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ASSESSING THE BOUNDARY CONDITIONS' EFFECT ON THE THERMO-MECHANICAL MODELING OF A BIAS-EXTENSION TEST OF FLAX/PP COMPOSITE

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ABSTRACT

The effect of the fixture's boundary conditions on the thermo-mechanical behavior of a flax/polypropylene composite sample during the bias extension test is evaluated in this paper. For this aim, two finite element models are developed in ABAQUS with and without the fixture. The developed numerical models are linked with the applied temperature and measured load during the bias extension test. The stress-strain distributions are compared in the developed models to assess the effect of model simplification.

Keywords: finite element model, natural fiber composites, flax fibers, thermoplastic composites, bias extension test, molten state test, high temperature.

INTRODUCTION

The potential of natural fiber-reinforced thermoplastic composites such as flax/polypropylene can be used towards promising applications in the automotive industry (Xiao et al., 2018). Manufacturing such parts involves techniques like thermoforming, in which the composite part is heated above the matrix's melting point and pressed into the desired shape (Längauer et al., 2021). To simulate these processes, it is required to determine the desired characteristics in the molten state by performing corresponding experiments such as the bias extension test. To determine the material properties accurately, one can combine the experimental measurements with numerical simulations, e.g., finite element models. However, developing and running a high-fidelity numerical model is time-consuming. Hence, researchers simplify the model by simulating the most critical part and neglecting the others. In this case, the fixture's effect and corresponding boundary conditions are usually ignored, which can affect both temperature and thermo-mechanical stress-strain distributions. To the authors' knowledge, the influence of this simplification for a bias extension test has not been addressed yet. To fill this gap, this paper compares two finite element models, one with and one without the fixture. The required load and temperature data for the models is acquired by performing bias extension tests on flax/polypropylene composites.

BIAS EXTENSION TEST SETUP AND EXPERIMENTS

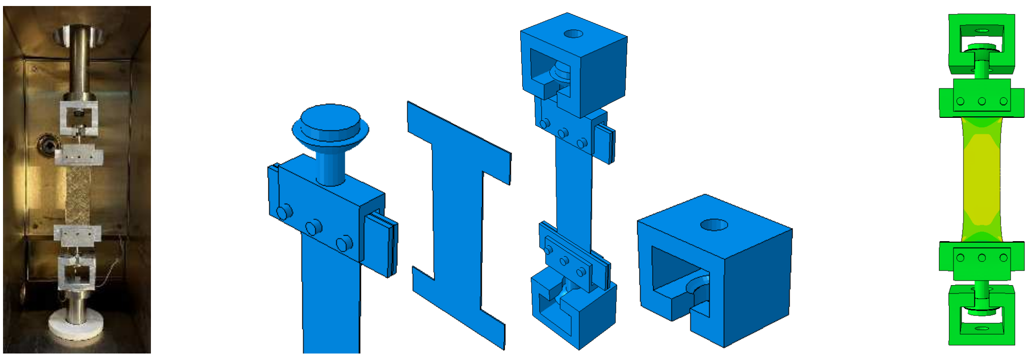
The bias extension test in this paper is performed at 170 degrees Celsius on a flax/polypropylene spread-tow woven thermoplastic composite using an Instron universal testing machine equipped with a climate chamber (Figure 1 (a)). Before performing the test, the sample should be placed inside the oven to reach the desired temperature. Based on previous studies (Abadi et al., 2022), achieving a uniform temperature distribution within the sample takes a long time and might cause oxidization. Therefore, a new fixture (Figure 1 (b)) was designed, which enables pre-heating the oven and placing the sample once the oven reaches the desired temperature. The samples are cut out from a 4-ply composite sheet with a 40% fiber volume fraction, ±45° layup, and a nominal thickness of 2.3 millimeters. Several type-K thermocouples are connected to the sample to record the temperature history. To have a continuous measurement of the local deformations on the composite surface, the Digital Image Correlation (DIC) technique is used.

THERMO-MECHANICAL MODEL

Two finite element models are developed in ABAQUS to study the effect of the fixture's boundary condition on the stress-strain distribution within the sample. The first model includes the designed fixture and the test sample together (Figure 1 (b)). However, in the second model the load is directly applied to the specimen and the fixture is not considered. The recorded load and temperature history during the test are imported to both finite element models to compute the stress-strain distributions.

RESULTS AND DISCUSSION

The shear stress- shear strain distribution is simulated using both models to evaluate the effect of the fixture's thermo-mechanical boundary conditions. Figure 1 (c) qualitatively displays the shear strain distribution for the first model. The temperature and stress-strain distributions in this model will be compared with the results of the second model without the fixture.



(a) (b (c)

Fig. 1 – (a) experimental test setup; (b) test sample and designed fixture; (c) shear strain distribution.

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