing: Sieve fine sand directly onto the pattern.

Ramming: Fill with bulk sand and ram in layers.

Inversion: Flip the drag, attach the Cope, and repeat for the top half.

Direct Withdrawal: Pull the pattern straight up.

Techniques for Complex Models: Cores

When a model has internal holes or hollow sections, we use **Cores**:

Core Boxes: Special molds used to create sand cores.

Core Prints: Added features on the pattern that create "seats" to hold the core in place.

Technique: The core is placed into the mold cavity after the pattern is removed but before the flasks are joined.

Handling Undercuts and Intricate Details

Complex shapes often have **undercuts** (parts that would get stuck if pulled straight out).

Loose Pieces: The pattern is designed with removable parts. When the main pattern is pulled, the "loose piece" stays in the sand and is removed sideways later.

Multi-Part Flasks (Cheeks): Using a third flask section between the Cope and Drag for very tall or tiered geometries.

Melting furnaces

Lec.13

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Mechanical Engineering technical

Second semester

Manufacturing Processes(1)

Introduction to Melting and Foundries

Melting (Fusion): A physical process resulting in the phase transition of a substance from solid to liquid

Foundry: A factory that produces metal castings by melting metal, pouring it into a mold, and removing the mold material after solidification.

Melting Furnace: A device used to heat and melt metal ore to extract the metal and remove impurities.

Selection Factors for Furnaces

Selecting the appropriate furnace type depends on several engineering and economic factors:

The casting alloy: Specifically its melting and pouring temperature requirements

Capacity requirements: The required volume of metal and the furnace's melting rate

Costs: Initial investment, operation, and ongoing maintenance

Environmental Impact: Pollution control and noise level considerations

Casting Alloy
Melting point and pouring temperature dictate baseline thermal requirements.
Economics
Capital expenditure (CAPEX) for installation vs. operational and maintenance costs (OPEX).
LTG
Capacity & Throughput
Required melting rate, total tonnage, and batch vs. continuous operation.
Melt Quality
Tolerance for gas absorption, burn-off, and required metallurgical purity.
Environmental Impact
Local emission regulations, CO2 footprint, and waste/slag disposal requirements.

Common Types of Melting Furnaces

Foundries typically utilize one of the following main types of furnaces:

- Cupolas: Primarily for cast irons
- Crucible Furnaces: Indirectly fired for non-ferrous metals
- Electric-Arc Furnaces: High-temperature arc melting
- Induction Furnaces: Utilizing electromagnetic currents
- Advanced Technologies: Including Microwave, Plasma, and Electron-beam furnaces

Furnace Taxonomy & Architecture

Primary Application / Dominant Energy Source	Chemical / Fuel	Electrical Energy
Ferrous / Heavy Tonnage	Cupolas: Vertical continuous melters.	Electric-Arc: High-power direct arc heating.
Non-Ferrous / Precision	Direct Fuel-Fired: Open-hearth reverberatory. Crucible: Indirect heating via gas/oil.	Induction: Electromagnetic joule heating.

Advanced / Specialized

Microwave, Plasma, and Electron-Beam (Bleeding-edge/Refractory applications).

Architecture

Cupola Furnaces

Vertical cylindrical furnace equipped with a tapping spout near the base, charged via a top door.

