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# Static Analysis and Topology Optimization of Steering Knuckle by Using Finite Element Method

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**ABSTRACT:** The main objective of this paper is to reduce the weight of a steering knuckle by applying the topology optimization technique and minimized the mass of steering knuckle. Steering knuckle is an important component of the vehicle and it's connected to the suspension system. CAD Model of steering knuckle has been done in Catia V5. 3D model has been meshed in HYPERWORKS. Static analysis part was done in HYPERWORKS V12 with the help of RADIOSS. We have applied load in different load s in the steering arm. Another part is topology optimization and it's been carried out in HYPERWORKS with help of Optistruct solver. Topology optimization is the systematic approach that optimized the material, layout with given the limited design space. Finally, we conclude compared the two different loads in maximum stress and deformation was taken and also topology optimization analysis has been achieved 2.84% reduction the weight.

**KEYWORDS:** Static analysis, topology optimization and HYPERWORKS.

## I. INTRODUCTION

Suspension system in any vehicle uses different types of joints, links and arms. In the front suspension system and also have to turn the wheel. It is also allows the front wheel to pivot and to attach rotating components to suspension components beside distribute load from road to body. They are used in three different types of suspension system, namely semi-independent, independent and dependent (rigid axle). The steering arm functions to change the direction and to combine various parts. There are divided into two types ones in hub and other joints in the spindle. Reduce the weight of steering knuckle components and also improve the quality, performance and durability. In suspension system, there are several parts that work together with steering knuckle such as spring, shock absorbers, control arms, ball joints and spindle. The steering knuckle can be classified according to the type of suspension. Their shape also differs between types of suspension the steering knuckle is required to varying the forces during its fatigue life and therefore design is an important process of the development cycle. The vehicle has been continuously developed in more accuracy, safety, performance and strength. Steering knuckle's weight is reduced and correspondingly there is an increase in energy fuel consumption. The topology optimization is to find the best solution of the problem and given sets of an objective and no of constraints. Therefore the model developed in topology optimization with involving three parameter, namely design objective (weight reduction), design variables (materials density), design constraints (volume). Finite element analysis, which is used too many types of analysis such as non-linear analysis, linear analysis and fatigue analysis. Finite element analysis has been developed to solve the topology optimization process involved in Optistruct linear solver method.

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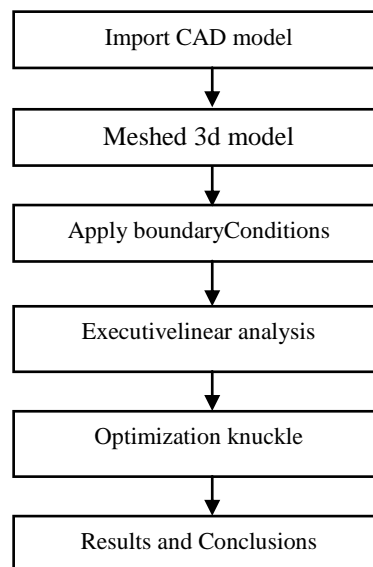
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## II. OBJECTIVE

The main objective of this paper is topology optimization process which involves in weight reduction of the steering knuckle.

## III. METHODOLOGY

The process involved in static analysis and optimization of steering knuckle by using finite element analysis. CAD Model of steering knuckle designed in Catia V5 and was imported in HYPERWORKS. The static analysis was done in RADIOSS such as linear analysis and optimization done by using OPTISTRUCT solver.



**Fig.1 Optimization of flow chart**

### 3.1 Material selection

There are different materials used in manufacturing processes such as grey cast iron, spheroidal graphite iron (SG Ductile Iron) and white cast iron. The grey cast iron mostly has been used, because demand the forged steel for this application. Now a present day's automobile industry has been put effort in Spheroidal graphite (SG) iron, due to its less density, low ductility and high hardness.

**Table 1 Physical and Mechanical properties of SG iron**

Young's modulus (MPa)	1.62
Poisson Ratio	0.26
Density(Kg/m <sup>3</sup> )	2770
Ultimate strength(MPa)	620
Yield strength(MPa)	420

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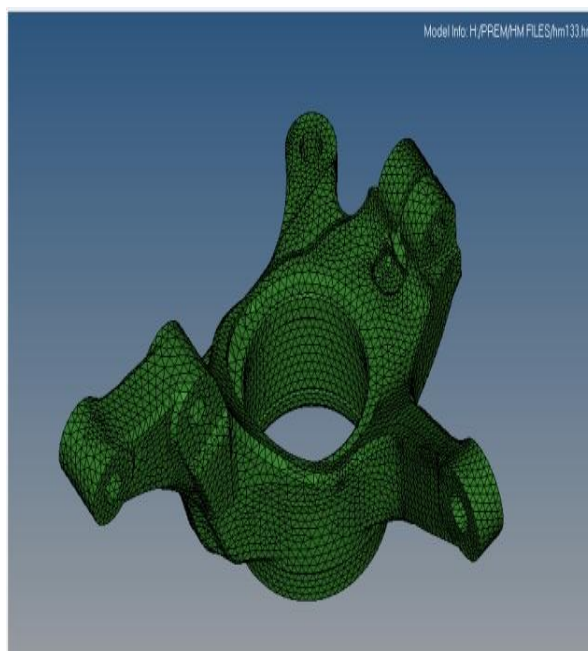
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## 3.2 Meshing

CAD model of steering knuckle has been converted into IGES file. . It consists of stub hole, brake calliper mounting points, steering tie-rod mounting points, suspension upper and lower A-arm mounting points the model is imported into HYPERWORKS V12 simulation and also 3D meshed has been done in HYPERWORKS.

