International Journal of Mechanical Engineering and Robotics Research

*ISSN 2278 – 0149 www.ijmerr.com*
*Vol. 3, No. 2, April 2014*


*Research Paper*

# AN INVESTIGATION ON STRESS DISTRIBUTION FOR OPTIMIZATION OF YOKE IN UNIVERSAL JOINT UNDER VARIABLE TORQUE CONDITION: A REVIEW

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An increased demand for greater performance of universal joint of steering column of passenger car has prompted the development of joints capable of long life at high torque, high angles and high loads. This can be easily achieved by investigating or evaluating the torsion loading and its effect over yoke by FEM. New variations of Universal joint have shown the ability to increase universal joint performance. As Yoke generally subjected to torsional and bending stresses due to wt of components also susceptible fatigue by nature of functioning. The purpose of this paper is an Investigation on Stress Distribution for Optimization of Yoke in Universal Joint under Variable Torque Condition. Yoke is analysed under torque load from steering rod observing hot spot location/Stress concentration region, hot area potentially carrying load, scope to optimize/improve part by eliminating/adjusting density in order to maximize area of hot region with reducing in dead region.

Keywords: Steering rod, Universal joint, Failure kit, FEA, Photoelasticity, Optimization

## INTRODUCTION

The universal joint consists of two forged-steel yokes joined to the two shafts being coupled and situated at right angles to each other. Comprised of three main component-two Yokes and cross trunnion a universal joint is linkage used to transmit rotational motion from one shaft to another when the axis are coplanar, but not coinciding. A universal joint is a positive, mechanical connection between rotating shafts, which are usually not parallel but intersecting. They are used to transmit motion, power or both. The research work deals with an Investigation on Stress Distribution for Optimization of Yoke in Universal Joint under Variable Torque Condition. The analysis will be carried out under steady state conditions using FEM by

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applying the boundary condition and stresses is visualized in the model by experiment method such as photo elasticity method. The highest stresses are occurred at the crack beginning location of the yoke. A possible surface fault could have started the crack propagation period at the highly stressed point of area. After a crack propagation period, the arm had completely fractured.

Heyes (1998) studied the common failure types in automobiles and revealed that the failures in the transmission system elements cover 25% of all the automobile failures. The crack beginning location of the joint yoke corresponds to highest stress points. Hummel and Chassapis (1998) revelled that internal interference in the input and output Yoke which will cause the large internal force which cause binding and failure of component it can be eliminated by changing the design variable. Hummel and Chassapis (2000) develop the methodology and derive the relationships necessary to optimize the geometry of universal joint with manufacturing tolerances and shows that the strength of joint is adversely affected manufacturing tolerances. Dong-Kyun Min and Min-Eung Kim (2003) explains or revealed that the manufacturing productivity and mechanical properties an united steering yoke largely depends upon the manufacturing process such as forging, however, the precision cold forging process for the steering yoke of an automobile has been analyzed by using a rigid-plastic finite-element analysis. The rigid-plastic finite-element method for precision cold forging has been used in order to reduce development time and die cost. Nick Cristello and Il Yong Kim (2006) represents shape optimization of an automotive universal joint, by simultaneously considering manufacturing cost, drivable joint angle and part volume. In this research, universal joint is analyzed and compared through the use of a Pareto frontier using Adaptive Weight Sum technique. Two cases of fatigue failures of components in the power transmission system of passenger cars are considered in Bayrakceken *et al.* (2007) study both failures are occurred as a result of fatigue process. Some modification on the initial design of the joint may be considered for prevention of later failures. Veloso *et al.* (2009) shows Failure of longitudinal stringer of vehicle was reported. Plastic deformation and cracks were observed during durability tests of prototype vehicle. Stress analysis was performed using FEM. Reinforced models were proposed and a combination of high strength and production costs were the reason of the choice of the best solution. The FEM of several different models lead to a reduction of physical and expensive tests. Consequently, it was not necessary the production of several prototypes. Compression tests were performed to compare with numerical results. Vehicles were produced with the reinforced stringer and failures were not observed. Siraj (2012) focus the relationship between manufacturing cost and joint angle performance measure of an automotive universal joint, the result illustrate that joint angle is directly proportional to the manufacturing cost an increase in the drivable joint angle requires corresponding increase in manufacturing cost. However for both the flange and weld yoke, a substantial reduction in manufacturing cost may be realized by restricting the joint angle to less than 30°. Farzad Vesali *et al.*

(2012) focuses on increased the performance and improve the life expectancy of the cardan joint. The used of the intermediate spring and damper increasing the torque arm, increasing the degree of freedom in order to remove the regularity in the impact load, installing rigid ring over cardan joint arm to act as the inner ring.