Mechanism

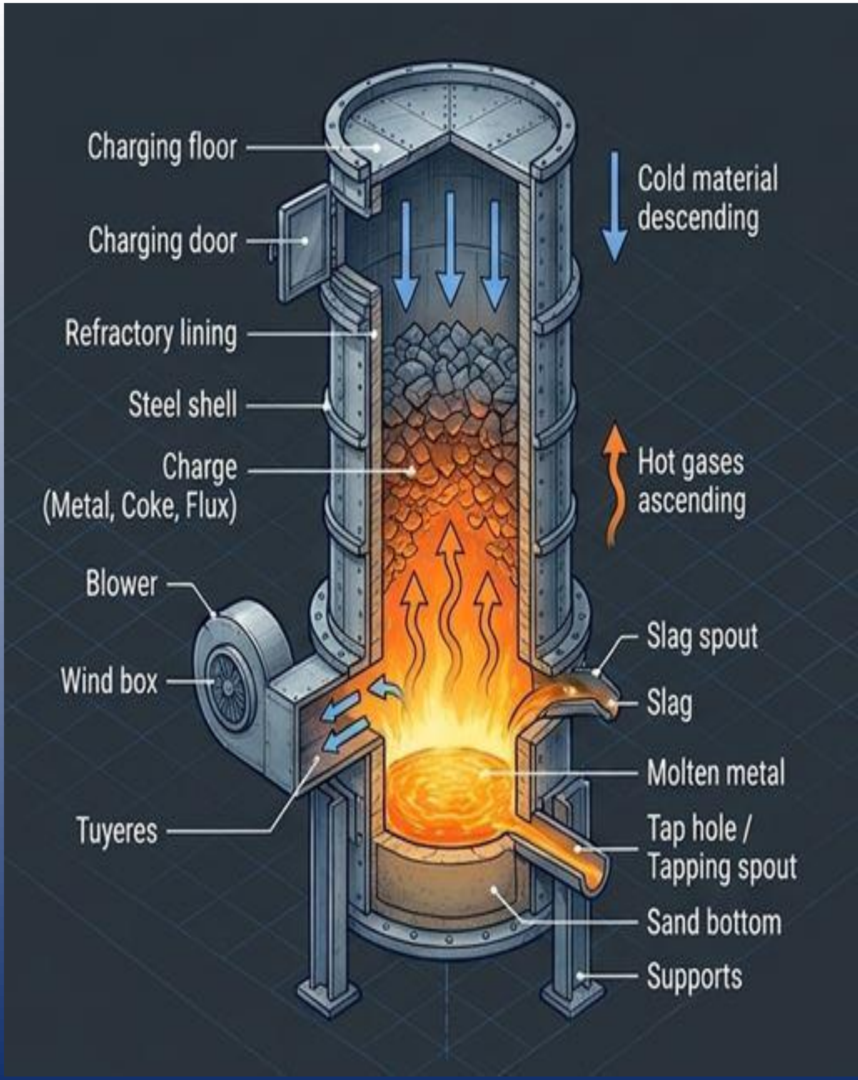
Counter-current heat exchange; ascending hot gases melt descending burden (metal, flux, solid fuel).

Primary Application

Exclusively focused on high-tonnage cast iron production.

Modern Evolution (Cokeless)

Replaces traditional coke with natural gas, propane, or pulverized coal. Uses refractory spheres for heat exchange and a well carburizer for carbon control. Eliminates CO emissions and reduces sulfur/slag

