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Design, Analysis and Topological Optimization of a Automobile Steering Yoke

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***Abstract* – In the 21st century ,Industry 4.0 led to many innovations in manufacturing possibilities, design variations and new materials have emerged. A steering yoke is a integral part of the steering assembly which not only allows positioning of angular steering columns but also the ease of driving and shock prevention from the suspension assembly. A study indicates that the accidents occurred due to the control lost over the vehicle indicated a fatigue failure in the steering yoke assembly comprising of about 71%. This project focusses on the analysis and topological optimization of steering yoke without compromising the required strength , stiffness and strength for it's function. A CAD model was prepared in the 3D modeling software (CATIA) which was used to have the FEA and for further topology optimization. The steering yoke will be further redesigned to compensate the material removed with composite material like Carbon Fiber.**

Keywords – Steering Yoke, Topology Optimization, 3D modelling, FEA, ANSYS, CATIA, composite material, Carbon Fiber

I. INTRODUCTION

The basic functionality of the steering assembly is to convert the rotational motion of the steering wheel to the linear and transverse motion of the rack and its associated linkages. The steering assembly consists of the rack and pinion gear which are engaged to steer a vehicle. Due to the ununiform stresses induced from the suspension and tires the rack and pinion tend to disengage at extreme conditions which causes loss in control over vehicle and mishaps. In order to prevent this a steering yoke is used which not only facilitates the angular positioning and motion of the steering columns but also the contact of the rack and pinion. For optimal results line contact is proposed for rack and pinion to reduce friction and wear.

Fig.1 Steering Yoke

II. LITERATURE REVIEW

Steering Yoke is a type of universal joint which is also known as Cardan joints which was invented and registered by Clarence Spicer in 1904. The cardan joint is used in Cardan shafts and various mechanical couplings to engage the drive and driven shaft [1].

Bayrakceken concluded from his fracture analysis that fatigue failures were the major concerns failing the universal joints. He stated that the failures occurred due to the high stressed regions propagating crack initiation. The analysis of the failure in pinion shaft was also encountered by him [2].

Heyes showed that 25% of failures in automobiles comprise of failure in transmission system from his study of common failures in automobiles. The failures were a indication of restriction in manufacturing and design outcomes and neglecting maintenance [3].

Hummel and Chassapis redesigned the universal joint in compliance with the manufacturing restrictions and tolerances. They suggested a optimal design for a ideal universal joint. They also proposed the methodology of design and optimization of a ideal universal joint [4].

To implement the universal joint in various applications depending on the functional ability Dodge and Everden designed the universal joint in reference to the minimum diameter, torque and angle at which it was transmitted. The failures occurred due to the cyclic uneven torque acting on the joint [5][6].

Wagner and Cooney proposed a precise guide neglecting the interference and assuming small angles between joints by analyzing the kinematics and strength of a ideal universal joint [7].

Sasaki studied surface texturing of the bearings in universal joint. Surface texturing involves the implementation of composite materials to achieve desirable properties required as per the application [8].

III. PROBLEM STATEMENT

In the era of electric vehicles and pollution the efficiency and sustainability of natural resources play a crucial role. The mileage of the electric vehicles can be increased by reducing the weight of components in compliance with safety also the increase in pollution due to traditional methods of mining, manufacturing and energy generation leads to generation of new designs and topology optimization for existing designs.

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IV. OBJECTIVES

- Design 3D model of steering yoke using CATIA software.
- Perform the torsional analysis on the steering yoke using finite element method.
- Perform topology optimization on the steering yoke and reduce the material where the minimum stress concentration is observed.
- Study on the topology optimization method for optimizing the structures and components.
- Redesign the steering yoke to reduce the weight and develop optimized model.
- Perform Finite element method on the new optimized model by applying same boundary condition.

V. METHODOLOGY

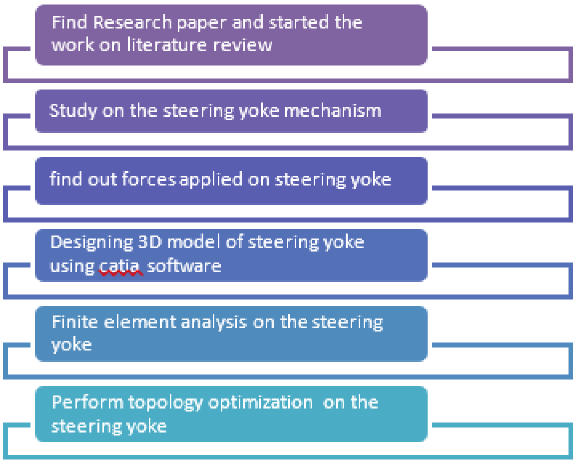


Fig.2 Methodology

VI. DESIGN OF THE STEERING YOKE

We select the Maruti Suzuki Ertiga steering yoke for to perform finite element analysis on the model. So we used CATIA software for the 3D modelling of the steering yoke.

