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TOPOLOGY OPTIMIZATION OF STEERING KNUCKLE ARM USING FINITE ELEMENT METHOD

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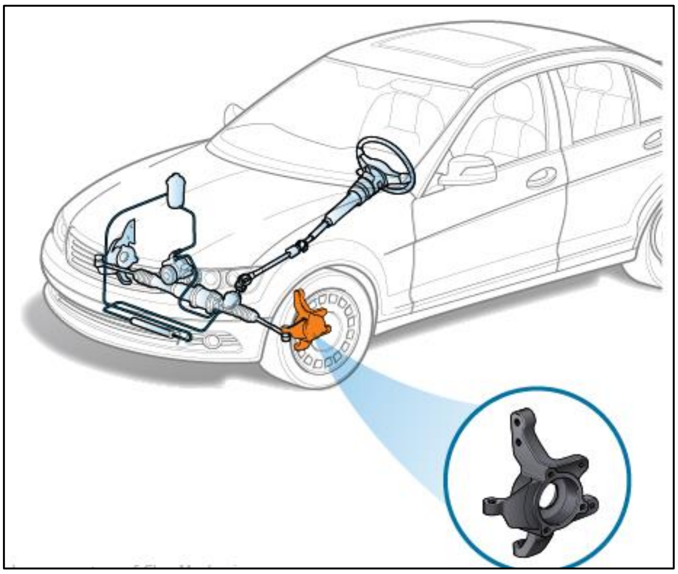
ABSTRACT

Mass reduction for the vehicle calls for a comprehensive evaluation of each component in the sub-assembly and the sub-assembly as a whole within the main assembly. The parts with higher mass are normally identified as 'eligible' candidates for the initial phase of the mass reduction exercise. This work has chosen steering knuckle arm for analysis and research while finding ways of reducing weight while addressing safety and manufacturability of the part. The chosen part is / about- Kg in weight. The attempt shall be to reduce the same to make it lighter by at least 3~4 % of its existing mass. Mathematical treatment might be limited in this case given the irregular geometry and uneven physical features of the knuckle arm. Topology Optimization using FEA software shall be deployed as computation technique while validating the solution using test setup with static loads.

KEYWORDS: *Topology Optimization, weight reduction, steering knuckle arm, Optistruct*

I. INTRODUCTION

In automotive suspension, a steering knuckle is that part which contains the wheel hub or spindle, and attaches to the suspension components. It is variously called a steering knuckle, spindle, upright or hub, as well. The wheel and tire assembly attach to the hub or spindle of the knuckle where the tire/wheel rotates while being held in a stable plane of motion by the knuckle/suspension assembly. The arm of the knuckle that sticks out, to which the steering mechanism attaches to turn the knuckle and wheel assembly. The forces exerted on this assembly are of cyclic nature as the steering arm is turned to maneuver the vehicle to the left or to the right and to the centre again. The weight of the vehicle is going on increasing due to additional luxurious and safety features. The increasing weight of the vehicle affects the fuel efficiency and overall performance of the vehicle. Therefore the weight reduction of the vehicle is the real need of today's automotive industry. Steering knuckle is one of critical component of vehicle. It links suspension, steering system, wheel hub and brake to the chassis. There is scope to reduce the un sprung weight vehicle. Steering Knuckle is a non-standard part and subjected to various loads at different conditions. Weight reduction of steering knuckle is the objective of this exercise for optimization.



Component of vehicle it links suspension, steering system, wheel hub and brake to the chassis. There is scope to reduce the unsprung weight vehicle. Steering Knuckle is a non-standard part and subjected to various loads at different conditions. Weight reduction of steering knuckle is the objective of this exercise for optimization. Typically, the finite element software like OptiStruct is utilized to achieve this purpose. For optimization, Nastran/Ansys/Abaqus could also be utilized. The targeted weight or mass reduction for this exercise is about 5% without compromising on the structural strength.

