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Design and Analysis of Steering Knuckle Component

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Abstract **– The Steering Knuckle component is the most important part of vehicle which is connected to front wheel with the help of suspension system, wheel hub and these are also connected to steering system and brake to the chassis. The Steering Knuckle component provides motion to desire directions with the help of steering system. It undergoes various types of varying load under different conditions. In Automobile industry low fuel consumption and light weight are the two main demands for the vehicle because the lighter steering knuckle resulting greater power and less vibration because of inertia is less. In this Paper we have done static analysis of steering knuckle component. The design of Steering Knuckle component is done with the help of Computer Aided Engineering (CAE). Steering Knuckle model is prepare in Creo(Pro-E) 2.0 and the static analysis is done in ANSYS WORKBENCH15.0 by constraining the steering knuckle and applying load on steering knuckle due to caliper mounting, longitudinal reaction, vertical reaction, vehicle weight and steering reaction. In this we have focused on optimizing the best use of material for the steering knuckle component and compare it, made from two material i.e. Cast Iron and Mild Steel which is recently using, and Forge Steel EN 47 which is suggested material. This result is verified by comparing with analytical calculations. Considering these results, model is modified.**

Keywords –Steering knuckle component, Static Analysis, Material,and ANSYS WORKBENCH 15.0.

I. INTRODUCTION

Steering knuckle is the critical component of the vehicle which is linked with suspension system. It allows steering arm to turn the front wheel and it also supports the vertical weight of the vehicle. The steering knuckle is the connection between stub axle, tie rod and axle housing with the help of using king pin, and these are also connected to the suspension system [6]. In this, wheel hub is fixed with steering knuckle with the help of bearing. The main function of steering knuckle is to convert linear motion of the tie rod into the angular motion of the stub axle [5]. In the automobile industry, the requirement of properties of steering knuckle is that it must be strong, inflexible and light as well as possible. When steering is turn by drivers, half portion of the steering knuckle component is subjected to tensile load and another half portion of steering knuckle component is subjected to compressive load and due to this rotation of wheel, steering knuckle is subjected to torsional load.

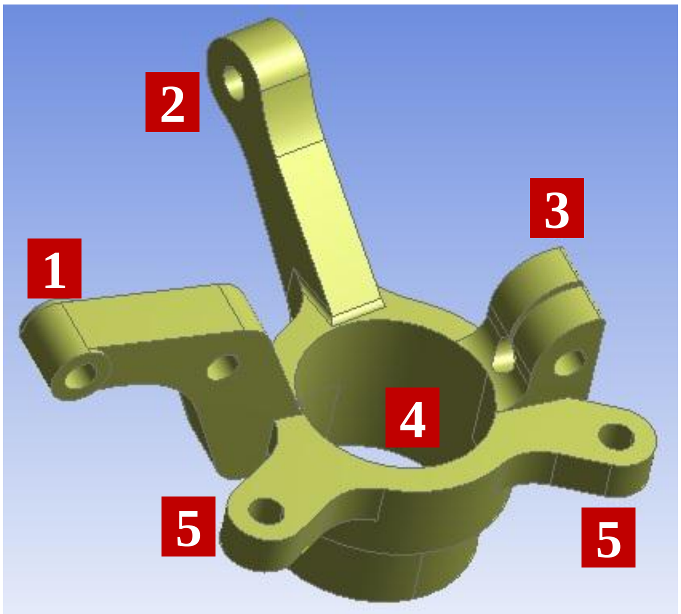

Fig 1.Steering Knuckle

The part of steering knuckle component are given below:

1. Suspension Mounting Upper Arm/Strut Mount
2. Tie Rod Mounting / Steering Arm
3. Lower Ball Joint /Suspension Mounting Lower Arm
4. Ball Bearing Location / Stub Hole
5. Brake Caliper Mounting

The shape and size of steering knuckle component depends upon the vehicle weight because vertical load of the vehicle is directly act on it and hence the steering knuckle component subjected to power thrust from tie rod to the stub axle and hence it must be strong and inflexible in nature. The steering knuckle in the automobile industry can be made either by forging or from casting. However, castings have blown-holes which are injurious from fatigue and durability points of view. The fact that forgings produce blow-hole free and good parts give them an advantage over cast parts. Due to large volume production of steering knuckle component, it is only logical that optimization of the steering knuckle for its volume orweight should be result in large-scale saving. The reduction of inertia load, torsional load, vehicle weight will improve the vehicle performance and fuel economy.

