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DESIGN AND COMPARISON OF THE STRENGTH AND EFFICIENCY OF DRIVE SHAFT MADE OF STEEL AND COMPOSITE MATERIALS USING FEM

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***Abstract*—Almost all automobiles (at least those which correspond to design with rear wheel drive and front engine installation) have transmission shafts. The weight reduction of the drive shaft can have a certain role in the general weight reduction of the vehicle and is a highly desirable goal, if it can be achieved without increase in cost and decrease in quality and reliability. It is possible to achieve design of composite drive shaft with less weight to increase the first natural frequency of the shaft and to decrease the bending stresses using various stacking sequences. By doing the same, maximize the torque transmission and torsional buckling capabilities are also maximized. This work deals with the replacement of a conventional steel drive shaft with High Strength Carbon drive shafts for an automobile application.**

***Index Terms*— Drive shaft, Composite, Ansys, modal analysis.**

I. INTRODUCTION

A drive shaft, propeller shaft (prop shaft), or Cardan shaft (after Girolamo Cardano) is a component for transmitting mechanical power and torque and rotation, usually used to connect other components of a drivetrain that cannot be connected directly because of distance or the need to allow for relative movement between them

There are two main objectives, with respect to the development of drive shaft. Firstly, the appropriate static characteristics and fatigue life of the existing shaft have to be determined. Secondly, there are many factors involve and must take into account, which can affect on the stability and fatigue life etc.

Today, there are many research and development programs available in the market especially by the international automotive manufacturers, which are very much related to this research work. Therefore, there are several technical papers from the 'Society of Automotive Engineering' (SAE).

II. OVERALL DISCUSSION ON RESEARCH

Drive shaft for Research and Development of the automotive industry also uses drive shafts at testing plants. At an engine test stand a drive shaft is used to transfer a certain speed / torque from the internal combustion engine to a dynamometer. A ―shaft guard‖ is used at a shaft connection to protect against contact with the drive shaft and for detection of a shaft failure. At a transmission test stand a drive shaft connects the prime mover with the transmission. Composite materials typically have a lower modulus of elasticity. As a result, when torque peaks occur in the driveline, the driveshaft can act as a shock absorber and decrease stress on part of the drive train extending life. Many researchers have been investigated about hybrid drive shafts and joining methods of the hybrid shafts to the yokes of universal joints. But this study provides the analysis of the design in many aspects. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and higher specific strength of composite materials. Composite materials can be tailored to efficiently meet the design requirements of strength, stiffness and composite drive shafts weight less steel or aluminium of similar strength

A. Advantages of Fiber Reinforced Composites

The advantages of composites over the conventional materials are-

- High strength to weight ratio
- High stiffness to weight ratio
- High impact resistance
- Better fatigue resistance
- Improved corrosion resistance
- Good thermal conductivity
- Low Coefficient of thermal expansion.
- As a result, composite structures may exhibit a better dimensional stability over a wide temperature range.
- High damping capacity.

B. Disadvantages of Composites

Joining processes are complicated. Poor compressive strength and Creep pose problems to the structure of the ship. Low vibration tolerance is a risk factor. Poor abrasion resistance leads to wear and tear. Quality Control is difficult. Lay-up and Assembly arelaborious.

Composites are highly combustible and vulnerable to heat and fire. Installation of systems proves to be a difficult task. High cost is a major drawback. A number of other technical issues combined with the above drawbacks are constraining the large scale introduction of composites into the large structure marine market. Composite ship joints often have similar design features as welded steel joints even though the joining process is difficult in joining composites, and as a consequence joints made of glass reinforced plastic can have lower strength and fatigue resistance.

III. DESCRIPTION OF THE PROBLEM

Stainless steel was mainly used because of its high strength. But this stainless steel shaft has less specific strength and less specific modulus. Stainless steel has less damping capacity. Because of its higher density of molecules of stainless steel, its weight is very high. Because of increase in weight fuel consumption will in increase, the effect of inertia will be more and increase in weight. The steel propeller shaft is replacing with the composite materials, which are very less weight when compared to that of stainless steel. The cost of composite materials is less when compared to that of stainless steel. The E-Glass/Epoxy and Carbon/Epoxy materials are selected for composite drive shaft. Since, composites are highly orthotropic and their fractures were not fully studied.

