Analysis of Drive Shaft of Hybrid and Conventional Composites

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***Abstract*— The optimal design and selection of material of drive shaft is very important in the field of automobiles. As the drive shafts are torque carriers, production of higher torques may lead to the failure of the shaft. In this paper, drive shafts made of hybrid composite (combination of short glass and carbon fibers) and conventional composite (Carbon fiber) are considered with variation in thickness and transient structural analysis is performed with the help of finite element method in ANSYS. The respective stresses, strains and deformations obtained from the analysis are compared.**

Keywords—Carbon fiber, Finite element method, Torsion, Transient structural analysis

I. Introduction

Drive shafts for power transmission are used in many applications, including cooling towers, pumping sets, aerospace, structures and automobiles. The drive shafts made of composite materials have high strengths when compared to that made of steel. But, when they are subjected to high torques, large deformations will be produced and thus leading to the failure of the shaft. In this project, a drive shaft made of hybrid composite material obtained from the combination of glass and carbon fibers is designed because they have unique features that can be used to meet various design requirements in a more economical way than conventional composites. Some of the advantages of hybrid composites include better ductility, fatigue, and balanced effective properties.

This paper deals with the transient analysis of the drive shaft with varying thickness keeping the length constant. The total deformation, equivalent stress, equivalent elastic strain and shear stresses obtained from the analysis of both hybrid and conventional composites are tabulated and compared. It was observed that the deformations and equivalent elastic strains were less in hybrid, equivalent stresses were almost the same and comparatively, shear stresses are higher in hybrid.

II. Survey of Related Works

In paper [1], a micromechanical analysis of the representative volume element of a hybrid composite is performed using finite element method. The variability in mechanical properties due to different locations and effects of volume fractions of two different fibers were studied.

In paper [2], finite element analysis was performed to study the different effects of layers stacking. Modal analysis, linear buckling analysis and static analysis were performed on a drive shaft.

In paper [3], static analysis, modal analysis and torsional analysis were performed on a drive shaft. Maximum stress theory was used to determine the torque transmitting capacity of the laminates.

III. Problem Statement and Main Contribution

At present, the maximum torque produced by the fastest car is 1500 Nm whose drive shaft is made of carbon fiber composite material and can withstand only up to 1600 Nm without plastic deformation [4]. If the torque exceeds the limit, the dimensions of the shaft would change which leads to improper mechanisms of the system. This is an undesirable condition. The research question we have come up is “What can be done for the shaft to resist torque more than 1600 Nm?” The tentative hypothesis is that the shaft made of hybrid composite could resist high torque when compared to that made of conventional composite material The main contributions of the project are,

- Modeling of drive shaft in AUTODESK Inventor 2016
- Analysis of drive shaft in ANSYS 14.5
- Comparison of results in MATLAB R2015b

IV. Problem Solution

A. Modeling

In this project, a hollow drive shaft is considered because it has less weight and uniform distribution of stress when compared to the solid shaft. Due to space limitations, the outer diameter cannot be altered. Therefore, to obtain different thickness, inner diameter is changed. The shafts with the dimensions of the following criteria are modelled in AUTODESK Inventor.

TABLE I. DIMENSIONS OF DRIVE SHAFT [5]

Criteria	**Factors**			
	Length(mm)	***Outer diameter (mm)***	***Inner diameter (mm)***	***Thickness (mm)***
1	1250	90	80	5
2	1250	90	75	7.5
3	1250	90	70	10

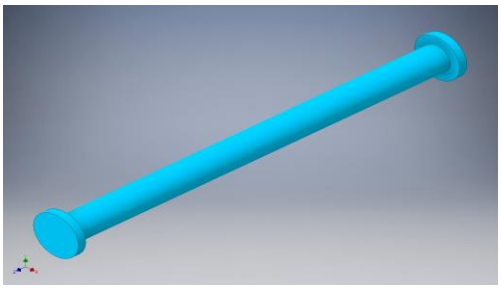

Fig. 1. Model of the drive shaft.

