ID: 2016-ISFT-146

Investigation of Mechanical Properties of E-Glass/Epoxy Hollow Rotor through FEM

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Abstract: *Composite materials have been widely used to improve the performance of various types of structures. This paper presents modeling and analysis of composite rotor and conventional stainless steel rotor. E-Glass/Epoxy, Carbon, Graphite and Kevlar are advanced composite materials with suitable resins and widely used because of their high specific strength and high specific modulus. In this analysis, the composite rotor is of E-Glass/Epoxy material of hollow circular cross- section was chosen because the hollow circular shaft are stronger in per kg weight than solid circular and the stress distribution in case of solid shaft is zero at the centre and maximum at the outer surface while in hollow shaft stress variation is smaller. In solid shaft the material close to the centre are not fully utilized. In this work, analysis of the mechanical behavior of the composite rotor and conventional rotor with the help of ANSYS has been done. Comparison of mechanical properties of composite rotor, which is made up a layer of E-Glass/Epoxy on the hollow Al alloy rotor and the conventional stainless steel rotor is also included in this paper.*

Keywords*: E-Glass/Epoxy, rotor, composite rotor, FEM, Al alloy, Stainless steel, stress distribution.*

1. INTRODUCTION

Rotors are one of the most important components of any rotating machinery. Their applications are found from various machines like turbine, compressors to Automobile, Aircrafts, submarines etc. Composite rotors have attracted the attention of researchers across the glob due to high strength to weight ratio. Hollow shaft has its advantage over solid shaft. In this work analysis of of E-Glass/Epoxy on the hollow Al alloy rotor through FEM has been done. Stress distribution on a computational model of hollow composite rotor is presented. Comparison of steel rotor is also presented in this paper.

1.1 COMPOSITE

Composite materials are obtained by combining two or more materials, all in order to make new materials with controlled and more favourable characteristics. As a result, these materials have improved mainly mechanical properties, such as strength, stiffness, toughness, than their constituent parts. The greatest advantage of composite materials is reflected in the fact that most of them use the best features of the component materials and characteristics that themselves do not possess individually. Mainly, the formation of composite materials improve the following characteristics: strength, stiffness, corrosion resistance, abrasion resistance, weight reduction, lifetime, thermal isolation, acoustic isolation and increase elasticity modulus. Replacement of steel composite shaft is a novelty all over the world. Composite materials have been applied, as mentioned earlier, in aviation with increased accent on their usage analysis in the automotive industry and all other vehicle types. Composites can be classified in different ways and by different criteria. The characteristics of composites depend largely on three factors strength and chemical stability of the matrix, strength and elasticity of reinforcing fibers,bond strength between the matrix and fibers arming [1]. The common application of composites are extending day by day. Now a days they are used in medical applications too. The other fields of applications are, automotive, aircraft, apace, marine, chemical industries, electrical & electronics and sports goods[2].

1.2 ROTOR

The modern world is built upon rotating machinery, it may be a turbine used for power generation, a mill used for manufacturing, or a jet engine used for travel, the rotor is considered as one of the most important parts that transmits power to other devices in the system [10,11]. Here we were used hollow composite shaft because the hollow circular shaft are stronger in per kg weight than solid circular and the stress distribution in case of solid shaft is zero at the centre and maximum at the outer surface while in hollow shaft stress variation is smaller. In solid shaft the material close to the centre are not fully utilized.[7,8]

2. DEVELOPMENT OF COMPOSITE ROTOR

A computational model of hollow composite rotor has been developed with E-Glass/ Epoxy Fibers are available with

ISBN: 978-93-84935-64-1

widely differing properties. Review of the design and performance requirements usually dictate the fiber/fibers to be used. Carbon/Graphite fibers: Its advantages include high specific strength and modulus, low coefficient of thermal expansion, and high fatigue strength. Glass fibers: Its advantages include its low cost, high strength, high chemical resistance, and good insulating properties. The disadvantages are low elastic modulus, poor adhesion to polymers, low fatigue strength, and high density, which increase shaft size and weight.The important considerations in selecting resin are cost, temperature capability, elongation to failure and resistance to impact (a function of modulus of elongation). The resins selected for most of the drive shafts are either epoxies or vinyl esters. Here, epoxy resin was selected due to its high strength, good wetting of fibers, lower curing shrinkage, and better dimensional stability. Resin system was prepared by mixing epoxy and harder with the volume fraction ration of 4:1 [3,9].A rotor model was generated on CATIA V5 R20. First a sketch was drawn on sketcher work bench after we used pad command for modeling of rotor in 3-D. After that we import the model in ANSYS software work bench for making composite rotor of E-Glass/Epoxy material.