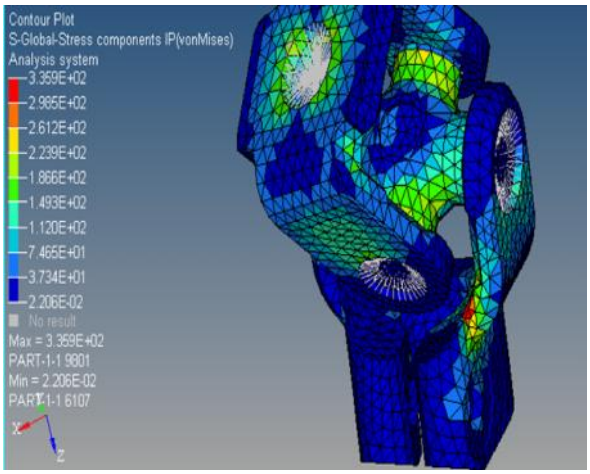
Chr. Seherr-Thoss *et al.* (2005) author of "Universal joint and Driveshaft analysis, Design and Application" explain the non uniformity of the transmission in the rotational motion of single universal joint can eliminated by putting the intermediate shaft between two appropriately phased universal joint therefore transmitting a constant angular velocity between shafts.

In this research Calculation of stress distribution and element density distribution in Yoke of universal joint to reduce stress concentration in affected region by iteration shape optimization and weight reduction .Identify and study failure region of Yoke in Universal Joint under Variable Torque Condition, compare stress distribution of Von Misses stress values by using FEM and failed yoke stress analysis result by experiments on it for possible improvement in design of Yoke in Universal Joint reduce stress levels below yield limit by modifying existing geometry without increasing deflection.

## PROBLEM STATEMENT

The universal joint which has failed before their life have been inspected and found to be broken in three key main regions: (1) Yoke part region (2) Spider region (3) Steering rod region as shown in Figure 1 shows the stress concentration and highly stresses region developed by the torque.

Figure 1: Universal Joint with Torque

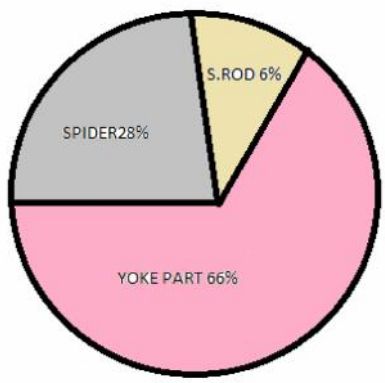



The statistical data obtained from a survey of broken universal joint carried out by Able tech central Lab. It has shown that the simulation results confirm the causes for the frequent failure of universal joint as cited in below Table 1.

Table 1: Comparative Analysis of Failure per Year in Percent ( % )

| Year | 2012 | 2011 | 2010 |
|---|---|---|---|
| Name of Part | Failure in percent (%) | | |
| Yoke Part | 66 | 69 | 71.5 |
| Spider | 28 | 26 | 25 |
| Steering Rod | 6 | 6 | 3.5 |

Figure 2: PIE Chart of % Failure in 2012



PIE chart demonstrating percent (%) of failure in 2012 at different location in steering rod of Universal joint.

Typical Universal joint kit failure history

**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.

**Spalling:** Spalling looks like the bearing surface of the U-joint has been "scraped "away. Spalling is usually caused by water or dirt contamination for avoidance of Spalling failure Check the U-joint kit seals for damage and replace as necessary and Check to make sure the service technician is using the proper lube type.