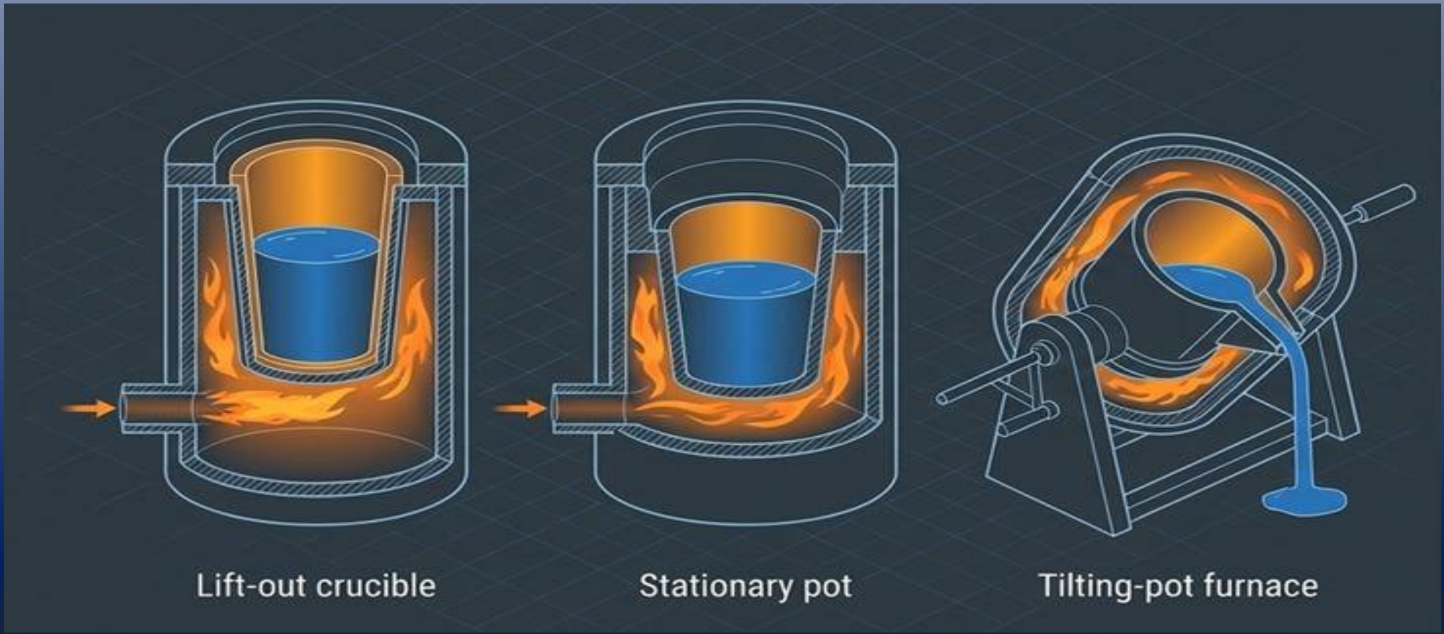


Crucible Furnaces (Indirect Fuel-Fired)

Mechanism: These furnaces melt metal without direct contact with the burning fuel mixture (indirect heating)

Applications: Ideal for non-ferrous alloys such as Aluminum and Copper-base alloys

Main Types: Lift-out type, stationary pot furnace, and tilting pot furnace



Electric-Arc Furnaces

Mechanism

Charge is melted by immense heat generated directly from an electric arc struck between electrodes and the metal bath.

Primary Application

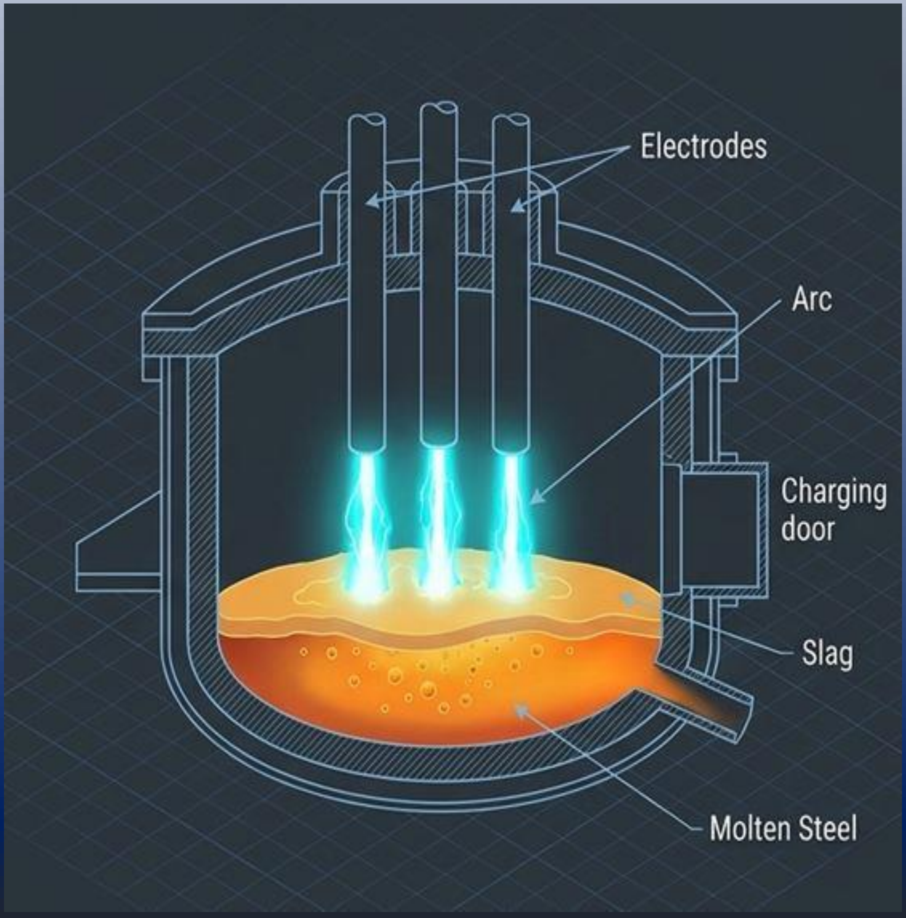
Preferred method for steel production and heavy alloy slabs (capacities generally up to 50 tons/hour).

