

Design and Analysis of Steering Knuckle for Electric ATV

Hemant Singh Rajput¹, Yash Agrawal² Navneet Tiwari³

¹Asistant Professor, Automobile Engg. Dept., Hindustan College of Science & Technology, Farah, Mathura

²Student, Automobile Engg. Dept., Hindustan College of Science & Technology, Farah, Mathura

³Student, Automobile Engg. Dept., Hindustan College of Science & Technology, Farah, Mathura

Abstract - The paper describes the design and analyses of steering knuckle. The steering knuckle on a vehicle is a joint connected to the upright that allows the steering arm to turn the front wheels. The knuckle is modeled in Solid works software and the analysis is carried out in Ansys workbench. The knuckle is tested under different loading conditions like Bump, Cornering and Braking. For carrying out the analysis two types of materials are chosen. They are Mild steel AISI 1018, Al-6082-T6 and Grey Cast iron. After analysis the material that has less deformation and good factor of safety is selected and further the manufacturing process was done.

Key Words: Knuckle, Factor of safety, Total deformation, Cornering, Braking, Mild steel AISI 1018, Al-6082-T6, Cast Iron

1. INTRODUCTION

The Purpose of this paper is to describe the improvement in the suspension of a car in development as well as develop a design process that can be used in formula racing cars and ATV. The main object is to limit the un sprung mass and add adjustability for the suspension using research and analysis method. The Project involves all the parts that connect wheels to the control arms of the suspension including the brake system at the wheels.

The wheel assembly of an ATV generally comprises of a Wheel rim attached to a hub and fastened using 4 bolts. Further the brake rotor is also mounted on this hub and through the hollow axis of this hub the spindle from the upright passes which supports the hub. The hub is mounted on the spindle using 2 roller bearings designed as per the requirement. The components procured for the BAJA vehicle are Douglas A5 rims with PCD holes at 118mm of 14mm dia. The hub and upright are designed custom to reduce the weight of the wheel assembly and provide appropriate strength to the wheel assembly components. The components are designed to ensure the safety of the driver and also look aesthetically pleasing. The advanced optimization techniques help to explore the light weight architecture. The process of designing light weight Knuckle from scratch which can be applicable for many casting components. To derive the optimal load path required for the major load cases a topology optimization is performed on the design volume and prepare a concept model from the topology results generated. The objective is to verify model for all the required extreme loads & the durability load which helps for significant mass reduction from model [1].

DESIGN, MATERIAL, PROCEDURE, TECHNIQUE OR METHODS FOR UPRIGHT OR STEERING KNUCKLE

A Steering Knuckle is one of the critical components of vehicle which connects brake, suspension, wheel hub and steering system to the chassis. It undergoes varying loads subjected to different circumstances, while not distressing vehicle steering performance and other desired vehicle characteristics.

Steering knuckle model of light utility vehicle (LUV) is modelled in solid works with existing dimension. This model is further used for process of optimization. The forces acting on the steering knuckle are due to forces created the tire due to static or dynamic conditions when vehicle is stationary or in running conditions. Analysis of steering knuckle is done in ANSYS for these forces which are acting on it. Forces are due to static load of vehicle, steering effort, breaking force (Moment force) and due to constraints of the vehicle. Cad model created in solid works in imported into ANSYS for analysis.

