Design, Failure Analysis And Optimization of Propeller Shaft By ANSYS

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Abstract- *Drive shafts, driving shafts, tail shafts, propeller shafts, and Cardan shafts transfer torque and rotation to drive train components that are too far apart or moving. Drive shafts experience torque and load-related torsion and shear stress.The propeller shaft powers the back axle through the differential unit's input pinion from the gearbox output shaft. resolve the gearbox output shaft-differential input shaft alignment issue. In this research, ANSYS modeled the Universal joint yoke using low-alloy steel AISI 4063 will be studied. Yield strength is 1476 Mpa, tensile strength 1338 Mpa. Spider mounting torque is 200Nm. 500rpm and torque. Keep material consistency, torsional moment loading, and rotating speed. ANSYS12 evaluated the model. The transmission system's drive shaft meets design standards. Auto gearbox propeller shaft parameters should match steel propeller shaft properties for best design. Three to four propeller shaft material characteristics will be investigated. This check measures propeller shaft tension and strain. Check propeller shafts. The research compares material attributes to increase propeller shaft performance.*

Keywords- steel AISI 4063, Propeller, Shaft, Ansys, Material Properties

I. INTRODUCTION

A drive shaft, driving shaft, tail shaft, propeller shaft or Cardan 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. They must therefore be strong enough to bear the stress, while avoiding too much additional weight as that would in turn increase their inertia. To allow for variations in the alignment and distance between the driving and driven components, drive shafts frequently incorporate one or more universal joints, jaw couplings, or rag joints, and sometimes a splined joint or prismatic joint. The movement of vehicles can be provided by transferring the torque produced by engines to wheels after some modification. The transfer and modification system of vehicles is called as power transmission system and have different constructive features according to the vehicle's driving type which can be front wheel drive.

Most automobiles today use rigid driveshaft to deliver power from a transmission to the wheels. A pair of short flexible driveshaft is commonly used in cars to send power from a differential to the wheels. 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.

The present project focuses on the design of propeller shaft and finding the causes of failure and optimization of shaft. The propeller shafts must be strong enough, low notch sensitivity factor, having heat treated and high wear resistant property so that it can sustain high bending and torsional load, such an automotive driveshaft made by composite materials. The propeller shafts must be strong enough, low notch sensitivity factor, having heat treated and high wear resistant property so that it can sustain high bending and torsional load. The common material for construction is high quality steel of grade SM45C.Due to high specific strength and high specific modulus the advanced composite materials like Epoxy composite, Carbon fibers, Kevlar, Glass fibers and thermoplastic polyamide etc. with suitable resins are widely used for long propeller shaft. For this application advanced composite materials seems ideally suited.

The term propeller shaft refers to the mechanism utilized to transmit motion from one place to another. Propellers are commonly linked with ships and planes because they are driven in the water or air by a propeller fan. The drive shaft of a car, on the other hand, is also known as the propeller shaft because, in addition to delivering rotational motion from the engine to the back end of the vehicle, these shafts also push the vehicle forward. The shaft is the fundamental link between the front and rear ends (engine and differential), and it is responsible for both conveying motion and pushing the front end. As a result, the phrases driving shaft and propeller shaft are interchangeable. A propeller shaft, in other terms, is a

longitudinal drive shaft used in vehicles when the engine is located at the opposite end of the vehicle from the driving wheels. A propeller shaft is a grouping of one or more tube shafts joined together by universal, constant velocity, or flexible joints. The number of tubular parts and joints required is determined by the distance between the gearbox and the axle. As with rear-wheel drive, some four-wheel drive vehicles employ one propeller shaft to power the back wheels and a second propeller shaft to power the front wheels. In this situation, one of the most significant components is the second propeller shaft, which is responsible for the actual motions of the vehicle after motion is created in the engine. The design of such important components is often strict, as a fracture in this element might result in a catastrophic failure of the vehicle while it is in motion.

1.2 Types of Shaft

Several different types of drive shaft are used in the automotive industry:

- One-piece drive shaft
- Two-piece drive shaft
- Slip-in-tube drive shaft

The slip-in-tube drive shaft is a new type that improves crash safety. It can be compressed to absorb energy in the event of a crash, so is also known as a collapsible drive shaft.

One-piece drive shaft is lighter weight Driveshaft for Enhanced Driveline Performance. It is a driveshaft that is designed for applications that call for increased horsepower, so we can hit the road with confidence.

The two-piece drive shaft is meant to prevent the drive shaft from pulling out under extreme axle movement. The front of the drive shaft slips into the transmission. The rear of the drive shaft bolts to the rear axle. Now a day's two pieces steel shaft are used as drive shaft.

