International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 1111-1117 www.ijaem.net ISSN: 2395-5252

# Design Calculations and Analysis of ALTO 800 Steering Knuckle Using Fea

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Submitted: 01-08-2021 Revised: 14-08-2021 Accepted: 17-08-2021

**ABSTRACT**: Steering knuckle is important component of vehicle which connects with brake caliper, suspension, steering system and wheel hub. Being a pivot point of the vehicle it undergoes various loads which results in failure of component. The paper describes the design calculations and analysis of alto 800 steering Knuckle. This is done by two step process that first one is modeling the steering knuckle as per the dimensions using CATIA V5 softwareand calculating the load acting on steering knuckle. The second step is performing stress analysis in ANSYS WORKBENCH 20.0 for different load combinations. Nodular cast iron material is used.

**KEYWORDS**:Steering knuckle, design calculation, finite element analysis (FEA), Nodular cast iron

## I. INTRODUCTION

Steering knuckle is the complex component of thevehicle 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 design of steering knuckle component depends on the vehicle weight and for what purpose it is used

Figure 1. Steering Knuckle

The parts of steering knuckle are:
1. Tie Rod Mounting / Steering Arm
2. Suspension Mounting Lower Arm
3. Suspension Mounting Upper Arm
4. Stub Hole
5. Brake Caliper

Steering Knuckle is subjected to time varying loads during its service life which may lead to fatigue failure. It accounts for maximum amount of weight of suspension components so there is need of weight reduction by optimizing process. In automobile Industry different type of knuckles are used for different vehicle models so there is scope for optimization of knuckle in such a way that a can be possible to use a single knuckle for various vehicles. An effective design is one which perform the required task efficiently and is safe under extreme operating load condition, while being economical in the material used and in manufacturing process.

[1]. Weight reduction of steering knuckle is done by using different optimization techniques. The CAD model is created in CATIA. And OptiStruct (Hyper works) software is used for finite element analysis. In this the targeted weight or mass reductions is about 5% without compromising on structural strength. Topology optimization is

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used to reduce the weight of existing knuckle component by 11% without compromising strength. Ferrite ductile material is used it has high impact resistance and also good for machinability.

[2]. Studied the fatigue life and compare fatigue performance of steering knuckles made from three materials of different manufacturing processes. The materials like forged steel, cast aluminium, and cast iron knuckles. In light of the high volume of forged steel vehicle components, the forging process was considered as base for investigation. Monotonic and strain-controlled fatigue tests of specimens machined from the three knuckles were conducted. Static as well as baseline cyclic deformation and fatigue properties were obtained and compared. In addition, a number of load-controlled fatigue component tests were conducted for the forged steel and cast aluminium 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 behaviours of the three materials and manufacturing processes are then compared iron reached 37% and 57% of forged steel ultimate tensile strength, respectively. The percent elongation of cast aluminium and cast iron werefound to be 24% and 48% of the forged steel, respectively. Component testing results showed the forged steel knuckle to have about two orders of magnitude longer life than the cast aluminium knuckle, for the same stress amplitude level. This occurred at both short as well as long lives. It is concluded that the forged steel knuckle exhibits superior fatigue behaviour, compared to the cast iron and cast aluminium knuckles.

[3]. Studied thefailure during sudden severe loading caused due to continual and repetitive usage while driving for extended timelineover the life of the component. The current Design of Steering Knuckle Arm is to generate the most optimal configuration of the component Design for the given input conditions of loading. From the test reports and analysis results they suggested the best suitable design of knuckle for different materials.

[4]. The steering knuckle CAD model was developed in Creo (Pro-E) 2.0. And for analysis ANYSIS 15.0 is used. Here they used three different material cast iron, mild steel and Forged steel EN 47.and from analysis results the forged steel En 47 gives best results compared to others. The mass reduction is about 6% is achieved, for various loading conditions.

[5]. The design improvement for steering knuckle by using shape optimization. Finite element model is developed in Hyper Mesh and HyperMorph us used for shape variables. The improved design achieved 8.64% reduction of mass without change in maximum stress.

