EXPERIMENTAL INVESTIGATION ON BONDED COMPOSITE PATCH REPAIR FOR AN EDGE-CRACKED AA 1080 ALUMINIUM ALLOY PLATE

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ABSTRACT. Bonded composite patch repair has got a high demand for repairing cracked components and weak aerospace structures because of its highly advantageous properties. These properties allow a significant increase in strength and durability. In this study, the experimental investigations on cracked and uncracked specimens of AA 1080 aluminium plates repaired with single-sided 4-ply glass/epoxy composite patches were represented. The AA 1080 aluminium plates were having a thickness of 3 mm. In accordance with the ASTM standards tensile, flexural and charpy, impact tests were conducted on the repaired structures to characterize its response. The aluminium specimens having three different crack lengths along with the patch lay-ups were analyzed. The test results that were observed were compared with the results for cracked, uncracked and repaired cracked specimens. As per the comparison it was found that the patching effect on the mechanical properties of the cracked plate is highly significant.

Keywords: Crack length, Composite patch repair, AA 1080 aluminium plate, Tensile test, Flexural test, Impact test.

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INTRODUCTION

An aircraft during its service life is meant to carry various types of structural and aerodynamic loads which can cause damage or weakening of the structure as the aircraft gets older and the load carrying capability of the aircraft gets affected. Therefore, the restoration of the structural efficiency of the aircraft by repairing or reinforcing the damaged or weakened structures is a significant issue for the operators. The use of adhesively bonded composite patches has become more popular worldwide for the repairing of cracked structural components and machines [2]. The method of adhesively bonded composite repair is very much useful and helpful. It is also cost-effective and efficient which helps to extend the durability of cracked components of the aerospace structures. The bonded patch repair helps in stopping the crack growth.Glass fiber reinforced polymerhas got great significance because of their properties such as high specific strength, low weight, low cost and high stiffness inwhich glass fiber and thermosetting epoxy acts as reinforcing and matrix phase respectively.Glass fiber/epoxy laminates is mostly used in many fields like automobile industries, space industries, power industry, oil industries etc.

Jones and Chiu [1**]** studied experimentally about the repair of cracks in thick structural components. A number of problems came into consideration after summarising the design guidelines for repairs to thin structural components like semi-elliptical surface flaws, interacting surface flaws, cracked fastener holes and cracked lungs. Marioli-Riga and Gdoutos [4] presented the composite patch repair methodology in a sequence which includes firstly the proper selection of patch materials and their dimensions and size, stacking sequence of the plies and adhesive material selection. The composite patch repair methodology was based on the Rose’s equations. This methodology is very useful in aircraft maintenance. Okafor et al. [5] investigated two different composite ply configurations i.e., 5-ply and 6-ply. For the test specimen pre-cracked 2024-T3 clad aluminium panels having dimensions (381 x 89 x 1.6) mm repaired with octagonal single sided boron/epoxy composite patch was used. The test specimen were gone through linear and non- linear finite element analyses using 8-noded 24 degree of freedom (DOF) hexagonal elements for the aluminium panel, boron/epoxy patch and adhesive material subjected to uni-axial tensile loading. The increase in strength and durability of the repaired structure were predicted by obtaining the stress distributions. The stress values at critical points were compared and various assumptions were made in the design of the composite patch.Sadeghi et al. [6] investigated the fatigue crack-growth behaviour of centrally cracked aluminium panels repaired with single side composite patches. The crack growth is occurring non-uniformly through the thickness of the repaired panels. The crack-front shapes of various repaired panels are patched with different patch thickness. According to the results, it was found that the differences between the crack-front shapes for thin repaired panels are considerable and in the case of thick repaired panels, the crack-front shapes did not changed with different patch thickness. The effects of thickness of the patches on crack growth life of thick and thin repaired panels also investigated. As per the result, it shows that in case of thin panels when a 16 layer patch is used, the crack growth life may increase up to 236%. But in thick panels when a 4 layers patch is used, the crack growth life may extend about 21-35%.

