STRUCTURAL ANALYSIS OF STEERING KNUCKLE

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***Abstract*: The steering knuckle most important part of vehicle which connect to front wheel with the help of suspension system, wheel hub and connecting steering system and chassis. Over all concept of my project is light weight reduction ratio in main reason. When using Mild steel, and Mild steel addition of Nickel to compare the weight and structural strength. Due to its large volume production its optimization of the steering knuckle for its weight or volume will result in large-scale savings. To apply loading on steering knuckle due to longitudinal reaction and vertical reaction and weight of vehicle and steering reaction. The design of the steering knuckle model prepare in CREO 2.0 and the static analysis is done in ANSYS WORKBENCH 15.0 consider the reaction .This result is verifying by compare with calculation. Consider these result model is modified.**

Index terms: Mild steel, and Mild steel addition of Nickel, weight or volume will result in large-scale savings.

1. INTRODUCTION

The steering knuckle is the connection between the tie rod, stub axle and axle housing. Steering knuckle is connected to the axle housing by using king pin. Another end is connected to the tie rod. Then the wheel hub is fixed over the knuckle using a bearing. Steering Knuckle is vehicle which links suspension, steering system, wheel hub and brake to the chassis. It undergoes varying loads subjected to different conditions, while not affecting vehicle steering performance and other desired vehicle characteristics. The function of the steering knuckle is to convert linear motion of the tie rod into angular motion of the stub axle. The lighter steering knuckle resulting greater power and less the vibration because of the inertia is less. The steering knuckle carries the power thrust from tie rod to the stub axle and hence it must be very strong, rigid and also as light as Possible. In the case of automobile vehicle, during steering and turning the steering knuckle is subjected to compressive and tension loads and due to the wheel rotation it is also subjected to torsional load. The knuckle is important component that delivers all the forces generated at the Tier to the chassis by means of the suspension system. The design of the knuckle is usually done considering the various forces acting on it which involves all the forces generated by the road reaction on the wheel when the vehicle is in motion. The design also includes various constraints that are related to the knuckle such as brake system, steering system, drive train and suspension system .Steering knuckle for automobile applications is typically manufactured either by forging or from casting. However, castings could have blow-holes which are detrimental from durability and fatigue points of view. The fact that forgings produce blow-hole-free and better parts gives them an advantage over cast parts. Due to its large volume production, it is only logical that optimization of the steering knuckle for its weight or volume will result in large-scale savings. It can also achieve the objective of reducing the weight of the vehicle component, thus reducing inertia loads, reducing vehicle weight and improving mass production in auto part industry.
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.

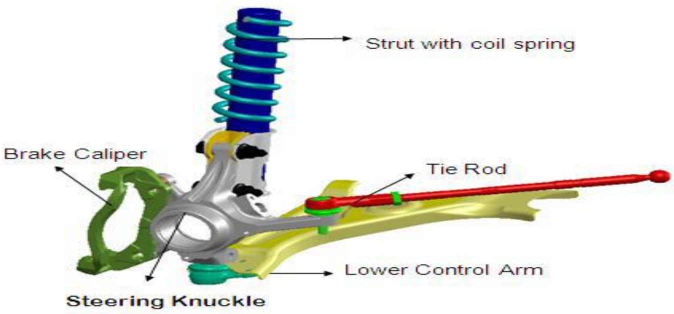


Fig no: 01 Steering knuckle assemble

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 knuckle steering mechanism of a car free to revolve on a on single axis. The knuckle is vital component that delivers all the forces generated at the Tier to the chassis by means of the suspension system. The design of the knuckle is usually done considering the various forces acting on it which involves all the forces generated by the road reaction on the wheel when the vehicle is in motion. Weight reduction is becoming important issue in car manufacturing industry. Weight reduction will give substantial impact to fuel efficiency, efforts to reduce emissions and therefore, save environment. Weight can be reduced through several types of technological improvements, such as advances in materials, design and analysis methods, fabrication processes and optimization techniques, etc.

2. LITERATURE REVIEW

A workshop report published by an agency of the United States government (Feb2013) focused on the development in light weighting and the technology gap for light duty vehicle. Also the set the goal for weight of vehicle for year 2020 to 2050.The target for reduction of weight of LDV chassis and suspension system is 25% by the year2020.

Prof.R. L. Jhala et. al. (2009) assesses fatigue life and compares fatigue performance of steering knuckles made from three materials of different manufacturing processes. These include forged steel, cast aluminum, and cast iron knuckles. Finite element models of the steering knuckles were also analyzed to obtain stress distributions in each component. Based on the results of component testing and finite element analysis, fatigue behaviors 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 (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.

Rajkumar Roy et. al. (2008) focus 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.

Purushottam Dumbre et al.in his paper "Structural Analysis of steering Knuckle for Weight Reduction" used steering knuckle for study. Weight reduction of steering knuckle is the objective of this exercise for optimization. Typically, the finite element software like OptiStruct (Hyper Works) is utilized to achieve this purpose. The targeted weight or mass reduction for this exercise is about 5% without compromising on the structural strength. Topology optimization can be used to reduce the weight of existing knuckle component by 11% while meeting the strength requirement, with limited design space given with or without change in material properties.

3. MECHANICAL TESTING

3.1 LIST OF TEST CONDUCTED

1. Tensile test
2. Impact test
3. Hardness test

3.2 ROCK WELL HARDNESS TEST:

Table no: 01 MILD STEEL

SPECIMAN	APPLIED LOAD	ROCKWELL HARDNESS NUMBER			MEAN
		TRIAL A	TRIAL B	TRIAL C	
MS steel	150	101	104	101	102HRC
Mild steel & nickel	150	110	132	146	129.33

Mild steel =102HRC
Mild steel & nickel =129.33HRC

Table no: 02 : MILD STEEL AND MILD STEEL & NICKEL

TESTS	MILD STEEL	MILD STEEL &NICKEL
Brinell Hardness Test	26.21 BHN	25.90 BHN
Izod Impact Test	1.22 J/mm²	3.83 J/mm²
Charpy Test	1.35 J/mm²	4.18 J/mm²

Table no: 03 Tensile test

Material	Yield point (KN)	Yield stress (N/mm²)	Ultimate Point (KN)	Ultimate stress (N/mm²)	Breaking Point (KN)	% of Area	Strain	Young's module (E)
Mild steel	17	216.56	19.8	252.20	25	52.75	0.145	5277.23
Mild steel &Nickel	20	254.6	28	356.55	34	64	0.113	11860.7

4. MATERIAL TREATMENT

4.1Heat treatment on Mild steel

The heat treatment includes heating and cooling operations or the sequence of two or more such operations applied to any material in order to modify its metallurgical structure and alter its physical, mechanical and chemical properties. Usually it consists of heating the material to some specific temperature, holding at this temperature for a definite period and cooling to room temperature or below with a definite rate. Annealing, Normalizing, Hardening and Tempering are the four widely used heat treatment processes that affect the structure and properties, and are assigned to meet the specific requirements from the semi-fabricated and finished components. Steels being the most widely used materials in major engineering fabrications undergo various heat treatment cycles depending on the requirements. Also aluminum and nickel alloys are exposed to heat treatment for enhancement of properties.

4.1.1Annealing

Annealing refers to a wide group of heat treatment processes and is performed primarily for homogenization, recrystallization or relief of residual stress in typical cold worked or welded components. Depending upon the temperature conditions under which it is performed, annealing eliminates chemical or physical non-homogeneity produced of phase transformations.

Types of annealing

1. full annealing
2. Isothermal annealing
3. Spheroidise annealing
4. Recrystallization annealing
5. Stress relief annealing.

Full annealing (conventional annealing)

Full annealing process consists of three steps. First step is heating the steel component to above (upper critical temperature for ferrite) temperature for hypoeutectoid steels and above (lower critical temperature) temperature for hypereutectoid steels by 30-50^{0}C. The second step is holding the steel component at this temperature for a definite holding (soaking) period of at least 20 minutes per cm of the thick section to assure equalization of temperature throughout the cross-section of the component and complete austenization. Final step is to cool the hot steel component to room temperature slowly in the furnace, which is also called as furnace cooling. The full annealing is used to relieve the internal stresses induced due to cold working, welding, etc, to reduce hardness and increase ductility, to refine the grain structure, to make the material homogenous in respect of chemical composition, to increase uniformity of phase distribution, and to increase machinability.

