Multiaxial Debonding Testing And Simulation Of Adhesively Bonded Joints

Yogiraj Nikam[1], Prof. Ananthrama A[2], Prof. Yogesh Ingulkar[3].

[1]P.G. Student, M.E. Mechanical Engineering, Dhole Patil College of Engg. Pune.

[2]Professor, M.E. Mechanical Engineering, Dhole Patil College of Engg. Pune.

[3]HOD, M.E. Mechanical Engineering, Dhole Patil College of Engg. Pune.

1. Abstract:

Now a days, Cohesive Zone Models (CZMs) is used for the fracture prediction of adhesively bonded joints. Adhesives are typically source system organized by the method of adhesion process. These are then organized into reactive and non-reactive adhesives, which refer to whether the adhesive chemically reacts in order to harden. The main aim of our project is to understand the relation between fracture behaviours of Lap joints with adhesives at various orientations. The CATIA model will be made with the help of CATIA software. The experimental observations will be carried out at different orientations for lap joints with adhesives. The Analysis will be carried out with the help of ANSYS software. The experimental & Analysis results will be compared & the result & conclusion will be drawn. The suitable future scope will be suggested.

2. Introduction

Most of the researchers have dealt with the either adhesive or bolted joints. I decided to study on adhesive joint. An adhesive, source process system also known as glue program process , cement, mucilage, or paste, is any non-metallic substance applied to one surface, or both surfaces, of two separate items that binds them together and resists their separation. Adjectives process system may be used in conjunction source process with the word "adhesive" to describe properties based on the substance's physical or chemical form, the type of materials joined source process, or conditions under which it is applied.

The use of adhesives offers many advantages process system over binding techniques such as sewing, mechanical fastening, thermal bonding, etc. These include process system the of the ability source system process to bind different materials together, to distribute stress more efficiently across the joint, source process the cost effectiveness of an easily mechanized process, an improvement source process system in aesthetic design, and increased design flexibility. Disadvantages source process system of the operation system process adhesive use include decreased stability at high temperatures process, relative weakness in bonding large objects with a small bonding surface area, and greater difficulty in separating objects during testing system process. Adhesives are typically organized by the method of adhesion system. These are then organized into reactive and non-reactive adhesives, which refer to whether the adhesive chemically reacts in order to harden. Alternatively they can be organized by whether the raw stock is of natural or synthetic origin, or by their starting physical phase.

3. Literature Survey

K. Tserpes [1] Adhesive joints find an increasing use in lightweight structures, which is proportional to the evolution of carbon fibre-reinforced plastics (CFRPs). Understanding of fatigue crack growth behaviour in adhesive CFRP joints is essential for the efficient maintenance and repair of existing joints and the design of new joints. Here, the fatigue crack growth behaviour of adhesive CFRP joints under Mode-I, Mode-II and Mixed-Mode I+II loading conditions is characterized experimentally by means of Mode-I fatigue fracture toughness tests, Mode-II fatigue fracture toughness tests and the Mixed-Mode fatigue lap shear test. For the three different tests, the Double Cantilever Beam (DCB), the End-Notch Flexure (ENF) and the Cracked Lap Shear (CLS) specimens are used, respectively. Crack growth versus number of cycles is reported and modified Paris-laws are derived. The DCB specimens failed in cohesive failure mode while the ENF and CLS specimens in adhesive. The crack growth in the DCB specimens was more stable and showed a smaller scatter among the different specimens than the ENF specimens. Crack propagation with number of cycles in CLS specimen was almost linear. The results reported herein suggest a full experimental characterization of fatigue crack growth behavior of the considered aerospace CFRP/adhesive material system and can be proved very useful in the development and validation of fatigue crack growth simulation models.

Şemsettin Temiz [2] Adhesively bonded joints are intensively used in many engineering fields. So, the mechanical research of the adhesively bonded joints is very important to use these joints safely. There are many studies performed by researchers to investigate the mechanical properties of the adhesive joints. There has been a considerable interest in nanoparticles added to structural adhesives recently because nanoparticles improve the mechanical properties of adhesives and joints. In this paper, different nanoparticles reinforced by epoxy adhesive, and neat adhesive were used to produce single lap joints. The static and fatigue strengths of single lap joints incorporating nanoparticles were compared to those without nanoparticles. Experiments were performed at 20 mm overlap length. DP460 epoxy was used as the adhesive material, and nano-Al2O3, nano-TiO2 and nano-SiO2 were used as the nanoparticles; and AISI 304 stainless steel plates were used as the adherents. The results of the experimental research revealed that average failure load increased significantly in nanoparticle-reinforced adhesive joints. The highest average failure load was obtained with 4wt% nano-Al2O3 in epoxy adhesive. Fatigue tests were performed at 10 Hz frequency, and 0.1 loading ratio (R). When the fatigue test results were examined, it was observed that the addition of the nano-Al2O3 and nano-SiO2 to the adhesive increased fatigue strength of the adhesive joints, on the other hand, the addition of the nano-TiO2 to the adhesive reduced fatigue strength of the adhesive joints.

4. Problem Statement

The various joints can be used for connecting various Automotive, Aerospace, etc. parts. so to enhance strength of already existing joints without changing existing design can be achieved by use of industrial adhesives.

5. Objectives

- Lap joints with adhesives using FEA.
- Strength analysis of adhesively bonded lap joint using FEA.
- Tensile test for joints at various orientations.
- Comparative analysis between FEA and Experimental model.
- Conclusions and Future scope.

