Analysis of Pin Joints in Fiber-Reinforced Composite Laminates

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Abstract

Present work deal with the the S-glass/epoxy and carbon/epoxy laminate which are used to compare the tensile strength and elastic strain of the plate individually. The simulation is done in the Ansys workbench software of the composite plate. All the parameter are specified in the examination and concluded some results like the maximum stress of carbon epoxy plate is 14.298 MPa and maximum stress of S-glass epoxy plate is 14.065 MPa and maximum strain in carbon epoxy plate is .0016487mm and maximum strain in S-glass epoxy laminate plate is 0.0016797mm. From these results the carbon epoxy plate with hole geometry has higher tensile strength as compare to S-glass epoxy plate with hole geometry under the same circumstances also the strain is little bit lower than the S-glass epoxy plate compare to carbon epoxy plate.

Keywords: Composite laminate, Tensile strength, ANSYS, Carbon Epoxy.

1. Introduction

A composite material structure comprising at least two or more macroscopically identifiable Constituent (basically matrix and reinforce) material/component/element that working together to perform significantly better in different applications.Desired parameter/property of composite material is like high strength, high-temperature stability, environmentally sustainable. composite mainly has a matrix that gives the material desired shape and another one is reinforcement which gives the strength to the material. Today the world is growing very fast and to develop these smart materials which can work properly. If the composites are made with layers of different laminates then the composites will be called hybrid composites material. There are different types of composite available in the industry that have different properties at different circumstances so the purpose of using hybrid composite material is that they can work with better performance and for a longer time period. It is studied that pin joint in parallel and series combination, the strength was increased by using hybrid composite material made up of synthetic fibers.[1], [2] The study will be done on the double lap rivet pin joints by using these hybrid composite that is carbon fiber, glass fiber, Kevlar fiber, epoxy, jute, etc. Very less research happened on these particular areas and by using these hybrids composite material strength can be improved, stability on high load, elasticity as desired, etc.These composite materials require the mechanical joint like a butt joint, bolt joint, pin joint to fulfill the structural stability with the other components of the structures.[3] Hybrid composite material used in huge verities of application in the interest of extremely desired property like strength, stiffness, non-corrosive, etc. For the decade hybrid composite material is being used in high-performance application like aerospace, defense system, communication system. Figure 1 is showing a broadways classification of composite material, its classification starts with the fibrous and particulate where all the classifications are based on the orientation. In hybrid composite, material each a laminates has signifying effect on the mass composite material.

