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Automotive Composite Hybrid Drive Shaft - A Review

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Abstract - *The drive shaft is a very important component of an automobile. By adding composite materials for conventional metallic structures have many advantages such as higher specific strength and stiffness of the composite materials. The aim of this work is examines the maximum torsion capacity of hybrid drive shaft for number of layers, different winding angles and stacking sequences. The hybrid shaft contains of aluminum tube wound outside by carbon fibers/epoxy composite.*

Key Words: Hybrid Shaft, Stacking sequence, Fundamental natural frequency, Torque transmission, Torsional buckling capacities.

1. INTRODUCTION

The drive shaft is a rotating element in circular cross-section that transmits the power from the engine to the differential gear of a rear wheel drive vehicles. The drive shaft must operate complete constantly varying angles between the transmission and axle. High class steel is a common material for manufacture. Steel drive shafts are usually produced in two pieces to increase the fundamental bending natural frequency since the bending natural frequency of a drive shaft is inversely proportional to square of beam length and proportional to square root of specific modulus. In a two piece steel drive shaft involves of three universal joints such as a center supporting bearing and a bracket, which raise the total weight of a vehicle. The power transmission can be enhanced through the reduction of inertial mass and light weight. Replacing the composite structures over the conventional metallic structures has many benefits because of higher specific strength and specific stiffness of composite materials

2. LITERATURE REVIEW

Lien-Wen Chen, Wen-King Peng [4] studied the stability behaviour of a rotating composite shaft subjected to an axial compressive loads using finite element technique. The laminated composite shaft is modelled as a Timoshenko shaft by applying the equivalent modulus beam theory. Mathematical results correlate with the reported beam models. The dangerous speed of the thin-walled composite shaft is in need of the stacking sequence, the length-radius ratio and the boundary conditions. In adding, the effects of the rotational speeds and the disk location on the rotating shafts' stability are studied as well.

R. R. Chang, J. M. Chu [5] studied the failure strengths of laminated composite drive shafts subjected to static bending load and or torque are calculated using both experimental and theoretical approaches. We investigate optimal angle-ply orientations of laminated composite drive shafts with the design of symmetric main fiber layups and anti-symmetric reinforcing fiber lay-ups for maximum stiffness. Different analytical techniques, together with various failure criteria, are used to forecast the first-ply failure strengths of the composite drive shafts. A hand lay-up and pressure bag technique was used to fabrication the composite drive shafts, which includes the stacking of pieces of pre-preg in the desired orientations and the curing procedure. The first-ply failure loads of laminated composite drive shafts were determined using acoustic emission. The failure types of the drive shafts are examined and experimental results are used to verify the theoretical predictions.

Dai Gil Lee, Hak Sung Kim, Jong Woon Kim, Jin Kook Kim [6] studied by substituting composite structures for conventional metallic structures has many benefits because of higher stiffness and higher specific strength of the composite materials. In this work single piece automotive hybrid aluminium/composite drive shaft was developed with a new manufacturing technique, in which the carbon fibre epoxy composite layer was co-cured on the inside surface of an aluminium tube rather than covering on the outer surface to avoid the composite layer from being damaged by external impact and absorption of moisture. The optimal stacking sequence of the composite layer was found by considering the thermal residual stresses of interface between the aluminium tube and the composite layer designed by finite element analysis. Press fitting technique for the connecting of the aluminium/composite tube and steel yokes was devised to increase reliability and to reduce manufacturing cost as compared to other joining techniques such as adhesively bolted or riveted, bonded and welded joints.

S. A. Mutasher [10] a hybrid aluminum/composite is an advanced composite material that consists of aluminum tube wound against outside by layers of composite material. The result from this combination is a hybrid drive shaft that has a higher fundamental natural bending frequency, a higher torque transmission capability and less noise and vibration. This paper examines the higher torsion capacity of the hybrid aluminum/composite drive shaft for different stacking sequences, number of layers and winding angle. The hybrid drive shaft consists of aluminum tube wound outside by carbon fibres/epoxy and E-glass composite. The finite element technique has been used to analyze the hybrid drive shaft under static torsion. Finite element software was used to achieve the numerical analysis for the hybrid shaft.

