THE EFFECT OF CURING CONDITIONS ON BONDED REPAIR WITH BORON/EPOXY COMPOSITE PATCH OF AIRCRAFT SKIN

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Introduction

Composite materials are becoming more important in the construction of aerospace structures. Bonded joints fulfil a significant role in the development of new technologies, particularly in the aerospace industry where they give new possibilities for connecting structural elements. The Composite Patch Bonded Repair is a method that can be used for repairing the metallic and composite structures. The method includes the following steps: surface preparation prior to bonding, the placing of Composite Patch and a cure cycle for the composite prepreg and the adhesive film [1].The primary advantages of composite materials for repair are their high strength, relatively low weight, and corrosion resistance.

The purpose of this research is to define the influence of the curing time and temperature on bonded repair structures, by bonding the boron patch composite to the Aluminium 7075-T6 with the use of Structural Adhesive Film FM73K for lower residual stresses by analysis the distortion due the bending curvature. A bending behaviour is observed at the bond area of samples were made for a study of Fatigue crack growth in bonded repair of damaged aircraft structure. [2]Analysis on metallic aircraft structures development and qualification aspect, indicated secondary bending structures curvature from both single side and double side doubler in the repair area did influence the behaviour; they recommended that would require detailed investigation. One way of minimising the level of residual stress is to cure the repair at the lowest possible temperature. FM-73K is a fracture toughened adhesive used for bonded repairs that are typically cured at 120°C for 1 hour [3]. However, during the curing process, adhesively bonded composite/metal laminate structures that are held at elevated temperatures over 120 °C as per data sheet recommendation for material processing, very high residual stresses could build up because of the difference in coefficients of thermal expansion (CTE) for different materials. This thermal mismatch results in delamination or debonding of materials, which facilitates fatigue crack growth in the polymer/metal interface.

Materials and methods

Patch repair materials description

Test materials utilized in this effort for the bonded repair of structures, as shown in Tab.1, include a 7075-T6 aluminium panel bonded to a six-ply unidirectional Boron/epoxy prepreg composite patch, with the use of the FM73-Knit Cytec/Solvay Structural Adhesive that is widely used in aircraft industry, as shown in Fig.1

Materials	Thickness (mm)
AA7075-T6 plate	2
Boron Prepreg 5521 tape 4 mil boron/epoxy Laminate with 5521resin	0.13 per layer 0.78 (6 Layers)
FM73K Structural film adhesive	0.25

Tab. 1 Thickness of the material used for the bonded structural repair

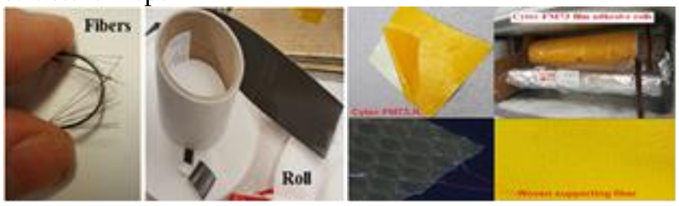

Fig.1 Boron fiber / Epoxy patch composite and a rollof FM73 Cytec film structural adhesive

Cure parameters

Two panels were made for each cure condition to ensure repeatability. The tests were performed with four types of cure conditions. The first was subjected to a cure cycle as per the data sheet – heating up in 30 minutes and held at 120°C for 60 min. The second was subjected to a prolonged cure cycle heating to 120°C for 105 minutes, to evaluate the prolonged curing time. The third was subjected to a lower temperature of 80ºC and held for longer time of 480min. A reduction in the cure temperature may affect important properties of the bonded repair integrity, and there for the fourth was subjected a combination of low temperature over a long cycle and post cured at the recommended cycle as per the data sheet to ensure adhesion at elevated temperatures . These cure conditions are summarised in Tab .2

Cure parameter		
Cure Conditions	Cure temperature °C	Time (min)
1	120	60
2	120	105
3	80	480
4	80 post cure at 120	480 post cure for 60

Tab.2 Bond cure cycles

MANUFACTURING THE SPECIMENS

Surface pre-treatments

An important factor influencing the strength of the bonded joint is the surface preparation of the metal. In order to prepare the bonded area, the metal surface was subjected to mechanical abrasion (sandblasting) with uniform grit blasting of the repair surface area as shown in Fig.2. The process employed 210µm alumina grit at a pressure of 300kPa and a working distance of 10 to 15cm to ensure the surface roughness without inducing compressive stresses. Trichloroethylene was used for cleaning to remove impurities and to avoid any oxidation.

