

# GUJARAT TECHNOLOGICAL UNIVERSITY

BE-4 SEMESTER – OLD PAPER – S22 TO W25 – QUESTION BANK SOLUTION

Subject Name & Code:

**Mechanical Measurement and Metrology- 3141901**

## Unit 2: System of Limits, Fits, Tolerance and Gauging

Repeated Questions:

1. **Define Tolerance. Differentiate between Unilateral and Bilateral tolerance with examples.**

Appeared in: W25 (Q2a, 03 marks), W24 (Q3a, 03 marks), S23 (Q4a OR, 03 marks)

**Answer:**

- **Tolerance:** The allowable variation in a part dimension (difference between maximum and minimum limits).

Type	Definition	Example ( $20 \pm 0.1$ mm)
<b>Unilateral</b>	Tolerance lies entirely on one side of nominal size	$20_{-0.05}^{+0.05}$ is actually bilateral? Wait – correct: Unilateral means only one direction. Example: $20_{-0.00}^{+0.10}$ (all positive) or $20_{-0.10}^{+0.00}$ (all negative).
<b>Bilateral</b>	Tolerance is split on both sides of nominal	$20_{-0.05}^{+0.05} \rightarrow$ range 19.95 to 20.05

- **Example:** A shaft of 20 mm diameter with unilateral tolerance  $20_{-0.05}^{+0.00} \rightarrow$  max 20.00, min 19.95.  
Bilateral:  $20_{-0.05}^{+0.05} \rightarrow$  max 20.05, min 19.95.

2. **Compare/Explain Hole Basis System and Shaft Basis System.**

Appeared in: W25 (Q3b, 04 marks), W24 (Q3b, 04 marks), S22 (Q2c, 07 marks), S23 (Q3b, 04 marks)

**Answer:**

Parameter	Hole Basis System	Shaft Basis System
<b>Definition</b>	Hole size is kept constant; shaft size varied to obtain different fits.	Shaft size is kept constant; hole size varied to obtain fits.
<b>Preferred for</b>	General engineering (easier to make holes accurate with reamers)	When shaft is standard (e.g., cold rolled bar, bearing shaft)

Parameter	Hole Basis System	Shaft Basis System
<b>Hole tolerance</b>	Zero (fixed basic size)	Varied
<b>Shaft tolerance</b>	Varied	Zero (fixed basic size)
<b>Example</b>	H7/g6 (hole H7, shaft g6)	h7/G6 (shaft h7, hole G6)
<b>Interchangeability</b>	High – standard drills/reamers	Moderate

**Conclusion: Hole basis is more common** because making a hole to exact size with standard tools is easier than making a shaft.

3. **Define Fit and explain its types (Clearance, Interference, Transition) with neat sketches.**

Appeared in: W25 (Q3b, 04 marks), W24 (Q3c, 07 marks), W22 (Q1b, 04 marks), S22 (Q2c OR, 07 marks), W23 (Q4c OR, 07 marks)

**Answer:**

- **Fit:** The degree of tightness or looseness between mating parts (hole and shaft).

**Three types:**

Fit Type	Definition	Condition	Example
<b>Clearance fit</b>	Shaft always smaller than hole – always gap	Max shaft < Min hole	Bearing assembly, free running fit
<b>Interference fit</b>	Shaft always larger than hole – always press fit	Min shaft > Max hole	Gear on shaft, bush press
<b>Transition fit</b>	Either clearance or interference depending on actual sizes	Overlap of tolerance zones	Locational fit (e.g., dowel pin)

