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Analysis and Material Optimization of Steering Knuckle using FEA

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ABSTRACT

Recent trends in automobile industry is to enhance vehicle performance by reducing weight of various components which in turn reduces overall weight of vehicle. The steering knuckle is the most critical component of a car. It experiences the continuous application of loads and deflections. Due to manufacturing feasibility, materials are chosen according to the strength with less considerations towards weight reduction. Increase in weight of the vehicle demands more energy to run the vehicle, thus increasing fuel consumption. Keeping this concept in mind an effort has been made to improve the vehicle's performance by reducing the weight of the steering knuckle. In this paper, structural analysis is carried out by considering static load conditions to study the nature and magnitude of stresses. The objective is to reduce weight through optimization without affecting its strength and rigidity. In this study, a CAD Model was generated using Catia v5, Hypermesh for pre-processing and post-processing and Optistruct as a solver was used.

Keywords: CAD Modelling, Static analysis, Steering Knuckle, Types of material, Weight optimization.

I.INTRODUCTION

Steering knuckle is one of the important components of the vehicle which facilitates to turn the front wheels for steering and also act as a load carrying member. It holds the wheel hub with the help of a bearing. It is the connection between suspension arms, shock absorber, steering tie rod and breaking system.

Mass or weight reduction is becoming important issue in car manufacturing industry. Reducing mass of vehicle components will contribute towards overall mass reduction of vehicle, lower its energy consumption, therefore will improve its fuel efficiency, efforts to reduce emission and therefore, contribute towards the environment. Weight can be reduced through several types of improvements in using advanced materials, design and analysis tools, fabrication processes and optimization techniques.

Optimization methods were developed to have lighter, less cost and may have better strength too. Many optimization types, methods and tools are available nowadays due to high speed computing and software development. There are four disciplines for optimization process:

a. Topology optimization: It is an optimization technique which gives the optimum material layout according to design space and loading case.
b. Shape optimization: This optimization gives the optimum fillets and optimum outer dimensions.
c. Size optimization: The aim of applying this optimization process is to obtain optimum thickness of the component.
d. Topography: It is an advanced form of shape optimization, in which a design region is defined, and a pattern of shape variable will generate reinforcement.

