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Failure Analysis and Modification of Yoke Assembly of Transmission System in Automobiles

Mr. S. K. Dhage
PG Student
Department of Mechanical Engineering
Jai Hind College of Engineering, Kuran Savitribai Phule Pune University India

Prof. Hredeya Mishra
Assistant Professor
Department of Mechanical Engineering
Jai Hind College of Engineering, Kuran Savitribai Phule Pune University India

Prof. P. G. Tathe
Head of Dept.
Department of Mechanical Engineering
SCSCOE, Rahuri Factory Savitribai Phule Pune University

Abstract

A Yoke assembly is a rotating element of transmission drive shafts. Yoke assembly consist of flange Yoke, tube Yoke, cross & needle roller bearing. Fatigue Failure is common mode of the Yoke assembly failure because all components are rotate about their respective position. In this study failure analysis of Yoke assembly of transmission drive shaft is carried out. By using finite element method high stress area of existing Yoke find out. Crack initiation takes place at high stress region where value of stress exceeds yield value. By observing failure data the primary observation show that assembly was failed at lug region of flange Yoke. If additional thickness provided on failed area of a existing part, Yoke will complete the desire life. After fabrication of Yoke assembly torque and torsional fatigue testing is carried out to check fatigue life of the component.

Keywords: Yoke Assembly, Fatigue Failure Analysis, FEA, Optimization, Lug Region

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I. Introduction

A. Universal Joint

Power transmission system consists of several components like yoke assembly, propeller shaft, differential. The yoke assembly consists of two forged steel yokes joined to the two shafts together. A spider hinges are used to connect two yokes together in such way that faces of both yoke situated at right angle to each other.An automotive drive train is an assembly of one or more driveshaft, universal joint, and slip joint that forms the connection between the transmission and the drive axle. The function of drive train is that it allows the driver to control the power flow, speed and multiple the engines' torque.

A universal joint (U joint) is a joint in a rigid rod that permits the rod to move up and down while spinning in order to transmit power by changing the angle between the transmission output shaft and the driveshaft. The most common types of U joint used in automotive industry is Hooke or Cardan joint. A basic U joint consists of driving yoke, driven yoke, spider and trunnions. Each connection part of the spider and trunnion are assembled in needle bearing together with the two yokes.[2]

In the transmission system of a motor vehicle, the transmission main shaft, propeller shaft and the differential pinion shaft are not in one line, and hence the connection between them is made by the universal coupling. One universal joint is used to connect the transmission main shaft and the propeller shaft, other universal joint is used to connect the other end of the propeller shaft and the differential pinion shaft.[1]

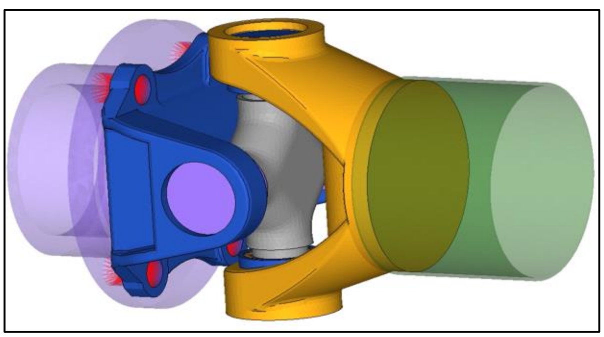


Fig. 1: Solid view of Yoke assembly

The universal joint on the other hand, consists of two forged steel yokes or forks joined to the two shafts being coupled and situated at right angles to each other. Friction due to rubbing between the spider and the yoke bores is minimized by incorporating needle roller bearings between the hardened spider journals and hardened bearing caps pressed into the yoke bores.(3)

B. Yoke Assembly General Failure Data

1) Brinelling

Brinelling is when needle marks appear on the surface of the U joint cross, which is usually caused by excessive torque, driveline angle. It can also be caused by a seized slip yoke or by a sprung or bent yoke.

Fig. 2: Universal Joint Brinelling(3)

2) Spalling

Spalling looks like the bearing surface of the U joint has been “scraped”away. Spalling is usually caused by water or dirt contamination.

