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Static Structural Analysis of Universal Joint to Study the Various Stresses and Strains Developed in Power Transmission Systems

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***Abstract*— Universal coupling, first invented in the 17th century by Robert Hooke, and perfected over the 19th and 20th century is an essential part in machines today where non-linear motion is to be transmitted. Universal coupling is an essential component used in automobiles and other industrial machines. As universal joints transmit non-linear motion, the joint is subjected to various forces and stresses and being asymmetric, vibrations. As such the failure rate of universal joints is quite high. Due to the advancements in computer aide designing and analysis technologies, it is possible to design better couplings with much improved failure rate. In this paper we conduct static structural analysis on a universal coupling using advanced computer aided engineering software and study the various stresses and strains developed in the joint.**

Keywords—Universal joint, ANSYS, Catia, CAE-Computer Aided Engineering, CAD- Computer Aided Designing, Meshing

I. INTRODUCTION

A universal coupling consists of two forks connected to the perpendicular arms of the center block by a pin known as fork pin. The fork pin is fixed with the help of pin and collar assembly, which allows the forks to rotate along the axis of center block. The forks also rotate along their respective shaft axes thus transmitting the motion.

As such the fork pin faces considerable compressive stresses especially at the point of contact with the fork. This wears out the fork pin considerably. The premature wearing of the fork pin causes undesirable wobbling in the shaft which causes unnecessary vibrations in the shaft leading to undesired noise

Failure of transmission system in automobiles and other industrial systems is often attributed to the failure of the universal coupling. As per some estimates 25% of all failure in automobiles is due to failure in transmission systems. Various reasons given for failure in universal couplings include defective manufacturing, faulty designs, low quality of raw materials, faulty use by users, poor maintenance etc.

Advancements in Computer Aided Designing (CAD) has led to better designed couplings. Also Computer Aided Engineering (CAE) has allowed us to simulate and recreate the working conditions of machines in real time. Feedback from CAE softwares can be provided to designers to improve design in real time. The focus of this paper will be to study and analyse a CAD model of a universal coupling.

II. CAD MODEL OF A UNIVERSAL COUPLING

The CAD model of the universal coupling has been designed using CATIA v5 by Dassault Systemes. Figure 1 shows the CAD model of a basic universal coupling used in power transmission systems. Figure 2 shows an exploded view of the coupling with parts labelled.

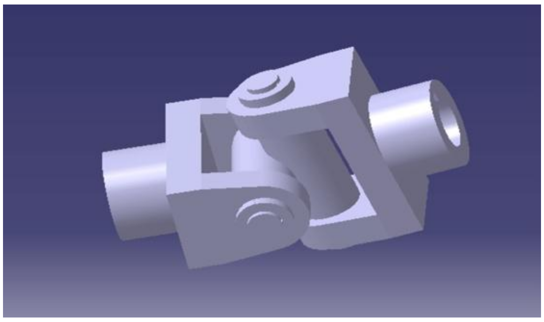

Figure 1: Universal Coupling

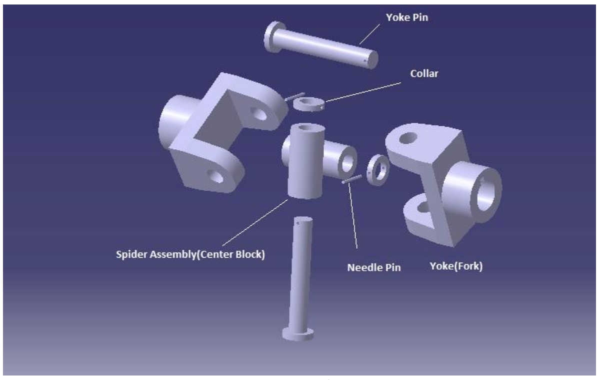

Figure 2: Exploded view of Universal Coupling

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CATIA is a mechanical design software. It is a feature based, parametric solid modeling design tool that takes advantage of the easy to learn Windows Graphical User Interface. Fully associative 3-D models with or without constraints can be created while utilizing automatic or user defined relations to capture design intent.

