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Analysis of Repair of Cracked Aluminium Structures Using Composites

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ABSTRACT:This research paper is about to analysis of repair of cracked aluminium structure using composite patch. In this analysis we have carried out the analysis on 27 different sample by interchanging the positions of patches on the crack, these combinations are carried out for remote
Force test and find maximum & minimum shear stress and maximum& minimum deformation.
Determining the success of the composite repair is more long term this comprise the durability and reparability of the composite repair itself, including the availability of clear,objectiveand documented criteria for inspecting the repair in future years and authorizing its continued service.
KEYWORDS:6061-T6 aluminium alloy, epoxy resin, B-C-K= Boron-Carbon-Kevlar. 200-200-300= Patches area.

I. INTRODUCTION

Aluminium alloy is widely used material because its properties of light weight, strong, high strength to weight ratio, corrosionresistant, heatconducting, malleabilityductility. there for it is used in manufacture of aircraft, aerospace, civil structure. Due to fatigue failure,accidental damage, environmental deterioration on structure fractureoccur on body or structure,for extending their service life and maintaining high structure efficiency. Require a substantial amount of inspection and defects monitoring at regular intervals.so, maintenance of aircraft, aerospace, civil structure is necessary so our analysis is finding the most preferable combination of composite patch.

The basic principal of this method is to adhesively bond composite patch over the damaged area in order to restore the load carrying capacity, fatiguelife. is highly cost-effective method for extending the service life and maintaining high structural efficiency .by using this method we eliminate the traditional of using metallic patches, such as no fasteners and no drilling operation, then no micro cracks and uniform stress transfer.

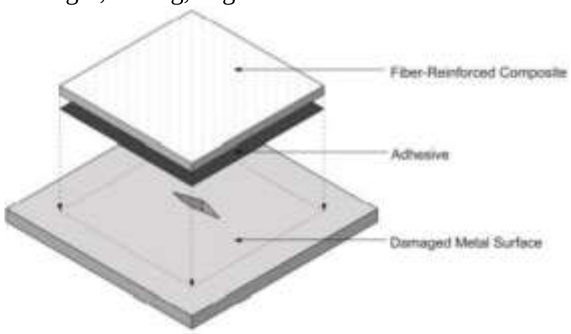

Fig 1 concept of patch application

II. METHODOLOGY

Thin Aluminium alloy 6061-T6 sheet of 1 mm thickness is chosen for the studysince it is widely used in manufacturing of aircraft structures. Aluminium alloy's (6061-T6) stress strain Values obtained for young's modulus, yield stress and ultimate tensilestress are 70 Gpa, 263 Mpa and 290 Mpa. Specimen and crack dimensions are shown infigure. It can be seen that crack is starting from the edge and it is extending up to themiddle line of the specimen.

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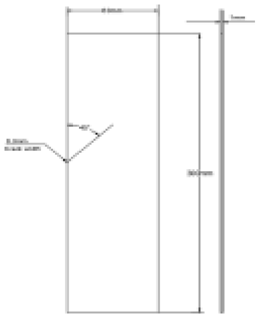
Fig. Specimen



Aluminium 6061-T6: Aluminium 6061-T6 is a precipitation-hardened Aluminium alloy, containing of 0.25% copper, 0.6% silicon, 1.0% magnesium and 0.25% chromium with magnesium and silicon as its major alloying elements. Originally called "Alloy 61S", it was developed in 1935. It has good mechanical properties, exhibits good weld ability, and is very commonly extruded. The typical value for thermal conductivity for 6061-T6 at 25 °C (77 °F) is around 152 W/m K. It is one of the most common alloys of aluminium for general-purpose use. This alloy also has good finishing. In addition to that, it offers good corrosion resistance and is very good for welding. Its strength and workability are comparable to mild steel. It is heat treatable.

Composite Material: CFRP (Carbon Fibre Reinforced Polymer) is considered for the study. The dimensions of the layers of carbon fibre are the biggest one is of 100 × 60 mm, the middle one is of 70 × 60 mm and the smallest one is of 60 × 60 mm and their thickness is taken as 0.60 mm, 0.22 mm and 0.11 mm respectively as show in below figure.

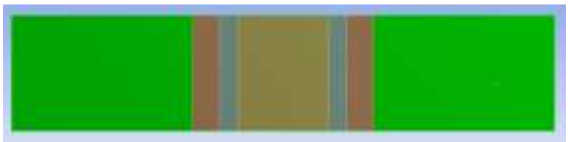


Fig 3.2 patches applied on cracks

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure, differentiating composites from mixtures and solid solutions. Fibre-Reinforced Polymer (FRP) composites are made from a polymer matrix that is reinforced with an engineered, man-made or natural fibre or other reinforcing material. Types of fibres that are required for reinforcement are glass,carbon, natural fibres, basalt etc. The composite material is prepared by vacuum bagging process.

