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Application of Kubelka-Munk-Theory for modelling the thermal wave generation in infrared irradiated thermoplastic polymer matrix composites

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Composites with thermoplastic matrices show favourable material properties and offer remarkable advantages in terms of processing [1]. Especially good forming properties and high design freedom make them particularly relevant for cost-effective manufacturing. Typically high-performance consolidated composite sheets (precursors), where woven fabrics are used as reinforcement are heated up by infrared radiation ensuring short heating times until the matrix melting temperature is reached [2]. Then the sheet is transferred from the heating station into the tool, where the forming process occurs. The process efficiency depends on the time interval which is necessary for heating up the composite sheet. Consequently, it is of high interest to predict the heating behaviour of infrared irradiated composite sheets. Heating rates are depending on the material (matrix and fibre combination) used, sheet thickness and radiator system. Especially the combination of material and radiator system, i.e. wavelength of the emitter, influences the penetration depth of the radiation into the material and further controls the heating time of the composite.

The challenge in modelling the heating behaviour of composite sheets is the material and radiator dependent optical depth where the photonic wave is transformed into a thermal wave. Due to the heterogeneous material, reflectance of the photonic irradiated wave takes place, especially at fibre-matrix interfaces and therefore scattering phenomena are involved. In the current work the authors apply Kubelka-Munk Theory [3,4] for describing the optical characteristics of the composite and solve the radiation problem with finite difference method. Results obtained from Kubelka-Munk approach are compared with simulations made by using pure radiative boundary conditions and Beer-Lambert Law. In comparison with experimental data obtained by infrared flash experiments, it could be shown that the simulation using the Kubelka-Munk theory is able to describe the thermal wave generation in the transition layer and consequently the heating behaviour of thermoplastic composite sheets for various sheet thicknesses can be predicted.

REFERENCES

[1] Ijaz, M., Robinson, M., Gibson, A.G., Composites Manufacturing 2007,**30**, 935-943
[2] Sweeney, G.J., Monaghan, P.F., Brogan, M.T., Cassidy, S.F., Composites Manufacturing 1995,**6**, 255-262
[3] Kubelka, P. and Munk, F., Ein Beitrag zur Optik der Farbanstriche. Zeitschrift für Technische Physik 1931, **12**, 593 601
[4] Kokhanovsky, A.A., Physical interpretation and accuracy of the Kubelka-Munk theory, J. Phys. D: Appl. Phys. 2007, 40, 2210-2216