Structural Strength Analysis for the Yoke in the Steering System to Determine Scope for Mass Reduction

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Abstract— The purpose of a steering system is to control the direction of the vehicle by applying effort to steering wheel. Steering system is one of the most important aggregate is automobile where mass reduction scope are more. In this paper study and review of structural optimization of steering yoke assembly is carried out. it has been found that there are two way of design process that structural optimization can carried out. In early stage of concept generation, optimization should be used to develop a structure, in later stage shape and size optimization should be used to fine tune the structural from optimization and carried out experimental to validate the component.

Key words: Yoke, universal joint, mass reduction, Hyper Works, Opti Struct, torque, steering system

I. Introduction

The steering system is often designed late in the build process. In a lot of cases it's best to mock up the steering when the engine and exhaust components are installed. Positioning the column, steering shafts, and u-joints early on with respect to the engine and steering box will ensure that you select the correct parts. Steep angles and limited space may require a little trial and error to achieve the correct geometry, but with a little ingenuity and careful measuring, it can be accomplished.

The steering system converts the rotation of the steering wheel into a swivelling movement of the road wheels in such a way that the steering-wheel rim turns a long way to move the road wheels a short way. The steering effort passes to the wheels through a system of pivoted joints. These are designed to allow the wheels to move up and down with the suspension without changing the steering angle.

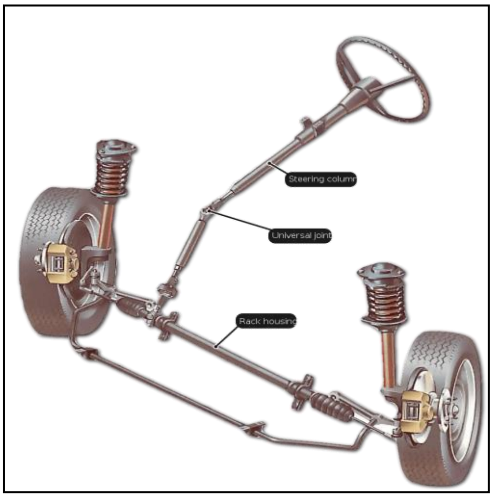

Fig. 1: A typical rack-and-pinion steering layout, showing how the rack acts directly on the road-wheel steering arms.

U-Joint: Universal joints, or U-joints, transmit rotary motion at an angle, allowing you to route the shafts around obstacles. As the angle increases, the strength of the joint decreases proportionately. U-joint strength is rated at a maximum angle by the manufacturer. Build your system with the least amount of angle that allows adequate clearance, and never exceed the angle at which the joint is rated, typically 30 to 35 degrees; if a greater angle is necessary, use more U-joints. Flaming River recommends 15 degrees as the optimum angle.

II. Literature review

In the interest of optimisation technique lot of research is completed and some are in process. Out of that many articles are focused on Topology Optimization and shape optimisation. The main aim of this researcher is to reduce maximum weight of component as well as reduce the cost of the components. Generally finite element analysis technique are used to finding out stress and corresponding strain induced in components, from this reference non affecting area are identify and researcher remove the material to optimize shape[3][4][5]

sometime optimisation is done by changing material property [8]

Before starting optimization, entire steering system or similar component used is in different system are studied [1][2][6]

The universal joint is prove to failure on account of the torsion loads or torque that it has to sustain during its operation. The application of manual or hydraulic force activated by the driver or the reaction experienced by the joint by virtue of road conditions poses a risk of failure of its structural elements. The joint made of 'steel' or its special alloys capable of bearing such loads. A suitable variety of 'steel' needs to be chosen while considering the options available in making a choice. The same needs to be evaluated using suitable popular technique or methodology like the Finite Element Analysis i.e. F.E.A. Also the geometry of the joint. the on struction/shape of the two halves, the spider or web acting as coupler for the halves and the provision of suitable mating parts or features for respective elements in the steering system all force towards reinforcing strength in this joint. The design of the joint needs to be feasible for manufacturing which considering the available methods of producing the part, the mating should be effected in a manner so as not to risk any slippage or sudden disengagement during the operation. The assembly or disassembly of the components within the universal joint should be easy for manual or automatic assembly techniques followed in the industry. The strength of the mating parts may not be compromised, though in recommending a feasible design. The weight of the entire vehicle is desired to be as low as possible in realizing a fuel efficient vehicle which is using the steering system. The components in the steering system including the yoke be evaluated for identifying scope of mass or weight reduction. This work should focus on mass reduction of the yoke to the tune of 2% while ensuring adequate structural strength. The same could be attempted using topology optimization as a technique or methodology for realizing this objective.