6. Methodology

Step 1: - I started the work of this project with literature survey. I gathered many research papers which are relevant to this topic. After going through these papers, I learnt about Multiaxial Debonding Testing & Simulation of Adhesively Bonded Joints.

Step2: - After that the components which are required for my project are decided.

Step 3: - After deciding the components, the 3 D Model and drafting will be done with the help of CATIA software.

Step 4:- The Analysis will be carried out with the help of ANSYS software.

Step 5:- The experimental observations will be taken on Universal Testing Machine.

Step 6:- Comparative analysis will be made between simulation and experimental results and then Results and conclusions will be drawn.

7. Static Analysis

1. Material Properties:

Steel

Modulus of Elasticity : 200GPa

Poisson's ratio : 0.30

Density : 7.85e-6 kg/mm3

Yield Strength : 520 MPa

Araldite Epoxy Resin(Adhesive)

Modulus of Elasticity : 3100 MPa

Poisson's ratio : 0.42

Density : 1.15 gm/cc3

Yield Strength : 83 MPa

Silicone Adhesive (Adhesive)

Modulus of Elasticity : 3200 MPa

Poisson's ratio : 0.40

Density : 1.16 gm/cc3

Yield Strength : 78 MPa

Finite Element Analysis:

Design of existing model is done by using CAD package CATIA V5 as per following;

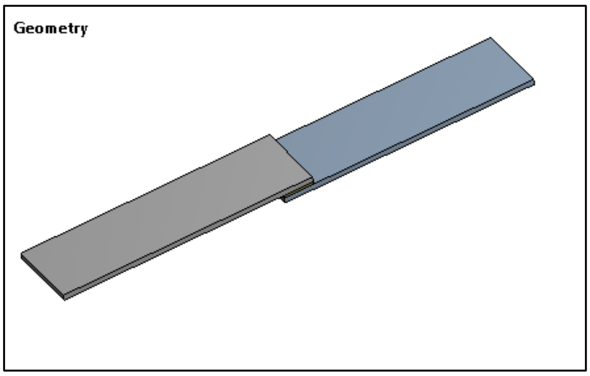
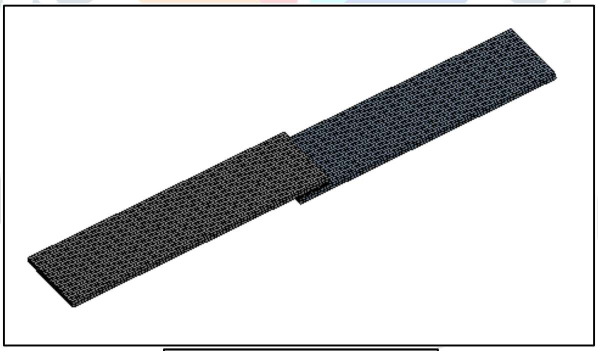


Fig. 1 CATIA model

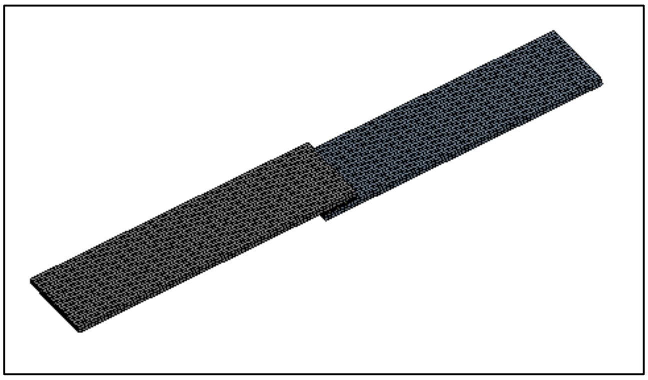
MESH

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient multiphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation.



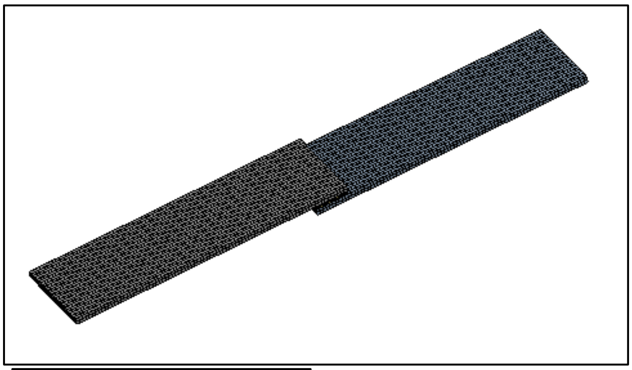
Statistics	
Nodes	60085
Elements	10500

Fig. 2 Meshing of zero-degree loading



Statistics	
Nodes	60085
Elements	10500

Fig. 3 Meshing of 30-degree loading



Statistics	
Nodes	60085
Elements	10500

Fig. 4 Meshing of 45 degree loading

Boundary Condition

A boundary condition for the model is the setting of a known value for a displacement or an associated load. For a particular node you can set either the load or the displacement but not both.

