Influence of Stacking Angle on Filament Wound Glass Epoxy Struts under Tensile Loading

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Abstract

As one of the most efficient structures glass fiber reinforced polymer composite truss is typically find its applications in advanced transport engineering field. The composite truss should consider not only in problem of mass but also the buckling load. The major applications of composite truss are airship, iso truss, and space truss bridges. This paper presents the results of an experimental investigation into the behaviour of filament wound multi directional glassfiber /epoxy strut under tensile loading, considered as both ends hinged condition.

I. INTRODUCTION

Reinforcement on tubes and pressure vessels and struts have been used for centuries to improve burst strength. The use of filament winding to manufacture high strength and low weight structures are relatively recent. The fiber reinforced polymer composites can also be used for strengthening or stiffening existing structures. The problem with cast iron is usually week in tension. The use of composite material is usually higher than that of the corresponding isotropic material and its strength to weight ratio is high, filament winding is one of the few automated processes currently available for producing composite components with continuous fibre reinforcement arranged carefully controlled directions. High strength, low weight and corrosive resistance have led to the use of such components. The winding angle is a major variable determining their mechanical performance. The object of this paper to find the influence of winding angle on the deformation and strength of filament wound glass fiber reinforced struts.

II. EXPERIMENTATION

By using ANSYS software a filament wound strut of 6 layers is designed. Each layer has 1mm thickness. The strut material is considered to be glass fiber and the resin is epoxy. According to ASME standards the diameter is 30mm.Using L/K ratio the length is calculated as 263mm. From EULERS buckling load formula, when both the ends are in hinged condition then different loads are calculated for different orientation angles with 60% volumetric fraction of glass fiber and 40% of resin. Among all the different loads (i.e distributed loads) under different orientation angles the maximum load of 4531N is achieved after taking 50% more than the safe load. Thus we obtain hoops stress and longitudinal stress for different orientation angles. By comparing these stresses we obtain the accurate orientation angle. For calculation of maximum load Euler's formula

$$\mathbf{P}= \frac{\pi 2EI}{L2}$$

And for distributed load $= \frac{P}{2\pi r}$

With young's modulus, poisons ratio and rigidity modulus as per the angle-ply layup Calculations .the axial and radial direction stresses are calculated. The main purpose of This research is to measure best filament stacking angles

III. RELATED WORK

Michael R.Wisnom et.al(1994) conducted experiments on carbon fiber/epoxy struts for buckling and failure of struts and they concluded that failure occurring due to either tension for relatively long struts or interlaminar shear for short struts and also concluded that shorter strut will buckle at much higher stresses and shear deformation has a significant effect on the response[1].Suzan A.A.Mustafa et.al (2011) used reinforced polymers to strengthening cast iron struts they used technique of finite element modeling and they concluded that full bond between the CFRP and cast iron if they use together shoes higher elastic modulus and deflections are predicted to be high[2].S.K.Deb Nath Et.al(2009) found displacement potential solution of stiffened composite struts subjected to eccentric loading and conducted experiments on Boron epoxy composite is considered as the strut material and concluded that compressive