B. Implementation

The designed model is imported to ANSYS 14.5 and is analysed for different criteria using transient structural analysis. The glass fibre composite and short glass carbon fibre hybrid composite materials with given mechanical properties are applied to the shaft. The shaft is divided into a number of tetrahedral elements using advanced and proximity mesh.

C. Comparison

After meshing, it is analysed with the application of boundary condition. One end of the drive shaft is fixed and other end is subjected to a twisting moment of 2000 Nm. It is also given a rotational velocity. Finally, the deformations, stresses and strains induced in the shaft are obtained. They are as follows.

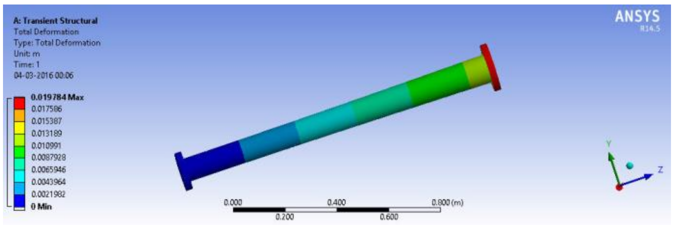

Fig. 2. Deformation of shaft of conventional composite with thickness T1

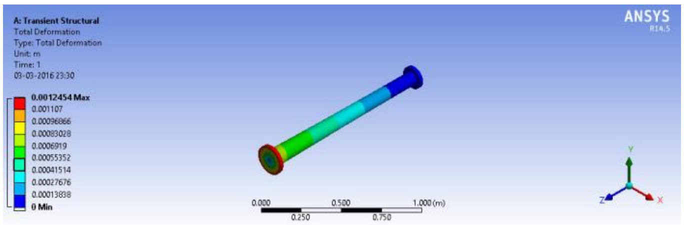

Fig. 3. Deformation of shaft of Hybrid composite with thickness T1

TABLE II. RESULTS

Results		Material	
		Short glass carbon fibre	***Carbon fibre composite***
Deformation (mm)	T1	1.2454	19.784
	T2	0.90401	14.438
	T3	0.7418	11.83
Equivalent stress(MPa)	T1	66.128	66.114
	T2	48.07	48.051
	T3	39.428	39.377
Equivalent elastic strain	T1	0.00044769	0.0066249
	T2	0.00032524	0.0048118
	T3	0.00026683	0.0039441
Shear stress (MPa)	T1	12.509	12.483
	T2	9.0923	8.4035
	T3	8.7066	8.1523

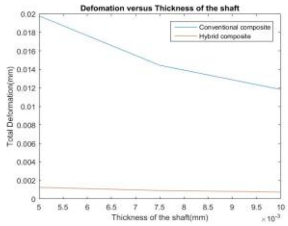

Fig. 4. Deformation Vs Thickness of the shaft

V. CONCLUSION

The deformations of the shaft were low for short glass carbon fiber and relatively high for carbon fiber drive shaft. From Table 2, it can be observed that, the deformations of the shaft decreased with increase in thickness. The Von-mises or the equivalent stresses are almost the same for both the shafts.

So, it is suggested to use hybrid drive shaft instead of composite one because of its high torque carrying capacity. The results and conclusions reported in this paper are mainly useful to the automobile industry.

Based on the idea generated in this paper, in future there is a scope for further development in the composition of a hybrid composite material.

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Biographies

Akhil Mora was born in Hyderabad, Telangana, India, in 1995. He received his secondary school of certificate from Bhashyam High School, Hyderabad, in 2010, Intermediate from Sri Gayatri Junior College, Hyderabad, in 2012. He completed his Bachelor of technology in mechanical engineering from Jawaharlal Nehru Technological University, Hyderabad, India in January 2016. Presently he is pursuing his Masters in Structural Mechanics at BTH, Karlskrona, Sweden.

He has carried out a work titled “Computation of thrust in high speed combustion chamber” in Defence Research and Development Laboratory, Defence Research and Development Organization, Ministry of Defence, India, in May-June 2015. He is the author of a paper entitled “Evaluation of Structural Integrity under bursting conditions of heat treated 2219 Al-Alloy pipes using Finite Element Analysis”. It was published in “International Journal of Scientific Engineering and Research (IJSER)”, in December 2015.

