International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.03, April 2018
www.ijarse.com

IJARSE
ISSN: 2319-8354

TOPOLOGICAL OPTIMIZATION OF STEERING KNUCKLE BY USING ADDITIVE MANUFACTURING PROCESS

Prof.P.S.Gorane[1],Mr. Piyush Jain[2]

Mechanical engineering, G. S.Mozecollege of engineering, Savitri Bai Phule Pune University, India

ABSTRACT

Additive manufacturing enables increased geometric complexity in structural configuration compared with conventional manufacturing methods. A Physics-first Computer Aided engineering (CAE) process beginning with structural topology optimization enables engineers to take advantage of this increased geometric design freedom. This work develops and demonstrates the steps and tools necessary to realize complex design configuration for additive manufactured. This report looks at the race car steering knuckle using the UTA FSAE upright as a case study. The stiffness driven upright component design is executed using topology optimization and NURBS based surface modeling tools. The topology optimization model is developed for 3 different load conditions driven by a maximum stiffness objective and volume fraction constraint. The resultant coarse, noisy, meshed isosurface is then translated to smooth Non Uniformed Rational Basis Spline (NURBS) based geometry. This work outlines the geometric operations and complexities involved in realizing the design. This process development effort shows the current capabilities and limitation of commercial Computer Aided Design (CAD) software and outlines procedures to realize complex design configurations for additive manufacturing.

Keywords:Desgn Analysis

I.INTRODUCTION

A knuckle is a primary component in the wheel assembly of the vehicle which supports the tie rod, brake caliper, & wheel to give stability. The critical part in the knuckle is the steering control arm. Stresses are more due to wheel toe in and toe out as the wheel travel is more for all terrain vehicles.

In this work the knuckle is designed for good factor safety and then manufactured using additive manufacturing technology so as to optimize the earlier design by shape optimization. The knuckle is modeled in Solid works software and the analysis is carried out in Ansys workbench.

Main design and functionality of steering knuckle depends on type of suspension implemented. Additionalfactors like brake caliper used, mounting of tie rod of steering sub-system also effects knuckle design. Suspension system in any vehicle uses different types of links, arms, and joints to let the wheels move freely; front suspensions also have to allow the front wheels to turn. Steering

knuckle/spindle assembly, which might be two separate parts attached together or one complete part, is one of these links.

The knuckle is tested under different loading conditions like Bump, Cornering and Braking. For carrying out the analysis type of material used is structural steel. After analysis the material that has less deformation and good factor of safety is selected and further conventional manufacturing process was done. After the optimization knuckle is manufactured using Additive manufacturing process.

Additive manufacturing process like 3D printing is been used to manufacture the knuckle which is optimized by changing shape will automatically reduce the weight. Also the process time required is minimized due to the 3D printing. Also by using conventional machining processes the machining of knuckle was complex due to the use of 3D printing complex part was easy to manufacture.

This report gives the details about the topological optimization of steering knuckle.

III.DESING OF STEERING KNUCKLE

The components like brake calipers, tie rod, ball joint, upper arm and lower arm will be connected to knuckle hard points. The wheel is assembled to it based upon hub and spindle. For good performance of vehicle, we have to reduce the un-sprung mass, which includes 90% of wheel assembly weight.

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 is must be very strong and rigid. The knuckle is designed based upon the parameters like kingpin axis inclination angle, caster angle, distance between upper and lower hard points and steering knuckle position. For positive steering the kingpin inclination should be 4-5 degrees.

A knuckle component is required to support the load and torque induced by bumping, braking and acceleration. A knuckle is conventionally manufactured by forging and casting. Casting may have blow holes which will result in failure of component, so the forged metal that is free of blow holes is used for manufacturing knuckle and material should be of light weight. Good factor of safety is necessary for the vehicle to withstand in bad conditions.