**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 to avoid this type of failure always make sure new, fresh grease is evident at all four U-joint seals. Using the wrong lube can result in burned Trunnions unless otherwise recommended, use a high quality E.P. (extreme pressure) grease to service most vehicular, industrial and auxiliary drive shaft applications.

**End Galling/Galling:** The end of the trunnion (of the U-joint cross) looks like material has been gouged out. Usual cause for this failure operating angles is too large.

**U-joint Fractures:** U-joint fractures are usually caused by a shock load, but can also be caused by an improper application to avoid U-joint failure Calculate the torque transmitted by the engine/trans combination. Check to make sure the drive shaft series is not too small for the application.

**Improper Assembly Procedures:** Striking the bearing plate with a hammer can cock it on the bearing and may cause the bearing to be pulled down crooked in the yoke. Cocking the bearing in the bore of the yoke may put undue loads on the cross, its bearings and the seals inside those bearings, which may cause premature failures and make proper lubrication difficult.

**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 shock load or by over torquing the yoke.

**Mixing Incompatible Greases:** All greases are a mixture of different additives and thickeners. Mixing greases from different manufacturers can lead to a mixture with a lower service performance than either of the original grease products.

**U-Joint Cross Broken at a Bearing Surface:** U-joints seldom break off at the bearing surface. It takes a very large shock load to cause this type of failure. It is also very difficult to inspect for this type of failure because they, many times, start as a small crack and progress into a complete failure some time further down the road. The Universal Joint Kit Failure Shown in Figure 3 below.

## OBJECTIVE FUNCTION

When optimizing the systems, one might focus on costs, Weight, service levels, environmental impact, safety, fatigue life, etc. The

Figure 3: Universal Joint Kit Failure

**Universal Joint Brinelling Trunnion** **Universal Joint Spalling** **Burned U-Joint**

**Industrial Joint Galling** **Universal Joint Fracture** **Weld Yoke Failure**

minimization of the stress developed in the joint, costs and weight is most common in this type of problem. In this research try to study the basic working principal of universal joint and try to identify and study failure of yoke of universal joint under variable torque condition. At the stress region to determine the stress distribution and possible design improvement to enhancing the life would be the objective of this research a static stress analysis is carried out by entering the obtained mechanical properties of the material for the solid model, finite element mesh, distribution of von Misses stress values and a comparison of failed yoke and stress analysis result with stresses developed in the experimental photoelastic method of prepared model same dimension.

## FUTURE METHODOLOGY

### Finite Element Method (FEM)

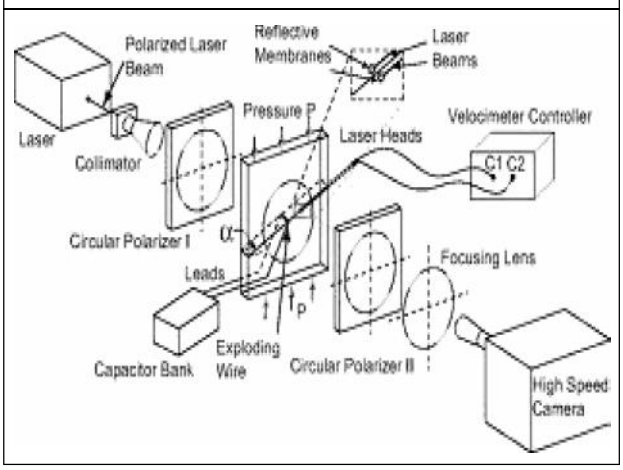
FEM simulates a FEM is a numerical technique for solving problems, which are described by partial differential equations or can be formulated as functional minimization. FEM are predominantly used to perform analysis of structural, thermal, and fluid flow situation. They are used to when hand calculation cannot provide accurate results and geometry is so complex. A domain of interest is represented as an assembly of finite

elements. Approximating functions in finite element are determined in terms of nodal values of physical field, which is sought. A continuous physical problem is transferred in to a discretized finite element problem with unknown nodal values.

### Photoelasticity

The photoelastic method for investigation of stresses in model should preferable because It should be free from all residual stresses used of photoelastic material model should be transparent possess required dimensional accuracy. The model should exhibit all properties of good photo elastic material. While the materials used as photoelastic model materials are epoxy resins, polymethacrylate, polycarbonate, cellulose nitrate, etc. The choice of materials will then depend on the objective of the experiment to be performed. The physical arrangement of photo elasticity experiment shown in Figure 4.

