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Analysis of a Pin Loaded FRP Composite Stress by Non Linear Analysis

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ABSTRACT

The use of mechanical fasteners to join composite parts is wide spread throughout a number of industries, such as the aeronautical, civil construction and chemical industries, as this technique offers a number of advantages over other joining methods. Composite materials have many advantages over conventional metal materials, due to their comparatively high strength to weight and stiffness to weight ratios. The present study is concerned with the effects of geometrical parameters such as edge distance to hole diameter ratio (E/D) and plate width to hole diameter ratio (W/D) on net tension plane, hoop and radial stress at the hole boundary will be discussed. The stress distribution along the joint region is given to stress distribution at different geometrical condition.

1.INTRODUCTION

Composite materials are commonly used in structures that demand a superior level of mechanical performance. High strength to weight and stiffness to weight ratios of composites has facilitated the development of lighter structures, which often replace conventional metal structures.

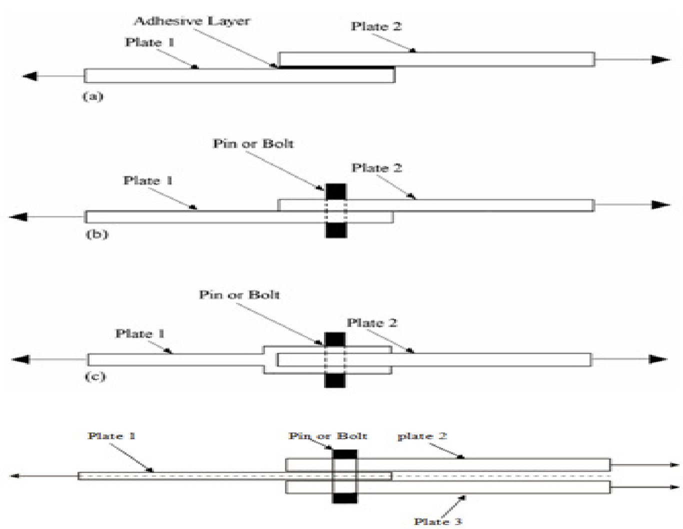

Fig. 1.1Types of joint configurations joint.

Basically, two types of composite joints are commonly used as shown in Fig. 1.1

- Adhesively bonded joints

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- Mechanically fastened joints (pinned or bolted joints)

The key methods used for joining metallic parts, mechanical fastening and adhesive fastening are also applicable to composites, provided care is taken to allow for the characteristics of composites. In mechanical joints, loads are transferred between the joint elements by compression on the internal faces of the fastener holes with a smaller component of shear on the outer faces of the elements due to friction. In bonded joints the loads are transferred by mainly shear on the surfaces of the elements. In both cases, the load transmission elements, fastener or adhesive, are stressed primarily in shear along the joint line; however, the actual stress distribution will be complex. However, adhesive joints are acceptable for secondary structures, but are generally avoided in primary structures due to their strength.

2. LITERATURE REVIEW

Fibre reinforced composite materials have potential advantages over conventional metal materials due to their comparatively high strength to weight and stiffness to weight ratios. Therefore, the use of these materials in engineering structures, especially on aircraft,has grown rapidly in recent years. In composite structures, types of joints commonly used are mechanically fastened joints, adhesively bonded joints, and hybrid mechanically fastened/adhesively bonded joints. Among these, mechanically fastened joints comprising of pinned and bolted joints are the dominant fastening mechanisms for transferring load among components and has received considerable attention by several researchers. Excellent review on the analysis of these joints in metallic structures was carried out by Rao [1978] and in composites by Dattaguru [1997], Ibrahim et al. [2005], Srinivasa et al [2008] and Amit P. Wankhade1 and Kiran K. Jadhao [2013].

Two dimensional finite element modelwas developed using ABAQUS by**VahidYavariet. al. [2009]**. They emphasized the need for modelling the contact between pin and the plate using master-slave algorithm which could take both friction and joint clearance in account. The maximum tangential stress was found to increase with friction and also there was reduction in joint strength with increasing in clearance.