Fig. 3: Universal Joint Spalling(3)

3) Burned U joint cross Trunnions

Improper lube procedures, where recommended purging is not accomplished, can cause one or more bearings to be starved for grease. Always make sure new, fresh grease is evident at all four Yoke joint seals.

Fig. 4: Burned U Joint Trunnion(3)

4) *U joint Fractures*
U Joint fractures are usually not only caused by a Torsion and Shear load, but also be caused by an improper application of torque load. To avoid this fracture apply safe calculated torque transmitted by the engine and transmission combination.

Fig. 5: Universal Joint High Torque Fracture (3)

5) *Bent or deflected end fitting*
Bent yokes will put abnormal loading on the U joint bearings and lead to premature failure. A yoke can be bent by a Torsion load or over loading torque on yoke.

Fig. 6: Weld Yoke Failure (3)

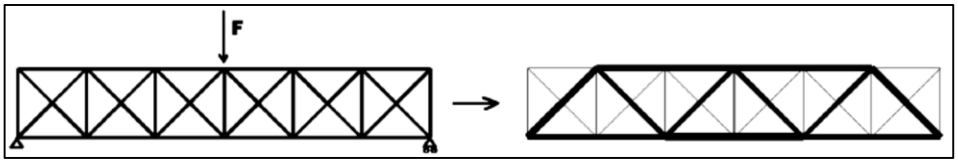
C. Structural Optimization

The basic principle of optimization is to find the best possible solution under given circumstances. Generally, optimization includes finding "best available" values of some objective function given a defined domain (or a set of constraints), including a variety of different types of objective functions and different types of domains. Structural optimization is one application of optimization. Here the purpose is to find the optimal material distribution according to some given demands of a structure.

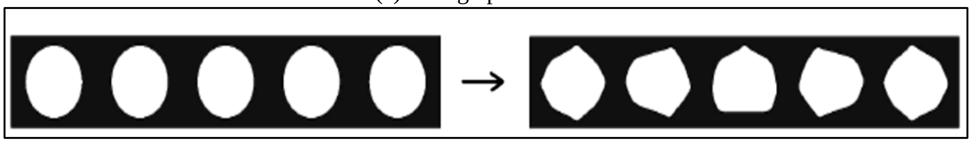
Structural optimization seeks to achieve the best performance for a structure while satisfying various constraints such as a given amount of material. Optimal structural design is becoming increasingly important due to the limited material resources, environmental impact and Technological competition, all of which demand lightweight, low cost and high performance structures. Over the last three decades the availability of high speed computers and the rapid improvements in algorithms used for design optimization have transformed the topic of structural Optimization from the previous narrowness of mostly academic interest to the current stage where a growing number of engineers and architects start to experiment with and benefit from the optimization techniques.

Some common functions to minimize are the mass, displacement or the compliance (strain energy). This problem is most often subject to some constraints, for example constraints on the mass or on the size of the component. This optimization is traditionally done manually using an iterative-intuitive process that roughly consists of the following steps:
1) A design is suggested
2) The requirements of the design is evaluated, for example by a finite element analysis(FEA)
3) If the requirements are fulfilled, the optimization process is finished. Else modifications are made a new improved design is proposed and step 2-3 are repeated.

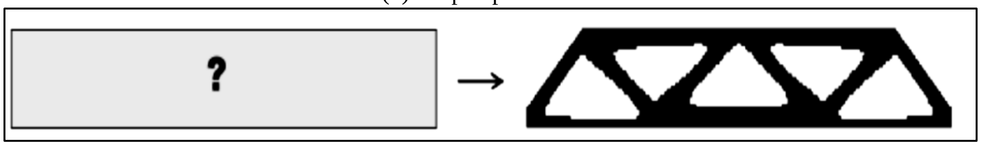
There have been more and more research and development activities directed towards making the structural optimization algorithms and software packages available to the end users in an easy, reliable, efficient and inexpensive form. The types of structural optimization may be classified into three categories, i.e. size, shape and topology optimization.