5. PROBLEM IDENTIFICATION

It has been seen from the knuckle producers that weight lessening and propelled materials are the genuine requirement for the present vehicle industry. The steering knuckle represents most extreme measure of weight of all suspension parts, which requires high need of weight decrease. Under working condition is subjected to element powers transmitted from strut and wheel. The weight lessening of steering knuckle is done to such an extent that the quality, firmness and life cycle execution of the steering knuckle are fulfilled. Topology advancement is completed to deliver lighter, less costly and more effective steering knuckle that displays exact measurements, unnecessary machining and requires less part handling.

Because of its huge volume generation, it is just intelligent that improvement of the steering knuckle for its weight or volume will bring about substantial scale reserve funds. It can accomplish the target of decreasing the heaviness of the vehicle part, in this way lessening idleness loads, diminishing vehicle weight and enhancing vehicle execution and fuel economy. So considering car improvement and significance of relative angle, for example, fuel utilization, weight, riding quality, and taking care of, subsequently advancement of new material is vital in the vehicle industry. Mass or weight decrease is getting to be distinctly vital issue in auto fabricating industry. Weight diminishment will give significant effect to fuel efficiency, endeavors to lessen emanations and hence, spare environment. Weight can be a few sorts of mechanical changes, for example, propels in materials, outline and investigation strategies, manufacture procedures and streamlining systems, and so forth.

6. DESIGN OF STEERING KNUCKLE

CREO model of steering knuckle component was made in 3D modeling software Creo 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 also needs to follow the criteria and regulations, which the size should be mainly depends on suspension system. 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. 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.

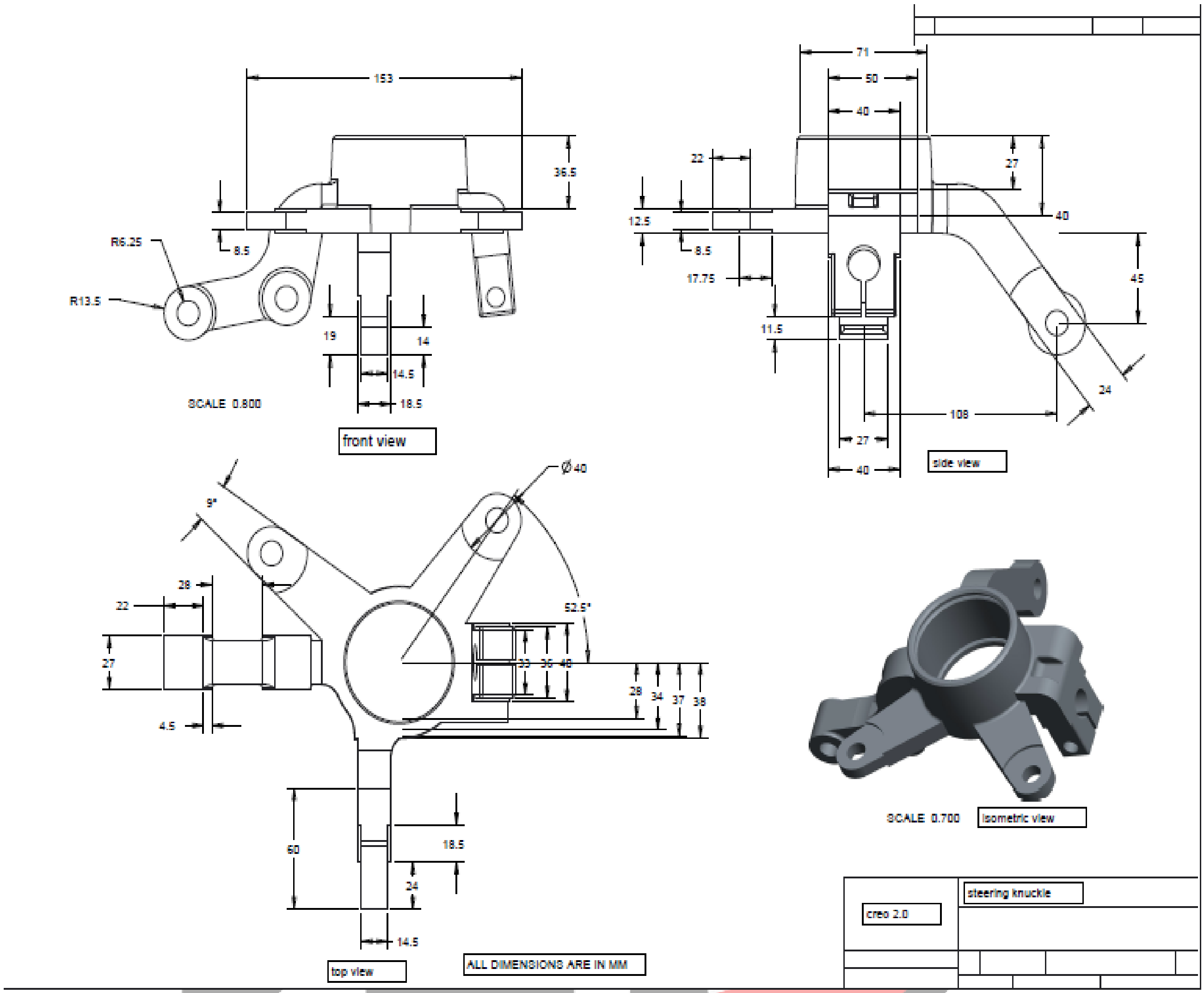


Fig no: 02 DESIGN OF STEERING KNUCKLE

7. DESIGN METHODOLOGY

7.1 ANALYTICAL EVALUATIONS

Digitizing steering knuckle geometry
Stress (FEA) Analysis
Modal Analysis

7.2 STEPS INVOLVED IN METHODOLOGY

Step 1: Modelling of steering knuckle using 3D modelling **CREO** software.
Step 2: Finite element modelling of the steering knuckle.
Step 3: Analysis of steering knuckle using **ANYSY WORKBENCH** software.
i. Element selection.
ii. Discretization
iii. Mesh generation.
Step 4: Finite element stress analysis.
Step 5: Modal analysis.

7.3 PROCEDURE FOR A STATIC ANALYSIS

1. Units

2. Model

Geometry
KNUCKLE
Coordinate Systems
Remote Points

Moment - Remote Point
Mesh
3. Static Structural
Analysis Settings
Loads
Solution
Solution Information
Results
4. Material Data
Mild steel
Mild steel & Nickel

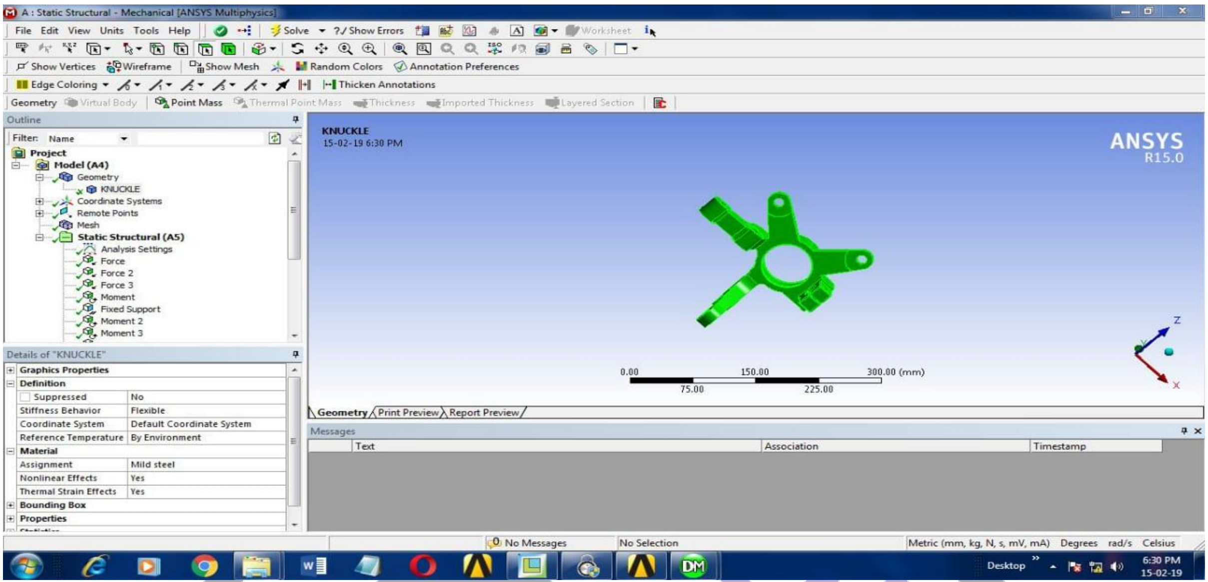


Fig no: 03 Analysis Summary

8. MESHING

CREO Model of steering knuckle component is produced in 3D modeling software such as CREO 2.0. This CREO model is imported into an ANSYSWORKBENCH 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. CREO model of knuckle converted into STEP file. This model is imported into Ansys Workbench simulation. Geometry cleanup was performed prior to meshing of model. For better quality of mesh fine element size is selected.

