International Journal for Ignited Minds (IJIMIINDS)

# Topology Optimization of Steering Knuckle using Finite Element Analysis

Santosh Gowda K R[a], Dr. A R Anwar Khan[b] & Mohammed Imran[c]

*[a]PG Scholar, Dept. of Mechanical Engg, Ghousia College of Engineering, Ramanagara, India.*
*[b]Principal & HOD, Dept. of Mechanical Engg, Ghousia College of Engineering, Ramanagara, India.*
*[c]Asst. Prof, Dept. of Mechanical Engg, Ghousia College of Engineering, Ramanagara, India.*

**ABSTRACT**

*Knuckle is a main member in the automobile steering system. The load transfer to the front axle is carried out by the steering knuckle. Steering knuckle is mainly a cast product which has inherent brittleness. Many times this brittleness is the main cause of failure of Knuckle under fatigue fracture. To eliminate this, the central portion of the knuckle should be made of ductile weld structure. The present work is concentrated on the elimination of central region to replace with a ductile weld structure. Initially the original knuckle structure is built using three dimensional modelling software and drafted for dimensions.*

***Keywords*** *– Knuckle, Topology, Steering, Optimization, Brittle, Ductile.*

## 1. INTRODUCTION

Automobile is a self-propelled vehicle used for transportation of the passengers from one place to another place. Automobiles changed the world in 18th, 19th, 20th and 21st Centuries. Initial automobiles are run by either horses or steam from water. The revolution in the automobile industry brought revolution in the human civilization along with maximum job creation in the manufacturing, repair and service sectors. But along with this development, it has created large pollution and accidents. But the development can't be stopped as it is becoming the essential mode of transportation.

Generally automobiles are classified based on size, number of doors, seats, built methodology and purpose etc. The naming like bike, car, passenger car, goods vehicle, two wheeler, four wheeler, 8 wheeler etc. depends on the requirements of the industry. Small vehicles generally designed for low load applications and heavy vehicles like Lorry; truck etc. for higher load applications. Heavy vehicles are more rugged compared to the smaller vehicles and even cost is vice versa.

## 2. LITERATURE SURVEY

Since an automobile has long history, many failures of knuckle can be observed from the literature. Since knuckle is subjected to fatigue type of loads, the main failure model is fatigue fracture.

A driver was running Hummer West on a state highway was struck with steering lock when he turned to the other street and was hit with other vehicle coming on the road. So locking of steering was the main cause of inability to turn to the other street. Eleonora [1] has studied the problems with steering lock and its effect on the knuckle.

He observed that the knuckle is made of SAEJ434 Grade D4512 material which is Cast Iron. From the Metals Handbook, it is observed that cast Iron can take only moderately stresses parts. The failure of this component was the reason for failure of steering system. He suggested that replace cast iron with Forged steel or cast steel. Cast Iron can't take the shock loads.

Bruce [2] advised Daimler Chrysler Corporation to recall a total of 26354 brand new models due to defective knuckle in the steering mechanism. He observed that the defective knuckle due to manufacturing defect may cause failure of the system any moment. The problem was identified when a fractured knuckle was found on just produced vehicle in one of the facilities of the company.

Chuse [3] has applied shape optimization techniques for weight reduction of steering knuckle for a heavy truck suspension. He faced so many problems of convergence with the element shape, uneven surfaces, number of load cases, and distortion of energy while applying finite element technology to shape optimisation. An interpolation function is used to find the shape vectors. Finally he was able to reduce the weight by 12.7% with the final design with second order elements.

## 3. GEOMETRY AND FE MODELLING

### 3.1 Material Properties

Material is essential input/part of any geometry and hence suitable material should be selected based different criteria such as strength, durability, availability and sustainability. For this project we have selected a material called Cast Steel –FCD440 based on all the above stated points. Material properties of Cast Steel –FCD440 are shown in the below table 1.

| **Material: Cast Steel –FCD440** | | |
|---|---|---|
| **Material Properties** | **Value** | **Units** |
| Young's Modulus | 151 | MPa |
| Poisson's Ratio | 0.3 | |
| Density | 7650 | kg/m3 |
| Yield Stress | 590 | MPa |
| Allowable Stress | 295 | MPa |

Table 1: Material Properties of Cast Steel –FCD440.