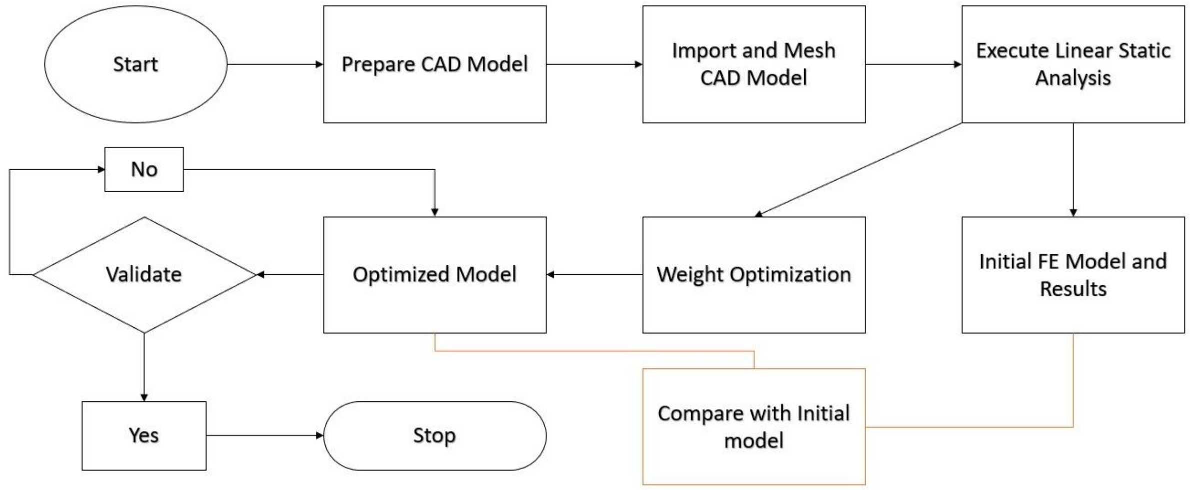

Figure 1: process methodology flowchart

II. PROCESS METHODOLOGY

2.1 Material Selection

The mechanical, chemical and physical properties are studied before proper selection of materials. There are several materials used for manufacturing of steering knuckle such as S.G. iron (ductile iron), white cast iron and grey cast iron. Usually, ductile iron is used for making steering knuckles. Nowadays automobile industry has put efforts to use aluminum alloy as an alternative. Due to the high strength to weight ratio of this material, it can reduce fuel consumption and thus exhaust emissions. So as per literature survey, we found suitable materials which can be used for manufacturing of steering knuckle which are Aluminum 6061-T6, Aluminum 7075-T6 Alloy and Steel EN 8.

Table 1: Materials and their Physical and Mechanical properties

PROPERTIES	MATERIALS			
	Cast Iron A536	Steel EN 8	Al 6061-T6	Al 7075-T6
Young's Modulus (MPa)	1.75E+05	2.10E+05	6.90E+04	7.20E+04
Poisson's Ratio	0.3	0.3	0.33	0.33
Density (tonne/mm^3)	7.10E-09	7.89E-09	2.70E-09	2.80E-09
UTS (MPa)	4.13E+02	4.20E+02	3.10E+02	5.72E+02
Yield Strength (MPa)	3.10E+02	2.50E+02	2.76E+02	5.03E+02

From the above table “Materials and their Physical and Mechanical properties”, the material Aluminum Al 7075-T6 is the most efficient of all the conventional materials in-terms of strength and density and can be considered as a suitable alternative for manufacturing steering knuckle.

2.2 Designing a CAD model

CAD model of steering knuckle is generated in CAD software **CATIA V5.** It consists of 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. Thus, hard point locations were measured using conventional instruments with reference to an origin.

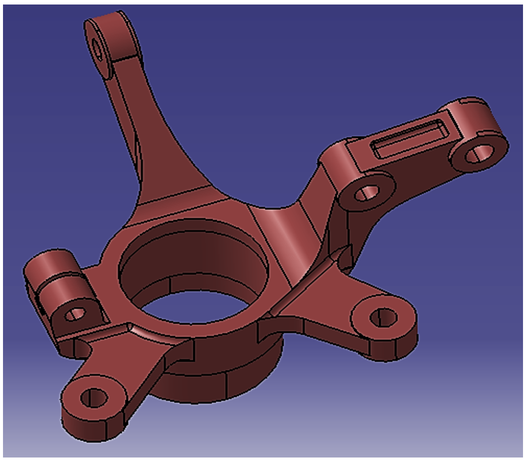

Figure 2: CAD model of steering knuckle

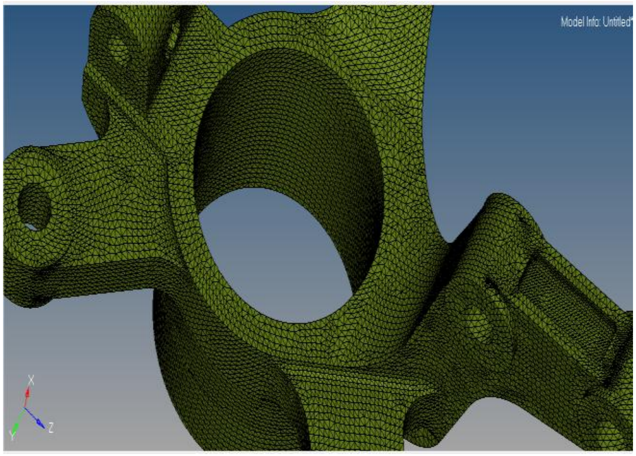

Figure 3: Meshed model of steering knuckle

2.3 Meshing

CAD model of knuckle generated in **CATIA V5** is converted into STEP file. This model is imported in **Hypermesh v13**. For better quality of mesh fine element size is selected.

