NUMERICAL ANALYSIS OF WOVEN GLASS-FABRIC POLYMER LAMINATED COMPOSITE WITH BOLT LOADED HOLE

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Abstract - In the present work we report the numerical analysis of single lap single bolted joint of woven glass fabric/epoxy composite laminate. The numerical analysis is performed using 3D finite element method along with the assistance of ANSYS. The numerical analysis reveals that when a tensile load of 45 N is applied, the maximum stress concentration is seen in the bolted joint area. Further we can expect that the failure of this case would be bolt shear failure.

Keywords - Laminated Composite; Finite element modelling.

I. INTRODUCTION

The demand for polymer based composites in the area of aerospace, automotive and other industrial applications is growing day by day. The polymer based laminated composites are widely used due to their low density, high specific strength, specific modulus, fracture toughness and good resistance to fatigue crack propagation. Most of these applications require joining of composites with other composite laminates and with other metal or alloy structures. The mechanical joints of these structures are accomplished using fasteners like pins, screws, bolts, rivets or by adhesive bonding. The combination of mechanical fasteners and adhesive bond joints are known as hybrid joints. The most common way of accomplishing a joint in the engineering structures is mechanical fastening which is economical and easier to realize when compared to that of adhesive bonded joints. For example in a wing of an aircraft, nearly 7, 50,000 bolted joints are used for joining 30,000 elements [1-3]. Out of all these mechanical fasteners, pin joints are vastly due to their simplicity, low cost, easy to assemble or disassembly for repair. However it is very important to note that these pin and bolted joints need to have holes in the composite laminates and requires special attention in the design process. This is mainly because these joints form weak point and load transfer from pins or bolts to the composite laminates can give raise to high stress concentrations which can lead to failure of composites at this composite/fastener interface. So it becomes very important to study the stresses around these fasteners because as the load increases the force distribution changes which have direction implication on strength and failure modes [4,5].

The strength and failure analysis of mechanically fastened joints is very important as it can help in proper design and in selection of appropriate joint size for a given application. Here the strength of joints depends on various factors which include type of the composite laminate, laminate lay-up sequence, geometric parameters, type of the joints and initial preload conditions. Literature published so far tells that there has been lot of experimental and numerical investigations on pinned and bolted joints [6-8]. Most of the studies were conducted on either carbon/epoxy or glass/epoxy composite laminates. But most of the studies are concentrated on glass fibre/epoxy composite laminates because of cost of the material and good mechanical properties. For instance Karakuzu et al [9] studied the failure analysis of woven laminated glass/vinylester composites with pin loaded hole by both numerically and experimentally. Glass/vinylester composite consisting of 12 laminas was subjected to mechanical testing to study the effect of edge distance to diameter and width to diameter ratio on failure load and failure modes. The numerical study was performed using 3D finite element method using LUSAS 13.4 analysis program. The numerical results obtained using Hashin criteria to predict failure modes were in well agreement with that of experimental results. It was found that by increasing the geometric parameters the bearing strength of the composite plates was found to be increasing. At the low values of edge distance to diameter ratio the failure modes were net-tension or shear-out. In another work, Kishore et al [10] studied the failure analysis of multi-pin joints in glass fibre/epoxy based composite laminates by finite element analysis using ANSYS software and further validating these results with the experimental work. The effect of various geometric parameters on behaviour of composite laminate made of glass/epoxy having three and four pin joints.

In order to predict the failure load and failure modes, a numerical analysis was performed using two dimensional finite element methods by implementing Tsai-Wu criteria. The experimental and finite element analysis results were almost similar with an error of 10% was obtained for failure loads. Here the work highlighted the advantage of finite element analysis in observation of damage propagation in every load step which is not possible in experimentation.

Apart from pin joints, both numerical and experimental studies were also carried out on bolted joints. Ozen and Sayman[11] carried out the numerical and experimental studies to investigate the failure load of bolted joints of woven glass fibre/epoxy laminated composites. The finite element method was used to conduct the numerical analysis and ANSYS 11.0 FE was used to develop the model. The failure mode obtained using Tsai-Wu criteria were similar to that of experiments while the error between the failure loads was less 10%. The higher values of K/D, W/D and E/D contributed in increase in failure load. The present work is preliminary investigations on numerical analysis of woven glass-fabric/epoxy composite laminates. Two composite laminates were mechanical fastened using bolted joint configuration and effect of this on displacement and strength has been reported. The numerical analysis on composite laminates is carried using finite element method using ANSYS software.

Problem statement

To start with we have considered a single lap bolted joint with both upper and lower plate made up of composite laminate loaded in tension. Here the single lap composite laminate joint is shown in Fig. 1 whose geometric parameters W is the width of laminate, D is the diameter of bolt hole, E is the vertical distance of bolt-hole centre to the edge and T is the thickness of the laminate. Here the composite laminate is made up of woven-glass fabric reinforced epoxy matrix with totally 8 number of lamina. The diameter of the bolt hole is 10 mm while E/D ratio is 2.