### 3.2 Geometry Modeling

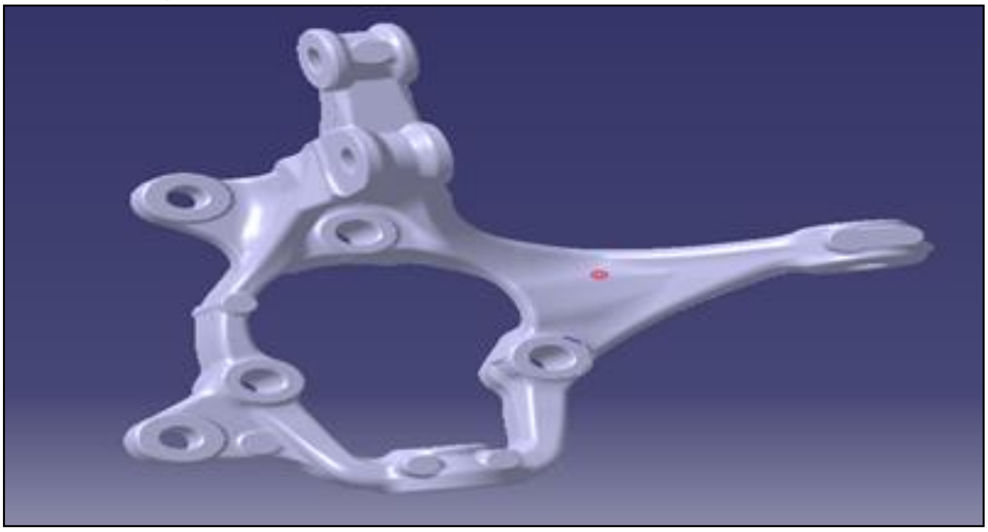

Fig 1: Final Optimized Geometry of Knuckle.

The Fig 1, shows final model of the knuckle. The geometry is removed in such as to distribute the stresses uniformly.

### 3.3 Boundary Conditions and Loadings

Boundary conditions and loads are the crucial input to any FE analysis, as wrong input or assumptions leads to erroneous results based on this the wrong results conclusion is drawn. Hence suitable inputs needs to be considered based on the practical experience or experimental results. The loads used for this FE Analysis is as shown in the below Table 2.

| Description | Loads |
|---|---|
| Damper Mount | 14.6KN |
| Ball Joint Mount | Maximum Load : 12300N |
| Caliper Mount | 3.2KN |

Table 2: Loads used in the Analysis.

### 3.4 FE Modeling

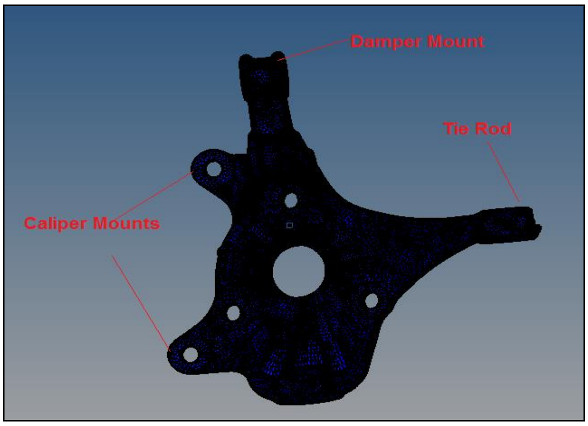


Fig 2: FE Model with Description of Main Points.

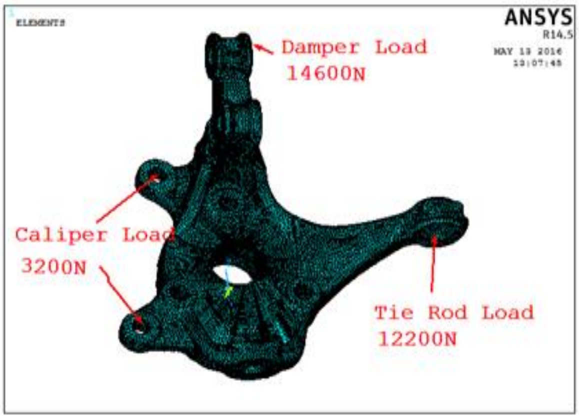


Fig 3: FE Model with Boundary Conditions.

Analysis is carried out for three different iteration based on the optimization called topology optimization which is based on the optimization of geometry shape. The maximum possible material is removed and shaped is optimized to withstand the working loads. All the three geometry is meshed individually with solid elements called Solid45 and the no of nodes and elements are tabulated in the below table 3.

| Details | Number of Elements | Number of Nodes |
|---|---|---|
| Configuration 1 | 169051 | 38482 |
| Configuration 2 | 165686 | 37991 |
| Configuration 3 | 133885 | 31242 |

Table 3: FE Mesh Description for all the Three Configuration.