FEA using the Same load for all Orientation

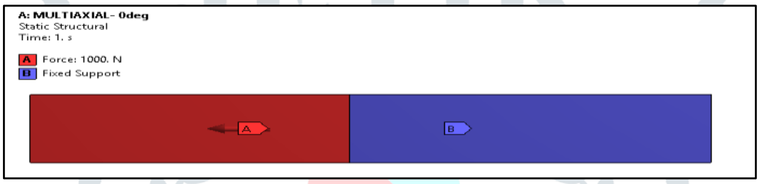


Fig.5 Boundary Condition at zero-degree orientation

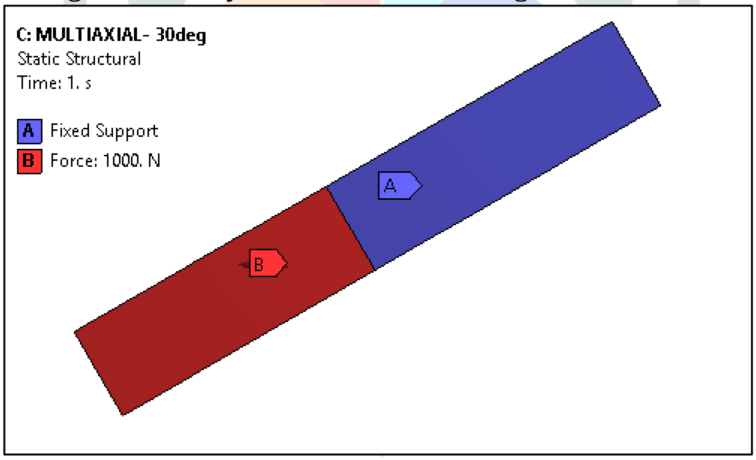


Fig.6 Boundary Condition at 30-degree orientation

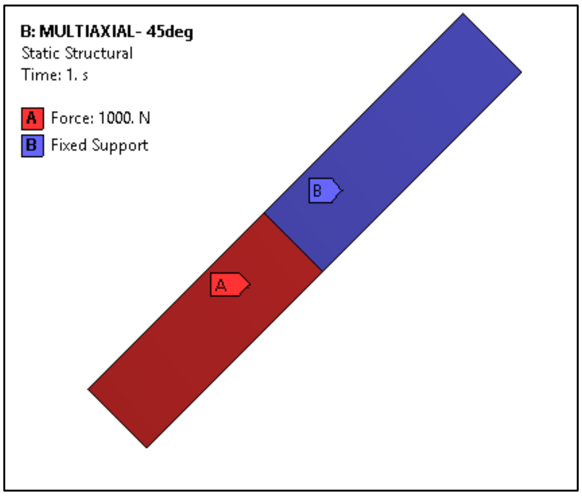


Fig.7 Boundary Condition at 45-degree orientation

Total Deformation

The total deformation and directional deformation are general terms in finite element method irrespective of software being used. Directional deformation can be put as the displacement of the system in a particular axis or user defined direction. Total deformation is the vector sums all directional displacements of the systems.