Key Benefits

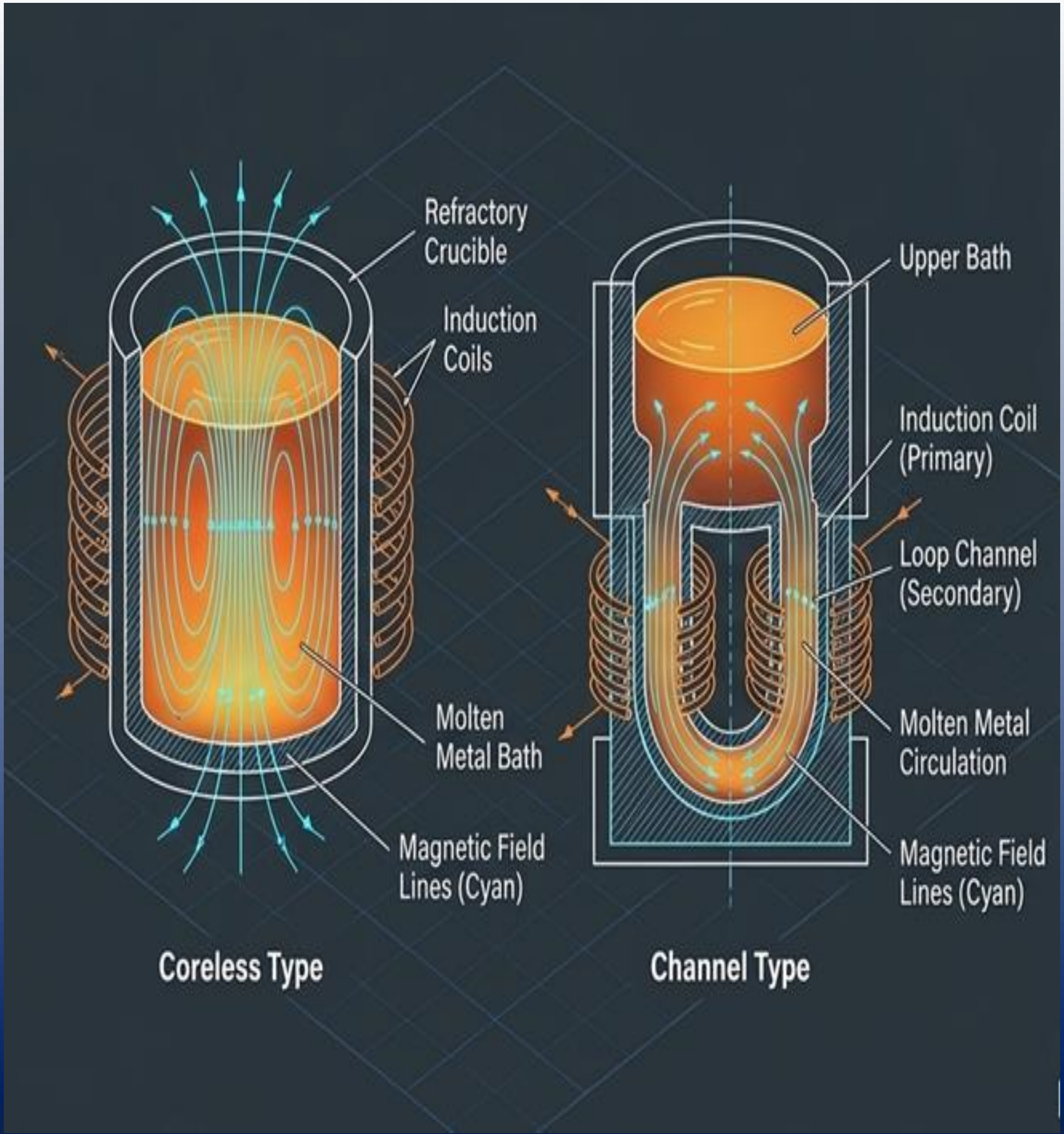
Exceptionally rapid melting rates, high bath homogeneity, precise holding times, and ease of incorporating pollution controls.

Drawbacks

High power consumption, continuous electrode/refractory degradation, and high acoustic/particulate emissions.



Induction Furnaces



Mechanism

Heat is generated entirely within the metal via Lenz's, Ohm's, and Joule's laws of electromagnetic induction.