TABLE 1: Mechanical properties of the E-Glass Epoxy

MECHANICAL PROPERTIES	SYMBOL	UNITS	E-GLASS EPOXY
Longitudinal Young's Modulus	E11	Gpa	52.36
Transverse Young's Modulus	E22	Gpa	8.02
Major Poisson Ratio	v12	Gpa	0.24
Inplane Shear Modulus	G12	Mpa	3.097
Ultimate Longitudinal Tensile Strength	(σ1c)u/t	Mpa	954.8
Ultimate Longitudinal Compressive Strength	(σ1c)u/t	Mpa	69.2
Transverse Tensile Strength	(σ2c)u/t	Mpa	27.29
Ultimate Transverse Compressive Strength	(σ2c)u/t	Mpa	38.66
Inplane shear strength	(τ12)u/t	Mpa	12.72
Density	p	Kg/m3	1980

TABLE 2: Mechanical properties of steel

Mechanical Properties	Symbol	Steel
Young's modulus (GPa)	E	207.0
Shear modulus (GPa)	G	80.0
Poisson's ratio	v	0.3
Density (Kg/m3)	ρ	7600
Yield strength (MPa)	S_y	370
Shear strength (MPa)	S_S	370

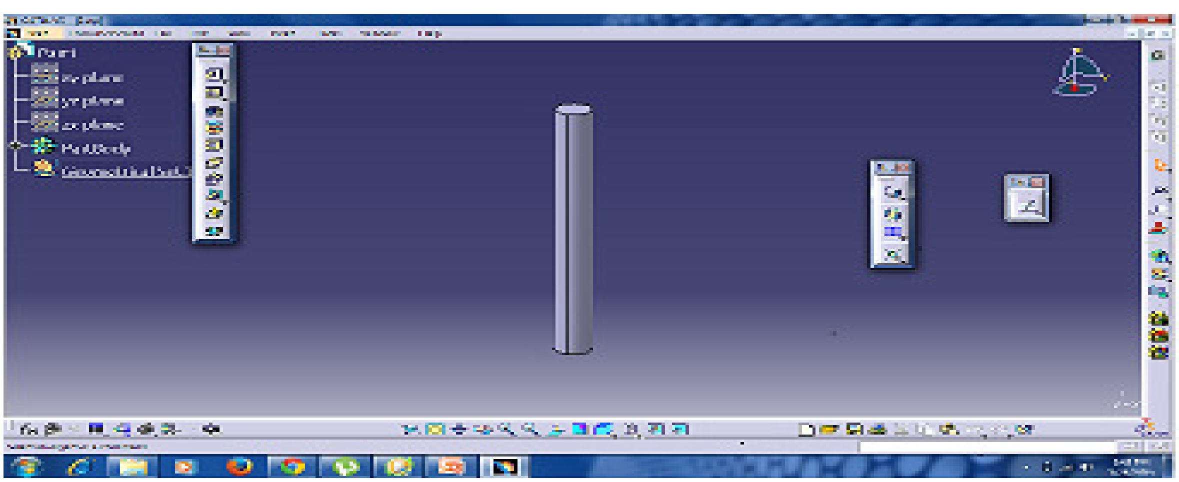

Fig. 1. Solid model of shaft

3. ANALYSIS

Finite element analysis is a computer based numerical technique is used to for calculating the strength and behavior of the engineering structures. ANSYS is an analysis tool which was applied for the analysis as it consider buckling, model, and static analysis by finite element technique[6,11].

