GUJARAT TECHNOLOGICAL UNIVERSITY

BE-4 SEMESTER – OLD PAPER – S22 TO S25 – QUESTION BANK SOLUTION

Subject Name & Code:

FUNDAMENTALS OF MACHINE DESIGN (3141907)

Unit 5: Introduction to Machine Design (Part of Unit-1 As per new Syllabus)

Repeated Questions

Q1. Explain the basic procedure for design of machine elements.
(Appeared in: SUM 25 (Q2b), WIN 23 (Q1a))

Answer:
(03-04 marks)

The general procedure for designing any machine element consists of the following steps:

1. **Recognition of need / Problem definition** – Identify the purpose, function, and constraints (cost, performance, safety).
2. **Synthesis (conceptual design)** – Propose possible mechanisms, materials, and configurations.
3. **Analysis of forces** – Determine the loads (static, dynamic, impact, thermal) acting on the element.
4. **Selection of material** – Choose material based on strength, weight, corrosion resistance, cost, and availability.
5. **Determination of stresses & allowable stress** – Calculate working stresses and apply factor of safety.
6. **Determination of dimensions** – Use design equations (e.g., bending, torsion, tension) to compute required size.
7. **Detailing & drawing** – Prepare detailed engineering drawings with tolerances, surface finish, and notes.
8. **Prototyping & testing** – Manufacture a prototype and test under actual or simulated conditions.
9. **Modification & final production** – Refine design based on test results and release for production.

Q2. Explain Manufacturing considerations in design.
(Appeared in: SUM 22 (Q1c), SUM 24 (Q3b), WIN 23 (Q2a))

Answer:
(04-07 marks)

Manufacturing considerations are crucial for cost-effective production:

1. **Material Selection:** Choose materials that are readily available, machinable, and suitable for intended manufacturing process.
2. **Tolerances and Fits:** Specify appropriate tolerances - tighter tolerances increase cost.
3. **Surface Finish:** Required surface finish affects choice of manufacturing process.
4. **Production Volume:** High volume justifies expensive tooling; low volume favors simpler methods.
5. **Standardization:** Use standard components, sizes, and materials to reduce cost.
6. **Simplicity:** Design simple shapes that are easy to manufacture.
7. **Avoid Sharp Corners:** Use fillets and radii to reduce stress concentration.
8. **Symmetry:** Symmetrical parts are easier to manufacture and assemble.
9. **Accessibility:** Ensure tools can access features for machining/assembly.
10. **Minimize Machining:** Design to use standard stock sizes and minimize machining operations.
11. **Design for Assembly (DFA):** Minimize part count, use self-locating features, standard fasteners.
12. **Heat Treatment Considerations:** Design to minimize distortion during heat treatment.

Example: A part with complex internal features might be better made as an assembly rather than a single complex casting.

Q3. Discuss the importance of selection of materials in machine design. / Explain various aspects of materials selection in Machine Design.
(Appeared in: WIN 22 (Q2a), SUM 22 (Q3c))

Answer:
(03-07 marks)

Material selection is critical in machine design as it affects:

1. **Mechanical Properties:** Strength, hardness, toughness, stiffness, wear resistance.
2. **Physical Properties:** Density, thermal conductivity, electrical conductivity, melting point.
3. **Manufacturing Considerations:** Machinability, castability, weldability, formability.
4. **Cost:** Material cost, processing cost, total life-cycle cost.

5. **Availability:** Lead time, reliable supply chain.
6. **Weight:** Critical for automotive, aerospace applications.
7. **Corrosion Resistance:** Environment compatibility.
8. **Temperature Resistance:** Operating temperature range.
9. **Reliability and Safety:** Fatigue strength, fracture toughness.
10. **Aesthetics:** Appearance, surface finish capability.
11. **Recyclability:** Environmental considerations.

Systematic Selection Process:

1. Identify design requirements and constraints
2. Screen materials based on primary requirements
3. Compare candidate materials using weighted objectives
4. Consider availability and cost
5. Make final selection with manufacturing in mind

Example: For gears: require high surface hardness (wear resistance) with tough core (impact resistance) → case-hardened steel.

Other Important Questions

Q4. Explain the design considerations in the casting.
(Appeared in: WIN 24 (Q1c))

Answer:
(07 marks)

Design considerations for cast components:

1. **Draft Angles:** All vertical faces need taper (1-3°) for pattern removal.
2. **Uniform Wall Thickness:** Avoid thick sections to prevent shrinkage defects.
3. **Fillets and Radii:** Use generous radii at corners to reduce stress concentration.
4. **Ribs and Bosses:** Use ribs for stiffness instead of thick sections.
5. **Parting Line:** Design for simple, straight parting line.
6. **Coring:** Use cores for internal features, but minimize complex cores.
7. **Machining Allowances:** Add extra material (1.5-6 mm) for machining critical surfaces.
8. **Shrinkage Allowance:** Account for material shrinkage (1-2% typically).
9. **Avoid Sharp Corners:** Rounded corners improve metal flow and reduce stress.

10. **Simplicity:** Design for easy pattern making and mold preparation.
11. **Material Flow:** Design for proper metal flow during pouring.
12. **Heat Dissipation:** Consider solidification pattern to avoid hot spots.

Diagram Prompt: "Draw a simple cast bracket showing: draft angles on vertical faces, uniform wall thickness, generous fillets at corners, ribs for stiffness, machining allowance on mounting surfaces, and simple parting line."

