Critical Analysis of Filament Wound Struts Under Compression Loading With One End Fixed Other End Free Condition

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Abstract- *Specific strength and stiffness ratios are important structural design parameters in aerospace and automotive industries.This development is motivated by the demand for corrosion resistant, lighter and and high specific stiffness components. Numerical analysis were conducted to determine the stress and strain behaviour and also to find the better orientation sequence of struts under compressive loading with one end fixed and other end free condition and compare the results with experimentation. The analysis were made by changing the orientation angle and tested and strain gauges were used to measure the strains in longitudinal and lateral directions.*

Keywords- Frp composite struts, compression loading, FEM analysis, strain gauges, orientation angle

I. INTRODUCTION

Properties of composites are strongly influenced by the properties of their constituent materials, their distribution, and the interaction among them. The composite properties may be the volume-fraction sum of the properties of the constituents. The orientation of the reinforcement affects the isotropy of the system. When the reinforcement is in the form of particles, with all their dimensions approximately equal, the composite behaves essentially as an isotropic material whose properties are independent of direction. FRP composites consist of an engineered polymer (plastic) and reinforcement (i.e. glass) and can be additionally enhanced with other elements such as additives and core materials. This combination can produce some of the strongest materials for their weight that technology has ever developed...and the most versatile. FRP composites have many benefits to their selection and use. The selection of the materials depends on the performance and intended use of the product. Polymer matrix composites offer several advantages over metals, ceramics and plastics such as low weight, flexibility in design, parts consolidation, dimensional stability and corrosion resistance. Glass fiber reinforced plastic composites offer exceptional properties in structural applications that require high strength to weight ratio therefore their demand in aircraft structures has been raising in recent years.

Commonly truss is the most efficient structural forms which has been widely investigated and used. FRP composite truss has been applied in various advanced transportation technologies such as airship, iso-truss and space truss bridges. The mass and buckling load were reported to be the most optimal objective to design one fiber system or ply stacking sequence.A comprehensive study of failure developing in composite structures under complex stress field is of vital importance in understanding material performance and establishing damage tolerant design practices.

This paper presents the results of struts with one end fixed and other end free condition and how the stresses and strains are vary according to the orientation angle and which is the best orientation angle for one end fixed and other end free condition.

