Modeling and Damping Analysis of High Grade Steel Alloy Drive Shaft in Automobile

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ABSTRACT: A drive shaft is a mechanical component for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them. As torque carriers, drive shafts are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. The functions of the driveshaft are it must transmit torque from the transmission to the differential gear box. The drive shafts must also be capable of rotating at high speeds required by the vehicle. The drive shaft must also operate through constantly changing angles between the transmission, the differential and the axles. The length of the drive shaft must also be capable of changing while transmitting torque. High strength steel is a new generation of steel material exhibiting improved properties over conventional steel grades. The Drive Shaft of the rough terrain vehicle (BAJA) suffered from a dynamic instability problems due to the nature of rigorous instability on rough terrain. This problem is inherent to study the vibration properties of the drive shafts as they tend to break down causing severe shaft dynamic loading. The multidisciplinary problem of drive shaft dynamics was to be addressed accurately in the time/frequency domain using traditional "strike method" of testing structures with modally tuned impulse hammer and data acquisition system. Modal testing is conducted with FFT Analyser using impact hammer as input force transducer and accelerometer to record the output signals. CAD modelling of drive shaft is done using available drawings & dimensions. FE simulation of drive shaft is carried out to solve modal analysis. Validating and comparing the result of both FE analysis and experimental modal analysis.

Key words: Damping, HSS, Steel alloy, Vibration, FEA

I. INTRODUCTION

A drive shaft is a mechanical component for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distanceor the need to allow for relative movement between them. As torque carriers, drive shafts are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia.

An automobile may use a longitudinal shaft to deliver power from an engine/transmission to the other end of the vehicle before it goes to the wheels. A pair of short drive shafts is commonly used to send power from a central differential, transmission, or transaxle to the wheels. An automotive drive shaft transmits power from the engine to the differential gear of a rear wheel drive vehicle. The torque capability of the drive shaft for passenger cars should be larger than 3500 Nm and the fundamental bending natural frequency should be higher than 9200 rpm to avoid whirling vibration. In front-engine, rear-drive vehicles, a longer drive shaft is also requiredto send power the length of the vehicle.

An automotive drive shaft transmits power from the engine to the differential gear of a rear wheel drive vehicle. The drive shaft is usually manufactured in two pieces to increase the fundamental bending natural frequency because the bending natural frequency of a shaft is inversely proportional to the square of beam length and proportional to the square root of specific modulus which increases the total weight of an automotive vehicle and decreases fuel efficiency. The torque that is produced from the engine and transmission must be transferred to the rear wheels to push the vehicle forward and reverse. The drive shaft must provide a smooth, uninterrupted flow of power to the axles. The drive shaft and differential are used to transfer this torque.

The Drive Shaft of the rough terrain vehicle (BAJA) suffered from a dynamic instability problems due to the nature of rigorous instability on rough terrain. This problem

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is inherent to study the vibration properties of the drive shafts as they tend to break down causing severe shaft dynamic loading. Vibration analysis of drive shaft component can characterize the structural dynamics, and can determine the fundamental frequencies and define a complete modal model ofthe component.

In the present work, it is proposed to develop and validate a vibration model for the prediction of dynamic response parameters of drive shaft of a rough terrain vehicle (BAJA).The multidisciplinary problem of drive shaft dynamics was to be addressed accurately in the time/frequency domain using traditional "strike method" of testing structures with modally tuned impulse hammer and data acquisition system.

Vibration analysis of a drive shaft component can characterize the structural dynamics, determine the fundamental frequencies and define the complete modal data of the component. From this data, engineers can objectively evaluate their concerns about the impact of vibrations on adjacent driveshaft components. These concerns have very real consequences since excessive vibrations can lead to premature component fatigue and failure [21]. For instance, drive shaft is acritical component that must meet very high quality standards. Also, modal analysis is not only useful in its own right, but it also provides the basis for a number of further dynamics analyses.