Q5. Explain the design considerations in casting process with neat sketch.
(Appeared in: SUM 23 (Q2a))

Answer:
(03 marks)

Casting design considerations (short answer):

1. **Draft angle** (1-3°) for easy pattern removal.
2. **Fillets** at internal corners to avoid cracking.
3. **Uniform wall thickness** to prevent shrinkage defects.
4. **Parting line** at largest cross-section.
5. **Shrinkage allowance** compensated in pattern.
6. **Avoid sharp corners & undercuts.**

Sketch Description: A simple L-shaped bracket casting showing 2° draft on all vertical faces, 5mm fillets at internal corners, uniform 10mm wall thickness, straight parting line at the corner, reinforcing ribs on the back, and mounting bosses with machining allowance.

Q6. Define: Hardness, Ductility, Poisons ratio, Bulk Modulus.
(Appeared in: SUM 24 (Q1b))

Answer:
(04 marks)

1. **Hardness:** Resistance of a material to permanent deformation, indentation, or scratching. Measured by Brinell, Rockwell, Vickers tests.
2. **Ductility:** Ability of a material to undergo significant plastic deformation before fracture. Measured by percentage elongation or reduction in area.
3. **Poisson's Ratio:** Ratio of lateral strain to longitudinal strain under axial load. For most metals, $\mu \approx 0.3$.
4. **Bulk Modulus:** Ratio of hydrostatic pressure to volumetric strain. Measures resistance to uniform compression. $K = -P/(\Delta V/V)$.

Q7. Define IS coding of steels and explain 45C8, 25Cr4Mo2, 10C8S10, SG80/2, FG60. (Appeared in: SUM 24 (Q3a))

Answer:
(03 marks)

IS Coding System for Steels:

- First 2 digits: Carbon content in hundredths of percent
- Letters: Alloying elements (C=Chromium, Mo=Molybdenum, Mn=Manganese, Ni=Nickel)
- Last digits: Average alloy content in percent

Explanations:

1. **45C8:** 0.45% Carbon, 0.8% Chromium
2. **25Cr4Mo2:** 0.25% Carbon, 4% Chromium, 2% Molybdenum
3. **10C8S10:** 0.10% Carbon, 0.8% Chromium, 0.10% Silicon (free cutting steel)
4. **SG80/2:** Spheroidal Graphite cast iron, 80 ksi tensile strength, 2% elongation
5. **FG60:** Grey cast iron, 60 ksi tensile strength

Q8. Find out the number of R5 basic series.
(Appeared in: SUM 24 (Q3a))

Answer:
(03 marks)

The R5 series is a geometric series with progression ratio = $\sqrt[5]{10} \approx 1.5849$.

Basic R5 Series numbers:
1.00, 1.60, 2.50, 4.00, 6.30, 10.00

Number of terms in basic series: 6 terms

Explanation: Each number is multiplied by 1.5849 to get the next. These are rounded preferred numbers used for standardizing sizes in engineering.

Q9. Explain the effect of different alloying elements on the properties of steels. (Appeared in: WIN 24 (Q5b))

Answer:
(04 marks)

Alloying Element **Effects on Steel Properties**

Alloying Element	Effects on Steel Properties
Carbon (C)	Increases hardness, strength; decreases ductility, weldability
Chromium (Cr)	Increases corrosion resistance, hardenability, wear resistance
Nickel (Ni)	Increases toughness, corrosion resistance, low-temperature properties
Molybdenum (Mo)	Increases strength at high temperatures, hardenability, creep resistance
Manganese (Mn)	Increases strength, hardenability, combines with sulfur to improve machinability
Silicon (Si)	Increases strength, electrical resistivity, oxidation resistance
Vanadium (V)	Refines grain size, increases strength, toughness
Tungsten (W)	Increases hardness at high temperatures, wear resistance
Sulfur (S)	Improves machinability but decreases ductility and weldability
Phosphorus (P)	Increases strength but decreases ductility and impact strength

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Q10. Explain Aesthetic and Ergonomic considerations in Design.
(Appeared in: Syllabus Outline)

Answer:
(03-04 marks)

Aesthetic Considerations:

- Shape, form, and proportions
- Color, texture, and finish
- Visual balance and harmony
- Brand identity and styling
- Surface details and graphics

Ergonomic Considerations (Human Factors):

- Controls: Size, shape, spacing, force required
- Displays: Readability, contrast, information hierarchy
- Safety: Guards, warnings, emergency stops
- Comfort: Seating, reach, viewing angles
- Anthropometrics: Design for human body dimensions
- Cognitive aspects: Intuitive operation, reduced mental workload

Importance: Good aesthetics improve market appeal; good ergonomics improve safety, efficiency, and user satisfaction.

Q11. Explain the ergonomic considerations in the controls and display.
(Appeared in: WIN 24 (Q4a, 03 marks))

Answer:
(03 marks)

Ergonomic considerations for controls and displays ensure safe, efficient, and comfortable human-machine interaction:

For Controls:

1. **Size and Shape:** Should fit average hand dimensions with comfortable grip.
2. **Spacing:** Adequate distance between controls to prevent accidental activation.
3. **Force Required:** Operating force should be within human capability limits.
4. **Location:** Positioned within easy reach (normal and maximum reach zones).
5. **Feedback:** Provide tactile, visual, or auditory feedback when activated.
6. **Direction of Movement:** Should follow population stereotypes (e.g., clockwise to increase).

For Displays:

1. **Legibility:** Clear characters with adequate size, contrast, and illumination.
2. **Information Hierarchy:** Most critical information should be most prominent.
3. **Positioning:** Within normal line of sight (15-30° from horizontal).
4. **Grouping:** Related information should be grouped together logically.
5. **Coding:** Use consistent color coding (red for danger, green for safe).
6. **Refresh Rate:** Updates should be timely without flickering.

Overall Principles: Consistency across similar systems, intuitive operation, and minimizing user fatigue and error.