There are several materials used for manufacturing of steering knuckle such as S.G. iron (ductile iron), white cast iron and grey cast iron. Forged steel is generally used for this application. For this application we are using structural steel. The mechanical properties of structural steel are as follows,

Young’s Modulus (E): 210000Mpa

Modulus of rigidity (G): 81000Mpa

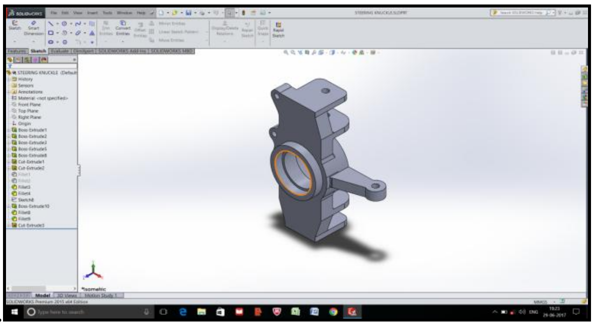
Poisson’s Ratio (υ): 0.3

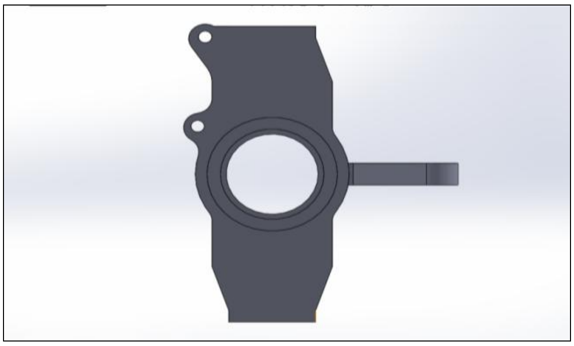
IV.MODELING

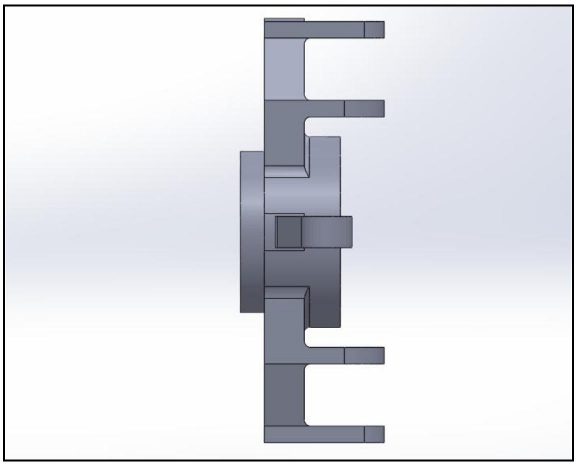
In the present work the knuckle is modeled in Solid works and further the analysis was carried out in Ansys workbench. During modeling the kingpin inclination is taken as 4-5 degrees for positive steering of the vehicle. It consists of stub hole, brake caliper mounting points, steering tie-rod mounting points, suspension upper and lower A-arm mounting points. Knuckle design mainly depends on suspension geometry and steering geometry. The holes provided at the hard points are 15mm diameter which is suitable to use all the Original Equipment

Manufacturer ball joints.

Following image shows the original model of knuckle before optimization







V.ANALYSIS OF KNUCKLE

The CAD model is converted to STEP file and is imported to Ansys workbench. The errors in geometry were corrected and the component is meshed. The type of mesh selected is fine mesh. Static structural analysis was carried out for knuckle. To observe maximum stress produce into steering knuckle, model is subjected to extreme conditions and static analysis is carried out in Ansys Workbench.

Steering knuckle was constraint at A arms mountings. Steering force from tie rod to steering knuckle was analytically calculated and applied to knuckle with its self weight. A combined load of 1.5g braking force and 1.5g lateral acceleration were applied to the model considering the longitudinal load transfer during braking and lateral load transfer during cornering.