Carbon Fibre: The material used for this experimentation is Carbon fibre. Carbon fibres or carbon fibres (alternatively CF, graphite fibre or graphite fibre) are fibresabout 5–10 micrometres in diameter and composed mostly of carbon atoms. Carbon fibres have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These properties have made carbon fibre very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. Carbon fibres are usually combined with other materials to form a composite. When permeated with a plastic resin and baked, it forms carbon-fibre-reinforced polymer which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle.

Carbon fibres are also composited with other materials, such as graphite, to form reinforced carbon-carbon composites, which have a very high heat tolerance. Depending upon the precursor to make the fibre, carbon fibre may be turbostratic or graphitic, or have a hybrid structure with both graphitic and turbostratic parts present. In turbostratic carbon fibre the sheets of carbon atoms are haphazardly folded, or crumpled, together.

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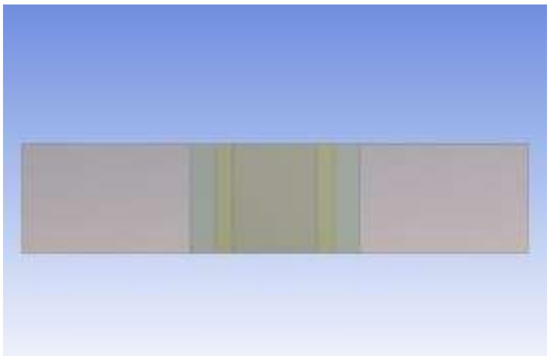
Carbon fibres derived from polyacrylonitrile (PAN) are turbostratic, whereas carbon fibres derived from mesophase pitch are graphitic after heat treatment at temperatures exceeding 2200 °C. Turbostratic carbon fibres tend to have high tensile strength, whereas heat-treated mesophase-pitch-derived carbon fibres have high Young's modulus (i.e., high stiffness or resistance to extension under load) and high thermal conductivity.

Epoxy Resin: Epoxy refers to any of the basic components or cured end products of epoxy resins, as well as a colloquial name for the epoxide functional group. Epoxy resins, also known as poly-epoxides, are a class of reactive prepolymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homo- polymerization, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols and thiols (usually called mercaptans).
These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of poly-epoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with favourablemechanical properties and high thermal and chemical resistance.

Vacuum Bagging:Vacuum bagging is a technique employed to create mechanical pressure on a laminate during its cure cycle. Pressurizing a composite lamination serves several functions. First, it removes trapped air between layers. Second, it compacts the fibre layers for efficient force transmission among fibre bundles and prevents shifting of fibre orientation during cure. Third, it reduces humidity. Finally, and most important, the vacuum bagging technique optimizes the fibre-to-resin ratio in the composite part. These advantages have for years enabled aerospace and racing industries to maximize the physical properties of advanced composite materials such as carbon, aramid, and epoxy.



III. SIMULATION ANALYSIS:

InthisexperimentationprojectANSYSsoftwareisusedforsimulationpurpose,belowarethe steps performed in thesimulation of Analysis:
MaterialAddition:
Afteropeningworkbenchwedragstaticstructuralmodulefromanalysissystemtotheprojectschematic.
Thenweselectthematerialsweneedtouseformengineeringdata,weneedthreetypesofmaterials in this analysis as follows:
1. WroughtAluminiumAlloy (6061, T6)
2.CarbonFibre (230GPa)
3.Epoxy Resin

Afterwehaveselectedthematerialsweneedtogobacktotheprojectschematicandselectgeometryoption tostarsketching.

IV. ANALYSIS:

- Geometry Designing is done in Creo Cad Software and then imported in Design modeller.
- Whereas in Design modeller, using edge split Edges are split to get fine mesh as possible.
- Using edge split , both horizontal edges are Divide into four parts so that meshing will be proper.