III. PROBLEM DEFINITION

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IV. SCOPE AND OBJECTIVES

Study the steering system of the given case study.

1) Study the material properties and load conditions for steering yoke.
2) FE modelling of the benchmark model
3) Analyze the results using HyperView interface and identify the scope for mass reduction using topology optimization technique
4) FE model of the new variant using same boundary condition
5) Validation of the alternate model through physical experimentation.
6) Proposed the best suitable alternative.

V. METHODOLOGY

A. Mathematical Methodology:

Torque applied in the yoke can be calculated with the help of standard empirical formulae. Distortion of the component can be calculated by considering the simplified geometry.

Torque Calculations

Operating load $= 30$ Kg

$= 30 \times 9.81$ N $=294.3$N

For calculation purpose we take 300N

Steering wheel radius $= 200$ mm

Torque $= 300 \times 200$

$= 60000$ N $-$ mm

$= 60$ Nm

Yoke analysed under torque of 60 Nm (Operating load)

B. Numerical Methodology / Computational Methodology:

In this method, FEA tools are used to compute the stress and displacement of the component. CAD model will be pursed from design department in .STEP or .IGES format.

Basic steps for structural analysis is as follows:

1) Pre-processing: In this step, Hyper Mesh interface will be used for meshing, assigning material properties, applying load and boundary condition. As per geometry of the component meshing technique would be decided.
2) Processing: Optistruct software will be used for static and optimization purpose.
3) Post-processing: Results will be studied as a post-processor as a Hyper View.

CAD Model

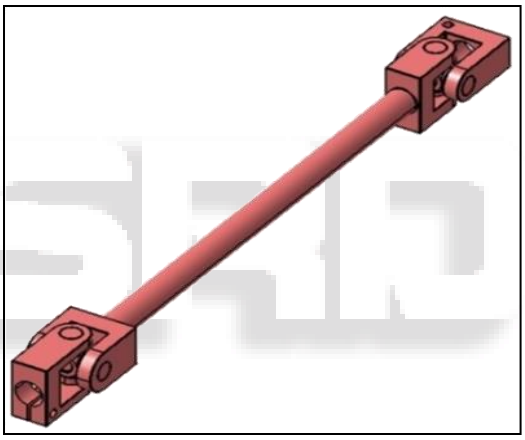

Fig. 2: Steering yoke 3D model

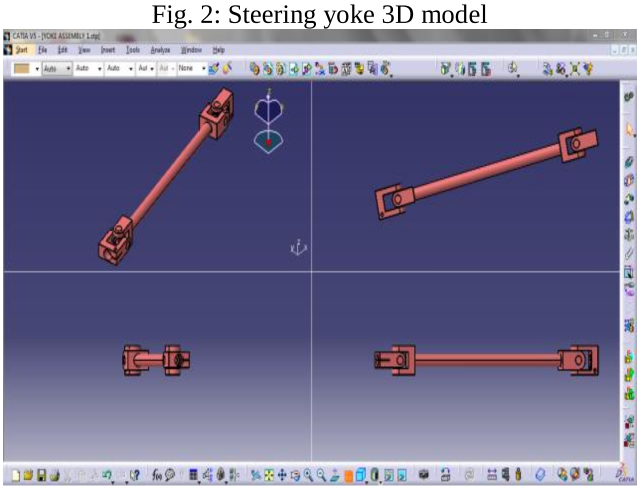

Fig. 3: Multiple views of steering yoke in CATIA V5 interface

C. *Experimentation Methodology:*

Fig. 4: Typical Test setup for Physical Experimentation

Figure shows the typical test setup for determining the distortion in the yoke. The gradually increasing torque will be applied and corresponding distortion is recorded.

VI. VALIDATION

The results for this work shall be validated through alternative methodology for Experimentation. An error margin of about 20% could be accommodated in such cases.

A. *Future Scope considering Stage2*

For stage 2 - Stresses developed in the steering yoke under given load and boundary conditions shall be evaluated using numerical methodology. Benchmark Analysis shall be done to per the expectations followed by analysis for the alternatives. The alternatives shall be based on the Design parameter of `Geometry' which shall involve change in the shape and or size to simplify the design or process.

VII. CONCLUSION

From results, it is conclude that Topology optimization method is helpful to reduce the weight of component. Reduction of weight by 26.0% keeping maximum stresses & displacement within limit. The stresses observed in optimized component is within limit so it shows that change in component weight can reduce cost of component and overall steering system weight.

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