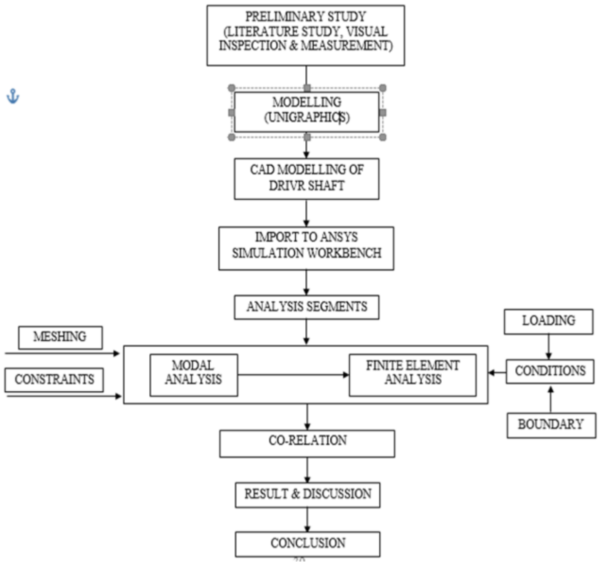
IV. RESEARCH METHODOLOGY

In this project, Modal Analysis and Finite Element analyses were used to determine the characteristics of the Drive shaft. The combination of all the analysis results were used to develop virtual model created using FEM tools and the model was updated based on the correlation process. Further analyses were then executed to the truck chassis design to determine the best suited material for chassis.

For the purpose of this study, the drive shaft was modeled using unigraphics software according to the original size of structures. The model was then imported into Simulation software ansys workbench. The purpose was to determine the natural frequencies and mode shapes. For the meshing analysis, 10 node-tetrahedral elements were chosen to model the solid shaft.

The next step was to undertake Experimental Modal Analysis. This was to determine the natural frequencies, mode shapes and damping ratio from the real structure of the drive shaft. In order to maintain the quality of results, the analysis were done on the Ansys workbench. Then, the result from finite element analysis and experimental modal analyses were then compared in order to find the best suited material for the drive shaft material

A. RM FLOWCHART



V. COMPUTATIONAL AND MODELLING ANALYSIS

Analysis is being categorizes into modal analysis and finite element analysis. The modal analysis is being performed to compute the frequency of the two materials and afterward, compare the stiffness of each material. And after that, finite element analysis is being performed to check the stress, displacement and strain segment of these materials. For the purpose of analysis meshing is to be done in order to get the desired result.

The FEM is a common tool for stress analysis. FEM with required boundary conditions was used to determine critical regions in theshaft. Static structural analysis is performed to identify critical regions and based on the results obtained design modification has been done the modal analysis of the shaft is carried out to determine the natural frequency and mode shapes of the system. The rigidity of the system was analysed and their resonance could be avoided.

A. SOLID MODELLING

Design of Drive Shaft

The design specifications of the Steel Shaft (SM45C) and Carbon fiber composite shaft is as follows,

The torque transmission capability of drive shaft is taken as **151 Nm**

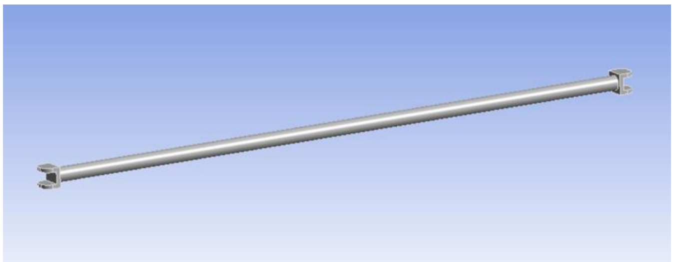
The outer diameter of shaft is (Ro) = **0.036 m**