Table no: 04 Bounding Box

Bounding Box	
Length X	199.79 mm
Length Y	110. mm
Length Z	208.9 mm

Table no: 05 Statistics

Statistics	
Nodes	18774
Elements	10295
Mesh Metric	None

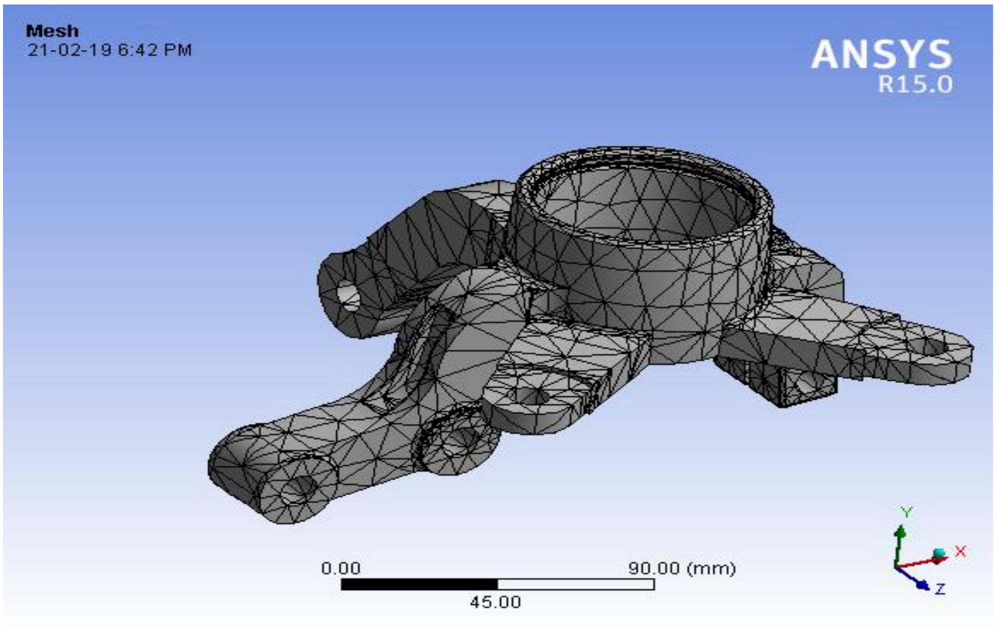


Fig: 04 Meshing

9. LOAD APPLICATION FOR STEERING KNUCKLE

9.1 LOAD CALCULATIONS ON NODES

To observe maximum stress produce into steering knuckle, model is subjected to extreme conditions and static analysis is carried out in Midas. Steering force from tie rod to steering knuckle was analytically calculated and applied to knuckle with its self-weight.

Table no: 06 loading condition

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

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

Braking force = 1.5mg = 1.5×310×9.81 = 4561.65 N

For calculation braking force acting on one wheel 1240/4=310kg for one wheel and

Perpendicular distance = 94mm (considered).

Moment = Braking force × perpendicular distance = 4561.65×94 = 422875.1 N-mm (for one wheel)

This moment is acting on steering knuckle where breakcaliper is mounted. Since all loads act in X, Y and Z direction are perpendicular to each other. Thus the resultant force is given by,

$F = \sqrt{X2 + Y2 + Z2}$

X = Y =3 mg = 3×310×9.81= 9123.3 N

Z = 1 mg = 1×310×9.81= 3441.1 N

$F = \sqrt{(9123.3)2 + (9123.3)2 + (3041.1)2}$ F = 13255.84 N.

Table: 07 Load applied on knuckle

LOAD APPLIED ON KNUCKLE		
Node	Description	Load
A	Steering Force	50 N
B	Force	9123.8 N
C	Force	9123.8 N
D	Moment	4.288e+005 N.mm
E	Fixed support	--
F	Moment	4.288e+005 N.mm
G	Moment	4.288e+005 N.mm
H	Force	9123.8 N

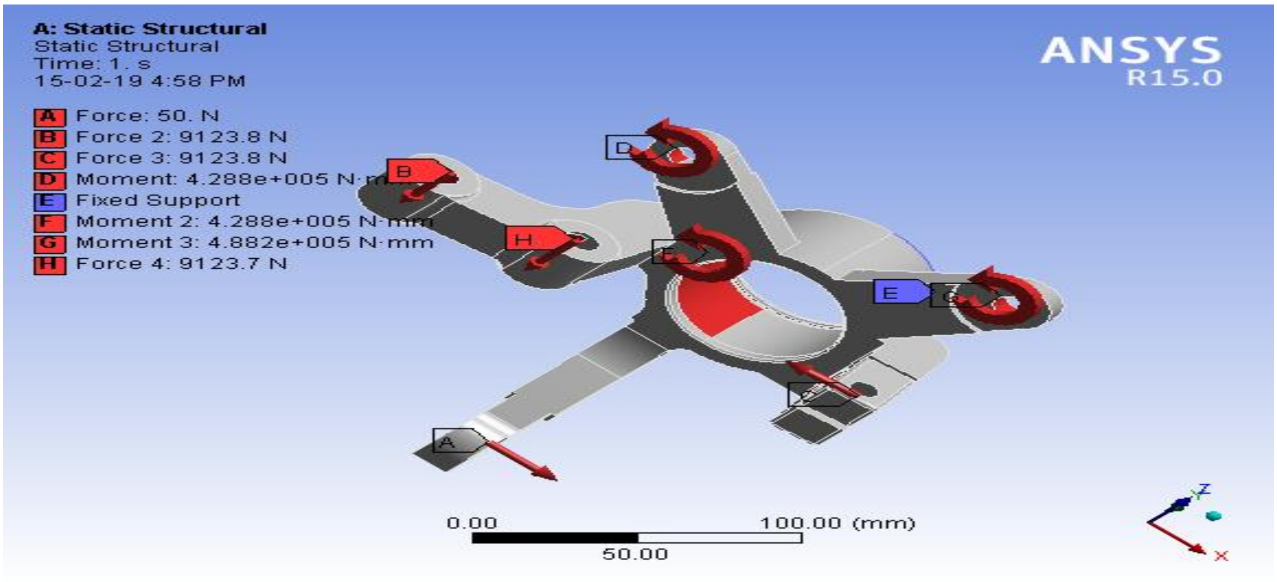


Fig no: 05 Static load acting of each node point

10. MATERIAL DATA

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. For this Ferrite ductile iron is used

In my project consideration of two material there are **Mild steel &Mild steel +nickel.**

Table no: 08 Material data

S.NO	DATA	MILD STEEL	MILD STEEL &NICKEL
1	Density	8.7421e-006 kg mm^-3	7.816 e-006 kg mm^-3
2	Coefficient of Thermal Expansion	7.2e+006 C^-1	7.2e+006 C^-1
3	Reference Temperature C	22 C	21 C
4	Young's Modulus	2.1e+005 MPa	2.1e+005 MPa
5	Poisson's Ratio	0.3	0.29
6	Bulk Modulus	1.75e+005 MPa	1.55e+005 MPa
7	Shear Modulus	80769 MPa	81769 MPa
8	Tensile Yield Strength	216.56 MPa	254.6 MPa
9	Compressive Yield Strength	135 MPa	155 MPa
10	Tensile Ultimate Strength	252 MPa	356.6 MPa

11. 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 project 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:

11.1 ANALYSIS OF MILD STEEL MATERIAL

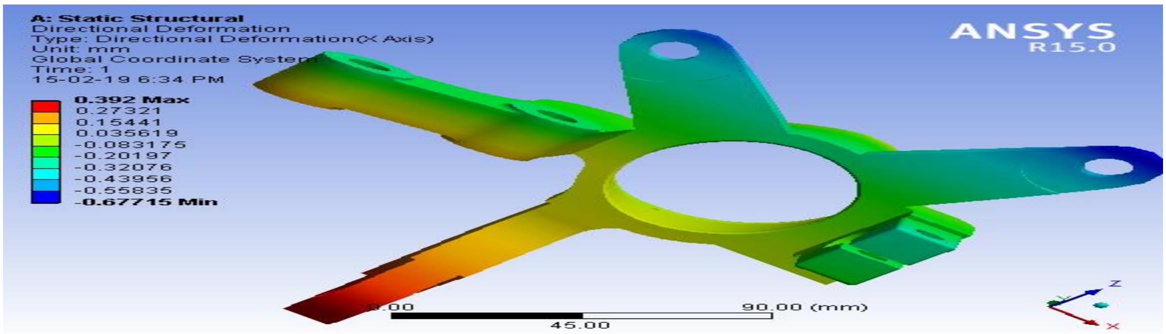


Fig no: 06 Directional Deformation of the mild steel about X axis

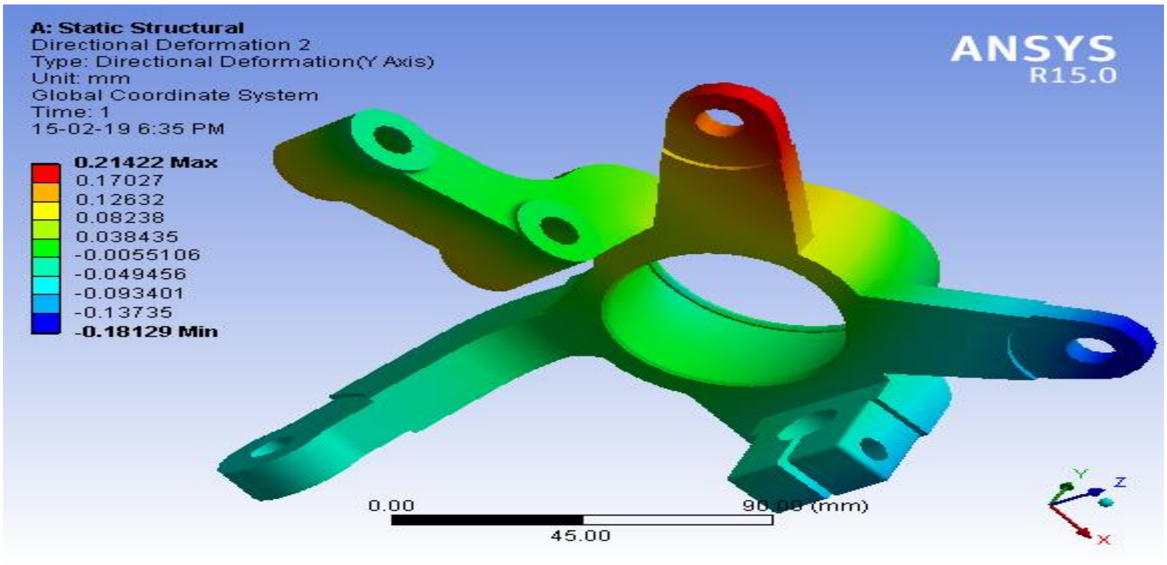


Fig no: 07 Directional Deformation of the mild steel about Y axis

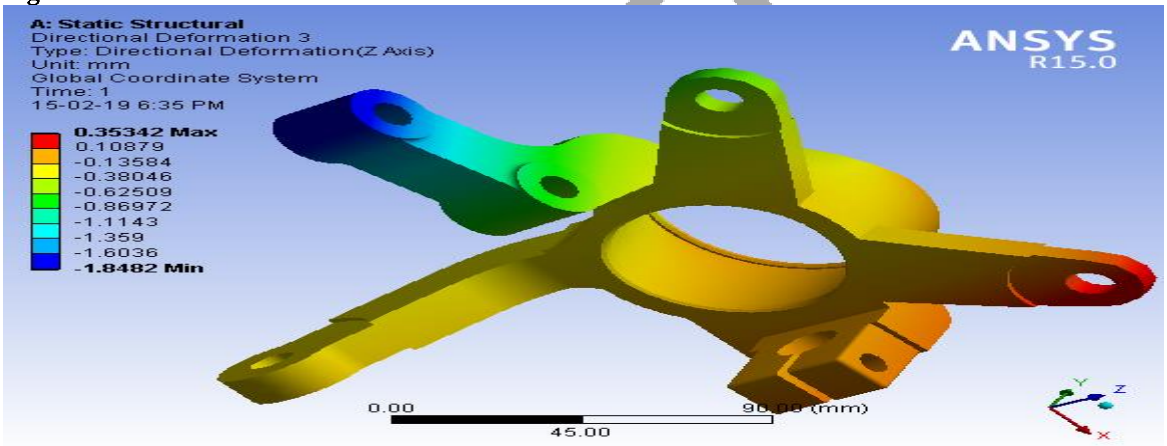


Fig no: 08 Directional Deformation of the mild steel about Z axis

In the above diagram representation of the static stress with direction al deformation about the axis -X, axis-Y, axis-Z respectively.

Table no: 09 Property

Volume	2.6759e+005 mm^3
Mass	2.3408 kg
Centroid X	-15.474 mm
Centroid Y	-1.9287 mm
Centroid Z	-7.6228 mm
Moment of Inertia Ip1	4304.7 mm^4
Moment of Inertia Ip2	8734.4 mm^4
Moment of Inertia Ip3	6131.4 mm^4

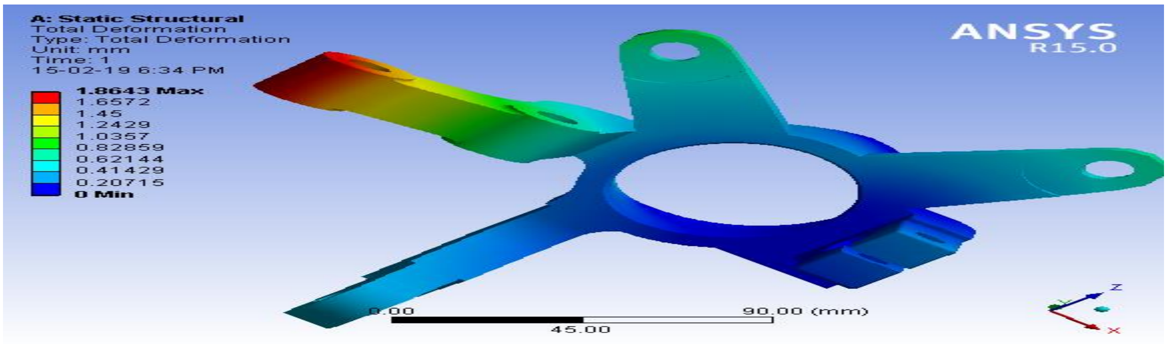


Fig no: 09 Total deformation of the steering knuckle in mild steel material

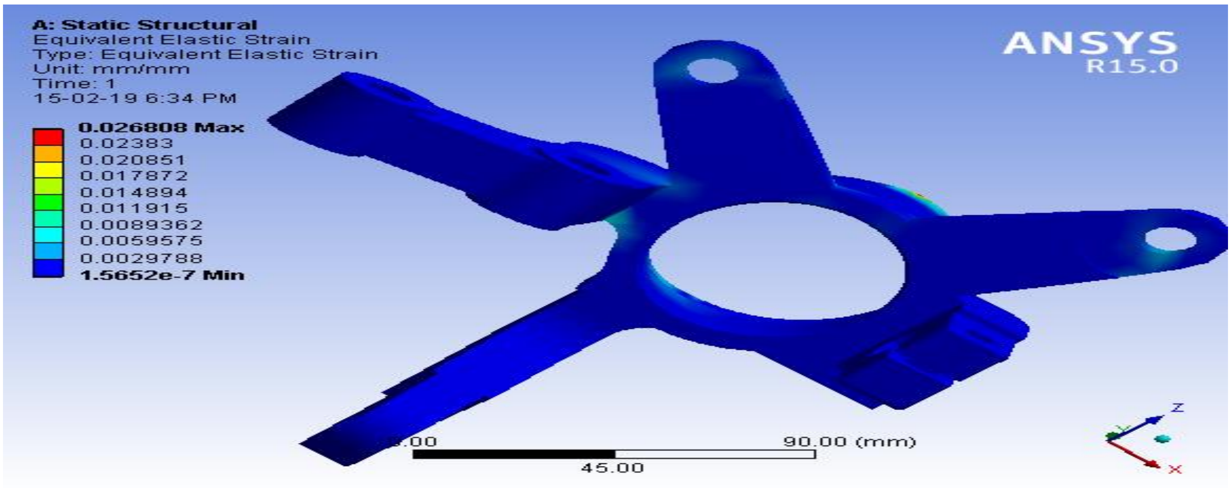


Fig no: 10 Equlvalent Elastic strain

Referring to the analysis results, the maximum stress on all the design are far below the material yield strength and very less deflection under the assigned loads.

