Investigation on New Designed Universal Coupling Joint

C. Mohan Naidu
Associate Professor, HOD Dept of Mechanical Engineering
Sri Krishnadevaraya Engineering College, Gooty, A.P, INDIA

Abstract- *The power produced from an engine of automobile can be transferred to the drive wheel by power transmission system. Each automobile has different power transmission system constructive features depend on the vehicle's driveline concept. (H.Bayrakceken et al., 2006) To transmit the driving torque from the engine or gear unit to the wheels, most of passenger car and light vehicle driven by combustion engine has at least two driveshaft as a basic requirement (Amborn, P. 1995). During operation, torsional stress and bending stress was experienced by driveshaft due to the weight of the car or misalignment of journal bearing (Asi, 2006). In order to meet the requirements of one of the most highly stressed components in automotive assembly, a failure investigation must be conducted. Finite element method was used as stress analysis to determine the stress conditions at the failed section. Nearly all of driveshaft are metal shafts or metal tubes that has special joint at each end called universal joint (Birch and Rockwood2005). Power transmission system of vehicles consist several components which sometimes encounter unfortunate failures. Some common reasons for the failures may be manufacturing and design faults, maintenance faults, raw material faults, material processing faults as well as the user originated faults. In this study, fracture analysis of a universal joint yoke and a drive shaft of an automobile power transmission system are carried out. Spectroscopic analyses, metallographic analyses and hardness measurements are carried out for each part. For the determination of stress conditions at the failed section, stress analysis is also carried out by the finite element method. The common failure types in automobiles and revealed that the failures in the transmission system elements cover 1/4 of all the automobile failures. Some common reasons for the failures may be manufacturing and design faults, maintenance faults, raw material faults as well as the user originated faults. This paper presents FEM analysis of universal coupling with the help of ANSYS for different torque or load condition and it verify by manual calculation.*

Keywords- Geometrics parameters, Creo elements and FEM

I. INTRODUCTION

A **coupling** is a device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings do not normally allow disconnection of shafts during operation, however there are torque limiting couplings which can slip or disconnect when some torque limit is exceeded.

The primary purpose of couplings is to join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both. By careful selection, installation and maintenance of couplings, substantial savings can be made in reduced maintenance costs and downtime.

Types of couplings

Clamped or compression rigid couplings come in two parts and fit together around the shafts to form a sleeve. They offer more flexibility than sleeved models, and can be used on shafts that are fixed in place. They generally are large enough so that screws can pass all the way through the coupling and into the second half to ensure a secure hold. Flanged rigid couplings are designed for heavy loads or industrial equipment. They consist of short sleeves surrounded by a perpendicular flange. One coupling is placed on each shaft so the two flanges line up face to face. A series of screws or bolts can then be installed in the flanges to hold them together. Because of their size and durability, flanged units can be used to bring shafts into alignment before they are joined together. Rigid couplings are used when precise shaft alignment is required; shaft misalignment will affect the coupling's performance as well as its life.

Sleeve or Muff coupling

A sleeve coupling consists of a pipe whose bore is finished to the required tolerance based on the shaft size. Based on the usage of the coupling a keyway is made in the bore in order to transmit the torque by means of the key. Two threaded holes are provided in order to lock the coupling in position.

Sleeve couplings are also known as Box Couplings. In this case shaft ends are coupled together and abutted against each other which are enveloped by muff or sleeve. A gib head sunk keys hold the two shafts and sleeve together. In other words, this is the simplest type of the coupling. It is made from the cast iron and very simple to design and manufacture. It consists of a hollow pipe whose inner diameter is same as diameter of the shafts. The hollow pipe is fitted over a two or more ends of the shafts with the help of the taper sunk key. A key and sleeve are useful to transmit power from one shaft to another shaft.

Clamp or Split-muff coupling

In this coupling, the muff or sleeve is made into two halves parts of the cast iron and they are joined together by means of mild steel studs or bolts. The advantages of this coupling is that assembling or disassembling of the coupling is possible without changing the position of the shaft. This coupling is used for heavy power transmission at moderate speed.

Tapered shaft lock

A **tapered lock** is a form of keyless shaft locking device that does not require any material to be removed from the shaft. The basic idea is similar to a clamp coupling but the moment of rotation is closer to the center of the shaft. An alternative coupling device to the traditional parallel key, the tapered lock removes the possibility of play due to worn keyways. It is more robust than using a key because maintenance only requires one tool and the self-centering balanced rotation means it lasts longer than a keyed joint would, but the downside is that it costs more.