loading in axial direction should normally lead to expansion in y-direction.the axial displacements at the stiffened boundaries and both the components of displacements at the supporting edge of the strut are zero[3].P.D.Soden et.al (1993) made investigations for finding the influence of winding angle on the strength and deformation of composite tubes subjected to uniaxial and biaxial loading and concluded that higher winding angle gave higher circumferential tensile strength and lower angles give higher axial tensile strengths and also maximum circumferential leakage and fracture stresses occurred at higher stress ratios [4].A.E.Antoniou et.al(2010)conducted experiments to find the failure prediction for a glass /epoxy cruciform specimen under static biaxial loading and
concluded that the compressive strength in the fiber direction was degraded along with shear modulus reduction and this formulation improved numerically strength predictions[5].A.S.Kaddour et.al(2003) tried to find the behaviour of ±450 glass/epoxy filament wound composite tubes under biaxial tensioncompression loading and found that minimum wall thickness of 3mm are necessary in order to prevent failure by shell buckling .And ±450 tubes were all softer and all exhibited much larger failure strains than those exhibited during testing of isolated lamina[6].P.Mertiny et.al(2004) explored on effect of multi angle filament winding on the strength of tubular composite structures and found that the failure modes at structural failure depend on the applied stress ratio and finally conclude that multi angle filament winding is a valuable method for proceeding tubular structures particularly if variable loading conditions need to be considered .Michele D'Ottavio et.al (2016) prepared kinematic model to test the sandwich strut for global and local buckling and concluded that if the axial stiffness of the core is neglected lowers buckling loads are usually obtained .[8].Qianqian sui et.al (2015) proposed the failure analysis of 1D lattice truss composite structures in uniaxial compression and they proposed four failure modes 1are fracture,global,shell lattice and monocell buckling by changing bay length and column length[9].H.Bansemir (1997)proposed recent and future developments in fiber composites to use as space applications and found that proper section of materials and laminate lay outs lead to efficient light weight structures which can meet the sophisticated requirements of future
developments for apace applications[10].Dawn C Jegley et.al (2012) found the structural efficiency of composite struts are approximately 30% less than the equivalent aluminum struts and struts are important load carrying element in antennae, solar panels,lander struts etc[11].M.Martens et.al (2000) explained the monotic behaviour or a multidirectional glass fiber epoxy pipe and found that the mode of failure, the type of accumulated damage ,the
linearity limits on both the stress-strain depends on the applied biaxial stress ratio[12]. F.Ellyin et.al(2001)tried to explain the biaxial fatigue behaviour of multi directional filament wound glass fiber /epoxy pipe and concluded
that the observed damage indicated that the amount of axial tension in the specimen governs the uniformity of the matrix cracking where internal pressured governed the amount of delamination[13]. Roham Rafiee(2016) tried to evaluate the long term performance of glass fiber reinforced plastic pipes with both ends in open condition with ply angle ±550 with pressure of 2.34 Mpa and concluded that at higher pressure levels all layers are failed almost at the same time however in lower pressure levels a considerable time gap can be realized between first ply failure event and functional failure[14].David L.MC Danels(1984) found that ductility of composites was dependent upon reinforcement content and matrix alloy and also composites with lower reinforcement contents exhibited a ductile shear fracture with a 5 to 12 %failure strain and higher degree composites preferred orientation tended to have higher ultimate tensile strengths in the direction of orientation[15]. Xiao lei Zhu et.al(2015) prepared a optimization technique using generic algorithm and concluded that thermal expansion coefficient was related to percentage of stacking techniques of the buckling load area influenced by percentage of stacking sequence [16].LCHollaway et.al(2002)conducted experiments on advanced polymer composite materials and elevated that frp plate bonding is becoming attractive to highway and consultant engineers for maintenance of buildings and bridges and cost wise it is saving 125% comparatively steel and other materials[17].