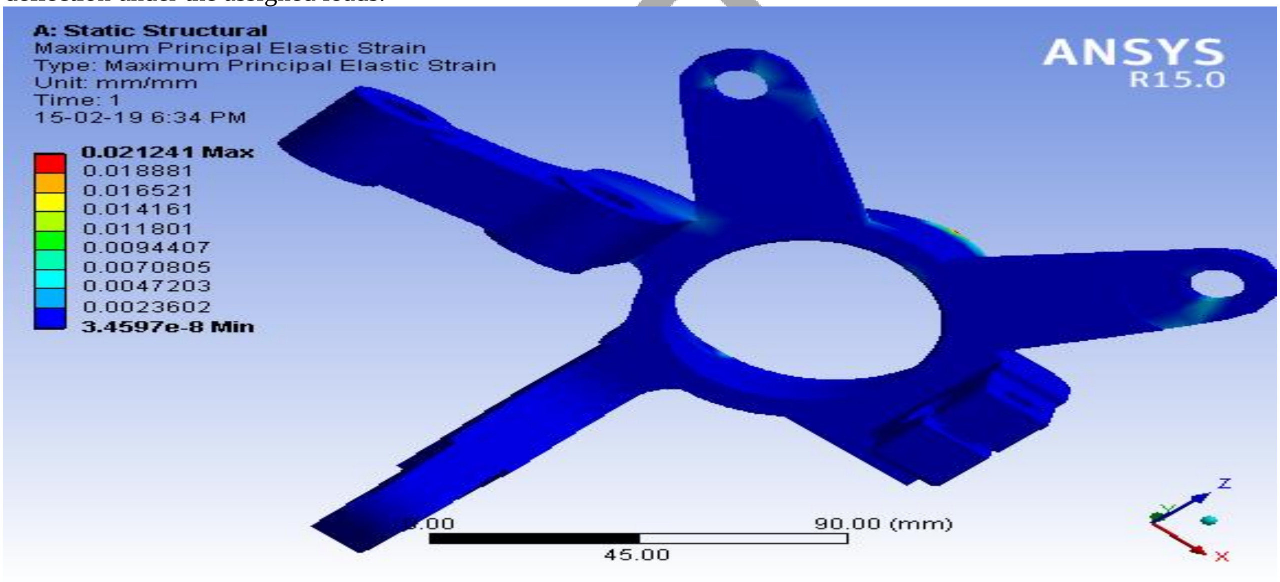


Fig no :11 Maximum Principle Elastic Strain

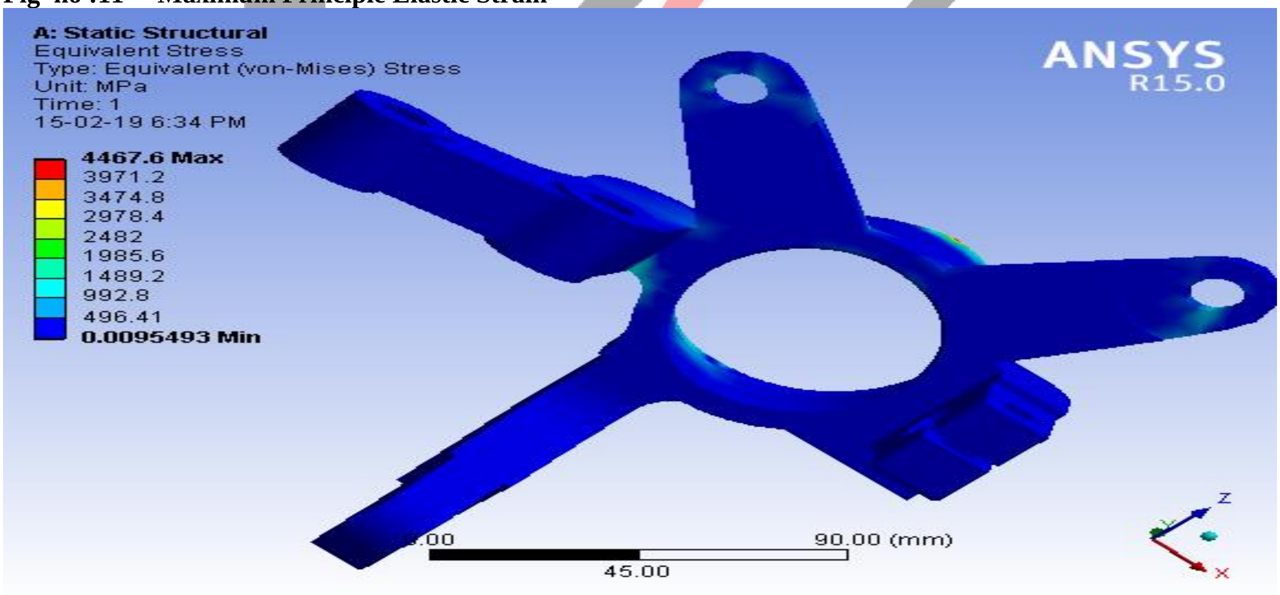


Fig no: 12 Equlvanlent (Von-Mises) stress

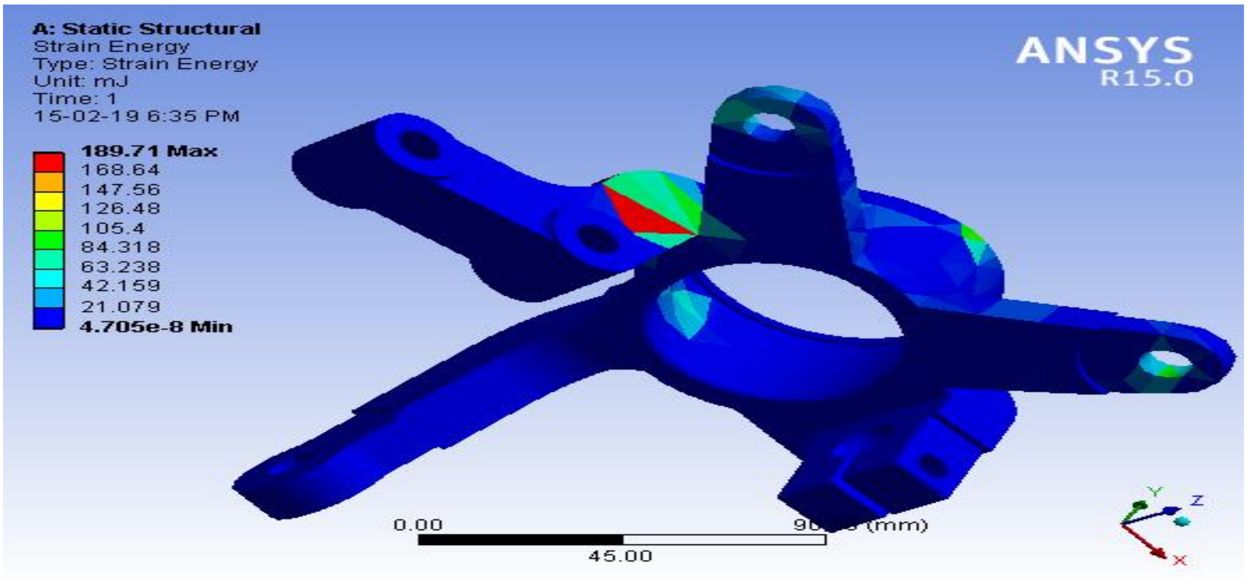


Fig no: 13 Strain Energy

11.2 ANALYSIS OF MILD STEEL & NICKEL MATERIAL

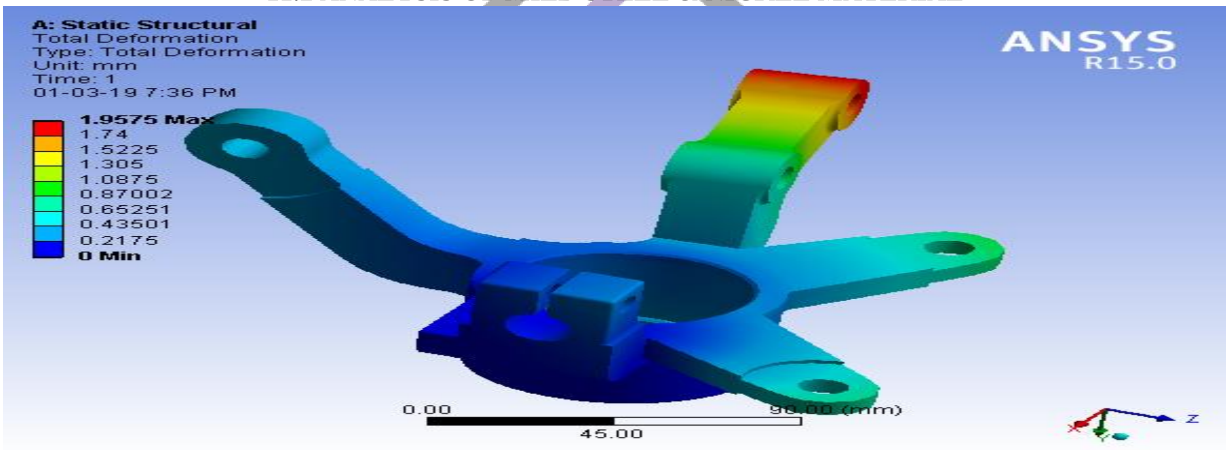


Fig no: 14 Total Deformation Mild steel & nickel Matrial

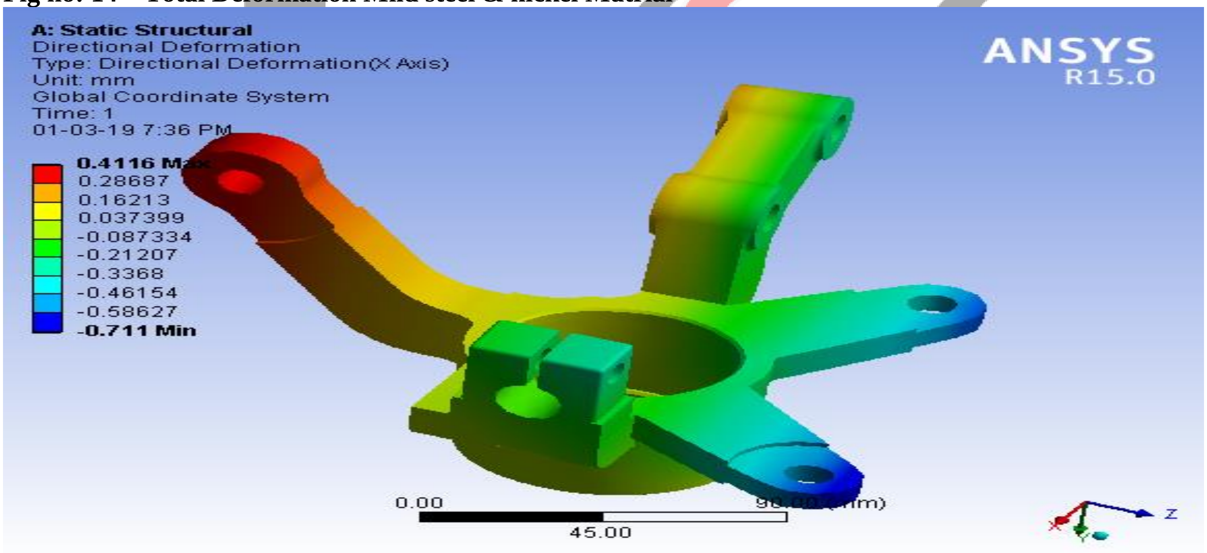