To this end, modal test plays an important role in the certification process of any new or extensively modified driveshaft. Modal testing of a drive shaft determines its natural frequencies, normal mode shapes and modal damping over a specified.

II. LITERATURE REVIEW

Rastogin has explained that this work presents a comprehensive approach to design drive- shafts for automotive applications. The two important aspects of driveshaft design, viz., (i)design of composite shaft tube, and (ii) design of adhesively bonded tubular joint between the yoke and the tube are discussed. Based on the closed-form analytical solutions preliminary design tools are developed to aid quick analysis and design of composite driveshaft for automotive applications. Furthermore, detailed finite element analyses are performed to validate the preliminary design tools.

Xiaomingchen et. al., have explained that the drive shaft modeling effects frontal crash finite element simulation. A 35 mph rigid barrier impact of a body on frame SUV with a one piece drive shaft and a uni-body SUV with a two piece drive shaft have been studied and simulated using finite element analyses. In the model, the drive shaft can take significant load in frontal impact crash. Assumptions regarding the drive shaft model can change the predicted engine motion in the simulation. This change influences the rocker at B-pillar deceleration. Two modeling methods have been investigated in this study considering both joint mechanisms and material failure in dynamic impact. Model parameters for joint behavior and failure should be determined from vehicle design information and component testing. A body on frame SUV FEA model has been used to validate the drive shaft modeling technique by comparing the simulation results with crash test data. These drive shaft models have also been applied to a unibody SUV model to demonstrate the contribution of drive shaft for simulated frontal impact performance.

Jaskulski et. al., stated that their study registers a finite element analysis of a seal boot used in constant velocity drive-shafts. By this analysis the structure's behavior is studied in its work life before construction of the actual prototype. Prototype development time can be saved in the design phase since the part can be improved by this theoretical prediction tool. Failure points are predicted by the analysis saving resources such as developing production tools, making prototypes and testing them to finally detect the items that have to be improved.

Duggan J et. al., has emphasized that improved automotive driveshaft performance can be obtained through the use of materials with improved specific stiffness. Lightweight drive-shafts made with base alloy 6061-T6 aluminum in a metal matrix composite tubing, on a pilot scale, have demonstrated improved critical speed performance characteristics over conventional steel and aluminum drive-shafts. In preparation for potential application, large scale manufacturing concerns and subsequent performance issues have become the focus. The production of metal matrix composite and its subsequent fabrication into tubing will be reviewed. Potential methods for non-destructive certification of tube properties will be discussed. In addition, the strength and dynamic performance of the resulting driveshaft assemblies will be presented and compared with conventional aluminum and steel counterparts.

Coutinho L. has explained that the study of the bending vibrations of front wheel drive automobile half-shafts,

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using various theoretical models results in comparison with published experimental data. It's well known that this kind of noise problem occurs when a vertical excitation frequency generated by the engine equals one of the bending natural frequencies of the half-shaft or its interconnecting shaft. The experimental modal analysis is today the preferred method used in the study of this kind of problem. This work, investigates the determination of the bending natural frequencies of a front wheel drive automobile half-shaft, using the transfer matrix method (TMM) and the finite element method (FEM) in the solution of a theoretical model. This model considers the boundary conditions existing in the vehicle, and also in the solution of other simplified models. These results are then compared with published experimental modal analysis results, and conclusion about the validity of the proposed methods and models in analyzing these resonance problems and in the design of automobile half-shafts is presented.

R Sino et. al., discussed that this paper is concerned with the dynamic instability of an internally damped rotating composite shaft. A homogenized finite element beam model, which takes into account internal damping, is introduced and then used to evaluate natural frequencies and instability thresholds. The influence of laminate parameters: stacking sequences, fiber orientation, transversal shear effect on natural frequencies and instability thresholds of the shaft.

III. RESULTS AND DISCUSSION

MODAL PARAMETERS OF DRIVE SHAFT

Modal parameters such as frequency, mode shapes and damping obtained from both experimental test set up and finite element analysis are recorded and are as shown below. However, damping values recorded is from experiments only.