When the length of steel drive shaft is beyond 2000 mm, it is manufactured in two pieces to increase the fundamental natural frequency, which is inversely proportional to the square length and proportional to the square root of specific modulus. Major features of the Drive shaft include its high resistance to dynamic load variations, large deflection angles and uniform load distribution throughout the axial displacement range, low rotational diameter, low weight, and versatile flange connections these features provide an ideal base for standardized drive train design and new power transmission concepts.

1.3. Function of Propeller Shaft

- Propeller shaft take power from the gear box output shaft without making any change in power, it transmits the same to the input pinion of the differential unit, from where power is transmitted to the drive wheels through rear axle.
- To accommodate the change in line and level between gear-box output shaft and differential input pinion shaft.

1.4. Propeller Shaft Detailing

The propeller shaft is a component used for transmitting mechanical power, torque, and rotation. These shafts as also known as driveshaft, driving shaft, tail shaft, or Cardan shaft. The driveshaft is used to transfer torque between components that cannot be connected directly because of distance or the need to allow relative motion between them.

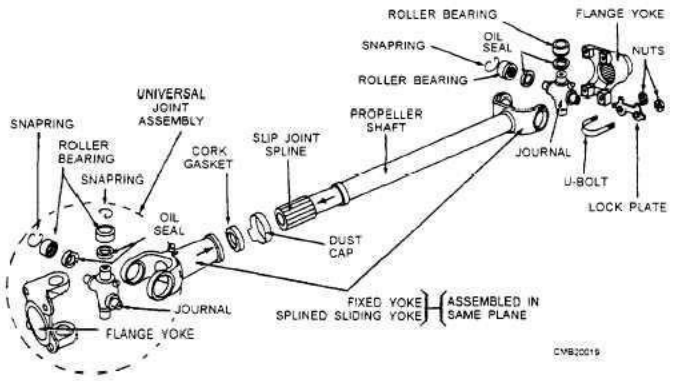

Figure No 1.1 Details Of Propeller Shaft

1.4.1 U-Bolt or U-joint

A universal joint (U-joint) is a mechanical joint used to connect rotating shafts. Nowadays, the driveshaft and universal joints are mostly seen on rear-wheel drive and four-wheel drive vehicles.

1.4.2 Tube

A tube is a part of a drive shaft, it is often used in front engine and rear drive automobiles. The purpose of using a tube is to keep the rear end in place during acceleration and braking.

1.4.3 Centre Bearing

Centre bearing is used to connect the two sections of the drive shaft. These bearings are meant to keep both parts of

the driveshaft solid to reduce harmonic vibrations when the vehicle is accelerating.

1.4.4 Midship Shaft

Midship shafts are the basic components of a coupling shaft and are part of a drive shaft that is attached to the frame on a center bearing.

1.4.5 End Yoke

An end yoke is used for accuracy and durability. The benefit of using an end yoke is to help reduce noise and vibration to keep your driveline running easily.

1.4.6 Slip Yoke and Tube Yoke

A slip yoke is attached to the driveshaft itself using a universal joint. The slip yoke is fitted to transfer power by sliding in and out of the transfer case. The tube yoke is also necessary to allow the U-joints to rotate well with the drive shaft.

1.4.7 Flanges Yoke

Flanges are used for automotive purposes to connect the driveshaft to the transmission, transfer case, and differential. The flanges are also used to connect drive shafts to power take-offs, hydraulic pumps, and a variety of accessories.

1.4.8 Propeller Shaft

The propeller shaft used to transmit the power from gear box output shaft to differential with tubular cross-section & one or two piece construction. Propeller shaft should be rigid enough to absorb the twisting action due to driving torque and the torsional shock. It should also be capable of resisting the vibration.

Tubular propeller shaft is generally used because its weight is less, it can resist is alignment. It has good torsional strength. It provides less resistance to change of angular speed caused when hook type coupling is used. Propeller shaft is running faster when overdrive is used, hence it should be produce as per required design specification and good limit of balances.

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.

So, a single piece drive shaft is preferred here and the material of it is considered to be Titanium alloy because of its high strength and low density. Drive shafts are carriers of torque and 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.

1.4.9 Sliding (Slip) Joint

A sliding (slip) joint, is also fitted between universal joint and propeller shaft on transmission side which takes care of axial motion of propeller shaft. Propeller shaft is made of a steel tube which can withstand torsional stresses and vibrations at high speeds.

It is important to note that the differential pinion shaft and transmission main shaft are not in single horizontal level. The rear axle and differential is attached to automobile frame via springs. Therefore, distance between differential and gear box keeps on changing as vehicle moves along irregular road surface. Angle of propeller shaft also changes due to this fact.

