NUMERICAL MODELING OF THE MICROMECHANICAL ANISOTROPY EFFECT ON FRICTION WHEN DRY CUTTING OF GREEN COMPOSITES

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ABSTRACT

Green composites are nowadays getting a particular interest in the automotive and aerospace industries because of the strengthful environmental constraints [1]. In the composite industry, green composites are manufactured with natural fibers (such as flax, hemp, jute … ect) embedded in natural polymers (such as polylactic acid (PLA), polyamide 11 (PA11) … ect) in order to have a 100% bio-based composites. The use of these eco-friendly materials in different industry fields is an interesting way to improve a circular economy and sustainable development [2].

Machining operations for green composites present many tribological issues due to the complex anisotropic structure of natural fibers that induces a high variability of the mechanical properties [3]. Therefore, the experimental validation of the machinability of these novel materials remains expensive and laborious to achieve. Developing a numerical predictive tool for the machinability of green composites could be an effective solution to reduce the complexity of the experimental validations in the composite industry.

In this paper, a finite element analysis (FEA) is considered to model the machining behavior of flax fibers reinforced PLA composites with the orthogonal cutting process. The FEA is investigated at microscale in order to model each composite phase separately (the elementary fibers, the polymer matrix, and the interfaces). Unlike synthetic fibers, natural fibers are modeled in this paper with a ductile criterion for damage initiation. The interfaces are modeled using cohesive elements. FEA is made for different fiber orientations to carry out the anisotropic behavior. The FEA results are validated with orthogonal cutting experiments at the similar FEA cutting conditions. The FEA/experiments correlation is based on the comparison of both the cutting friction and the microscopic cutting behavior of natural fibers regarding their orientation within the composite.

Results show that the proposed FEA model is able to reproduce efficiently the cutting friction behavior of natural fibers composites in function of their microscopic anisotropy. The ductile criterion used in this model allows the plastic deformation of elementary flax fibers during machining which corresponds to the real cutting behavior of natural fiber composites. Changing the fiber orientation in the micromechanical model leads to a better understanding of the tribological mechanisms that occur on the elementary fibers, the polymer matrix, and the interfaces which is strongly important to control and improve the machinability of these eco-friendly materials.

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