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Static Analysis of Steering Knuckle and Its Shape Optimization

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ABSTRACT: *Steering knuckle is one of important component of vehicle which is connected to steering, suspension and brake to chassis of vehicle. It undergoes different loading under different conditions. In this paper we have done static analysis of steering knuckle. We have design a knuckle which accommodates dual caliper mountings for increasing braking efficiency & reducing a stopping distance of a vehicle. CAD modal of knuckle was prepared in CREO2.0. Static analysis was done in ANSYS WORKBENCH by constraining the knuckle, applying loads of braking torque on caliper mounting, longitudinal reaction due to traction, vertical reaction due to vehicle weight and steering reaction. Also, reducing the weight of vehicle component plays vital role in increasing efficiency of vehicle and reducing fuel consumption. In this paper we have also done shape optimization of same knuckle and saved material resource. Shape optimization of knuckle was done using ANSYS WORKBENCH making objective function as reducing weight. These FEA results are verified by comparing with analytical calculations. Considering these results modal is modified.*

Keywords*: FEA, Model, Optimization, Static Analysis, Steering Knuckle.*

II. INTRODUCTION

1.1 About steering knuckle

In this investigation, steering knuckle was used as component for study. Main design and functionality of steering knuckle depends on type of suspension implemented. Additional factors like brake caliper used, mounting of tie rod of steering sub-system also effects knuckle design. Suspension system in any vehicle uses different types of links, arms, and joints to let the wheels move freely; front suspensions also have to allow the front wheels to turn. Steering knuckle/spindle assembly, which might be two separate parts attached together or one complete part, is one of these links. In this paper we have designed double caliper steering knuckle to increase braking efficiency and reduce the stopping distance of vehicle.

1.2 Static analysis of steering knuckle

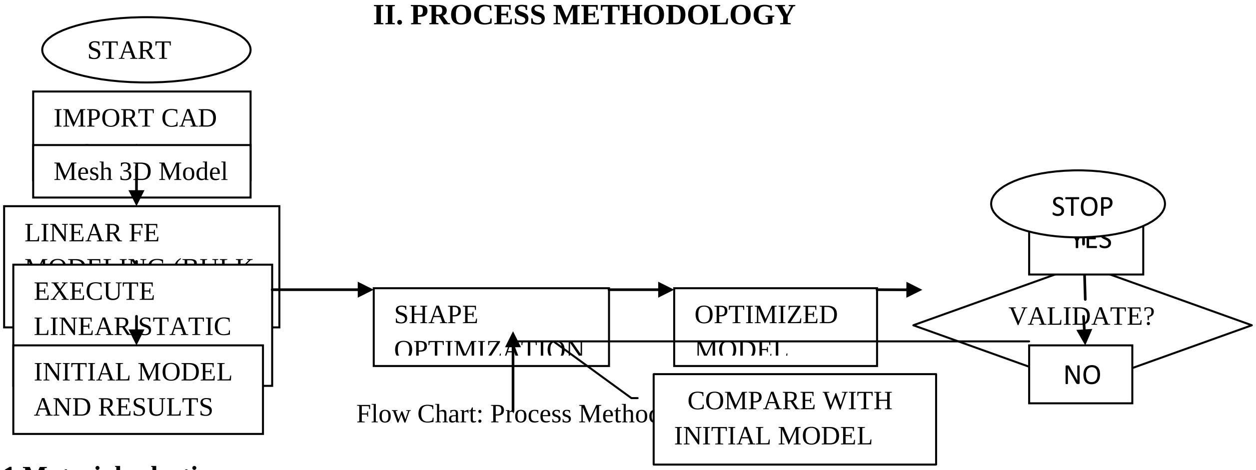
To observe maximum stresses and deformation of steering knuckle when different forces such as braking force, load transfer during acceleration and braking etc. are applied on it static analysis is performed.

1.3 Shape optimization

All manufacturing enterprises strive to develop the optimized product commonly by reducing the weight while ensuring they produce cost effective products that meet their design functionality and reliability. Structural optimization tools like topology and shape optimization along with manufacturing simulation are becoming attractive tools in product design process. These tools also help to reduce product development time. Shape optimization gives the optimum fillets and the optimum outer dimensions.