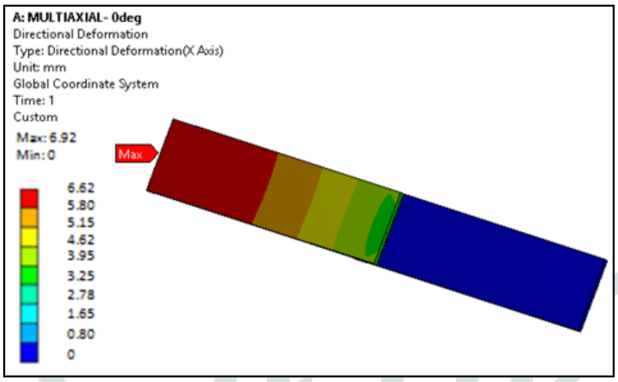


Fig.8 Total Deformation at zero degree orientation

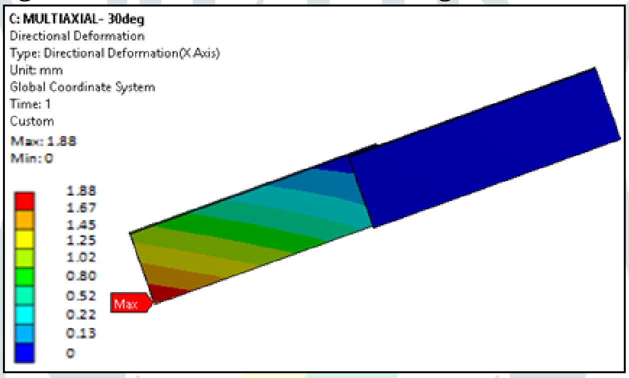


Fig.9 Total Deformation at 30-degree orientation

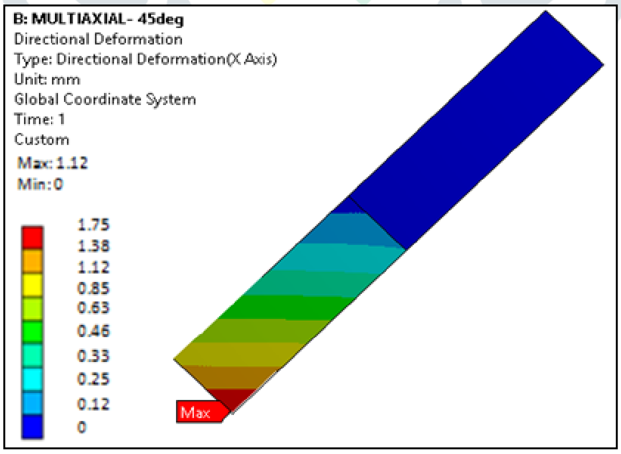


Fig.10 Total Deformation at 45-degree orientation

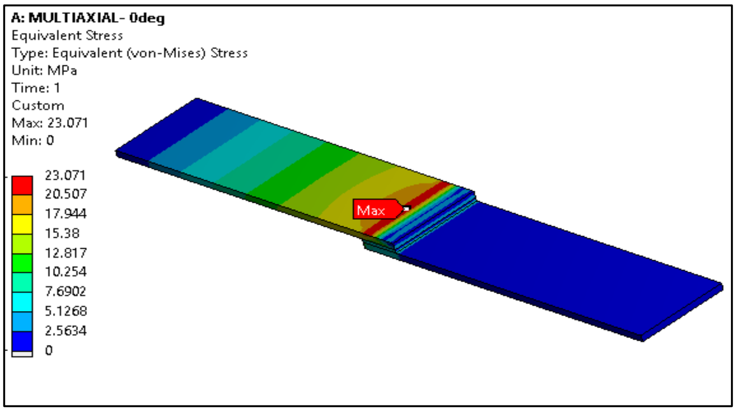


Fig.11 Equivalent stress at zero-degree orientation

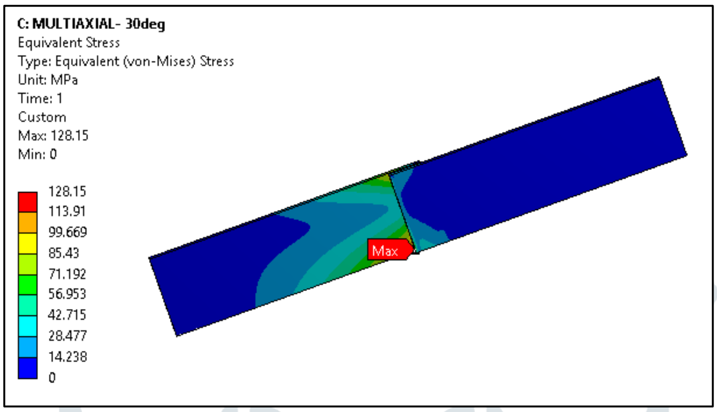


Fig.12 Equivalent stress at 30-degree orientation

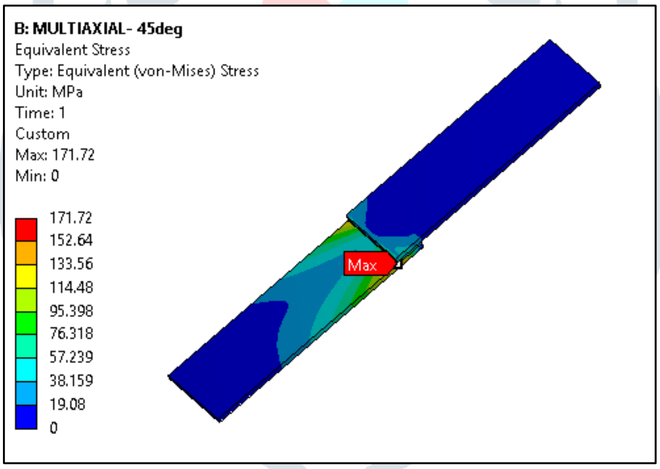


Fig.13 Equivalent stress at 45-degree orientation

8. Experimental Testing

The UTM (Instron 1342) is a servo hydraulic fluid-controlled machine, consists of a two column dynamically rated load frame with the capacity of load up to 100kN (dynamic), hydraulic power pack (flow rate 45 litre/minute) and 8800 Fast Track 8800 Controller test control systems is stand alone, fully digital, single axis controller with an inbuilt operating panel and display. The controller is fully portable and specifically designed with all the condition for materials testing requirement. This controller has position to system, load and strain control capability. The software's available with the machine are: (a) Merlin Testing Software for Tensile Test system (b) da/dN Fatigue Crack Propagation Test system. (c) Kic Fracture Toughness Test system. (d) Jic Fracture Toughness Test system.

