Optimal Process Design for Large-Scale Pultrusion Structures

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ABSTRACT

Computational and experimental methods for optimal design of the pultrusion process of structural profiles are developed in this study. The methods are based on computational modeling of composite material behavior during manufacturing process, including impregnation of reinforcement [1], polymerization of thermoset matrix [2], evolution of residual strains and stresses [3], formation of process induced defects (porosity, transverse cracking) [4]. Mechanical constitutive models (linear elastic, path-dependent, and viscoelastic) were implemented within the ABAQUS software. The subroutines verification was performed using data available in literature.

The special simulation scheme was developed in pSeven software for numerical optimization and sensitivity analysis of process parameters. The main goal of process parameters optimization is to maximize pulling speed in order to increase production rate, while satisfying temperature, curing degree, residual stress, and shape distortions constraints. The multi-objective surrogate-based optimization (MSBO) algorithm was used. One of the main features of MSBO algorithm realization in pSeven is a possibility to allocate the computational budget (number of model evaluations) [5]. The constraints considered in this study are transverse stress in pultruded profile, maximum temperature of the material and minimum degree of curing at the end of a die zone. Maximum spring-back angle is used to control the shape distortion of the profile.

To validate the simulation tool on a reasonably complex real world case the pultruded C-section of a stair tread panel was manufactured, shape distortions were measured and compared with predicted ones. The process parameters study was performed in two steps: the uniform design of experiments was chosen in order to study the model behavior and sensitivity, and the two-criterion optimization problem was solved to obtain a Pareto-frontier in speed vs. deformation coordinate system. The approximation model based on Gaussian processes was built. The approximation model allows us to visualize different constraints violation areas. The maximum achieved speed is about 18 % higher compared to the initial one.

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