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II. METHODOLOGY

This study has been has been followed in two parts. First part of this study includes modeling of steering knuckles component and analysis of stresses under actual load conditions. CAD models of steering knuckle were developed in 3D modeling software, such as Creo (Pro-E) 2.0. Whilethe second part is of the models were then obtained and compared using finite element analysis (FEA) via ANSYS WORKBENCH Simulation software.

Approach of this study is shown in Fig -2.

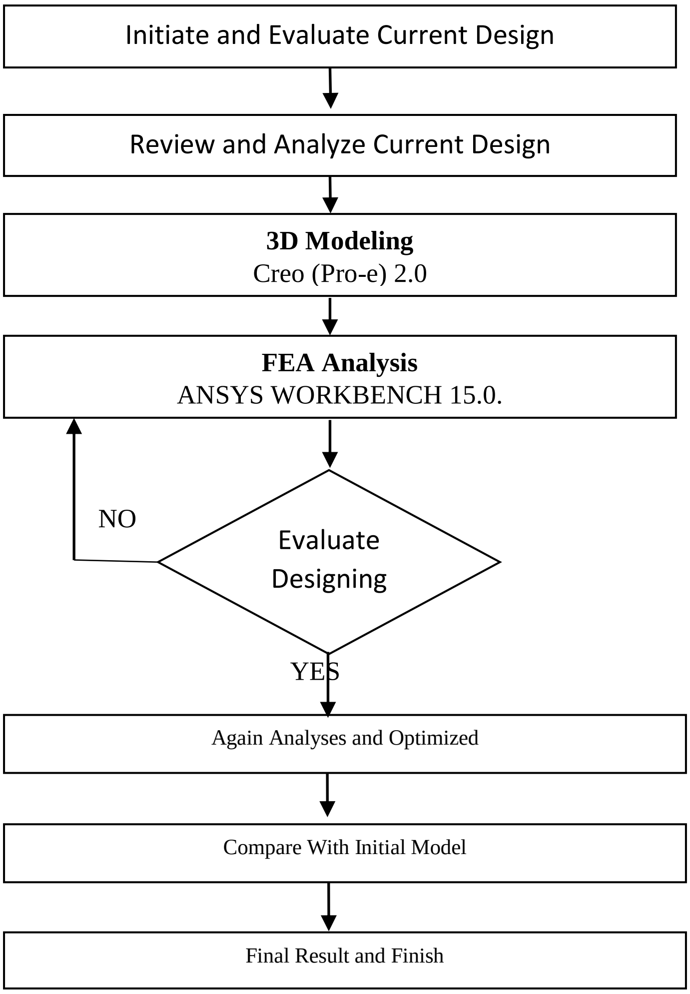

Fig.2 Design Methodology Process Flowchart

III. DESIGN MODELING

CAD model of steering knuckle component was made in 3D modeling software Creo (Pro-E) 2.0. It consists of Stub-hole Brake Caliper mounting points, Steering tie-rod mounting, Suspension upper arm mounting and Suspension lower arm mounting. Steering knuckle component design mainly depends on suspension system geometry and steering geometry. The design processes were started with preliminary study on the current steering knuckle component used for the previous including investigating the existing knuckle design especially from the published design of Formula Society of Automotive Engineering (SAE)[4]. The design also needs to follow the criteria and regulations, which the size should be mainly depends on suspension system. The previous steering knuckle was made by Mild Steel (yield strength 250*MPa*) and the mass is about 3.7*kg*. And Forge Steel which is suggested material which yield strength is 350*MPa*.In general, a steering knuckle has three connections on the body part; connection to the tie rod, suspension upper arm and suspension lower arm. Therefore the design needs to be stressed on these three connections, as well as one side of connectors where brake caliper mounting is attached.

