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MECHANICAL RESPONSE OF PA6 UNDER ENVIRONMENTAL CONDITIONS: A DUAL APPROACH USING EXPERIMENTS AND NUMERICAL ANALYSES

Nicolae ȘTEFĂNOAEA[1], Olivia Laura PETRAȘCU[2], Adrian Marius PASCU[3]

1 0000-0003-1745-1978, „Lucian Blaga" University of Sibiu, Faculty of Engineering, Department of Industrial Machinery and Equipment, Emil Cioran, no. 4, Sibiu, Romania, E-mail: nicolae.stefanoaea@ulbsibiu.ro

2 0000-0002-6910-4727, „Lucian Blaga" University of Sibiu, Faculty of Engineering, Department of Industrial Machinery and Equipment, Emil Cioran, no. 4, Sibiu, Romania, E-mail: olivia.petrascu@ulbsibiu.ro

3 0000-0001-8720-138X, „Lucian Blaga" University of Sibiu, Faculty of Engineering, Department of Industrial Machinery and Equipment, Emil Cioran, no. 4, Sibiu, Romania, , E-mail: adrian.pascu@ulbsibiu.ro

1. Introduction

Polyamide 6 (PA6), also known as Nylon 6, is a thermoplastic material that belongs to the nylon polymer class. Its structure includes repeating amid groups (-CONH-) within the molecular chain. Due to its semicrystalline configuration, this polymer is characterized by outstanding mechanical properties, such as high tensile strength and a significant ability to resist impact [1], [2], [3].

This paper focuses on the impact of environmental factors on the mechanical and elastic characteristics of PA6, with the main objective of identifying how various external factors influence the mechanical and elastic characteristics of this material used in various industrial applications, all of which is intended to support future investigations on the behavior of these types of materials in different other working environments.

However, the interaction of these materials with various environmental factors leads to structural and functional changes that can compromise or, in some cases, improve their performance. Recent studies in the field of materials science and mechanical engineering are based on the impact of environmental factors such as temperature, humidity, ultraviolet radiation, and exposure to various chemicals on the mechanical and elastic properties of polymers.

2. Materials and method

This study aimed to determine the mechanical and elastic properties of the PA6 subjected to different exposure environments: ambient, distilled water, cooling oil, saline solution, and UV-C radiation by means of uniaxial tensile tests. The results obtained allow a comparative analysis of the influence of the working environment on the mechanical and elastic behavior of this type of polymeric material.

In addition to the experimental analysis, a numerical simulation of the mechanical behavior of the PA6 material was carried out using the Abaqus software to validate and correlate the results obtained in the physical tests. The shape and dimensions of the specimens used for the tensile tests are shown in Figure 1 and are realized in accordance with ISO 527-2:2012 [4], which covers uniaxial test methods for plastics.

Specimens for immersion in distilled water, cooling oil, or saline were first dried in an oven at 500°C for 24 hours in accordance with ISO 62:2008—Plastics: Determination of water absorption [5]. After exposure, the specimens were weighed again to assess the liquid uptake for distilled water, cooling oil, and saline solution, according to the procedure described in the standard. In the last step, after the drying process, the specimens were weighed once more to quantify the amount of liquid absorbed. Formula (1) was used to calculate the liquid uptake. The steps involved in preparing specimens for testing are shown in Figure 1.

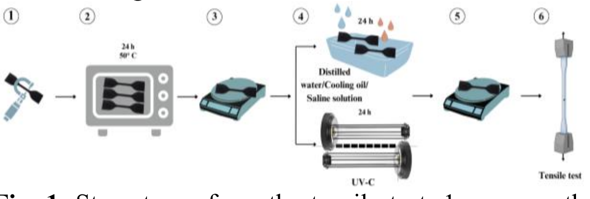


Fig. 1. Steps to perform the tensile test: 1-measure the specimens, 2 - oven drying, 3 - weighing after drying, 4 - immersion / exposure to the medium of interest, 5 - absorption weighing, 6 - uniaxial tensile test.

$$c = \frac{m_2 - m_1}{m_1} \times 100\% \quad (1)$$

3. RESULTS AND DISCUSSION

3.1 Experimental results

The results obtained from the uniaxial tensile tests performed out on specimens maintained in the five environments analyzed are presented in Figure 3. To ensure the accuracy and relevance of the data, ten specimens were used for each medium tested.

