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NUMERICAL SIMULATION OF PULTRUSION PROCESSES: ALGORITHMS' COMPARATIVE STUDY

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Summary: Pultrusion is a continuous and cost-effective process for a production of composite structural components with a constant cross-sectional area. To provide better understanding of the pultrusion processes, to support the pultrusion tooling design and process control, a lot of numerical simulations have been done in the last thirty years. Most of them are focusing on the analysis of the heat transfer and cure, on the pressure rise in the tapered zone of the die and on problems related to impregnation of reinforcing fibres to obtain a final product characterised by the desired mechanical properties. The effects of the processing parameters, like die temperature, pulling speed, post cure temperature and time, filler and fibre type and content, on the mechanical properties of composites produced with a pultrusion have been also intensively investigated. It is necessary to note that numerical simulations of the pultrusion processes are carried out by using non-commercial FE codes and general-purpose FE software. In most cases the developed numerical models are firmly connected with the final product and applied technology, and therefore no more than one algorithm is utilized for a simulation purpose. For this reason in the present investigation, two different approaches for a numerical simulation of pultrusion processes are proposed, compared and discussed. Each of them is constructed by using the general-purpose FE software that results in considerable savings in development time and costs, and also makes available various modelling features of the FE package. The first procedure is developed in ANSYS Mechanical environment and based on the mixed time integration scheme and nodal control volumes method to decouple the coupled energy and species equations. Movement of the resin-saturated composite is simulated by shifting the temperature and degree of cure fields after each calculation step. Within each time step the species equation is solved outside the software by using the control volume method to obtain the degree of cure at each nodal point. An effect of the convection and exothermic terms on temperature is computed from the known temperatures of the previous time step. The algorithm allows an obtaining a temperature field for the current time step by solving of the remaining transient heat conduction problem. The second procedure is performed by using ANSYS CFX software and presents quite new approach not used widely for a pultrusion modelling. ANSYS CFX easily combines fluid flow and heat transfer options but there is no implemented model for the cure reaction. The cure reaction in our case is introduced as an additional variable.

The described procedures have been validated by the results of other authors that additionally gave the possibility to compare the developed algorithms in their applicability for an accurate thermo-chemical simulation of pultrusion processes. Good agreement between present finite element results and published numerical-experimental results has been observed for the temperature and degree of cure fields in all test problems studying the pultrusion of cylindrical rod, flat plate and I-beam profiles.