**Diagram:**

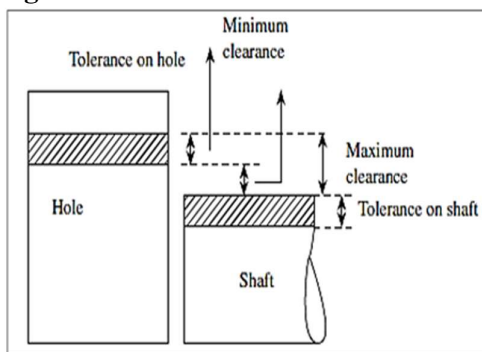


Fig.2.2 - Clearance fit

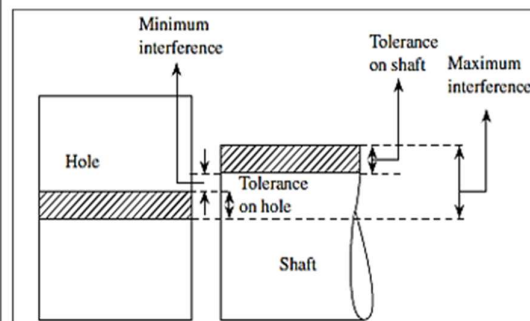


Fig.2.4 - Interference fit

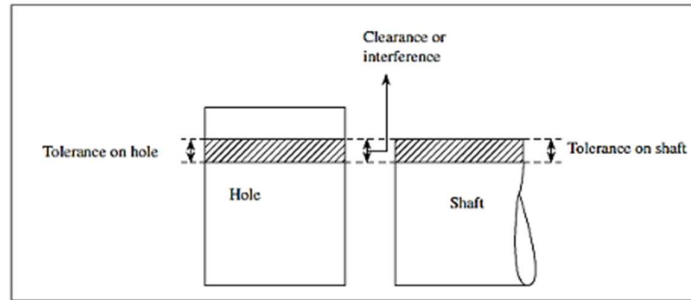


Fig.2.3 - Transition fit

#### 4. Explain Plug Gauge and Ring Gauge.

Appeared in: W25 (Q4b, 04 marks)

**Answer:**

Gauge	Purpose	Types	Material
<b>Plug Gauge</b>	Checks internal dimensions (holes) – GO and NO-GO ends	Single-ended, double-ended, progressive	Hardened steel (60–65 HRC)
<b>Ring Gauge</b>	Checks external dimensions (shafts) – GO and NO-GO rings	Plain ring, threaded ring, taper ring	Tool steel, chrome plated

- **Working (Plug Gauge):** GO plug should enter hole fully; NO-GO plug should not enter. Ensures hole diameter within tolerance.
- **Working (Ring Gauge):** GO ring should pass over shaft; NO-GO ring should not pass.
- **Wear allowance:** Provided only on GO gauge (as explained earlier).

**Diagram:**

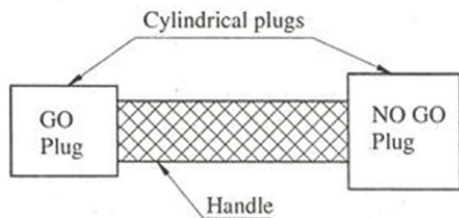


Fig.1.40 – Double ended plug gauge

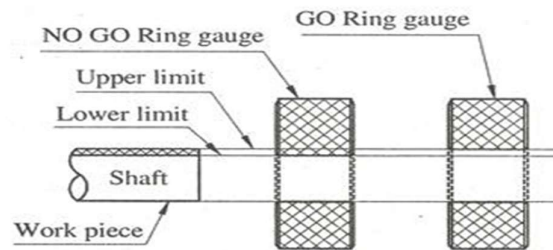


Fig.1.43 – Ring Gauges

#### 5. List the characteristics of good comparators. / List desirable features of a comparator.

Appeared in: W25 (Q4c, 07 marks), W22 (Q4a OR, 03 marks)

**Answer:**

1. High magnification (up to 10,000×).
2. Frictionless and play-free mechanism.
3. Quick in response and easy to read.
4. Robust and stable under shop conditions.
5. Adjustable zero and magnification.
6. Low cost and maintenance.

7. No wear during operation (non-contact preferred).

**OR For 7 Marks:**

1. Robust design and construction: The design and construction of the comparator should be robust so that it can withstand the effects of ordinary uses without affecting its measuring accuracy.
2. Linear characteristics of scale: Recording or measuring scale should be linear and uniform (straight-line characteristic) and its indications should be clear.
3. High magnification: The magnification of the comparator should be such that the smallest deviation in the size of a component can be easily detected.
4. Quick in results: The indicating system should be such that the readings are obtained in the least possible time.
5. Versatility: Instruments should be designed that can be used for a wide range of measurements.
6. Minimum wear of contact point: The measuring plunger should have hardened steel contact or diamond to minimize wear effects.
7. Further, the contact pressure should be low and uniform.