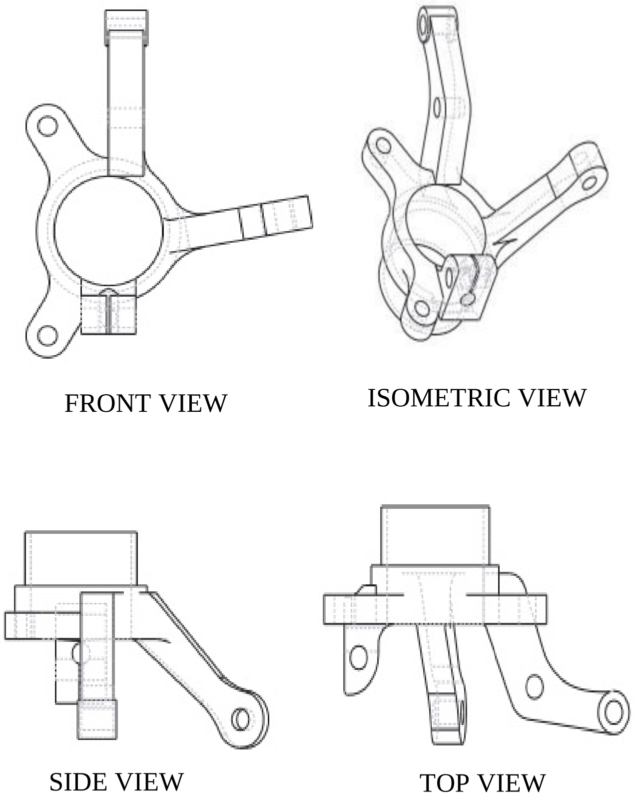

Fig. 3 Projection View of Design Modeling

IV. DESIGN OF STEERING KNUCKLE

(A) Calculation of Load

i). Axial Loads

There are two axial load acting on the steering knuckle such as tensile load and compressive load[5]. The stress due to this load can be findout using the following formula,

$$\text{Tensile Load } (P_t) = \text{Tensile stress} \times \text{Area}$$

$$\text{Compressive Load } (P_c) = \text{Compressive stress} \times \text{Area}$$

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ii). Inertia Load

This load act on Steering Knuckle due to the inertia of the moving parts[5] .The inertia load can be find out using the following formula,

$$\text{Inertia Load } (F_a) = \omega^2 R\left[\cos\theta + \frac{R}{L}\cos(2\theta)\right]$$

iii). Bending Load

This load acts on the steering knuckle due to the weight of the vehicle and this tends to bend the steering knuckle outward away from the centerline [5].Total inertia bending load is given by,

$$\text{Bending Load } (F_b) = \frac{\rho A_t L \sin(\theta+\emptyset)}{2} N$$

(B) Calculation of Stresses

i). Stress Due to Axial Loads

The force of resistance per unit area, offered by a body against deformation is known as stress.
This is given by,

$$\text{Stress } (\sigma) = \frac{P}{A}$$

ii). Stress due to Inertia bending force

Inertia bending load sets up a stress which would be tensile on one side of the knuckle and compressive on another side and that these stress change sign each half revolution [5].The bending moment at any section 'X' *m* from the small end is given by,

$$M = \frac{x}{a}\left[1 - \frac{x^2}{L^2}\right]$$

The Stress is calculated by,

$$\sigma_b = \frac{M}{Z}$$

$$M = \frac{I}{2.5 \times t}$$

$$I = 419 \times t^4$$

(C) LoadingCondition on Knuckle

For the calculation of load acting on steering knuckle component, the required loading condition which are follows:

LOADING CONDITION	
Braking Force	1.5*mg*
Lateral Force	1.5*mg*
Steering Force	45-50*N*
Force on knuckle hub in X- axis	3*mg*
Force on knuckle hub in Y- axis	3*mg*
Force on knuckle hub in Z- axis	1*mg*

Table 1.Loading Condition on Steering Knuckle

If the knuckle is design for the vehicle of 1240*kg* weight .Thus braking force acting on it produced moment. This calculated as,

Braking force = 1.5*mg*

= 1.5×310×9.81

= 4561.65 *N*

For calculation braking force acting on one wheel i.e.1240/4=310*kg* for one wheel and perpendicular distance is 94*mm*considered.

Moment = Braking force × perpendicular distance

= 4561.65×94

= 428795.1 *N-mm* (for one wheel)

This moment is acting on steering knuckle where breakcaliper is mounted [6].Since all loads act in X, Y and Z direction are perpendicular to each other as shown in fig 3.

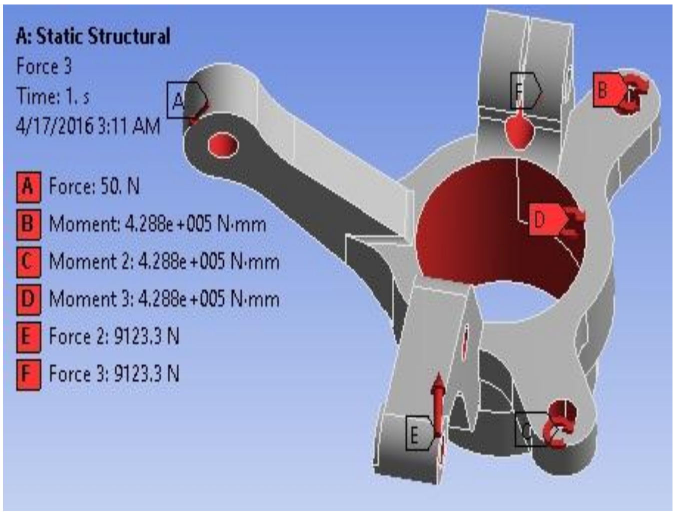

Fig 4. Direction of Forces and Moments

Thus the resultant force is given by,

$$F = \sqrt{X^2 + Y^2 + Z^2}$$

X=Y=3mg =3×310×9.81= 9123.3 *N*

Z=1mg = 1×310×9.81= 3441.1 *N*

$$F = \sqrt{(9123.3)^2 + (9123.3)^2 + (3041.1)^2}$$

F = 13255.84 *N*

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V. MATERIAL SELECTION

The steering knuckle is made by different type of materials such as Cast iron, Mild steel and Aluminum. Cast Iron and Mild steel have a good strength but it contributes more weight to the vehicle. Forged steels are the most demanding materials for the steering knuckle in future. Due to the low weight of the materials fuel consumption can be stretch to the optimum level [1]. In this paper Forge steel EN 47 is used as it offers a better strength and lightweight for the steering knuckle component. Forge Steel materials are generally used where high tensile strength and toughness is required thus the Forge Steel EN 47 materials are suited for the steering knuckle component. Due to this low weight of materials, it can decrease the fuel consumption and it have low density and sufficient yield strength. The mechanical physical and chemical properties of Forge Steel materials are given below:

PHYSICAL PROPERTIES		
QUANTITY	VALUE	UNIT
Density	7.7	*g/cm^3*
MECHANICAL PROPERTIES		
QUANTITY	VALUE	UNIT
Tensile strength, Ultimate	650	*Pa*
Tensile Strength, yield	350	*Pa*
Young's Modulus	200	*GPa*
Poisson Ratio	0.3	—