(a) Sizing optimization



(b) Shape optimization



(c) Topology optimization

Fig. 7: Different types of structural optimization

1) Sizing Optimization

Sizing optimization is the simplest form of structural optimization. The shape of the structure is known and the objective is to optimize the structure by adjusting sizes of the components. Here the design variables are the sizes of the structural elements. The result depend heavily on the designer's knowledge, experience and intuitive understanding of the problem. Figure 1.3(a) consists of sizing optimization.

2) Shape Optimization

As with sizing optimization the topology (number of holes, beams, etc.) of the structure is already known when using shape optimization. The shape optimization will not result in new holes or split bodies apart. In shape optimization the design variables can be thickness distribution along structural members, diameter of holes, radii of fillets or any other measure. A fundamental difference between shape versus topology and size optimization is that instead of having one or more design variable for each element the design variables in shape optimization each affect many elements.Figure1.3 (b) consists of shape optimization.

3) Topology Optimization

The most general form of structural optimization is topology optimization. As with shape and size optimization the purpose is to find the optimum distribution of material. With topology optimization the resulting shape or topology is not known, the number of holes, bodies, etc., are not decided upon shown in Figure 1.3(c). From a given design domain the purpose is to find the optimum distribution of material. To solve this problem it is discredited by using the finite element method (FEM) and dividing the design domain into discrete elements (mesh).The resulting problem is then solved using optimization methods to find which elements that are material and which are not.

A key difference when performing a topology optimization versus a shape optimization is that for topology optimization the resulting FE model is a mesh of the whole design domain while for shape and size optimization the mesh is just of the existing component.

D. Fatigue

In material science, fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values are less than the ultimate tensile stress limit, and may be below the yield stress limit of the material. Fatigue occurs when a material is subject to repeat loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin to form at the stress concentrations such as the surface, persistent slip bands (PSBs), and grain interfaces. Eventually a crack will reach a critical size, and the structure will suddenly fracture. Fatigue is generally understood as the gradual deterioration of a material which is subjected to cyclic loads. In fatigue testing, a specimen is subjected to periodically varying constant amplitude stress. The applied stresses may alternate between equal positive and negative value from zero to maximum positive or negative value, or between equal positive and negative values or between unequal positive and negative values.

1) Fatigue Analysis

- Fatigue is a type of failure occurring under altering loads.
- Fatigue life is the number of cyclic stresses, causing failure of the material.
- Fatigue limit is the maximum value of repeatedly applied stress that the material can withstand after an infinite number of cycles.

E. Objectives of Research

The main objective of current research is that to study the failure analysis of existing yoke assembly of transmission drive shaft. By using finite element method to check out stress analysis and fatigue life cycle plot for yoke assembly. The target of research is the modify yoke assembly will passes targeted 5,00,000 cycles.

In this research the focus is on change in geometry of failure yoke at fracture region without changing materials. Weight optimization simultaneously consider in this scope of the research.

F. Methodology

The objective of this thesis work is to create a methodology of failure analysis and how to use optimization of yoke assembly.

1) Analytical Method

After the construction of the geometry (3D model) and preprocessing (meshing), a static stress analysis is planned by using the mechanical properties of the material (Elasticity modulus = 205GPa, Poisson's ratio = 0.29 of the typical Carbon steel material variant) as input data for preparing the model for analysis. The solid model followed by finite element mesh followed by static analysis for assessing the distribution of stress values should offer good inputs, in turn, to review the design in the light of these results. The analytical/ computational approach offers results through analyses for the case study predefined for the solver. The technique would deploy on following software HyperMeshtools in the `Structural' domain. MSC domain utilized for fatigue analysis of given case study.

2) Experimental Method

After Finite element analysis creates a physical prototype of modified yoke assembly identical in geometry and mechanical properties to the intended component during production, the same is for testing the component on field. A comparison of the results obtained through physical experimentation and the analytical (using Hypermesh software) could offer a basis for validation. Fabricated component tested for following test Torque test, Torsional fatigue test and Static test .with given slandered.