6. Explain the construction and working of a Sigma Comparator with a neat diagram.

Appeared in: S25 (Q2c OR, 07 marks), S22 (Q3b OR, 04 marks)

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**Answer:**

- **Sigma comparator** is a mechanical–optical comparator used for precision comparisons.
- **Construction:**
  - Plunger contacts workpiece.
  - Plunger movement transmitted to a **Y-shaped knife-edge** (notch) mounted on crossed flat springs.
  - A **pointer** attached to the notch.
  - **Scale** with optical magnification (lens + mirror) to enlarge pointer movement.
- **Working:**
  - Workpiece height variation moves plunger.
  - Plunger rotates the Y-notch around its axis.
  - Pointer attached to notch deflects.
  - Deflection magnified by optical system (mirror + lens) to project an image on scale.
  - Magnification up to 5000×.
  - Least count up to 0.00025 mm.
- **Advantages:** No friction (crossed springs), high magnification, robust.
- **Limitations:** Mechanical wear in knife edge, limited range.
- **[Diagram:**

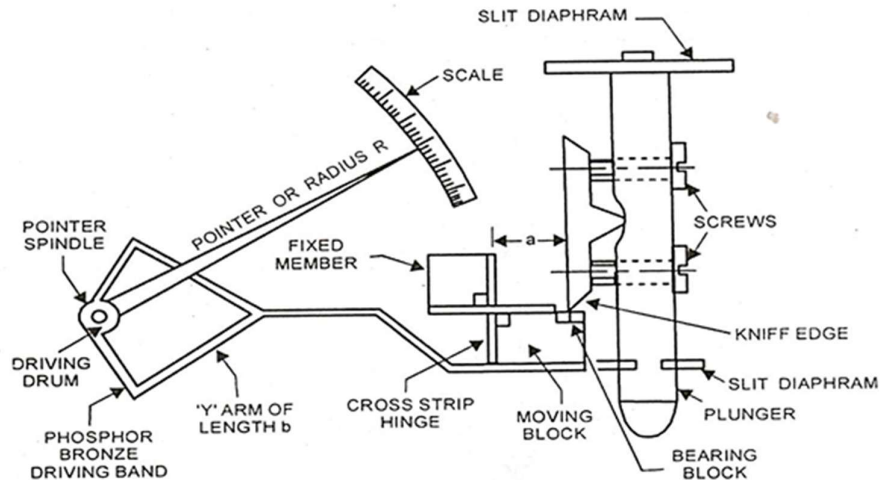


Fig.2.27 – Sigma Comparator

(Appeared in S25 Q2c OR, S22 Q3b OR – 7 marks)

7. Explain the construction and working of a Dial Indicator with a neat sketch. / Write a short note on Dial Indicator.

Appeared in: W23 (Q2b, 04 marks), S23 (Q5c OR, 07 marks)

**Answer:**

• **Construction:**

- Plunger/spindle with rack teeth.
- Gear train (rack & pinion, compound gears).
- Main pointer and small counter pointer.
- Bezel with graduated dial (0–100 divisions, each 0.01 mm).
- Spring to return plunger.

• **Working:**

- Plunger moves up/down → rack drives gear train → gears rotate pointer.
- One full rotation of main pointer = 1 mm (or 0.5 mm).
- Counter pointer counts rotations.
- Least count typically 0.01 mm or 0.001 mm.

• **[Diagram:**

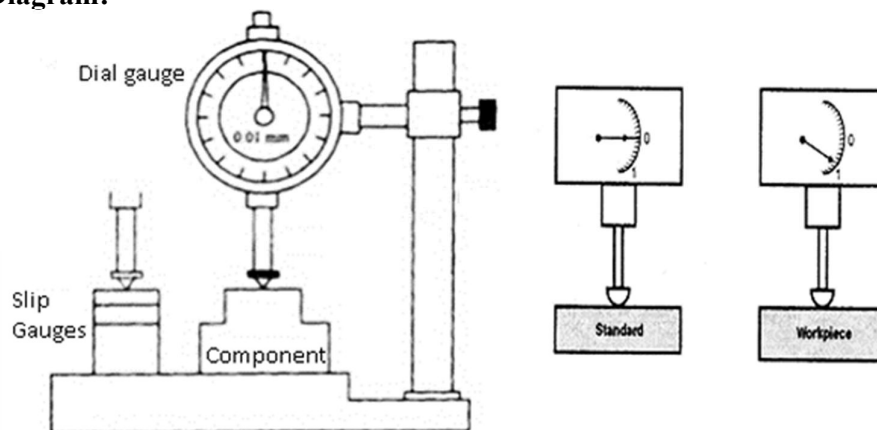


Fig.2.24 – Dial comparator

• **Applications:** Checking runout, flatness, alignment, concentricity.

