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MODELING AND STRUCTURAL ANALYSIS OF KNUCKLE STEERING USING FEM WITH DIFFERENT MATERIALS

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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 Project Main concept Over all concept of my project is light weight reduction ratio in main reason. we have done static analysis of steering knuckle. 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.

The design of Steering Knuckle component is done with the help of Computer Aided Engineering (CAE). Steering Knuckle model is prepare in catia and the static analysis and modal 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 conventional materials AL2011T3, EN24, AL 7075 T6, GREY CAST IRON, Finally concluded the suitable material for the steering knuckle compared with recently using material Based on the static results Von-misses stress, strain, deformation, strain and Modal analysis find out the total deformation at different frequencies.

I INTRODUCTION

1.1 INTRODUCTION OF KNUCKLE STEERING

In automotive suspension, a steering knuckle is that part which contains the wheel hub or spindle, and attaches to the suspension components. It is variously called a steering knuckle, spindle, upright or hub, as well. The wheel and tire assembly attach to the hub or spindle of the knuckle where the tire/wheel rotates while being held in a stable plane of motion by the knuckle/suspension assembly. The wheel assembly is attached to the knuckle at its centre point. Note the arm of the knuckle that sticks out, to which the steering mechanism attaches to turn the knuckle and wheel assembly. 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 . 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. 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.

The part of steering knuckle component is 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

1.2 WORKING PRINCIPLE OF KNUCKLE STEERING:

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.

1.3 APPILICATIONS OF STEERING KNUCKLE:

In a non-drive suspension, as shown in the first photo, the knuckle usually has a spindle onto which the brake drum or brake rotor attaches. (In this picture, the central spindle upon which the wheel assembly rides cannot be seen.) The wheel/tire assembly then attaches to the supplied lug studs, and the whole assembly rotates freely on the shaft of the spindle.

In a drive suspension, the knuckle has no spindle, but rather has a hub into which is affixed the bearings and shaft of the drive mechanism. The end of the drive mechanism would then have the necessary mounting studs for the wheel/tire and/or brake assembly. Therefore, the wheel assembly would rotate as the drive shaft (or half-shaft) dictates.

II LITERATURE REVIEW

AmeyaBhusari et al. (2015) considered steering knuckle for optimization. Weight reduction of steering knuckle is the objective of this exercise for optimization. Typically, the finite element software solidTHINK INSPIRE V9 (Solidworks) is utilized to achieve this purpose. For optimization, Nastran/Ansys/Abaqus could also be utilized.The targeted weight or mass reduction for this exercise is about 62% without compromising on the structural strength.

Viraj Rajendra Kulkarni his study focuses on optimization of steering knuckle targeting reducing weight as objective function, while not compromising with required strength, frequency and stiffness. Taking into consideration static and dynamic load conditions, structural analysis and modal analysis were performed.

Purushottam Dumbre et al performed structural analysis on steering knuckle for static condition found out the stress level generated and used topology optimization to reduce the weight by 11% while meeting the strength requirement.

Kamlesh Lalsaheb Chavan et al.(2014) in this paper, author studied the failure during sudden severe loading caused due to abuse or due to continual and repetitive usage while driving for extended timeline over the life of the component. The challenge posed for the Design Engineer is to recreate the actual conditions during the analysis phase and determine the best material or the specifications of the component that would be most suited to the given application. The current Design challenge for the Steering Knuckle Arm is to generate the most optimal configuration of the component Design for the given input conditions of loading. The Sponsoring Company is working on the soon to be launched automotive model and is expected to take this task to completion through the use of CAD (CATIA or UG) for creating the geometry and further use the CAE tools (HyperWorks/Optistruct/ or suitable) for conducting analysis for the component. The Test Report/s for the component would form a basis for verifying the results with the Analytical method of analysis. For validating the Design of the component, a good match of the corresponding readings is desired. Typically, depending on the type of Test and the application, an error margin or about 5 to 20% could be considered close towards validating the proposed