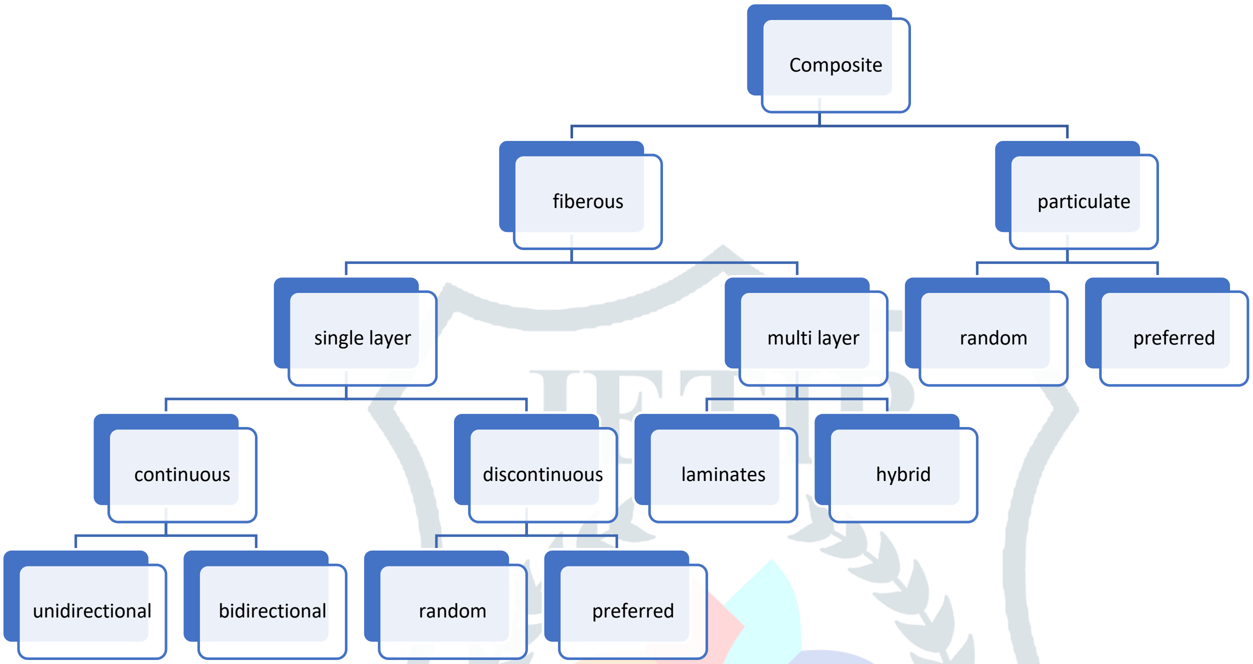

Figure 1. Composite material classification

1.1 Hybrid fiber-reinforced polymer composite

Wide utilizations of the hybrid strengthened polymer composite as for the application. These are less weighted.The set-up of hybrid fiber compositesis toward the improvisation of the mechanical properties,damping properties distinguished by single-fiber composite materials. Hybrid fiber-reinforced composites comprise of at least two fiber in composition system.[4]Various strands were reinforced with a matrix for setting up the hybrid composites utilizing different assembling approach. Hybrid composites are used many applications like replacing wood fiber composites and old materials. Examination of the novel property of mixture composites has been of profound enthusiasm to the scientists for a long time as confirm by phenomenal reports. The joining of at least two fibers inside a solitary matrix, known as hybridization. Hybridization suggestions a worthwhile mode for creating products with high specific modulus, reduced cost, corrosive resistance, and strength, different types of hybrid composite material could be fabricated.[4]–[7]

1.2 Mechanical joint use in Fiber reinforcement polymer composite

There are different forms of joints used like a butt joint, corner joint, edge joint, Tee-joint, single-double bolted lap joint, single pin joints, double pin joint as shown in figure 5, and adhesively bonded joints as showing in figure 6 by using these joints we can make parallel and series combination.[8]–[20] These joints have different applications depending on the material used in composite, strength, failure criteria of these composite joints.

