The Contact Analysis of Pin Joints in CFRP Laminates

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Abstract

A three-dimensional finite element model is developed to predict damage progression and strength of mechanically fastened joints in carbon fibre-reinforced polymers. To make the useful structures using composite materials, consideration must be given to the way structural components are joined together. The term "composite joint" is generally used to describe the way two composite components held together or how to attach a composite to non-composite component. Basically, two types of component joints are commonly used; they are bonded joints, and pinned or bolted joints (Mechanically Fastened joints).The model is based on three-dimensional finite element model, on three dimensional criterion and on a failure of pins of comparison between the values in stress in Y-direction of adjacent side circular holes pattern and zigzag pattern circular holes by varying diameter of pins comparing stress variations.

***Keywords**: Mechanically fastened joints, Composite laminates, Composite-joint, CFRP Laminate.*

1. Introduction

Review papers on the strength of mechanically fastened joints in fibre-reinforced plastics were written by Godwin & Matthews [1] and Camanho & Matthews (1997). Effects of material properties, fastener parameters and design parameters have been summarized and discussed.

Several authors have highlighted the importance of width (W), end distance (E), hole diameter (D) and laminate thickness (t) on the joint strength. Kretsis & Matthews [2] showed, using E glass fibre-reinforced plastic and carbon fibre-reinforced plastic, that as the width of the specimen decreases, there is a point where the made of failure changes from one of bearing to one of tension. A similar behaviour between the end distance and the shear-out mode of failure was found. They concluded that lay-up had a great effect on both joint strength and failure mechanism.

Hart-Smith [3] considered that net-tension failure occurs when the bolt diameter is a large fraction of the strip width. This fraction depends on the type of material and lay-up used. Bearing failure occurs predominantly when the bolt diameter is a small fraction of the plate width. Shear-out failure can be regarded as a special case of bearing failure. This mode of failure can occur at very large end distances for highly orthotropic laminates.

Quinn & Matthews [4] have studied experimentally the effect of stacking sequence on the pin bearing strength in glass fibre reinforced plastic. The results suggested that placing the 900 layer (normal to the applied load) at or next to the surface increases the bearing strength.

Collings [5] has discussed the effects of variables such as ply orientation, laminate thickness and bolt clamping pressure.

Collings [6] has also tested CFRP for a range of laminate configurations and hole sizes, and investigated the relation between joint strength and W/D, E/D and t/d.

Pyner &Matthews [7] have made experimental investigation about comparison of single and multi hole bolted joints in glass fibre reinforced plastics. The results suggest that the joint strength decreases as the joint geometry becomes increasingly complex.

Cohen [8] investigated experimentally for failure loads and failure modes in thick composite joints. Thickness effect of pinned joints for composites was also investigated by Liu [9].

Buket Okutan [10] determines the stresses, strength and life prediction of pinned joints, and the effects of geometry, stacking sequence. The main aim of this project is stress determine the stresses, strength and life prediction of pinned joints, while capturing the Difference between adjacent circular holes and zigzag circular holes.

This paper describes tests to determine the basic properties of multi-directional CFRP around a adjacent circular holes vs. zigzag pattern circular holes in a plate loaded in tension by means of a pin in the hole (multi-hole joint). Multi-hole tests are also described which provide an extension to the data obtained from the single-hole tests and allow the measurement of any interaction effects between holes in various pin groups. Results are presented for several types of multi-directional CFRP laminate and are discussed in terms of possible optimum pin joint design.

2. Problem – Modeling

2.1 Geometric Modeling

In this geometric modeling we are having two cases. In case-1 we are having adaptor, pin and composite laminate plate having two holes on both ends which are shown in below Figures. And coming to case-2 we are having same objects but different in design. Like composite laminate plate having 4 holes on both the ends and in these two cases pin diameter is same.