Design. Mahendra L. Shelar and H. P. Khairnar (2014) in this paper author had identified the problem of process optimizing the design using a methodology based on durability and design optimization through probabilistic models of design variables (DOE). Their study deals with creation of geometric model of steering knuckle (LUV) in solid works after that that model will be imported to NFX Nastran for finite element modeling where the meshing properties, element properties will be generated. Loads and model conditions applied to model there by generating file that file will be submitted to solver (Nastran) and linear static structural analysis will be performed. To conduct model analysis to understand the dynamic behavior of the structure and thereby followed by transient structural response analysis Tagade, P. et al. (2015) in this paper, authors aimed to a light weight and optimized design of steering knuckle is proposed to be used for an EIMARace car; a small high performance formula-style car, with suitable material selection as well as valid finite element analysis and optimization studies. First part of this study involves modeling of steering knuckles and analysis of the stresses and displacement under actual load conditions. A CAD and FEA software; Solid Works, is applied for modeling as well as for static analysis studies. Shape optimization is the second part of this study, utilizing solid Thinking software from Altair Engineering packages. As the ultimate aim of this study is to reduce mass of the existing knuckle with target to achieve low fuel consumption, selection of the best material and simple geometry are crucial. Aluminum 6061- T651 alloy (yield strength 276 MPa) was found to be the best material for the component due to the good physical and mechanical properties as well as light weight. Obtain the best use of material for the component was justified in reducing the weight of existing knuckle to 45.8% while meeting the strength requirement. The minimal weight of the steering knuckle component may contribute to the reduction of the overall weight of the race car thus may improve the fuel efficiency as well as the overall performance.

Wan Mansor Wan Muhammad et al. (2012) in this paper finite element software, HyperWorks which contains several modules is used to achieve this objective. HyperMesh was used to prepare the finite element model while HyperMorph was utilized for defining shape variables. For optimization purpose, OptiStruct was utilized. The improved design achieves 8.4% reduction of mass. Even though there are volume reduction and shape changes, maximum stress has not change significantly. This result is satisfactory considering using optimization in shape only, with limited design space given and no change in material properties. Optimization method used in this study succeeded in reducing the mass of existing knuckle component to 8.4%. Even though there are volume reduction and shape changes, maximum stress has not change significantly. This result is satisfactory considering using optimization in shape only, with limited design space given and no change in material properties. Other vehicle components, similarly, have the potential to be reduced with respect to mass using shape optimization.

III OBJECTIVE OF THE PROJECT

3.1 SCOPE OF THE PROJECT

1. Design of the knuckle steering using the catia software.
2. Perform static and modal Analysis by using the ansys software .
3. Perform the analysis using various materials.
4. Find out the stresses, deformation in static analysis and find out the deformations at different frequencies in modal anlaysis.
5. Conclude the best material for the knuckle steering.

3.2 METHODOLOGY OF THE PROJECT

Initially the study literature survey for the steering knuckle collected and then the problem statement is formed and then the initial concept of the knuckle is formed. Then the modeling of the knuckle is started by fixing the ball joints and the stub axle diameter and done with the help of catia v5 software Different models of the concepts are generated by using optimization materials concept and they are analyzed for structural analysis using Ansys. The study is on modeling a suspension system and the analysis of its Vonmisses stresses, shear stress, Total deformation, Strain involved and displacement under random loading conditions. Using different materials AL2011T3, EN24, AL 7075 T6, GREY CAST IRON and CAD models of the suspension system of a vehicle were developed with a 3D modeling software and perform the static and modal analysis using ansys software. The stress analysis of the models were obtained and compared using FEA with Ansya16 software to optimize for weight reduction. Finally conclude the suitable material based on the stresses, deformation values.