Table 2. Mechanical And Physical properties of Forge SteelEN 47

ELEMENT	% WIEGHT
Carbon, C	0.45- 0.55
Manganese, Mn	0.50 – 0.80
Silicon, Si	0.05 Max
Chromium, Cr	0.80 – 1.20
Sulphur, S	0.05 Max
Phosphorous, P	0.05 Max

Table 3. Chemical Composition of Forge Steel EN 47

VI. MESHING THE COMPONENT

CAD Model of steering knuckle component is produced in 3D modeling software such as Creo (Pro-E) 2.0. This CAD model is imported into an ANSYS WORKBENCH 15.0. In this, it is not necessary to set a mesh control because these have default mesh control. There are we can used smart mesh control to produce the fine mesh generation.

NODES	5384
ELEMENTS	2705

Table 4. Nodes and Elements of Model

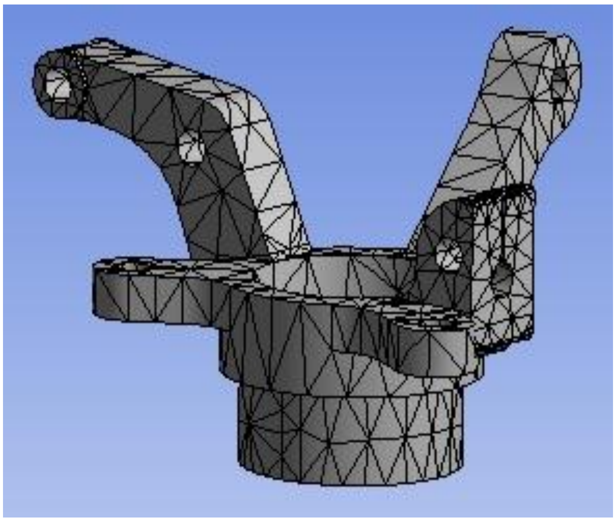

Fig. 5. Meshing Model

VII. ANALYSIS

The analysis of steering knuckle component is done in ANSYS Workbench 15.0. The required load of steering knuckle component was determine from various research paper. According to papers we assume average weight of vehicles is 1240 *kg*. The weight are directly acted on all the four knuckle. Thus the weight of vehicles acted on one wheel is 310 *kg*. Thus the average weight of vehicles acted on each wheel is $310 \times 9.81 = 3041.1$ *N*. There are various force act on this such as braking force, moment, lateral force, steering force as well as loads on knuckle hub in X, Y and Z-direction. The various analysis results are shown in figures which are given below:

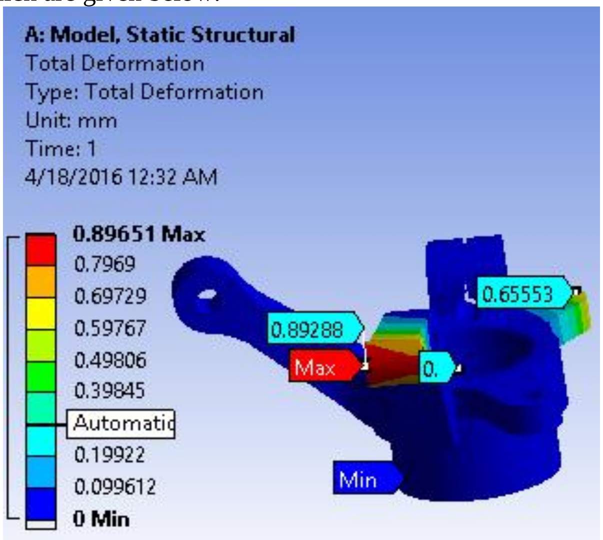

Fig. 6. Total Deformation (Forge Steel EN 47)