Figure 4: Photo Elasticity Experiment




Photoelasticity can be used to determine the stress intensity factor of a stable crack in a specimen experiencing failure. Experimental results and analysis includes finding the stresses distribution in the model to calibrate photo elastic material, finding the stresses developed in a model and scaling model to prototype. As the accuracy of photoelastic model has got the major effects on the results obtained, the preparation of the model bears its own importance in the whole problem of photo elastic stress analysis.

## CONCLUSION

The main objective of this work is to take an account of previous work carried out on a Universal joint. From the review, it can be noted that failure of component is occur due manufacturing and design fault, raw material faults, maintains faults, material processing faults, drivable joint angle, cyclic load to avoid this problems various method such as a topology optimization method, Weight reduction method, Shape optimization method, manufacturing method etc are implemented in the previous research paper for designing a Universal joint by this method utilizes or used to find out the best design of joint with considering the all the factor such as weight, cost, Fatigue life, stress distribution, stiffness, etc. The investigation of stress in the joint can give engineer an efficient and easy way to design a Universal joint. FEM analysis and experiments are included in study research paper to validate the feasibility of the proposed approach in the paper.

## ACKNOWLEDGMENT

The authors wish to express their appreciation Prof R D Palhade for his valuable assistance and commets during this review and all teaching staff of Mechanical Department, SSGMCE, Shegaon 444203 (MH).

## REFERENCES


1. Bayrakceken H, Tasgrtiren S and Yavuz I (2007), "Two Cases of Failure in the Power Transmission System on Vehicles: A Universal Joint Yoke and a Drive Shaft", *Engineering Failure Analysis*, Vol. 14, pp. 716-724.
2. Chr. Seherr-Thoss H, Schmelz F and Aucktor E (2005), *Universal Joint and Driveshaft Analysis, Design and Application*, 2nd Edition, Springer-Verlag, Berlin, Heidelberg, New York.
3. Dong-Kyun Min and Min-Eung Kim (2003), "A Study on Precision Cold Forging Process Improvements for the Steering Yoke of Automobiles by the Rigid-Plastic Finite-Element Method", *Journal of Materials Processing Technology*, Vol. 138, pp. 339-342.
4. Farzad Vesali, Mohammad Ali Rezvani and Mohammad Kashfi (2012), "Dynamics of Universal Joints, its Failures and Some Propositions for Practically Improving its Performance and Life Expectancy", *Journal of Mechanical Science and Technology*, Vol. 26, No. 8, pp. 2439-2449.
5. Heyes A M (1998), "Automotive Component Failures", *Eng. Fail. Anal.*, Vol. 5, No. 2, pp. 129-141.
6. Hummel S R and Chassapis C (1998), "Configuration Design and Optimization of Universal Joints", *Journal of Mechanism and Machine Theory*, Vol. 33, No. 5, pp. 479-490.
7. Hummel S R and Chassapis C (2000), "Configuration Design and Optimization of Universal Joints with Manufacturing Tolerances", *Journal of Mechanism and Machine Theory*, Vol. 35, pp. 463-476.
8. Nick Cristello and Il Yong Kim (2006), "Design Optimization of an Automotive Universal Joint Considering Manufacturing Cost", Proceeding of the 17th IASTED International Conference Modeling and Simulation, May 24-25, Momtreal, QC, Canada.
9. Rao S S (1999), *The Finite Element Method in Engineering*, 3rd Edition, BH Publications, New Delhi.
10. Siraj Mohammad Ali Sheikh (2012), "Analysis of Different Universal Coupling Under Different Torque Condition", *International Journal of Engineering Science & Advanced Technology*, Vol. 2, No. 3, pp. 690-694.
11. Veloso V, Magalhaes H S, Bicalho G I and Palma E S (2009), "Failure Investigation and Stress Analysis of a Longitudinal Stringer of an Automobile Chasis", *Engineering Failure Analysis*, Vol. 16, pp. 1696-1702.