Numerical study

The finite element model of the composite laminate joint along with the bolt is shown in Fig. 2 (a) and (b). Here the 3D model of the bolted joint is created using the ANSYS FE code using eight-noded SOLID46 3D ANSYS layered element. Here load is applied by fixing boundary condition a one end and prescribing displacement at exactly opposite end of the model that is in x-direction.

Simulation results and discussion

It is well known that FEM has many advantages which include so study the failure load and failure models along with the crack initiation and propagation in every step of load. Here it should be noted that the joint problem is 3D contact finite element problem.

Model analysis

Fig. 2 (c) and (d) shows the FEM model of bolted joint of composite laminate fixed at one end and a load of 45 N is applied in exactly opposite direction of fixed direction. Further Fig. 2 (e) and (f) shows the stress distribution in the bolted joint for the load applied. It can be seen that the maximum equivalent stress obtained from the analysis of the bolted joint of composite laminate is 109.15 MPa for an applied load of 40N. Further Fig. 3 (a) – (c) shows the stress distribution in the bolt. It can be seen that maximum stress concentration is in bolted joint region. From this it is reasonable to expect that the failure mode in the present case would be bolt shear failure. This indicates that the effects are damage accumulation in the laminated composite is in the region of joint area and we can expect the ultimate shear failure of the bolt [12].

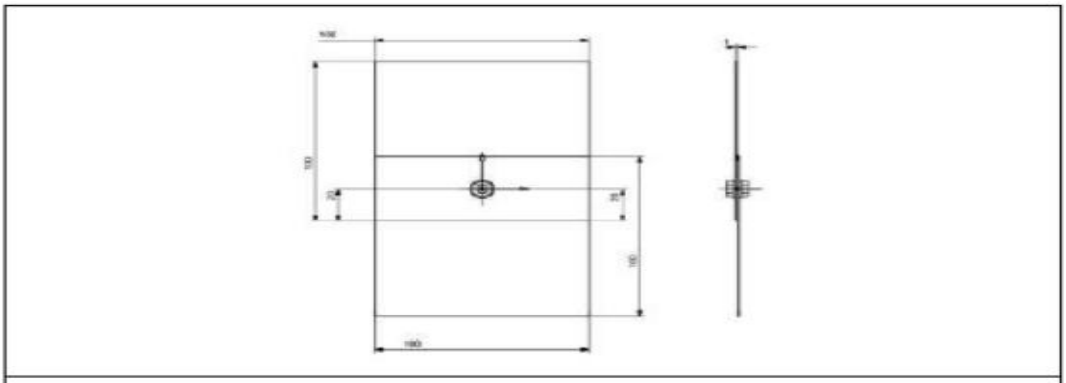
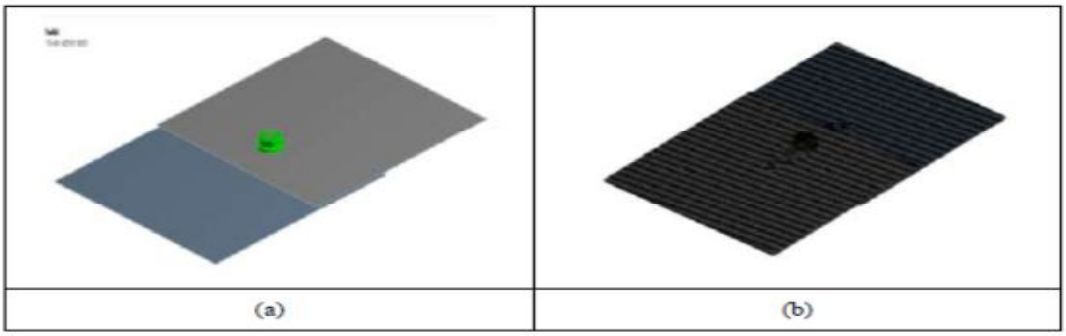
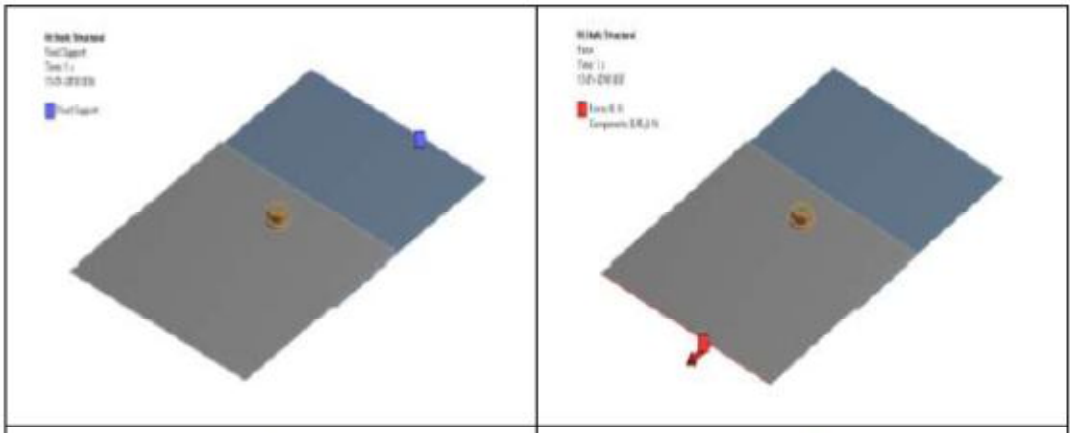