Static analysis deals with the conditions of equilibrium of the bodies acted upon by forces. A static analysis result of structural displacements, stresses and strains and forces in structures for components caused by loads will give a clear idea about whether the structure or components will withstand for the applied maximum forces. If the stress values obtained in this analysis crosses the allowable values it will result in the failure of the structure in the static condition itself. To avoid such a failure, this analysis is necessary [5]. Fig.2 and 3 shows the model under analysis.

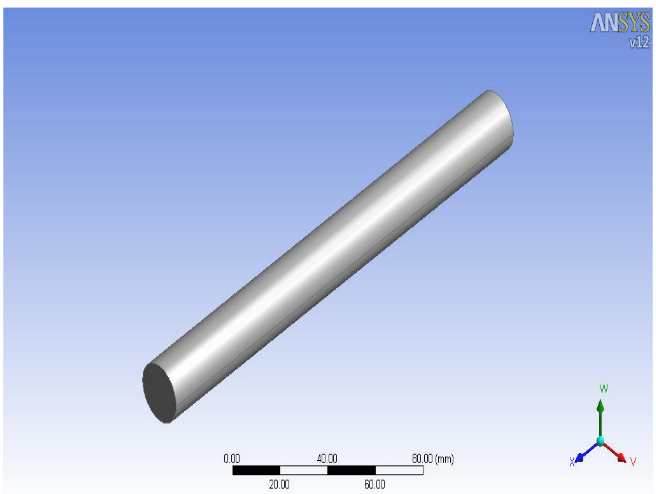

Fig. 2. Model imported in ANSYS from CATIA

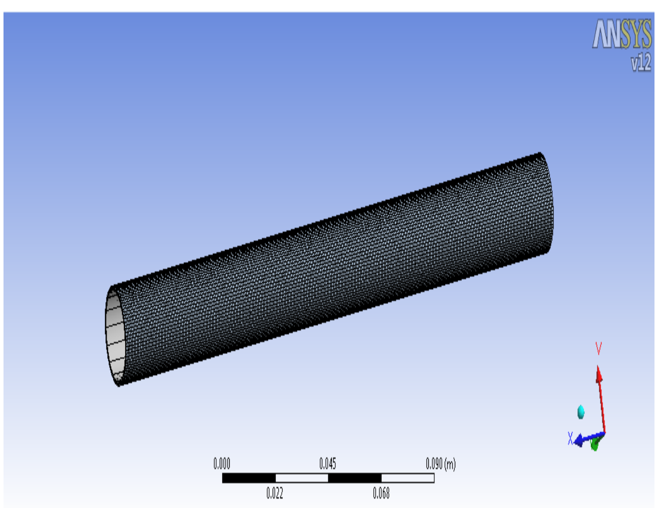

Fig. 3. Meshed model of shaft

Analysis of computational models has been done by using finite element method technique through ANSYS software. Static analysis of the composite rotor as well as the conventional rotor/steel rotor has been performed. By analysis Principle stresses, vonmises stress induced and deformation of both rotor obtained. Fig.4 shows the force applied on the model.

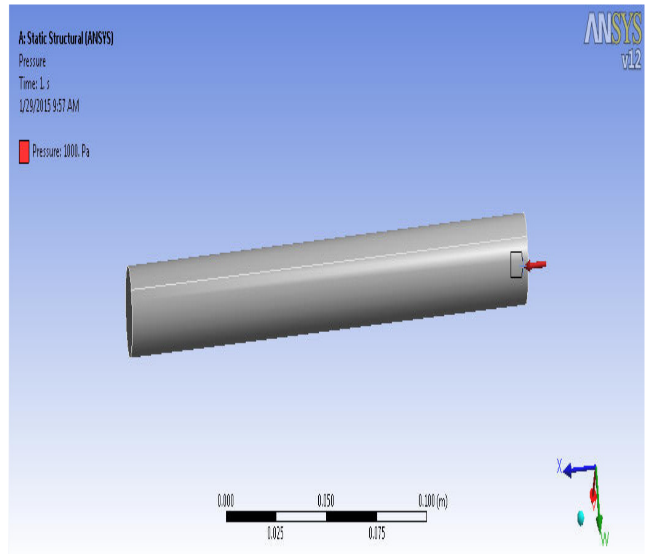

Fig. 4. Force applied on model

4. RESULTS

From Analysis of both models deformation, principle stresses, Von-Mises stresses are obtained. From Fig. 5 to Fig. 10 one may obtain the level of principle stresses, deformation, Von-Mises stresses in composite rotor as well as in metal alloy rotor.