McCarthyC.T et. al. [2005]developed three-dimensional finite element models using finite element code MSC. Marc to study the effects of bolt-hole clearance on the mechanical behaviour of bolted composite (graphite/epoxy) joints. Both quasi-isotropic and zero-dominated lay-ups were studied. It was observed that clearance results in increased bolt rotation, decrease in bolt-hole contact area, and joint stiffness.Increase in clearance resulted inincrease in peak radial stress, a shift of the location ofthe peak tangential stress towards the bearing plane,slight increase in the peak value of the tangential stress,and compressive tangential stress at the bearing plane.

Using ANSYS software 3D non linear contact analysis was performed to examine the effects of clearance and interference fit on the failure load, mode, and bearing strength of a pin loaded joint in composite plate by**Binnur Goren Kiral[2010]**. The same was compared with experimental results and it was observed that interference is beneficial as it introduces local pre-compression stresses and in this way reducesthe magnitude of the tensile stress during real loading.

Sang-Young Kim et. al. [2013]. They were found to be in fairly good agreement. An interference of 0.4 % was found to be ideal for cross-ply Glass-fibre reinforced plastic.

Influence of specimen stacking sequences on the bearing strength, failure stress and displacement were studied for four configurations $[0/90]_{2s}$, $[15/\pm75]_{2s}$, $[30/\pm60]_{2s}$, and $[45/\pm45]_{2s}$by**KhashabaU.A et. al.[2013]**.It wasconcluded that $[45/\pm45]_{2s}$ stacking sequence has the maximum in-plane shear strength and modulus compared to the other stacking sequences. FRP composite component that subjected to bearing loads with $\pm45^0$ layer is important to maximize the bearing load and displacement. Layers with $90^0$are important for resisting the displacement of the pin and increases the energy absorbed in their inter-laminar shear. The presence of the 0^0 layer is important for maximizing the ultimate load to failure and the apparent bearing stiffness of the specimen.

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Objective of the Project Work

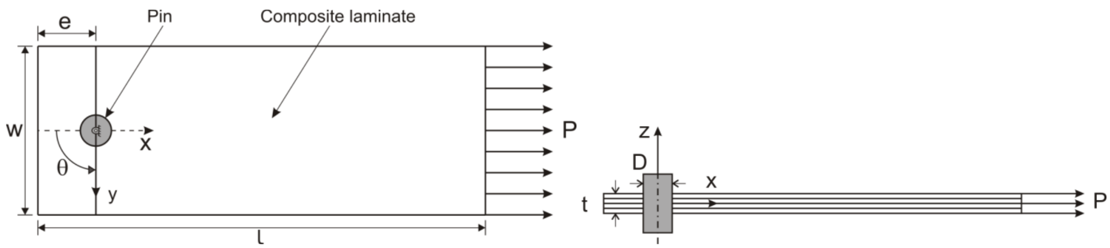

Fig. 1 The geometry of the pin loaded plate

The use of FRP composites in modern structure is constantly increasing due to their ability to tailor the properties of a material. Due to the requirements of assembly and disassembly such structures have mechanical fastener joints. These joints are often weak parts of the structure and thus have received considerable attention. This study deals with three dimensional non-linear contact stress analyses of pin-loaded GFRP composites using Ansys 14.5 to study the effects of load variation,type of fit (interference, clearance, and push-fit), Interface friction, geometry parameters such as:specimen width (W) or ratio of width to hole diameter (W/D) and edge distance (e) or ratio of the edge distance to hole diameter (e/D),

The dimensions of the configuration considered for analysis of pin joints is as in table 1

3. METHODOLOGY

1. Geometrical modelling of the configuration is carried out. One half of the model is generated sincethe problem under consideration is single axis symmetric.
2. The mesh consisting of eight-noded layer solid elements (SOLID185) for the laminate and eight-noded solid elements (SOLID185) for the pinwill be used.
3. 3-D surface-to-surface contact elements (CONTA174 & TARGE170) for the interface between the pin and the hole will be generated by using the contact finite elements.
4. Force and geometrical boundary conditions will be incorporated.
5. Processing and post processing will be carried out to.
   - Examine the effect of load and interference on stress distribution in Glass/epoxy (GFRP) laminate $[[(0/90)_3/\bar{0}]_s]$.
   - Examine the effect of geometric parameters such as W/D and e/D ratios and coefficient of friction on hoop and radial stress distribution with constant load on stress distribution of Glass/epoxy (GFRP) laminate $[0/\pm 45/0/\overline{90}]$.