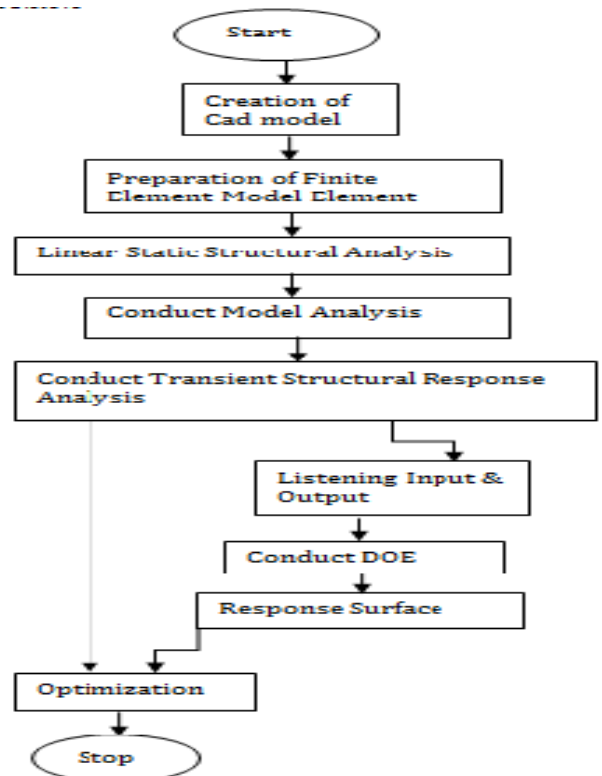


Fig-1: Design and Optimization chart

MATERIAL SELECTION

This knuckle uses mild steel material. Mild steel has properties and characteristics such as tough, ductile, malleable and good tensile strength. This material is suitable to be used as knuckle, which principally designed as a support, so it needs materials which suit the properties, and also Mild Steel AISI 1018 was chosen because of its availability. Three essential criteria for material selection are mechanical, chemical, and physical properties. Such as white cast iron, S.G. (ductile metal), and grey cast iron that is preferred to be material of the steering knuckle.

Properties of Mild Steel AISI 1018, Al alloy and Grey cast iron:

Table-1 Mild Steel AISI 1018 composition

Fe	C	P	Mg	S
98.81-99.26	0.14-0.20	0.04	0.60-0.90	0.05

Properties of alloy material are as follows:

- Density = 7870 kg/m³.
- Tensile yield strength = 370 MPa.
- Ultimate tensile strength = 440 MPa.
- Young’s modulus = 205 GPa.
- Shear Modulus = 80 GPa.

Mild steel is a good conductor, so it has weld ability which suits with any welding.

Table2. Aluminium-6082-T6 alloy composition

Al	Si	Mg	Mn	Fe	Cr	Zn	Cu	Ti	residual
95.2-98.3	0.7-1.3	0.6-1.2	0.4-1.0	0-0.5	0-0.25	0-0.2	0-0.1	0-0.1	0-0.15

The properties of alloy material are as follows:

- Density = 2710 kg/m³.
- Tensile yield strength = 270 MPa.
- Ultimate tensile strength = 330 MPa.
- Young’s modulus = 71 GPa.
- Shear Modulus = 26 GPa.

Table-3 Grey Cast Iron composition:

Fe	C	Si	Mg	P	S
93.2-94.1	3.2-3.5	1.8-2.4	0.5-0.9	<=0.2	<=0.2

The properties of grey cast iron:

- Density = 7200 kg/m³.
- Tensile yield strength = 0.
- Ultimate tensile strength = 240 MPa.
- Young’s modulus = 110 GPa.
- Shear Modulus = 42 GPa.

MODELLING

In the present work the knuckle is modeled in Solid works and further the analysis was carried out in Ansys workbench. During modeling the kingpin inclination is taken as 4-5 degrees for positive steering of the vehicle. The holes provided at the hard points are 15mm diameter which is suitable to use all the Original Equipment Manufacturer ball joints.



Fig -2: Knuckle Design in solid work

STATIC ANALYSIS

The load type which will be given is Static load, Moment braking force, and Cornering force. This simulation will be conducted in extreme condition to Accommodate big force that could actually happen. There are three types of load. [2]

- Static Load
- Cornering Load
- Braking Load
- Moment Braking Load

Static load is the amount of weight that is held by knuckle; the braking force is longitudinal load transfer during braking, then cornering is the force that pushes when knuckle starts to cornering. Moment braking force is applied in brake mounting, the braking moment is calculated by multiplying brake force with distance from center point of the knuckle to the center point of brake mounting. Knuckle is

designed to withstand the car and the driver’s mass, which approximately 315 Kg for four wheels.

Load Calculation

Total weight of the vehicle (4-wheeler) = 350 Kg.

Weight on front portion of vehicle = 50% = 175 Kg.

Weight on rear portion of vehicle = 50% = 175 Kg.

For one wheel = (175/2) = 87.5 Kg.

Loading types:

Bump condition = 3G = (3*9.81*87.5) = 2575 N.

Cornering condition= 3G = (3*9.81*87.5) = 2575 N.