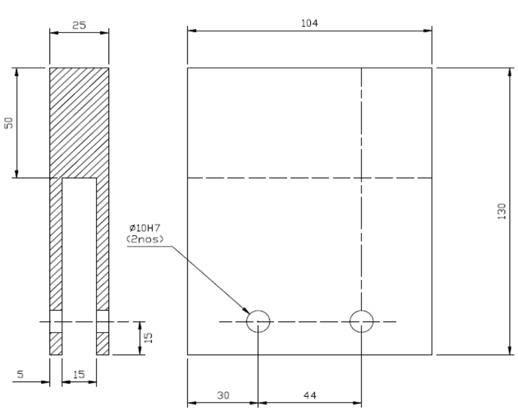

Fig.1: Adaptor – 1

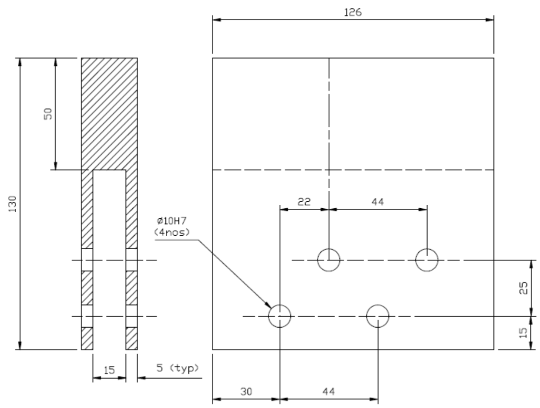

Fig.2: Adaptor - 2

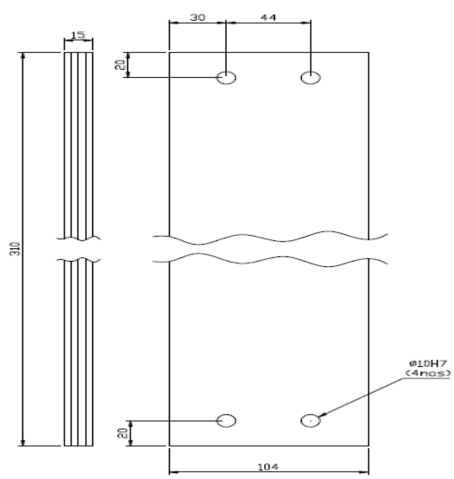

Fig.3: Panel-1

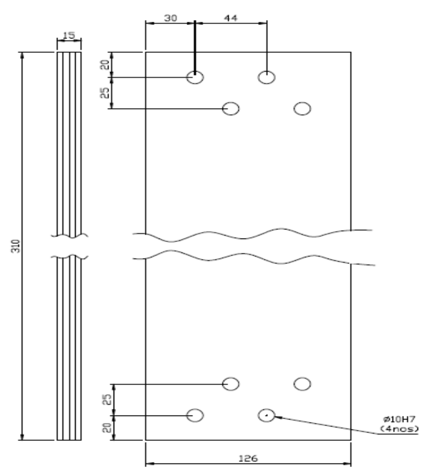

Fig.4: Panel-2

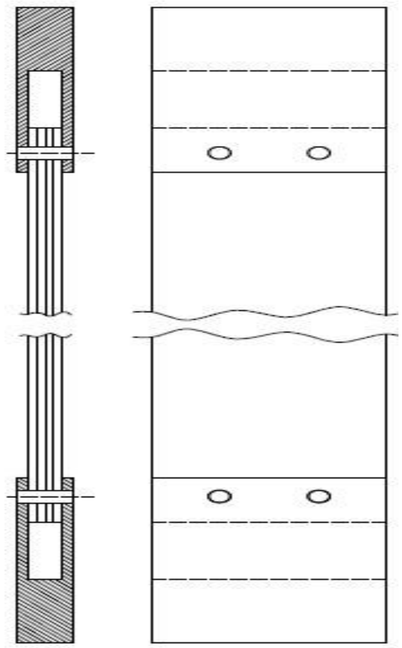

Fig.5: Laminate joint -1

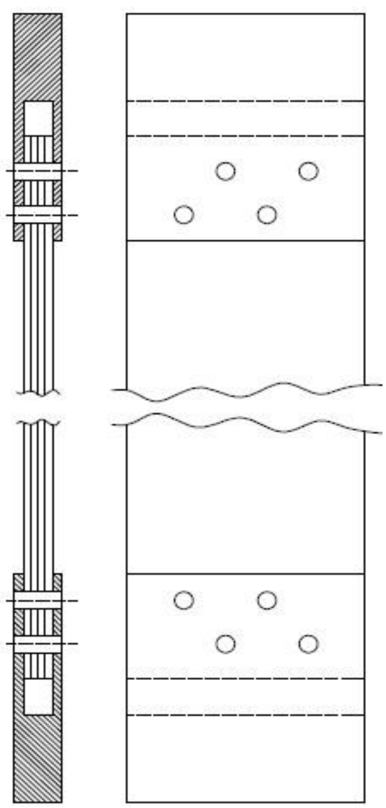

Fig.6: Laminate joint -2

2.2 Finite Element Modelling

Figure (7) gives the assembly of complete laminate joint. This assembly comprises of adaptor and pin which are made of steel and composite laminate. The model for this joint is created in ANSYS 12.1 By using key points, lines and areas. After creating areas by using the extrude command volumes are created.

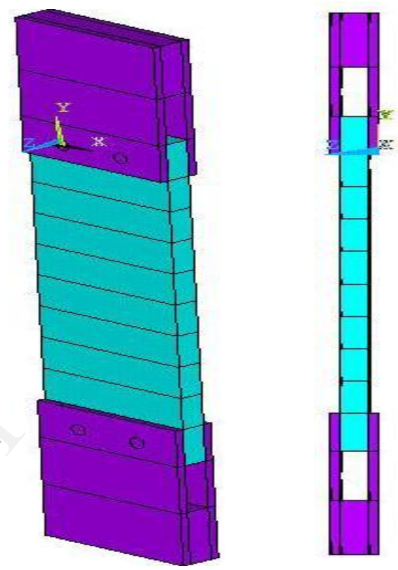

Fig.7: Views of laminate with adaptor and pins

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Angle	90/10/-10/60/-60/45/-45/-45/45/30/-30/10/-10/90/10/-10/90/10/-10/90/10/-10/90/10/-10/90/ 90/-10/10/90/-10/10/90/-10/10/90/-10/10/90/-10/10/-30/30/45/-45/-45/45/-60/60/-10/10/90
I Thickness	0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.65/0.13/0.13/0.26/0.13/0.13/0.26/0.13/0.13/0.26/0.1425/0.1425/0.26/0.26/0.1425/0.1425/0.26/0.13/0.13/0.26/0.13/0.13/0.26/0.13/0.13/0.65/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365/0.365

Table.1: Details of Lay-up sequence

In the laminate joint, laminate is the only part which is made of composite material. This laminate is assembled to the adaptor through the pins on both the ends of the laminate plate.

2.3 Material properties

The following material properties are used:

Material – 1:- **T-700 epoxy composite**

Young's modulii	Poisson's Ratios	Rigidity Modulii
E_1 = 1.1e5 MPa	γ_{12} = 0.2	G_{12} = 5600 MPa
E_2 = 8000 MPa	γ_{23} = 0.3	G_{23} = 3080 MPa
E_3= 8000 MPa	γ_{13} = 0.2	G_{13} = 5600 MPa

Material – 2:- **Steel**

E = 2.1E5 MPa
ν = 0.3

2.4 Creating contact pair

In solving the problem of contact between two elements, it is necessary to create contact pair. After creation of contact pair, boundary conditions are given.