(Highest weightage: 7 marks – for dial indicator as per S23 Q5c OR)

8. Explain the principle and working of an LVDT (Linear Variable Differential Transformer).

Appeared in: W23 (Q5b, 04 marks), S25 (Q4b, 04 marks), S22 (Q5a, 03 marks)

**Answer:**

- **Principle: Mutual inductance change** with core position. When the ferromagnetic core moves inside three coaxial coils (primary in center, two secondaries on sides), the induced EMF in secondaries changes.
- **Construction:**
  - Primary coil (P) energized with AC (5–10 kHz).
  - Two secondary coils (S1 and S2) connected in series opposition.
  - Movable core attached to the object whose displacement is to be measured.
- **Working:**
  - Core at center → equal voltage induced in S1 and S2 → net output = 0.
  - Core moves left → flux linkage with S1 increases, S2 decreases → net output voltage (amplitude) proportional to displacement, **phase** indicates direction.
  - Output is AC; demodulated to DC for display.
- **Advantages:** High linearity ( $\pm 1\%$ ), frictionless, infinite resolution.
- **Applications:** Thickness measurement, pressure transducers, material testing machines.
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**Other Important Questions:**

1. Why is wear allowance provided on GO gauges only? Justify.

Appeared in: W25 (Q5a OR, 03 marks)

**Answer:**

- **GO gauge** (No-Go is NOT GO) is used to check the lower tolerance limit (hole) or upper limit (shaft). It is intended to pass over the workpiece if within tolerance.
- During repeated use, the GO gauge experiences **wear** on its measuring surface because it enters the part frequently.
- Wear allowance is a **positive** allowance added to GO gauge size so that after some wear, it still correctly passes acceptable parts.
- **No-Go gauge** is used less frequently and should not contact the part much – no wear allowance provided, otherwise it might pass reject parts.
- **Justification:** To prolong life of GO gauge without altering inspection accuracy.

2. Explain Taylor's principle of gauge design.

Appeared in: (Implied in syllabus under "brief concept of design of gauges")

**Answer:**

- **Taylor's principle** (also called GO/NO-GO principle):
  - A single gauge can check both size and geometric features (straightness, roundness) by using **full form** (GO) and **point contact** (NO-GO).
  - **GO gauge:** Checks maximum metal condition (MMC) and all related geometric errors simultaneously. It should be of full form (e.g., full cylinder).

- **NO-GO gauge:** Checks minimum metal condition (LMC) and only size, not form. It should be of point or line contact.
- **Example for hole:**
  - GO plug gauge: full cylindrical plug, length = hole length.
  - NO-GO plug gauge: short cylindrical or spherical end, only checks size.
- **Benefit:** Ensures both size and shape compliance in one checking operation.
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- 3. **Explain the construction and working of a Johnson Mikrokator.**  
Appeared in: W25 (Q4c, 07 marks)

**Answer:**

(mechanical–optical comparator using twisted strip principle):

- **Construction:**
  - One end of a thin twisted phosphor-bronze strip (called a "twisted strip" or "flea" spring) attached to a plunger.
  - Other end fixed to the body.
  - A light pointer attached at the center of the twisted strip.
  - Scale and optical magnification for pointer reading.
- **Working:**
  - Plunger moves vertically due to workpiece variation.
  - Pulls one end of the twisted strip → strip untwists, rotates the pointer.
  - Rotation is proportional to displacement.
  - Magnification up to 5000× easily achieved.
- **Advantages:** No friction, very high sensitivity, inexpensive.
- **Limitations:** Not suitable for dirty environments, delicate.
- **[Diagram:**