Fig. 14 Experimental testing

Experimental Testing for Araldite Epoxy Resin Material

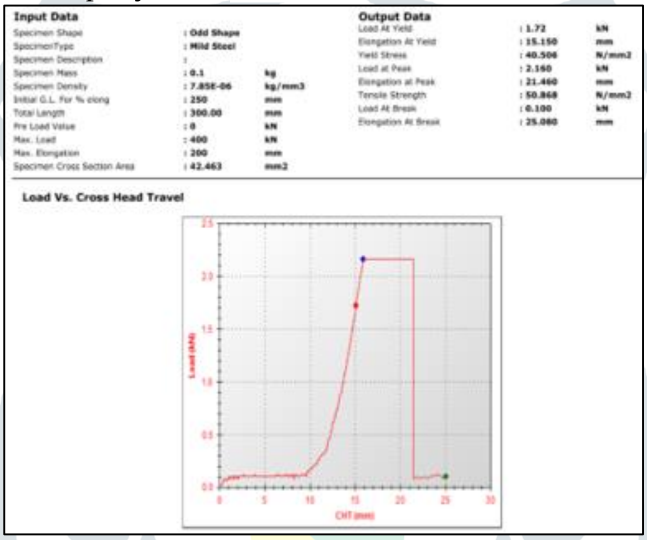


Fig. 15 Peak Load of Zero-degree loading

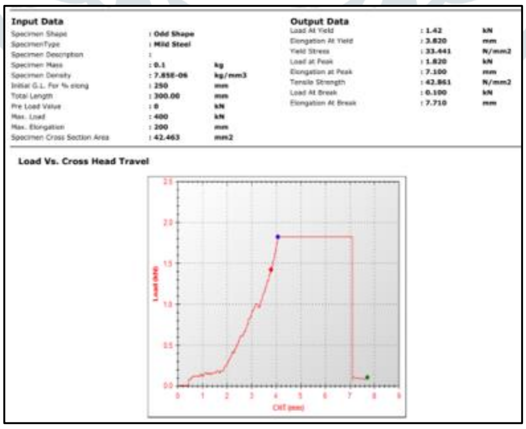


Fig. 16 Peak load of 30-degree loading

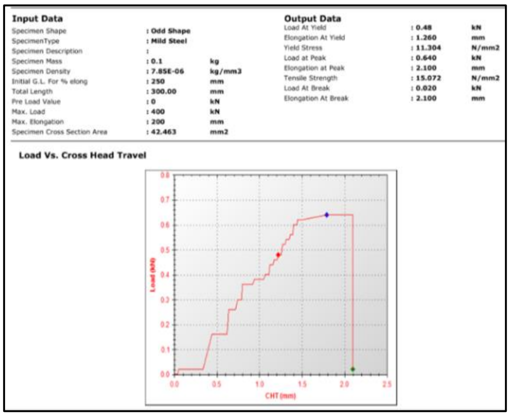


Fig. 17 Peak load of 45-degree loading

FEA using the Peak Load from the Experiment

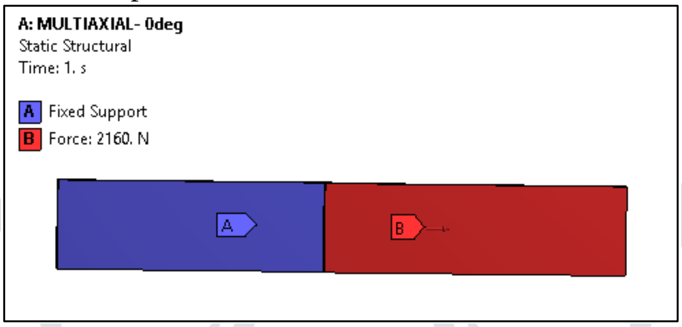


Fig. 18 Boundary condition of zero-degree loading

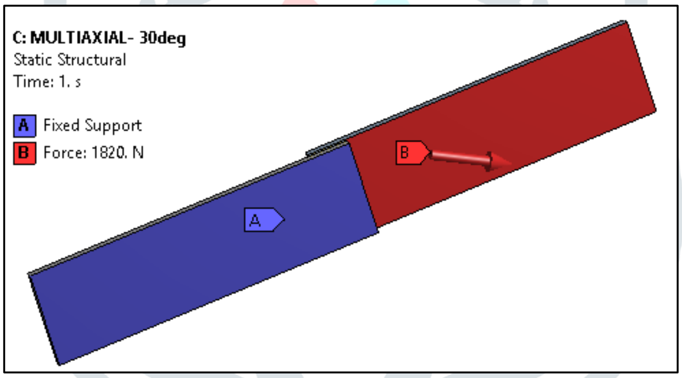


Fig. 19 Boundary condition of 30 degree loading

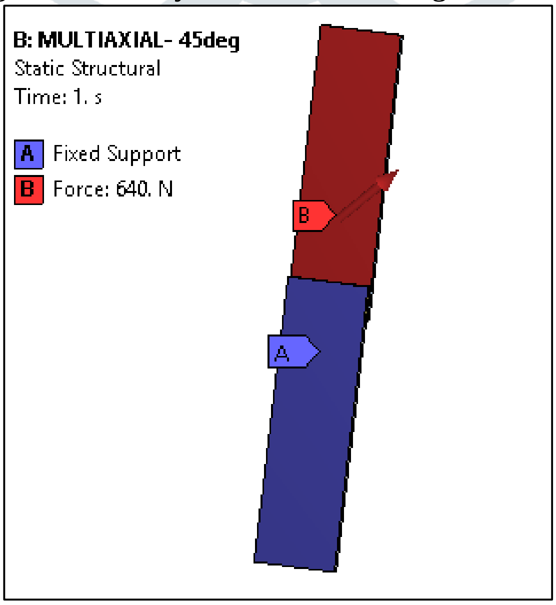


Fig. 20 Boundary Condition of 45 degree loading

Total Deformation Plot

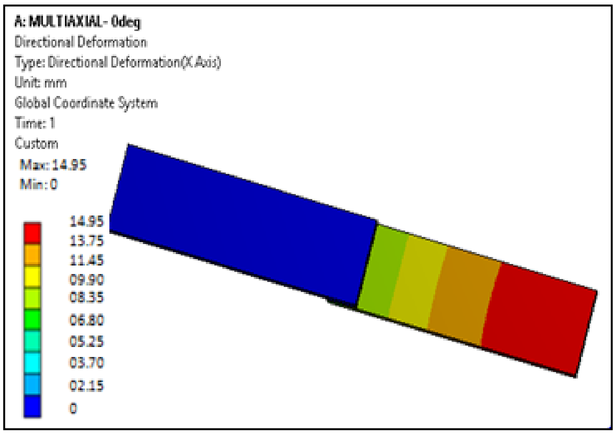


Fig. 21 Total deformation of zero-degree loading

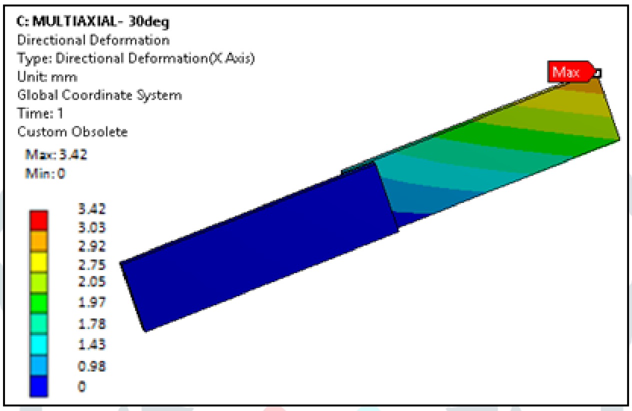


Fig. 22 Total deformation of 30 degree loading

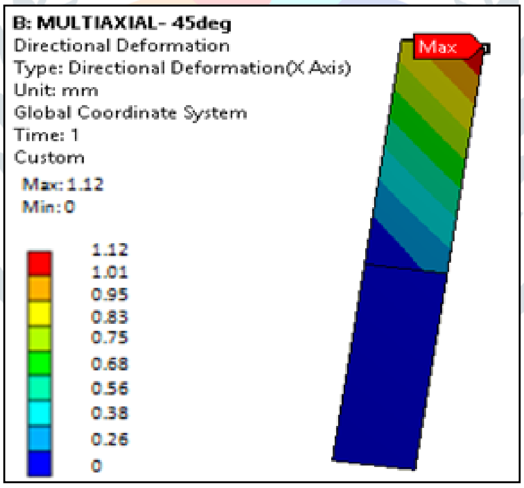


Fig. 23 Total Deformation of 45-degree loading

Stress Plot

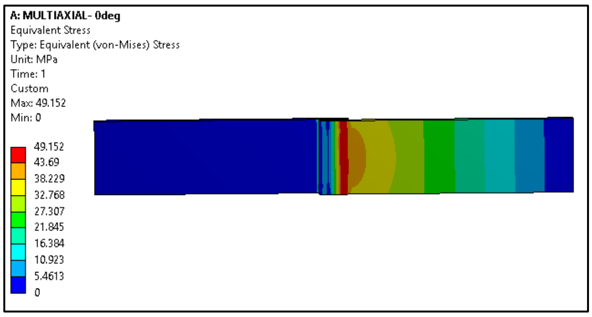


Fig. 24 Equivalent stress of zero loading

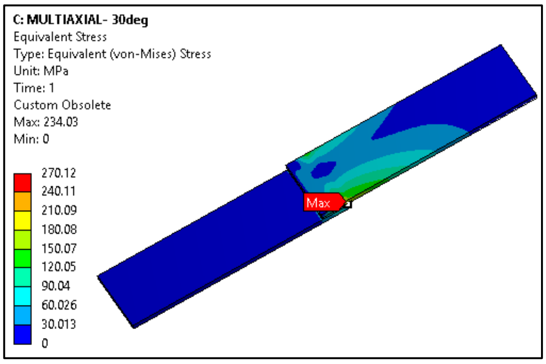


Fig. 25 Equivalent stress of 30-degree loading

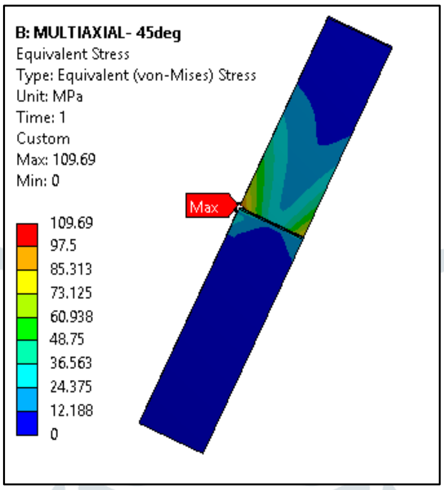


Fig. 26 Equivalent stress of 45-degree loading

Experimental Testing for Silicone Adhesive Material