The universal joint has been designed in CATIA using parametric solid modelling and assembly. The individual parts were then assembled in using the assembly feature of CATIA with proper constraints.

III. Computer Aided Engineering (CAE)

A. Finite Element Modelling Of Universal Coupling

Finite Element Modelling (FEM) is the modelling of products and systems in a virtual environment for observing the behavior of the aforesaid in simulated environment conditions. The purpose of FEM is to model and solve problems which are too complex and difficult to solve by conventional method. In FEM a model is divided into multiple small parts called elements. These elements are connected to each other by nodes. This process of creating elements and nodes is called meshing and a so divided model is called mesh. Figure 3 shows a meshed model of a universal coupling. Greater the number of mesh more accurate the results but more computing power is needed.

The meshing is done in Ansys 16.0 by ANSYS Inc. The CAD model is designed in CATIA v5 as it offers easier and better designing platform than Ansys. After the model is completed it is saved as CATPart and imported into the Ansys workbench. Then the materials are assigned and meshing is done as the first step of Finite Element Analysis. The details of the meshed model is given in table 1.

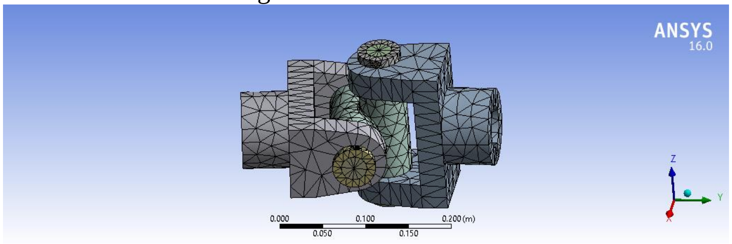

Figure 3: Meshed model of universal coupling

S.No	Parameter	Value
1	Preprocessor	Ansys Mesh
2	No. of Nodes	11502
3	No. of Elements	5548
4	Solver	Ansys Mechanical
5	Min Edge Length	$2.5 \times 10^{-3}\ m$
6	Transition Ratio	0.272
7	Max Layers	5

B. Static Structural Analysis of Universal Coupling

Static structural analysis is a finite element analysis used to simulate and ascertain the various loads, stresses, strains, deformations, etc. acting on a system. In this analysis the inertia and the effects of inertia is neglected.

The main aim of the paper is to analyse the forces acting on a universal joint and the various stresses and strains developed so as to ascertain the cause of the frequent failure of the joint. As referenced earlier, the main reason for the failure of the universal joint is the wearing out of the fork pin. The premature wearing out of the yoke pin causes undesirable wobbling of the transmission shaft which leads to frequent breakdown of the rolling mill causing production loss.

To find out the various stresses and strains we perform static structural analysis on the universal joint in ANSYS Workbench. The material of the joint is structural steel (SAE 4340), the properties of which are given in table 2. One end of the coupling is fixed while other end is subjected to a moment of 6400 N/m. On solving the meshed model with the given boundary conditions give the following results.

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S.N.	PROPERTY	VALUE
1	Density (at STP)	7850 kg/m
2	Tensile Yield Strength	250 MPa
3	Compressive Yield Strength	250 MPa
4	Tensile Ultimate Strength	460 MPa
5	Compressive Ultimate Strength	0 MPa

Table 2: Properties of material used-Structural Steel (SAE 4340)

IV. RESULTS

A. The result obtained from the ANSYS simulation is summarized as follows :

S.N.	PARAMETER	VALUE
1	Equivalent Elastic Strain (Von-Mises Strain)	0.0026 m/m
2	Maximum Principal Elastic Strain (Maximum Tensile Strain)	0.00248 m/m
3	Minimum Principal Elastic Strain (Maximum Compressive Strain)	$-6.728\text{x}10^{-7}$ mm
4	Shear Elastic Strain	0.00218 m/m
5	Equivalent Stress	520 MPa
6	Maximum Principal Stress (Maximum Tensile Stress)	602 MPa
7	Minimum Principal Stress (Maximum Compressive Stress)	163 MPa
8	Normal Stress	377 MPa
9	Shear Stress	168 MPa
10	Strain Energy	0.04 J
11	Total Deformation	0.5 mm
12	Design Life	10^8 cycles