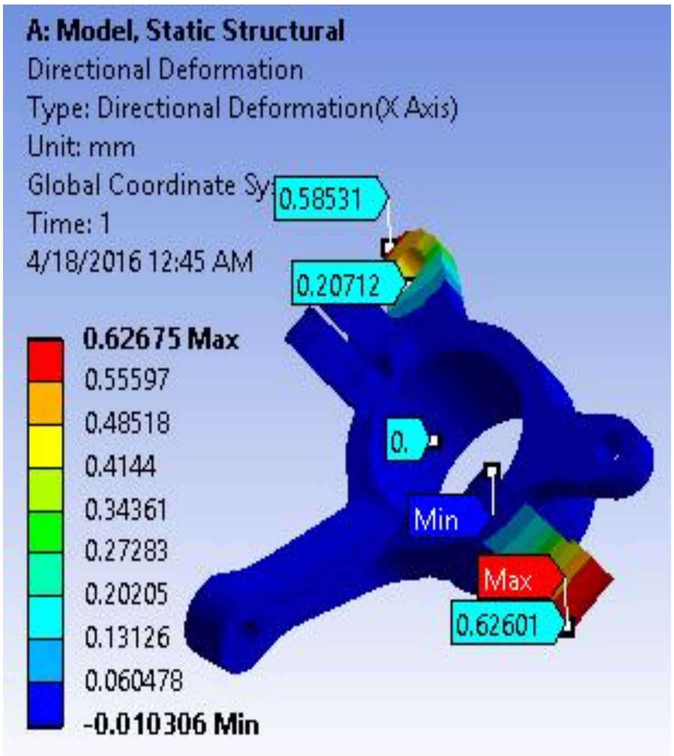

Fig. 7 Directional Deformation (Forge Steel EN 47)

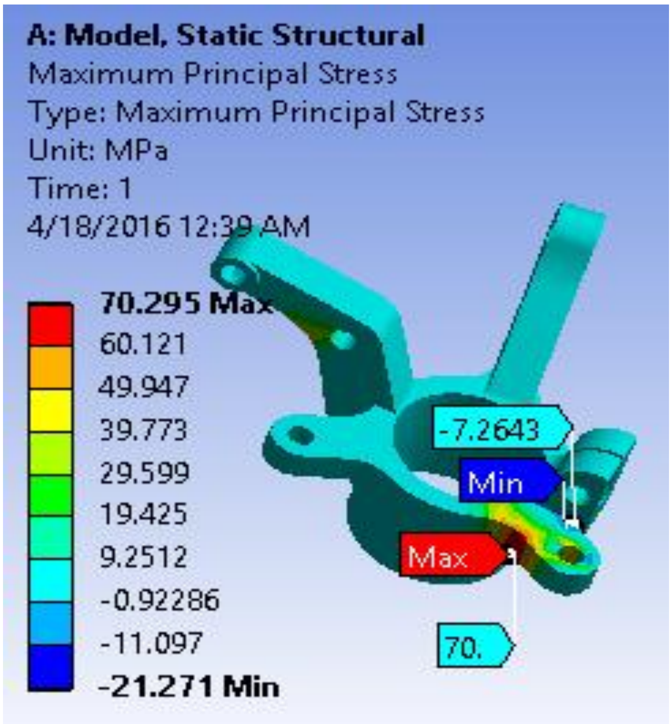

Fig. 9Maximum Principal Stress (Forge Steel EN 47)