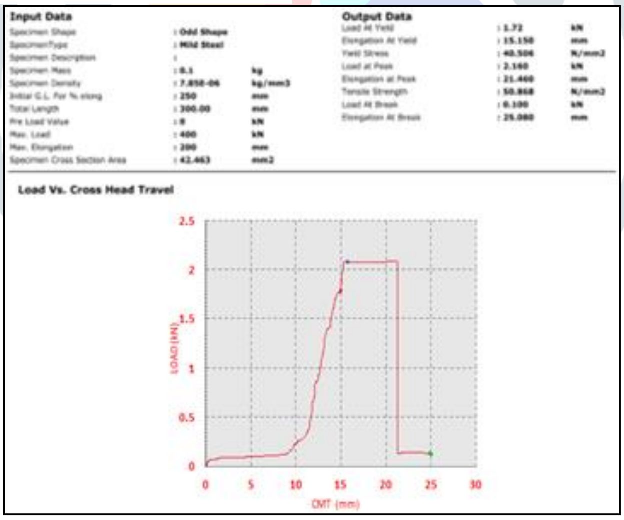


Fig. 27 Peak Load of Zero-degree loading

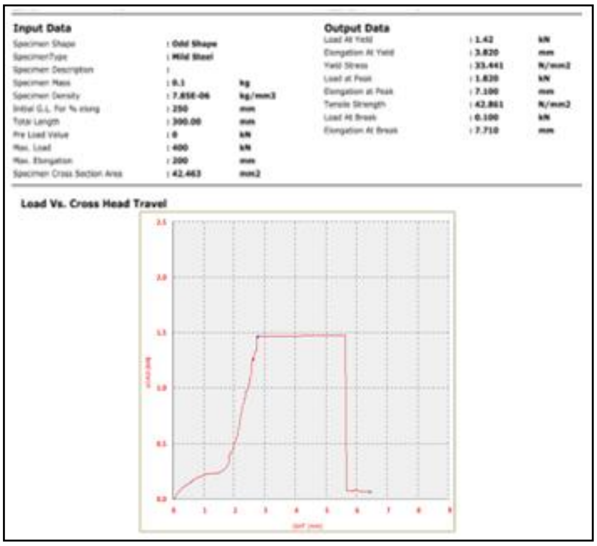


Fig. 28 Peak load of 30-degree loading

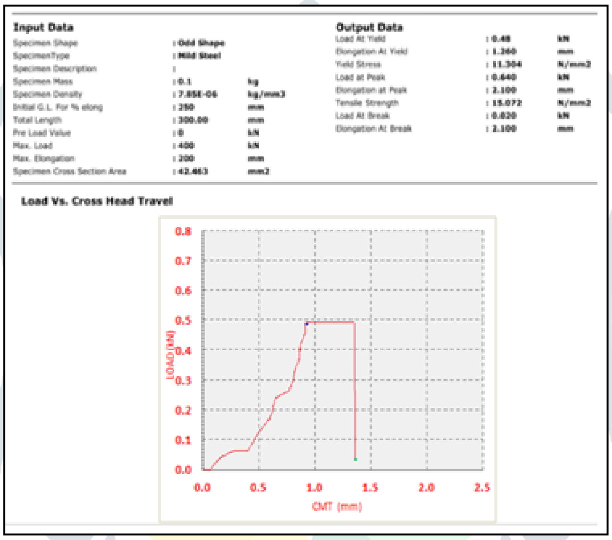


Fig. 29 Peak load of 45-degree loading

FEA using the Peak Load from the Experiment for Silicone Adhesive Material

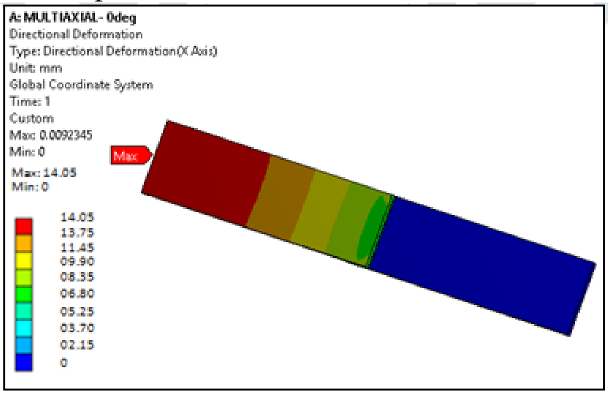


Fig. 30 Total deformation of zero-degree loading

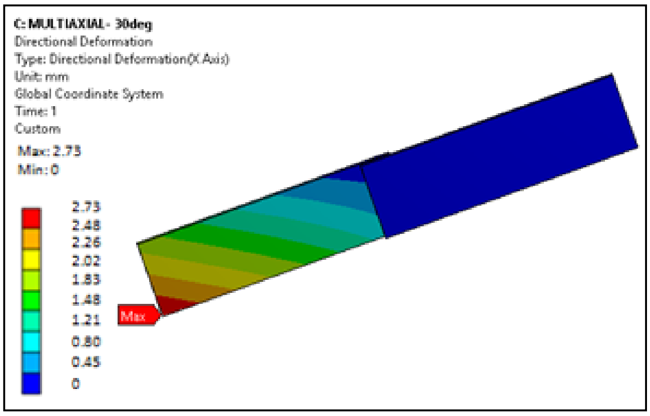


Fig. 31 Total deformation of 30 degree loading

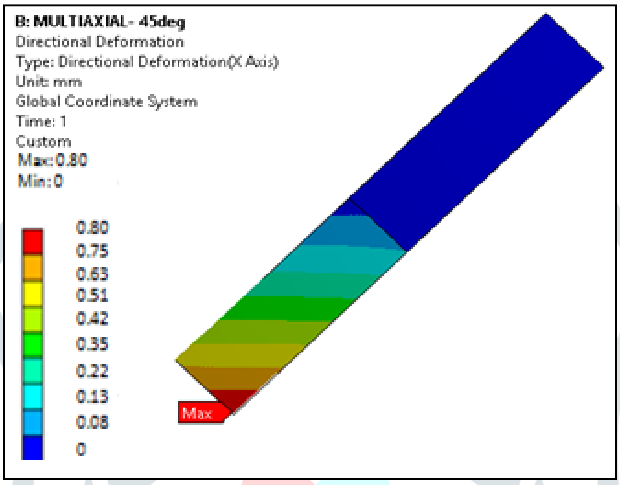


Fig. 32 Total Deformation of 45-degree loading

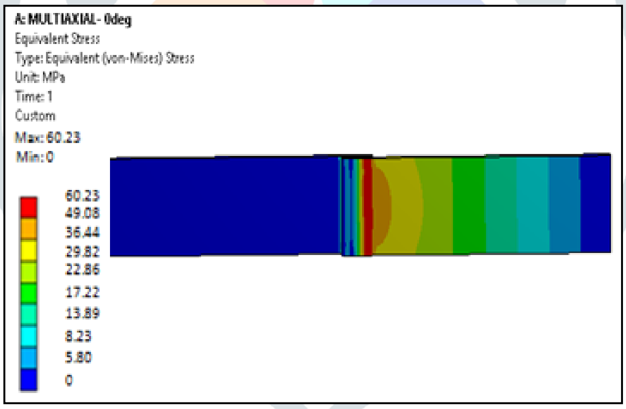


Fig. 33 Equivalent stress of zero loading

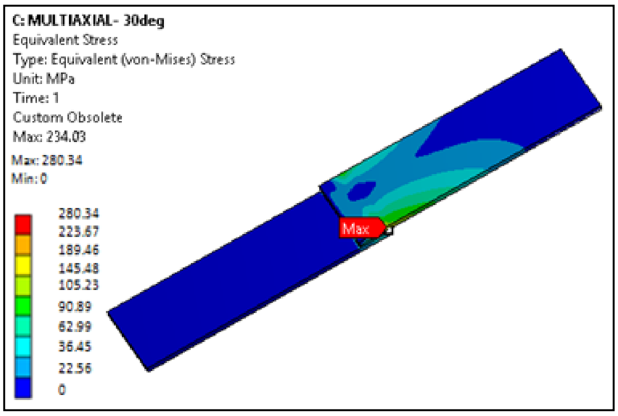


Fig. 34 Equivalent stress of 30-degree loading

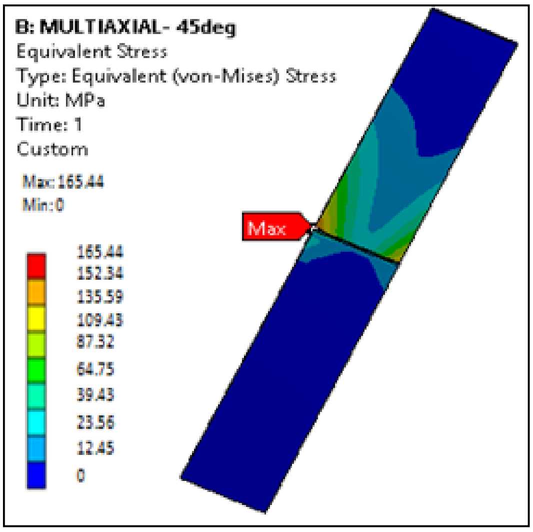


Fig. 35 Equivalent stress of 45-degree loading

9. Results

FEA using the same load for all Orientation

Loading	Directional Deformation (mm)	Equivalent stress (MPa)
0 Degree Loading	6.92	23.071
30 Degree Loading	1.88	128.15
45 Degree Loading	1.75	171.72

It is proved from the FEA that the adhesive joint with the 45° orientation withstands for less amount of load compare to the 30° and 0° orientation.