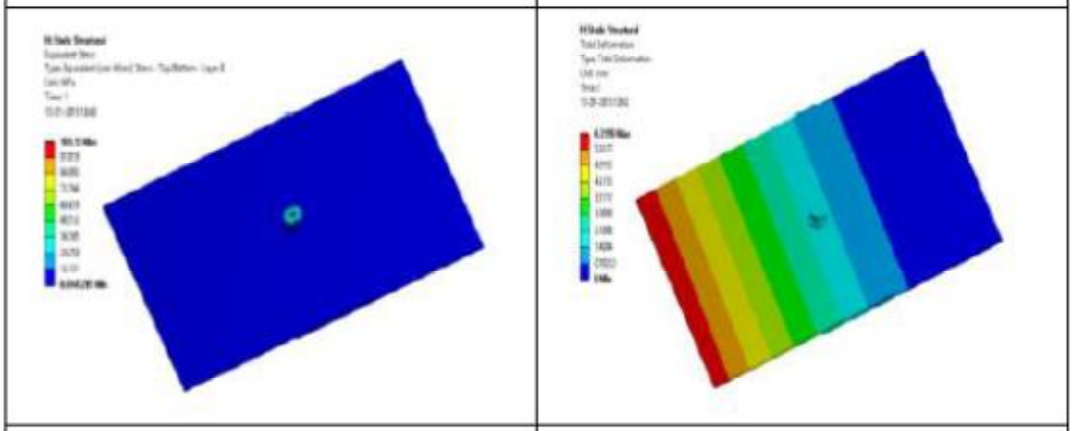
Fig. 1 Geometry of single lap bolted joint



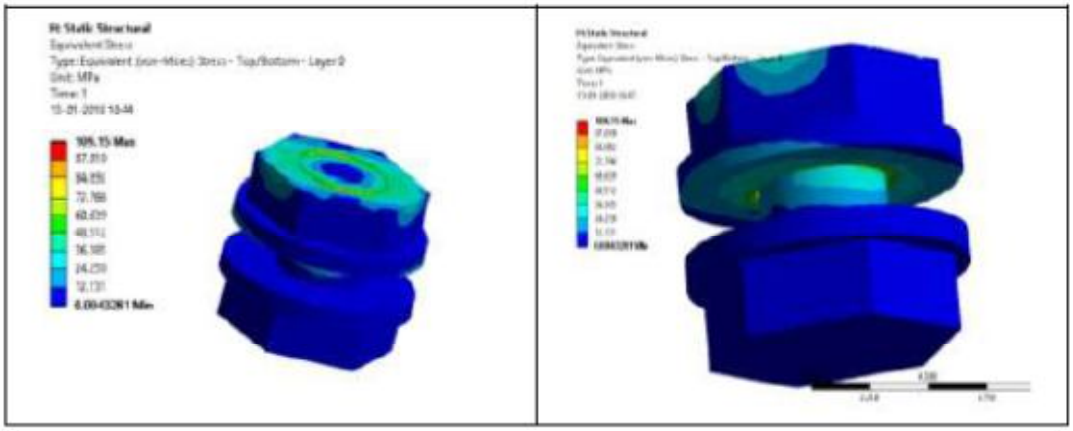
(a) (b)

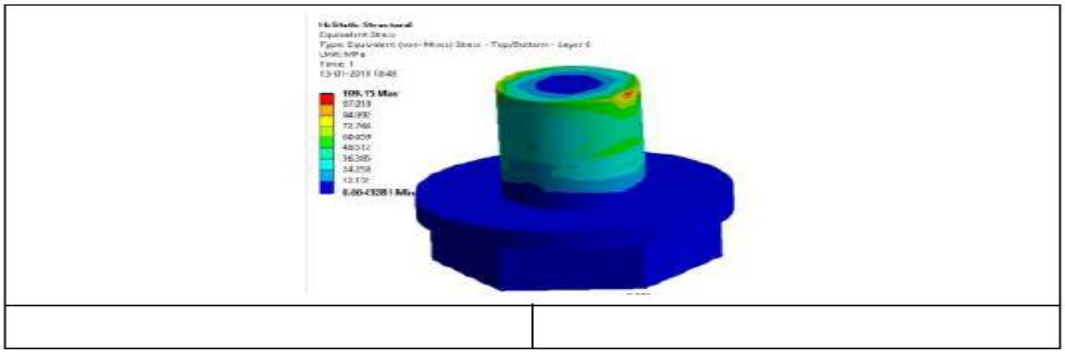


(c) (d)



(e) (f)





CONCLUSIONS

In the present work we have carried out the numerical analysis of single lap joint of single bolted joint of woven glass fabric/epoxy composite laminate. The numerical analysis done using the finite element method along with the ANSYS on single lap single bolted joint reveals that the when a tensile load of 45 N is applied the maximum stress concentration is seen in bolt region.

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