Objective of this investigation is to reduce weight of steering knuckle of rear driven vehicle having double wishbone type suspension system. This paper focuses of static analysis and shape optimization. Finite element analysis has been used to implement optimization and maintaining stress and deformation levels and achieving high stiffness. Reduction of weight has been one the critical aspects of any design. It has substantial impact on vehicle performance, fuel efficiency and in turn reduces the emissions.

II. PROCESS METHODOLOGY



Flow Chart: Process Metho

2.1 Material selection

There are several materials used for manufacturing of steering knuckle such as S.G. iron (ductile iron), white cast iron and grey cast iron. But grey cast iron mostly used. Forged steel are most demanding material for this application. Now a day's automobile industry has put effort to use aluminium alloy as an alternative. Due to low weight of this material, it can reduce fuel consumption and CO_2 emission. So as per survey best suited material was aluminium alloy. It has low density and compatible yield strength. This material was chosen for designing knuckle by comparing its result with other material.

Table 1: Chemical properties of aluminium 2011 T3 alloy

Silicon (Si)	Iron (Fe)	Copper (Cu)	Lead (Pb)	Bismuth (Bi)	Zinc (Zn)	Others (Total)	Aluminium (Al)
0.40 max	0.70 max	5.00 - 6.0	0.20 - 0.60	0.20 - 0.60	0.30 max	0.15 max	91.2 - 94.6%

Table 2: Physical and mechanical properties of aluminium 2011 T3 alloy

Young's Modulus	7.1e+4 MPa
Poisson's Ratio	0.33
Density	2770 kg/m3
Ultimate tensile strength	310Mpa
Yield Strength	280Mpa

2.2 Designing a CAD model

CAD model of steering knuckle was developed in 3D modeling software CREO 2.0. it consists of stub hole, brake caliper mounting points, steering tie-rod mounting points, suspension upper and lower A-arm mounting points. Knuckle design mainly depends on suspension geometry and steering geometry.

2.3. Meshing

CAD model of knuckle converted into STEP file. This model is imported into Ansys Workbench simulation. Geometry cleanup was performed prior to meshing of model. Finite element model was developed using Ansys Workbench Simulation. For better quality of mesh fine element size is selected.

Table 3: Nodes and Elements of model

NODES	18055
ELEMENTS	7776

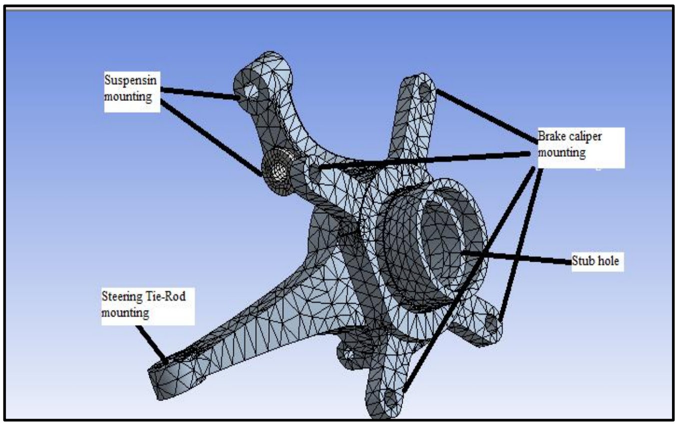


Fig.1 Detail and meshing of model

2.4 Static Analysis

To observe maximum stress produce into steering knuckle, model is subjected to extreme conditions and static analysis is carried out in Ansys Workbench. Steering knuckle was constraint at A arms mountings. Steering force from tie rod to steering knuckle was analytically calculated and applied to knuckle with its self weight. A combined load of 1.5g braking force and 1.5g lateral acceleration were applied to the model considering the longitudinal load transfer during braking and lateral load transfer during cornering.

