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FIBER OPTICS IN PROCESS MONITORING FOR SUSTAINABLE CRADLE TO CRADLE COMPOSITE MANUFACTURING

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Introduction

In the nautical sector, the processes of choice for composite manufacturing have become resin infusion, especially Vacuum Assisted Resin Transfer Molding (VARTM). However, a thorough understanding of the process parameters is needed. Hence the importance of manufacturing monitoring, for which optical fibers sensors stand out as very effective. This becomes even more relevant when processing new materials, as the ones developed to increase the sustainability of the composite industry. These materials prompt a "cradle to cradle" monitoring approach, to optimize both the process and the usage of composite components to get high quality products while reducing costs and waste.

Material and Methods

The validation was carried on a carbon-epoxy and a basalt-thermoplastic composites with standard optical fibers. The process monitoring covered two steps: resin flow and curing. The first was observed using Fresnel reflection, the second using Rayleigh backscattering. This last was also applied for the monitoring of deformations in the fully consolidated component. Experiments on resin only were made to fine-tune the technique. Then, it was applied to monitor the production through VARTMof composite panels and the following mechanical tests.

Results

The tests proved that fiber optic tip immediately detected the arrival of the resin during infusion as a sudden sharp drop in the signal intensity. The crosslinking reaction changes three parameters influencing the optical signal: refractive index, mechanical strain and temperature. When the sensitivity to them is calibrated, it is possible to observe during curing: an initial drop of the signal due to the increase in temperature produced by the exothermic reaction, followed by a subsequent re-increase when the refractive index of the resin lowered going from liquid to gel, and finally, a new gradual drop linked to the passage of the resin to the glassy state.

Discussion

Fiber optic interferometry proved to be an effective technique for the monitoring of resin infusion, curing and usage. Detecting the non-wetted areas of the preform, the gel point and the passage to the glass phase triggers the possibility to adjust the infusion parameters ensuring a good quality of the process. The use of the same fiber got embedded during the production process to also monitor the deformations of the component during usage not only increases performance and safety, but also elevates its useful life. Overall, the monitoring joined to the use of sustainable materials allows obtaining high-performance products and efficiency in terms of time, life-cycle costs, and quality.