Hirth Coupling

Hirth joints use tapered teeth on two shaft ends meshed together to transmit torque.

Flexible Couplings

Flexible couplings are used to transmit torque from one shaft to another when the two shafts are slightly misaligned. Flexible couplings can accommodate varying degrees of misalignment up to 3° and some parallel misalignment. In addition, they can also be used for vibration damping or noise reduction. This coupling is used to protect the driving and driven shaft members against harmful effects produce due to misalignment of the shafts, sudden shock loads, shaft expansion or vibrations etc.

Types of Flexible Couplings:

Most small to medium size couplings are basically one of three types.

Universal Joints

A universal joint is a linkage consisting of two yokes, one on each shaft, connected by spider as shown on *Figure 2*. Since universal joints are frequently used, and their analysis is complex, a separate section is devoted to them following this section.

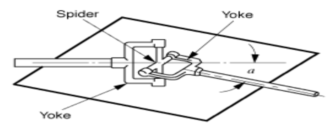

Figure 2 - Spider and Yoke Construction

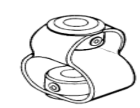

Figure 2 - Elastomeric Construction

By substituting an elastomeric member in place of the conventional spider and yoke construction Such as in the design shown in *Figure3* backlash is eliminated.

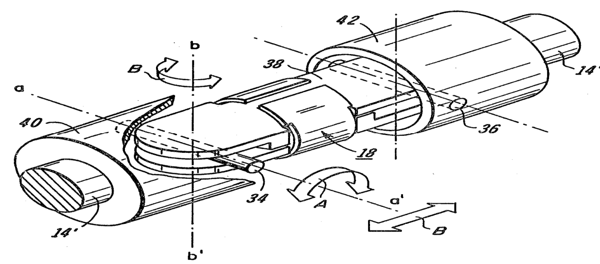

Fig: 3Backlash

Lubrication is no longer a consideration because there are no moving parts and a fairly large amount of lateral misalignment can be accommodated. The Illustrated coupling is available in the product section of the catalog. Please refer to *Figures 4* and *5* for specific design data for this type of Coupling.

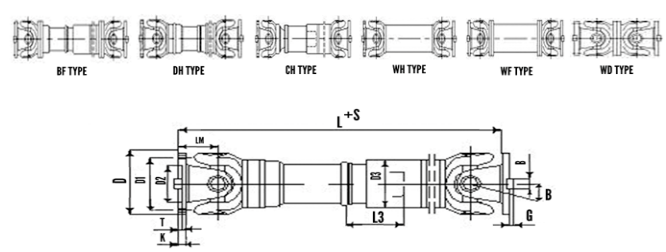

Fig: 4 and 5 details of universal coupling

Universal coupling is used in rotating shaft that transmits rotary motion. It is a specialized rotary joint used to allow a rotating split shaft to deflect along its axis in any direction. It is a positive mechanical connection between rotating shafts which are not parallel but intersecting. The flexibility is achieved by constructing the joint with two U-shaped yokes which is joined by a cross shaped hub. One of the yoke is attached to the end of each portion of the split shaft and joined with the cross hub, with the U-sections oriented at 90 degree to each other. It is one of the oldest of all flexible couplings. It is commonly known for its use on automobiles and trucks.

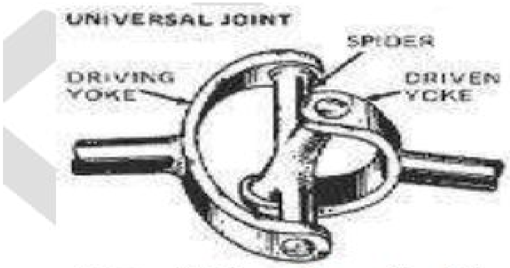

Figure 1 Universal coupling [1]

The purpose of a steering system is to control the direction of the vehicle by operating the steering wheel of the steering system. Movement of steering wheel by the driver should cause an accurate response of the road wheels. The intermediate shaft connects the steering shaft to the steering pinion. These components cannot be arranged on the same axis due to the vehicle design limitations. They are arranged with the universal joints. The stresses in either direction, while moving the vehicle to the right or to the left, happen to be a source of failure of the mechanical joint. The two halves of the yoke, the web connecting the two halves or the shaft in the linkages are prone to failure. In such event, the driver could lose control leading to an accident.