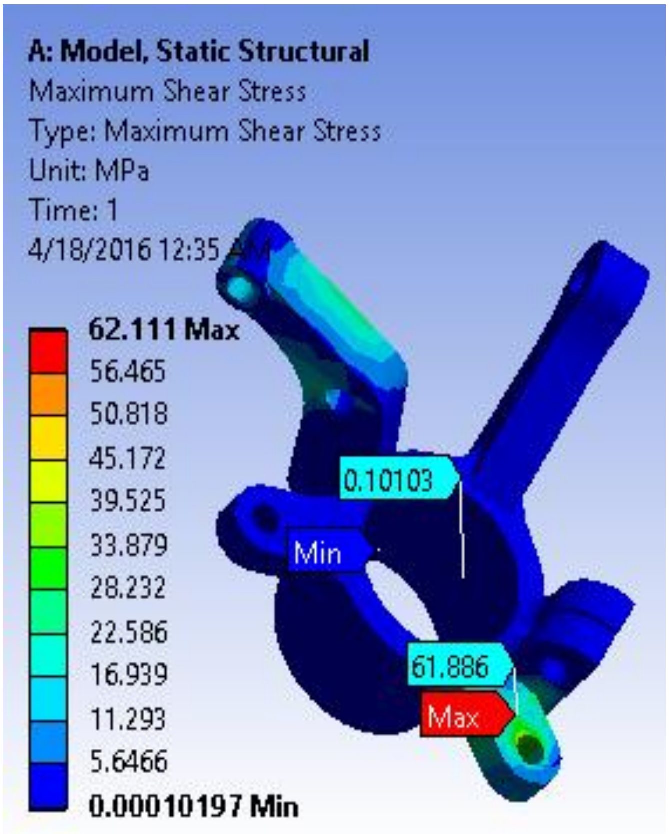

Fig. 8Maximum Shear Stress (Forge Steel EN 47)

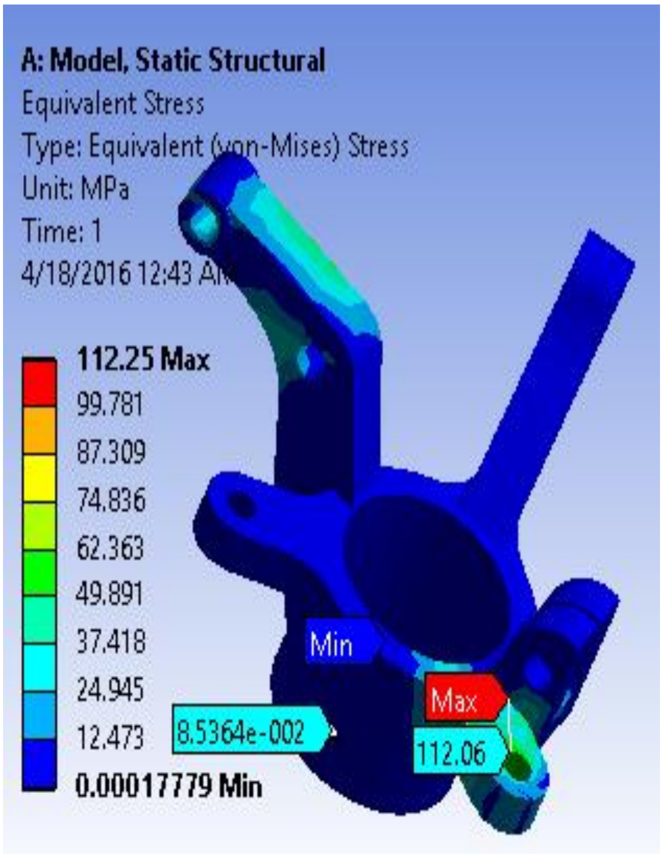

Fig. 10 Equivalent "Von-Mises" Stress (Forge Steel EN 47)

International Journal of Engineering Research & Technology (IJERT)
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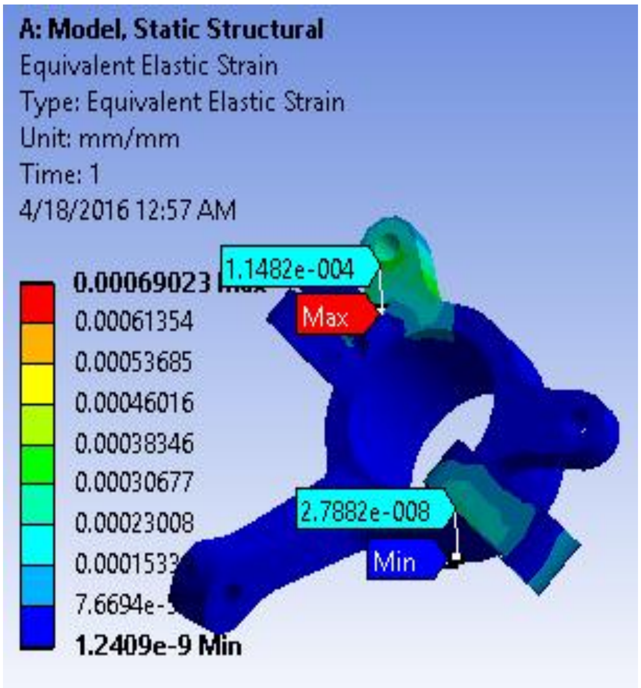