Table 1 Principal dimensions of the laminate

Length, L+E	203mm
Thickness of each lamina	0.27mm
Number of lamina	N
Total laminate thickness, t	0.27xn mm
Hole diameter, D	6.35 mm
Ratio of the edge distance to hole diameter (e/D)	2,3 and 4
Ratio of width to hole diameter (W/D)	1,2,3 and 4

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4.MODELLING, ANALYSIS AND RESULTS

4.1 Geometrical Modelling

The configuration of pin loaded composite plate shown in Fig. 2.1 is single axis symmetric.

Table 2 Mechanical properties

Material	Glass/Epoxy	Isotropic steel pin
E_{11} (GPa)	36.00	E=209.00 GPa, ϑ =0.25
E_{22}=E_{33} (GPa)	8	
G_{12}=G_{13} (GPa)	4.1	
G_{23} (GPa)	4.00	
$\vartheta_{12} = \vartheta_{13}$	0.23	
ϑ_{23}	0.25	

4.2 Loads and Boundary Conditions

The centre of pin is fixed and the plate end that is far from the pin (x=l-e) is subjected to uniformly distribute force equivalent to net tension force P/2. The plate end at x= -e is stress free. The y and z direction translation constraints are applied at the upper edge of the plate that is at symmetrical plane (y= 0). Contact is generated at pin - hole interface for the path to the stress and load transfer. Pin surface area is considered as the target and the plate hole surface area is considered as surface for the contact geometry. Friction coefficient µ is considered between the pin and the hole surfaces to simulate the real situation. The interference condition is created by simply modeling the oversized pin with respect to the hole. [4] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences. Elements and speed vectors were thought to be inaccessible, along these lines a NN eyewitness was intended to recoup the limitless states. At that point, a novel NN virtual control structure which permitted the craved translational speeds to be controlled utilizing the pitch and the move of the UAV. At long last, a NN was used in the figuring of the real control inputs for the UAV dynamic framework. Utilizing Lyapunov systems, it was demonstrated that the estimation blunders of each NN, the spectator, Virtual controller, and the position, introduction, and speed following mistakes were all SGUUB while unwinding the partition Principle.

4.3 Mechanical Properties

In this study, Glass/epoxy materialis used for the composite plates and steel for isotropic pin. The properties are as given in Table 2.

4.4 Finite Element Mesh

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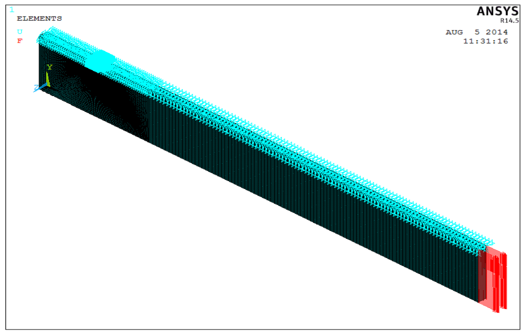

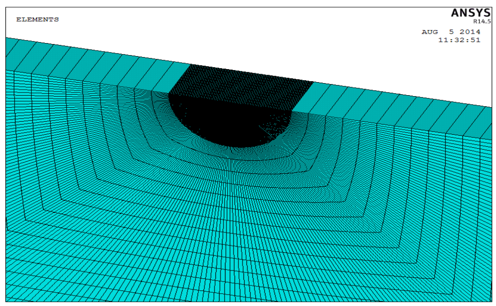

As a bench mark problem, finite element simulations were carried out for the pin loaded configuration with the following details.

