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Effect of Winding Angle and Failure Analysis of Struts Made of Filament Wound Glass Epoxy Polymer

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Abstract: *The aim of this paper is to explore and investigate the usefulness of filament wound struts in construction field and roof structures. The present study focuses on the effect of winding angle of strut made of filament wound glass epoxy with both ends hinged condition. To obtain the best helix angle Euler's critical load equations and mathematical techniques and finite element analysis have been incorporated in order to verify the simulation results of our experiments. The design of struts made with glass fiber reinforced polymers is essential in respect of its functional and structural load bearing behaviour for internal pressure containers with excellent cost and weight effective. The outcome of our study will be handy reference for designing light weight engineering structures.*

Keywords: *Composite Struts, Euler's critical load, finite element analysis, ansys.*

I. Introduction

It is well known that the most composite materials developed thus far have been fabricated to improve mechanical properties such as strength, stiffness, toughness and high temperature performance [1],[2],[3].As a matter of fact that the strength mechanism strongly depends on the Geometry of the Reinforcement [4]. The outstanding features of oriented fiber composites are their high strength – weight ratio and controlled anisotropy. The principle advantage of glass fiber is the low cost and high strength. Their usefulness is growing rapidly owing to a significant reduction in their price and increase in their availability. The composites are now used not only for Aerospace applications but also utilized in Automotive and civil engineering infra structures and many other consumer applications. The matrix has a strong influence on several mechanical properties such as transverse modulus, strength, and shear properties in compression. The present paper reports new results on the effect of winding angle of filament wound glass epoxy struts under both ends hinged condition. The present results includes stress vs. winding angles and strain vs. winding angles, Graphs showing the variation of Mechanical Properties .This paper begins with the description of numerical model ,material properties and structure analysis.

II. Related Work

Orientation of fibers with respect to the loading axis is an important parameter, for instance, fiber orientation directly affects the distribution of load. Many research scholars worked on the composite materials and tests were carried out to find the properties of materials under various analyses. *Ekaterina demianouchko et.al* (1997) explains the stress analysis of a $\pm 55^0$ filament wound composite tubes with damage on the periphery, and concluded that stresses inside the transition zone do not depend on the size of the element and depends on its character of anisotropy [1]. *A.E.Antoniou et.al* (2010) tried to explain the failure prediction of composites under biaxial loading and conclude that failure of delamination occurs while applying loads because load weakens the interlaminar shear stresses[2].The composites can also used for under water applications.chul-jin moon et.al (1010)explains the buckling and post buckling behaviour of composites under water[3].*Huselyn Arikan* (2010) explains the failure analysis under static internal pressure and also explains the effect of crank angle[4]. The mechanical properties of composites were investigated and studied by M.Torres Arellano et.al (2010) and observed that the strain variations of composites [5]. Xiaolong Jia et.al (2013) explains the effect of geometric factor, winding angle and crushing behaviour of filament wound cylinder and explains at lower winding angle of $\pm 20^0$ the material should be brittle and crushing made at $\pm 40^0$ and compressive strength initially decreases and then increases[6].P.D Soden et.al (1993) also explains the influence of winding angle and found that higher winding angle gave higher circumferential strength and lower winding angles give lower strengths[7].Some research scholars explains the rate dependent beheaviour of frp tubes ,the rate depends on the stresss –strain ratio and rate of loading[8]C.S Lee et.al (1999) failure of composite tubes under combined axial and torsional loading and conclude that there is a strong interaction between axial and shear stresses at failure[9].the effect of frequency is mainly due to a creep/fatigue interaction and damage depends on stress ratio[10].

Many are tried to explain the effect of winding angle.J.Rousseau et.al(1999) explains the influence of winding pattern after conducting many mechanical tests revealed that residual strains are very low and winding angle greatly influenced[11].Martyn Hucker et.al (2003)also worked on Glass/epoxy composites under compressive loading and found that CRPF posses a high elastic modulus and good performance under tensile loading than the compressive loading[12].composites are not only used in flat and circular shapes but also used in cone shape. *Asad A. Khalid* et.al (2001) performed experiments on composite cones and explains that when cone angle increases can with stand high loads [13].*E.Mahdi* et.al (2001) explains that cone vertex angle between 20^0 to 25^0 exhibits good absorption capability [14]. Rust is the serious problem in concrete structures so some research scholars contribute their work on the composite with effect of sea water.*Heien-Kuang Liu* et.al(2002) contributed their work for strengthen the reinforced columns with composite polymers, for this they kept specimens under water for 450 days and conclude that winding effect is more on mechanical properties[15].*Wei-Chong Liao* et.al (2004) used composites fibers for civil engineering structures like pillars and found that there is a good correlation between concrete and composite structures.[16].*Hsien –Kuang Liu* used the composites to increase the strength of concrete cylinders under compressive loading[17].*Garret Meijer* et.al (2008) worked with $\pm 60^0$ winding angle and found that failure under hoop load is because of Matrix failure but not Fiber fraction[18-19]. *A.S Kaddour* et.al (1996) worked on filament wound epoxy tubes and explains the burst behaviour of $\pm 75^0$ [20].