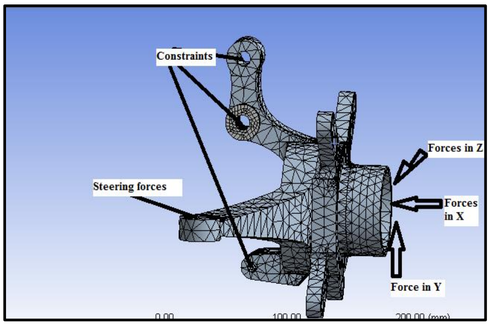
Table 4: loading conditions

LOADING CONDITIONS	
Braking force	1.5G
Lateral force	1.5G
Steering force	Steering effort of 40-50N
Load on knuckle hub in X-direction	3G
Load on knuckle hub in Y-direction	3G
Load on knuckle hub in Z-direction	1G

There are two types of load acting on knuckle i.e. force and moment. This knuckle is designed for vehicle of 400 kg weight so braking force acting on it produces moment:

Moment = force * perpendicular distance
= 1.5G* 97 N mm
= 1.5*100*10*97= 145500 N mm (for one wheel)

By static analysis of knuckle under extreme conditions
Max. Deformation: 0.138 mm (Fig.4)
Max. Stress produced: 63.814 MPa (Fig.5)



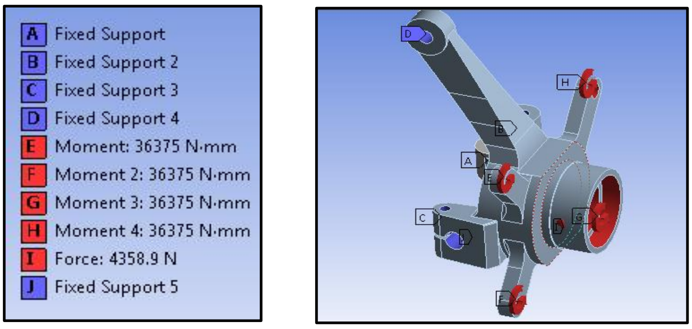


Fig.2 Detail of forces and constraints

Fig.3 Forces and constrain

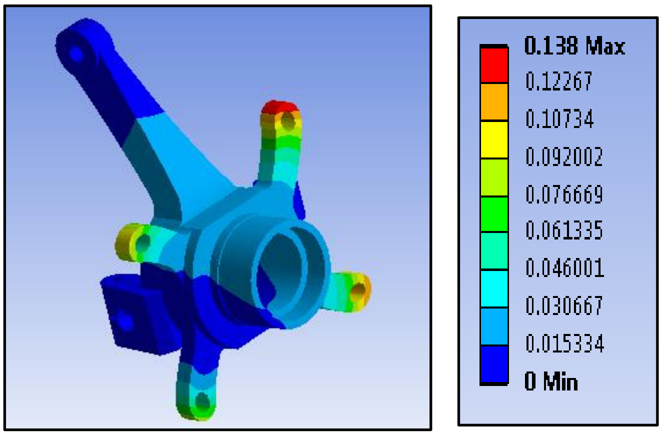


Fig.4 Deformation

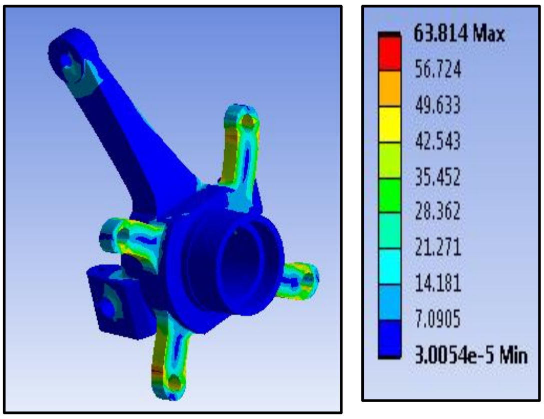


Fig.5 stress produced

2.5 Shape Optimization

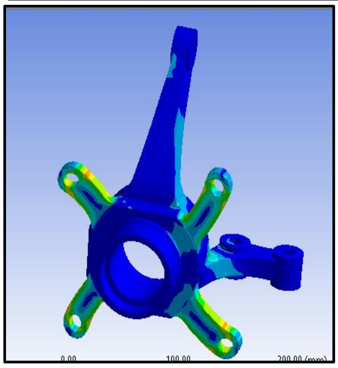
Shape optimization is technique to modify the structural shape based on predefined shape variables to obtain optimal shape. Size optimization defines ideal component parameters, such as material values, cross-section dimensions and thicknesses. Shape optimization is different from topology optimization in that it is used once the component's topology has already been defined. Topology optimization is used to generate material layout concepts whereas shape optimization refines and improves the topology within the concept. In shape optimization, the outer boundary of the structure is modified to solve the optimization problem.