3.3 PROBLEM IDENTIFICATION

Improper material leads to the failure Weight reduction is most important in automobile field Steering knuckle requires lots of attention in selection because once it is damaged then it have to replace with the new one. This problem can be solved by redesigning the steering knuckle. So, the steering knuckle can be made compact by integrating with spindle which helps in good steering capabilities

Figure 1 PROBLEM OF KNUCKLE STEERING

3.4 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.

The stress due to this load can be findout using the following formula, Tensile Load ( )= Tensile stress × Area

Compressive Load ( ) = Compressive stress ×Area.

ii). Inertia Load:

This load act on Steering Knuckle due to the inertia of the moving parts .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 .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 .The bending moment at any section 'X' m from the small end is given by,

(C) Loading Condition 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*

Table1: Loading Condition on Steering Knuckle

3.5 MATERIAL PROPERTIES:

3.5.1 AL2011T3 MATERIAL:

Aluminum alloy 2011 is a high mechanical strength alloy that machines exceptionally well. Often called a Free Machining Alloy or 'FMA' it is well suited to use in automatic lathes. Machining at high speeds produces fine chips that are easily removed. The excellent machining characteristics allow the production of complex and detailed parts. In some circumstances 2011 can replace free machining brass without the need for alterations to tooling. It has poor corrosion resistance, which means parts made from 2011 tend to be anodized to provide additional surface protection. When higher levels of corrosion resistance are required, may be a suitable replacement.

Applications - 2011 is typically used in applications that require parts manufactured by repetition machining. These applications may include:

- Appliance parts & trim
- Automotive trim
- Fasteners and fittings
- Ordnance

3.5.2 EN24 MATERIAL:

EN24 is a very high strength **steel** alloy which is supplied hardened and tempered. The grade is a nickel chromium molybdenum combination - this offers high tensile **steel** strength, with good ductility and wear resistance characteristics.EN24 is usually supplied in the finally heat treated condition (quenched and tempered to "T" properties) EN24 is a very popular grade of through the "T" condition. (Refer to our machinability). EN24 is most suitable for the manufacture of parts such as heavy-duty axles and shafts, gears, bolts and studs.

3.5.3 AL 7075 T6 MATERIAL:

General 7075 characteristics and uses (from Alcoa): Very high strength material used for highly stressed structural parts. The T7351 temper offers improved stress-corrosion cracking resistance.

Applications: Aircraft fittings, gears and shafts, fuse parts, meter shafts and gears, missile parts, regulating valve parts, worm gears, keys, aircraft, aerospace and defense applications; bike frames, all terrain vehicle (ATV) sprockets.

3.5.4 GREY CAST IRON MATERIAL:

MATERIAL PROPERTIES	DENSITY	ULTIMATE TENSILE STRENGHT(Mpa)	Possions ratio(u)	Yield strength(Mpa)
AL2011 T3	2830	620	0.3	360
EN24	7830	850	0.3	680
AL 7075 T6	2810	620	0.31	500
Grey cast iron	7200	550	0.3	190

Table 2: MATERIAL PROPERTIES

IV INTRODUCTION TO CATIA

Welcome to **CATIA (Computer Aided Three Dimensional Interactive Application)**. As anew user of this software package, you will join hands with thousands of users of this high-end CAD/CAM/CAE tool worldwide. If you are already familiar with the previous releases, you can upgrade your designing skills with the tremendous improvement in this latest release.

CATIA V5, developed by Dasssault Systems, France, is a completely re-engineered, Next-generation family of CAD/CAM/CAE software solutions for Product Lifecycle Management. Through its exceptionally easy-to-use and state-of-the-art user interface, CATIA V5 delivers innovative technologies for maximum productivity and creativity, from the inception concept to the final product. CATIA V5 reduces the learning curve, as it allows the flexibility of using feature-based and parametric designs.

4.1 DIMENSIONS AND DESIGN PROCEDURE IN CATIA:

Steering knuckle component was made in 3D modeling software catia. 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.