Comparative Deformation result between FEA and Experiment for Araldite Epoxy Resin

Loading	Deformation (mm) FEA	Deformation (mm) Test
0 Degree Loading	14.95	15.16
30 Degree Loading	3.42	3.82
45 Degree Loading	1.12	1.26

Comparative Deformation result between FEA and Experiment for Silicone Adhesive

Loading	Deformation (mm) FEA	Deformation (mm) Test
0 Degree	14.05	14.78

Loading		
30 Degree Loading	2.73	2.93
45 Degree Loading	0.80	0.95

Comparative Stress Result between Araldite Epoxy Resin Silicone Adhesive

Loading	**Equivalent stress (MPa)**	**Equivalent stress (MPa)**
0 Degree Loading	49.152	60.23
30 Degree Loading	234.03	280.34
45 Degree Loading	109.69	165.44

10.Conclusion

- It is proved from the experimental testing that the adhesive joint with the 45° orientation withstands for less amount of load compare to the 30° and 0° orientation.
- Adhesive joint with 0° orientation shows the highest load bearing capacity.
- Application of adhesive should be in parallel to the direction of the loading.
- Araldite Epoxy Resin adhesive having the better strength over the Silicone Adhesive material.

11.References

[1] Floros, K. Tserpes- Fatigue crack growth characterization in adhesive CFRP joints - International Journal of Composite Structures (2018) PII: S0263-8223(18)32525-X