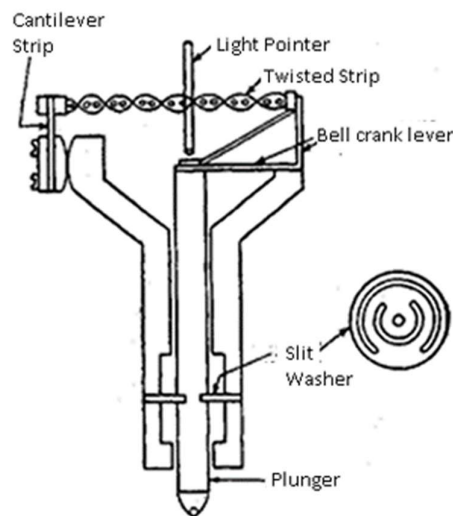


Fig.2.25 – Johansson Mikrokator comparator

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- 4. **Explain the working of Optical Comparators with a neat sketch.**  
Appeared in: W22 (Q3b OR, 04 marks)

**Answer:**

- **Principle:** Optical projection of workpiece shadow onto a screen, compared with

master outline.

- **Construction:**
  - Light source, collimating lens, condenser.
  - Workpiece resting on stage.
  - Optical system (lenses and mirrors) projects shadow onto ground glass screen.
  - Master template overlapped on screen.
- **Working:**
  - Light passes through workpiece profile → shadow projected at 20× to 100× magnification.
  - Operator aligns workpiece shadow with master grid or drawing on screen.
  - Differences indicate deviation.
- **Types:** Horizontal and vertical.
- **Applications:** Checking gear tooth profiles, thread forms, complex contours.
- **[DG:**

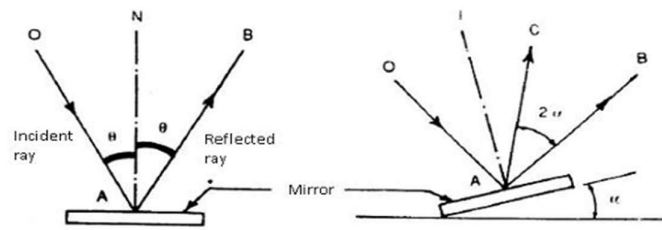


Fig.2.28 – Optical principle

$$\angle OAN = \angle NAB$$

(Appeared in W22 Q3b OR – 4 or 7 marks)

5. Explain with a neat sketch the construction and working of the Zeiss Ultra Optimeter.

Appeared in: W22 (Q3c OR, 07 marks)

**Answer:**

- **Zeiss Ultra Optimeter** is a high magnification optical comparator using the principle of optical lever.
- **Construction:**
  - Plunger with a mirror attached to a torsion pivot.
  - Light source, collimator, and a scale (graticule) in the eyepiece.
  - Light from scale reflects off the mirror to objective, then to eyepiece.
- **Working:**
  - Workpiece variation moves plunger → tilts mirror.
  - Tilt changes the angle of reflected light beam.
  - Image of scale moves across eyepiece reticle.
  - Movement is proportional to plunger displacement.
  - Magnification up to 4000×, least count 0.0001 mm.
- **Advantages:** No friction, high resolution, robust.
- **Limitations:** Requires clean environment, limited measurement range.
- **[DG:**

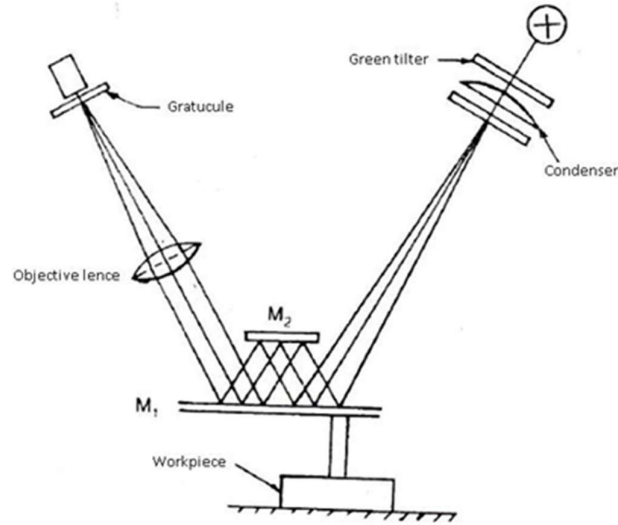


Fig.2.30 – Zeiss ultra optimer

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6. **Explain the principle of electrical comparators.**

Appeared in: (From syllabus)

**Answer:**

- **Principle:** Convert small linear displacement into an electrical signal (voltage, current, inductance, capacitance change) and display it on an ammeter/voltmeter or digital readout.
- **Types:**
  1. Inductive (LVDT): displacement changes mutual inductance.
  2. Capacitive: displacement changes capacitance.
  3. Resistive (strain gauge or potentiometer): changes resistance.
- **Working example (LVDT):**
  - Core moves inside coils → differential output voltage proportional to displacement.
  - Amplified and displayed.
- **Advantages:** High sensitivity, remote reading, easy data logging.
- **Limitations:** Requires power supply, sensitive to temperature.