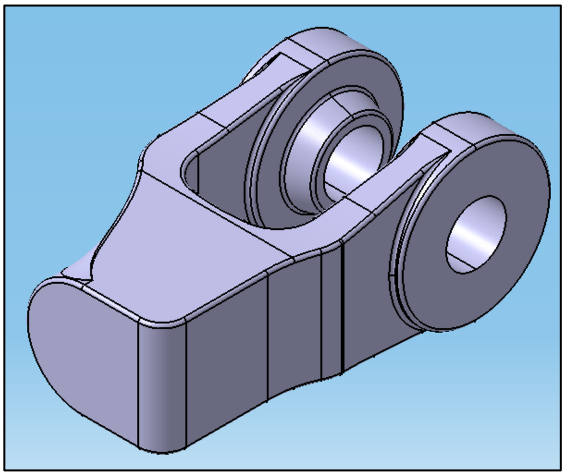
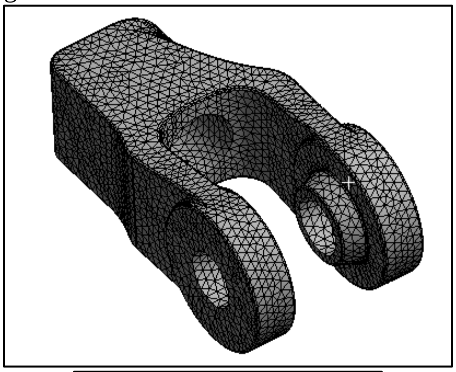


Fig.3 CAD model

VII. FINITE ELEMENT ANALYSIS

After importing the CAD model into ANSYS the material properties were added in to the software and meshing was carried out.



Statistics	
Nodes	72155
Elements	46609

Fig.4 Meshing details

A bending torque of 350 Nm was implemented on the model with fixed constraints and gravitational forces.

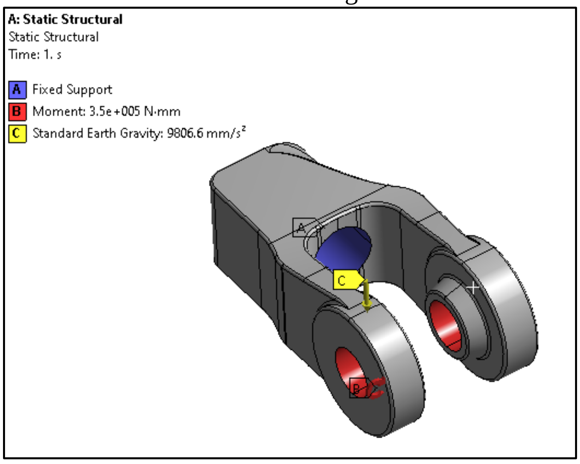


Fig.5 Boundary Conditions

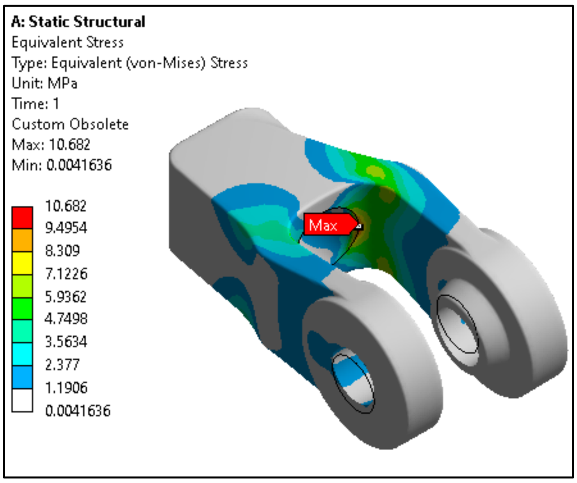


Fig.6 Equivalent Stress

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VIII. TOPOLOGY OPTIMIZATION

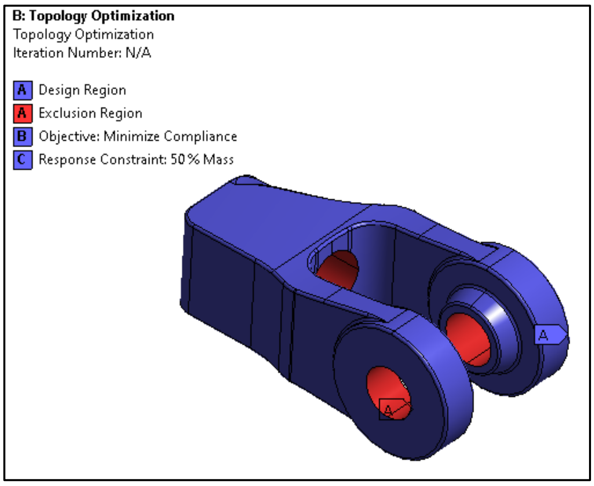

Fig.7 Conditions for topology optimization

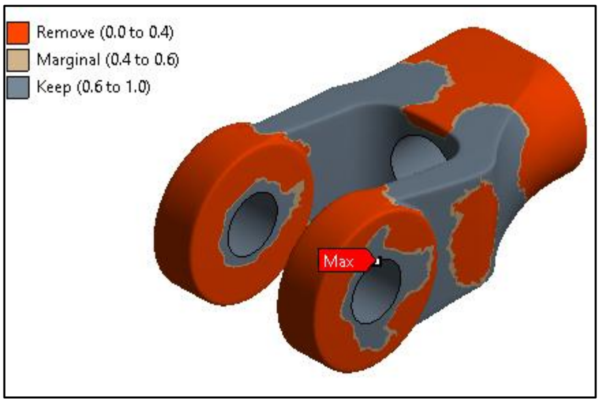

Fig.8 Result of topology optimization

IX. FUTURE SCOPE

The optimized topological model will then be infused with various composite materials to satisfy the required constraints. On successful physical experimental trials it can be implemented to various other applications like Cardan Shafts.

X. CONCLUSION

- In this project, design and optimization of the steering yoke is done for the weight optimization and strength improvement by means of topology optimization.
- The 3D modelling of the steering yoke is done using CATIA software.
- The stress analysis of the steering yoke is completed by using static structural analysis with the help of ANSYS software.
- The static structural analysis performed to find out equivalent stress and total deformation on the yoke after applying moment on the geometry. The equivalent stress and total deformation is observed on the steering yoke is 10.68 MPa and 0.01 mm.
- Topology Optimization was carried out with constraints and compliance of 50% mass.

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