MATERIALS SELECTION IN MECHANICAL DESIGN

Mirzayev Islambek Umarali ugli
Kokand branch of Tashkent State Technical University, Student

Bakhriddinova Dilnora Sharifjon kizi
Kokand branch of Tashkent State Technical University, Student

Abstract:
This article discusses the materials selection process in mechanical design.

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Introduction:

Materials selection is a critical aspect of mechanical design, as the quality and reliability of a mechanical system depend on the suitability of the materials used. Mechanical design is the process of creating a machine, subsystem, or system using engineering principles and materials. Materials selection is a preliminary step in the design process that involves choosing the optimal materials for a given mechanical application, based on the desired properties and stress. The selection of materials involves considering many factors that could affect the performance and reliability of the mechanical system. Engineers must consider the cost, availability, durability, and mechanical properties of the materials, among other factors.

Materials Properties

The mechanical properties of materials are among the most important factors in materials selection. The properties of materials can be described as physical or mechanical. Physical properties include density, specific heat, coefficient of thermal expansion, thermal conductivity, electrical conductivity, and optical properties. Mechanical properties include strength, elasticity, ductility, toughness, and fatigue resistance.

Strength is the ability of a material to withstand external loads without deformation or fracture. Elasticity is the property of a material that enables it to return to its original shape after deformation. Ductility is a material's ability to undergo plastic deformation without easily fracturing. Toughness is the material's resilience to cracking under stress. Fatigue resistance is the ability of a material to withstand repeated or cyclic loads without failure.

Materials Importance in Mechanical Design

Materials are critical to the design of mechanical systems because they determine the system's strength, durability, and functionality. The properties of materials are used to calculate the stresses on the system components, which, in turn, determine the required quality of the materials. In applications where high strength is important, materials such as steel, titanium, and aluminum are used. In applications where weight is important, materials such as composites and alloys are used. In applications where corrosion resistance is critical, materials such as stainless steel and other alloys that resist corrosion are used. The selection of materials has a significant impact on the cost of the mechanical system. Less expensive materials, like plastics, can be used when the application requires less strength. However, more expensive materials like titanium or nickel alloys are usually used when high strength is needed. Materials selection involves balancing the cost with the mechanical properties to ensure that the final product meets the desired specifications while remaining affordable. In many cases, the material's properties are in tension and cannot be fully optimized simultaneously. Engineers must, therefore, make trade-offs among the different properties while considering the available resources.

Materials Selection Process

Materials selection involves a combination of scientific principles and engineering judgment to select the best material for the specific application. The selection process is iterative, trying different materials until one is found that meets the requirements for the application.

The materials selection process can be broken down into six main steps:

1. Define the design criteria- This step involves identifying and understanding the design requirements of the mechanical system. Design criteria may include strength, durability, weight, and cost.
2. Identify candidate materials- This step involves creating a list of materials that may be suitable for the application. The list should be based on the materials' general properties, availability, and cost.
3. Evaluate materials- This step involves evaluating the materials on the list to determine their suitability for the application. Factors to consider include physical and mechanical properties, corrosion resistance, and cost.
4. Select materials to meet the design criteria- This step involves selecting the materials that best meet the design criteria. The final selection should be based on a trade-off between the materials' properties and cost.
5. Test the materials- This step involves testing the selected materials to ensure that they meet the design requirements.

6. Finalize the materials selection- This step involves finalizing the materials selection and using the chosen materials in the design of mechanical system.

Materials Selection Tools

A variety of tools can be used to assist in the materials selection process, including material databases, software, and handbooks. Material databases provide access to the properties of various materials for use in the selection process.

Software can assist in materials selection by allowing engineers to input design criteria and calculate the weight and stress of various materials. Handbooks provide general guidance on the selection of materials based on specific applications or requirements. Material databases can provide useful information on the properties of materials, cost, availability, and appropriate applications. The properties of materials can be found in databases such as the Materials Science and Engineering database, Matweb, and Granta Materials.

Mechanical design software can assist in the materials selection process. The software can evaluate stress ratios, geometric aspects, material compatibility, and other relevant factors into account. Software packages such as SolidWorks and Ansys are commonly used in mechanical design.

Handbooks such as ASM Handbooks or MIL-HDBK provide information on materials selection based on specific applications or requirements. These resources are usually organized by material class or industry.

Materials Selection Example

To illustrate the materials selection process, consider the design of a bicycle wheel hub. The design criteria are as follows:

- Low weight
- High strength
- Corrosion resistance
- Low cost

Candidate materials for the hub include titanium, aluminum alloy, and steel. Initial analysis indicates that titanium has the most desirable properties, but its high cost may exceed the project budget. Aluminum has lower strength, but it is worth considering due to its lower cost and lighter weight.

The properties of the candidate materials are compared in the table below:

Material Titanium Aluminum Steel

Density 4.5 g/sm^3 2.7 g/sm^3 7.8 g/sm^3

Tensile strength 900 MPa 400 MPa 600 MPa

Fatigue strength 500 MPa 120 MPa 180 MPa

Corrosion resistance Excellent Good Poor

Cost High Low Medium

While titanium has the most desirable properties, its high cost is a significant disadvantage. Given the design criteria, aluminum is the preferred material because of its lower weight, lower cost, and reasonable strength. However, corrosion protection is an issue. To address this issue, anodizing can be used to improve the corrosion resistance while keeping the costs low.

Conclusion

Materials selection is a critical aspect of mechanical design that involves the selection of the optimal materials for a given application based on the desired properties and stress. The mechanical properties of materials, followed by the cost, availability, and durability of the materials, are the major factors to consider in the selection process. The materials selection process is iterative, and it uses a combination of scientific principles and engineering judgment to select the best materials for the application. A variety of tools can assist in the materials selection process, including material databases, software, and handbooks. Engineers must carefully evaluate the tradeoffs among the different properties before selecting the ideal materials for a mechanical system.

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