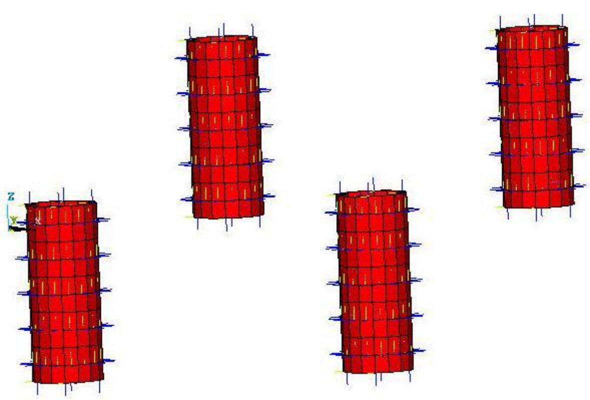

Fig.9: Contact elements with the normals.

2.5 Boundary conditions and Loads

a) All DOF's have to be arrested on the top portion of the adaptor ring.
b) A pressure of 5 MPa is applied on the external areas of adaptor ring as shown in the Figure-10.

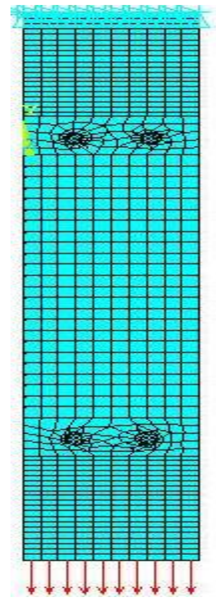

Fig.10: Model with Loads and Boundary conditions

3. Analysis of Results

The response of the pins for contact analyses under the specified loads is obtained through finite element analysis. The response of the pins for static analysis under the specified loads is obtained through 3-D finite element analysis. Stress variations are plotted for two ways of pins (adjacent and zigzag). From the results it is clearly observed that fixed side end pins having more stress than applied pressure end but composite of adjacent side pattern taking less stress than zigzag pattern.

3.1 Comparison "Adjacent Vs Zigzag Pattern"

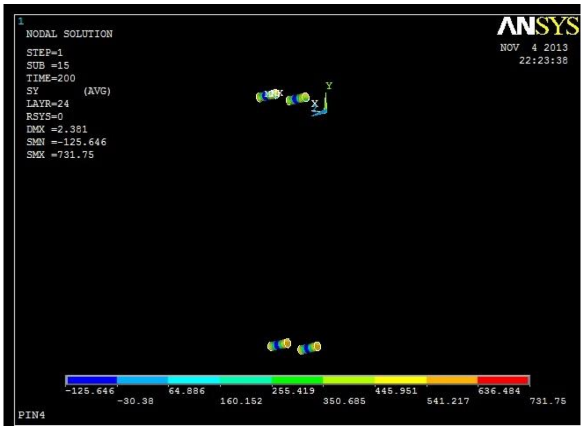

Fig.11: 250 MPa Adjacent Pins (4+4)

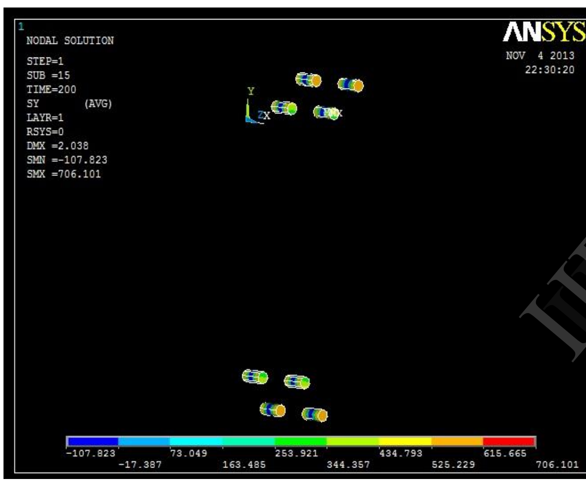

Fig.12: Zigzag Pins (2+2 Pins)

