A STUDY ON CURING PROCESSES AND ENVIRONMENTAL EFFECTS FOR RAPID COMPOSITE REPAIR

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Introduction

Battle damage repair (BDR) becomes to be significant for military aircrafts, as they are vulnerable to ballistic impact damage from small arms fire. Therefore, a rapid repairing technique is very important either to keep the aircraft operational with a minimum level of mission capability or otherwise to send it back to depot level maintenance center. A scarf repairing technique seems to be more suitable for rapid repairing of composite structures since it does not require depot level capability instead it requires only a few simple hand tools [1-6].

The first objective of this study was to determine the effects of vacuum bag and autoclave curing processes on the mechanical properties of scarf repaired parent materials to indicate how these two techniques differ from each other. The second one was to determine the environmental effects, i.e., moisture uptake and service temperature, on the tensile and interlaminar shear strengths of repaired laminates.

Test materials and processes

Materials

The material used in this study was Ciba Geigy Fiberdux 913G/7781 fabric prepreg which consisted of woven glass reinforced impregnated with epoxy resin. A film adhesive, (FM73), manufactured by American Cyanamid, was used in scarf joint type repairs and the repairs were cured under vacuum at a temperature of 125 ^{0}C. The stacking sequence of the laminates was $[+45/-45/0/90]_s$. Patch patterns with a stacking sequence of $[90/0/90/0]_s$ which were almost identical to the parent laminate.

Procedures

The mechanical properties of laminates and adhesives are expected to be affected by the curing process. In this study, two curing processes for repair (autoclave and vacuum bag cure) have been used to process parent materials and patches. Patches were also processed by vacuum curing in-situ with cured parent laminates, which was generally called cocure. Through these, the effects of each curing process and environmental exposures on the material properties have been investigated.

To determine the effects of moisture uptake on the mechanical properties of the parent materials and repaired specimens, some of the specimens were conditioned in an environment controlled at 70 ^{0}C and 85 % relative humidity until they were saturated.

The average moisture uptakes in terms of weight gain percentages for ILSS specimens and tension specimens were 1.3 % and 1.2 % respectively. For the repair tensile test specimens, the average moisture uptake was approximately 1.8 %. It is shown that higher moisture content was obtained for the repaired parts.

Results and discussion

Tensile Strength

It can be seen that the average ultimate tensile strength (343 MPa) of dry specimens at R.T. for the autoclave cure is 10 % higher than the strength (309 MPa) of dry specimens at R.T. for the vacuum cure. The wet specimens had differences in tensile strength between the autoclave and vacuum cures of 9 % and 6 % at 70 ^{0}C and 100 ^{0}C respectively. These differences were considered insignificant and they indicated that vacuum cured patches could be an alternative to autoclave cured patches for repair in the field level maintenance facility, see Fig 1.

It was also noted that moisture (wet) conditioned specimens showed a decrease in tensile strength of up to 8 % (from 343 MPa to 316 MPa) at a test temperature of 70 ^{0}C and up to 23 % (from 343 MPa to 268 MPa) at 100 ^{0}C for autoclave cured material. The maximum decrease in strength was about 23 %, which came from the effect of combining moisture, temperature and curing process, see Fig. 2. Therefore, it is important in design to take the elevated temperature strength for this material into account as the room temperature strength is significantly higher.

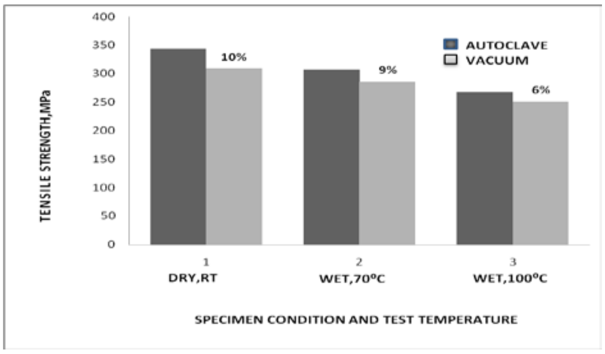

Fig. 1 Effect of Curing Process on Tensile Strength

The ultimate tensile strength (UTS) of repair specimens dropped rather drastically at elevated temperatures (70 ^{0}C and 100 ^{0}C). It is considered that this might have been due to debonding between parent material and patches. However, the difference in tensile strength between precured and cocured repair specimens was not significant at room temperature, since bonding strength does not change with the curing technique.

At elevated temperature (70 ^{0}C and 100 ^{0}C), repair efficiencies were low, and all of the failures occurred in adhesives (FM73).

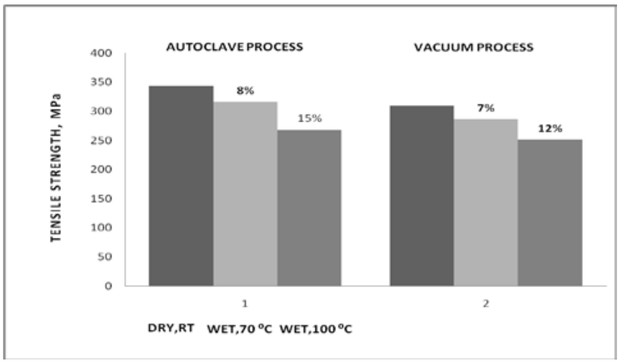

Fig. 2 Effect of Moisture and Temperature on Tensile Strength

Inter Laminar Shear Strength (ILSS)

The ILSS values measured at R.T., 70 ^{0}C and 100 ^{0}C of the short-beam three point bend tests show that the ILSS of saturated specimens dropped considerably at test temperatures of 70 ^{0}C and 100 ^{0}C. Voids and blisters caused by the entrapped moisture during the conditioning phase may contribute to this degradation of the shear strength of the bonding at elevated temperatures. But no significant difference was observed between the ILSS of the autoclave and vacuum cured materials.

Conclusions

It is concluded that the tensile strength and interlaminar shear strength (ILSS) decrease considerably when the material has been exposed to a combination of moisture and elevated test temperature.

It is also concluded that scarf repair with precured or cocured patches under vacuum curing conditions can be safely performed in field level maintenance facilities. Vacuum curing process requiring less equipment and not any autoclaving facility seems to be a serious potential alternative to the composite patch repair requiring autoclave conditions but still not qualified since only limited testing so far has been conducted.

References

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