1.4.10 Universal Joint

Universal joints provided at two ends take care of these two changes. A universal joint allows driving torque to be carried through two shafts that are at an angle with each other. A simple universal joint consist two Y- shaped yoke, one on the driving shaft and other on the driveshaft.

The four arms of spider are assembled in needle bearings in the two yokes. The driving shaft and yoke force the spider to rotate. The other two trunnions of the spider then cause the driven yoke to rotate. When the two shafts are at an angle with each other, the needle bearings permit the yokes to swing around on the trunnions with each revolution.

A simple universal joint does not transmit the motion uniformly when the shafts are operating an angle. Because of this, two universal joints are used in a vehicle, one between the gear box and the propeller shaft and other between the propeller shaft and the differential pinion shaft.

Scope of the Study

The project aims to reduce the weight of the propeller shaft assembly by using different materials. For this project

work, the drive shaft of a car was chosen. The modeling of the propeller shaft assembly was done using Catia V5. A Leaf spring has to be designed to meet the stringent design requirements for automobiles. A comparative study of five different materials was conducted to choose the best-suited material. Steel (SMC 45) was chosen for reference and the rest of the five different materials were analyzed. The analysis was carried out using ANSYS 10.0 Workbench for the following materials.

1.7. Objective

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.

- Finding the cause of failure
- Design and analysis of propeller shaft
- Optimize the design of propeller shaft which should be compatible and cost effective

II. LITERATURE REVIEW

M Manoj, P.Satish Reddy, et.al. (2015), "Design and Analysis of a Propeller Shaft in CAE tool and ANSYS" A Propeller Shaft is a device on which a propeller is attached to and transfers the power from the engine to the propeller. In the design of automobiles, the industry is exploiting in order to obtain reduction of weight without significant decrease in vehicle quality and reliability. This is due to the fact that the reduction of weight of a vehicle directly impacts its fuel consumption. Particularly in city driving, the reduction of weight is almost directly proportional to fuel consumption of the vehicle. A Propeller Shaft is a longitudinal drive shaft used in vehicles where the engine is suited at the opposite end of the vehicle to the drive wheels. A propeller shaft is an assembly of one or more tubular shaft connected by universal, constant velocity or flexible joints. Thus, in this project work the propeller shaft of a vehicle was chosen and analyzed by replacing it with different materials

Akash Devendra Rathod et.al. (2021), "Design and Analysis of Propeller Shaft" In current scenario, the most important in automobile power transmission application is the drive shaft. Drive shaft is a mechanical component used to connect the drive train components which are not connected due to the distance between them. Drive shaft is used for transmitting torque and power which subjects the drive shaft to high torsional and shear stress. This work deal with the study of replacement of conventional two-piece steel drive shaft with one-piece composite drive shaft. Automobile industries exploring composite materials in order to obtain reduction of weight without significant decrease in vehicle quality and reliability, this is due to fact that the reduction of weight of a vehicle directly impacts its fuel consumption. Hence design, analysis and comparison are done among material to obtain the most optimized and efficient material for drive shaft.

Jaleta Sori, Edosa Ketema, et.al. (2022), "A Composite Propeller Shaft Analysis Using Ansys Software" In the automobile, one of the most significant components is the drive shaft, which transmits power from the engine to the rear wheels via the differential gear. Steel drive shafts are often utilized in the vehicle industry; however, composite drive shafts are increasingly being employed to replace steel drive shafts. The purpose of this article is to investigate a composite propeller shaft. The use of composite materials instead of traditional steel materials for drive shafts has increased the design benefits due to their high specific stiffness, strength, and possible life with a high critical speed. The design parameters are scrutinized with the goal of reducing the weight of the composite drive shaft. The concept demonstrates a considerable potential increase in propeller shaft performance. Pro/E is used to create the propeller shaft model. FEA analysis is successfully completed using ANSYS 11.0 Multi physics. The FEA findings are utilized to calculate deflection, stresses, and natural frequencies under applied loads. A further comparison of steel and composite materials will be performed to examine the torsion, buckling, and bending natural frequency weight savings of the propeller shaft.

