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# Analysis of the compression process of an angle made of flax fibers in a PLA resin matrix

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## Abstract

The ongoing development of technology worldwide is creating increasing opportunities for engineers to design structures that are both durable and environmentally safe. The significance of not only the material's strength but also its origin, and the possibilities for recycling or disposal, is becoming more prominent. An informed society pays more attention to what it purchases and whether it has the option of choosing elements or structures that are more environmentally friendly. Consequently, materials that can be widely used to produce strong and durable components while maintaining a lower carbon footprint compared to conventional materials are the subject of intensive research worldwide.

In the case of fiber-reinforced composites, natural materials that can replace synthetic fibers (e.g., carbon and glass) include flax, hemp, sisal, and jute. The production of one kilogram of flax fiber consumes 4 MJ (1.1 kWh) of electrical energy, which is 99% less than that of carbon fiber (900 MJ – 250 kWh). Furthermore, the production of flax fibers results in lower CO<sub>2</sub> emissions into the atmosphere (1.65 kg per 1 kg of fiber) compared to carbon fiber (24 kg per 1 kg of fiber), representing a 93% improvement in air quality.

Given these benefits of using flax, it was decided to conduct research on the failure of a simple structural element (an angle) due to axial compression. Studies were carried out using both numerical and experimental methods. In the experimental study, failure occurred for five samples made from natural composite materials (flax fibers with a polylactic acid (PLA) matrix). Compression tests were conducted on a testing machine to determine the performance characteristics of the laminates. A non-contact measurement system, Aramis, was used to monitor the geometry. Additionally, an acoustic emission system was implemented to register sound signals generated during the tests, which allowed for the identification of when fiber or matrix damage occurred.

A numerical analysis was performed on an ideal model rounded to correspond with the real object. The Abaqus software was used, employing the finite element method (FEM). The critical force for the first mode of buckling was determined. An initiation damage analysis was conducted using maximum stress criteria, Tsai-Wu, Tsai-Hill, and Azzi-Tsai-Hill criteria. The Hashin criteria were used to determine the mechanism leading to material failure. A stability loss analysis was performed based on the Hashin parameters, and equilibrium paths were established along with the value at which load-bearing capacity is lost.

Further research on biocomposite materials will increase the potential for their effective use across various industrial sectors, which could contribute to reducing negative environmental impacts.

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