Braking force =1.5G = (1.5*9.81*87.5) = 1287 N.

Force acting up on each brake mount =

$$(1287/2) = 643.7N.$$

Distance from knuckle centre to brake mount = 80 mm.

Moment acting up on each mount =

$$(\text{brake force per Mount} * \text{perpendicular distance}) = (643.7 * 80) = 51496 \text{ N-mm.}$$

Moment on upper brake mounting point = 51496 N-mm.

Moment on lower brake mounting point = 51496 N-mm.

displacement of the knuckle is minimum. And because of it, this knuckle gets high safety factor

RESULT AND DISCUSSION

Static analysis:

Static analysis was done in Ansys workbench. The combined load is given to the knuckle (Bump and cornering forces, moments on the brake mounting points). After applying the material properties the analysis is carried out.

Mild Steel AISI 1018

The below figure shows the factor of safety and total deformation of Mild steel AISI 1018.

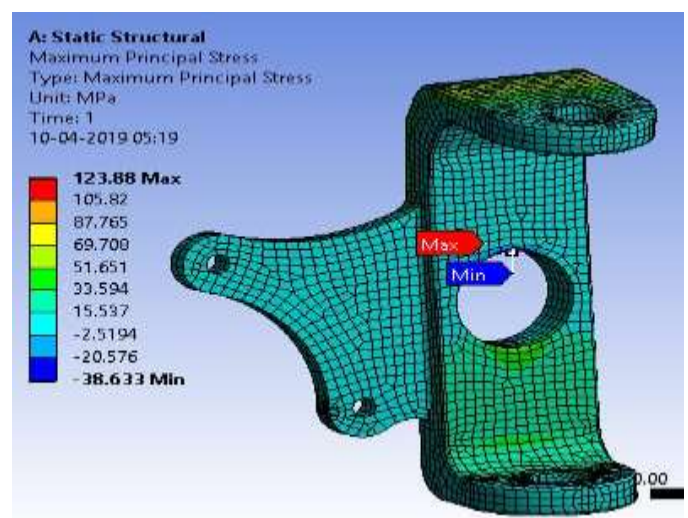


Fig - 5: Stress Distribution

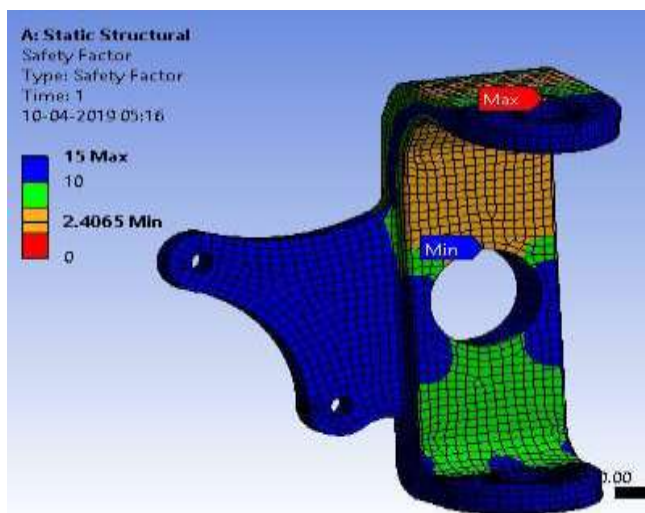


Fig - 3: Factor of safety

Figure 3 shows the safety factor number. It gets 15 for maximum and 2.4 for the minimum. 4.27 is safety enough, because the minimum target is 3. It’s as expected before, that stress is spreaded evenly in the knuckle, and this situation didn’t make the only little area that holds so the

