INTEGRITY OF GLASS/EPOXY AIRCRAFT COMPOSITE PART REPAIRED USING FIVE DIFFERENT METHODS.

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Abstract

Aircraft repairs are considered permanent repairs. This type of permanent repair is time- consuming and needs to be accomplished in a well-guided specification and precise accuracy. The critical demand for aircraft repaired part is to meet the integrity of the original parent body while in-service, which does not give room for trial and error. Similarly, the cost of discarding parts that have minor to medium surface damage is very high. In this work, an experimental work was carried out to find other viable repair method that could be applied to surface repair of an aircraft. It was found that the pre-preg method is still the most preferred. The infusion process, if performed under well-controlled environment, can be good substitute for wet layup.

Keywords: Aircraft, Composite, Glass/Epoxy, Hot Bond Pre-preg, Vacuum Infusion, Wet lay-up

1. Introduction

Most components on the aircraft are increasingly being replaced with composite materials. The main attraction is the effective reduction in mass with a comparative increase in stiffness, strength, fatigue and impact resistance, thermal conductivity and corrosion resistance. Through these replacements, the structural weight can be reduced, which will in turn lead to a more economical commercial aircraft.

Using advanced manufacturing techniques, it is possible to produce large identical composite structures with complex shapes, thus providing a high degree of parts integration and lowering manufacturing and assembling cost.

The main disadvantage of using composite materials is the resultant complex mechanical properties of the materials, which make the design and repair of composite structures intricate and costly 1997]. In order to utilize the potential of composite materials in engineering application, the strength and failure criteria must be fully understood [1983]. The most commonly used composite material in aviation is the glass/epoxy reinforced composite. Glass/epoxy reinforced composite consist of thermosetting - polymers with irreversible cure process. Thus making any damage to its structure to be either discarded or repaired. The cost of the material generally favours the repair of the structure [1992].

For any repair to be carried out in composite materials, the understanding of the failure modes is necessary. The repair of ageing aircraft, made from composite materials, is on the increase according to Wen and Vedhagiri [2001]. The repair mechanism is becoming an important research area in the design of composite structure.

In composite materials for aircraft repair edited by Baker and Hoskin, the damage assessment in composite structures were analysed and categorised as: manufacturing induced defect, mechanical defect and service environment damage. Whereas the repair techniques were outlined by Baker as patch and non-patch repairs [1986]. The patch repairs are generally taken as a joint to the parent structure. These joints are classified into mechanical joints and adhesively bonded joints.

These joints can be use simultaneously in a single repair as bolted/bonded joints or separately. It is generally accepted that a well-designed bonded joints are stronger than mechanical joints [1990]. The strength and durability of these joints depend strongly on the design and adequate knowledge of the stress distribution in the joint areas. Mathews [1990] attributed good bonding in adhesively bonded joints, on the correct preparation of the surfaces, prior to bonding. Hart-Smith [1984] on the other hand, considers the adherent thickness as being vital to the relative strength of different joint configurations; this favours the use of ductile adhesives to brittle ones.

The monitoring of the integrity of any repair is vital to ensure premature failure of the joint before routine check. Diamanti and Soutis [2010] have studied the structural health monitoring techniques for aircraft structures. Qing et al [2006] investigated similar damage monitoring.

In this work, the repair of a damaged surface of commercial aircraft part made from glass/epoxy composite was studied. The five methods compared are:

- Infusion
- Pre Impregnated (Pre Preg)
- Room temperature wet lay up (RTWL)
- 121°C cured infusion (121-infusion)
- Resin rich room temperature wet lay up (RRRTWL)

The aim of the study is to determine the repair method with best structural integrity that can be an alternative to the current pre-preg repair method.

2. Materials and Methods

Glass Cloth: Type 7781 Class 3 Grade 1.