Fig.11 Equivalent Elastic Strain (Forge Steel EN 47)

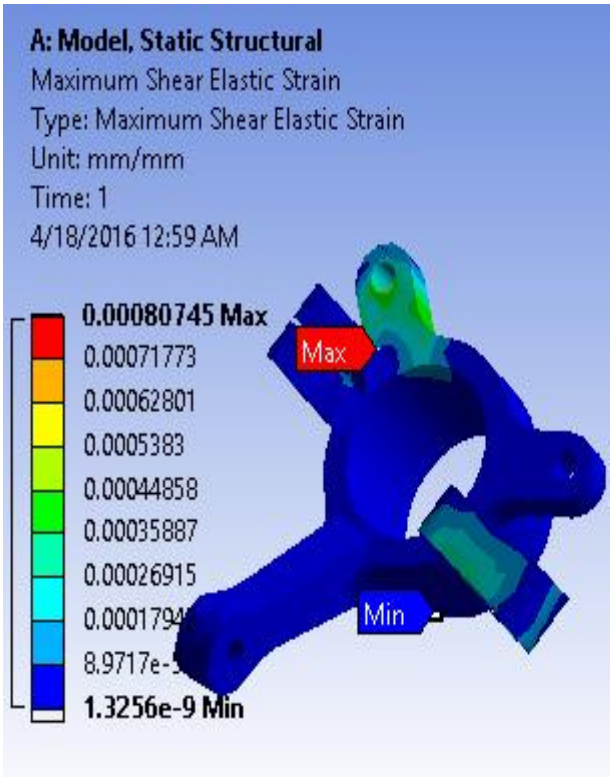

Fig.12 Equivalent Shear Elastic Strain (Forge Steel EN 47)

VIII. RESULT

Previous model of steering knuckle components which has made of Mild Steelwhich has max yield strength 250. *MPa*and mass is about 3.72*kg* And Forge Steel EN 47 have Max yield strength 650 *MPa* and mass is about 3.51*kg*. The mass reduction for the steering knuckle component was found 5.64%, compare to mild steel which are currently used.The optimized value of result is shown in Table 5.

Parameter	Initial Material(Mild Steel)	Final Material(Forge Steel EN47)
Total Deformation	0.854*mm*	0.626*mm*
Directional Deformation	0.595*mm*	0.896*mm*
Maximum Stress (Von-Mises)	109.34*MPa*	112.25*MPa*
Maximum shear stress	60.347 *MPa*	62.11 *MPa*
Maximum Principal Stress	70.111 *MPa*	70.295 *MPa*
MASS		
Initial Material(Mild Steel)	Final Material(Forge Steel EN47)	% Reduction
3.72*kg*	3.51*kg*	5.64 %

Table 5. Analysis Result of Knuckle Component

IX. CONCLUSION

The steering knuckle component has been modelled using Creo (Pro-E) 2.0 and analyzed using ANSYS WORKBENCH15.0. The various parameters such as total deformation, directional deformation, Maximum principal stress, And Maximum Shear Stressare completely analyzed. This paper represent that the areas where the stress concentration is maximum due to the applied load. The study of steering knuckle component gives the small change in directional deformation and reduced the overall weight of vehicles due to decrease in weight of steering knuckle component as well as save the materials and cost and improved the vehicles performance and fuel economy.

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