II. RELATED WORK

Thamir.A.D.M.S Almula et.al [2015] conducted tests on orientation angle of ±450,550,650,750 and observed the stress-strain behaviour with the in tension of to find the effect of ply angle and concluded that hoop strain decreases with increase in orientation angle and get high stiffness and tensile stress in tensile hoop direction and longitudinal strain is reduced. Interestingly Qian Zhang et.al[2019] discussed the effect of layer thickness, winding angle and reinforced volume fractions and effective elastic constants and indicates that the pipes with small winding angle has good stiffness in circular direction and poor stiffness in axial direction and winding angle could influence the stress distribution of the reinforced laminate and plays quite important role in mechanical properties.(drew graphs between angle in horizontal axis and modulus of elasticity in vertical axis and angle in horizontal axis and poison’s ratio and modulus of elasticities in other y axis) and P.B.Ataabadi.et.al[2019] carried a series of experiments of different combinations of mass and velocity of the striker and concluded that no significant effect on crushing behavior of the lay ups and strain rate is independent and also concluded that 35% of the energy is absorbed by quasi static compression and the remaining energy is absorbed by the damage mechanism in other layers and some people are used frp struts with sand which material, matrix.Michele D'Ottavio et.al [2016]found FE solutions for local and global buckling of sandwich struts and prepared series of equations to find the buckling and also concluded that initial load is carried by the skins only and if axial stiffness of the core is neglected lower buckling loads are usually obtained.some scientists tested these material under internal pressure ,Roham Rafiee Et.al [2016]prepared glass fiber reinforced plastic pipes to evaluate the performance by applying internal pressure. They analysed the creep evaluation, stress analysis, failure analysis and degradation of mechanical properties. They prepared a computer code for to analyse all the properties and also stress/strain distribution and concluded that filament winding methods are stronger against creep phenomenon and some are tested its burst strength, A.Hawa et.al[2015] tried to find the Burst strength and impact behaviour of hydro thermally aged glass fibre/epoxy composite pipes and concluded that force and displacement increased as the impact energy increased and also impacted by higher energy yielded lower burst strength.Some scientists are used frp material to repair the concrete bridges as a supports so Dylan Brown et.al[2015] prepared strut-and tie models for of repaired precast concrete bridge structures with CRPF shells and concluded that frp shells can also use for supporting of existed columns and also for repair works and Qianqian Sui et.al [2015]explained the failure modes of one dimensional lattice composite structures and explained the fracture of the strut, global buckling, shell like buckling and monocell buckling and concluded that buckling is greatly depends on length. They proposed theoretical equations to explain the failure modes. Xiaolei Zhu et.al[2015] proposed the theoretical equations and optimization techniques for composite struts and theses are compared with FEA results and concluded that shear deformation must considered for orthotropic composite materials and also conclude that buckling load was influenced by stacking sequences. Some are tried the theoritical results with their practical work to extract the good results,M.Menshykova et.al[2013] tried to compare the results of thick walled composite pipes with fem theoretical bending equations .The results are developed using mat lab.Surprisingly some sceintists tested their samples after immersion of sea water for 3,6,9 months , Mehmet Emin Deniz Et.al [2013]prepared glass –epoxy composite pipes and immersed in sea water for 3,6,9 months and conducted tests on those pipes by impact and compression tests and concluded that these pipes exhibits more elastic properties than the dry pipes and matrix debonding also increases ,matrix failure increases with increase in immersion time. Xiaolong Jia et.al[.2013] interestingly analysed the effect of geometric factor, winding angle and pre-crack angle on quasi-static crushing behavior of filament wound cylinder and concluded that with winding angle increasing the compressive strength, compressive modulus and crack length of the cylinder exhibited decreasing trend.some are used mat lab to check the results but some are used abacus also,Luiz A.L.Martins et.al[2012] investigate the failure pressure of filament wound composite tubes using ABACUS with different winding angles with closed end conditions and concluded that properties are depends on fiber angle and volumetric fraction.Suzan A.Aet.al[2011] tested struts under pin jointed and applied load under gradually ,interestingly the struts are used to strengthen the cast iron struts and observed failure modes ,first the frp struts fails and then cast iron struts but they have given prior indication before fail.A.E.Antonio et.al[2010] made research on glass/epoxy under compressive loading in cruciform specimen and concluded that compressive strength in fiber direction was degraded along with shear modulus reduction and compared the results with fem analysis.Chul-jin moon et.al[2010] investigations made on filament wound composite cylinders under compression loading and the cylinders are used for under water applications and concluded that winding angle is the predominant factor and compressive strains in the circumferential direction are larger than those in axial direction .Hseyin Arikanet.al [2010]investigated the failure analysis of filament wound glass reinforced plastic pipes made of e-glass/epoxy with different winding angles with crack –to –thickness ratio 0.05 and applied internal pressure under open end conditions and concluded that the angle of the crack in GRP pipes increases the burst pressure increases and the effect of the crack angles decreases and also concluded that burst strength is highest for 550.

Finite element modelling

To obtain the accurate simulation of the actual behaviour of the FRP strut s,the elements composing the finite element model has to be choosen properly.In addition ,it was essential to carefully select the mesh size to give good accuracy for the results and a reasonable computational time.The analysis was performed using the ANSYS program.Material and geometric non-linearity were included in the analysis . At first a 4-node shell element [shell181] was used to model the strut.This gave good results for the FRP struts.

Materials and manufacture

Glass fiber reinforced polymer tubes were fabricated using a filament winding machine.This machine has a capacity of producing parts up to 3000 mm of length and 500 mm in diameter.E-glass fiber roving with 16 µm diameter was used as reinforcement .Six rovings were used forming a band width approximately 18 mm wide.Five tubes were manufactured ±200,±250,±300,±350,±400 After fabrication the tubes were cut and mapped to obtain the dimensions data to be used.The struts can be manufacture with 30 mm outer diameter and 24 mm internal diameter and 250 mm length..

Test procedure

Before every test .the pipe was visually inspected to determine any obvious defects that may have occurred during manufacturing or transportation to the lab.The pipe was carefully placed on the workbench,and the end fittings were installed.Next the strain gauges were placed in the middle of the pipe diametrically opposite to one other.Before placing the strain gauge the top coating from the pipe surface was removed sing sand paper in order to obtain a direct contact between the strain gauges and the pipe wall.The strut were placed with one end fixed and other end is free to move condition.This was to prevent any influence of the support on the measured strains .During the procedure either hoop or axial strain was measured where axial strain measurement was preferred for axial dominated loading.The strains along longitudinal as well as hoop direction was carefully measured

Tabular forms

From Ansys

S.no	Orientation angle	Load kn	Longitudina l strain	Hoop strain	Longitudin al stress	Hoop stress
1	0	56	0.000575	0.0011	6.65	204.322
2	10	54.5	0.00057	0.0014	6.59	193.665
3	15	53,75	0.00042	0.00126	6.29	200.72
4	20	53	0.000165	0.0013	5.92	206.58
5	25	24	0.00053	0.00068	2.53	92.21
6	30	22.5	0.000587	0.00078	2.12	82.417
7	35	21	0.000992	0.00092	1.67	73.886
8	40	20	0.0012	0.0012	1.26	70.07