Table 2: Mesh Characteristics

No. of nodes	2,08,216
No. of elements	52,233
Type of elements	Tetrahedral Elements

2.4 Preliminary Analysis

We have used FEA (Finite Element Analysis) for linear static structural analysis of a knuckle component. FEA is a computational tool used for engineering analysis. It includes meshing technique in which complex geometry (problem) is divided into small elements for precise results.

The basic idea of FEA to make calculation at only limited (Finite) number of points and then interpolate the results for the entire domain (surface or volume). Any continuous object has infinite degree of freedom and it's just not possible to solve the problem in this format. So FEA reduces the degree of freedom from infinite to finite with the help of discretization or meshing (nodes and elements).

FEA is a good choice for analyzing the knuckle component under various loads like lateral force, braking force, steering force and loads on the knuckle in X-Direction, Y-Direction, and Z-Direction respectively under static conditions. FEA consists of following steps for analysis of knuckle.
Steering Knuckle component experiences certain loads in static condition. The required loading conditions are considered as mentioned in the table. As per the Literature Survey we found that the maximum braking force applied is not greater than 1.5mg in commercial vehicles and forces on steering knuckle in X, Y and Z direction are 1mg, 3mg and 3mg respectively.
Where, m=Distributed mass on each wheel in kg; g=Acceleration due to gravity=9.81m/s^2
There are two types of loads acting on the steering knuckle i.e. force and moment. This knuckle is designed for a vehicle of 1300 kg weight. Braking force acting on the steering knuckle produces a moment.

Table 3: Load table

Braking Force	1.5mg
Lateral Force	1.5mg
Steering Force	50 N
Force on Knuckle in x-direction	mg
Force on Knuckle in y-direction	3mg
Force on Knuckle in z-direction	3mg

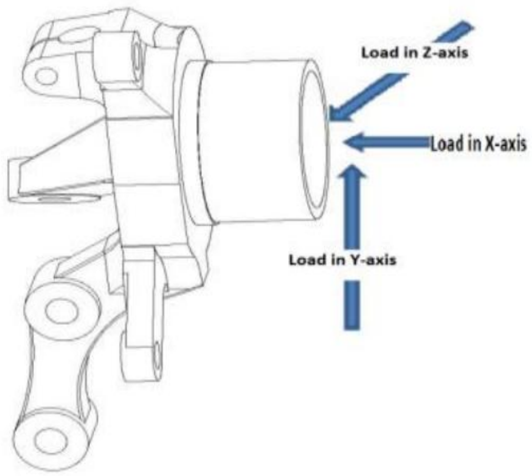

Figure 4: Direction of Loads

III.CALCULATIONS

For calculating braking force acting on one wheel we must distribute the weight of the vehicle for four wheels so that we get vehicle weight acting on one wheel i.e. 1300/4=**325 kg on one wheel**.

(1) Braking Force = 1.5*m*g = 1.5*325*9.81 = 4782.375 kg-m/s^2

(2) Braking moment = Braking force*Perpendicular distance of caliper bolts

= 4782.375*91

= 435196.125 N-mm

This moment is acting on the mountings of steering knuckle when brake is applied. Brake caliper is mounted at two locations, therefore distributing moment at two points.