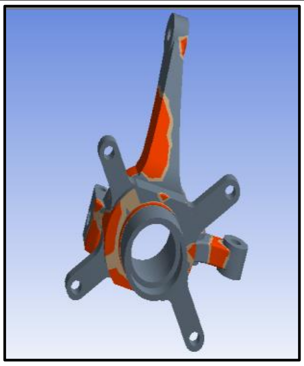
The purpose of a shape optimization analysis is to find the best use of material for a body. Typically this involves optimizing the distribution of material so that a structure will have the maximum stiffness for a set of loads.

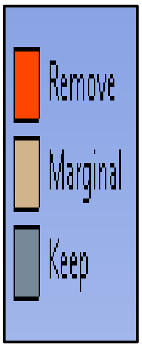
In this paper, shape optimization of knuckle was done by using Ansys Workbench Shape Optimization. Here objective function is to reduce weight of knuckle. Design constraints are applied as in static analysis.

III. RESULTS AND DISCUSSION

Initial model of knuckle is shown in Fig.6. It has max. Stress of 63.814 MPa. After applying load and design constraints shape optimization was performed. Fig. 7 shows material which can be removed from model (shown in orange) after optimization. The objective of the research is to reduce the mass (represented by reduction volume) using shape optimization. The mass reduction for the front knuckle was found to be 19.35%, compared to the currently used model. Optimized model is shown in fig.9.







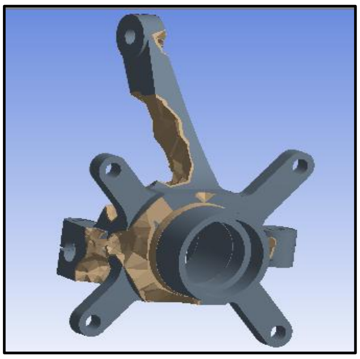


Fig.6 Initial model Fig.7 model after shape optimization Fig.8 Material removed

This result is satisfactory considering using optimization in shape only, with limited design space given and no change in material properties. Summary of results is shown in Table 5:

Table 5: Summary of results

	Initial design	Optimized design	% Reduction
Displacement	0.138 mm	0.150 mm	
Stress	63.814 MPa	65 MPa	
Mass	1.3331 kg	1.0751 kg	19.35%

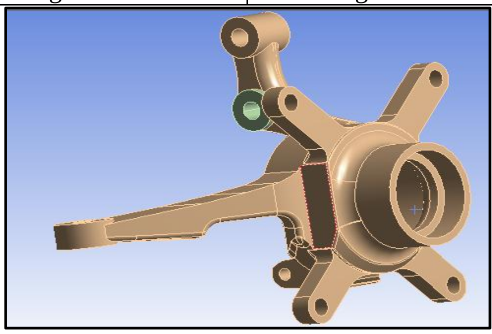


Fig.9 Optimized model

IV. CONCLUSION

Shape optimization method used in this study in reducing the mass of knuckle by 19.35%. Also factory of safety is between 3 to 4. Maximum stress and displacement are within control. This optimization process also gives small change on the displacement. It means that change of volume and shapes doesn't influence significantly to stiffness of the structure. Therefore, the overall weight of the vehicle can be reduced to achieve savings in costs and materials, as well as, improve fuel efficiency and reduce carbon emissions to sustain the environment.

REFERENCE

[1] Rao, S.S., *Engineering Optimization Theory and Practice*(John Wiley & Sons, Inc., 2009, 4th edition).
[2] Wan Mansor Wan Muhamad, Endra Sujatmika, Hisham Hamid, & Faris Tarlochan,' Design improvement of steering knuckle using shape optimization' 2012.
[3] Thomas D. Gillespie, *Fundamental of vehicle dynamics* (society of automotive engineers)