Table 3 Principal Dimensions

Length, L+E	203mm
Thickness of each lamina	0.27mm
Number of lamina	13
Total laminate thickness, t	3.51 mm
Hole diameter, D	6.35 mm
Ratio of the edge distance to hole diameter (E/D)	4.00 mm
Ratio of width to hole diameter (W/D)	8.00 mm
Laminate	$[(0/90)_3/\bar{0}]_s$
Material	GFRP
Co-efficient of friction μ	0.1

Fig. 2: Convergence Modeling

A finite element model of the pin-loaded plate was created and analysed using finite element analysis software ANSYS 14.5. Figure shows the mesh employed for the symmetric half section of the GFRP composite laminate and Figure for the boundary conditions applied. The mesh consisted of eight-noded layer solid elements (SOLID185) for the laminate, eight-noded solid elements (SOLID185) for the pin and 3-D surface-to-surface contact elements (CONTA174 & TARGE170) for the interface between the pin and the hole. Figure gives the finite element mesh around the pin hole contact region. By using the contact finite elements as shown in Figure the contact condition could be simulated.. Finite element models representing a joint with different e/D and W/D ratios along with different interference fit conditions, varied load conditionsand five different friction values were created using Finite Element Analysis software ANSYS 14.5. [1] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e.,

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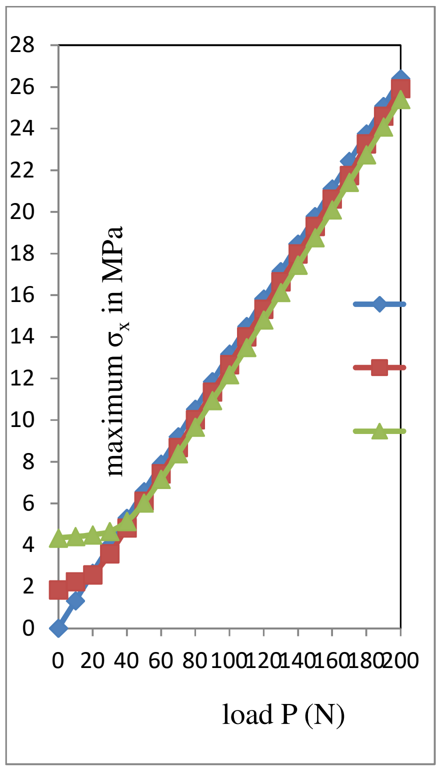
velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased. Mesh convergence were carried out by increasing the number of elements so as to get finer mesh at the hole boundary. The values of maximum net tension stress at the hole boundary for different meshes with increasing number of elements is shown in Table 3.The in-plane stress component σx is normalized with nominal stress and its variation along the net-tension plane of the pin-loaded laminate is shown in Figure for mesh four and compared with the reference. The results were found to be in good agreement with the reference. This mesh is taken as a final mesh for the analysis.



Sl. No.	Number of elements on plate	Number of elements on pin	Net-tension stress MPa
1	2400	37120	4.06
2	3600	82680	5.73
3	6400	146240	6.41
4	11800	244800	6.60

Fig. 3 Net-tension plane stress distribution around the edge of the hole for Interference I=0, I=20x10^{-5}, I=40x10^{-5} for varying load P=0 N to P=200 N

5. CONCLUSION AND SCOPE FOR FUTURE WORK

Mechanically fastened joints are inevitable in complex composite structure because of requirement of assembly and disassembly. However they are the potential location of failure due to stress concentration. Several parameters like plate dimension, hole location, co-efficient of friction, type of fit and load effect the design of a composite structure with pin joints. The present work involves the determination of critical stresses influenced by these parameters. Some of the important conclusions are as follows: The variation of critical stresses with applied load for the laminate considered was found to be non linear for interference fit and linear for push fit. Interference fit has beneficial effect under fatigue loading as observed in literature also. The interference fit introduces local pre-compression stresses and in this way reduces the magnitude of the tensile stress during real loading. As a result of this redistribution of high stresses surrounding the joint can be looked upon as a method of modification of the stress field to enhance the strength of the joint.

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