A universal joint also known as universal coupling, U-joint, Cardan joint, Hardy-Spicer joint, or Hooke's joint is a joint or coupling used to connect rotating shafts that are coplanar, but not coinciding. A universal joint is a positive, mechanical connection used to transmit motion, power or both. Each universal joint assembly consists of three major components: two yokes (flange and weld) and a cross trunnion. An automotive flange yoke has a machined flat face which may be affixed through a bolted connection to the rear differential of a vehicle. A weld yoke incorporates a machined step, and is inserted into the end of the driveshaft and welded in place. The cross trunnion is used to deliver rotation from one yoke to another using four needle pin bearings.

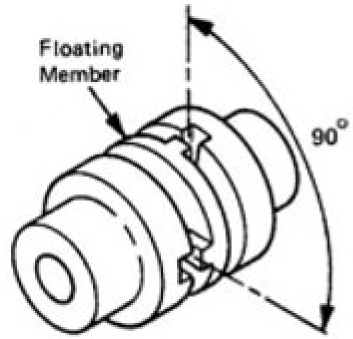

Figure 6 - Oldham Coupling

Oldham Coupling

Oldham couplings consist of three members. A floating member is trapped by 90 displaced grooves between the two outer members which connect to the drive shafts as shown in *Figure6*. Oldham couplings can accommodate lateral shaft misalignments up to 10% of nominal shaft diameters and up to 3 angular misalignments. Lubrication is a problem but can in most applications be overcome by choosing a coupling that uses a wear resistant plastic or an elastomeric in place of steel or bronze floating members.

II. PROBLEM STATEMENT

Yoke assemblies are one of the most important components in steering system of an automobile. It generally subjected to tensional stresses and bending stresses due to weigh of the components. The stresses in either direction, while moving the vehicle to the right or to the left, happen to be a source of failure of the mechanical joint. The two halves of the yoke, the web connecting the two halves or the shaft in the linkages are prone to failure. In such event, the driver could lose control leading to an accident. The steering yoke being a component posing threat to the 'safety' of the vehicle and its occupants, the design of the same needs to be reviewed for encoring structural integrity. The design review could look into aspects dealing with the material properties and/or the geometry of the part/s. For this work no radical change is sought in design and the existing design shall be reviewed for feasible alternatives calling for minimal changes in the development or production further.

Objectives

The main aim of this project is to determine the Von-Misses stresses, element displacement, and optimization in the existing steering yoke. If the existing design shows the failure, then suggest the minimum design changes in the existing steering yoke. In this project, only the static FEA of the steering yoke and the steering shaft has been performed by the use of software. After word's Determine design alternatives and analyze for iterations. Then the combination of finite element technique with aspect of weight reduction is to be made and finally Comparison of analytical results of any one variant with Experimental results for validation.

III. LITERATURE REVIEW

Siraj MohammadAli Sheikh

In this paper titled analysis of universal coupling under different torque condition. Drive shafts are one of the most important components in vehicles. It generally subjected to tensional Stress and bending stress due to weights of components. Thus, these rotating components are susceptible to fatigue by the nature of their operation. Common sign of driveshaft failure is vibration or shudder during operation. Driveshaft mainly involves in steering operation of vehicle. Drivers will lose control of their vehicle if the drive shafts broke during high speed cornering. Because of this human life can be in great danger if we don't know when, where and how the drive shaft will failed. It is very important to know the accurate prediction for the drive shaft to fail.

Cristello and I.Y. Kim (Canada)

In this paper titled Design Optimization of an Automotive Universal Joint Considering Manufacturing Cost. In this research, universal joint designs are analyzed and compared using a weighted sum of three objective functions: minimization of machining cost, maximization of adjoining shaft joint angle, and minimization of total part volume.

Vishal Rathi, N. K. Mandavgade

In this paper titled FEM Analysis of Universal Joint of TATA 407.Traditional design has been done by simple calculation. But with increase in product performance and reliability it is difficult to follow the traditional iterative design procedures. To satisfy the market needs it is necessary to provide a computational capacity along with the creativity of the human being. A widely used numerical method for solving structural problems in both industry and academia is "FINITE ELEMENT METHOD. For effective and efficient FEM analysis the software should have: 1. Preprocessor 2. Solver 3. Post processor Thermal analysis to calculate for finite element Analysis of Propeller Shaft &Universal joint, SOLID92- Tetrahedral element has been used. The heat flux, temperature gradient & temperature variation in the structural and thermal aspects in case of Universal Joints.

John R. Dharte

In this paper titled Universal Joint Grease Development. A project was conducted where different types of greases with different additives were evaluated in an effort to determine if performance improvements could be obtained in the universal joint application. Several different types of greases, calcium, lithium, lithium complex and polyurea were evaluated and compared to the current universal joint grease. The required grease for a universal joint must be a maintenance free grease that is used in a full complement of needle bearings.