[2] Ismail Saraca, Hamit Adin SemsettinTemiz - Experimental determination of the static and fatigue strength of the adhesive joints bonded by epoxy adhesive including different particles- (Accepted Manuscript) International Journal of Composite Part B (2018), PII: S1359-8368(18)31464-1

[3] H. Ejaza, A. Mubashara, I. A. Ashcroftb, Emad Uddina, M. Khan -Topology Optimisation of Adhesive Joints Using NonParametric Methods - (Accepted Manuscript) International Journal of Adhesion and Adhesives (2017) PII: S0143-7496(17)30196-3

[4] Xiaonan Hou, Armin YousefiKanani, Jianqiao Ye - Double lap adhesive joint with reduced stress concentration: Effect of slot - International Journal of Composite structures- Volume 202,(Jan. – March.2018), PP 635-642

[5] Jun Zhang, Jiaqi Wang, Zhenwei Yuan, Hong Jia - Effect of the cohesive law shape on the modelling of adhesive joints bonded with brittle and ductile adhesives- International Journal of Adhesion and Adhesives- Volume 85,(March. – May 2018), PP 37-43

[6] J.C.P. Figueiredoa, R.D.S.G. Campilhoa, E.A.S. Marquesb , J.J.M. Machadob , L.F.M. da Silva - Adhesive thickness influence on the shear fracture toughness measurements of adhesive joints – (Accepted Manuscript) International Journal of Adhesion and Adhesives(2017) PII: S0143-7496(18)30048-4