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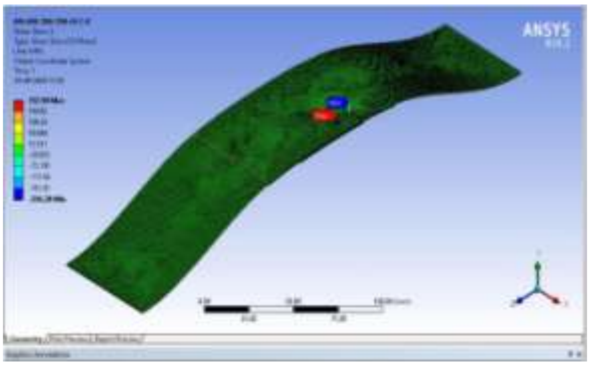
Fig. Geometry



Assigning material and meshing:
The design we imported and edited in the modeler is automatically loaded in mechanical view.
We then have to give the plate and the patches the materials we selected at the beginning which we can do by selecting them through the tree on the left side.
In mesh we use the edge meshing option for the edge splits we have done for horizontal edge and also use for vertical edges as well as and give number of divisions accordingly.
And then we apply face meshing by using sphere of influence so that we can refine the meshing near the crack as fine as we can go result.
Then we generate a mesh.

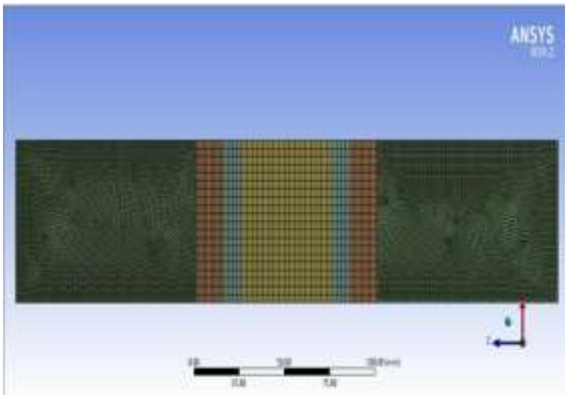


Fig. Meshing

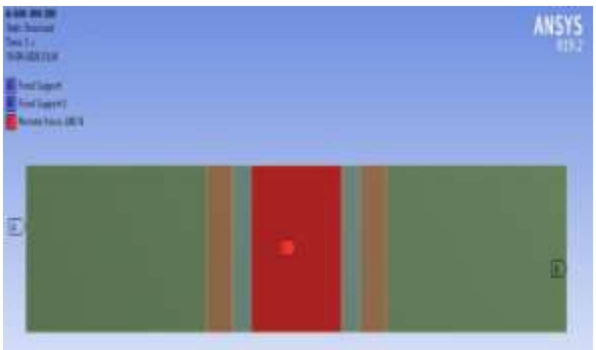


Fig.FixedsupportsandRemoteForce (InYdirection)

V. ANALYSIS RESULT:

In his research paper we show only higher shear stress and their maximum deformation of patch combination.

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- 600-200-200

B-C-K
XY Plane: Max:59.701 Mpa
Min: -71.427 Mpa

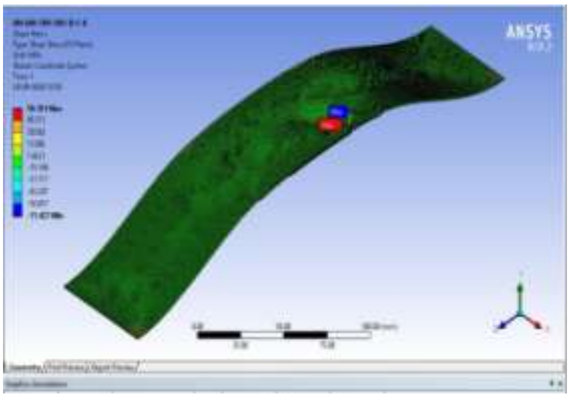

Fig. B-C-K (600-200-200) XY Plane.

- 600-200-200

YZ Plane: Max: 192.98 Mpa
Min: -206.28 Mpa
Fig. B-C-K(600-200-200) YZ Plane.

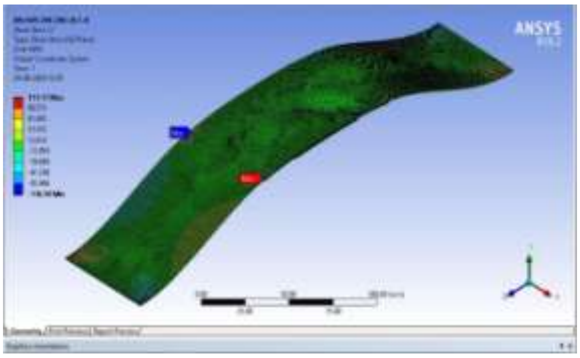

Fig: B-C-K (600-200-200) YZ Plane

- 600-200-200

B-C-K
XZ Plane: Max: 111.17 Mpa
Min: -110.59 Mpa
Fig. B-C-K (600-200-200) XZ Plane