Fig. 8: Torque test set up

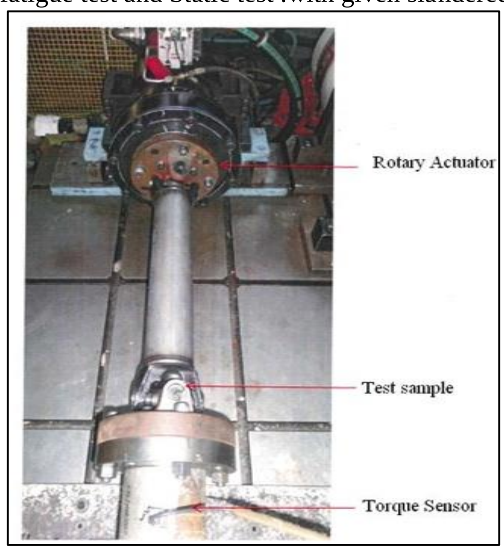


Fig. 9: Torsional fatigue test set up

G. Finite Element Analysis

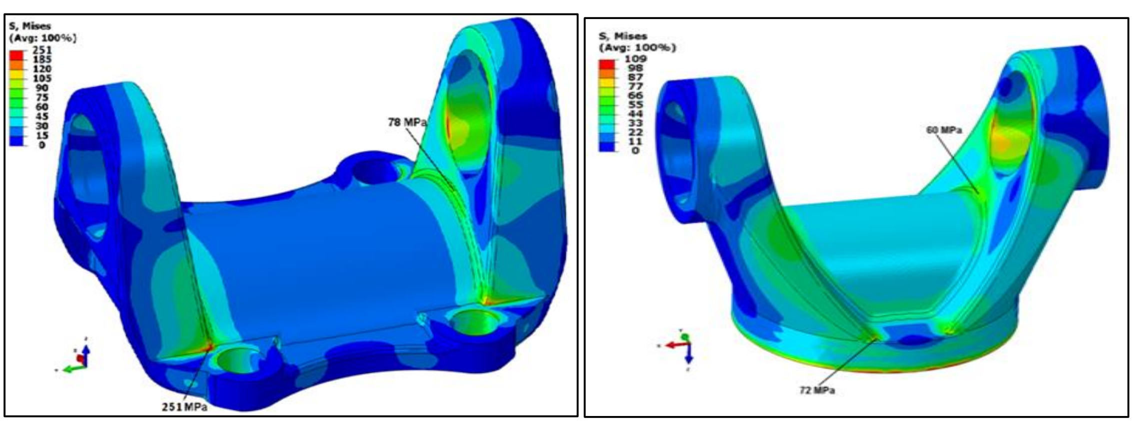


Fig. 10: Finite element analyses of existing yoke assembly

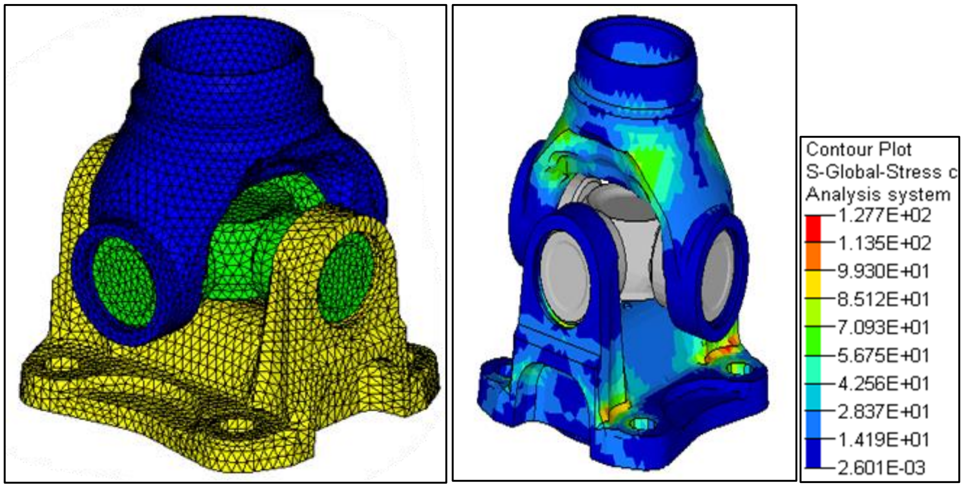


Fig. 11: Finite element analysis of modified yoke assembly

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