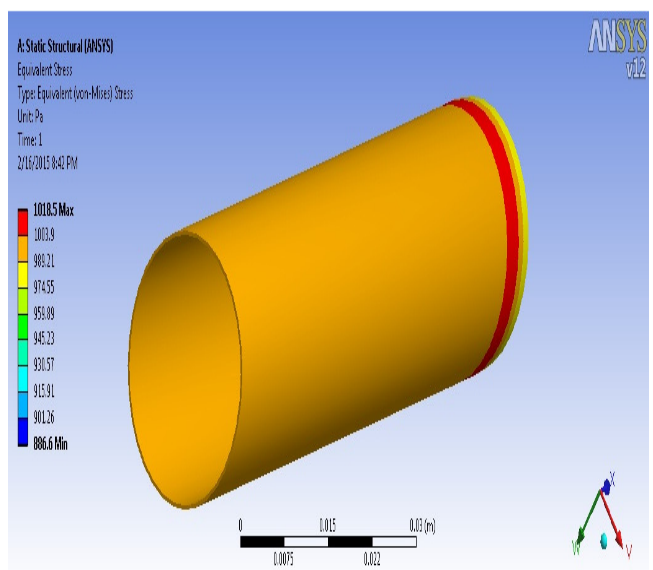

Fig. 5. Von-Mises stress of stainless steel

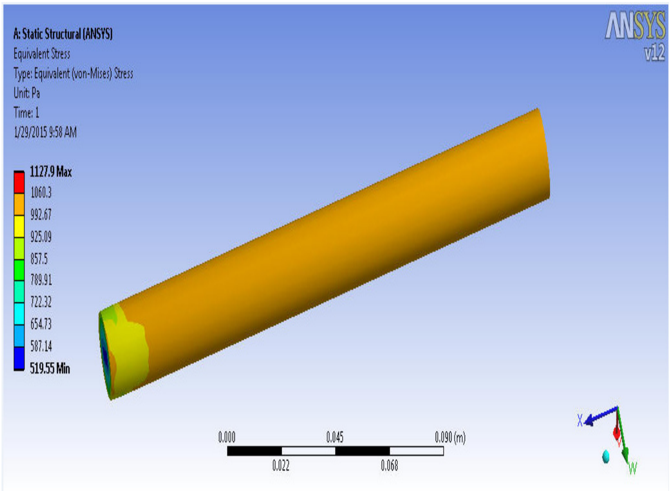

Fig. 6. Von-Mises stress of composite

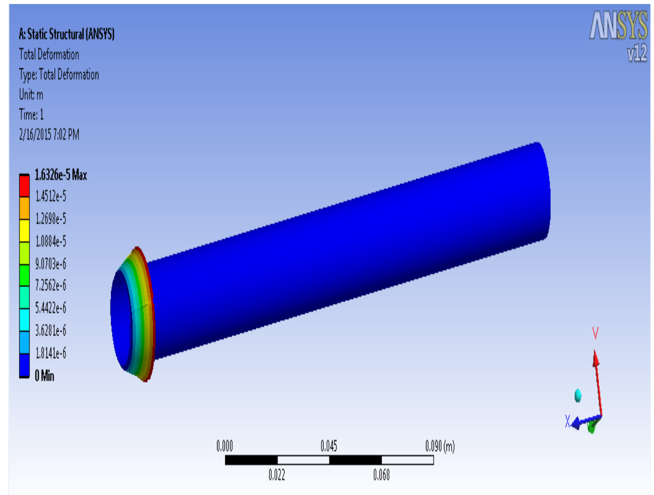

Fig. 9. Deformation of Stainless Steel

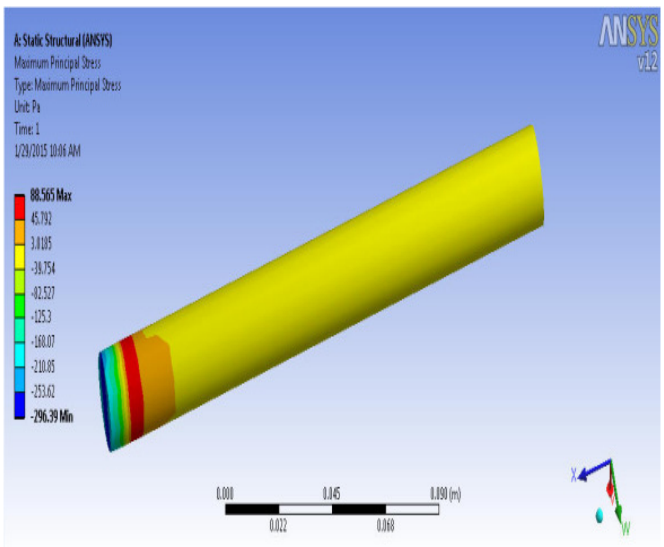

Fig. 7. Maximum principal stress of steel

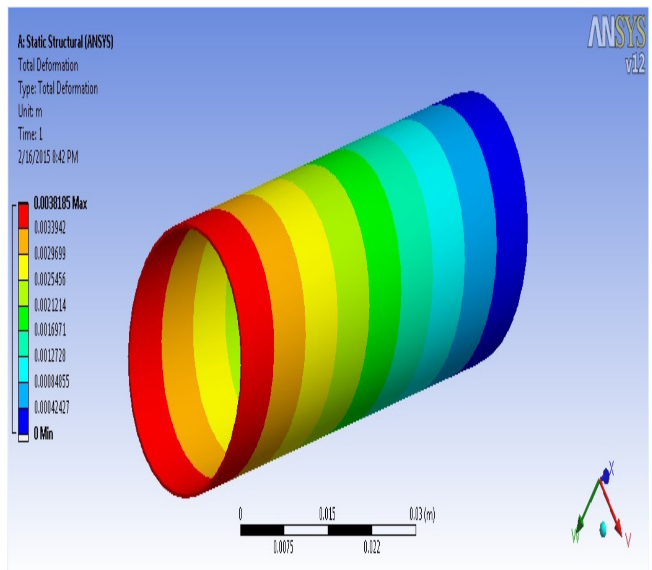

Fig. 10. Deformation of composite rotor

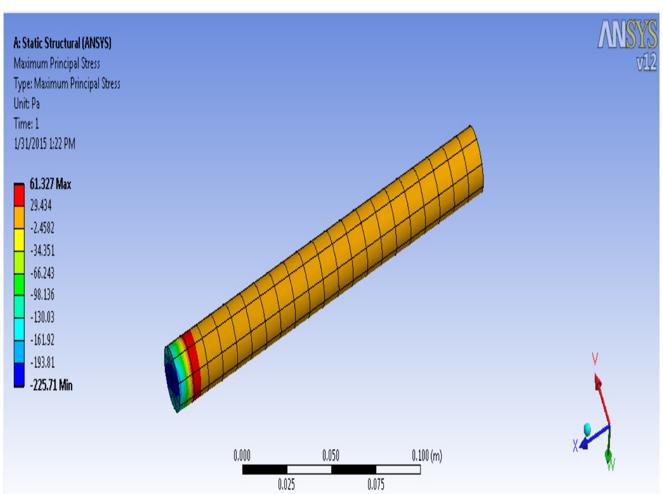

Fig. 8. Max principal stress of composite

After analysis on Ansys, all the above figures indicates that stress distribution in steel rotor and composite rotor. One may easily observe from above figures that stresses in steel rotor is more than the composite rotor. Hence it is evident that composite hollow rotor may be a good choice over solid stainless steel shaft.

5. CONCLUSIONS

A computational model of composite rotor and metal alloy rotor has been developed on CATIA. Imported model were analyzed for static condition through FEM. For this purpose Ansys software has been used. It is observed from the analysis that the strength and the stiffness of composite rotor is more than the stainless steel. Composite rotors may be a suitable replacement over a metal alloy rotor for same application. In future dynamic analysis may be done for the composite rotor.

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