V FINITE ELEMENT METHOD

5.1 INTRODUCTION

The Basic concept in FEA is that the body or structure may be divided into smaller elements of finite dimensions called “Finite Elements”. The original body or the structure is then considered as an assemblage of these elements connected at a finite number of joints called “Nodes” or “Nodal Points”. Simple functions are chosen to approximate the displacements over each finite element. Such assumed functions are called “shape functions”.

The Finite Element Method is a mathematical tool for solving ordinary and partial differential equations. Because it is a numerical tool, it has the ability to solve the complex problems that can be represented in differential equations form. The applications of FEM are limitless as regards the solution of practical design problems.

5.2 ANALYSIS PROCEDURE IN ANSYS:

Designed component in catia workbench after imported into ansys workbench now select the steady state thermal analysis

1.ENGINEEERING MATERIALS (MATERIAL PROPERTIES).

2. CREATE OR IMPORT GEOMENTRY.

3. MODEL (APPLY MESHING).

4. SET UP (BOUNDARY CONDITIONS)

5. SOLUTION

5.3 STATIC STRUCTURAL ANALYSIS

The static structural analysis calculates the stresses, displacements, strains, and forces in structures caused by a load that does not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that the loads and the structure’s response are assumed to change slowly with respect to time.

5.4 BOUNDARY CONDITIONS:

The boundary conditions for the Steering Knuckle and apply axial load, inertia load, moments and forces as shown below figure

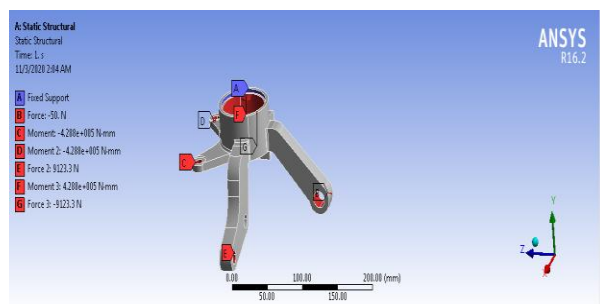

Figure 2 Boundary conditions of knuckle steering

VI RESULTSAND DISCUSSIONS

6.1 STATIC AND MODAL ANALYSIS RESULTS:

The analysis of steering knuckle component is done in ANSYS Workbench 16.0. The required load of steering knuckle component was determine from various research papers. According to papers we assume average weight of vehicles is 1240 kg. with different materials EN24, AL 7075 T6, GREY CAST IRON .The weight are directly acted on all the four knuckle. the weight of vehicles acted on one wheel is 310 kg. Thus the average weight of vehicles acted on each wheel is 310 × 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 Zdirection. The various analysis results are shown in figures which are given below:

