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Monitoring the Production of Large Composite Structures Using Dielectric Tool Embedded Capacitors

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Abstract : With the rise of public awareness on climate change comes an increasing demand for renewable sources of energy. As a result, the wind power sector is striving to manufacture longer, more efficient and reliable wind turbine blades. Currently, one of the leading causes of blade failure in service is improper cure of the resin during manufacture. The infusion process creating the main part of the composite blade structure remains a critical step that is yet to be monitored in real time. This stage consists of a viscous resin being drawn into a mould under vacuum, then undergoing a curing reaction until solidification. Successful infusion assumes the resin fills all the voids and cures completely. Given that the electrical properties of the resin change significantly during its solidification, both the filling of the mould and the curing reaction are susceptible to be followed using dieletrometry. However, industrially available dielectrics sensors are currently too small to monitor the entire surface of a wind turbine blade. The aim of the present research project is to scale up the dielectric sensor technology and develop a device able to monitor the manufacturing process of large composite structures, assessing the conformity of the blade before it even comes out of the mould. An array of flat copper wires acting as electrodes are embedded in a polymer matrix fixed in an infusion mould. A multi-frequency analysis from 1 Hz to 10 kHz is performed during the filling of the mould with an epoxy resin and the hardening of the said resin. By following the variations of the complex admittance Y*, the filling of the mould and curing process are monitored. Results are compared to numerical simulations of the sensor in order to validate a virtual cure-monitoring system. The results obtained by drawing glycerol on top of the copper sensor displayed a linear relation between the wetted length of the sensor and the complex admittance measured. Drawing epoxy resin on top of the sensor and letting it cure at room temperature for 24 hours has provided characteristic curves obtained when conventional interdigitated sensor are used to follow the same reaction. The response from the developed sensor has shown the different stages of the polymerization of the resin, validating the geometry of the prototype. The model created and analysed using COMSOL has shown that the dielectric cure process can be simulated, so long as a sufficient time and temperature dependent material properties can be determined. The model can be used to help design larger sensors suitable for use with full-sized blades. The preliminary results obtained with the sensor prototype indicate that the infusion and curing process of an epoxy resin can be followed with the chosen configuration on a scale of several decimeters. Further work is to be devoted to studying the influence of the sensor geometry and the infusion parameters on the results obtained. Ultimately, the aim is to develop a larger scale sensor able to monitor the flow and cure of large composite panels industrially.

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