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Topology Optimization of Steering Knuckle for Additive Manufacturing

Jawahar Raja[1], Jeshurun Paul[2], Kannan[3], Toral Anandkumar[4]

1(Mechanical Department, Meenakshi Sundarajan Engineering College, and Chennai
Email: rajajawahar97@gmail.com)

2 (Mechanical Department, Meenakshi Sundarajan Engineering College, and Chennai
Email:jeshupauls@gmail.com)

3(Mechanical Department, Meenakshi Sundarajan Engineering College, and Chennai
Email: kannanmc12@gmail.com)

4(Mechanical Department, Meenakshi Sundarajan Engineering College, and Chennai
Email: tdgandhi@gmail.com)

Abstract:

The main objective of the project is to redesign the steering knuckle in such a way that the material could be reduced without affecting its functionalities, as it is one of the major components of the vehicle system. It connects the wheel, suspension system and the steering of the vehicle. By the process of optimization, the topology of the steering knuckle gets more complex when compared to the normal one. The process of doing so with the help of finite element is called Topology Optimization. The finite element analysis is done for the unoptimized steering knuckle and for the iterations of optimized components, the finite element analysis values of the iterations are compared and the most effective design is selected from all the three iterations. The optimized component can be manufactured by additive manufacturing processes, like Powder Bed Fusion, Material Extrusion, Vat polymerization, as it is the only process in which complex shapes can be manufactured with ease. And thus finally a weight reduction of about 55% is obtained using Topology Optimization for the steering knuckle.

Keywords* — *Topology, additive manufacturing, steering knuckle, optimization

I. INTRODUCTION

The increasing pollution drives the entire world to stick with stringent norms for vehicles, but this cannot be achieved overnight and with just finding out new materials of less weight. Topology optimization along with additive manufacturing gives the solution to this with humungous reduction in material without compromising strength.

II. TOPOLOGY OPTIMIZATION

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. TO is different from shape optimization and size optimization in the sense that the design can attain any shape within the design space, instead of dealing with predefined configurations.

The conventional TO formulation uses a finite element method (FEM) to evaluate the design performance. The design is optimized using either gradientbased mathematical programming techniques such as the optimality criteria algorithm and the method of moving asymptotes or non-gradient based algorithms such as genetic algorithms.

Topology Optimization has a wide range of applications in aerospace, mechanical, bio-chemical and civil engineering. Currently, engineers mostly use TO at the concept level of a design process. Due to the free forms that naturally occur, the result is often difficult to manufacture. For that reason the result emerging from TO is often fine-tuned for manufacturability. Adding constraints to the formulation in order to increase the manufacturability is an active field of research. In some cases results from TO can be directly manufactured using additive manufacturing; TO be thus a key part of design for additive manufacturing.

III. ADDITIVE MANUFACTURING

Additive manufacturing is any of various processes in which material is joined or solidified under computer control to create a three-dimensional object, with material being added together (such as liquid molecules or powder grains being fused together), typically layer by layer. 3D printing techniques were considered suitable only to the production of functional or aesthetical prototypes and, back then, a more comprehensive term for 3D printing was rapid prototyping. Today, the precision, repeatability and material range have increased to the point that 3D printing is considered as an industrial production technology, with the name of additive manufacturing. 3D printed objects can have a very complex shape or geometry and are always produced starting from a digital 3D model or a CAD file.

IV. STEERING KNUCKLE

In automotive suspension, a steering knuckle is that part which contains the wheel hub or spindle, and attaches to the suspension and steering 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 knuckle we have chosen is a double wishbone type from a SAE baja vehicle which is an All-Terrain Vehicle (ATV).

V. OPTIMIZATION AND ANALYSIS

We carried out our design using creo parametric 2.0 software and for optimization purpose we used Altair Inspire Solid Thinking student edition software. This is an iterative process which goes on until you are satisfied with your objective of material reduction without compromising the strength. Material chosen for our analysis is: Structural steel, the properties of which are as follows

A. material properties

Minimum yield stress	250MPa
Ultimate tensile stress	400-550MPa
Young's Modulus	200Gpa
Poisson's ratio	0.26
Density	7800kg/m3