6.1.1 STATIC ANALYSIS OF GREY CAST IRON MATERIAL:

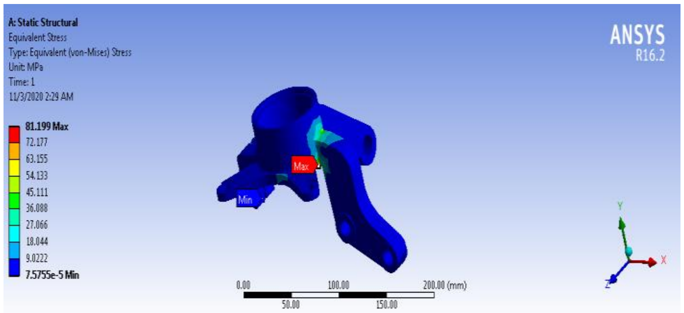

Figure 3 Von-misses stress of grey cast iron material

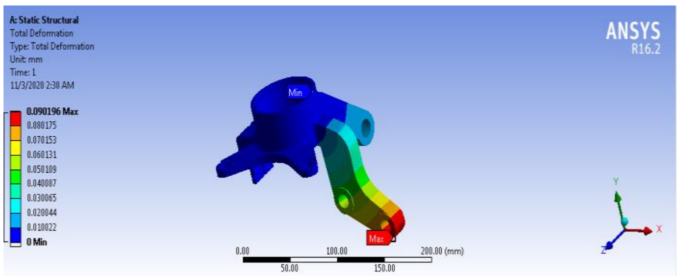

Figure 4Total deformation of grey cast iron material

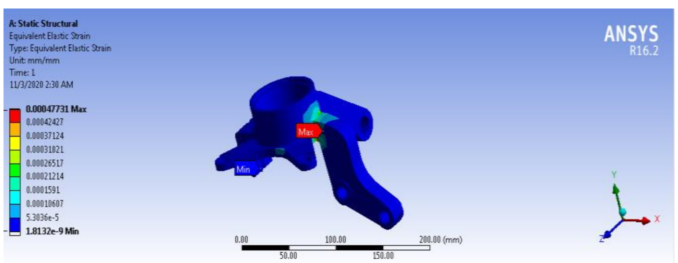

Figure 5 Strain of grey cast iron material

6.1.2 STATIC ANALYSIS OF Al 7075 T6 MATERIAL:

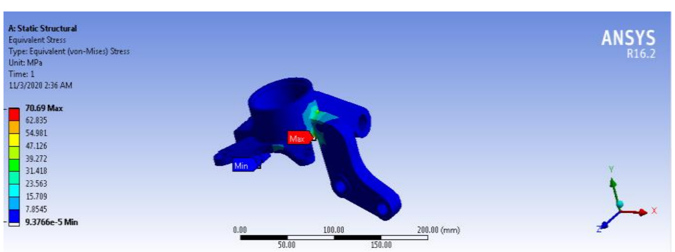

Figure 6 Von-misses stress of Al 7075-T6 Material

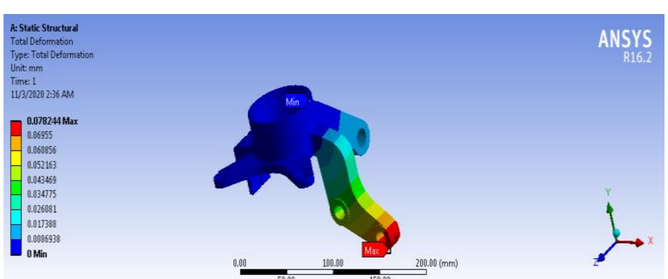

Figure 7 Total deformation of Al 7075-T6 Material

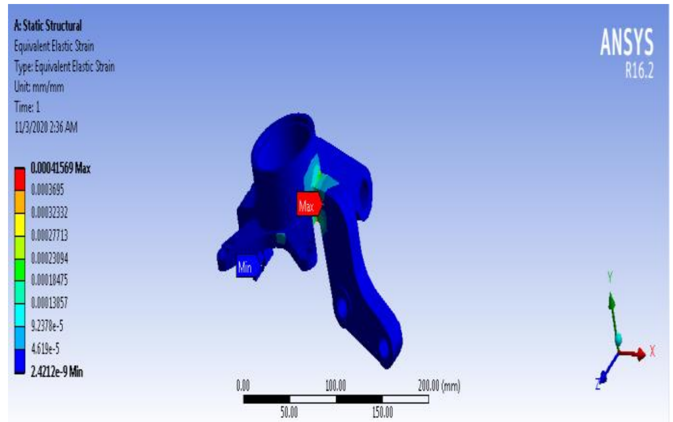

Figure 8 Strain of Al 7075-T6 Material

6.3 STATIC AND MODAL ANALYSIS GRAPHS:

From below figure, we can observe that in case of equivalent (von-misses) stress, Total deformation, shear stress, strain Steering knuckle applied different forces and moments fixed at one end finally generate the graphs with different materials EN24, AL 7075 T6, GREY CAST IRON as shown below graphs