Pre-preg: Hexply 916G-7781-37%

Matrix: EY3804 A/B Laminating resin. (BMS 8-301, CL2)

Table 1: Materials used and their Mechanical and physical properties

Property	**Units**	**Glass Fibre 7781**	**EY3804 A/B Matrix**	**Hexply 916 Matrix**	
Tensile Strength	MPa	3447 b	55 e	50 [a.]	**Mechanical Properties**
Tensile Modulus	MPa	72400 b	3500 e	4170 [a.]	
Tensile Strain	%	4.8 b		1.4 [a.]	
Poison's Ratio		0.22	0.35 e	0.373 [a.]	
Shear Modulus	MPa	37921 d	1296 c	1520 [a.]	
Flexural strength	MPa		53	92 [a.]	
Flexural Modulus	MPa			3780 [a.]	
Density	g/cm^3	2539 kg/m^3 b	1.1 e	1.30 [a.]	**Physical Properties**
Thickness	mm	0.25 b			
Strands count	25 mm	57 x 54			

Table 1 shows the mechanical and physical properties of the materials employed in this investigation.

Preparation of Specimens:

Infusion and 121°C cured infusion (121 infusions) specimen

Three strips of dry glass fibre fabric for each pair of plates were cut. 50mm x 150mm, 100mm x 150mm and 150mm x 150mm, to fill up the "v" shaped ground pair of plates representing the damaged part of the parent body. Pieces of resin transfer braiding, large enough to cover the layup with an additional 100 mm around the layup were cut. A resin inlet line and an exhaust line were installed, one on either side of the layup. The samples were vacuum and cured at 0.08MPa pressure. The 121°C cured infusion was a combination of dry glass and Pre impregnated material. The additional heat from the heater blanket created the difference between the normal infusion and the 121-infusion.

Pre impregnated (Pre-preg) specimen

The lay-up with pre preg material was covered with heater blanket connected to a HEATCOM control box, which regulated the temperature used to calculate the ramp up heat, dwell time cooled down cycle. The same sizes of material and pressure were used for all the specimens.

Room temperature wet lay up (RTWL) and Resin rich room temperature wet lay up (RRRTWL) specimen

The laminate was laid up and cured at room temperature whereas the resin rich had extra resin added to the repair part.

Experimental method

Tensile test were carried out using an Instron 5582 machine and tested according to BS 2782 testing standards. The flexural test were carried out according to ISO 335A - determination of flexural properties. The water absorption test was equally carried out in the method set out in ISO R62 - determination of water absorption.

The test specimens for the water absorption test were machined from the same laminates used for the other tests. The sizes were, 50mm ± 1mm square and The specimens are dried in an oven for 24 hours ± 1 hour at 50ºC ± 2ºC then weighed (W1), placed in distilled water for 24 hours ± 1 hour at 23ºC ± 0.5ºC then weighed again (W2). The specimens are dried again in the oven for 24 hours ± 1 hour at 50ºC ± 2ºC then weighed (W3).

Scanning electron microscope (SEM)

Fractured specimen surfaces of the five types of laminate studies were carbon-coated and observed using JEOL-JSM scanning electron microscope at different magnifications.