**Table 2 Number of nodes and element model**

Elements	68,617
Nodes	16,827
Type	Tetra Element
No of rigid elements	2



**Fig.2 Meshing of model at SG iron**

## 3.3 Force Reaction on Steering Knuckle

A Steering Knuckle is one of the critical components of vehicle which connects brake, suspension, wheel hub and steering system to the chassis. It undergoes varying loads subjected to different circumstances, while not distressing vehicle steering performance and other desired vehicle characteristics

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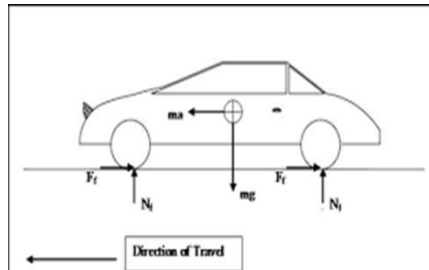


Fig. 3 Force reaction on steering knuckle

## 3.4 Loading conditions

The steering knuckle hub is arrested and the boundary condition was applied in steering arm for different loads at case 40KN and 45KN as shown in fig 4.

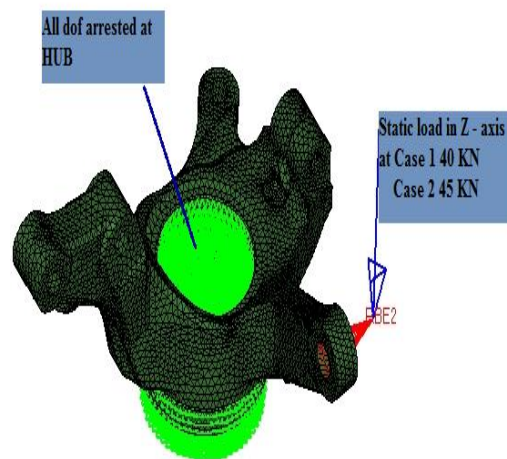


Fig. 4Applying boundary conditions

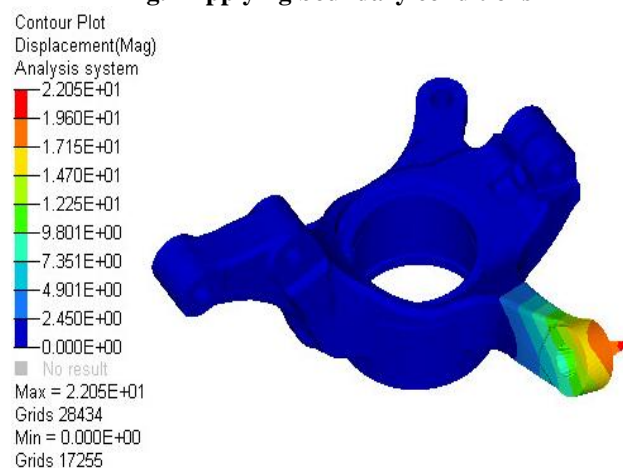
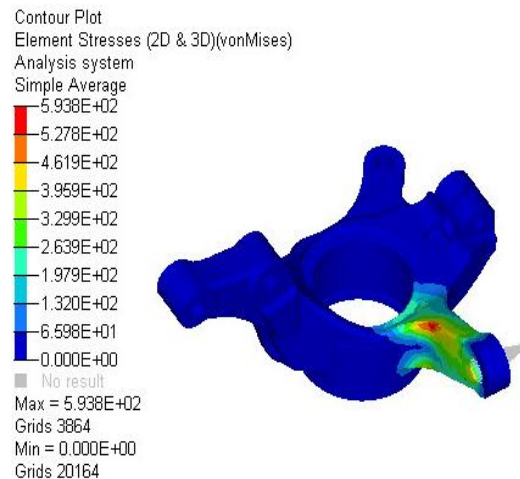