Primary Application

Steel, cast iron, and high-purity non-ferrous metals. Unsuitable for slag metallurgy (only heats metal, not slag).

Types

- Coreless (High/Medium Freq): Used for primary melting. Allows quick alloy changes.
- Channel: Primarily used as a holding and temperature maintenance furnace.

Key Benefits

Exceptional atmospheric control, precise temperature regulation, and unparalleled melt purity with no fuel or electrode contamination.

Induction Furnaces

Mechanism: Uses alternating magnetic fields to induce eddy currents that heat and melt the charge

Mixing: Strong electromagnetic stirring provides excellent homogeneity for alloying

Configurations: Coreless (crucible) units for high frequency and Channel-type units for lower frequency holding or melting

Purity: Produces very pure metal as there is no contamination from the heat source

Specialized and Modern Technologies

Microwave Furnaces: Provide a controlled atmosphere for clean casting with no oxidation and require no water cooling.

Plasma Furnaces: Use gas-stabilized plasma arcs to melt steel scrap and recover valuable metals from flue dust

Electron-beam Furnaces: Essential for melting and refining refractory metals like Niobium and Tantalum under vacuum

Casting Defects and Casting Inspection

Lec.14

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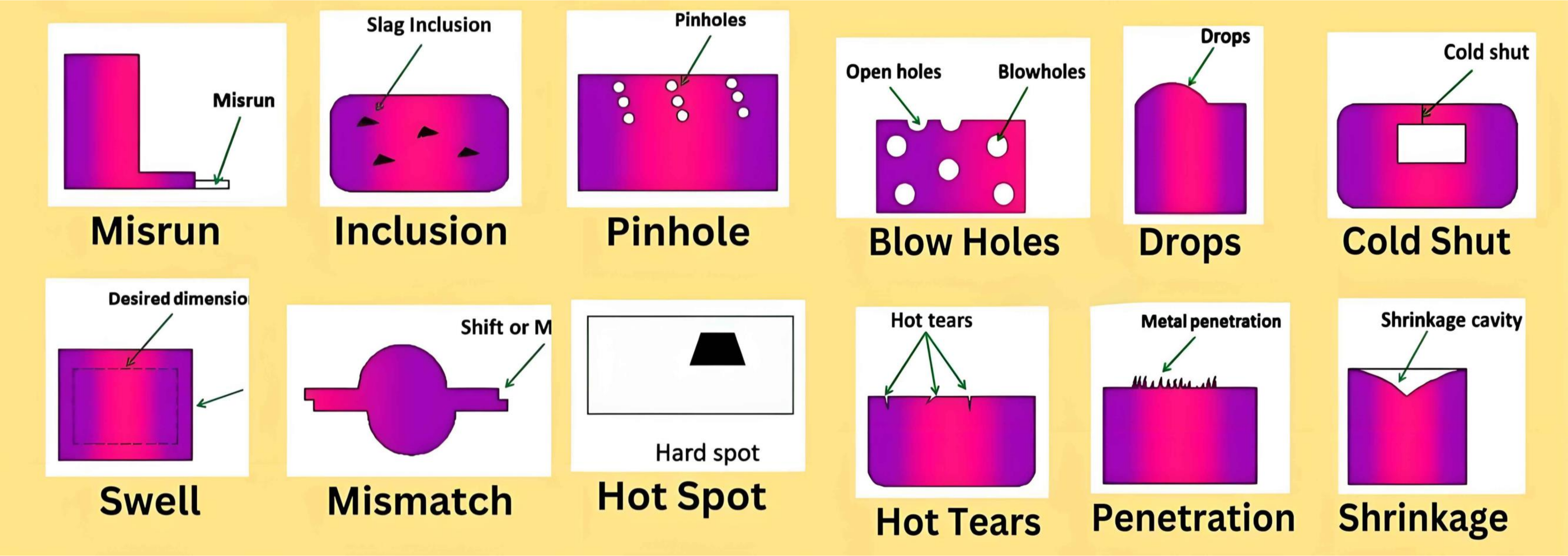
Mechanical Engineering Techniques

Casting defects are irregularities or imperfections that occur during the metal casting process, impacting the structural integrity, functionality, or appearance of the finished component.

These issues can stem from mold design flaws, improper pouring, gas entrapment, or cooling issues, often requiring rigorous inspection to detect and correct.