IV. RESULTS AND DISCUSSIONS

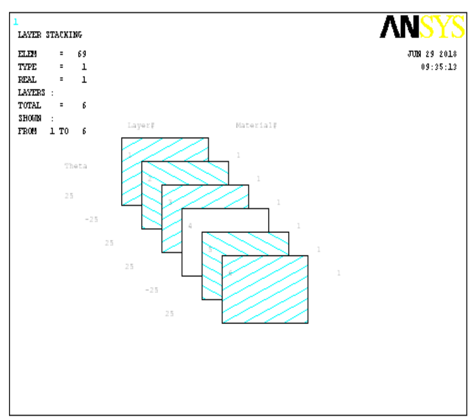


Figure 1

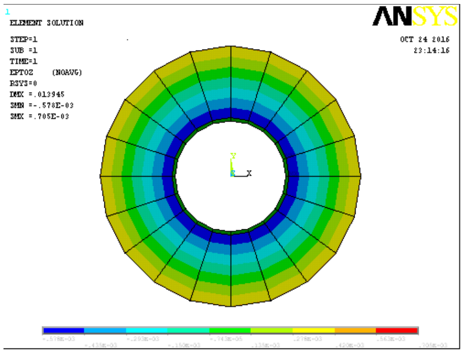


Figure 2

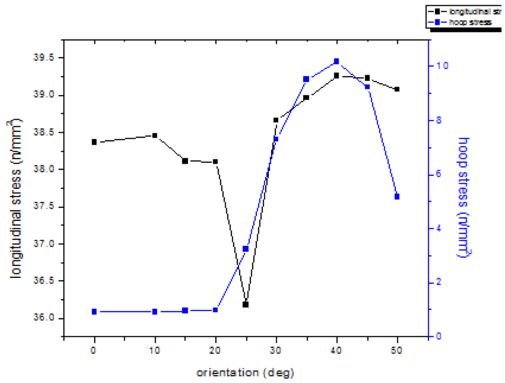
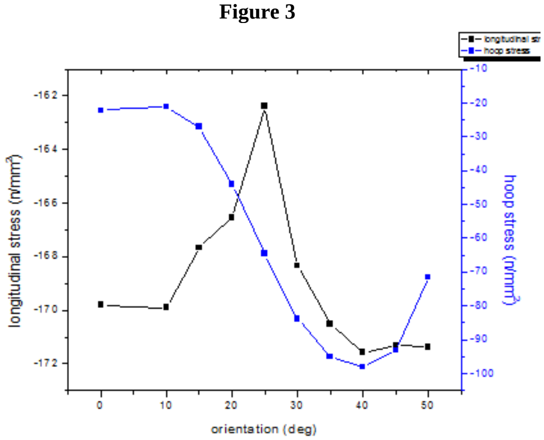


Figure 3



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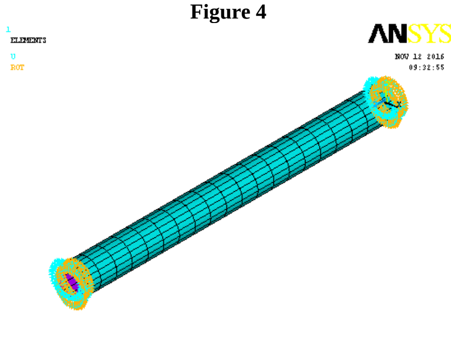

Figure 5

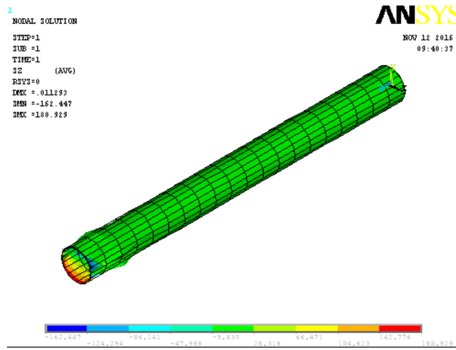

Figure 6

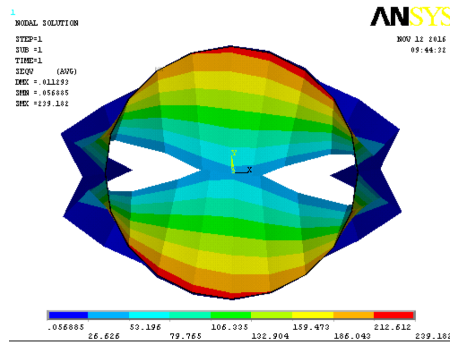

Figure 7

Figure .1 explains the layered element. Here stacking of the element is ±00 to 500 are considered. At each stacking of the element applied the loads from highest (4531) and minimum load (2981).Figure 2 explains the stress distribution across the strut and we abserve that the major stress is appeared at the inner layers of the stress and the strut may fail near the end which the load is applied. Figure 3 and 4 explains the stress distribution of the strut at maximum loads and minimum loads. The fibers are strong in longitudinal direction and weak in transverse direction and longitudinal stress is increasing from bottom to top and hoop stress is decreasing from top to bottom but at 250 the two stresses are nearby values and moderate in both the stresses neither too high nor too low.figure 7 explains the strain distribution across the strut and the strain values are below 0.002.

V. CONCLUSION

As per the above discussions the filament stacking angle is 250 is suitable for filament wound struts which can withstand the longitudinal stresses as well as hoop stresses and their strain value is below 0.002.The analysis is made by ansys and the design is safe and acceptable too. The design is much more useful to analyze the composite truss where ever light weight structures are required.

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