The frequencies and damping obtained for the drive shaft are shown in table 4.1 below.

***Table 1:** Modal frequencies and Modal Damping for Drive shaft*

Mode Number	Experimental Modal Testing		Finite Element Modal Analysis
	Frequency (Hz)	Damping (%)	Frequency(Hz)
1	872.152	0.010	735.56
2	1753.0553	0.031	2094

Table 1 indicates the modal parameters obtained from both experimental and FEA techniques for three modes. Natural frequencies, damping and corresponding mode shapes have been recorded. It is evident from the above table that both experimental and FEA results are in good agreement with deviation less than 15%. Damping values recorded, however, is thru' modal testing which employs half-power bandwidth method. It can be observed from the above datathat for higher modes, the modal response of the drive shaft is vulnerable to changes from one dominant mode to another. Measured variation of relative magnitudes of peak FRFs associated with the first two modes of the drive shaft is presented in 5.1a to 5.3b. First mode corresponds to symmetric bending followed by asymmetric bending in the second mode, dominance of the variation.

GRAPH

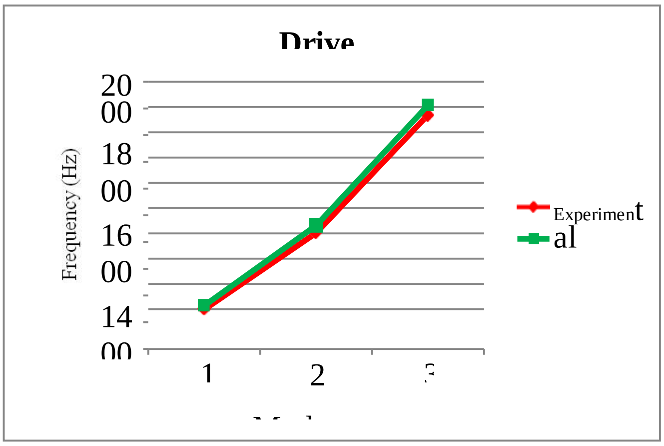

***Fig 1:** Mode Number versus Frequency –Drive shaft (Expt. and FEA)*

Fig 1 depicts the comparison between experimental and FEA results of mode number versus frequencies plotted on a single graph. It can be observed that as the mode number increases,there is steep increase in the frequency in drive shaft. The deviation between experimental resultsand FEA results are found to be well within 15%

IV. CONCLUSION

The drive shaft of the all-terrain vehicle, BAJA, is subjected to various dynamic loads, which was procured and experimented upon. The focus of this work was to develop a finite element model capable of accurately predicting the observed modes of vibrations in drive shaft. In addition, experimental modal testing was successfully carried out to validate results obtained. A summary of the investigation performed for this paper is stated below.

- Procuring of Drive shaft was carried out from BAJA workshop in RVCE campus, Bangalore. The dimensions and the build of drive shaft were successfully studied.
- Experimental modal analysis was performed on drive shaft using traditional "strike method" in order to obtain modal parameters of the test component. An average value of 301.289 Hz was found for the first modal frequency for the first bend mode of drive shaft. FEA results had predicted a first modal response of 327.44 Hz.
- The difference in the results obtained thru' experiments and FEA was investigated, since the manufacturing of actual drive shaft can create variations in the specified material properties of the metal alloy, effects of variation in thickness, orientation etc.
- The use of Finite Element technique as a powerful numerical tool to predict the modal parameters of drive shaft was very successful & faster. Results obtained were in good agreement with experimental ones.

Finally, it is concluded that the significance of evaluating the modal parameters of drive shaft from both experiments and numerical techniques has yielded good results. This

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result forms a vital input to the further analysis in vehicle dynamics.

Thus the result obtained through this work provides an insight to the designers' in the field of automobiles and correct choice of ingredients when the structures are designed under dynamic environment.

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