Fig no: 15 Directional Deformation of Mild steel & nickel Material about X axis

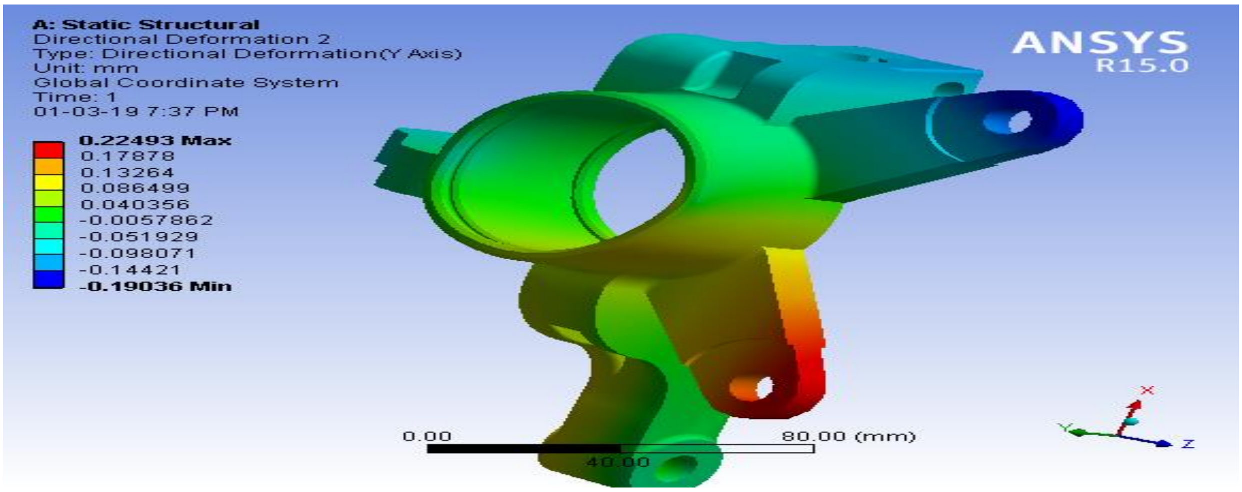


Fig no:16 Directional Deformation of Mild steel & nickel Material about Y axis

Table no: 10 Property of mild steel & nickel

Volume	2.6759e+005 mm³
Mass	2.0914 kg
Centroid X	-15.474 mm
Centroid Y	-1.9287 mm
Centroid Z	-7.6228 mm
Moment of Inertia Ip1	3942.8 mm^4
Moment of Inertia Ip2	8000 mm^4
Moment of Inertia Ip3	5615.8 mm^4