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7. **Explain Pneumatic comparators (e.g., Back pressure gauge, Solex comparator).**

Appeared in: (From syllabus)

**Answer:**

- **Working principle:** Air flow through a nozzle is restricted by workpiece displacement; back pressure changes proportionally.
- **Solex pneumatic comparator type:**
  - Constant pressure air supply → passes through a control orifice to measuring jet (nozzle).
  - Workpiece surface near the nozzle creates gap.
  - Gap variation changes air flow, hence back pressure measured by sensitive manometer.
  - Manometer scale calibrated directly in microns.

- **Construction:**
  - Air filter, pressure regulator, two parallel columns with manometer fluid.
  - Adjustable zero and magnification.
- **Advantages:** Non-contact, no moving parts, high magnification (up to 10000×), suitable for soft parts.
- **Limitations:** Requires clean, dry air, slow response, affects measurement of porous materials.

8. **List the applications of comparators.**

Appeared in: W25 (Q3a OR, 03 marks)

**Answer:**

1. **Calibration of working gauges** (plugs, rings).
2. **Inspection of mass-produced parts** (automotive, bearing components).
3. **Checking geometric features** (roundness, straightness, parallelism).
4. **Measuring small dimensional deviations** (tenths of microns).
5. **Setting and verifying reference standards** (slip gauges).
6. **Sorting parts into tolerance groups** (selective assembly).

9. **Briefly explain comparators.**

Appeared in: W23 (Q5a OR, 03 marks)

**Answer:**

- **Comparator** is a precision instrument used to compare a workpiece dimension with a standard (e.g., slip gauge). It does not measure absolute size; it shows deviation from the standard.
- **Principle:** Converts small linear displacement into a magnified mechanical, optical, or electrical signal.
- **Types:** Mechanical (dial indicator, sigma), Optical (Zeiss optimeter), Electrical (LVDT), Pneumatic (Solex), Electronic.
- **Advantages:** Fast inspection, high magnification, suitable for mass production.
- **Example:** Checking 10 mm diameter shaft – comparator set to zero using a 10 mm slip gauge; deviation of workpiece shown on dial.

10. **Explain Maximum Material Condition (MMC) and Least Material Condition (LMC) with a suitable example.**

Appeared in: S22 (Q3b, 04 marks)

**Answer:**

Term	Definition	Example (Hole diameter $10 \pm 0.1$ mm)
<b>MMC</b>	Condition where part contains maximum material (largest shaft, smallest hole)	Hole = 9.9 mm (smallest)
<b>LMC</b>	Condition where part contains least material (smallest shaft, largest hole)	Hole = 10.1 mm (largest)

- **MMC for shaft:** largest diameter; for hole: smallest diameter.
- **Significance:** GO gauges are designed for MMC; establishes maximum possible mating interference.

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**11. Explain the need for tolerance.**

Appeared in: W23 (Q4a, 03 marks)

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**Answer:**

- **Tolerance** is the permissible variation in part dimension.
- **Need:**
  1. No manufacturing process is perfectly accurate – cost infinite for zero tolerance.
  2. Ensures **interchangeability** without selective assembly.
  3. Balances **functionality vs cost** – tighter tolerance increases cost.
  4. Allows for **thermal expansion, wear, and measurement uncertainty**.
  5. Standardization (ISO) enables global trade.

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**12. Define: Tolerances, Fits, Shaft basis system.**

Appeared in: S25 (Q2a, 03 marks)

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**Answer:**

- **Tolerance:** Allowable deviation from nominal size; expressed as upper and lower limits.
- **Fits:** Relationship between mating parts (hole & shaft) – clearance, interference, transition.
- **Shaft basis system:** A system where shaft diameter is kept constant and hole sizes are varied to obtain different fits. Used when shaft is standard (e.g., cold rolled bar).

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