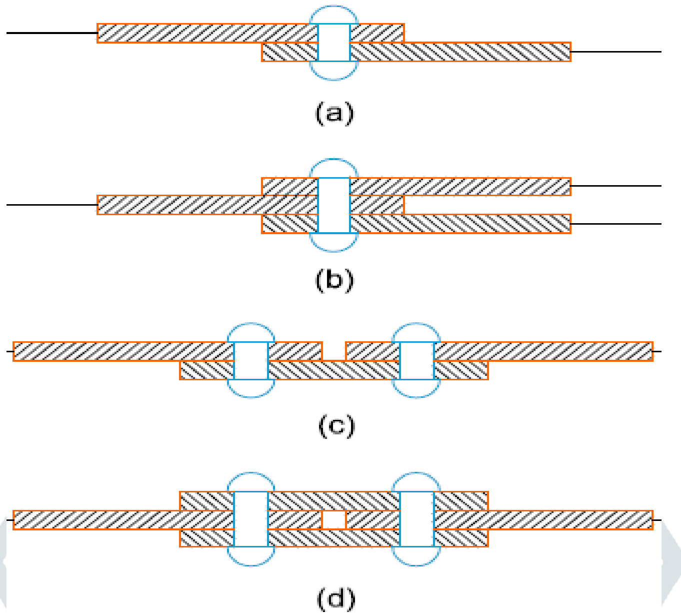

Figure 5. Types of bolted joints

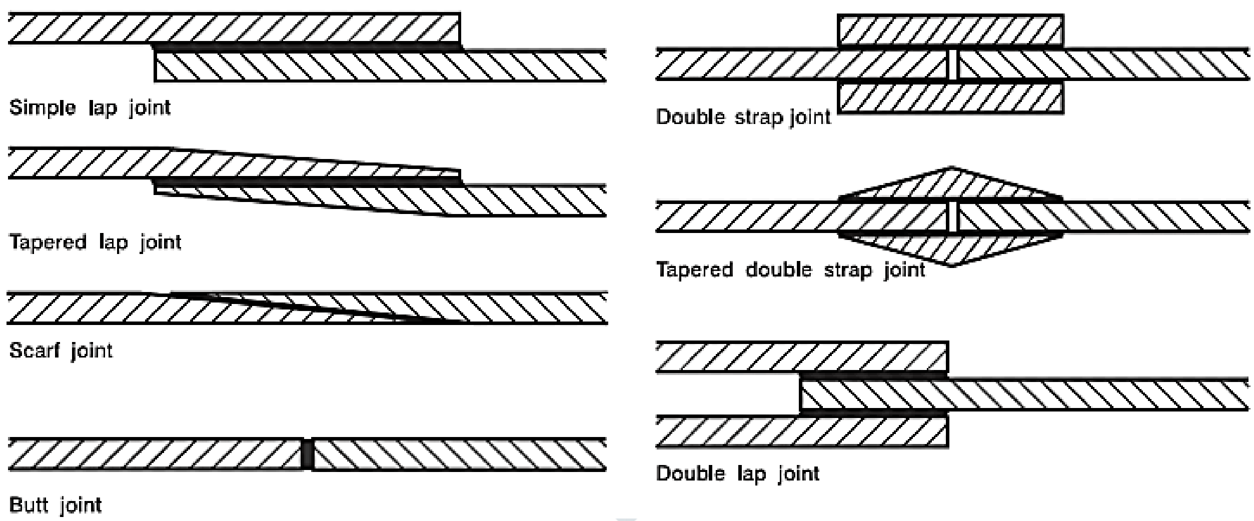

Figure 6. Adhesively bonded joints

2.Development of hybrid composite material

Synthetic fiber laminates like Kevlar fiber,Carbon fiber, glass fiber and epoxy resin commonly used in this study to prepare the hybrid composite laminate as shown in Figures 2, 3, 4 respectively.

Figure 2. Kevlar fiber

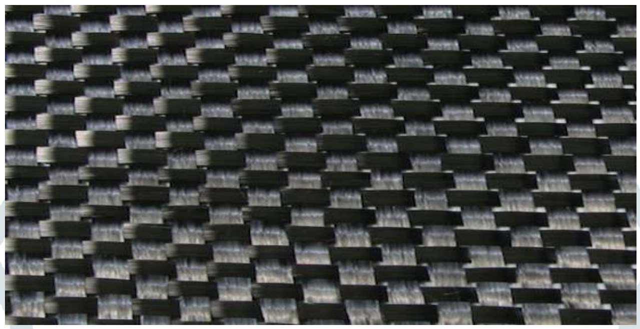

Figure 3. Carbon fiber

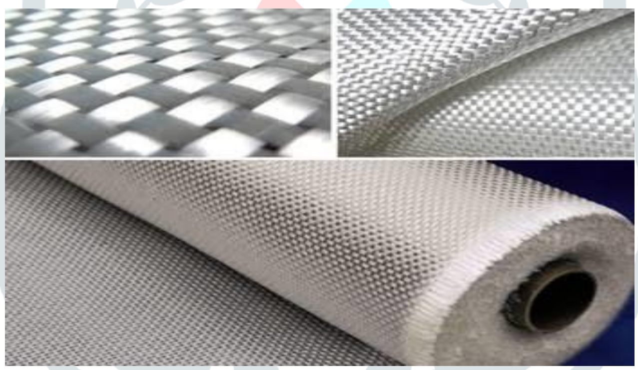

Figure 4. Glass fiber

These fibers possess remarkable properties like tensile strength is 58.9 (Mpa), density is 1.4 (g/cm^3), tensile yield strength is 2758 (Mpa) of the Kevlar fiber. Tensile modulus is 240GPa, Density is 1.7(g/m^3), tensile strength is 3800 Mpa of the carbon fiber. Density is 2.59 (g/m^3) and Tensile strength is 1300-2070Mpa of the glass fiber. Tensile strength is 320-800 Mpa and Density is 1.3 (g/m^3) of the Jute fiber. A hybrid composite material made by the compression molding machine with a stacking sequence of 45º followed by the ASTM standards.

2.1 Application and literature review of hybrid composite material

- These materials are used in mechanical joints like single lap pin joint and double lap pin joint etc.
- Carbon FRPs are used in higher resistance to erosion and electromagnetic transparency of carbon fiber reinforced polymer is important.