## II METHODOLOGY

The methodology used in this paper is to create a model of the alto 800 steering knuckle in CATIA V5 and FEA in Ansys 20.0.

a) **Design model of the centrifugal blower in CATIA V5:**The design of a model is done by using CATIA V5
b) **Analysis in Ansys 20.0:**Deformation of material under different load condition.

## III MATERIAL SELECTION

Materials are selected based on for what purpose they are used. For manufacturing of steering knuckle different types of material are used such as white cast iron, ductile iron, and grey cast iron. Forged steel are most demanding material for this application here we consider Nodular cast iron it has high mechanical strength and corrosion resistance and low cost.

Table 1: Physical and Mechanical Properties of Nodular cast iron A536

| | | |
|---|---|---|
| Density | 7100 | Kg/m$^3$ |
| Young's Modulus | 1.7 E$^{+05}$ | Mpa |
| Poisson's ratio | 0.31 | |
| Ultimate tensile strength | 448 | Mpa |
| Yield Strength | 310 | Mpa |

## IV DESIGN OF CAD MODEL

CAD model of steering knuckle was developed in 3D modeling software CATIA V5 as per the desired dimensions. It has brake caliper mounting points, steering tie rod mounting points, suspension upper and lower A-arm mounting points.

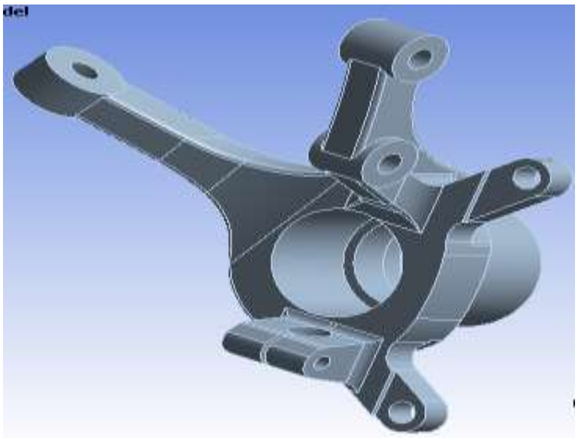

Figure 2: CATIA model of steering knuckle

## V DESIGN CALCULATIONS

The geometrical and physical constraints of every vehicle are different, hence the forces acting knuckle and the points of application of the forces are very important. For this study the forces are formulated in multiple of G forces with the weight of car to present standard value. The center of gravity of the vehicle is nit fixed but varies according to mass transfer during different load case.

The forces acting on knuckle are:

**A. Lateral Force due to Turning:**

Lateral force or side force is the cornering force produced by a vehicle tyre during cornering. It is equivalent to the centrifugal force generated due to cornering.

**B. Brake Force due to Torque Required for Braking:**

Brake force is generated on the knuckle at the points of brake caliper mountings when brake is applied to retard the motion of the vehicle. It is calculated as the product of the pressure generated in fluid line with net area of caliper piston and the coefficient of friction between the brake pads and the brake disc.

**C.Force due to Steering Gearbox during turning:**

This is the force exerted by the steering gearbox on the steering arm mounting of the knuckle through the tie rod while turning.

**D. Weight Transfer during Breaking or Turning:**

During acceleration and braking, inertia of the vehicle chassis causes a load transfer in longitudinal direction on the vehicle; i.e. the load form the rear is transferred to the front while braking and the opposite effect takes place while accelerating. This load transfer (or weight transfer) exerts a force on the knuckle. A similar effect takes place while negotiating a corner. Inertia causes load transfer in lateral direction; i.e. the load form the right side is transferred to the left side while taking a right turn and vice versa.

**E. Bump Force:**

When the vehicle undergoes a ground disturbance in the form of a bump or a hole a force is exerted on the knuckle. For design considerations, it is assumed that the suspension spring has attained full travel which is 4 inches.

**F. Force on Impact:**

When the vehicle is subjected to a front, rear or side impact an impulse force is exerted on the knuckle. For this study purpose, this force has been neglected as it is ambiguous to predict the nature of such impact force.