- Directional Deformation:

Max: 34.047 mm
Min: -0.0020413 mm

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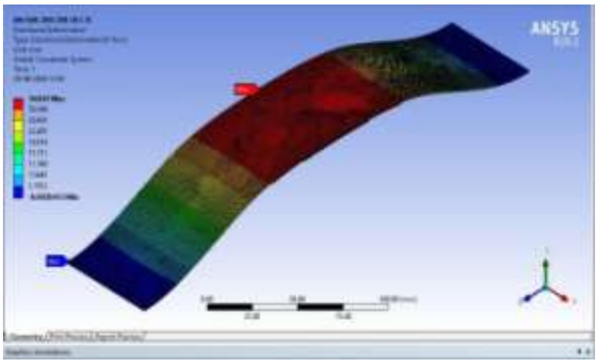
Fig: Directional Deformation.



VI. RESULTS:

As mentioned earlier the analysis is carried out on the Ansys Software whereas the models are prepared on the Cad Software's. In methodology the steps are shown to perform thee analysis. In this experimentation we have carried out the analysis on 27 different sample by interchanging the positions of patches on the crack, these combinations are carried out for both remote force test as well as for impact test. following are the results of maximum and minimum Shear stress that are been calculated by using Ansys software for remote force of 200 N and the maximum and minimum Deformation due to applied conditions.

From this analysis it has been found that the maximum shear stress from all the combinations is produced for the 600-200-200 combination which is 355.85 Mpa in YZ plane. The maximum shear stress in XY plane and XZ plane are 75.37 Mpa and 143.35 Mpa and minimum shear stress for respective plane in XY, XZ and YZ plane are -46.864 Mpa ,-142.62 Mpa and -302.33 Mpa whereas deformation is 25.509 mm.

The minimum shear stress from all the combinations is for 200-200-300 combination which is -357.28 for YZ plane. And the maximumshearstressforrespectivecombination is 181.22 Mpa, 243.93 Mpa, and 146.34 Mpa for XY, XZ, and YZ planesrespectivelyand the maximumdeformationis 47.182 mm.

Maximum Deformation is 50.81 mm in Y direction for 200-200-600 combination. Whereas deformation for all the combinations is in Ydirection only. These are the results from the Remote force applied on thepatcheswhichare pastedon the crack.Whereasthe impact testaretocalculated same for all the combinations. Following are the maximum andminimum shear stress and directional deformations for all twenty-sevencombinations.

	Maximum			Minimum			DD	
Configuration	XY	XZ	YZ	XY	XZ	YZ	Max	Min
1. 600-300-200	55.026	131.77	112.4	-54.307	-161.88	-112.59	35.118	0
2. 200-300-600	193.57	219.04	109.3	-55.643	-238.6	-163.34	47.395	-0.0025862
3. 200-200-200	190.94	219.04	111.24	-62.994	-238.6	-162.77	48.708	-0.0026398
4. 200-200-300	181.22	243.93	146.34	-106.54	-215.06	-357.28	47.182	-0.0025696
5. 200-200-600	178.91	192.46	111.67	-54.395	-206.23	-186.4	50.81	-0.0025937
6. 200-300-200	170.07	199.07	109.81	-75.72	-206.21	-185.03	47.563	-0.0026071
7. 200-300-300	175.63	181.37	111.34	-65.435	-187.8	-153.78	45.375	-0.0025392
8. 200-600-200	182.67	198.53	157.02	-58.196	-210.75	-191.66	49.031	-0.0026396
9. 200-600-300	183.38	191.47	151.42	-54.518	-205.75	-182.46	48.512	-0.0026243
10. 200-600-600	186.94	185.64	142.32	-50.024	-199.24	-170.43	47.405	-0.0025921
11. 300-200-200	159.27	124.63	166.26	-86.362	-125.07	-242.56	44.7	-0.0024786
12. 300-200-300	127.66	124.68	141.02	-124.93	-124.84	-263.31	44.895	-0.0024768
13. 300-200-600	127.22	123.99	108.03	-124.32	-124.11	-269.16	47.571	-0.0024561
14. 300-300-200	38.384	128.6	100.85	-37.943	-126.32	-100.81	37.751	-0.0022431
15. 300-300-300	44.466	125.66	99.491	-43.049	-121.93	-99.44	36.473	-0.0021988
16. 300-300-600	47.056	126.79	99.738	-44.6	-121.19	-99.663	36.514	-0.0021932
17. 300-600-200	134.45	160.06	257.91	-71.556	-171.01	-171.01	44.707	-0.002453
18. 300-600-300	84.495	146.18	235.52	-67.765	-123.89	-123.89	42.592	-0.0023848
19. 300-600-600	46.612	126.1	161.56	-45.881	-128.48	-141.77	39.573	-0.0022028
20. 600-200-200	75.37	143.35	355.85	-46.864	-142.62	-302.33	25.509	-0.0015564
21. 600-200-300	49.547	145.68	213.65	-50.371	-140.96	-208.3	25.448	-0.0015537
22. 600-200-600	54.237	106.74	285.33	-51.909	-104.73	-217.31	24.773	-0.0015403
23. 600-300-300	35.631	92.746	95.612	-48.339	-92.704	-84.701	25.032	-0.0015406
24. 600-300-600	35.563	92.733	95.599	-48.188	-92.691	-84.646	25.027	-0.0015405