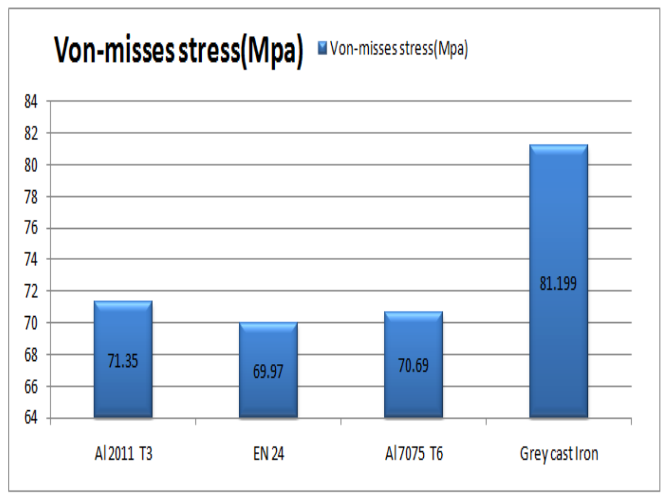

Figure 9: Von-misses stresses with different materials

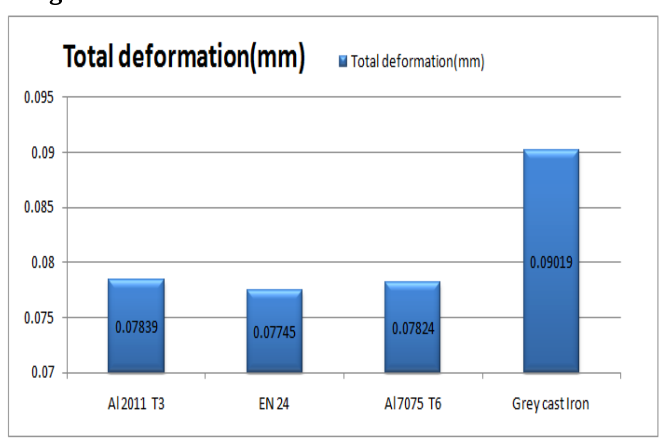

Figure 10: Total deformation with different materials

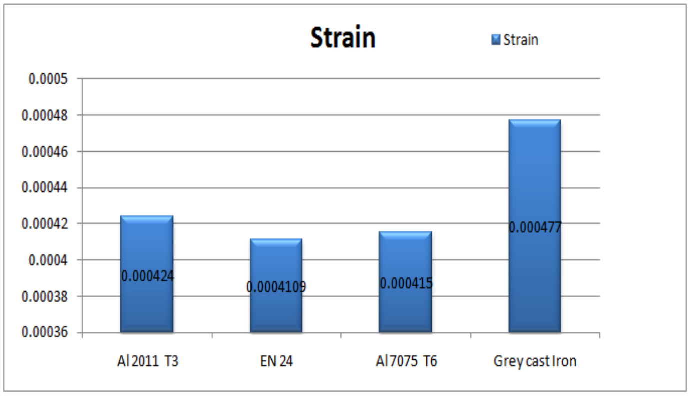

Figure 11:Strain graph with different materials

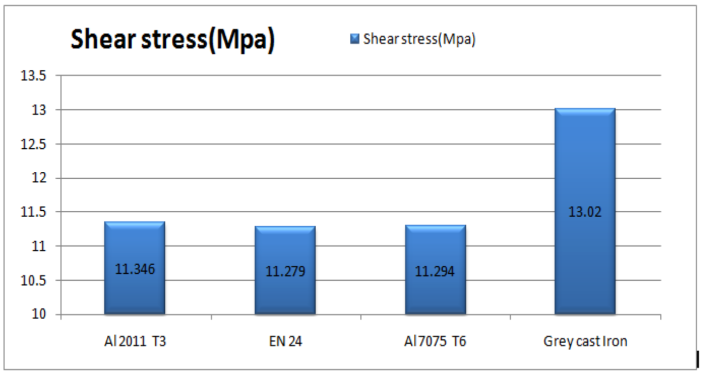

Figure 12: Shear stress with different materials

6.4 MODAL ANALYSIS GRAPHS

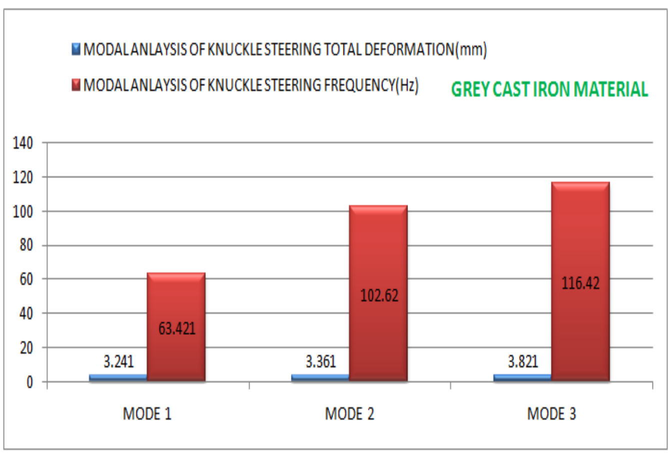

Figure 13: MODAL ANALYSIS OF GREY CAST IRON

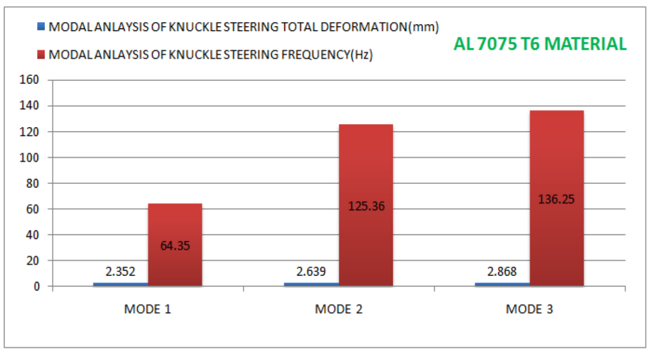