The inner diameter of shaft is (RI) = **0.011 m**

The length of the shaft is (l) = **1.5 m**

PROPERTIES OF MATERIAL APPLIED

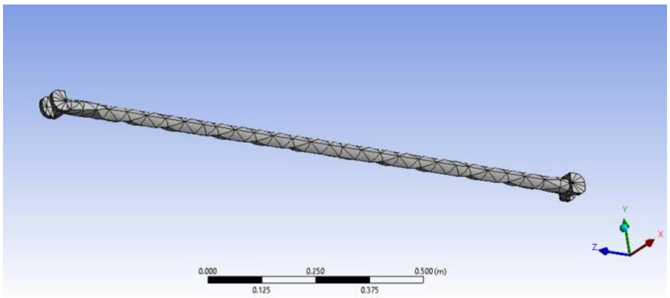
Material Properties	Steel	Carbon Fiber
Density (kg/m^3)	7850	1570
Young's Modulus (MPa)	200	190000
Poisson's Ratio	0.3	0.25
Yield Stress (MPa)	250	220



SOLID MODEL OF DRIVE SHAFT (UNIGAPHICS)

B. MESHING OF DRIVE SHAFT

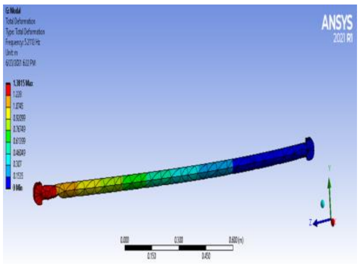
The meshing is done on the model with 6234 No. of nodes and 3143 No. of Tetrahedral elements. In order to get a better result, locally finer meshing applied in the region which is suspected to have the highest stress.

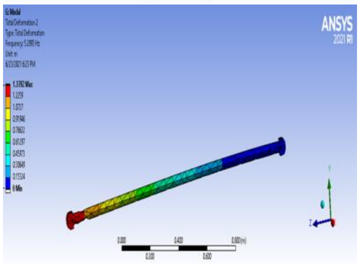


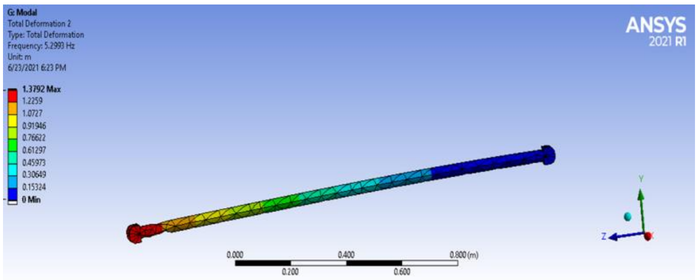
MESHING OF DRIVE SHAFT MODEL

VI. RESULTS

A. MODAL ANALYSIS OF THE CHASSIS WITH MATERIAL AS STRUCTURAL STEEL







FREQUENCIES AND DEFLECTION FOR THE SHAFT CONSIDERING THE STEEL MATERIAL

STEEL MATERIAL	FREQUENCY (Hz)	DEFLECTION (m) AVERAGE
DEFORMATION 1	5.212	0.5317
DEFORMATION 2	5.2993	0.5325
DEFORMATION 3	32.631	0.57425
DEFORMATION 4	33.249	0.57481
DEFORMATION 5	91.155	0.5847