Miao Yu was born in Shanghai, China, in 1993. He received the double B.S. degrees in mechanical engineering from Blekinge institute technology, Karlskrona, Blekinge, Sweden, in 2014 and mechatronics engineering from Shanghai Second Polytechnic University, Shanghai, China, in 2014.

From 2011 to 2013, he was a Shop Assistant with Decathlon, JinQiao store. Since 2009, from 2012 to 2013, he was a Student Journalist with Shanghai Second Polytechnic University. In 2016, he was student assistant for Solid Mechanics. His research interest includes automation of robotic techniques.

Mr. Miao’s award and honor include the Third Prize of the Second Machinery Innovation Contest.

Hemanth Bugga was born in Hyderabad, Telangana state, India on 4th September 1994. He completed his schooling from Loyola Montessori High School, Hyderabad, India in 2010 and higher education from Sri Chaitanya College, Hyderabad, India in 2012. He did his Bachelor's degree from Jawaharlal Nehru Technological University, Hyderabad, India in 2015 in the field of mechanical engineering and pursuing his Masters degree from Blekinge Institute of Technology, Karlskrona, Sweden in the field of structural mechanics.

He was an Intern for 2 weeks in Dr Narla Tata Rao Thermal Power Plant, Vijayawada, India with emphasis laid on "Coal Mills" in 2015 . Under the partial fulfillment for Bachelors degree he has done a project on "Dynamics and control of flexible composite robotic manipulators based on Finite Element Method" in Jawaharlal Nehru Technological University, Hyderabad in 2016.

Wlodek J. Kulesza received the M.Sc. and the Ph.D. degrees from Lodz University of Technology, Poland, and a docent degree from Linköping University, Sweden. In 2001 he became Professor in Measurement Science at the University of Kalmar, Sweden. Since 2005 he has held a Professor position at the Blekinge Institute of Technology, Sweden.

His current research interests are multi-sensor systems and wireless sensor networks.

Prof. Kulesza has been IEEE member since 1995.

Appendix

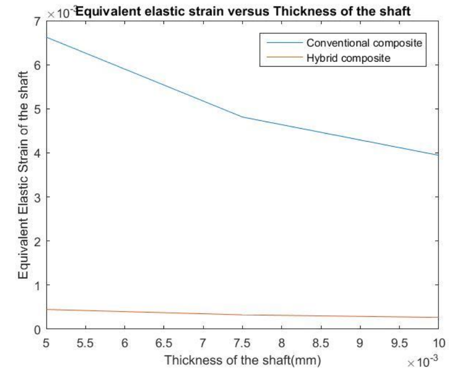

figure A-1 Elastic strain Vs Thickness

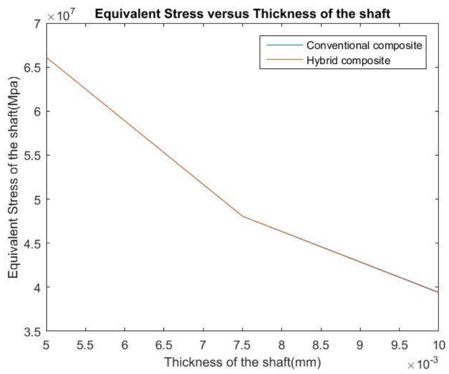

figure A-2 Equivalent stress Vs Thickness

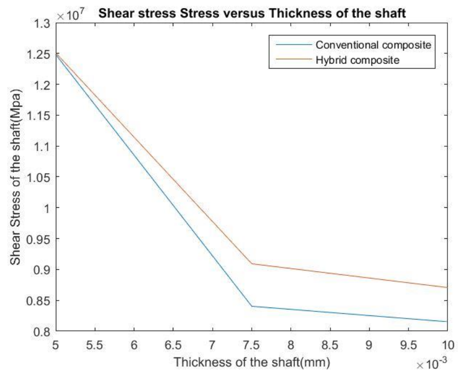

figure A-3 Shear stress Vs Thickness