From project work

S.no	Orientation angle	Load kn	Longitudinal strain	Hoop strain	Longitud inal stress	Hoop stress
1	0	56	0.00056	0.0011	6.65	204.322
2	10	54.5	0.00045	0.001102	6.59	206.29
3	15	53,75	0.000615	0.0011	6.29	207.28
4	20	53	0.00085	0.001104	5.92	208.7
5	25	24	0.000705	0.00173	2.53	94.314
6	30	22.5	0.000759	0.00128	2.12	88.457
7	35	21	0.000856	0.00838	1.67	82.527
8	40	20	0.000912	0.0012	1.26	78.628

III. RESULTS AND DISCUSSIONS

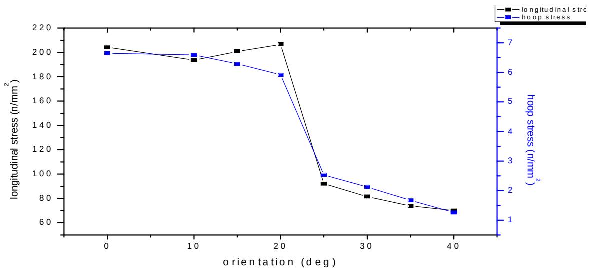


Figure 1

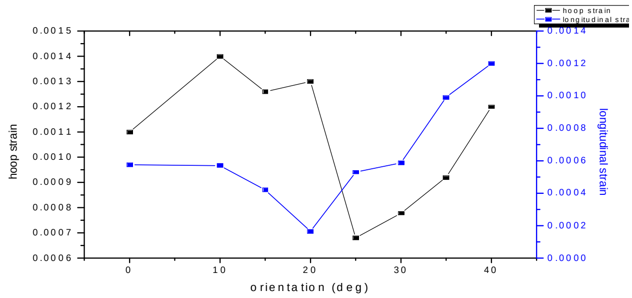


Figure 2

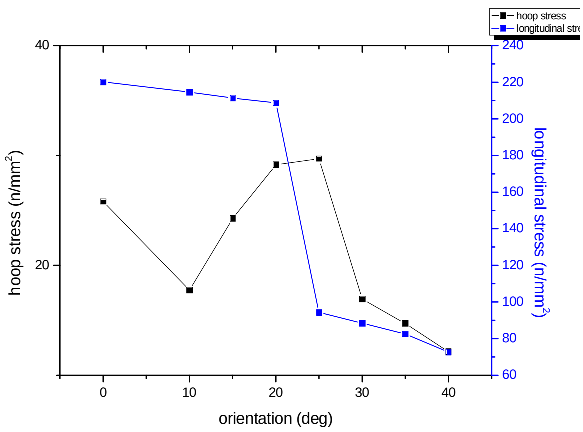
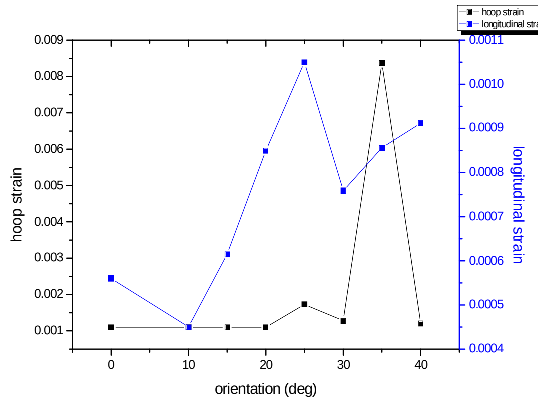


Figure 3



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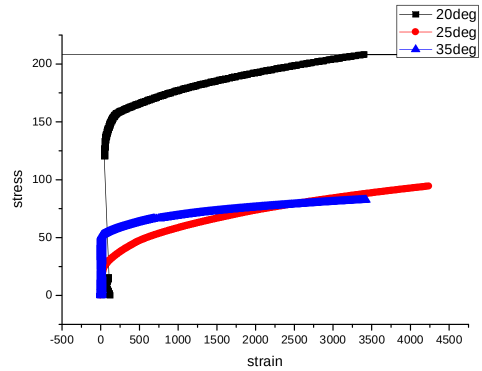
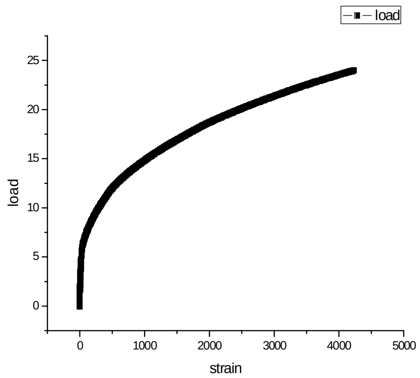


