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STUDY ON THE REPAIR OF CFRP COMPOSITE PANELS SUBJECTED TO LOW VELOCITY IMPACT DAMAGE

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ABSTRACT

The paper aims at analyzing the life of different shaped repair patches on a fiber reinforced composite panel subjected to high cycle loading. Prolonged fatigue loads or low velocity impact from foreign objects tend to damage the structure of an aircraft. For the further extension of the life of the composite structure, epoxy resin matrix reinforced with carbon fiber is patched on the repaired section. The primary focus is to compare the effective life of composite repaired using square shaped patch against the octagonal shaped patch. This study shows that the shape of patch is influencing the life of the repaired composite panel.

INTRODUCTION

Damage to composite components caused by low velocity impact is not always visible to the naked eye. Non Destructive Test (NDT) methods are made use of to determine the extent of damage for structural components. The magnitude of impact energy affects the visibility as well as the severity of damage in composite structures. High and medium energy impacts are easy for the detection. However, the hidden damages are usually in the case of low velocity impact. Cracks in fibers and matrix to delamination are the consequence of these impact energies. The severity of these regions of damage develops greater when subjected to fatigue loads experienced by the aircraft at service-ceiling. Catastrophic and unpredictable failure of primary structure can lead to disastrous events. Adhesively bonded patches offers an economical means to extend the service life of the composite parts. For achieving maximum period of combat readiness in fighter jet aircrafts, composite repair provides an effective platform. For reliable and cost-effective engineering design, understanding damage and failure of composite materials is critical. The separation of the laminate at the interface between two layers is caused by impact or repeated cyclic stresses. Individual fibers can separate from the matrix causing composites to fail on microscopic or macroscopic scale. Removal of composite material from damaged zone and adhesively bonding a patch of similar material to the panel is usually carried out to repair the section. The stress in the repaired structures is concentrated near the crack tip leading to high stress intensity factor. The peak shear stress occurs at the edge of the patch in the adhesive [2]. A study to compare the performance of rectangular and trapezoidal patches revealed that the latter decreased the adhesive stress and improved the patch durability. The use of Tsai-Wu failure criteria can predict the degree of damage and failure of composite structures. To predict the maximum impact force and deflection of the thermoplastic laminates when subjected to impact energies between 4 and 16 J, a simple energy-balance model can be used.

PROBLEM DEFINITION

Two cases of damage repair are considered for a composite specimen bearing same dimensions. The repair patch shapes considered for the cases are a square and an octagonal shape. Carbon fiber reinforcement and epoxy resin matrix constitute the composite material. Sixteen plies of hundred square centimeter area are stacked and the layers are removed depending on the case. These samples are modeled and analyzed using numerical approach with the aid of ABAQUS CAE FEA software package.

MODELING AND PROPERTIES

The modeling of the composite panel consisting of square shaped patch repair is implemented as shown in the figure 1. The panel is a square of 100 millimeter sides. The repair patch is a square of 50 millimeter sides. The modeling of the composite panel with octagonal shaped patch repair is implemented as shown in figure 2. The octagonal patch is of 50 millimeter width between parallel sides.

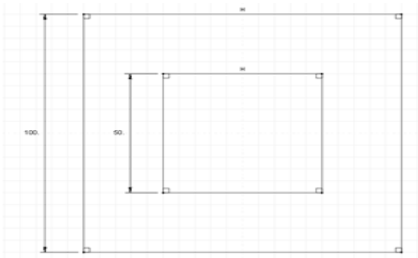

Figure 1: Panel for square shaped patch repair

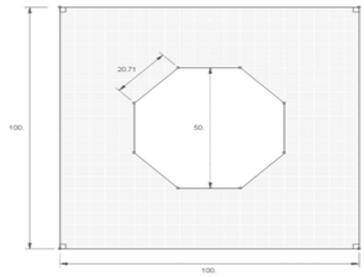

Figure 2: Panel for octagon shaped patch repair

The dimensions of the patches are reduced by 0.3 millimeters to accommodate the adhesive film of thickness 0.15 millimeters. The Square shaped patch is shown in figure 3 and the octagon shaped patch is shown in figure 4.

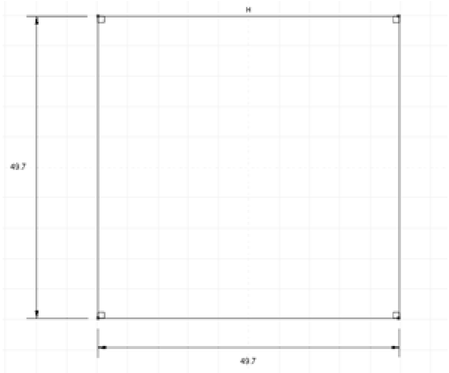

Figure 3: Square shaped patch

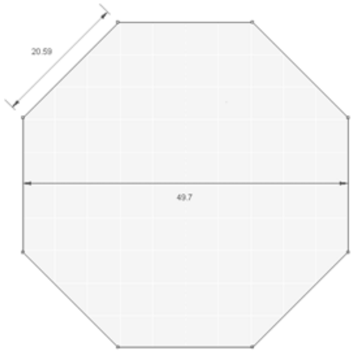

Figure 4: Octagon shaped patch

MATERIAL PROPERTIES

Fibers are orthotropic in nature and their mechanical properties vary with direction. These variations are imparted to the composite when fibers are used in conjunction with matrix material. The properties of carbon fiber are given in table 1. The properties of epoxy resin are given in table 2. The adhesive in use is FM-73 and the properties are given in table 3.