## 4. RESULTS & DISCUSSION

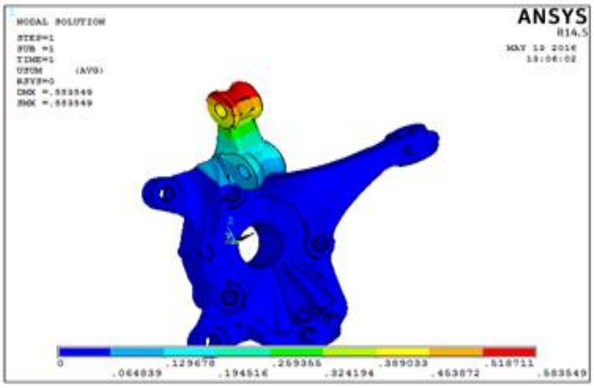


Fig 4: Deformation for Damper Loads.

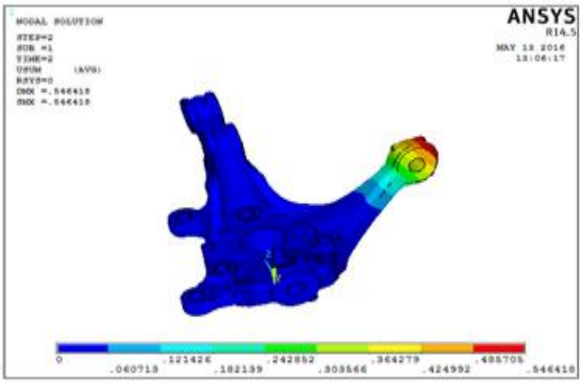


Fig 5: Deformation plot for Tie Rod Loads

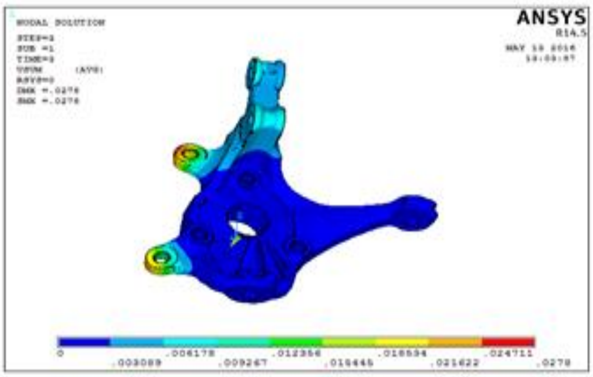


Fig 6: Deformation plot for Caliper Load.

Fig 4 shows, Maximum of 0.583mm deformation is taking place at the damper mount for the given loading conditions i.e. for damper position load of 14600N and from the figure 5 shows deformation developed due to tie rod loads is 0.546mm is less than the allowable deflection limit of 0.7mm. So structure is safe for the given loading.

| **Details** | | **Damper Mount Loads** | **Tie Rod Loads** | **Caliper Mount Loads** |
|---|---|---|---|---|
| Configuration 1 | Deformation, (mm) | 0.583 | 0.546 | 0.0278 |
| Configuration 2 | | 0.60473 | 0.273 | 0.0283 |
| Configuration 3 | | 0.635 | 0.304 | 0.029 |

Table.3.Comparative Results for All three configurations for Safety Parameters.

## 5. CONCLUSION

For damper mount load for initial configuration, it is observed that maximum stress developed is 260Mpa. The maximum induced stresses are less than the allowable stress of the material, hence, structure is safe for the given load. For tie rod load, the maximum deformation of 0.546mm is observed which is less than the allowable deflection limit of 0.7mm, hence, structure is safe for the given loading. The results for all the members show safety of the component for the given loading conditions.

## REFERENCES


1. Eleonora, "*fatigue life comparisons of competing manufacturing processes: a study of steering knuckle*" - sae international 2001.
2. Bruce. "*The effect of hip processing on the properties of a356 t6 cast aluminum steering knuckles*", sae technical paper 2004-01-1027, 2004, doi: 10.4271/2004-01-1027.
3. Chuse, "*structural optimization of a knuckle with consideration of stiffness and durability requirements*", the scientific world journal, Volume 2014 (2014), article-763692.
4. David gerken, d, ogiwara, t., "*squeeze cast permanent mold (scpm) processes for automotive aluminum castings"*, sae technical paper 981188, 1998, doi: 10.4271/981188.
5. Mehrdad zoroufi, "*manufacturing process effects on fatigue design and optimization of automotive components: an analytical and experimental study*", the university of toledo the university of toledo digital repository.
6. Yong kim, byung man kwak, "*design space optimization using a numerical design continuum method*", international journal for numerical methods in engineering, int. J. Number, meth engng -2002.