Figure 7



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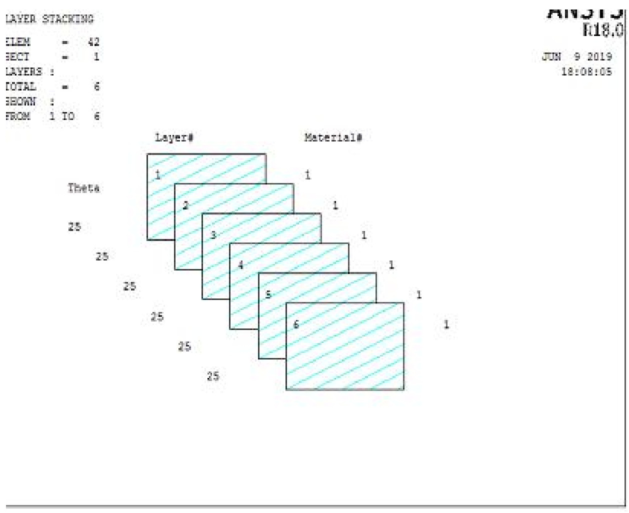

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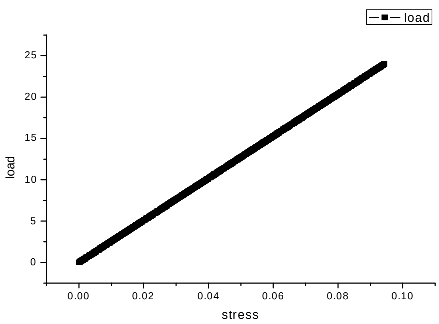

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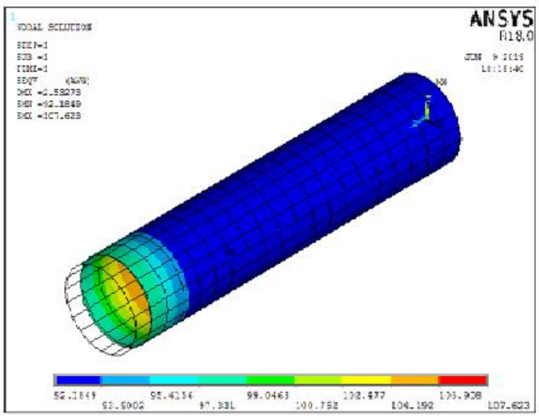

Figure 9

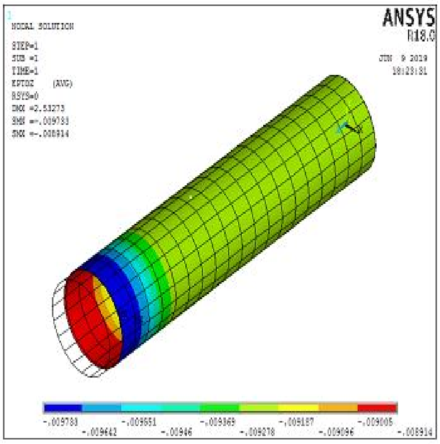

Figure 10

Figure 11

Fig-1 explains the longitudinal stress and hoop stress along with orientation angle obtained from the analysis using with analysis soft ware ansys.Fig-2 explains the longitudinal and hoop strains from the analysisFig-3 explains the longitudinal stress and hoop stress along with orientation angle which is obtained from practical results Fig -4 explains the longitudinal strains and hoop strains along with orientation angle from the practical results Fig -5 explains the load vs strain Fig -6 explains the load vs stressFig-7 explains the comparison of stress vs strains with different orientation anglesFig-8 explains the staking element or layered elementFig-9 explains the stress distribution along the strut Fig -10 explains the strain distribution along the strut,Glass fibers are strong in longitudinal direction weak in hoop direction.If we observer the figres1,2,3,4 longitudinal stresses are decreasing along with fiber orientation angle but they are increasing along with orientation angle but both are shoeing moderate stresses and strains at ±250 orientation angle.From the figures 5&6 shows that they exhibits linear curves but there is no break point because the fibers are not collapse/breaks at a particular point but first they whitening the surface and delaminate and then finally collapse.From figure 7 we can compare the stress -strain diagrams of different orientation angles at a time from the diagram also we can estimate that ±250 orientation angle is exhibiting moderate stresses and strains among all the orientation angles.

IV. CONCLUSIONS

According the diagrams and results obtained from the Analysis software Ansys and the practical work we can assume that ±250 orientation angle is best among all the orientation angles and also the theoritical results and practical results are very nearby values so we can conclude that struts with one end fixed and other end free condition ±250 orientation angle suggestible.

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