Loading Conditions	
Braking Force	1.5G
Lateral Force	1.5G
Steering Force	Steering effort of 40-50 N

Load on Knuckle hub X- Direction	3G
Load on Knuckle hub Y- Direction	3G
Load on Knuckle hub Z- Direction	1G

Loads applied on loading points are,

A – Fixed Supports

B – Moment: 36.37 N-m

C – Moment 2: 36.37 N-m

D – Moment 3: 36.37 N-m

E – Force: 4359.9 N

Fig.1

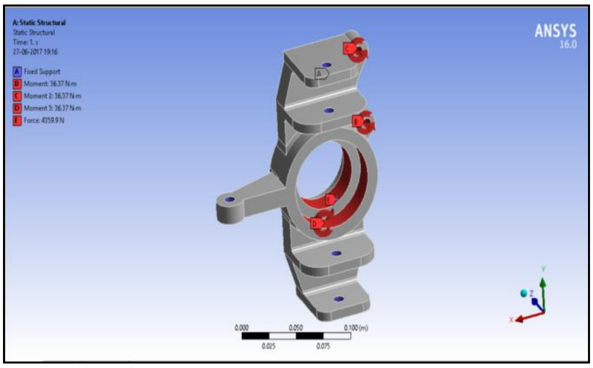
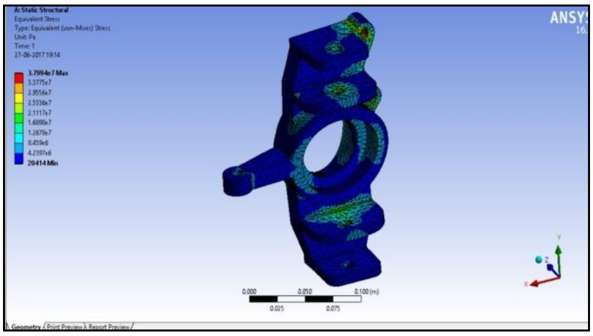