Iqbal, J. and Qatu, M

In this paper titled "Vibration Analysis of a Three-Piece Automotive Shaft Drive shafts are major automotive components in rear wheel and four wheel drive vehicles. They can be made of single or multi-piece segments. The segments of a multi-piece driveshaft in automotive applications are joined using constant velocity or universal joints or a combination of frequency. This paper uses an exact solution for the vibration of a three-piece driveshaft with multiple intermediate joints. The joint is modeled as a frictionless internal hinge. Thin beam theory is used. The solution should be of value to engineers interested in the design and optimization of the system.

IV. INTRODUCTION TO CAD/CAM

Computer Aided Design (CAD):

Computer Aided Design (CAD) is the use of wide range of computer based tools that assist engineering, architects and other design professionals in their design activities. It is the main geometry authoring tool within the product life cycle management process and involves both software and sometimes special purpose hardware. Current packages range from 2D vector based drafting systems to 3D parametric surface and solid design models.

Introduction:

CAD is used to design and develop products, which can be goods used by end consumers or intermediate goods used in other products. Cadis also extensively used in the design of tools and machinery used in the manufacturer of components. Cadis also used in the drafting and design of all types of buildings, from small residential types (house) to the largest commercial and industrial types. CAD is used thought the engineering process from the conceptual design and layout, through detailed engineering and analysis of components to definition of manufacturing methods.

INTRODUCTION TO PRO/E:

PRO/E is the industry's de facto standard 3D mechanical design suit. It is the world's leading **CAD/CAM /CAE** software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model. Because that ***PRO/E*** is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains.***PRO/E*** is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. ***PRO/E*** provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.

MODAL IS DRAWN:

