

University: University of Mohamed Kheider - Biskra

Faculty: Faculty of Science and Technology

Department: Common Core in Science and Technology

Electrical Engineering Materials

Pedagogical Handout

Dr.Toufik DJIMAOU

Academic Year: 2025/2026

Chapter 7: Material Selection Criteria

2nd Year Engineering students

Contents

7.1 Introduction	3
7.2 Material Selection Criteria	4
A. Functional Requirements.....	4
B. Environmental Constraints	4
C. Economic Considerations	5
7.4 Durability and Sustainability.....	5
A. Service Life and Reliability.....	5
B. Recycling and Environmental Impact	6
7.5 Case Studies	6
A. Transformer Material Selection	6
B. Electric Motor Material Selection	7
C. High-Voltage Insulator Material Selection	7
References	9

7.1 Introduction

The selection of materials is a critical step in the design of electrical and electronic systems. The performance, reliability, safety, and cost of any device depend strongly on the properties of the materials used in its construction [1], [21].

In practical engineering, no material can provide all required properties simultaneously. Therefore, engineers must select materials by balancing several factors, including electrical, magnetic, thermal, mechanical, environmental, and economic requirements [2].

A suitable material must not only perform its main function but also maintain its properties under operating conditions throughout the expected service life of the system. Factors such as temperature, humidity, electromagnetic fields, ageing, and maintenance requirements must be considered during the selection process [21], [22].

This chapter presents the main criteria used for selecting materials in electrical engineering and demonstrates their application through practical examples involving transformers, electric motors, and high-voltage insulation systems.

7.2 Material Selection Criteria

The selection of a material for an electrical engineering application requires evaluating several criteria to ensure the required performance, reliability, and economic efficiency of the system. The main criteria include functional requirements, environmental conditions, and economic factors [1], [21].

A. Functional Requirements

The selected material must satisfy the specific function required in the electrical system. properties include:

- Electrical properties: conductivity for conductors and dielectric strength for insulating materials.
- Magnetic properties: permeability and magnetic losses for cores and magnetic components.
- Thermal properties: heat resistance and thermal conductivity.
- Mechanical properties: strength, flexibility, and resistance to mechanical stresses.

The choice depends on the role of the material within the device and the operating conditions [2].

B. Environmental Constraints

Electrical materials are exposed to different environmental conditions that may affect their performance and lifetime. factors include:

- Operating temperature.
- Humidity and moisture.
- Corrosion and chemical exposure.
- Mechanical vibrations and external stresses.

The material must maintain its electrical and mechanical properties under these conditions to ensure reliable operation [10], [21].

C. Economic Considerations

Material selection must also consider the total cost of the system, not only the initial price of the material. Its aspects include:

- Raw material cost.
- Manufacturing and processing requirements.
- Maintenance needs.
- Expected service life.

The optimal choice is usually a compromise between technical performance, durability, and overall cost [21], [23].

7.4 Durability and Sustainability

The selection of electrical materials must consider not only their initial performance but also their ability to operate reliably over a long period while minimizing environmental impact. Durability and sustainability have become important criteria in modern engineering design [21], [22].

A. Service Life and Reliability

The service life of a material depends on its ability to maintain its required properties under operating conditions.

Main factors affecting reliability include:

- Thermal ageing caused by continuous temperature exposure.
- Electrical stress, especially in insulation systems.
- Mechanical fatigue and vibration.

- Corrosion and environmental degradation.

Materials with high durability reduce maintenance requirements, improve system reliability, and increase the lifetime of electrical equipment [1], [10].

B. Recycling and Environmental Impact

Modern material selection also considers the environmental impact throughout the product life cycle.

Important aspects include:

- Recyclability of materials such as copper and aluminum.
- Reduction of hazardous substances.
- Lower energy consumption during manufacturing.
- Sustainable management at the end of equipment life.

Selecting recyclable and environmentally friendly materials contributes to more sustainable electrical technologies while maintaining required technical performance [22], [23].

7.5 Case Studies

This section illustrates how material selection criteria are applied in real electrical engineering systems. The objective is to show how functional, environmental, and economic constraints guide the choice of materials in practical devices [1], [21].

A. Transformer Material Selection

A power transformer requires materials with high magnetic performance and excellent electrical insulation.

- **Core material:** Silicon steel (Fe-Si) is used due to its high permeability and reduced hysteresis and eddy current losses. Laminated structures are applied to further reduce losses [2].
- **Winding material:** Copper or aluminum is selected depending on cost and weight constraints, due to their high electrical conductivity [2].
- **Insulation system:** Mineral oil or solid polymer insulation is used to ensure dielectric strength and thermal stability [10].

The selection aims to minimize energy losses while ensuring thermal and electrical reliability.

B. Electric Motor Material Selection

Electric motors require materials that combine magnetic efficiency, electrical conductivity, and mechanical strength.

- **Stator and rotor core:** Laminated Fe-Si sheets to reduce magnetic losses.
- **Windings:** Copper is preferred for its high conductivity and compact design.
- **Permanent magnets (if applicable):** NdFeB or ferrite magnets depending on performance and cost requirements [20].

The main objective is high efficiency, reduced losses, and long operational life.

C. High-Voltage Insulator Material Selection

High-voltage insulators must withstand strong electric fields and harsh environmental conditions.

- **Solid insulators:** Porcelain or polymer-based materials (e.g., XLPE) for high dielectric strength and mechanical support.
- **Surface design:** Special profiles are used to increase creepage distance and reduce flashover risk.

- **Environmental resistance:** Materials are selected to resist humidity, pollution, and temperature variations [10], [21].

The key requirement is maintaining insulation integrity under long-term electrical and environmental stress.

These case studies demonstrate that material selection is always a compromise between electrical performance, mechanical requirements, environmental resistance, and cost optimization.

References

- [1] M. F. Ashby, *Materials Selection in Mechanical Design*, 4th ed., Burlington, MA, USA: Butterworth-Heinemann, 2011.
- [2] W. D. Callister Jr. and D. G. Rethwisch, *Materials Science and Engineering: An Introduction*, 10th ed., Hoboken, NJ, USA: John Wiley & Sons, 2018.
- [10] P. Hipault, *Materials for Electrical Engineering*, Paris, France: Ellipses, 2019.
- [21] M. F. Ashby, *Materials Selection in Mechanical Design*, 5th ed., Oxford, UK: Butterworth-Heinemann, 2016.
- [22] M. F. Ashby, *Materials and Sustainable Development*, 2nd ed., Oxford, UK: Butterworth-Heinemann, 2015.
- [23] G. Dieter and L. Schmidt, *Engineering Design*, 5th ed., New York, NY, USA: McGraw-Hill, 2012.