(3) Moment on the brake caliper mounts = 435196.125/2

= 217598.062N-mm

(4) F_x = mg = 9.81*325 = 3188.25 N

(5) $F_y = F_z$ = 3mg = 3*9.81*325 = 9546.75 N

(6) Resultant Force=$\sqrt{(F_x^2+F_y^2+F_z^2)}$ =13872.48 N

IV. RESULTS

4.1 Cast Iron A536 (60-45-18)

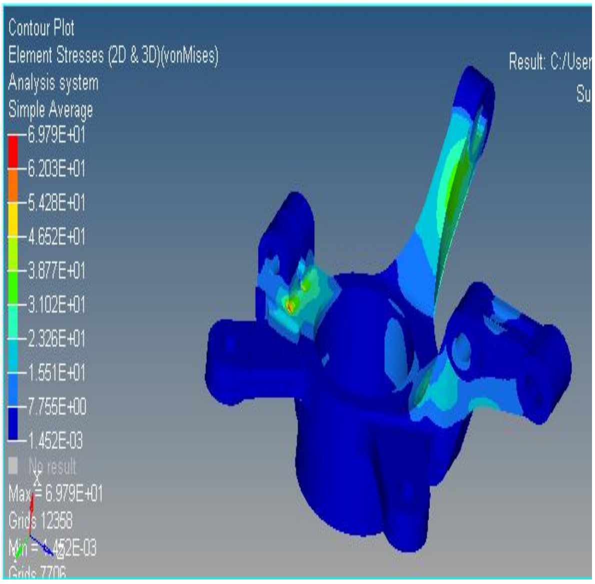

Figure 5: CI stress contour plot

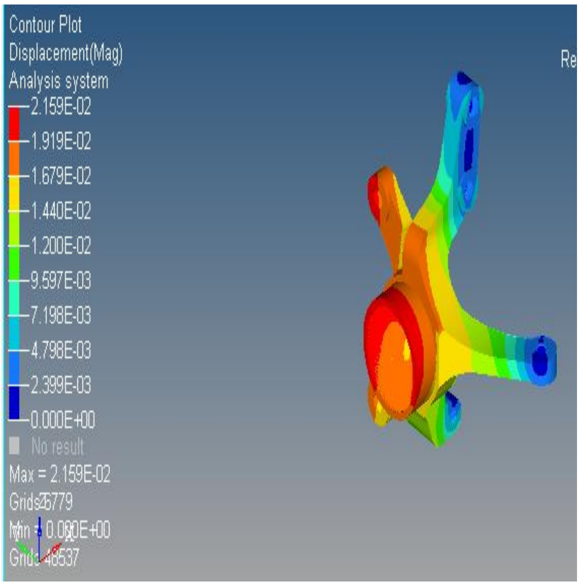

Figure 6: CI displacement contour plot

4.2 Steel EN 8

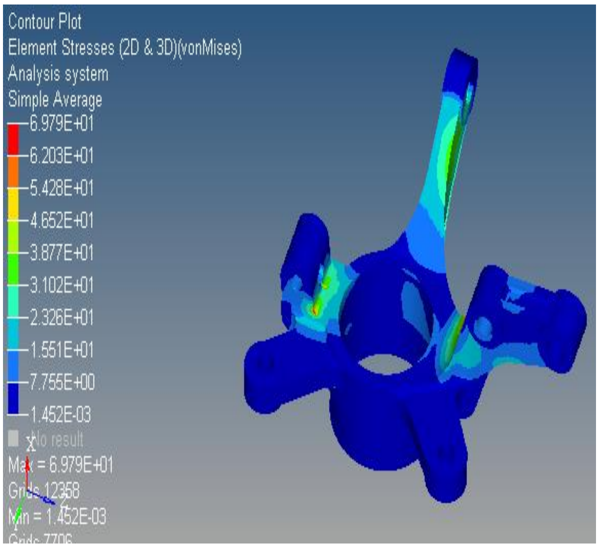

Figure 7: EN 8 stress contour plot

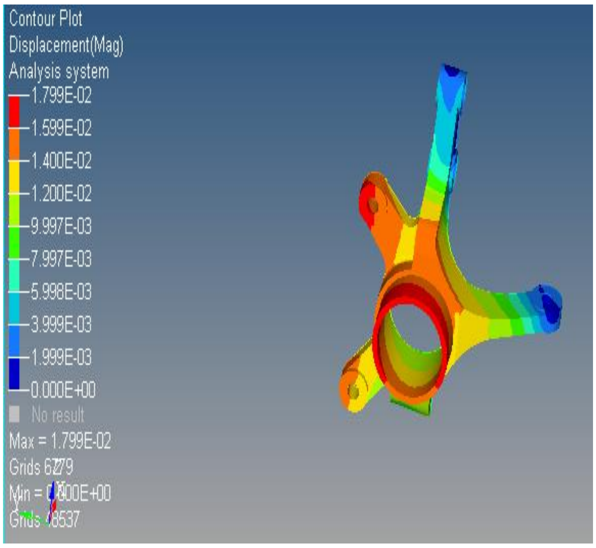

Figure 8: EN 8 displacement contour plot

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4.3 Aluminum 6061-T6

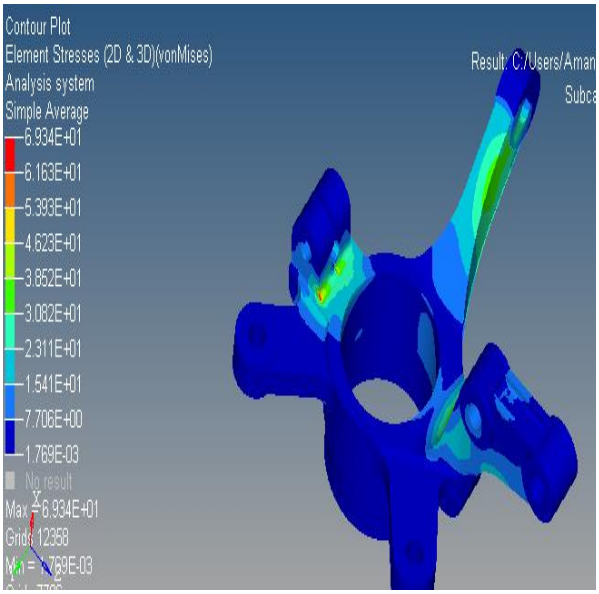

Figure 9: Al 6061-T6 stress contour plot

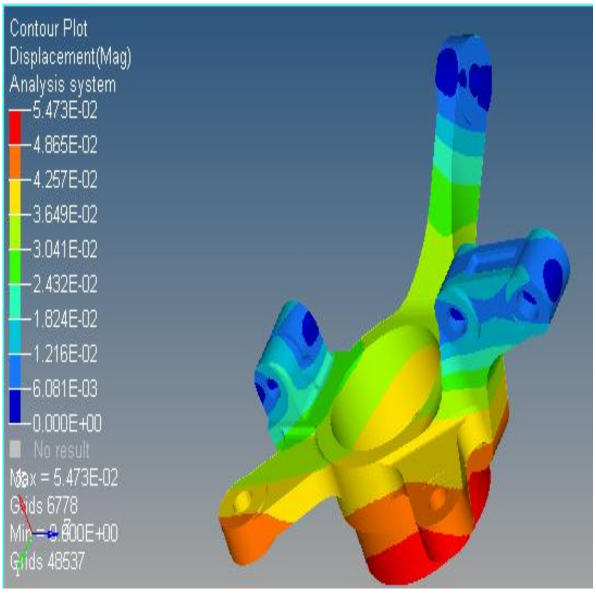

Figure 10: Al 6061-T6 displacement contour plot

4.4 Aluminum 7075-T6

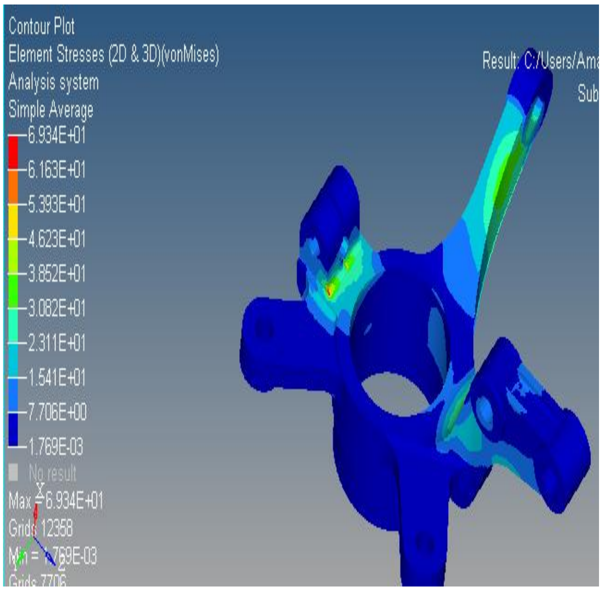

Figure 11: Al 7075-T6 stress contour plot

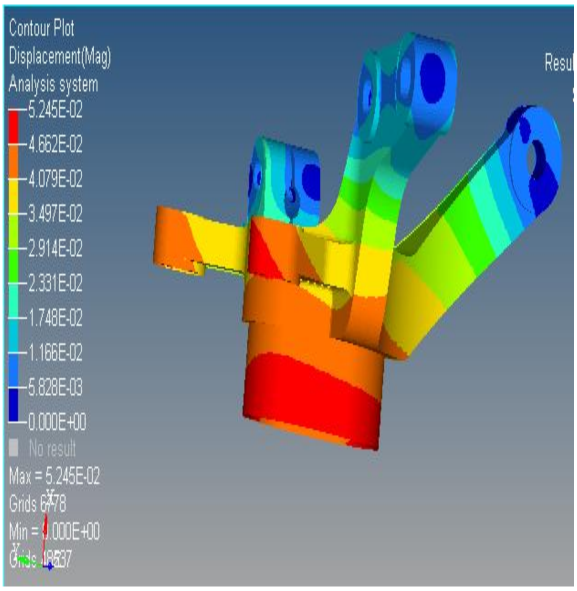

Figure 12: Al7075-T6 displacement contour plot

MATERIALS	RESULTS	