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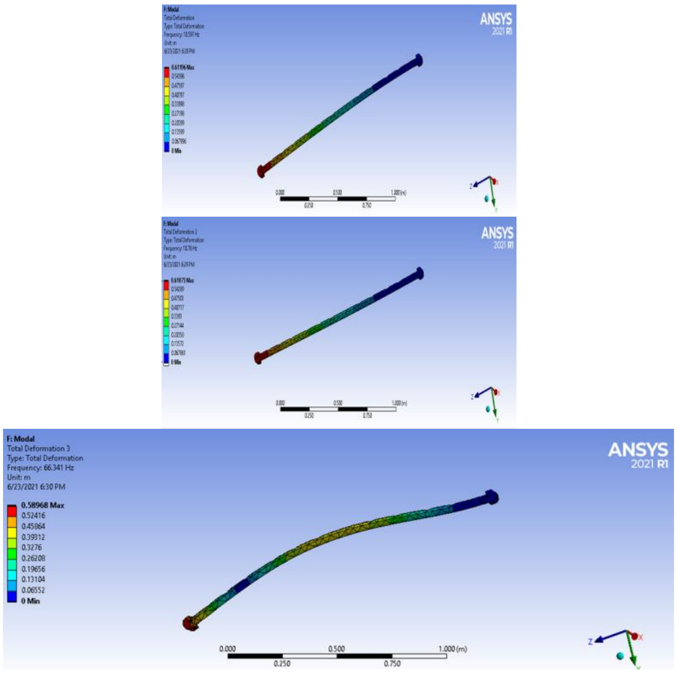
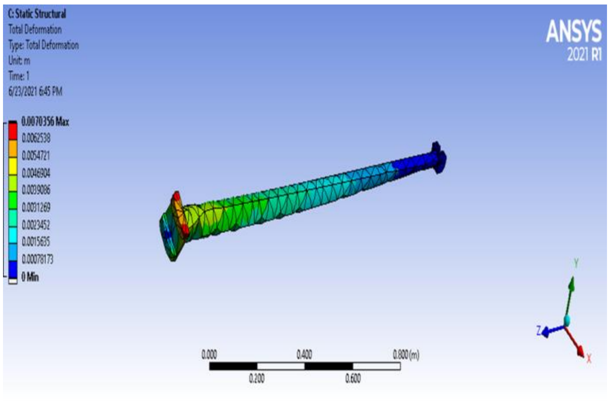
B. MODAL ANALYSIS OF THE CHASSIS WITH MATERIAL AS CARBON FIBER



FREQUENCY AND DEFLECTION FOR COMPOSITE SHAFT

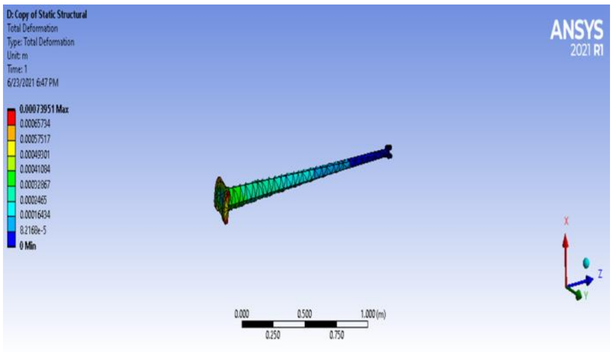
STEEL MATERIAL	FREQUENCY (Hz)	DEFLECTION (m) AVERAGE
DEFORMATION 1	10.597	0.23551
DEFORMATION 2	10.76	0.23593
DEFORMATION 3	66.341	0.25435
DEFORMATION 4	67.461	0.25466
DEFORMATION 5	185.22	0.25901

C. STATIC STRUCTURAL ANALYSIS BY USING STEEL



TOTAL DEFORMATION STEEL

D. STATIC STRUCTURAL ANALYSIS BY USING CARBON FIBER



TOTAL DEFORMATION CARBON FIBER

PARAMETER	STEEL	CARBON FIBER
EQUIVALENT STRESS (MPa)	40.209	40.2091
EQUIVALENT STRAIN	0.070032	0.002
TOTAL DEFORMATION (m)	0.0073951	0.0070356

VII. CONCLUSION

The modal analysis and static structural analysis on the DRIVE SHAFT was carried out. From the above results of steel and carbon fibers, it can be seen that von equivalent stress for carbon fibers has increased and the total deformation has reduced. Thus the stress values for carbon fibers are under acceptable limit. So it is ideal to use the carbon fiber as a drive shaft material for vehicles because of its high strength and low weight. Also for the same load carrying capacity, carbon fibers are preferable instead of steel for the manufacturing of driveshaft because it reduces the weight by 60-68% and increase the stiffness of the shaft. But on the economic point of view, the cost of the carbon fiber is relatively higher than that of the steel materials.

From figure show the variation of frequency at different mode number during the modal analysis of drive shaft, therefore it is concluded that the carbon fiber are having more stiffness as compared to the steel material. Therefore, from this study it is concluded that for the same load carrying capacity the efficiency of the carbon fibers materials are more as compared to the steel materials.

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