II. LITERATURE REVIEW

Rajkumar Roy etc. al. [1] (2008) focuses on recent approaches to automating the manual optimization process and the challenges that it presents to the engineering community. The study identifies scalability as the major challenge for design optimization techniques. GAs is the most popular algorithmic optimization approach. Large-scale optimization will require more research in topology design, computational power and efficient optimization algorithms.

S. Vijayaranganet.al. [2] (2013) uses the different material than regular material for optimization of steering knuckle. They use Metal Matrix Composites (MMCs) as it has potential to meet demanded design requirements of the automotive industry, compared with conventional materials. Structural analysis of steering knuckle made of alternate material Al-10 weight % Tic was performed using commercial code ANSYS. It is found from the analysis; the knuckle strut region has maximum stress and deflection during its life time. The results obtained from numerical analysis and experimental testing using particulate reinforced MMCs for steering knuckle with a weight saving about 55% when compare with currently used SG iron.

Prof. R. L. Jhala etc. al. [3] (2009) assesses fatigue life and compares fatigue performance of steering knuckles made from three materials of different manufacturing processes. These include forged steel, cast aluminium, and cast iron knuckles. Finite element models of the steering knuckles were also analysed to obtain stress distributions in each component. Based on the results of component testing and finite element analysis, fatigue behaviours of the three materials and manufacturing processes are then compared. They conclude with that forged steel knuckle exhibits superior fatigue behaviour, compared to the cast iron and cast aluminium knuckles.

K. h. Chang and P.S. Tang [4] (2001) discuss an integrated design and manufacturing approach that supports the shape optimization. The main contribution of the work is incorporating manufacturing in the design process, where manufacturing cost is considered for design. The design problem must be formulated more realistically by incorporating the manufacturing cost as either the objective function or constrain function.

Patel Nirala and Mihir Chauhan [5] (2013) carry out the topology optimization of clamp cylinder t using CAE tools to reduce weight with the constraints of standard operating condition. The new optimized design of configuration is proposed. FEA of optimized cylinder is also carried out and compared with acceptance criterion. The optimized model is equally strong and light in weight compared to existing model. The topology optimization of the component is carried out and substantial reduction in weight about 70 kg is obtained and also obtained stress and deformation within acceptance criteria.

Rajeev Sakunthala Rajendran etc. al. [6] (2013) discusses the process of designing a light weight knuckle from scratch. The design space is identified for the knuckle and subsequently a design volume satisfying the packaging requirements is created from it. Using OptiStruct, topology optimization is performed on the design volume to derive the optimal load path required for the major load cases. Hyper morph is used to create the required shape variable and Hyper Study is used as optimizer. The process of using Topology optimization for load path generation& Parametric study using shape optimization, reduces the design iteration and intermediate concept models and there by reduces the design cycle time.

There are four disciplines for optimization process:

Topology optimization: It is an optimization process which gives the optimum material layout according to the design space and loading case.

Shape optimization: This optimization gives the optimum fillets and the optimum outer dimensions.

Size optimization: The aim of applying this optimization process is to obtain the optimum thickness of the component.

Topography: It is an advanced form of shape optimization, in which a design region is defined and a pattern of shape variable will generate the reinforcements.

III. SUMMARY FROM LITERATURE

i. Use of MMC (metal matrix composite) gives weight saving up to 55% but it is costly as well complex manufacturing process, requires skilled operator

ii. Review of literature shows that many authors have reported the design to study effect of weight reduction in steering knuckle; they also study stresses developed and material properties.

iii. Analysis is to done to check the effect of variation in the significant design parameter with suitable boundary conditions.

iv. Computational method (CAE software) is identified as the prospective methodology to find effect of weight reduction in steering knuckle with appropriate changes in steering knuckle geometry.

v. Mathematical calculation used to find the stresses developed in steering knuckle geometry and results to be compared with computational method used

IV. CONCLUSION FROM LITERATURE REVIEW

1) Review of literature shows that many authors have reported the design to study effect of weight reduction in steering knuckle; they also study stresses developed and material properties.