Fig.2 Surface preparation with sand blasting method

Curing

The curing process is controlled by computer to ensure repeatability. An overview of the process is shown in Fig.3.

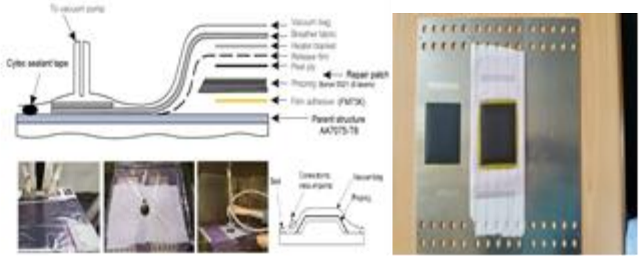

Fig.3 Detail of vacuum bag lay-up and manufactured specimens

Results and Discussion

The thickness and distortion due to bending of the samples before and after curing was measured.

Fig.4 Thickness measurement with electronic height gage and distortion measurement with CMM

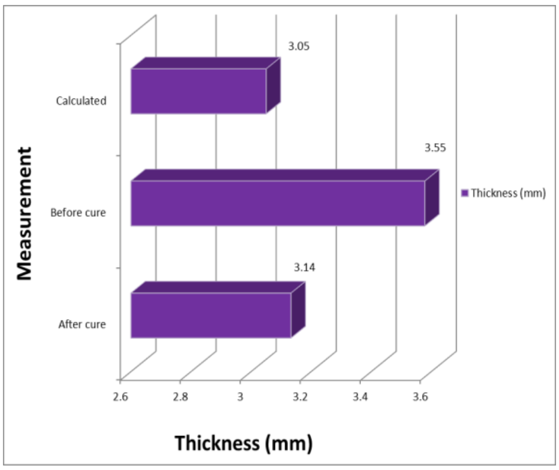

Fig. 7 Summary of the measured thicknesses

There was little variation in the cured laminate thickness across the samples with different curing condition; however the thickness was reduced by 11 percent from the uncured samples to the cured ones, as shown in Fig.4. Results in Fig.5 indicate that samples prepared at 80°C for 8 hours (condition 3) had less bending curvature in comparison with other cycles but these may have reduced bond properties due to the lower temperature.
Elevating the curing temperature may enhance the bonding between the metal surface and the composite patch, but this may also increase the residual stresses (condition 2). The prolonged curing time for this condition may ensure higher homogeneity but also more distortion, which results in higher stresses in the bond area. The combined cycle (condition4), can help reduce the distortion and thereby reduce the residual stresses without compromising on bond adhesion.

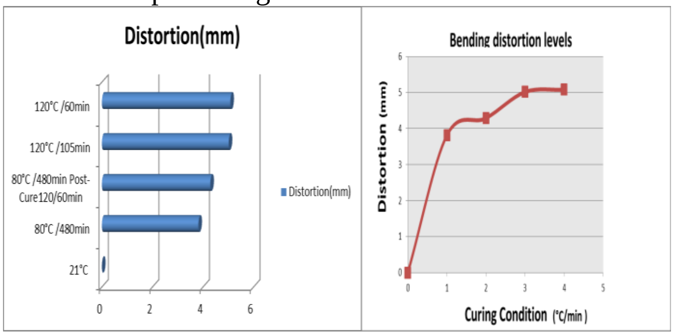

Fig.5 Distortion variation of bonded repair samples in different curing conditions

Conclusion

To enhance the durability and reliability of bonded repairs, the curing processes relevant to boron/epoxy prepregs, AA7075-T6 and FM73 K adhesive were investigated.

The overall curing condition affects the structural bending distortion. The influence of the resulting residual stresses on the durability of the repair is a matter of concern.

The understanding gained from this work suggests that the best process to minimise the curvature is the combined cure condition (condition number 4), which may enable increased durability at the lower temperature cure. This will form the basis of future work.

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