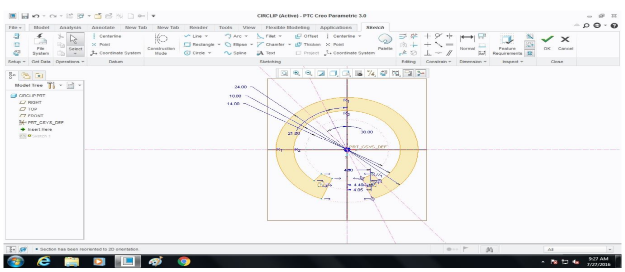

Fig: Sketch view

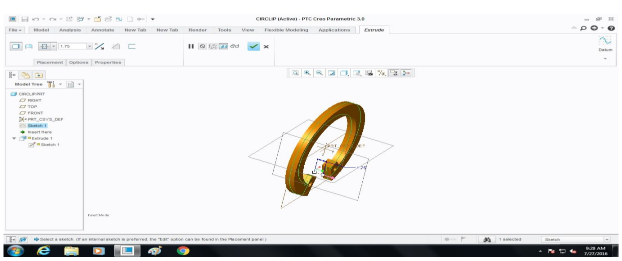

Fig: 3d View

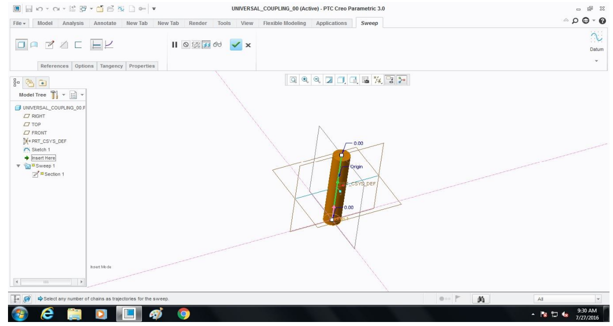

Fig: 1st Step of Pin joint

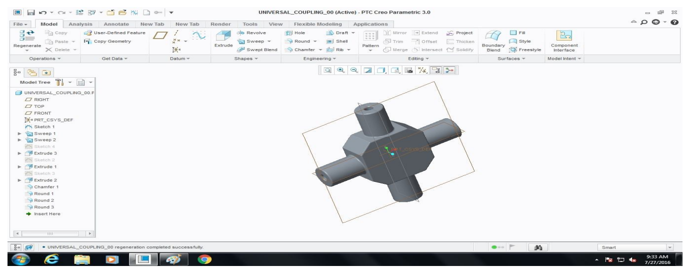

Fig: Final view of pin

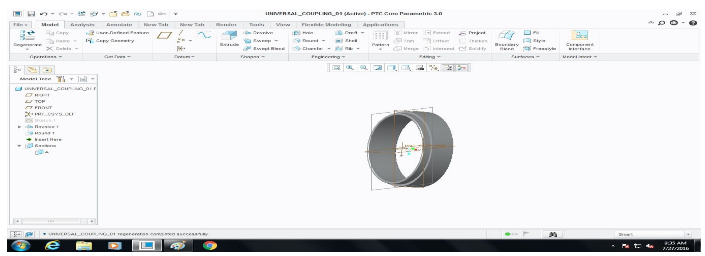

Fig: supporter ring

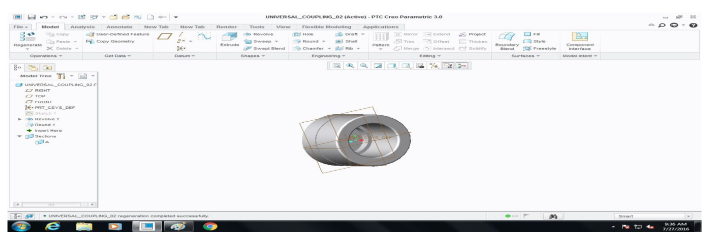

Fig: Bearing Cup

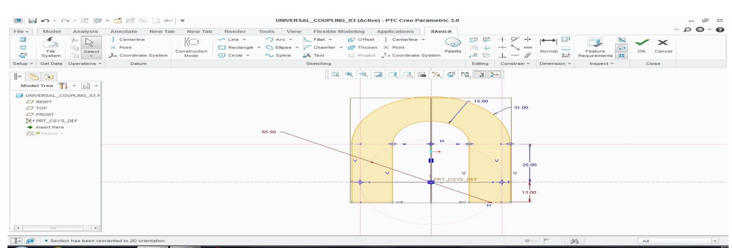

Fig: U shape coupling sketch

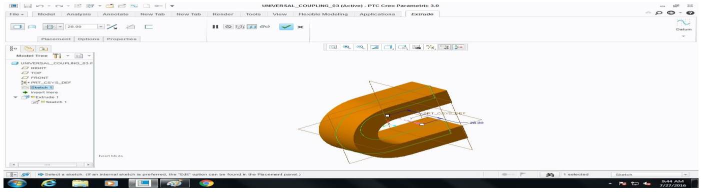

Fig: 3D view

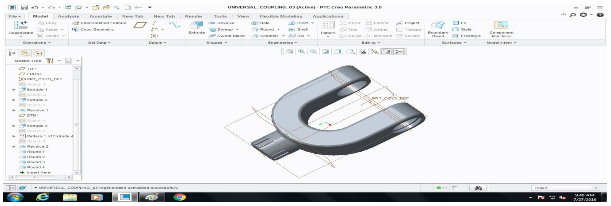

Fig: Final View

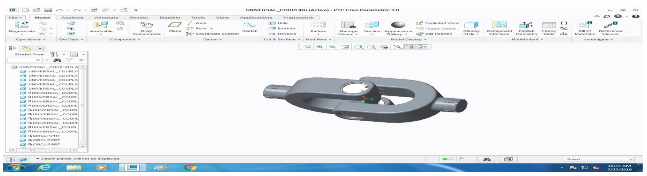

Fig: Assembly view of universal coupling

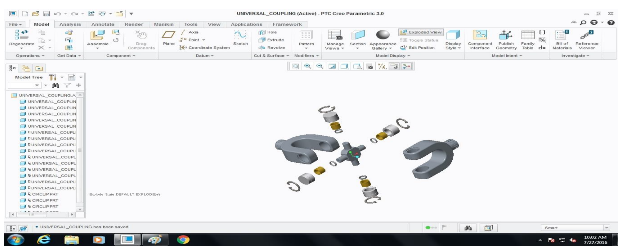

Fig: Explode view of final universal coupling

V. ANALYSIS

Introduction of FEA:

Finite Element Analysis (FEA) is a numerical method which provides solutions to problems that would otherwise be difficult to obtain. Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Top established a broader definition of numerical analysis. The paper centered on the stiffness and deflection of complex structures.