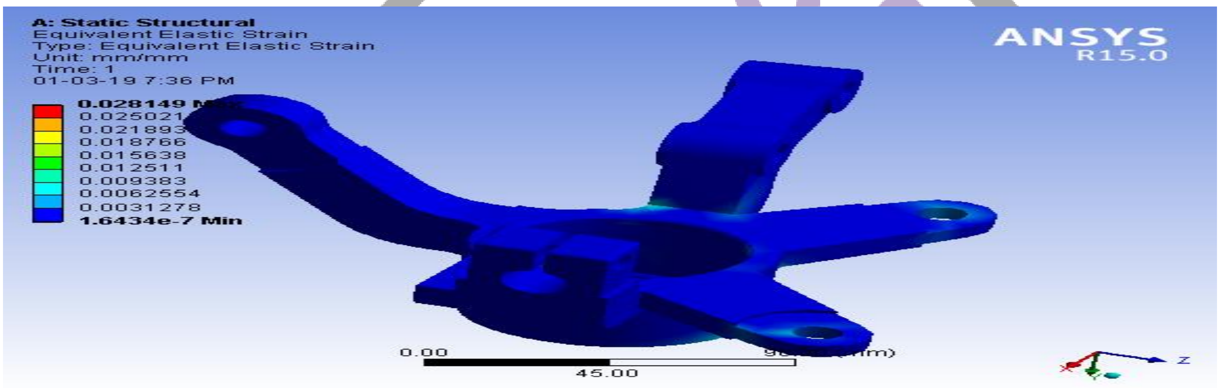


Fig no: 17 Equivalent Elastic Strain Mild steel & nickel material

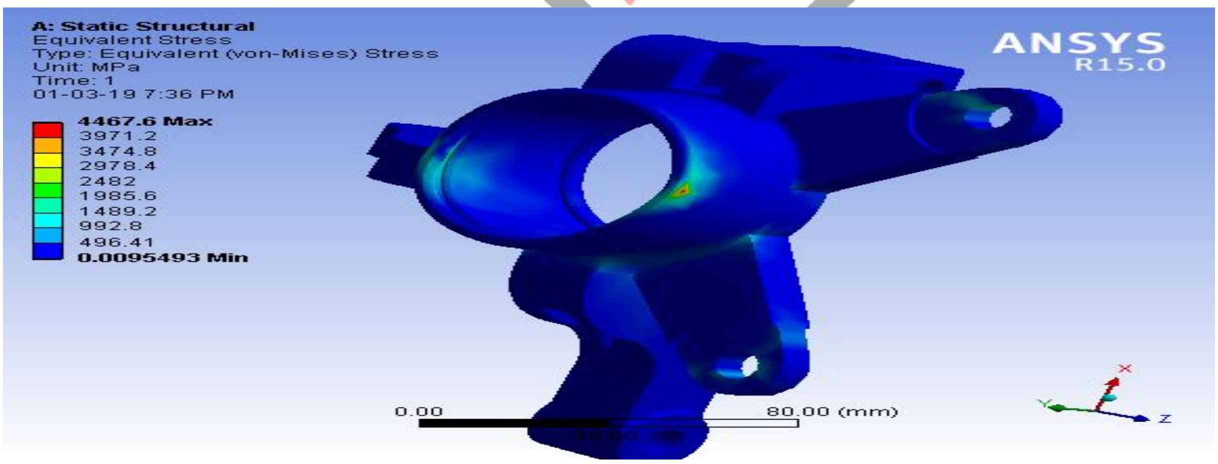


Fig no: 18 Von-Mises stress

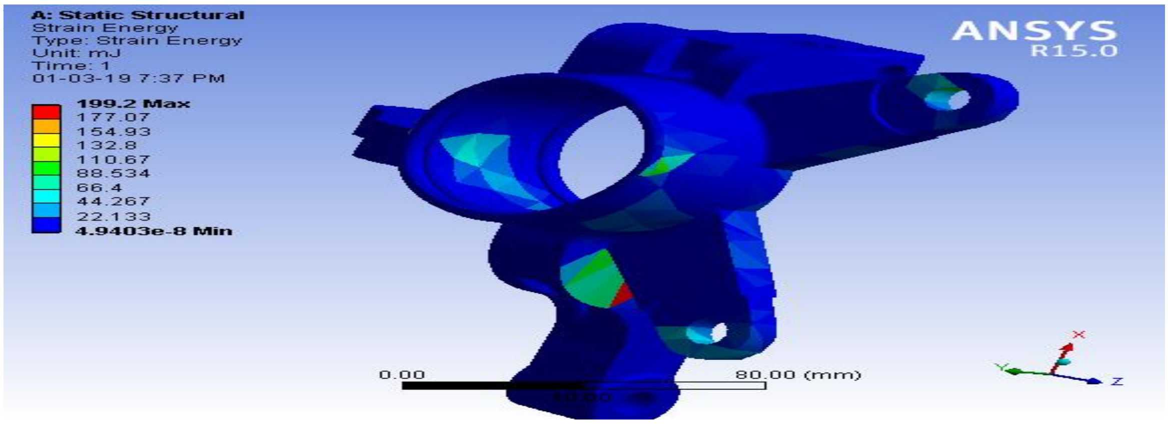


Fig no: 19 Strain Energy

12. RESULT

The following table represents the various results obtained in the base model, modified model of Mild steel and Mild steel& Nickel.

Table no: 11 Result

Parameter	**MILD STEEL**	**MILD STEEL &NICKEL**
Total Deformation	0.18643	0.19575
Directional Deformation	0.392	0.4116 mm
Von-Mises stress	4467.6 MPa	4467.6 MPa
Strain Energy	189.71 mJ	199.2 mJ
WEIGHT	2.3408 Kg	2.0914 kg

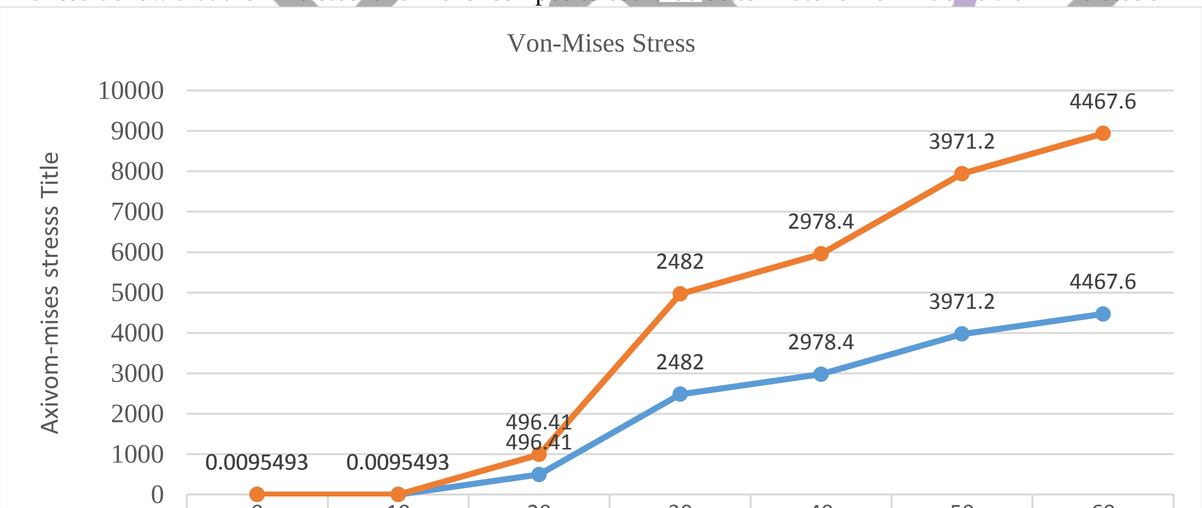
Percentage of weight reduction = **(Existing-Optimum) / Existing**

= (2.3408-2.0914) / 2.3408

=0.1065×100

Total percentage of weight reduction = 10.65 %

The result show that the mild steel and nickel composite could be better material for knuckle than mild steel.



	0	10	20	30	40	50	60
Series2	0.0095493	0.0095493	496.41	2482	2978.4	3971.2	4467.6
Series1	0.0095493	0.0095493	496.41	2482	2978.4	3971.2	4467.6

