Modeling the Squeeze Flow of a Thermoplastic Composite Tape During Forming

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Abstract

Thermoplastic composite such as APC2 (made of PEEK matrix and carbon fiber) is an new alternative to thermoset composite in the aeronautic industry. Forming cycle for such composite can be highly shortened compared to thermosets, thanks to the non necessity to cure the matrix. Those materials are usually shipped as semi-finished preimpregnated tapes. Several forming processes are then available to produce a final part : autoclave consolidation, tape placement, press forming, etc. In order to better control those forming processes the squeezing of a single tape is always one of the basic mechanism that needs to be understood. This paper focuses on the modeling of the complex squeeze flow of a such a single prepreg tape. For the sake of clarity, we here consider one single tape compressed between two rigid parallel plates. Because the unidirectional fiber prevent the flow in the third direction, the flow is modeled in two dimension under plane strain assumption (see Fig. 1). The tape is then modeled by a rectangle. The flow problem is solved using the CFD Module in COMSOL. Following existing work on squeeze flow of APC2, an equivalent homogeneous material is considered. Because of the non-Newtonian behavior of the matrix, a Carreau law for the equivalent viscosity is considered such that the problem is nonlinear. The thermal dependency of the viscosity follows a classical Arrhenius law. A given vertical displacement is applied on the upper boundary representing the tool effect. On the other hand, the heat transfer in the tape is modeled using the Transient Heat Conduction physics in COMSOL. The contact with the tool imposes a given temperature on the upper and lower part of the mold. Because the flow leads to large deformation, special care has to be taken for the geometrical representation. Indeed, the upper boundary is moving down as the tool applies pressure and the width of the tape increases. Those large deformations are handled using a moving mesh representation in COMSOL. Several closing force and temperature conditions are investigated. For each case, the average width of the tape can be plot versus time. Those full FEM results are compared to existing simplified model under the lubrication assumption and experimental results. The FEM results concerning heat transfer show that the steady state is rapidly reached so that the process mainly occurs under isothermal conditions. The FEM model appears to accurately predict the experimental data. The simplified model is also accurate for the given initial tape thickness. This study focuses on the behavior of a single composite tape. It validates the range of accuracy of the simplified squeeze flow model used extensively in the literature. The present work is a preliminary to understand more complex forming processes involving, for instance, multiple layers or non isothermal conditions. Future work aim at using the obtained behavior for one tape in order to model the forming of Randomly-Oriented Strips (see Fig. 2).

Reference

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Tierney, J., & Gillespie, J. W. (2006). Modeling of in situ strength development for the thermoplastic composite tow placement process. Journal of Composite Materials, 40(16), 1487–1506.

Figures used in the abstract

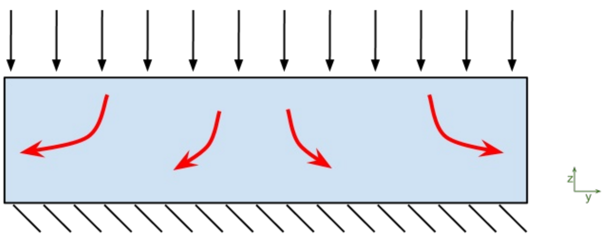

Figure 1: Initial geometry.

Figure 2: Randomly oriented strips ready to be processed.