2) Analysis is to done to check the effect of variation in the significant design parameter with suitable boundary conditions.

3) Computational method (CAE software) is identified as the prospective methodology to find effect of weight reduction in steering knuckle with appropriate changes in steering knuckle geometry.

4) Mathematical calculation used to find the stresses developed in steering knuckle geometry and results to be compared with computational method used.

V. PROBLEM DEFINITION

The bulk of the vehicle automotive chassis, steering system, suspension system, etc constitutes casting, forging and fabricated parts made of steel. Components like the steering knuckle arm are critical to the safety of the vehicle. Any failure shall expose the occupants to safety hazard as the vehicle could swerve in such event causing grave accident. This has contributed to the tendency to ‘over-design’ the part to rule out any mishap. Although the same has also contributed to an ‘added’ mass of material that the automotive is expected to carry with a subsequent bearing on its fuel-efficiency and handling at the macroscopic level. There is a need to review the design in the light of above to identify if there exists a scope to reduce 'mass' Computational technique could be considered for deployment as the trial and error method could prove costly in finding solution.

VI. Objectives/ Scope Of Work

1. To study literature related to steering knuckle design and optimization.
2. To study the geometry of steering knuckle for FE modeling.
3. To study the stresses developed in benchmark geometry of steering knuckle of automobile using CAE software.
4. Identify the area for improvement and change the geometry.
5. Experimental testing over identified model for validation of results
6. Finding out the best alternative design for benchmark model.

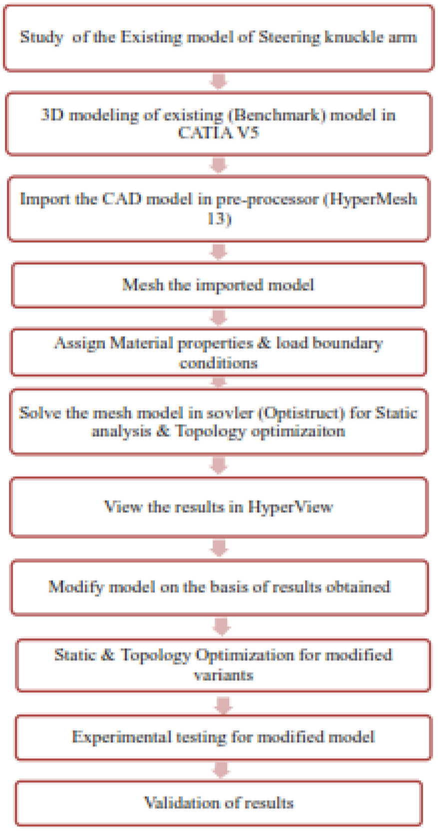
VII. Methodology

1. Computational Method-

- CAD model of the steering knuckle of automobile.
- Pre-processing the CAD model in Pre-processor
- Applying Material properties, loads, Boundary conditions.
- Exporting to solver to find out the stress developed.
- Viewing results through post-processor
- Revision in geometry and Analysis for improvement
- Find out the best suitable alternative

Software Used & to be Used:

- 3D modeling: CATIA V5 (Dassault Systems)
- Pre-processor: HyperMesh (Altair Engineering)
- Solver: Radioss or Optisruct (Altair Engineering)
- Post-processor: Hyperform (Altair Engineering)



2. Experimentation-

Figure. Typical Test setup for Physical Experimentation for determining Stiffness

Figure shows the typical test setup for determining the stiffness of the steering knuckle. The gradually increasing load will be applied and corresponding deformation is determined. The load from the load cells present on the UTM machine will be applied gradually. Display attached to the machine will give a corresponding plot for load Vs displacement i.e. stiffness of the component.

Validation

In this project work we will be validating the stiffness of the component by comparing results obtained from experimentation with results of FEA analysis.

Summary of stage 1

1. Structural and optimization analysis using FEA software's
2. Mathematical calculations
3. Experimentation for stiffness
4. Improvement in geometry for weight optimization

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