M.Ratwanic et al. [9] investigatedon theanalysis of both the single and double-sided composite patch repairs meant to reduce the concentration of the stresses at circular notches and cracks by finite element method.As per the result, a huge reduction is observed in the asymptotic estimation of the stress-intensity factors and the normal stresses at the crack tip. The double-sided patch decreases the bending effect due to the eccentricity of the patch on one side only and reduces the shear stresses in adhesive. Chellil et al. [10] investigated the mechanical characteristic on fatigue crack propagation in aluminium plate based on strain and stress distribution. It was identified that the crack growth and the changes occurred in shear strain and stress distribution during the fatigue test. According to the numerical model analysis the Eigen frequencies of aluminium plate were decreased after cracking and it is non-linear. As per the results, it was proved that this can provide a reference for analysis and designing of aluminium alloys in aeronautical systems.Hart et al. [11] studied the fatigue behaviour of cracked aluminium plates repaired with composite patch. E-Glass epoxy composite patches were used for repair method. These patches are water tight, low modulus and mitigate crack growth. The patched central cracked test specimens of 0.25-inch aluminium plate as delivered and oven sanitized plate were tested in tension-tension fatigue. The result showed that the composite patch repairs increased fatigue cycle to failure by more than 4 times.

EXPERIMENTAL PLAN

Table1 Properties of patch material

PROPERTIES	INFERENCE
Tensile strength	282.8 Mpa
Compressive strength	580.1 Mpa
Density	2.58 g/cm^3
Thermal expansion (10^{-6}/k)	8.82
Thermal conductivity	2.24 W/m.k
Softening point	846 ^{0}C
Melting point	1121 ^{0}C
Hardness	435.113 Mpa
Bulk modulus	6.236 A

Table 2 Properties of Epoxy Resin

CHARACTERISTICS PROPERTIES	INFERENCE
Tensile Strength	85 N/mm^2
Tensile Modulus	10,500 N/mm^2
Flexural Strength	112 N/mm^2
Flexural Modulus	10,000N/mm^2
Glass transition temperature (T_g)	120 - 130˚C
Surface Resistivity	1.2 E +16 Ω
Thermal Conductivity	0.22 W/m-K
Lap Shear Strength	17.6 Mpa
Coefficient of Thermal Expansion	8.5 × 10^{-5} ˚C
Compressive Strength	190 N/mm^2

The experimental program was conducted according to the mechanical characteristics of the materials. Different specimens were prepared and testedby various testing methods to evaluate different properties. Aluminium alloy, E-glass fiber and epoxy resin were used for making the composite. E-glass fiber is used for reinforcement in the epoxy matrix to fabricate fiber reinforce composite.

Tensile Test

Tensile test were carried out according to ASTM E8 using universal testing machine UTE-20-HGFL at a crosshead speed of 5 mm/min. The dimension of specimens (250 x 30 x 3) mm and the patch length are 5 mm, 10 mm and 15 mm. The gripping length on both sides of the specimens was 50 mm each and the gauge length was 150 mm. Tests were conducted on both cracked and uncracked specimens and specimen’s with4-plies bonded glass/epoxy patches.

Figure 1 Specimen failure after tensile test

Flexural Test

Flexural test carried out according to ASTM E8 using universal testing machine UTE-20-HGFL mentioned above at the same crosshead speed. The dimension of specimens (50 x 10 x 3) mm and patch length is 1.5 mm, 3 mm and 6 mm respectively.The flexural tests were also conducted on the cracked specimens as well as on the un-cracked specimens with adhesively bonded glass/epoxy of 4-plies patch.

Figure 2 Specimen failure after Flexural Test

Charpy Impact Test

The specimens having a dimension of (80 x 10 x 3) mm were placed horizontally and the crack surface facing away from the pendulum. Crack length of 1.25 mm, 2.5 mm and 5 mm were produced. The patch sizes as well as the crack length were tested on three different specimensand the material property is considered by taking the average values of the test results.

