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Modelling of Exothermic Reactions during Carbon Fibre Manufacturing and Coupling to Surrounding Airflow

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Abstract : Carbon fibres are fibrous materials with a carbon atom amount of more than 90%. They combine excellent mechanicals properties with a very low density. Thus carbon fibre reinforced plastics (CFRP) are very often used in lightweight design and construction. The precursor material is usually polyacrylonitrile (PAN) based and wet-spun. During the production of carbon fibre, the precursor has to be stabilized thermally to withstand the high temperatures of up to 1500 °C which occur during carbonization. Even though carbon fibre has been used since the late 1970s in aerospace application, there is still no general method available to find the optimal production parameters and the trial-and-error approach is most often the only resolution. To have a much better insight into the process the chemical reactions during stabilization have to be analyzed particularly. Therefore, a model of the chemical reactions (cyclization, dehydration, and oxidation) based on the research of Dunham and Edie has been developed. With the presented model, it is possible to perform a complete simulation of the fibre undergoing all zones of stabilization. The fiber bundle is modeled as several circular fibers with a layer of air in-between. Two thermal mechanisms are considered to be the most important: the exothermic reactions inside the fiber and the convective heat transfer between the fiber and the air. The exothermic reactions inside the fibers are modeled as a heat source. Differential scanning calorimetry measurements have been performed to estimate the amount of heat of the reactions. To shorten the required time of a simulation, the number of fibers is decreased by similitude theory. Experiments were conducted to validate the simulation results of the fibre temperature during stabilization. The experiments for the validation were conducted on a pilot scale stabilization oven. To measure the fibre bundle temperature, a new measuring method is developed. The comparison of the results shows that the developed simulation model gives good approximations for the temperature profile of the fibre bundle during the stabilization process.

Keywords : carbon fibre, coupled simulation, exothermic reactions, fibre-air-interface
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