Fig.2



VI.RESULT TABLE

Table No.1

Stress Produced	
Equivalent Stress	37.99 MPA (Max.)
Total Deformation	0.0389 mm

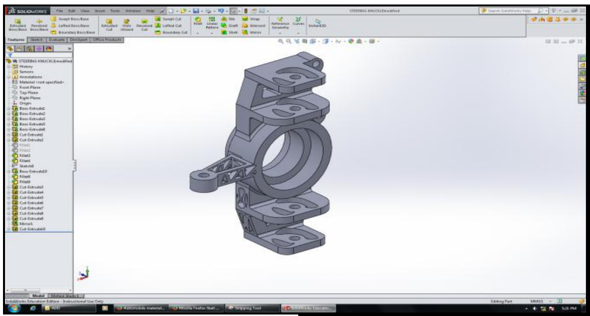
IJARSE
ISSN: 2319-8354

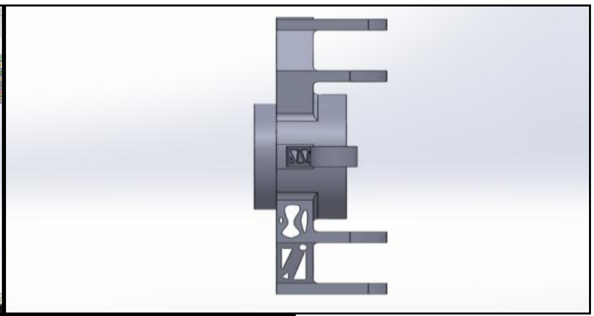
VII.TOPOLOGICAL OPTIMIZATION

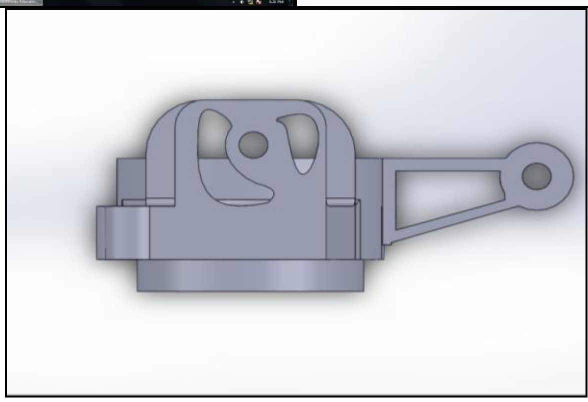
Topology optimization is different from shape optimization it is used once the component's topology has already been defined. *Topology optimization* (TO) is a mathematical method that optimizes material layout within a given design space, for a given set of loads, boundary conditions and constraints with the goal of maximizing the performance of the system. Shape optimization is technique to modify the structural shape based on predefined shape variables to obtain optimal shape. Size optimization defines ideal component parameters, such as material values, cross-section dimensions and thicknesses.

Topology optimization is used to generate material layout concepts whereas shape optimization refines and improves the topology within the concept. In shape optimization, the outer boundary of the structure is modified to solve the optimization problem. The purpose of a shape optimization analysis is to find the best use of material for a body. Typically this involves optimizing the distribution of material so that a structure will have the maximum stiffness for a set of loads. In this paper, optimization of knuckle was done by using Ansys Workbench Topology Optimization. Here objective function is to reduce weight of knuckle using additive manufacturing process which is generated by using layer technique. Design constraints are applied as in static analysis.

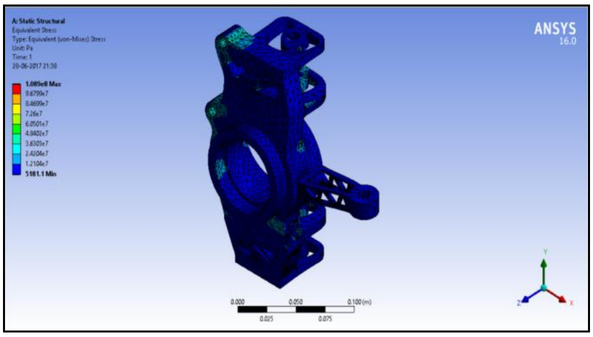
Following figures shows the optimised model of knuckle and further analysis using Ansys workbench. Same load conditions were used for optimised knuckle and the stress produced and the total deformation is foun out using Ansys workbench.

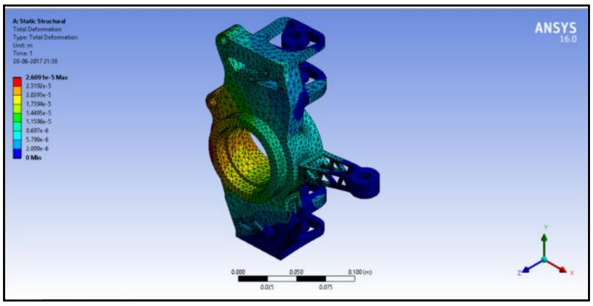






International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.03, April 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354





VIII.RESULT TABLE

For optimized knuckle the stress produced and the deformation found is given as follows.

Table No.2

Stress Produced	
Equivalent Stress	108.9 MPA (Max.)
Total Deformation	0.02609 mm

IX.CONCLUSION

Initial model of knuckle is shown in Fig.1. It has max. stress of 37.99 MPA. After applying load and design constraints shape was changed with topological optimization was performed. Fig.4 shows material which was removed from model after optimization. The objective of the research is to reduce the mass (represented by reduction volume) using shape and topological optimization which was successfully attempted. For manufacturing of this knuckle additive manufacturing process like 3D printing can be used. Which supports the topological optimization of the knuckle.

REFERENCES

1. Rao, S.S., *Engineering Optimization Theory and Practice*(John Wiley & Sons, Inc., 2009, 4th edition).
2. Wan Mansor Wan Muhamad, Endra Sujatmika, Hisham Hamid, & Faris Tarlochan,' Design improvement of steering knuckle using shape optimization' 2012.
3. Thomas D. Gillespie, *Fundamental of vehicle dynamics* (society of automotive engineers)
4. https://en.wikipedia.org