- Helicopters, chemical processing, aircraft and spacecraft, ships, automobiles,sports, civil infrastructure such as bridges and numerous equipment.
- Carbon fiber reinforced polymer composites are working for submerged piping and mechanical parts of the offshore stand.
- Fiber reinforcement plastic declines the risk of fire.
- It is used in high-performance hybrid structures.
- Fiber reinforcement polymer bars are used as internal reinforcement for concrete structures.
- FRPs are employed for seismic retrofitting.[21]

M. Tercan *et al.*[22]The weft-knitted rib Bearing strength of the GFPC plate pinned- joint in 3 dimension 0º, 45º, 90º were examined. Hot-press machine was used in this experiment. Knitted fabrics used for the study of epoxy resin manufacturing with 200 tex glass yarn. ASTM D953 was used in this experiment. Both parameter, ratio of the specimen width with pin dia. (W/d) and the ratio of edge distance to pin dia. (E/d) were steadily changed. Concluded that the extreme load arisen can be understood to 0.5 to 2 mm in pin-displacement for the three dimensions. To increase geometric parameter i.e. edge distance to dia. (E/d) bearing strength increases but keeping W/d ratio constant. Isotropic structures of knitted fiber composite material were shown. Width to dia. ratio Edge to dia. ratio and alldirections gave us bearing mode and this is the greatest manner of resisting the load. The net-tension weak type of failure mode shown when the ratio of Width to dia. is 4 and Edge to dia. the ratio was two. Kolesnikov *et al.*[23] Evaluated that a fundamental test aimed at the development of the composite aerospace structures; individual basic inter-linking implies an augmentation of an improved structure conveying about an extension in by and large common weight. The potential effect of cutting advancement and best performance materials of fiber composite is affected more strongly due to mechanical securing systems comparing with the general metallic materials because of the less shear value and bearing abilities of carbon fiber reinforced plastics materials. Thin titanium films adjacent installation into the laminate in coupling locale brings about a significant development in secondary efficiency of rivet joint or bolted joints in carbon fiber reinforced plastic structures. This improvement does not give clear ideas about the expansion in bearing capacities and shear, still additionally in the consequent potential results for plan no extensive burdened thru adjacent material solidifying, eccentricities and furthermore near bending stress it energized. This report shows experimental outcomes exhibiting the worthwhile impact of titanium hybridization on specific traits of carbon fiber reinforced plastic materials, along these lines representing the mechanical potential of carbon fiber reinforced plastic /titanium hybrid materials when cast-off as unconventional strengthening technique for extremelyoverloaded composite joints.The most extreme joint effectiveness utilizing hybrid laminates at an estimation of 65.7% on account of 0º on-pivot stacking (axis loading).Lee *et al.*[24] The main concern of this paper was to estimate and relate the strength of hybrid composite joints, mechanical joints, and adhesive joints. They used the failure area index method along with damage region method to forecast the strength of hybrid joint. Acoustic emission signal analyzer and high-speed camera were used to analysis of failure mechanism. Adhesive failure has arisen earlier mechanical joints for entirelybelongings. This paper also recommended the study of dynamic characteristics of hybrid joints like fatigue life and crack propagation in the interested element of the material. The catastrophe load of the hybrid joint was predicted to within 23.0%.Hai *et al.*[25] The numerical examinations on the auxiliary conduct of dual lap joint of steel plates bolted to pultruded half and half carbon fiber strengthened polymer/glass fiber strengthened polymer laminates. An aggregate of 45 ductile examples with twofold (double) lap reinforced joints and 6 huge gauge flexural shaft examples with or without the butt joints in the half-length area were led. 2 sorts of twofold lap joints were explored counting hybrid joints and darted joints (blasted and reinforced). Outcomes show that hybrid joint which consolidated of adhesive bonding, SS bolts, furthermore, V-scored splice plates is a powerful technique for linking the hybrid fiber-reinforced polymer laminate.Numerical investigation was completed to predict the load–removal curve of hybrid joints and outcomes indicated a decent relationship with the trials. Finite element analysis tensile test aftereffects of the hybrid joints with 2-jolt setup indicated a decent relationship with the trial in terms of the load-displacement curve.Franco *et al*.