REINFORCEMENT OF PARTIALLY CURED AEROSPACE STRUCTURES WITH B-STAGED PATCHES

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Introduction

This work is addressing the challenge of reinforcing fastener areas for the connection of the CFRP floor beam to the fuselage, as shown in Figure 1, without using adhesives. The area of the rivet will be reinforced by a load introducing patch while the rest of the part will have a nominal thickness. The part and the patch are produced separately and the cure is interrupted at an intermediate B-stage. Later the patch will be co-cured on the part to achieve a full cure in both components, i.e. uniform glass transition temperature, T_g, and elastic modulus in the matrix. This approach results in stress reduction around the hole, simpler geometries of the single parts and high flexibility of reinforcement in the patch. The reinforcement can be adapted to the individual load case by the choice of the reinforcement material, layup and resin system. The co-curing stage of the cure eliminates a bonding step and the use of adhesives and results in the ideal case of a monolithic part.
To achieve this, a detailed analysis of the curing reaction is required. It is necessary to predict the degree of cure, α, and T_g evolution for any time/temperature profile so that the cure cycles of the part and the patch may be optimized. The influence of the interrupted curing cycle on the mechanical and thermal properties is investigated. The effect of the interface treatments are also discussed.

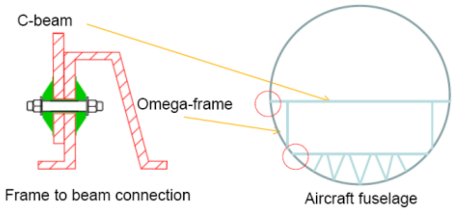

Figure 1: *Floor beam to omega frame connection in a fuselage, including reinforcement patches.*

Materials and Methods

The part and the patch were produced using resin transfer moulding (RTM) and compression resin transfer moulding (CRTM) respectively. The part is a 3.8 mm thick plate with a quasi-isotropic layup made from 16 plies of a biaxial stitched non-crimp fabric (ECS6090 Series HTS 40, Saertex), and the patch is 2 mm thick disc with a diameter of 30 mm with a quasi-isotropic layup from 24 plies of spread tow (20 mm tape, 80g/m2 HTS, Oxeon). The resin used is the mono-component epoxy-amine system RTM6 (Hexcel). In the first stage of cure the part and the patch were heated until reaching an intermediate value of α. For the second stage of cure, the patch is fixed on the part with a co-cure jig and put in an oven to be fully cured. The optimum curing cycles for both stages were identified with cure kinetic and

T_g model. The coupon samples were tested according to the standard ASTM D 5961 [1] in single lap bearing.

Modelling

For the cure kinetic modelling, pure resin samples of RTM6 were cured in a differential scanning calorimeter (DSC) either at an isothermal temperature or at constant heating rate. For the T_g model partially cured resin was described with temperature modulated DSC to obtain α and T_g. The degree of cure α was analyzed with a Ruiz model [2] which includes the possibility of adding an α_{max} model, which describes the decrease of reaction rate due to diffusion control as the crosslinking reaction proceeds. The evolution of T_g. depending on α was modelled using the DiBenedetto model [3]. With these two models, a complete curing cycle could be described through all phases of co-curing.

Results and Discussion

The model predictions for α from the partially cured plates were compared to α measured by DSC. A good agreement of the predicted and the measured values of α was achieved. In Figure 2 (left), an example of a simulated cure cycle is shown. The comparison of plates produced with the usual curing cycle at 180°C or an interrupted curing cycle showed that the curing cycle has no influence on the mechanical and thermal properties of the composite. The bearing strength of the patch reinforced plate highly depends on the failure mechanism; mainly whether or not the patch is delaminates. This shows the importance of adhesion and surface preparation in this process.

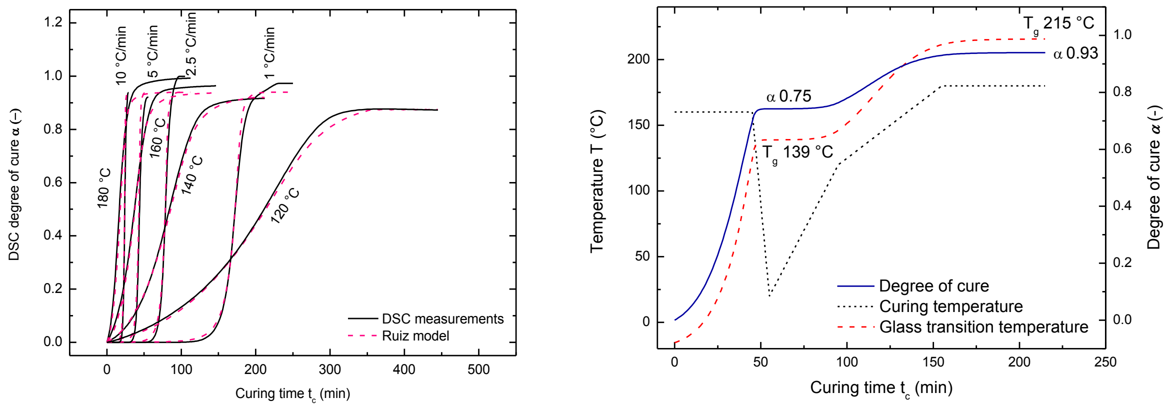

Figure 2: *Left, Comparison of the Ruiz model to measured DSC data. Right, Example of a simulated curing cycle for a part, where in the second stage the Tg being above the cure temperature allows free-standing cure.*

Conclusion

A full process for co-curing B-staged composite parts was successfully developed, including kinetic and T_g modelling of the curing reaction of an epoxy resin, simulation of curing cycles, development of the tools and optimizing of the process. The effect of the co-cured patch on bearing strength and mode 1 fracture toughness is currently investigated.

References

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