Misrun
Misrun
Slag Inclusion
Inclusion
Pinholes
Pinhole
Open holes
Blowholes
Blow Holes
Drops
Drops
Cold shut
Cold Shut
Desired dimensio
Swell
Shift or M
Mismatch
Hard spot
Hot Spot
Hot tears
Hot Tears
Metal penetration
Penetration
Shrinkage cavity
Shrinkage

Gas Defects

Gas Porosity: Clusters of small holes throughout the casting caused by gas being unable to escape before the metal hardens.

Causes:

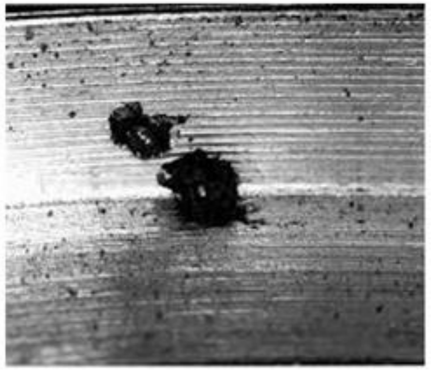
Moisture: High moisture content in the molding sand turns into steam when it hits the molten metal.

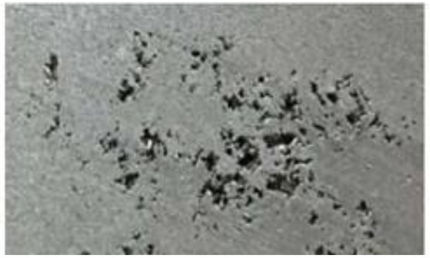
Poor Permeability: If the sand is too fine or packed too tightly, gases cannot escape through the mold walls

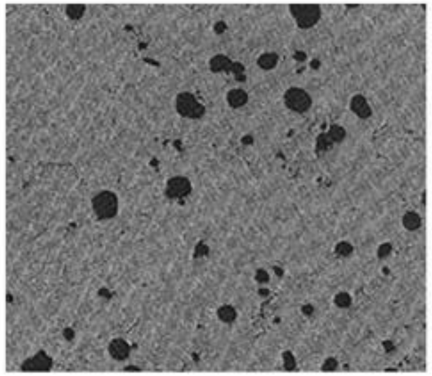
Low Pouring Temperature: Metal that is too cold may solidify before gases have a chance to rise and escape

Turbulent Pouring: Pouring too fast or from a great height traps air bubbles within the liquid metal.

Prevention: Venting, Degassing, Sand Control







Shrinkage Defects

Occur due to metal contraction during solidification.

Types: shrinkage cavity and shrinkage porosity.

Causes: improper feeding and riser design.

Prevention: proper risers and controlled cooling.

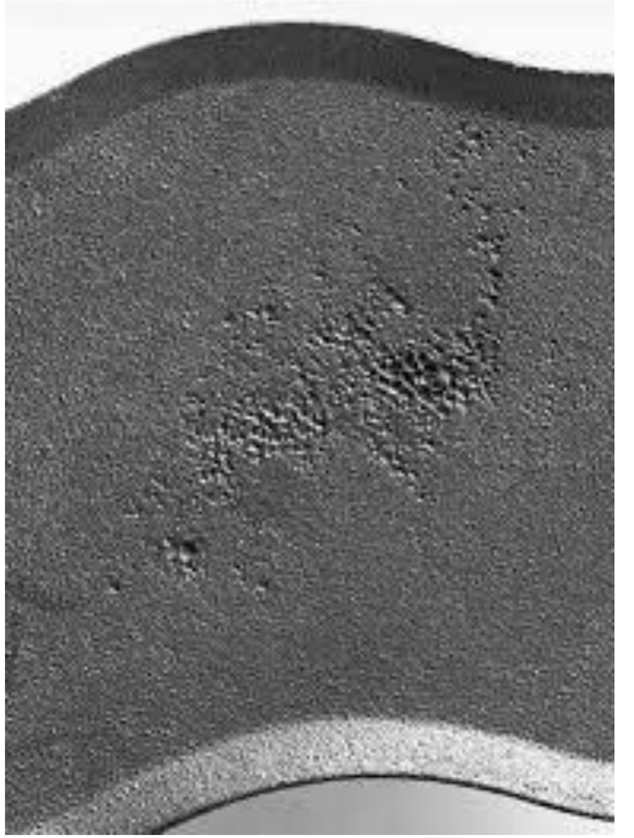
Mold and Surface Defects

Sand inclusion: loose sand trapped in casting.