V. Jose Ananth Vino, Dr. J. Hameed Hussain, et.al. (2015), "Design and Analysis of Propeller Shaft" Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. This work deals with the replacement of conventional two-piece steel drive shafts with a single-piece e-glass/ epoxy, high strength carbon/epoxy and high modulus carbon/epoxy composite drive shaft for an automotive application. The design parameters were optimized with the objective of minimizing the weight of composite drive shaft. The design optimization also showed significant potential improvement in the performance of drive shaft. The main concept of our project is to reduce the weight of automotive drive shaft with the utilization of composite material. Composite materials have been used in automotive components because of their properties such as low weight, high specific stiffness, corrosion free, ability to produce complex shapes, high specific strength and high impact energy absorption etc .As the automotive drive shaft is a very

important component of vehicle. The modeling of the drive shaft assembly was done using ANSYS software. A shaft has to be designed to meet the stringent design requirements for automotives. In automobiles the drive shaft is used for the transmission of motion from the engine to the differential. An automotive propeller shaft, or drive shaft, transmits power from the engine to differential gears of rear wheel-driving vehicle. In present work an attempt has been to estimate deflection, stresses under subjected loads & natural frequencies using Ansys software.

Ravi Vattipalli, P. S. Naga Sri, (2019), "Design and Analysis of Automotive Composite Propeller Shaft" Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. This work deals with the replacement of conventional steel propeller shafts with Kevlar and high modulus carbon/epoxy composite propeller shafts for an automotive application. The design parameters were optimized with the objective of minimizing the weight of composite propeller shaft. The design optimization also showed significant potential improvement in the performance of propeller shaft.

K. Krishnaveni, Ponnapally Threenadh, et.al. (2019)' "Design And Analysis Of A Drive Shaft By Using Composite Materials" Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. This work deals with the replacement of conventional two-piece steel drive shafts with a single-piece e-glass/ epoxy, high strength carbon/epoxy and high modulus carbon/epoxy composite drive shaft for an automotive application. Use of advanced composites has resulted in remarkable achievements in many fields including aviation, marine and automobile engineering, medicine, prosthetics and sports, in terms of improved fatigue and corrosion resistances, high specific strength and specific modulus and reduction in energy requirements owing to reduction in weight. The aim of this work is to replace the conventional steel driveshaft of automobiles with an appropriate composite driveshaft. The finite element analysis results are compared with already existed steel drive shaft values and it is observed that the single piece composite drive shaft is suitable for driveline application. The design optimization also showed significant potential improvement in the performance of drive shaft. In this present work an attempt has been to estimate the deflection, shear stresses by using ansys 14.5.

Mahtab Ali Machhi, et.al. (2020), "Design and Analysis of Drive Shaft with a Critical Review of Advance Composite Materials and the Root Causes of Shaft Failure" A review paper seeks to examine the numerous forms of shaft failure, shaft reliability and traditional material substitution for certain advanced lightweight alloys and composite materials. We have examined extensive literature in this regards to tackle this issue. Specific materials were examined in this review as contrasted with traditional heavy weight steels. They performed FEA and analytical estimation. The results demonstrate that lightweight alloys and composite materials find strong strength, low weight, low stress rate , high impact tolerance, high stability, high resistance to corrosion, plasticity and shaft weight reduction. This paper demonstrates the different forms, and also the root causes of shaft damage. A crack surface defect through analysis of the macroscopic and microscopic morphologies. The chemical structure, metallographic study and mechanical properties of the material, and theoretical measurements of finite elements of the shaft, also a vast range of light weight composite and alloy materials are compared with their Torsional capacity, Natural bending frequency and deformations.

G Giridharaa , H K Rangavittal, et.al. (2018), "A Review on the design and analysis of composite drive shaft" In current scenario, the most important component in any power transmission application is the drive shaft. Drive shaft is a mechanical component used to connect the drive train components which are not connected due to the distance between them. Drive shafts are used for transmitting torque and power which subjects the drive shafts to high torsional and shear stress. Composite materials are having high specific stiffness, strength, specific modulus, corrosion resistance, wear resistance, fatigue life and light weight properties. Automobile industries are exploring composite materials usage by replacing the conventional one because of light weight properties reduces the vehicle weight without compromising the quality and reliability. The literature raises the issue on torsion, buckling, natural bending frequency and the weight of the drive shaft. The objective of the paper is to review: (a) the work carried out on the composite drive shafts which are used in the automotive applications; (b) fabrication techniques and materials used in the fabrication of composite shafts (c) finite element analysis on composite shaft and steel shaft.

III. METHODOLOGY

The model (Universal joint yoke) was analysed in ANSYS considering the component to be made up of AISI 4063, which is a material in the low alloy steel group. The typical mechanical properties are1338 Mpa as ultimate tensile strength and 1476Mpa as the yield strength. A force applied at the spider mounting location is a torsional moment of 200Nm.In addition the given torsional moment, a 500rmp

speed was also considered. The material as well as the loading conditions of torsional moment and the rotational speed is kept the same. The model was analysed in ANSYS12. However there were some changes made in the geometry of the existing model.