3. Results and discussion

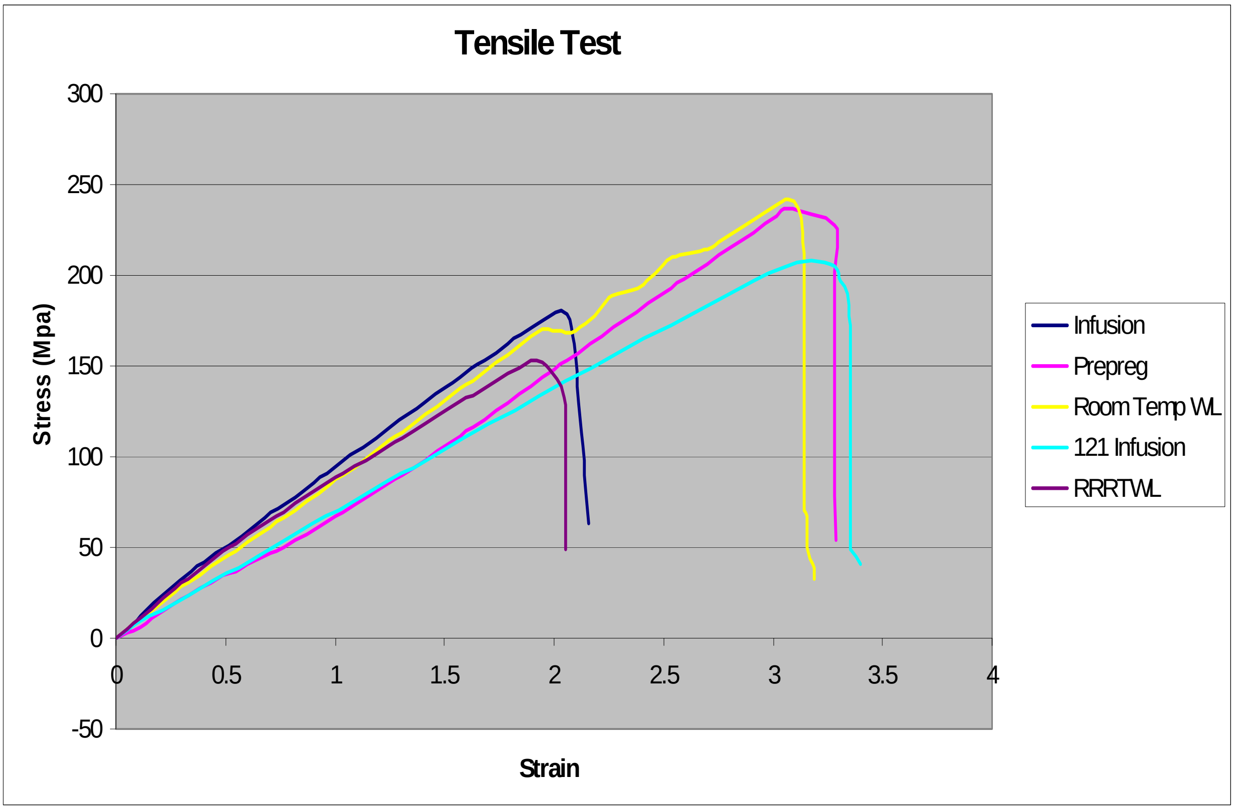

Fig. 1: Tensile test results for infusion, pre-preg, RTWL, 121 infusion and RRTWL

Figure1 shows the comparative results of the different repair methods studied. It is seen that the infusion and RRRTWL are weaker in tensile than the pre-preg, 121 infusions and RTWL. The low strength observed in infusion and RRRTWL can be attributed to the resin starved laminate in the infusion and resin rich in the RRRTWL.