[26] Methodical examination of mechanical demonstration of hybrid double lap Aluminum glass fiber reinforced polymer-bonded bolted joints was done by utilizing test examinations and arithmetic imitations. To identify ideal symmetrical or geometrical setup, just to feature the commitment of epoxy resin (adhesive) and bolts, the outcomes comparative with hybrid joints were contrasted and basically bolted joints were adhesively reinforced.The test furthermore, arithmetical(numerical) outcomes were demonstrated that by utilizing the minimum overlay length gave since hypothesis, the bolt prompts huge reducing in most extreme shear and most extreme peel stress in the epoxy resin layer, thusly, the hybrid joint displays a static tensile strength that is equivalent to the aggregate of relative qualities comparing to essentially bonded joint or bolded joint. Besides, the arranged hybrid joint shows weakness quality and energy absorption higher than double of bonded joint over bolded joint. Uncertainty the improved bolt tightening torque is used in high cycles fatigue strength, the fatigue strength increased about +150% bypassing after the bolted or bonded joints to hybrid bolted bonded.Abdelkarim *et al.*[27] Examined the impact of type on bolt-on fatigue besides static performance of basalt fiber-reinforced polymer multi-bolted dual lap connection. Total 3 kinds of bolts were utilized, of basalt fiber-reinforced polymer, stainless steel, and hybrid steel Fiber-reinforced polymer bolts. Static tensile tests utilized on the steel single-bolted twofold lap connotations were led to decide failure modes and mechanical properties of projected bolts. Besides, the static test and exhaustion test were utilized on basalt fiber-reinforced polymer sandwich connections through 6 bolts of Stainless steel, basalt fiber-fortified polymer, hybrid steel-FRP were directed. Basalt fiber-fortified polymer bolts can be replaced by stain steel without influencing static and fatigue execution of joints. What's more, contrasted with the brittle failure of both the Stainless steel andbasalt fiber-fortified polymer bolts, the proposed hybrid steel fiber reinforces plastic bolts that displayed ductile actions which might be the way to accomplishing ductile composite constructions. In addition, hybrid steel-FRP bolts significantly drawn out the exhaustion life of composite joints contrasted withjoints with Stainless steel and Basalt-FRP jolts. The normal shear strength of hybrid steel-FRP bolts was 40.7 % higher than that of the Basalt-FRP jolts.Jeevi *et al*.[28] Composites have been utilized widely in different building applications including car, aviation, and building enterprises. Hybrid composites produced using at least two distinct fortifications show improved mechanical properties required for propelled designing applications. Numerous segments in the car are consolidated either by lasting or impermanent clasp, for example, bolts, welding joint furthermore, adhesively reinforced joints. Expanding utilization of reinforced structures is visualized for decreasing clasp check and bolted joints and thereby definitely decreasing in cost get together. Adhesive holding applied effectively in numerous advancements. A few parameters, for example, surface treatment, material properties, joint arrangement, geometric parameters, modes of failure, and so on that influence the exhibition of the adhesive reinforced joints were talked about. Natural features as preboned dampness and the temperature, technique for epoxy resin (adhesive) application were likewise referred. A hybrid bonded reinforced adhesively bolted joint is explained. Novel applications stand reaching out in field of composites connection and adhesive joint, it is essential to usage the data on different reign and they are direct in dissimilar regular circumstances to make enhanced adhesive joint structure in mechanical applications. This examination programming is useful in concocting systems to expand the joint execution and to diminish the heaviness of structure.