Fig no: 20 Von-Mises Stress

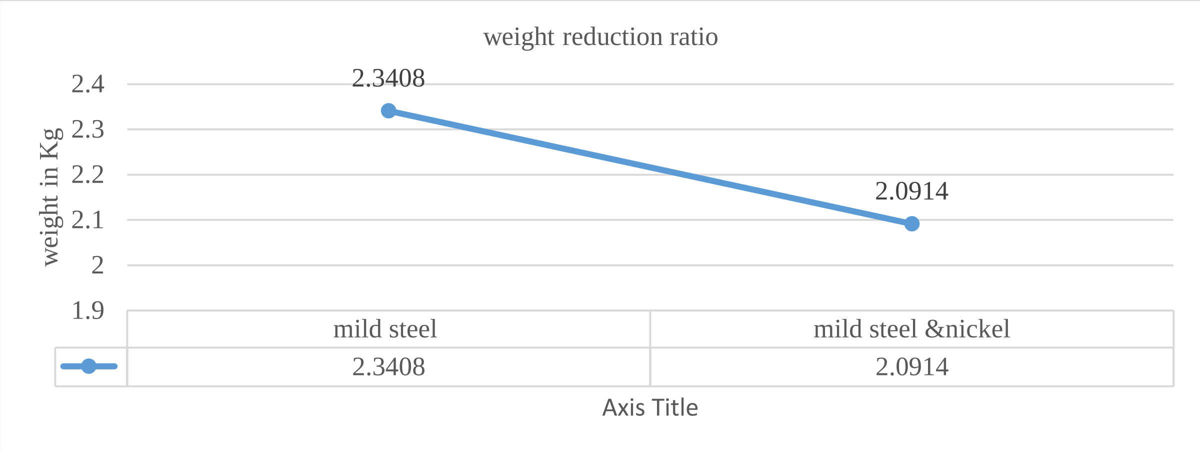


Fig no: 21 total weight reduction ratio

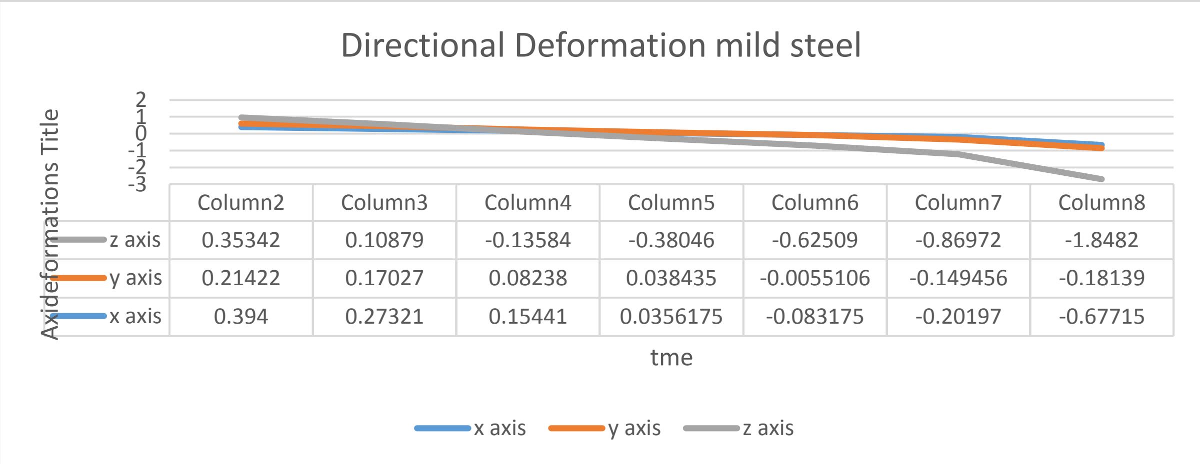


Fig no:22 Directional deformation of Mild steel

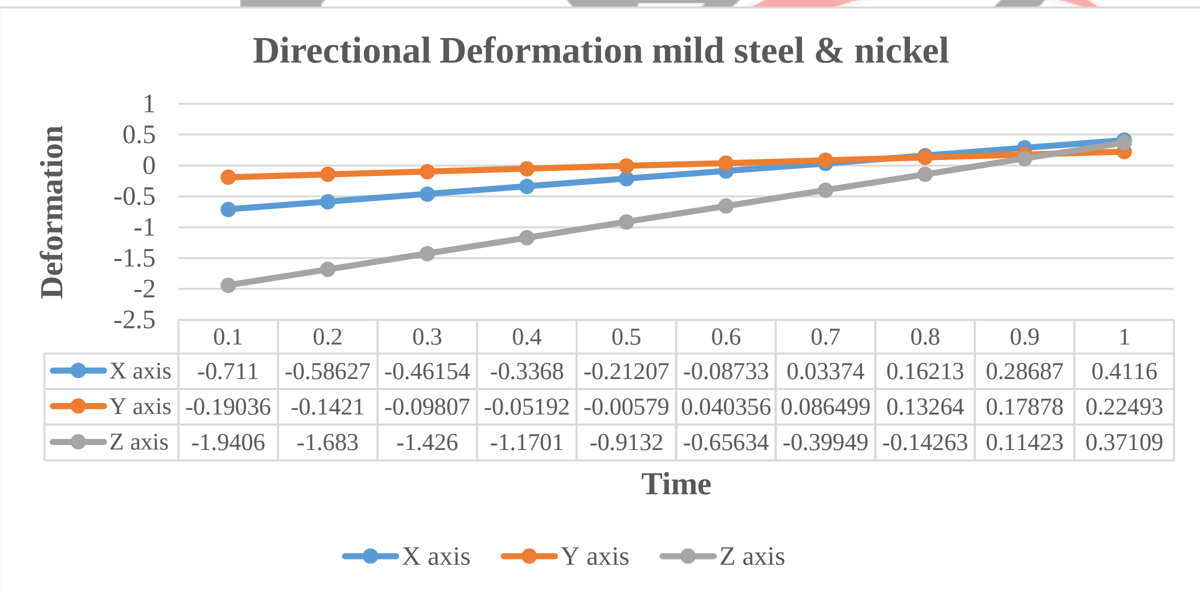
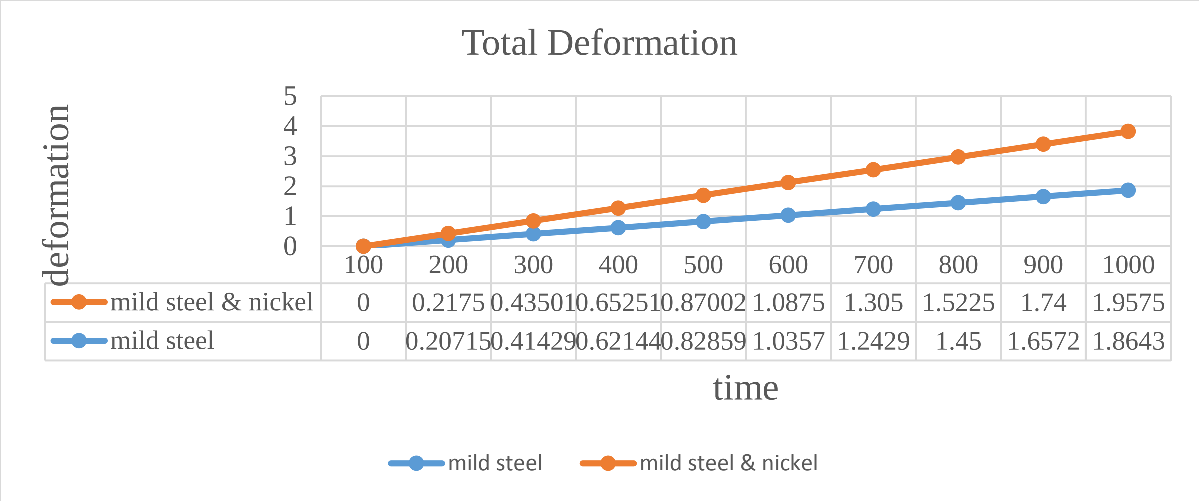


Fig no: 23 Directional defamation of Mild steel &Nickel



	100	200	300	400	500	600	700	800	900	1000
mild steel & nickel	0	0.2175	0.43501	0.65251	0.87002	1.0875	1.305	1.5225	1.74	1.9575
mild steel	0	0.20715	0.41429	0.62144	0.82859	1.0357	1.2429	1.45	1.6572	1.8643

Fig no: 24 total deformation of two materials

CONCLUSION

The steering knuckle has been modeled and analysed using ANSYS WORKBENCH 15.0. The multiaxial force acting on the suspension component was analysis for three load case. To study effect of force a ANSYS model of steering knuckle geometry was developed and analyszed two material, mild steel& nickel, cast iron .To various parameter such as total deformation, directional deformation, maximum principal stress and maximum shear stress completely analyzed. The study steering knuckle joint component give the small change in directional deformation and reduce the overall weight of the vehicle. The result show that the mild steel and nickel composite could be better material for knuckle than mild steel.

REFERENCES

1. R. d'Ippolitoa, M.Hackb, S.Dondersa, L.Hermansa, Improving the fatigue life of a vehicle knuckle with a reliability-based design optimization approach, R. d'Ippolitoa, M.Hackb, S.Dondersa, L.Hermansa, Journal of Statistical Planning and Inference 139 (2009) 1619 – 1632.
2. Reliability Based Shape Optimization of a Knuckle Component by using Sequential Linear Programming, JTH Research Report 2011:06.
3. Wan Mansor Wan Muhamad, Endra Sujatmika, Hisham Hamid, & Faris Tarlochan Design Improvement of Steering Knuckle Component Using Shape Optimization.
4. A. Fuganti and G. Cupitò, 2000, “Thixoforming of aluminium alloy for weight saving of a suspension steering knuckle”Italy, 2000.
5. R. L. Jhala, K. D. Kothari and S.S. Khandare , 2009,“Component Fatigue Behaviors And Life Predictions Of A Steering Knuckle Using Finite Element Analysis” Proceedings of the International MultiConferenceofEngineers.
7. Savaidis, G., “Analysis of Fatigue Behavior of a Vehicle Axle Steering Arm Based on Local Stresses and Strains,” Material wissenschaft und Werkstoff technik, Vol. 32, No. 4, 2001, pp. 362, 368.
8. Purushottam Dumbre, Prof A.K.Mishra, V.S.Aher, Swapnil S.Kulkarni, Structural Analysis of steering Knuckle for Weight Reduction8974April-June,2014, International Journal of Advanced Engineering Research and Studies EISSN2249/ pp. 86-86.
9. A.H. Falah, M.A. Alfares and A.H. Elkholy “Failure investigation of a tie rod end of an automobile steering system” Engineering Failure Analysis 14 (2007) 895–902
10. R. d'Ippolito, M.Hack, S.Donders, L.Hermans, N.Tzannetakis ,and D.Vandepitte “Improving the fatigue life of a vehicle knuckle with a reliability-based design optimization approach” Journal of Statistical Planning and Inference 139 (2009)1619 – 1632.
11. Seung K. Koh “Fatigue analysis of an automotive steering link” Engineering Failure Analysis 16 (2009) 914–922.
12. Savaidis, G., “Analysis of Fatigue Behavior of a Vehicle Axle Steering Arm Based on Local Stresses and Strains,” Material wissenschaft and Werkstoff technik, Vol. 32, No. 4, 2001, pp. 362, 368.