Design and calculations are done to redesign and optimize the model considering weight and shape of the model. The testing is done by applying individual load to the steering knuckle to avoid more complexity during measuring the actual testing results. For calculation purpose individual load case and testing results are simulated in ANSYS WORKBENCH.

From FEA software applying various combination of load case can be simulated with minimum expenses, so here in his paper worst case combination is considered for further analysis and design modification.

The passenger car alto 800 specifications are listed in Table 2.

Table 2. Alto 800 specifications

| **Parameter** | **Specification** | **Unit** |
|---|---|---|
| Mass | 1456 | kg |
| Wheel Base | 2175 | mm |
| Track Width | 1295 | mm |
| Height of Center of Gravity | 950 | mm |
| Ground Clearance | 170 | mm |

The C.G is calculated by considering front left tire contact with ground as origin (with respect to driver). As load acting on lower arm connection point is highest. Forces are shown in figure 3, act on mounting points only. By fixing the Stub Hole.

As weight is equally distributed on each wheel, here loads for one knuckle is calculated. The factor of safety is 1.6.The load distribution for this is case is different, the standard equation of 1G will be [6]

$$1G = \frac{m * g * 1}{4} * 0.35$$

$$G = \frac{1456 * 9.81 * 1 * 0.35}{4}$$

$$G = 1249.79N \approx 1250N$$

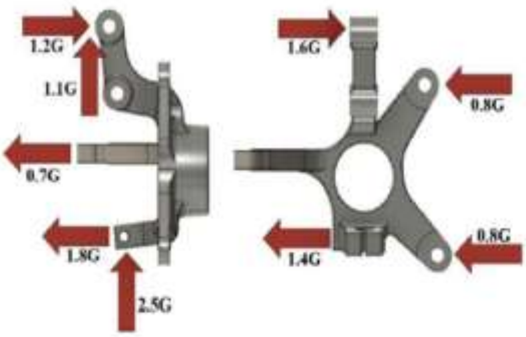


Figure 3: Application of loads on steering knuckle

Load case:

1. Braking condition:

Load applied,

$$P = 0.8 * G = 0.8 * 1250$$

$$P = 1000N$$

For applied the deformation is,

$$\delta = \frac{PL}{AE}$$

$$\delta = \frac{1000 * 12}{25 * 12 * 1.7 * 5^5}$$

$$\delta = 0.00021mm$$

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Stress is calculated as

$$\sigma = \frac{P}{A}$$

$$\sigma = \frac{1000}{25 * 12}$$

$$\sigma = 3.33\ \mathrm{N/mm^2}$$

**Table 3.** Calculation for other load case

| No | Load case | Load P N | Deformation mm | Stress $N/mm^2$ |
|---|---|---|---|---|
| 2 | Tie rod | 875 | 0.00018 | 2 |
| 3 | Strut Mounting | 3000 | 0.00068 | 7.6 |
| 4 | Lower Arm | 4300 | 0.00052 | 7.3 |

Because the steering knuckle design is intricate so normal cross section area is considered, where ever resultant forces are acting.

## VI FINITE ELEMENT ANALYSIS

Finite element analysis is used to carry out structural analysis of steering knuckle, as itprovides information with stress concentration regions on application of loads and variation of materials. In ansys there are three steps to solve the problem

i. Pre-processing
ii. Solver
iii. Post-processing

The solid model created in modeling software of steering knuckle are shown in Fig. 4

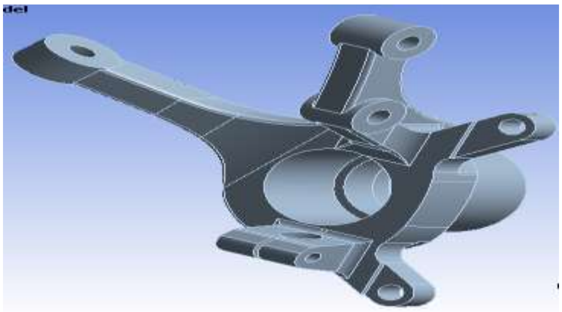

Figure 4: CAD model of steering knuckle

Meshing is most important part.It helps to get the exact results. In this mesh convergence criteria is used. In first place coarse pattern is used and after geometry clean up the mesh size is taken to 2.5mm. The meshed model is shown in Fig.5