Figure 14:MODAL ANALYSIS OF Al 7075 T6 Material

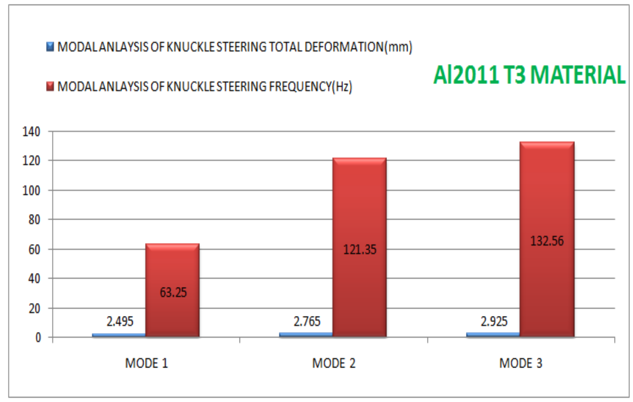

Figure 15: MODAL ANALYSIS OF Al 2011 T3 Material

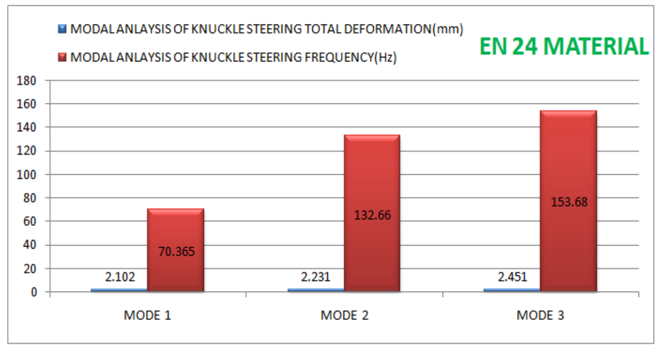

Figure 16: MODAL ANALYSIS OF EN 24 Materials

VII CONCLUSION

The design of Steering Knuckle component is done with the help of Computer Aided Engineering (CAE). Steering Knuckle model is prepare in catia and the static analysis and modal 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 conventional and composite materials AL2011T3, EN24, AL 7075 T6, GREY CAST IRON,

