An investigation of the interfacial strain transfer of optical fibres embedded in fast curing epoxy resins.

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Carbon fibre reinforced plastics are becoming more and more popular in the aerospace and automotive industries due to their high specific strength and stiffness. However, one major drawback of more traditional composite manufacturing techniques is that they have very long processing times. This is primarily due to the need to slowly increase and decrease the processing temperature to avoid residual stress formation and warpage after cure. In recent years, “snap-curing” or very fast curing resins have been developed to reduce the processing time required to cure parts. However, the effect of shorter processing times on residual stress formation is still not well understood and if these manufacturing techniques are to be adopted for structural applications this gap in knowledge must be addressed. Therefore, this research aims to investigate ways in which to evaluate residual stress in fast curing composites and to determine the effect that residual stress has on the mechanical performance of the finial composite part. In this work, the applicability of the use of embedded optical fibres with Fibre Bragg Gratings (FBGs) in fast-curing composite systems for the measurement of residual strain is investigated. The use of FBGs in standard curing resin systems has been growing in recent years with increasingly accurate results [1, 2, 3]. However, the basis of this technique relies on the assumption that there is a sufficient bond strength and transfer of strain between the embedded optical fibre and the epoxy matrix. The use of FBGs in fast-curing resins is still a relatively unexplored area and little is known about the strain transfer between fibre and matrix in these fast curing systems. Therefore, it is the aim of this research to investigate the strain transfer between epoxy-carbon and epoxy-optical fibre interfaces in fast curing composites. Work by Gao et al [4] found that the interfacial shear strength of a carbon-epoxy bond is influenced by the degree of conversion and diffusion temperature which are two factors that are affected by increasing the curing rate of an epoxy matrix. Recent work by Qi et al [5] has found that increasing the curing rate of epoxy matrices decreases the thickness of the interfacial region between carbon and epoxy within a laminate. These factors have led to the need for an investigation into the effect of an increased cure rate on the interfacial shear strength of carbon-epoxy bonds as it is clear that multiple factors affect this region.

In the current research, single fibre fragmentation testing (SFFT) is conducted on carbon-epoxy and optical fibre-epoxy specimens with both conventional and fast curing resins. In this case, SFFT will be conducted by preparing a sample consisting of a single carbon or optical fibre running along the centre of an epoxy dog-bone sample. This sample is then strained which causes the single fibre to fracture. The applied load is then transferred to the remaining fibre fragments via the shear lag effect of the epoxy matrix. The applied strain is then further increased and more fibre fractures occur. This continues until the fibre lengths are insufficient to cause enough load introduction into the fibre fragment and any further fibre breaks to occur [6]. At this point it is possible to calculate the interfacial shear strength of the fibre/matrix interface by measuring the length of the fibre fragments. To aid this process, polarised light is shone through the specimen as it is loaded at the saturation point which clearly shows the fibre breaks. These data are then analysed and comparisons between all cases can be made. The bonding is then qualitatively evaluated with the use of scanning electron microscope images to ensure no debonding in the interfacial region has occurred. Automated micro-photoelasticity will also be used to attempt to quantify the strain in the interface region. This research is key to the advancement of the use of optical fibre sensors in fast curing resin systems as without the validation of the key assumptions as previously outlined it is not possible to make any meaningful correlation between experimental results and the system under investigation.

References

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