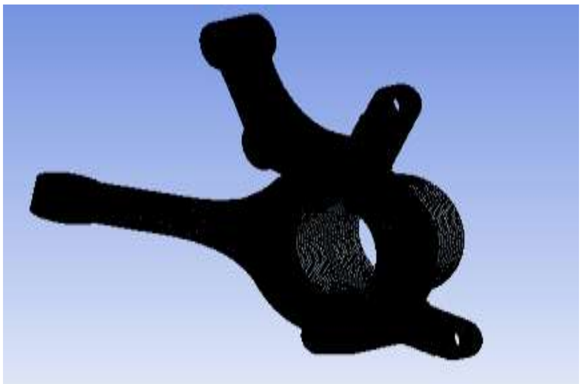

Figure 5: Meshed model of steering knuckle

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Table 4: Nodes and Elements of model

| | |
|---|---|
| Nodes | 197893 |
| Elements | 968712 |

For calculating force acting on steering knuckle the required loading conditions are given in Table 5.

Table 5: Loading conditions

| | |
|---|---|
| Brake force | 1.5mg |
| Lateral Force | 1.5mg |
| Steering force | 50N |
| Force on knuckle hub in X axis | 3mg |
| Force on knuckle hub in Y axis | 3mg |
| Force on knuckle hub in Z axis | 3mg |

Figure 6: Applying loading conditions

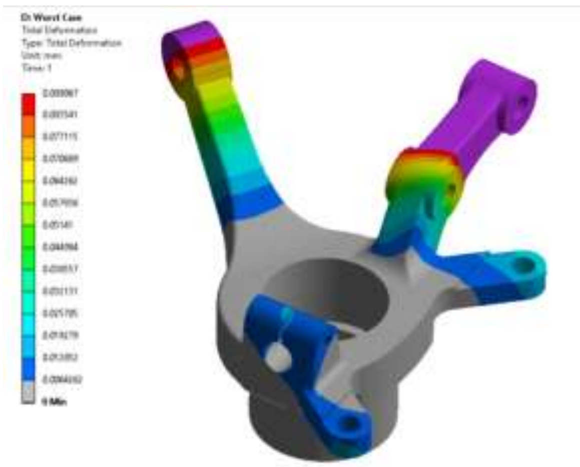

Figure 7:Von misses stress in steering knuckle Nodular casr iron A536

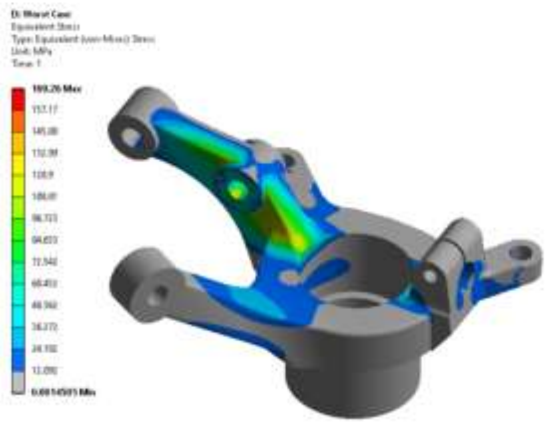

Figure 8: Total Deformation in steering knuckle Nodular cast iron A536

## RESULTS AND DISCUSSION

The considered steering knuckle model is safe for applied loads and boundary conditions. The maximum deformation 0.08mm and maximum value of von misses stress is found as 169Mpa and the factor of safety for steering knuckle is in the range of 1.5 to 2 so the stresses are within the elastic limit. Because Factor of safety is 1.6 hence there is lot more scope to optimization. Moreover it seems that the steering knuckle design can be further modified and can be considered for weight and shape optimization.

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