Vibration Analysis of Propeller Shaft Using FEM.

Akshay G. Khande, Shreyash A. Sable, Vaibhav R. Bidwai, Chandrasekhar B. Aru, Brahmanand S. Jadhav

Mechanical Engineering Department, Babasaheb Naik College of Engineering, Pusad, Maharashtra, India

Abstract — Propeller shaft is the major component of transmitting power from gear box to the wheel drive. This work involved static and dynamic analysis to determine key characteristics of a propeller shaft. The static characteristics include identifying location of high stress area and determining the torsion capacity of the propeller shaft. The dynamic characteristics of propeller shaft such as the natural frequency and mode shape were determined by using finite element analysis. A propeller shaft is subjected to torque which causes stresses, strains, deflections, vibrations and noise to it. To achieve a quality of propeller shaft, i.e. one having longer fatigue life, reduced weight, reduced cost, and so on, it becomes necessary to use materials of appropriate strength and stiffness property with the most appropriate geometry.

Keywords— ANSYS, Composite Material, Drive Shaft, Optimization.

I. INTRODUCTION

Rapid technological advances in engineering design field result in finding the alternate solution for the conventional materials. The design engineers brought to a point to finding the materials which are more reliable than conventional materials. Researchers and designers are constantly looking for the solutions to provide stronger and durable materials which will answer the needs of fellow engineers. Drive shafts are used as power transmission tubing in many applications, including cooling towers, pumping sets, aerospace, trucks and automobiles. In the design of metallic shaft, knowing the torque and the allowable shear stress for the material allows the size of the shaft’s cross-section to be determined. Beard more at al. [2] is also states the potentials of composites in structural applications. Conventional steel drive shafts are manufacture in two pieces to increase its fundamental natural bending frequency. The conventional assembly of drive shaft is made up in two pieces and joined together by u-joints due to which the overall weight of the assembly is increased. The composite drive shaft [3] has advantages like considerable weight reduction, symmetric composite assured the dynamic balance of increasing operating speed, electrically non conductive, custom end fitting considerations, vibrations and harshness (NVH), long fatigue life and also it reduce the bearing & journal wear. The materials usually have a lower modulus of elasticity which results in when torque peaks are occurred the drive shaft may works as a shock absorber. A drive shaft must operate through constantly changing angles between the transmission and rare axle. A GA proposed by the Goldberg [6] based on natural genetics will be studied in the second phase of study. Rajiv and Krishnamurthy [4] proposed a method for converting a constrained optimization problem into an unconstrained optimization problem. Kim et al. [9] minimizes the weight of composite laminates with play drop under a strength constraint using GA.

JH Park et al. [10] explains the various loading and boundary conditions for the optimal design of laminated composites. Vijayrangan et al. [7] had proposed the GA for the optimization of Composite Leaf spring. T Rangaswamy et al. [8] defines the procedure to design and optimized the composite drive shaft using HM – Carbon / Epoxy by Genetic algorithm. Now days all automobiles (which are having front engine rear wheel
drive) have the transmission shaft as shown in fig.1 [3]. The reduction in weight of the drive system has the advantageous in overall weight reduction of automobiles which is a highly desirable goal of design engineer.

II. COMPOSITE MATERIAL

Composite consist of two or more material phase that are combine to produce a material that has superior properties to these of its individual constituent. Technologically the most important composite are those in which the dispersed phase is in the form of fiber. The composite materials can be classified on the basis of micro structures, multi phases, reinforcements, manner of packing of fibers layered compositions, method of compositions, matrix system, processing methods, etc. Composite materials can be classified as:

1) Polymer Matrix Composites.
2) Metal Matrix Composites.
3) Ceramic Composites.

The fibers are either long or short. Long and continuous fibers are easy to orient and process, whereas short fibers cannot be controlled fully for proper orientation. The principal fibers in commercial use are various types of glass, carbon, graphite and Kevlar. All these fibers are incorporated in matrix form either in continuous length or in discontinuous length.

2.1 Advantages of composite materials over conventional materials


Table 2.1- Properties of steel material

<table>
<thead>
<tr>
<th>Sr No.</th>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Modulus of Elasticity E(GPa)</td>
<td>207</td>
</tr>
<tr>
<td>2</td>
<td>Density</td>
<td>7600</td>
</tr>
<tr>
<td>3</td>
<td>Poissons Ratio</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Table 2.2 - Properties of Composite material

<table>
<thead>
<tr>
<th>Property</th>
<th>Units</th>
<th>E-glass/epoxy</th>
</tr>
</thead>
<tbody>
<tr>
<td>E11</td>
<td>GPa</td>
<td>50.0</td>
</tr>
<tr>
<td>E12</td>
<td>GPa</td>
<td>12.0</td>
</tr>
<tr>
<td>G12</td>
<td>GPa</td>
<td>5.6</td>
</tr>
<tr>
<td>ν12</td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td>σ^11 = σ^22</td>
<td>MPa</td>
<td>800</td>
</tr>
<tr>
<td>σ^12 = σ^21</td>
<td>MPa</td>
<td>40</td>
</tr>
<tr>
<td>τ12</td>
<td>MPa</td>
<td>72</td>
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</tbody>
</table>