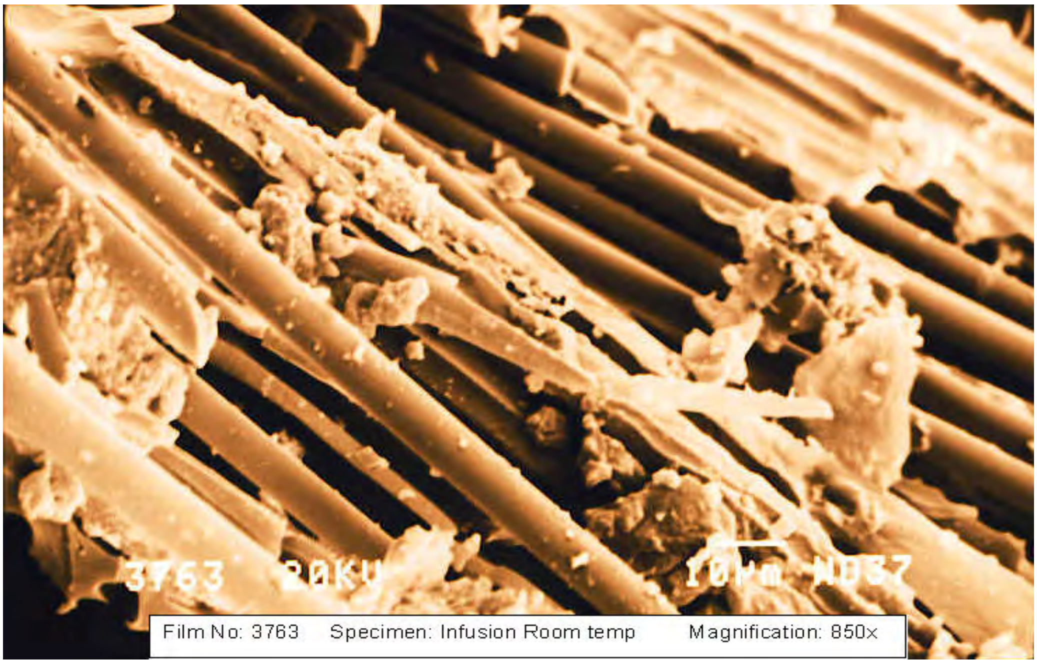

Fig. 2: SEM micrograph of 850-x magnification of the infusion repair method showing resin starved laminate.

Fig. 3: SEM micrograph of 450-x magnification of the RRRTWLrepair method showing resin rich laminate with exposed glass fibres.

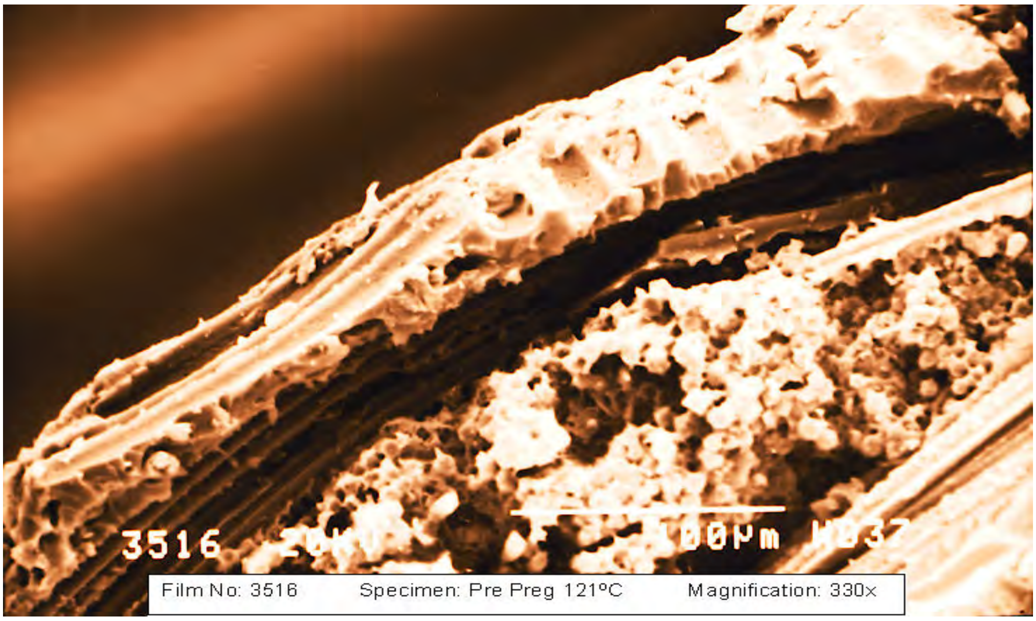

Fig. 4: SEM micrograph of 330-x magnification of pre-preg repair showing uniform breaking of the fibres. These are clean breakages of the glass fibres

Fig. 5: SEM micrograph of 330-x magnification of 121 infusion repair showing partial uniform breaking and delamination on one side of the laminate

The observations from the SEM micrographs show the breakage pattern of the five different laminates studied. From figure 2, it was noticed that the resin starved laminate, did not allow sufficient load transfer from the resin to the fibre. Therefore, the fibres did not break rather the resins flaked off the fibres, causing delamination. This explains the low strain and strength shown in figure 1, for infusion repair. The uncontrolled resin transfer caused this observation since no resin flow-monitoring device was attached to to ensure all fibre surfaces are resin-coated.