Finally concluded the EN24 and Al 7075 is the suitable materials because less stress and deformation modal analysis(frequencies and total deformation) is also satisfied so concluded the EN24 and Al 7075 is suitable for manufacturing for the steering knuckle compared with recently using material Grey cast iron because of 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

REFERENCES

[1] Purushottam Dumbre, Prof A.K.Mishra, V.S.Aher, Swapnil S. Kulkarni, "Structural Analysis Of Steering Knuckle For Weight Reduction", International Journal of

Advanced Engineering Research and Studies, Int. J. Adv. Engg. Res. Studies/III/III/April-June, 2014/86-86 .

[2] Kiran S.Bhokare, G.M.Kakandikar, Swapnil S. Kulkarni, “Predicting the Fatigue of Steering Knuckle Arm of a Sport Utility Vehicle While Deploying Analytical Techniques Using CAE”, International Journal of Scientific Research and Management Studies (IJSRMS), Volume 1 Issue 11, pg: 372-381 .

[3] Mahesh P. Sharma1, Denish S. Mevawala2, Harsh Joshi3, Devendra A. Patel, “Static Analysis of Steering Knuckle and Its Shape Optimization”, International Conference on Advances in Engineering & Technology, 2014.

[4] EshaanAyyar, Isaac de Souza, Aditya Pravin, SanketTambe, Aqleem Siddiqui & Nitin Gurav, “Selection, Modification and Analysis of Suspension System for an All-Terrain Vehicle”, ISSN : 2319 – 3182, Volume-2, Issue-4, 2013

[5] Wan Mansor Wan Muhamad, EndraSujatmika, Hisham Hamid, &FarisTarlochan, “Design Improvement of Steering Knuckle Component Using Shape Optimization”, International Journal of Advanced Computer Science, Vol. 2, No. 2, pp. 65-69, Feb. 2012.

[6] Nassir S. Al-Arifi, Abu S. Zamani, and Jalaluddin Khan, “Billet Optimization for Steering Knuckle Using Taguchi Methodology”, International Journal of Computer Theory and Engineering, Vol. 3, No. 4, August 2011.

[7] MehrdadZoroufi and Ali Fatemi, “Fatigue Life Comparisons of Competing Manufacturing Processes: A Study of Steering Knuckle”, SAE International, 2003.

[8] 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, ICQUEST, 2015.

[9] Manik A. Patil, Prof.D.S.Chavan, Prof.M.V.Kavade, Umesh S. Ghorpade, “FEA of Tie Rod of Steering System of Car”, International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 2, Issue 5, May 2013.

[10] Sharad Kumar Chandrakar, Dheeraj Lal Soni and ShohelGardia, “FEA of A Steering Knuckle for Life Prediction”, International Journal of Engineering Research and Technology.ISSN 0974-3154 Volume 6, Number 5, 2013.

[11] B.Babu, M. Prabhu, P.Dharmaraj, R.Sampath, “Stress Analysis on Steering Knuckle of the Automobile Steering System”, IJRET: International Journal of Research in Engineering and Technology, ISSN: 2319-1163 | ISSN: 2321-7308.

[12] Dinesh Shinde, Kanak Kalita, “Fe Analysis of Knuckle Joint Pin Used in Tractor Trailer”, ARPN Journal of Engineering and Applied Sciences, VOL. 10, NO.5, MARCH 2015