Table 1: Carbon fiber properties

Young's Modulus 0°	135 GPa
Young's Modulus 90°	10 GPa
In-plane Shear Modulus	5 GPa
Major Poisson's Ratio	0.30
Ult. Tensile Strength 0°	1500 MPa
Ult. Comp. Strength 0°	1200 MPa
Ult. Tensile Strength 90°	50 MPa
Ult. Comp. Strength 90°	250 MPa
Ult. In-plane Shear Strength	70 MPa
Density	1.60 g/cc

Table 2: Epoxy resin material properties

Density	2.09 g/ml
Tensile strength	82 MPa
Compressive strength	120 MPa
Poisson ratio	0.3

Table 3: Adhesive material properties

Shear Modulus	0.42 GPa
Poisson's ratio	0.3
Film thickness	0.15 mm

Volume fraction of fiber is 50% or 0.5. Stacking sequence is $[0/45/90/-45/90/45/90/-45]_s$. Ply thickness is of 0.15mm.

MESHING AND ANALYSIS

The parts are meshed after seeding with 5 units. The edges in contact are given 15 seeds for better presentation of its deformation. Figure 5 shows the meshing of square shaped patch repair panel. Figure 6 shows the meshing of octagon shaped patch repair panel.

ABAQUS CAE software package is used in this work which is a comprehensive FEA analysis tool for meshing, structural analysis, including linear, nonlinear and dynamic studies. The engineering simulation product provides a complete set of elements behavior, material models and equation solvers for a wide range of mechanical design problems. The software package makes use of modified classical plate theory to solve problems relating to composite materials.

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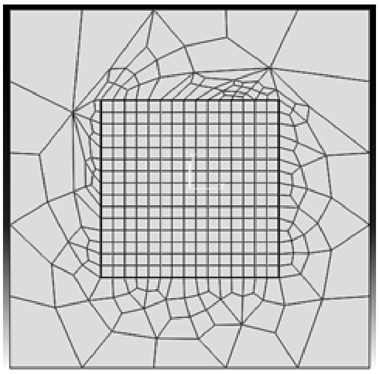

Figure 5: Meshing of square shaped patch repair panel

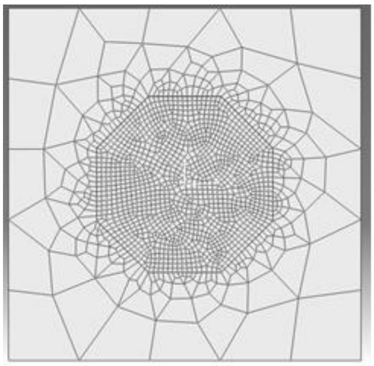

Figure 6: Meshing of octagon shaped patch repair panel

RESULTS AND DISCUSSION

An encastre boundary condition is added are one surface and axial force of 250MPa at the other end. A job is created for full analysis and submitted to be processed. Results can be accessed in the job for different stress, strain relations, deformation. The result of square shaped patch repair panel subjected to axial loading is shown in figure 7. The maximum strain observed in the system is 1.562×10^{-11} units. The minimum strain observed is 8.731×10^{-12} units.

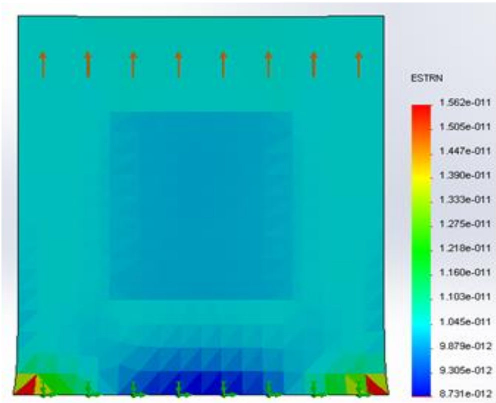

Figure 7: Result of square shaped patch repair

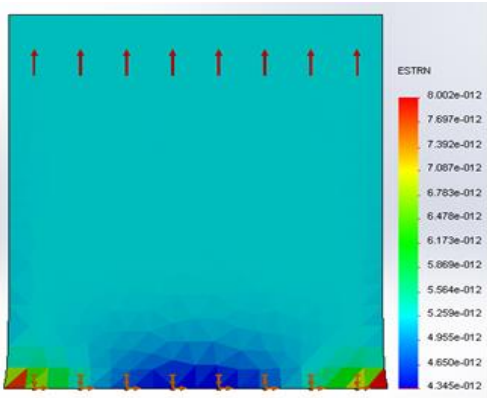

Figure 8: Result of octagon shaped patch repair

The result of octagon shaped patch repair panel subjected to axial loading is shown in figure 8. The maximum strain observed in the system is 8.002×10^{-12} units. The minimum strain observed in the system is 4.345×10^{-12} units. Upon comparison, we find that the panel with square shaped patch repair experiences greater magnitudes of maximum strain and minimum strain. The strain variation across patch to substrate is substantially less in the case of octagon repair patch. The low strain variation points at low deformation and consequently lower adhesive stresses. This indicates that the octagon shaped patch has greater durability than square shaped patches.

CONCLUSION

The two cases of patch repair with respect to shapes are analysed and compared. A decrease of 48% in strain is observed when changed from square to octagon shaped repair patch. It is concluded that the shape of the repair patch influences the performance and life of the panel and that the octagon shaped patch deforms lesser than square patch. This makes octagon shaped repair patch more effective during composite repair and maintenance.

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