25. 600-600-200	52.506	90.356	122.88	-54.235	-90.315	-109.81	23.584	-0.0014918
26. 600-600-300	55.772	89.995	130.89	-66.22	-89.954	-119.86	23.314	-0.0014836
27. 600-600-600	60.065	89.271	106.57	-76.189	-89.229	-108.47	22.825	-0.0014703

Table: Result of 27 combinations with carbon fibre.

Another set of same test were conducted on the three patches which have highest and lowest stresses deformation which are 600-200-200, 200-200-300,and 200-200-600 combinations using different set of materials which are Carbon ,Boronand Kevlar as composites.Theresults of thetests areas follows:

The maximum shear stress found in 200-200-300(B-C-K) combination which is which is231.91MpainXZplanewhereasstressesinXYandYZplaneare208.44Mpa and 153.38 Mpa and the minimum stresses is also fund in this combination which is 359.8 Mpa in YZ plane and other minimum stresses are produced -87.323 and -209.81 Moa in XY and XZ plane and deformation is 47.676 mm.

Maximum deformation is found the 200-200-600 in both B-C-K and B-K-C variants which is 50.877 mm whereas the minimum deformation is found in 600-200-200 combination in B-K-C variant which is 33.684 mm.

	Maximum			Minimum			DD	
Configuration	XY	XZ	YZ	XY	XZ	YZ	Max	Min
1. 600-200-200								
B-C-K	59.701	111.17	192.98	-71.427	-110.59	-206.28	34.047	-0.0020413
B-K-C	40.257	111.5	178.64	-71.154	-110.95	-204.17	33.684	-0.002031
C-K-B	81.664	115.47	171.8	-86.141	-115.66	-206.09	38.465	-0.0022258
K-B-C	90.118	116.6	132.88	-90.952	-119.36	-203.47	39.322	-0.0022745
K-C-B	90.052	118.1	184.01	-93.861	-120.34	-208.74	40.647	-0.002311
2. 200-200-300								
B-C-K	208.44	231.91	153.38	-87.323	-209.81	-395.8	47.676	-0.0026101
B-K-C	218.65	226.66	150.04	-86.819	-208.72	-392.53	47.443	-0.0026061
C-K-B	208.47	226.58	145.78	-82.486	-209.39	-370.71	47.42	-0.0026135
K-B-C	207.29	225.44	129.43	-79.526	-207.5	-352.82	47.539	-0.0026103
K-C-B	210.03	224.43	135.42	-79.661	-209.09	-355.29	47.429	-0.002614
3. 200-200-600								
B-C-K	190.71	187.75	108.74	-58.428	-202.5	-180.35	50.877	-0.0026329
B-K-C	190.71	187.75	108.74	-58.428	-202.5	-180.35	50.877	-0.0026329
C-K-B	190.78	184.08	116.09	-58.328	-201.3	-178.02	49.152	-0.0026329
K-C-B	190.45	184.08	116.81	-58.485	-201.28	-177.98	49.153	-0.002633
K-B-C	187.85	187.61	108.73	-57.075	-202.08	-179.32	50.87	-0.0026326

Table: Result of three different patches

VII. CONCLUSION:

Throughthisprojectweallintendtoresearchandfindther eliabletechniqueforrepairingcracks and for the maintenance of cracked aluminium structures which can be verydangerous.

As from the analysis performed on the ansys software the maximum shear stress is foundin 600-200-200 Specimen which is 355.85 Mpa and minimum shear stress is found in200-200-300(B-C-K) which is-359.8 Mpa.Whereas maximum Deformation is found in 200-200-600 (B-C-K & B-K-C) which is 50.887mm.

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