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

Procedural Steps Followed in ANSYS WORKBENCH: Structural Analysis:

Importing the Model:

In this step the PRO/E model is imported into ANSYS workbench as follows:

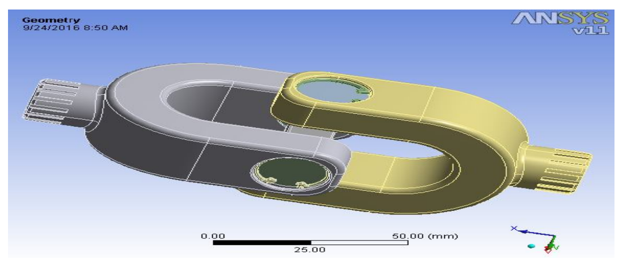

Fig- 4.1: Imported model

Details of "Mesh"	
Defaults	
Physics Preference	Mechanical
Relevance	0
Advanced	
Relevance Center	Coarse
Element Size	Default
Shape Checking	Standard Mechanical
Solid Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Initial Size Seed	Active Assembly
Smoothing	Low
Transition	Fast
Statistics	
Nodes	213427
Elements	121442

Fig- 4.2: Details of Mesh

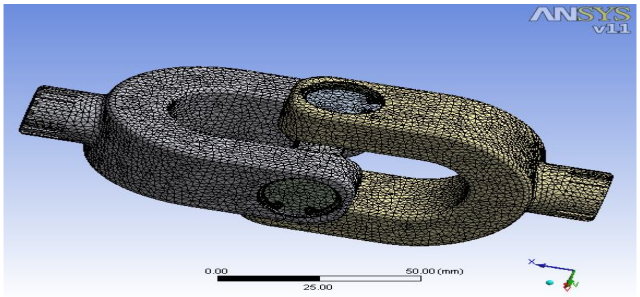

Fig- 4.3: Meshing model

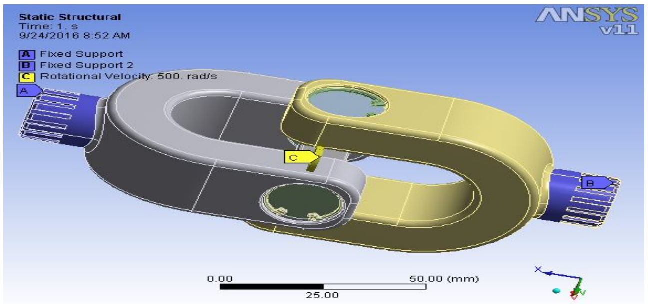

Fig- 4.4: Fixed support& Rotational velocity

Structural Steel	
Structural	Add/Remove Properties
Young's Modulus	2.e+005 MPa
Poisson's Ratio	0.3
Density	7.85e-006 kg/
Thermal Expansion	1.2e-005 1/°C
Alternating Stress	
Strain-Life Parameters	
Tensile Yield Strength	250. MPa
Compressive Yield Strength	250. MPa
Tensile Ultimate Strength	460. MPa
Compressive Ultimate Strength	0. MPa
Thermal	Add/Remove Properties
Thermal Conductivity	6.05e-002 W/mm·°C
Specific Heat	434. J/kg·°C
Electromagnetics	Add/Remove Properties
Relative Permeability	10000
Resistivity	1.7e-004 Ohm·mm

Fig-4.5: Structural steel details

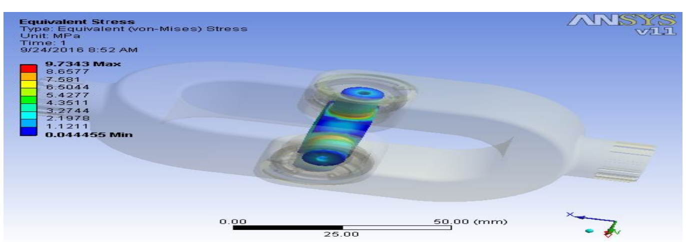

Fig- 4.6: Stress

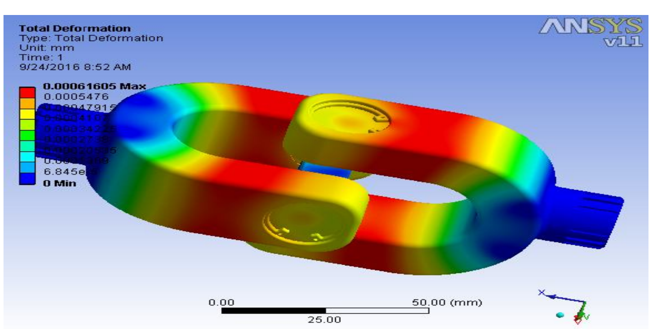

Fig- 4.7: Total Deformation

Gray Cast Iron	
Structural	Add/Remove Properties
Young's Modulus	1.1e+005 MPa
Poisson's Ratio	0.28
Density	7.2e-006 kg/
Thermal Expansion	1.1e-005 1/°C
Tensile Yield Strength	0. MPa
Compressive Yield Strength	0. MPa
Tensile Ultimate Strength	240. MPa
Compressive Ultimate Strength	820. MPa
Thermal	Add/Remove Properties
Thermal Conductivity	5.2e-002 W/mm·°C
Specific Heat	447. J/kg·°C
Electromagnetics	Add/Remove Properties
Relative Permeability	10000
Resistivity	9.6e-005 Ohm·mm