	Maximum Displacement (mm)	Maximum Stress (MPa)
Cast Iron A536	2.20E-02	69.79
Steel EN8	1.80E-02	69.79
Aluminum 6061-T6	5.47E-02	69.34
Aluminum 7075-T6	5.25E-02	69.34

Table 4: Result Table

V. CONCLUSION

The existing knuckle is made up of SG Iron (Ductile Iron) having high density and comparatively less strength. The maximum stress is also marginally more in case of Ductile Iron. After analysis and material optimization we found that the stress generated is within the permissible limit of the material. Moreover, the weight of knuckle in case of Al 7075-T6 is 67% less than the cast iron and steel. Also, the strength is approximately 1.5 times greater than cast iron. Hence, after comparing various material results, Aluminum 7075-T6 is selected as a viable alternative for making a steering knuckle. But, due to its high market price, 7000 series Aluminum are used specially in space-engineering or motorsports industries. Reduction in the market price of 7000 series Aluminum might result in improvised usage for various industries, thus, promoting energy savings.

REFERENCES

[1] Sanjay Yadav, Ravi Kumar Mishra, Varish Ansari, Shayam Biharilal, *Design and analysis of steering knuckle components*, International journal of Engineering research & technology, International Journal of Engineering Research and Technology, *Vol.5 Issue 04, April 2016, ISSN:2278-0181*

[2] Purushottam Dumbre, V.S Aher, Prof.A.K Mishra, Swapnil S.Kulkarni, *Structural analysis of Steering Knuckle for weight reduction*, International Journal of Advanced Engineering Research and Studies, 2014, *E-ISSN:2249-8974*

[3] Poonam P.Tagade, Anil R.Sahu, H.C Kutarmare**,** *Optimization and Finite Element Analysis of Steering Knuckle***,** International Conference on Quality Upgradation in Engineering, Science and Technology, 2015, *International Journal of Computer Applications (0975-8887)*

[4] Ch. Syam Kumar, B.Kiran Kumar, J.Kantha Rao, R.Anil Kumar, *Design optimization of Steering Knuckle using conservative method of Finite Element Analysis*, International Journal for Research in Applied Science and Engineering Technology, *Volume 5, Issue XI*, November 2017, *, ISSN:2321-9653*