3.Results and discussion

Figure 5 is showing the final dimension of the specimen as per the ASTM standard the distance of hole is 20mm from the edge of the plate. Examination performed on carbon epoxy laminate and S-glass epoxy laminate under the tensile load of 400N. The main interest is to compare the stresses and strain in the plate with hole geometry.

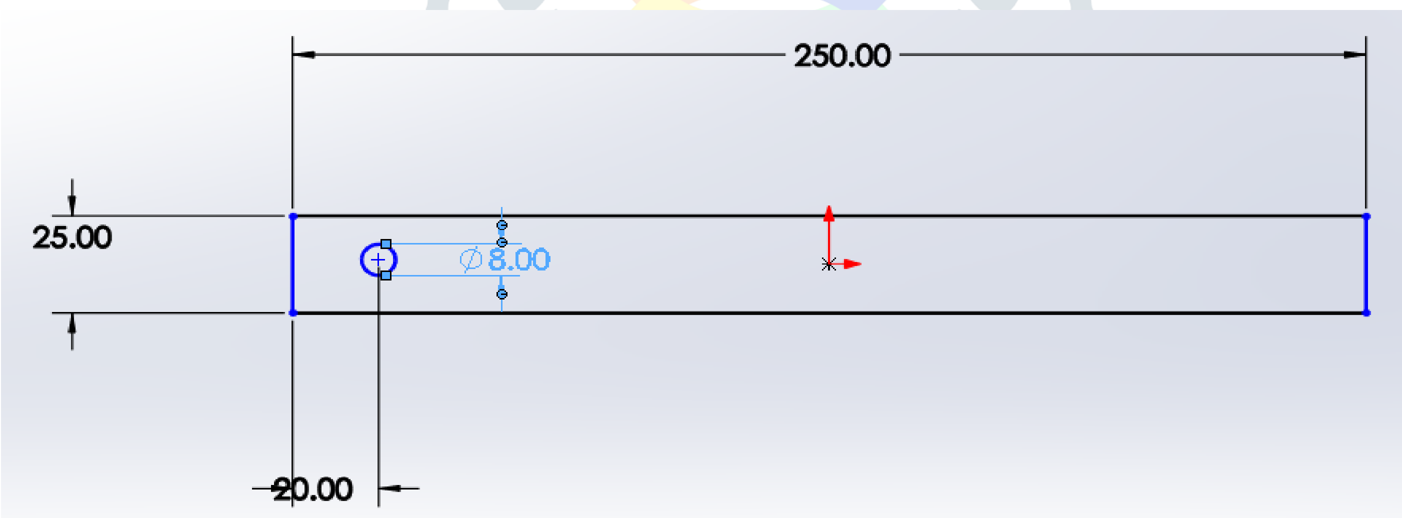

Figure 5. Specimen geometry

Carbon epoxy plate shows the maximum stress value is 14.298 MPa and minimum stress value is .026869 MPa and maximum strain is .0016487mm and minimum strain is $7.84e^{-7}$mm under the 400N tensile load. The stress produced around the hole of the plate as shown in figure 6 and figure 7.