Fig. 5 Displacement at 40 KN

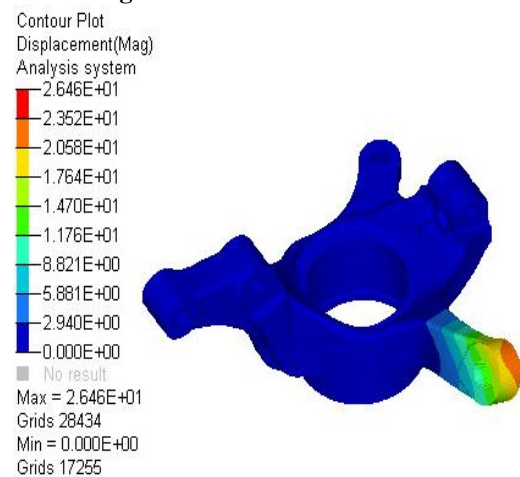
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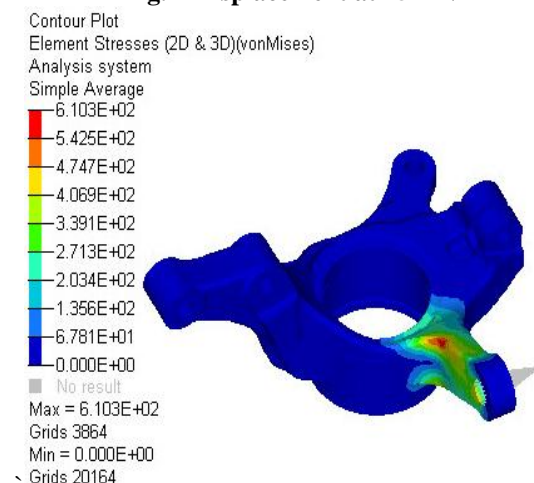
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**Fig. 6 Vonmisses Stress at 40 KN**



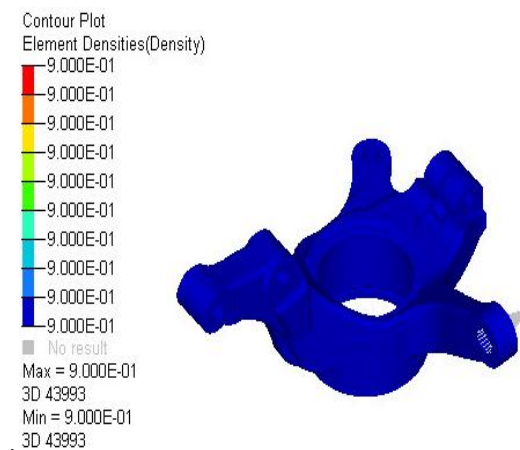
**Fig. 7 Displacement at 45 KN**



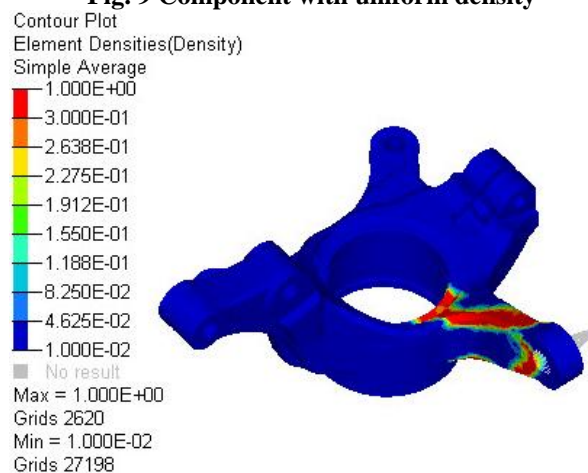
**Fig. 8 Vonmisses Stress at 45 KN**

## IV. TOPOLOGY OPTIMIZATION

The maximum stress value for steering arm at 45 KN load is 610.3 MPA which is below the ultimate strength, therefore the knuckle has more strength and ductility. Hence the topology optimization has been done with the maximum stress value obtained.



**Fig. 9 Component with uniform density**



**Fig. 10 Optimized component**

From the Fig.9 shows steering knuckle with uniform density. Optistruct take this model as initial iteration. Optistruct identifies stress distribution pattern throughout the steering arm and remove the material from that region in successive iterations based upon set of constraints and objectives. The material removal is given by varying density of each element from 0 to 1. By removing the material from this design space of the knuckle component objective of weight reduction will be fulfilled by changing the volume.

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**Table 3 Analysed results for both different loads and optimized mass**

Properties	SG Iron knuckle		Optimization 45 KN		
			Initial mass (kg)	Optimized mass (kg)	Percentage %
Load (KN)	40	45	3.4459	3.3500	2.84
Maximum stress (MPa)	593.8	610.3			
Max displacement (mm)	22.05	26.46			

## IV. CONCLUSION

In this paper, the static analysis has been done in steering arm with the load of 40 and 45 KN. From the analysis result has been concluded that, the values obtained for the SG iron in maximum stresses (610.3 MPa) and maximum displacement (26.46) of the steering arm. SG iron is good material for high strength and ductility with safe limit. Topology optimization of the steering knuckle generates an optimized material distribution pattern set of constraints and loads within a given limited design space. Optimization reduces weight initial weight of mass 3.4459 (KG) and optimized mass 3.3500 (KG).

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