Table 3: Static structural analysis result

B. Graphical representation of results:

- Maximum Principal Elastic Strain (Maximum Tensile Strain)

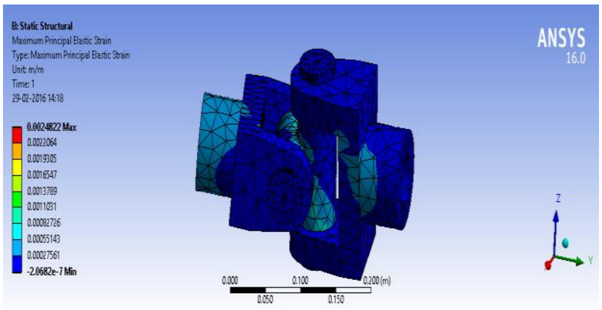

Figure 4

- Minimum Principal Elastic Strain (Maximum Compressive Strain)

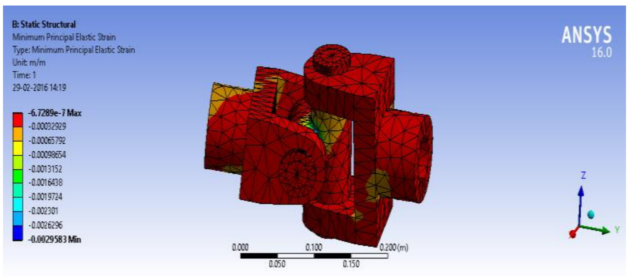

Figure 5

- Maximum Principal Stress (Maximum Tensile Stress)

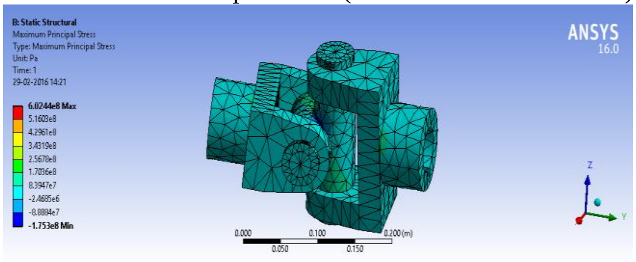

Figure 6

- Minimum Principal Stress (Maximum Compressive Stress)

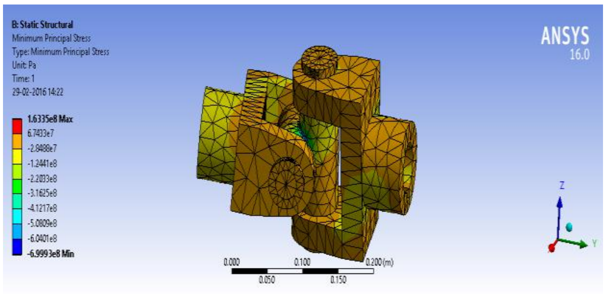

Figure 7

- Total Deformation

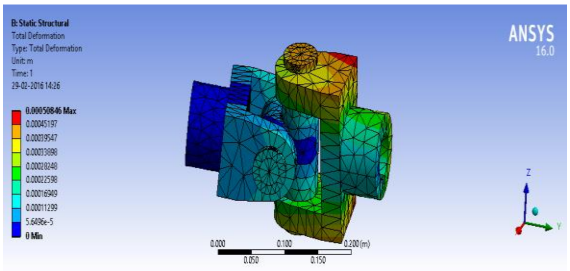

Figure 8

V. CONCLUSION

From the above results we can easily conclude that the fork pin experiences the maximum compressive stresses and strains as referenced earlier. The region where the fork and the fork pin makes contact experiences generally higher compressive stress and bending stresses. There is also stress concentration in the collar and pin due to the presence of notch. This leads to frequent wearing out of the pin which causes the shaft to wobble unnecessarily which reduces the mechanical efficiency of the transmission system. This leads to failure of the transmission system.

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