Doctoral School of Engineering and Mathematics

Doctoral Field: Mechanical Engineering

DOCTORAL THESIS

STUDIES AND RESEARCH ON THE INFLUENCE OF VARIOUS ENVIRONMENTAL FACTORS ON THE MECHANICAL AND ELASTIC PROPERTIES OF POLYMERIC MATERIALS

- ABSTRACT-

PhD Student:
Eng. Olivia-Laura PETRAȘCU

PhD Supervisor:
Professor Adrian-Marius PASCU, Eng. D.

SIBIU 2025

This paper investigates the influence of environmental factors on the mechanical and elastic properties of various polymeric materials. The primary objective is to determine how different external environments affect the mechanical behavior of widely used polymers in industrial applications, providing insights to support future studies on material performance under diverse working conditions.

The motivation for this research arises from the increasing use of polymeric materials in modern industry, particularly in the automotive sector, both nationally and internationally. The initial part of the paper addresses the challenges posed by environmental factors on the mechanical and elastic behavior of polymers.

As previously noted, many industrial sectors have progressively replaced traditional materials, especially metals, with polymers and composites. This transition is driven by the high technical performance of these materials, their favorable cost-to-performance ratio, and their significantly lower specific weight. Initiated decades ago, this shift continues to evolve, aiming to enhance material characteristics and optimize resource efficiency.

Polymeric and composite materials now play a vital role across numerous industries due to their unique properties, including ease of processing, corrosion resistance, and adaptability to various technological requirements.

Chapter 1 introduces the relevance of polymeric materials in modern industry and the necessity of assessing their behavior under real-world conditions. Their advantages over metals—such as low density, reduced cost, corrosion resistance, and processability—are highlighted.

Chapter 2 outlines the historical development and current state of polymer use, focusing on the impact of environmental factors on their mechanical and elastic behavior. This chapter also includes a bibliometric analysis based on international databases to assess the scope and influence of relevant publications. Data were sourced from Web of Science, Scopus, and the *Polymer Testing* journal, covering literature published up to December 2024. Search terms included "mechanical behavior" & "polymers" and "accelerated weathering" & "polymers." The selection process applied inclusion and exclusion criteria to filter relevant studies.

This chapter underscores the importance of mechanical characterization in relation to manufacturing technologies, recognizing that fabrication methods can significantly affect polymer performance. The mechanical and elastic properties of materials exposed to various environments—ambient conditions, distilled water, cooling oil, saline solution, and UV-C radiation—were assessed through uniaxial tensile testing.

Chapter 3 presents the experimental evaluation of quasi-static tensile behavior in five polymers: polyoxymethylene (POM), polyamide 6 (PA6), glass-fiber-reinforced polyamide 6 (PA6-GF30), polyvinyl chloride (PVC), and polypropylene (PP). The study explores correlations between environmental exposure and the mechanical response of these materials, considering factors such as fluid absorption and UV-C degradation.

Chapter 4 continues the experimental work through four-point bending tests on the same materials and under the same environmental conditions. These tests further explore the influence of external factors on flexural behavior and structural integrity. Results confirm trends observed in the tensile tests and provide additional insights into stiffness and performance under transverse loading.

This comparative approach enhances understanding of how environmental exposure affects both tensile and flexural properties, offering a broader perspective on the durability and reliability of polymers in industrial settings.

Chapter 5 details the development of a numerical model using finite element analysis (FEA) to simulate mechanical behavior under tensile and bending loads. The simulations, performed in Abaqus/Explicit, utilized C3D8R elements—8-node linear brick elements with reduced integration and hourglass control—chosen for their suitability in modeling plastic deformation. The simulation results correlated well with experimental data, validating the modeling approach and enabling deeper analysis of stress–strain distributions and potential failure mechanisms.

This numerical framework also allows for parametric studies, facilitating optimization of polymeric components for industrial applications.

Chapter 6 concludes the study by summarizing key findings and outlining directions for future research. The results highlight the significant influence of environmental conditions on polymer performance. Notable contributions of the study include:

- A comprehensive experimental protocol,
- Comparative analysis of five polymers in five distinct environments,
- Integration of experimental data with FEA simulations, and
- Identification of the most environmentally sensitive and resistant materials.

As a conclusion, this thesis investigates the influence of environmental factors on the mechanical and elastic properties of five commonly used polymeric materials: polyoxymethylene (POM), polyamide 6 (PA6), glass-fiber-reinforced polyamide 6 (PA6-GF30), polyvinyl chloride (PVC), and polypropylene (PP). Motivated by the growing industrial use of polymers, particularly in the automotive sector, this research aims to understand how various working environments affect the structural performance of these materials.

The experimental program included uniaxial tensile and four-point bending tests conducted under five environmental conditions: ambient air, distilled water, cooling oil, saline solution, and UV-C radiation exposure. The mechanical behavior was assessed in relation to material degradation, fluid absorption, and exposure to radiation. Results revealed significant variations in mechanical and elastic responses, with certain polymers demonstrating greater sensitivity or resistance to specific environments.

The study provides a comprehensive comparative evaluation of environmental effects on polymeric materials, contributing to the optimization of material selection for industrial applications operating under diverse environmental conditions. These findings offer a valuable foundation for the design of durable polymer-based components tailored to specific service environments.