III. DESIGN PARAMETERS

<table>
<thead>
<tr>
<th>Parameter of shaft</th>
<th>symbols</th>
<th>values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer Diameter</td>
<td>d_i</td>
<td>100</td>
<td>mm</td>
</tr>
<tr>
<td>Inner Diameter</td>
<td>d_o</td>
<td>95</td>
<td>mm</td>
</tr>
<tr>
<td>Length of the shaft</td>
<td>L</td>
<td>900</td>
<td>mm</td>
</tr>
<tr>
<td>Thickness of shaft</td>
<td>T</td>
<td>2.5</td>
<td>mm</td>
</tr>
</tbody>
</table>

IV. WEIGHT CALCULATION

A) For steel Propeller shaft-

Weight of shaft (W) = Density x Volume

\[ W = 7600 \times \frac{\pi}{4} \times (d_o^2 - d_i^2) \times L \]

\[ W = 7600 \times (0.1^2 - 0.095^2) \times 0.9 \]

\[ W = 5.23 \text{ Kg} \]

Section of Modulus Z = \( \frac{\pi}{32} \times (d_o^2 - d_i^2) / d_o \)

\[ Z = 1.82 \times 10^{-5} \text{ m}^4 \]

Bending Moment (M) = \( \frac{W \times L}{2} \)

\[ M = \frac{5.23 \times 9.81 \times 0.9}{2} \]

\[ M = 23.08 \text{ N-m} \]

Stress (σ) = \( \frac{M}{Z} \)

\[ \sigma = \frac{23.08}{1.82 \times 10^{-5}} \]

\[ \sigma = 1.26 \times 10^6 \text{ N/m}^2 \]

Shear stress (τ) = \( \frac{T}{\pi/16 \times (d_i^4 - d_o^4) / d_o} \)

\[ \tau = \frac{3700}{\pi/16 \times (0.1^4 - 0.095^4) / 0.1} \]

\[ \tau = 101.58 \times 10^6 \text{ N/m}^2 \]

Equivalent stress = \( \sqrt{\sigma^2 + \tau^2} \)

\[ \sigma_{\text{eq}} = 101.50 \times 10^6 \text{ N/m}^2 \]

B) For Composite Propeller Shaft-

Mass = Density x Volume

\[ M = 2000 \times \frac{\pi/4 (d_o^3 - d_i^3)}{L} \]

\[ M = 2000 \times \frac{\pi/4 (0.1^3 - 0.095^3)}{0.9} \]

\[ M = 1.53 \text{ Kg} \]
Bending Moment = M = (W X L)/2
= (1.53 X 9.81 X 0.9)/2
= 6.75 N-m

Stress (σ) = M / Z = 6.75/1.82 X 10^{-5}
= 3.7 X 10^5 N/m^2

% weight reduction = (5.23-1.53)/2 X 100
= 70.73%

DESIGN ANALYSIS

Finite element analysis is a computer based analysis technique for calculating the strength and behavior of structures. In the FEM the structure is represented as finite elements. These elements are joined at particular points which are called as nodes. The FEA is used to calculate the deflection, stresses, strains temperature, buckling behavior of the member. In our project FEA is carried out by using the ANSYS 12.0. Initially we don’t know the displacement and other quantities like strains, stresses which are then calculated from nodal displacement.

Static analysis

A static analysis is used to determine the displacements, stresses, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects. A static analysis can however include steady inertia loads such as gravity, spinning and time varying loads. In static analysis loading and response conditions are assumed, that is the loads and the structure responses are assumed to vary slowly with respect to time. The kinds of loading that can be applied in static analysis includes, Externally applied forces, moments and pressures Steady state inertial forces such as gravity and spinning Imposed non-zero displacements. 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.

Modal analysis

When an elastic system free from external forces can disturbed from its equilibrium position and vibrates under the influence of inherent forces and is said to be in the state of free vibration. It will vibrate at its natural frequency and its amplitude will gradually become smaller with time due to energy being dissipated by motion. The main parameters of interest in free vibration are natural frequency and the amplitude. The natural frequencies and the mode shapes are important parameters in the design of a structure for dynamic loading conditions. Modal analysis is used to determine the vibration characteristics such as natural frequencies and mode shapes of a structure or a machine component while it is being designed. Modal analysis is used to determine the natural frequencies and mode shapes of a structure or a machine component. The rotational speed is limited by lateral stability considerations. Most designs are sub critical, i.e. rotational speed must be lower than the first natural bending frequency of the shaft. The natural frequency depends on the diameter of the shaft, thickness of the hollow shaft, specific stiffness and the length.

Material comparison for various results

STATIC ANALYSIS

STEEL
Total deformation

Maximum Principle Stresses

EPOXY

Maximum Shear Stress

Table – Comparison of static structural analysis of Propeller Shaft

STEEL

Mode 1

Mode 2
### CONCLUSION

- The replacement of conventional drive shaft results in reduction in weight of automobile.
- The finite element analysis is used in this work to predict the deformation of shaft.
- The natural frequency of epoxy material was found to be less than steel material.
- 70.73% weight reduction was done by using Epoxy glass material.
REFERENCES