Scab: rough metal projection on surface.

Misrun: incomplete filling of mold cavity.

Cold shut: weak joint due to poor fusion of metal



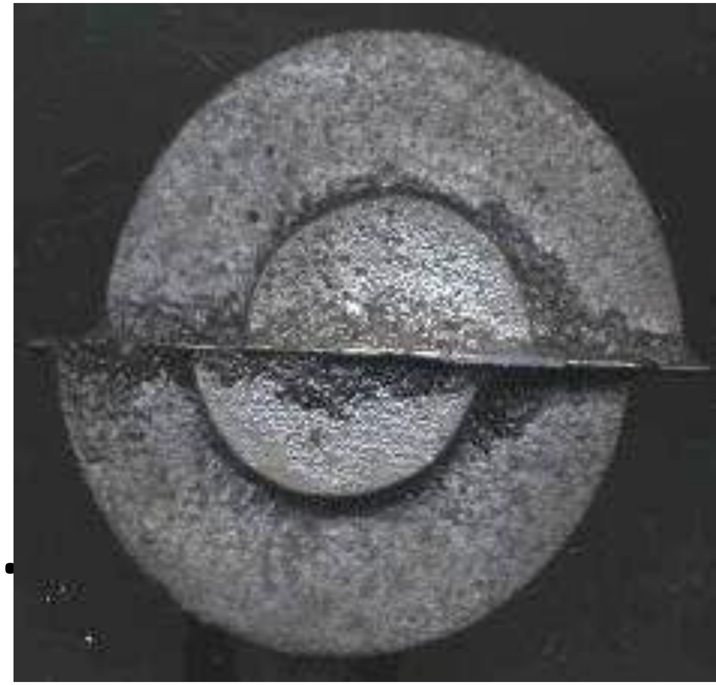
Cracks and Distortion

-Hot tears occur during solidification.

-Cracks reduce mechanical strength.

-Distortion changes casting dimensions.

-Proper cooling design reduces these problems.



Cleaning and Inspection of Castings

Lec.15

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First Year

Polytechnic Karbalaa Collage

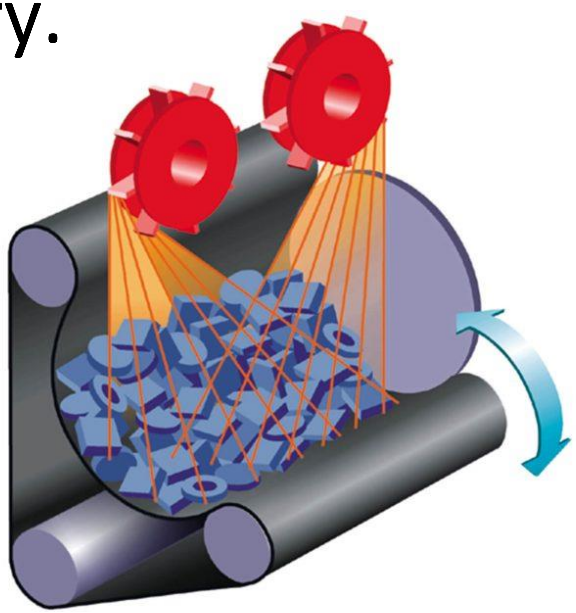
Mechanical Engineering Techniques

Common Cleaning Methods

- Hand cleaning using brushes and hammers
- Shot blasting and sand blasting.
- Grinding and chipping.
- Chemical cleaning for special applications.

Shot Blasting Process

- Metal shots are projected onto the casting surface.
- Removes rust, sand, and oxide layers.
- Provides a smooth and clean finish.
- Widely used in industry.