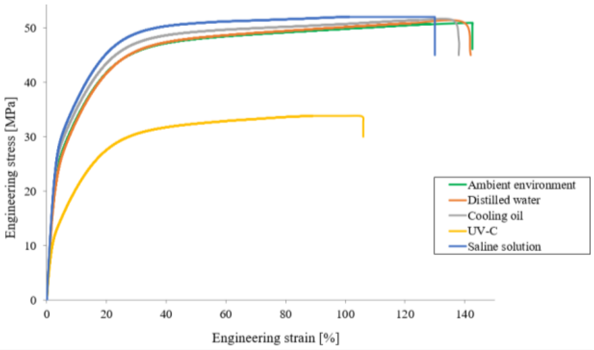
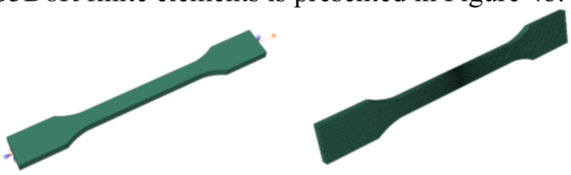


Fig. 3. Mean stress – strain curves for tensile testing of PA6 in five different environments.

3.2 Numerical results

To simulate the uniaxial tensile behavior of specimens made of PA6 material, a 3D model of the specimen was realized with the CATIA V5R20 software package. This model was imported into the ABAQUS software package, where it was discretized into C3D8R finite elements, and the material data, constraints, and loads related to each test performed experimentally were applied.

Thus, the specimen is fixed (recessed) at one end, and at the opposite end a displacement is applied in the direction of the longitudinal axis of the specimen, equal to the mean displacement recorded experimentally at the time of the occurrence of the breakage, as shown in Figure 4a. The 3D model of the tensile specimen discretized in C3D8R finite elements is presented in Figure 4b.



(a) with constraints and loads applied (b) discretized in finite elements

Fig 4. The 3D model of the tensile specimen.

The plastic be behavior of the materials was defined using stress – strain curve obtained after the uniaxial tensile tests for all five studied cases. Figure 5 shows the comparative force-displacement curves (experimental vs. numerical/FEM) for specimens made of PA6 and tested at uniaxial tensile in the ambiental enviroment.

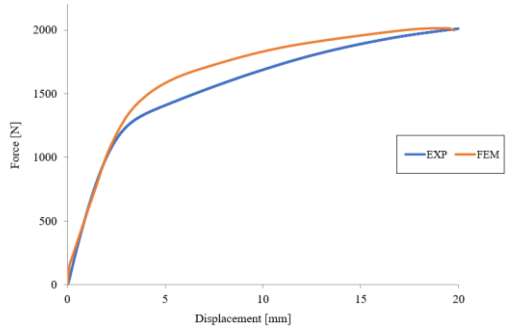


Fig 5. Results of numerical simulation using FEM.

4. CONCLUSIONS

Following the numerical simulations performed using the finite element method (FEM) for uniaxial tensile tests on specimens made of PA6 and comparing the obtained results with those determined from experimental tests, several conclusions can be drawn. Regarding the comparison between the force–displacement curves obtained experimentally and those generated through numerical simulation using FEM, it can be observed that there is a very good correlation between these curves (experimental vs. numerical) for all five studied environments (ambient conditions, distilled water, cooling oil, saline solution, and UV-C radiation exposure).

5. Bibliography

[1] R. Hsissou, R. Seghiri, Z. Benzekri, M. Hilali, M. Rafik, și A. Elharfi, „Polymer composite materials: A comprehensive review”, *Composite Structures*, vol. 262, p. 113640, apr. 2021, doi: 10.1016/j.compstruct.2021.113640.

[2] T. Liu, „A Bibliometric Analysis of the Performance of Advanced Materials Research from 2005 to 2012”, *AMR*, vol. 803, pp. 165–168, sep. 2013, doi: 10.4028/www.scientific.net/AMR.803.165.

[3] A. Molea, V. V. Merie, și R.-C. Suciu, Ed., *Materiale utilizate în construcția și întreținerea autovehiculelor*, Editura UTPRESS. Cluj_napoca, 2023.

[4] *ISO 527-2:2012 Plastics - Determination of tensile properties*.

[5] *ISO 62:2008 - Plastics - Determination of water absorption*, 2008.