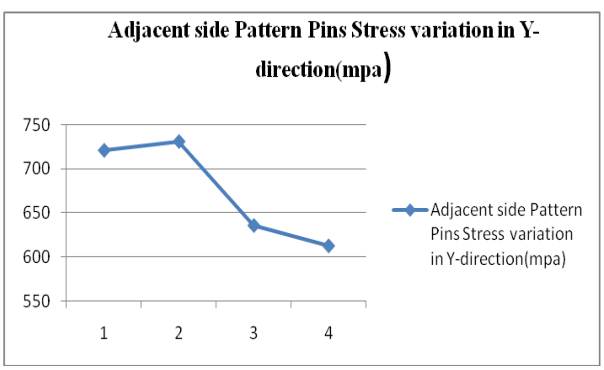

Fig.13: Adjacent Side Pattern Pins Stress Variation in Y- direction (MPa)

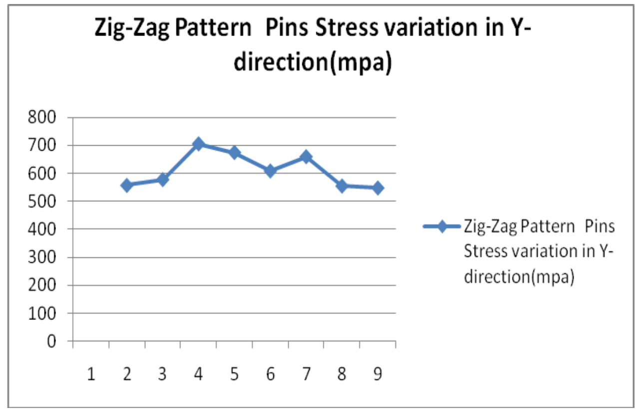

Fig.14: Zigzag Pattern Pins Stress Variation in Y-direction (MPa)

4. Conclusions

From the results it is clearly observed that fixed side end pins having more stress than applied pressure end but composite of adjacent side pattern taking less stress than zigzag pattern.

From the Analysis, Compared to Adjacent pattern with Zigzag pattern, Zigzag pattern is more effective and Failure chances of pins lesser than adjacent pattern pins.

REFERENCES

1. Camanho, P.P., & Matthews, F.L. (1997). Stress analysis and strength prediction of Chang, Fu-Kuo (1986, July). "The effect of pin load distribution on the strength of pin loaded holes in laminated composites." *Journal of Composite Materials*, 20, pp. 401- 408.
2. Kretsis, G., & Matthews, F.L. (1985, April). "The strength of bolted joints in glass fibre/epoxy laminates." *Journal of Composite Materials*, 16, pp. 92-102.
3. Hart-Smith, L.J. (1980). "Fibrous composites in structural design. In E.M. Leneo, D.W. Oplinger & J.J. Burke (Eds.)", "mechanically fastened joints for advanced composites phenomelogical considerations and simple analysis". New York: Plenum Press.

4. Quinn, W.J., & Matthews F.L. (1977, April). “The effect of stacking sequence on the pin-bearing strength in glass fibre reinforced plastic.” *Journal of Composite Materials*, 11, pp. 139-145.
5. Collings, T.A. (1977, January). “The strength of bolted joints in multi-directional CFRP laminates.” *Composites*, pp. 43-54.
6. Collings, T.A. (1982, July). “On the bearing strengths of CFRP laminates.” *Composites*, pp. 241-252.
7. Pyner, G.R., & Matthews, F.L. (1979, July). “Comparison of single and multi-hole bolted joints in glass fibre reinforced plastic.” *Journal of Composite Materials* 13, pp. 232-239.
8. Cohen, D., Norton, F.M., & Hodgson, M.E. (1989, October 3-5). “Experimental investigation of failure modes and failure loads in thick composite joints.” *Proceedings of the American Society for Composites*, pp. 72-81.
9. Liu.D, Raju, B.B., & You J. (1999). “Thickness effects on pinned joints for composites.” *Journal of Composite Materials*, 33, pp. 2-21.
10. De Jong, T. (1977, July). “Stresses around pin-loaded holes in elastically orthotropic or isotropic plates.” *Journal of Composite Materials*, 11, pp. 313-331.
11. ANSYS Reference Manuals, 2012.