Fig-4.14: Gray Cast Iron details

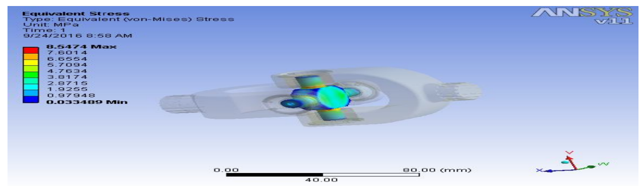

Fig-4.15: Stress

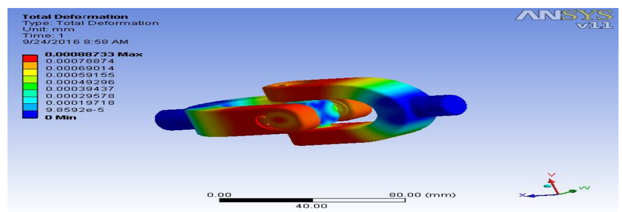

Fig-4.16: Total deformation

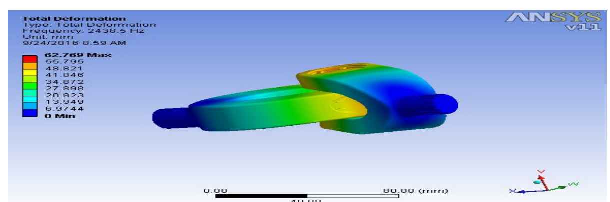

Fig-4.17: Model-1

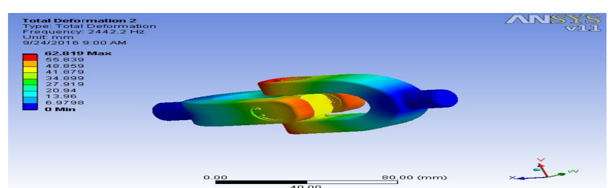

Fig-4.18: Model-2

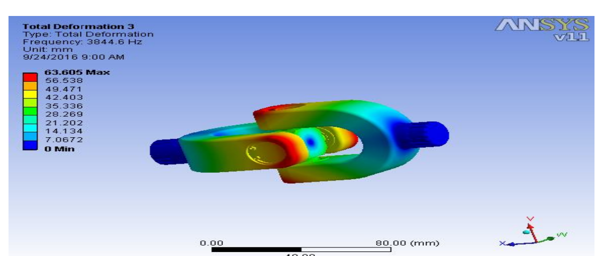

Fig-4.19: Model-3

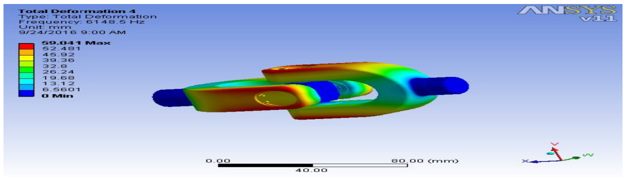

Fig-4.20: Model-4

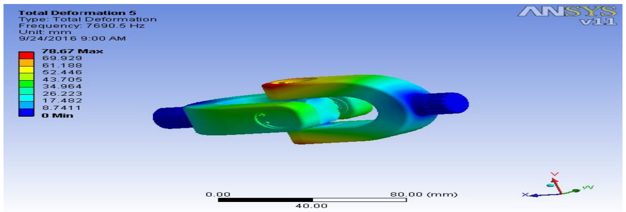

Fig-4.21: Model-5

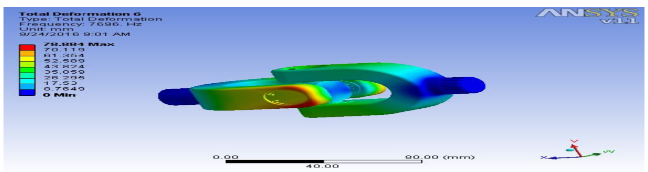

Fig-4.22: Model-6

Total deformation Model Table

Table- 4.1: Total deformation Model Table

Material	Structural Steel	Gray Cast Iron	CSI	Cast Iron
Model-1	60.71	62.76	62.62	60.93
Model-2	60.76	62.81	62.67	60.99
Mode-3	62.02	63.60	63.47	62.08
Mode-4	56.89	59.04	58.52	57.05
Mode-5	76.20	78.67	78.41	77.30
Mode-6	76.41	78.88	78.62	77.54