This was a different observation for the 121-infusion repair of figure 5 that show good clean break in some areas and fibre pull out in other areas. The 121-infusion repair, show good comparative strength to the preferred pre-preg repair method. The room temperature resin rich laminate of figure 3, displayed neat breakage on one side and fibre pull out on the other side. The pre-preg exhibit neat breakage.

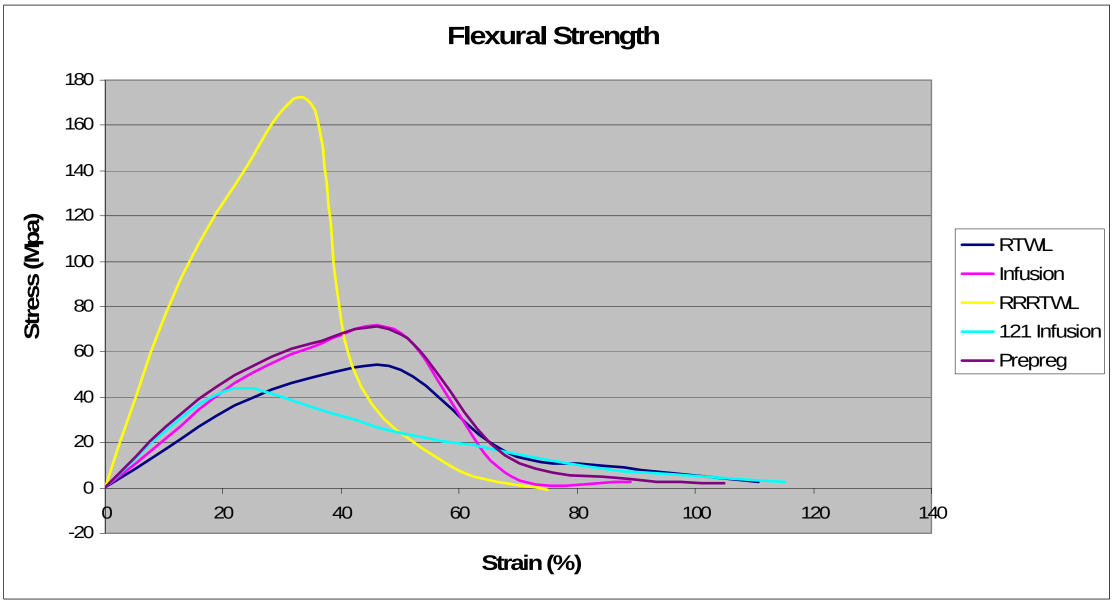

Figure 6: Flexural test results for infusion, pre-preg, RTWL, 121 infusion and RRTWL

From figure 6, an unsustained rise in the flexural strength, at low strain, is observed for RRRTWL repair. This is expected because of the resin richness in the repair. The load carrying capacity suddenly dropped, as the resin cracks and breaks. The pre-preg and infusion repair methods, show comparative flexural properties, whereas the 121-infusion has the lowest flexural strength. This is caused by the high temperature that weakens the resin.

Table 2. Water absorption results for infusion, pre-preg, RTWL, 121 infusion and RRTWL

Infusion	**RRRTWL**	**Pre-preg**	**121 infusion**	**RTWL**
0.32%	0.26%	0.18%	0.165	0.08%

The water absorption test shows that the infusion repair has very high water absorption rate of 0.32%. The lowest absorption rate of 0.08% was recorded for RTWL. This can be attributed to the inconsistency of the hand layup. On the other hand, the pre-preg falls at the mid point with absorption of about 0.18%. Mechanical integrity of pre-preg can be controlled thereby guaranteeing the consistency of the repair. It is rather a more permanent repair than any other repair method studied.

Conclusion:

Five different repair methods were studied and it was found that the pre-preg has the best structural integrity. On the other hand, if the infusion and 121 infusion methods are well controlled, it can be a better alternative to the pre-preg repair method.

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