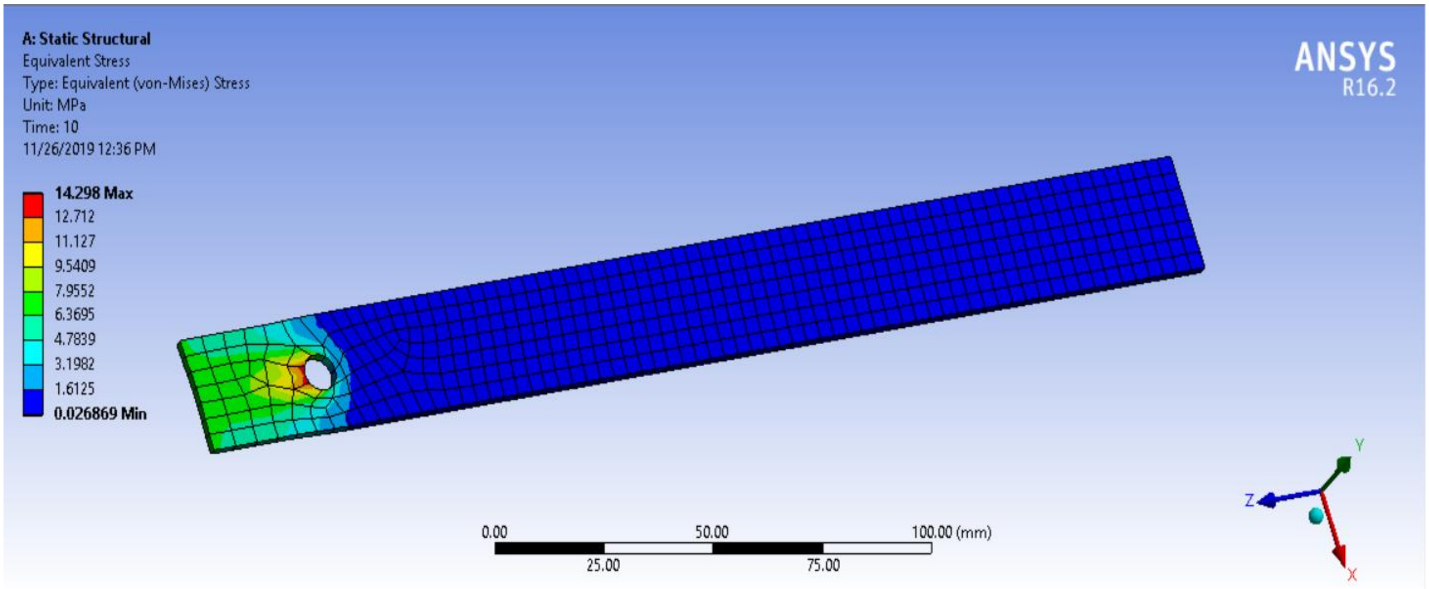

Figure 6. Stress in carbon epoxy lamiate plate

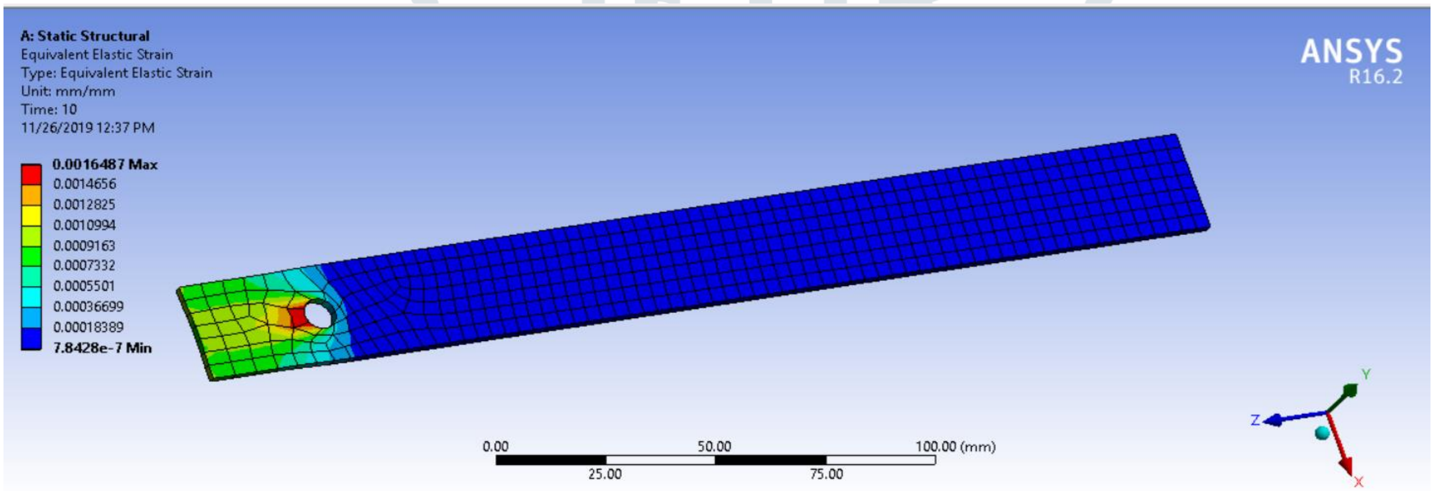

Figure 7. Strain in carbon epoxy laminate plate

Maximum stress in S-glass laminate plate is 14.065 MPa along with minimum stress is 0.0278 MPa and maximum strain is 0.0016797mm with minimum strain is $3.117e^{-7}$ under the 400N tensile load as showing in the figure 8 and figure 9.