Grinding and Fettling

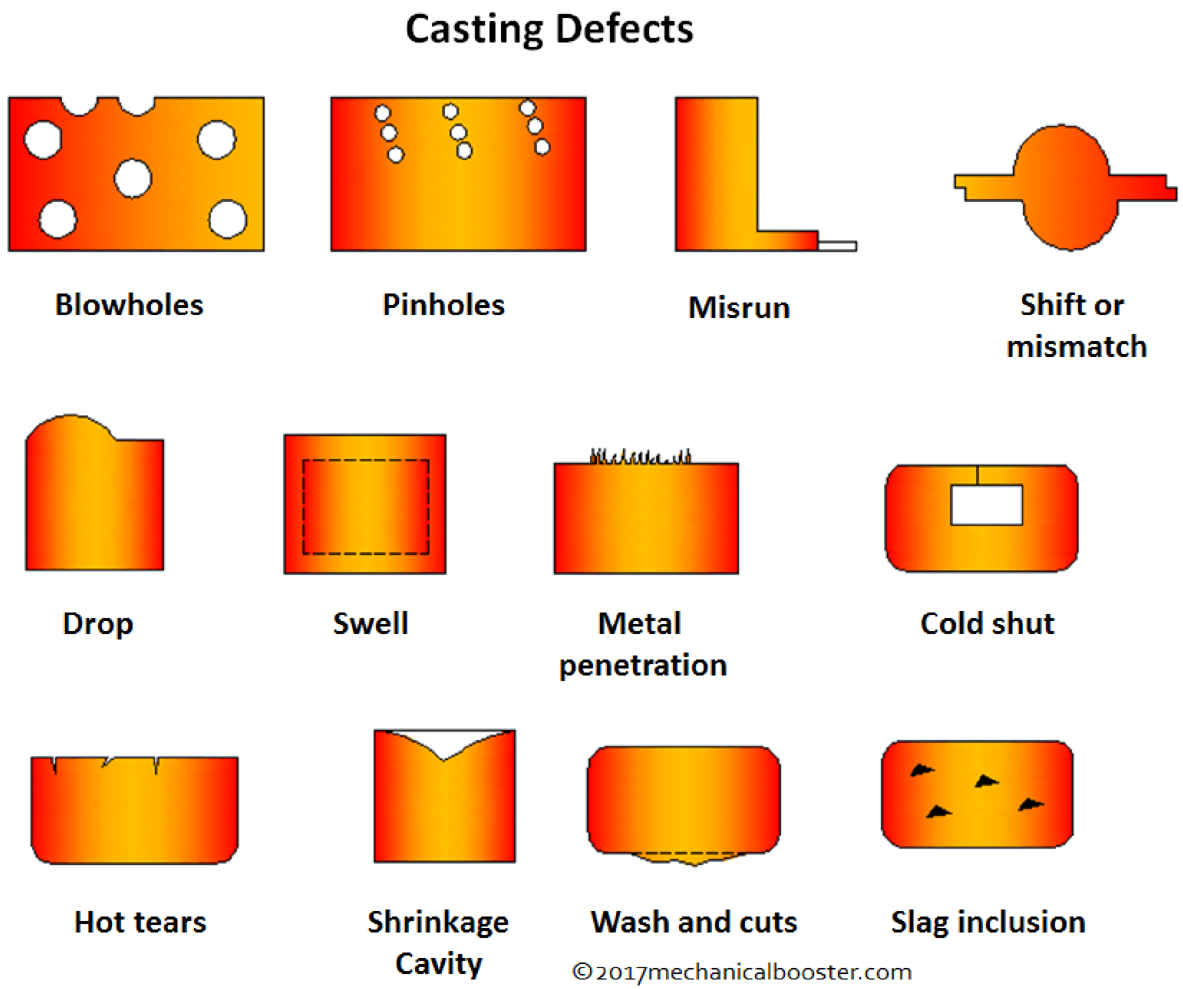
- Fettling removes excess metal such as gates and risers.
- Grinding smooths rough surfaces.
- Portable and fixed grinding machines are used.
- Safety equipment is essential.

Inspection of Castings

- Inspection checks the quality of finished castings.
- Defects must be identified before use.
- Visual and dimensional inspections are common.
- Non-destructive testing may also be used.

Common Casting Defects

- Blow holes and gas porosity.
- Cracks and shrinkage cavities.
- Misruns and cold shuts.
- Surface roughness and inclusions



Inspection Techniques

- Visual inspection.
- Dimensional measurement using calipers.
- Ultrasonic testing.
- Magnetic particle and dye penetrant testing.

Non-Destructive Testing (NDT(

-Ultrasonic testing uses sound waves.

-Radiographic testing uses X-rays.

-Magnetic particle inspection detects surface cracks.

-Dye penetrant testing reveals fine surface defects.