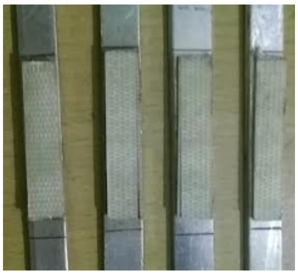

Figure 3 Specimen before charpy test

RESULTS AND DISCUSSION

Tensile Test

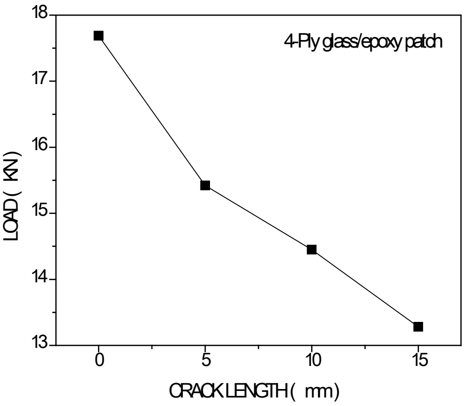

Figure 4 Load vs. crack length curve for tensile loading

Each of the tensile tests were organised in a normal atmosphere on specimens already acclimatized, by methods of a high-precision universal testing machine and directed under displacement control. Tensile tests were performed on both cracked and uncracked specimens with reinforced glass/epoxy of 4-plies patches. The load-crack length curves were separated to consider the effects of composite patches on mechanical properties of repaired aluminium plates. The load-crack length curves of specimens under tensile loading are shown in Figure 4. The results obtained possible to uncracked specimens material with higher mechanical properties, followed by the cracked specimens. If increases the crack length then loading condition is less as compared to the un-cracked specimens.

Flexural Test

These tests were done to obtain the load capacity of the reinforced specimens. Also the flexural tests were performed both on the cracked and un-cracked specimens with adhesively bonded glass/epoxy of 4-plies patches. In Figure 2 the load-crack length curves of all samples tested.An edge-notch to the specimen to increase the crack length, decrease the bending stiffness, ultimate bending strength of the specimens by 1426.23 Mpa, 1401.10 Mpa, 1381.01 Mpa and 1306.534 Mpa respectively.

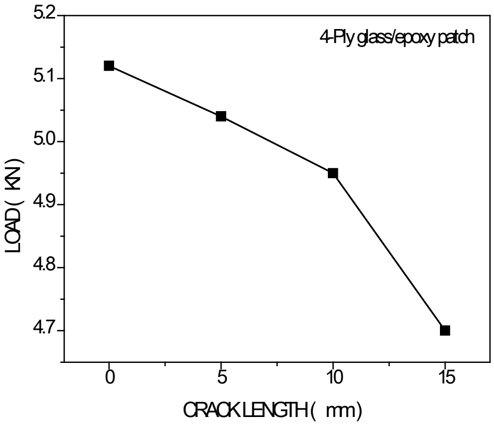

Figure 5 Load vs. crack length for flexural loading

Charpy Test

Table 3 Value of energy consumed by specimens with various repaired charpy test

a/w	GFRP REPAIR
0.125	31
0.25	24
0.5	12

Table 4 Energy consumption (J) efficiency for uncrackedspecimen for charpy test

a/w	GFRP REPAIR
0.125	73.8
0.25	57.14
0.5	28.5

The experimental results of thecharpy testare considered according to the ratio of the crack length to the widthof the specimen (a/w). The obtained results on various specimens after charpy impact test are shown in Table 3. Un-cracked specimens consumed 42J energy. In Table 3 it is observed that the energy which is absorbed till fracture of the specimens totally depends on the type of composite. Table 4 shows the energy consumption efficiency of repaired samples as percentage of energy absorbed by an uncracked specimen.

CONCLUSIONS

In aggregate, the patches were very useful in partially stopping the crack growth in the repaired samples, especially the thinner material of 3 mm of aluminium alloy. The various stresses in the metal seem to restrict the efficiency in the thicker specimens.

The results of this experimenthave many applicationswhere controlled surface treatments can be fully performedand the required pressure can be applied with the help of appropriate techniques in order to achieve a proper cure.In some situation, materials and equipmentswill apparently not be present for this kind of bonding.The capability exists to do this kind of repair with the help of room temperature cure systems with fiber glass clothin humid layups.

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