M. A. Badie et al. [12] studied that the effect of stacking sequence and fibre orientation angles on the torsional stiffness, buckling strength, natural frequency, fatigue life and failure types of composite tubes. Finite element analysis has been used to predict the fatigue life of drive shaft using linear dynamic analysis for the different stacking sequence. Experimental program on climbed woven fabric composite models was done to investigate the torsional stiffness. The composite drive shaft has a decrease equal to 54.3% of its frequency when the alignment angle of carbon fibres at one layer, amongst other three glass ones, transformed from 0^0 to 90^0 On the other hand, the critical buckling torque has a highest value at 90^0 and lowest at a range of 20^0- 40^0 when the angle of one or two coatings in a hybrid or all layers in non-hybrid changed likewise.

M. R. Khoshravan, A. Paykani [15] studied design method and vibrational analysis of composite propeller shafts. A propeller shaft is not limited to vehicles, but in several transmission applications can be used, but the aim is to exchange a metallic shaft by a two-piece composite shaft. Designing of a composite drive shaft is divided in two main sections such as design of the composite drive shaft and design of couplings. In composite shaft design some parameters such as static torque, adhesive joints and critical speed are studied the behaviour of materials is considered linear isotropic for metal, nonlinear isotropic for adhesive and orthotropic for composite shaft.

Hamouda [16] studied that fatigue resistance, weight reduction, vibration damping and design flexibility to meet critical vibration significance are offered by replacing fibrous composites for conventional metals for the power transmission shafts, which utilized in many engineering practical uses an including automotive. It is strongly related to stiffness, the optimal design constrained by rotational frequency, applied torque and torsional frequency which are to be traversed by increasing the critical speed, critical torque and torsional stiffness, respectively. However, composite drive shaft design is a problem of given stiffness with the variables of layers material, thickness and stacking sequence.

Secil Eksi et al. [17] studied that the buckling is characterized by a quick failure of a structural member subjected to maximum compressive load. In this study, the buckling performance of the aluminium tubular beam was analysed using finite element method, and the reinforcing arrangements as well as its combinations were decided for the composite beams based on the FE results. Buckling and bending behaviours of thin-walled aluminium tubular beams with internal cast polyamide and external glass and carbon fibre reinforcement polymers were investigated systematically. The use of plastics and metal composed as a reinforced structure yields better mechanical performance properties such as peak resistance to bending loads and buckling, dimensional stability and high energy absorption capacity, including weight decline.

Ercan Sevkat, Hikmet Tumer [18] studied experimental and numerical investigation regarding residual torsional properties of composite shafts subjected to impact loadings. Carbon/epoxy and E-glass-carbon/ epoxy hybrid composite shafts were produced by filament winding technique. Composite drive shafts were impacted at 5, 10, 20 and 40 J energy levels. Force-time and energy-time histories of impact tests were noted. One composite drive shaft with no impact, and four composite shafts with impact damage, five in total, was tested under torsion. Torque-twisting angle relations for each test were obtained. Decreasing at maximum torque and twisting angle induced by impact loadings were calculated.

R. Srinivasa Moorthy, Yonas Mistake and K. Sridhar [20] studied the use of advanced composites has resulted in remarkable accomplishments in many fields containing aeronautics, marine and automobile engineering, sports and medicine, in terms of enhanced fatigue and erosion resistances, high specific modulus and specific strength and reduction in energy requirements owing to reduction in weight. The purpose of this work is to exchange the conventional steel drive shaft of automobiles with an appropriate composite drive shaft.

The conventional drive shafts are made in two pieces for decreasing the bending natural frequency, whereas the composite shafts can be prepared as single-piece shafts, thus decreasing the overall weight.

3. MATERIALS AND METHODS

Various materials like Aluminum/composite, Carbon/Epoxy, E-glass/Epoxy, Graphite/Epoxy, Boron/Epoxy and Kevlar/Epoxy followed by authors by their techniques such as experimental, finite element analysis, MATLAB, genetic algorithm and classical lamination theory. Above all techniques such as experimental, FEA and classical lamination theory are used to find out the static analysis, modal analysis, buckling analysis, torque transmission and natural frequency of composite drive shaft.

4. CONCLUSION

An efficient design of composite drive shaft can be achieved by selecting the proper variables, which can be recognized for safe structure against failure and to achieve the performance requirements. As the length and outer radius of drive shafts in an automotive applications are limited to spacing, the design variables include the inside radius, layers thickness, fiber orientation angle, number of layers and layers stacking sequence. In optimal design of drive shaft these variables are constrained by the lateral natural frequency, torsional strength, torsional vibration and torsional buckling.

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