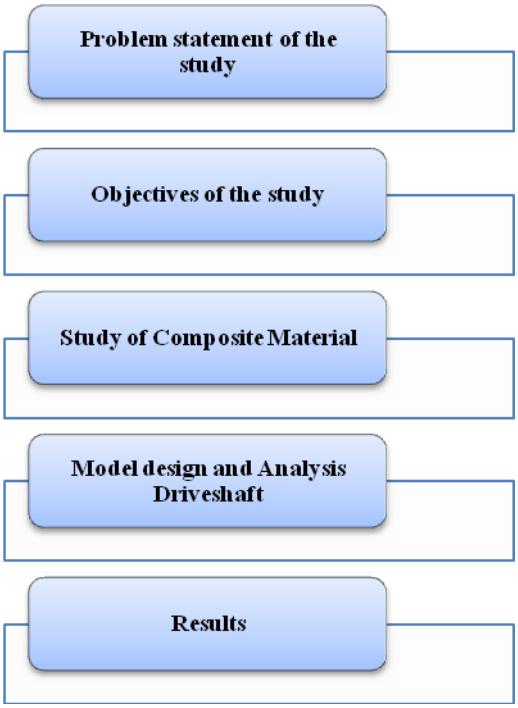

Figure No 3. 1 Flow chart

3.1 Problem Statement

The torque transmission capability of the propeller shaft should be 700 Nm bending frequency of the propeller shaft should be 1200-1600 rpm. Here outer diameter of the shaft is taken as 102 mm and length L of the drive shaft considered is 2100 mm. The drive shaft of transmission system will be designed optimally to the specified design requirements The specifications of the propeller shaft of an automotive transmission are same as that of the steel propeller shaft for optimal design.

Vehicle Type: Heavy Duty Vehicle
Vehicle Weight: 25000 kg
Max. Power: 177 hp@2500 rpm
Max. Torque: 700 Nm@1200-1600 rpm
Gearbox: G750, 6F-Synchromesh, 1R- Constant mesh
Max Speed: 80 km/ph.

DIMENSIONS OF PROPELLER SHAFT

Length of the Shaft, L: 2100mm
Outer diameter of shaft, Do: 102mm
Inner diameter of shaft, Di: 41.28mm
Cross Holder: Plate Dia 6mm/ 150mm, 8 hole, 12mm bolt, RSB cross-42mmx119.2mm
Universal Pin: Dia 42mm, Height: 180mm
Plate: Dia1-150mm, Dia2-102mm, Length-56mm
Slip Joint: Di 72mm, Do 102mm
Cap: Di 102mm, Do 128mm, Thickness 20mm
Seal: Di 102mm, Do 128mm, Thickness 20mm
Bolt: Dia 12mm, Length 20mm, Head 6mm
Washer: Di 12mm, Do 16mm, Thickness 2mm
Nut: Di 12mm, Do 16mm, Thickness 2mm
Weight of Propeller Shaft: 15.621 kg
Total load acting on Propeller Shaft: (Capacity of the Propeller Shaft + Weight of the body) * Gravity = (2500 + 15.621) * 9.81 = 24,678.24201 N = 25 Kn

3.4 MATERIAL PROPERTIES

Currently, drive shafts for automobiles are made of steel (AISI 1045). The table below lists the steel AISI 1045 characteristics. Three design requirements, including torque transmission capability, buckling torque capability, and bending natural frequency, must be met by the steel drive shaft.

Material: AISI 1045
Density (kg/m^3): 7850
Young's Modulus (Mpa): 206E3
Poisson Ratio: 0.29
Tensile Yield Strength (Mpa): 530
Tensile Ultimate Strength (Mpa): 625

Design on strength basis

When an axial tensile force is applied to a shaft, the tensile the source of stress is,

Tensile stress= $P / \pi r^2$

The bending stress of a shaft exposed to a pure bending moment is given by,

Bending stress= $32M / \pi d^3$

The torsional shear stress is given when the shaft is exposed to a pure torsional moment.

$\tau = 16M_t / \pi d^3$

When a shaft is exposed to a mixture of loads, Mohr's circle is used to calculate the primary stress and shear stress.

However, since only torsional shear stresses operate substantially in propeller shafts, must design the shaft.

3.5 Expected Outcome

Within the context of this investigation, three to four distinct material characteristics will be considered for the propeller shaft. The stress and strain distribution on the propeller shaft will be determined over the course of this investigation. Will also investigate if the propeller shaft has become fatigued or deformed. During the study, a comparison will be carried out using a variety of material qualities in order to determine which material properties are most useful for propeller shafts in order to improve their overall efficacy and performance.

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