III. Experimentation

This investigation was explored by using the most popular numerical tool, namely, ANSYS to design and analyze a filament wound strut of 6 layers. Each layer has 1mm thickness. The strut material is considered to be glass fiber and the resin is epoxy. According to standards the diameter is considered as 30mm.Using L/K ratio the length is calculated as 263mm. From EULERS buckling load formula and other mathematical formulations, under the end conditions are both the ends hinged, and then different loads are calculated for different orientation angles with 60% volumetric fraction of glass fiber and 40% of resin. The maximum load is calculated from Euler's buckling load formula. The load is applied as distributed load, under different orientation angles the maximum load is calculated and took 50% more than the safe load then the maximum load is calculated as 4529KN and minimum load is 906KN.Then calculated the hoop stress and longitudinal stress for different orientation angles. By comparing these stresses we obtain the accurate orientation angle. 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 winding angles of composite strut.

IV. Results And Discussions

The longitudinal stress and hoops stresses are taken on y axis and winding angles are taken on x axis and the curves are obtained as per the load calculations. fig.1 is drawn between the maximum longitudinal and hoop stresses at maximum load, As per fig.1 the longitudinal stress is first decreasing and then after ±30º orientation angle the stress is increasing up to $\pm 50^0$. The hoop stress is first decreasing and after ±20º orientation it is increasing up to ±40º and then decreases. So this reveals that the fibers with ±0º angle are weak in circumferential direction and strong in longitudinal direction. But at ±25º both hoop and longitudinal stresses are almost same, and for fibers at ±50º the stresses in longitudinal direction are more and the stresses in circumferential direction are less. It explains that fibers are strong longitudinal direction is strong but weak in circumferential direction. Fig.2 is drawn between the minimum longitudinal and hoop stresses at maximum load, From fig.2 ±0º orientation longitudinal stress are is less than hoop stresses after ±30º orientation longitudinal stresses are decreased and hoop stresses are increased but around ±25º both the stresses are almost equal and at this condition strain should be less than .004. Fig.3 shows the stresses at minimum loading conditions and fig.4 explains the longitudinal and hoop strains. Fig.5 depicts the end conditions of strut i.e. both ends hinged position. Fig.6 explains the layer arrangement of the strut. Fig.7 illustrates the crushing beheaviour of the strut and at this condition the maximum stress is 180.92N/mm^2 in longitudinal direction and 162.447N/mm^2 in radial direction