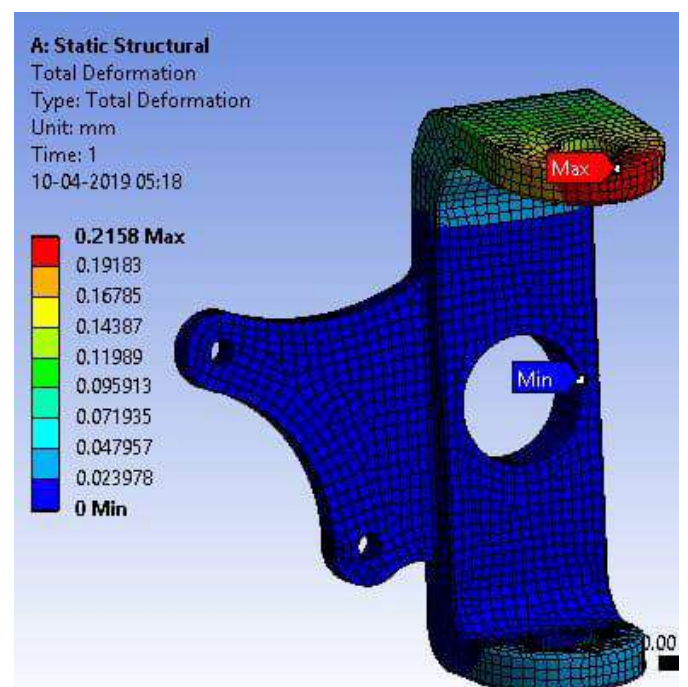


Fig -6: Total Deformation analysis

Al-6082-T6:

The stress distribution and total deformation of Al-6082-T6 material.

Maximum equivalent Stress = 103.98 MPa.

Maximum displacement = 0.090742 mm.

Grey cast iron:

The stress distribution and total deformation of Grey cast iron material.

Maximum Stress distribution = 103.73 MPa.

Maximum Total Deformation = 0.058524 mm.

RESULT

Factor of safety for all three materials are:

Factor of safety = Ultimate stress / Working Stress.

- For Mild steel AISI 1018 = $440/103 = 4.27$
- For Al-6082-T6 = $330/103.98 = 3.17$
- For Grey cast iron = $240/103.73 = 2.31$

CONCLUSION

From the above analysis it can be concluded that factor of safety is higher for Mild steel AISI 1018 than Al-6082-T6 and Grey cast iron this Also the above comparison shows that the knuckle design of Mild steel AISI 1018 is very safe to withstand a load of 857.5 N, 2575 N for cornering force, and double of 51496 N-mm for moment braking force, and there is no significant deflection happened after load. The right choice of material determines the strength of the knuckle. Mild steel is suitable for knuckle material because of its mechanical properties, which is hard and tough, ideal for the knuckles property needs, due to its light weight, metal characteristics and the ease with which it can be used. Finally Mild steel AISI 1018 material is selected and manufactured.

REFERENCES

- [1] J. Sri Harsha, D. V. Kumar Reddy, A. V. R. K. Teja, N. S. K. Teja, E. Bhargav Sai, "Imperial Journal of Interdisciplinary Research (IJIR)" Vol. 2, Dec. pp 315-318.
 - [2] Saputro, Bagus & Sabino, Ubaidillah & Triono, Dicky & Pratama, Dzaky & C., Sukmaji & Imaduddin, Fitriani. "Static load simulation of steering knuckle for a formula student race car. AIP Conference Proceedings". 1931. 030049. 10.1063/1.5024108
 - [3] Analysis of Steering Knuckle of All Terrain Vehicles (ATV) Using Finite Element Analysis To cite this article: S V Dusane et al 2016 IOP Conf. Ser.: Mater. Sci. Eng. 149 012133
 - [4] M. Prabhu, B. Babu, P. Dharmaraj, R. Sampath "Stress Analysis on Steering Knuckle Of The Automobile Steering System". International journal of Research in Engineering and Technology, Volume-3; issue-3, march-2014, page no. 363.
 - [5] Mahesh P. Sharma, Denish S. Mevawala, Harsh Joshi, Devendra A. Patil "Static analysis of steering knuckle and its shape Optimization". IOSR Journal of Mechanical and Civil Engineering, (ICAET- 2014), page no. 34.
 - [6] R. Prem Raj, K. Palpandi "Static analysis and Topology Optimization of Steering Knuckle using Finite Element Method". International journal of Innovative research in Science, Engineering and Technology, Volume-4; special issue-13, December-2015, page no. 201
 - [7] Tune to Win by Carroll Smith, Aero publishers, Inc. 1998.
- DuVall, J.B., and Hillis, D.R. Manufacturing Process: Materials, Productivity, and Lean Strategies 3rd Edition (The Goodheart-Willcox Company, Inc, Lincoln, 2012)