Stress vs. Total Deformation Table

Material	Equivalent stress (Mpa)		Total Deformation	
	Minimum	Maximum	Minimum	Maximum
Child Cast iron	0.037395	8.6844	0	0.00083653
Gray Cast Iron	0.033489	8.5474	0	0.00088733
Stainless Steel	0.044455	9.7343	0	0.00061605
Cast iron	0.043256	8.6791	0	0.00098729

V. RESULTS AND CONCLUSION

RESULTS

The software results obtained from existing universal coupling with different materials like child cast iron, gray cast iron and stainless steel. By comparing these resultsthe stress levels observed from above three materials, the equivalent stress value of gray cast iron is satisfactory by comparing with remaining three materials.

The results from analysis can be replaced the universal coupling. The universal coupling is analyzed by the FEA with four materials like **stainless steel, cast iron, child cast iron** and **gray cast iron**. Analysis parameters of universal coupling are From the above table I concluded that, the material gray cast iron is preferable one, by comparing to child cast iron, stainless steel and cast iron.

From static structural and modal analysis, the material **gray cast iron** is preferable one, because the material gray cast iron is got less deformation as 0.00088733 mm and stress 8.5474 MPa from static structural analysis.

CONCLUSION

Finite Element Analysis of the universal joint has beendone using ANSYS Workbench. From the results obtainedfrom FE Analysis, many discussions have been made. Theresults obtained are well in agreement with the available existing results. The model presented here, is well safe and under permissible limit of stresses.

1. On the basis of the current work, it is concluded thatthe design parameters of the universal coupling with modificationgive sufficient improvement in the existing results.

2. The weight of the universal coupling is also reduced by 9.64 %, thereby reducing the cost of the material.
3. The stress is found maximum near the sharp edges.

REFERENCES

[1] S.G.Solanke and A.S.Bharule, “An Investigation OnStress Distribution For Optimization Of Yoke InUniversal Joint Under Variable Torque Condition”International Journal of Mechanical Engineering andRobotics Research Vol. 3, No. 2, April 2014 ISSN 2278 – 0149

[2] Anup A. Bijagare, P.G. Mehar and V.N. Mujbaile,“Design Optimization & Analysis of Drive

Shaft",VSRD International Journal of Mechanical, Auto. &Prod. Engg. Vol. 2 (6), 2012.

[3] S.K.Chandole, M.D.Shende, M.K. Bhavsar" StructuralAnalysis Of Steering Yoke Of An Automobile ForWithstanding Torsion/ Shear Loads",IJRET:International Journal of Research in Engineering andTechnology Volume: 03 Issue: 03 | Mar-2014

[4] Farzad Vesali, Mohammad Ali Rezvani* andMohammad Kashfi, "Dynamics of universal joints, itsfailures and some propositions for practicallyimproving its performance and life expectancy" Journalof Mechanical Science and Technology 26 (8) (2012)2439~2449

[5] Naik Shashank Giridhar, Sneh Hetawal and BaskarP.,"Finite Element Analysis of Universal Joint andPropeller Shaft Assembly", International Journal of Engineering Trends and Technology (IJETT) - Nov2013 – Volume Number 5

[6] Sunil Chaudhry, Ani tBansal, Gopal Krishan "FiniteElement Analysis and Weight Reduction of UniversalJoint using CAE Tools "International Journal ofEngineering Research & Technology (IJERT) ISSN:2278-0181 Vol. 3 Issue 10, October- 2014

[7] P.G. Tathe, Prof. D.S. Bajaj and Swapnil S. Kulkarni,"Failure Analysis And Optimization In Yoke AssemblySubjected By Torsion And Shear", International Journalof Advanced Engineering Research and Studies EISSN2249–8974. July-Sept, 2014

[8] S.K. Chandole, M.K. Bhavsar, S.S. Sarode, G.R.Jadhav"Design Evaluation And Optimization OfSteering Yoke Of An Automobile"International Journalof Research in Engineering and Technology | pISSN:2321-7308Volume: 03 Issue: 11 | Nov-2014,

[9] Kamal Kashyap, D.G.Mahto"Analysis of Hooks JointUsing Ansys by Von-MisesMethod"InternationalJournal of Engineering and Advanced Technology(IJEAT)ISSN: 2249 – 8958, Volume-3, Issue-3,February 2014

[10] H. Bayrakceken, S. TasgetirenI. And Yavuz, "Twocases of failure in the power transmission systemonvehicles: A universal joint yoke and a drive shaft",EngineeringFailure Analysis 14 (2007) 716–724.