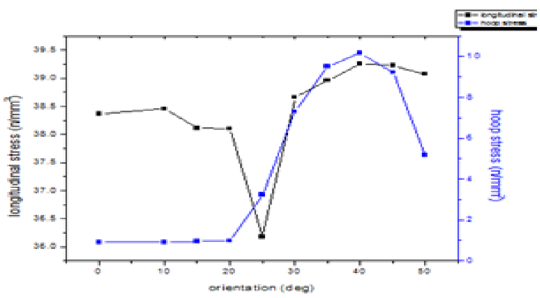

Figure 1

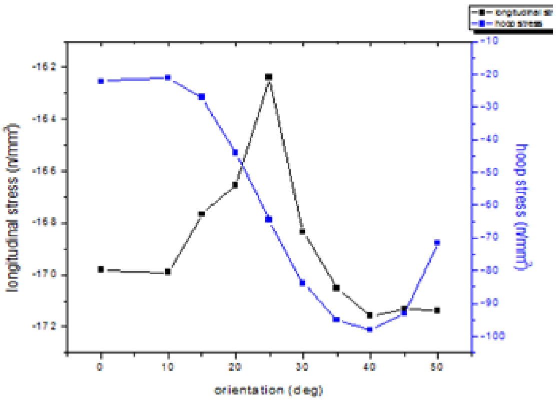

Figure 2

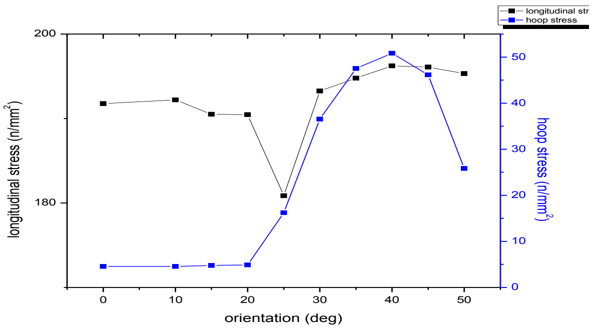

Figure 3

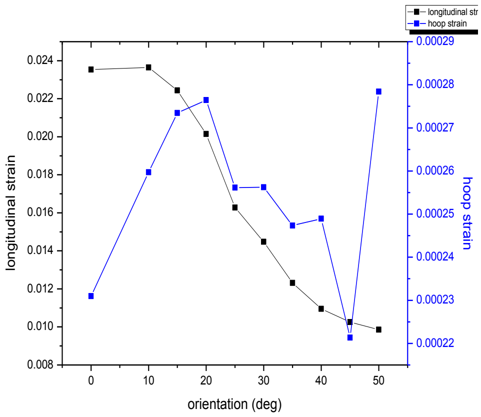

Figure 4

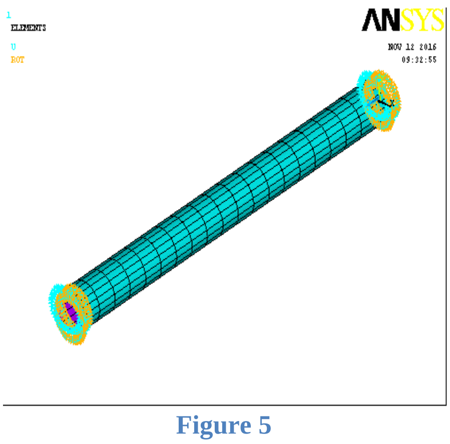

Figure 5

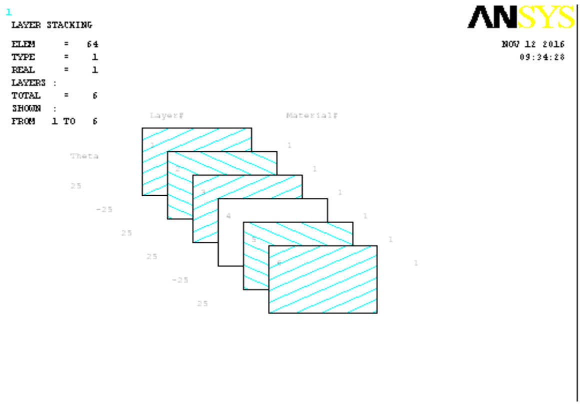

Figure 6

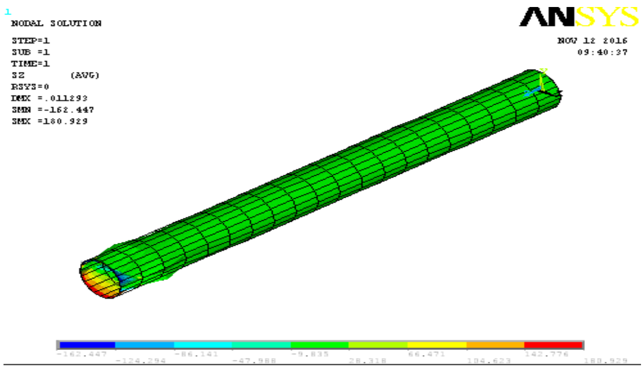

Figure 7

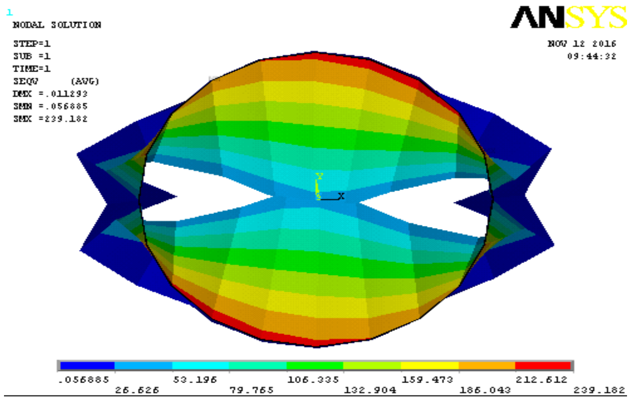

Figure 8

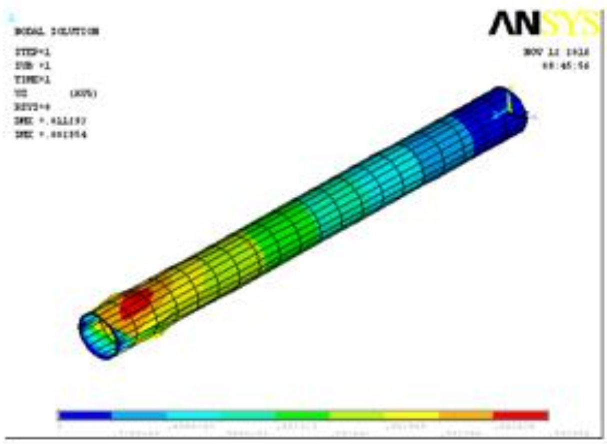

Figure 9

V. Conclusions And Future Work

In this proposed paper, we have investigated the effect of filament winding angle made with glass epoxy polymer strut with both ends hinged conditions. Our simulation results prove that $\pm 25^0$ is the best filament winding angle and thus the results will be beneficial for hardware manufactures of light weight engineering structures. In future, we are intending to verify the stress analysis of struts using MATLAB and other simulation tools and also optimize the design life cycles.

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