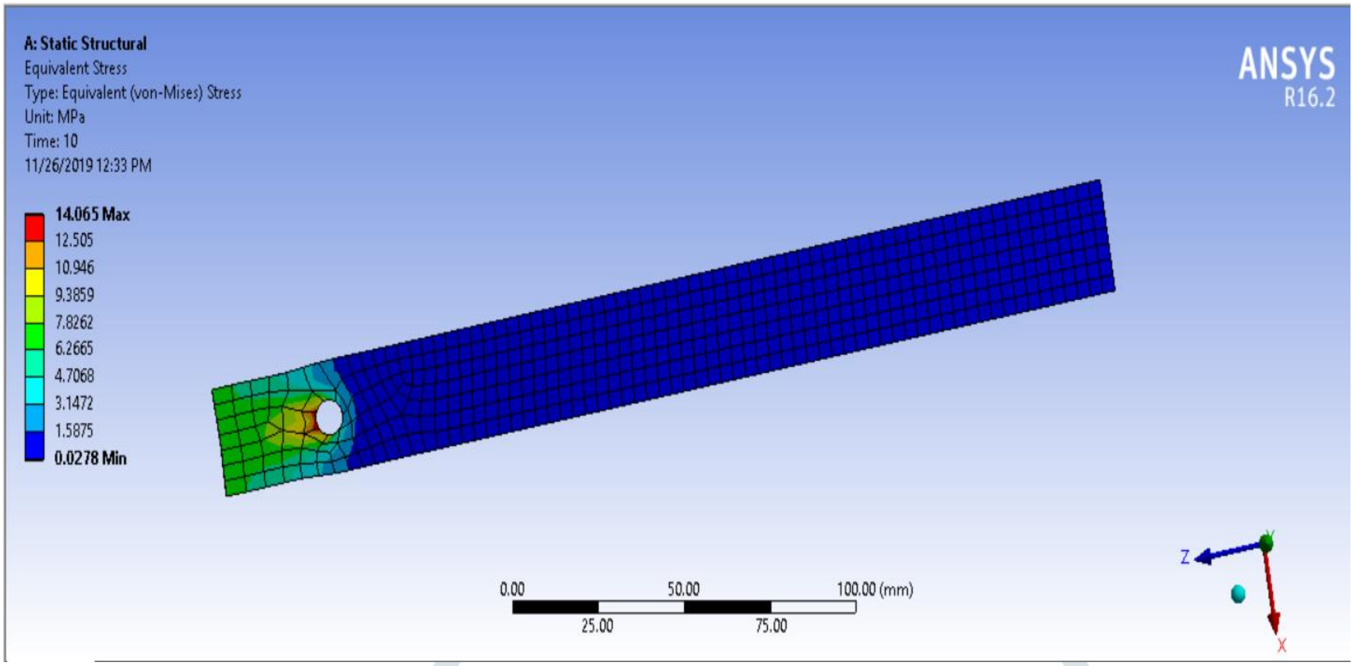

Figure 8. Stress in S-glass epoxy laminate plate

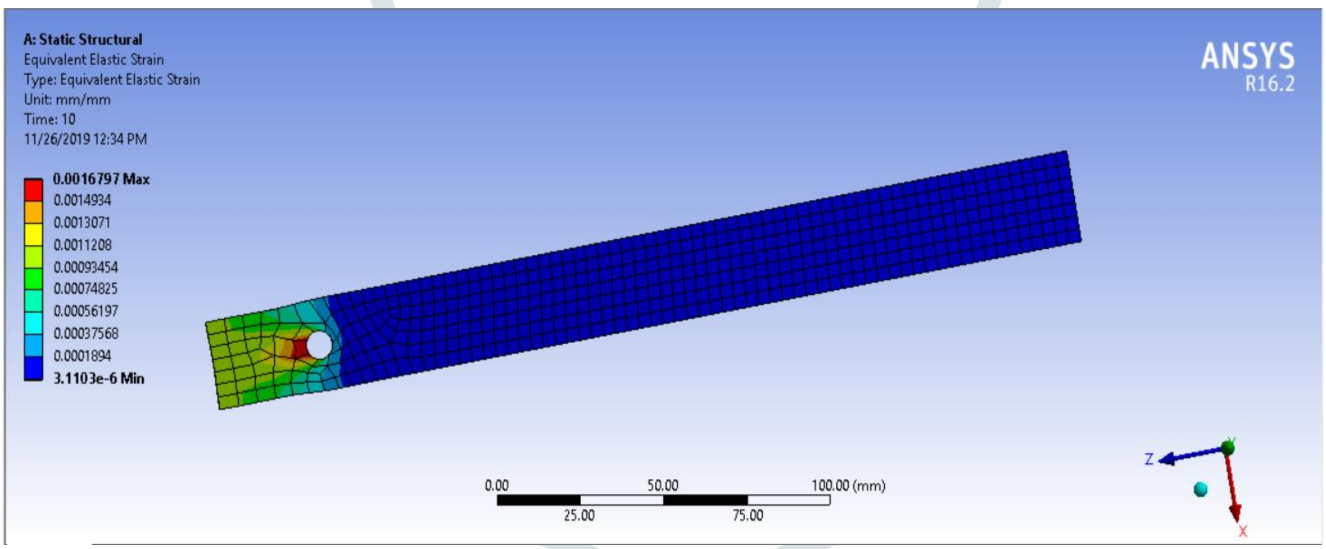

Figure 9. Strain in S-glass epoxy laminate

4. Conclusion

The S-glass epoxy and carbon epoxy is used to compare the tensile strength and elastic strain of the plate individually. The simulation is done in the Ansys workbench software of the composite plate.400N force is applied on the plate in both cases. All the peremater is specified in the examination and concluded some results like the maximum stress of carbon epoxy plate is 14.298 MPa and maximum stress of S-glass epoxy plate is 14.065 MPa and maximum strain in carbon epoxy plate is .0016487mm and maximum strain in S-glass epoxy laminate plate is 0.0016797mm. From these results the carbon epoxy plate with hole geometry has higher tensile strength as compare to S-glass epoxy plate with hole geometry under the same circumstances also the strain is little bit lower than the S-glass epoxy plate compare to carbon epoxy plate.

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