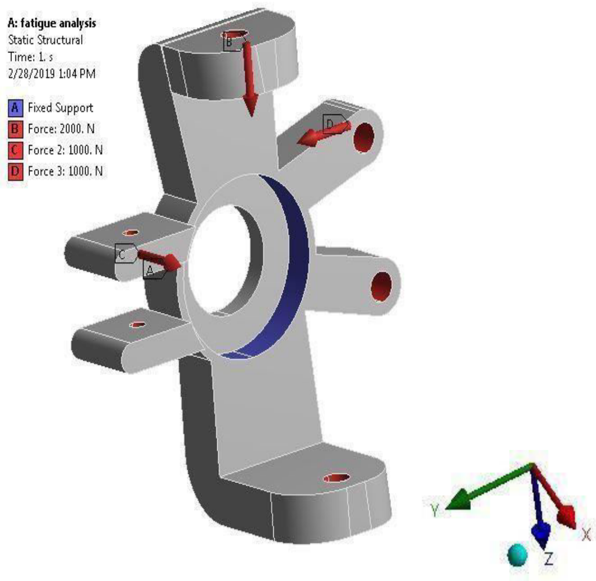

Fig. 1 Boundary conditions of steering knuckle

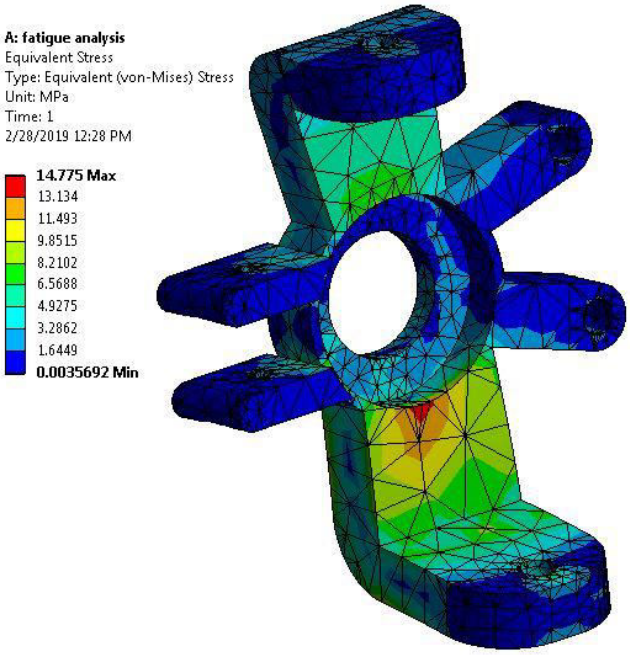

Fig.2 stress analysis of unoptimized knuckle

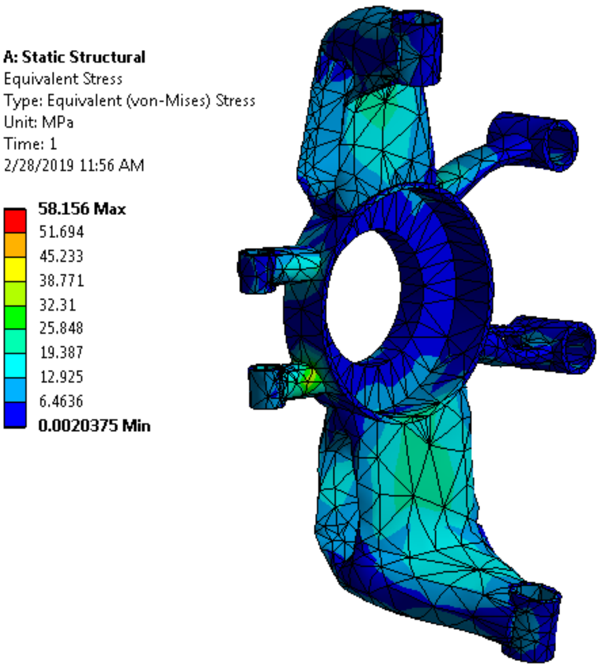

Fig. 3 stress analysis of optimized component with 55% material reduction

Out of three iterations that we have done we found second iteration of 55% material reduction satisfied our objectives.

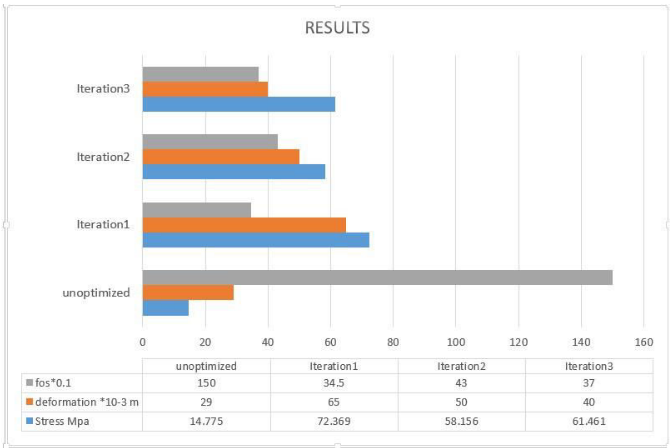

Fig.4 comparison of three iterations with unoptimized one

V.CONCLUSION

Additive manufacturing is already in market in various industries like aircraft, children accessories, etc. by incorporating this in automobile sector with topologically optimized components will see a drastic reduction in material usage, organic shaped structures, which will lead to reduction in fuel consumption thus finally a significant reduction in pollutant emission. The cost of AM machines might seem to be costly but the benefits will outweigh the costs like large amount of material reduction, freedom in design, elimination of tooling, jigs & fixtures design and cost, reduction in emissions, increased performance of vehicle due to less weight and more importantly increased customer satisfaction.

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REFERENCES

1. *Ian Gibson, David Rosen, Brent Stucker, "Additive Manufacturing Technologies" Springer, Second edition 2015.*

2. *Jalaludeen. S. Md, "Finite Element Analysis in Engineering" Anuradha Publications, 2016 edition.*

3. *Kamlesh Lalasaheb Chavan, Sanjay Deodas, Swapnil Shashikant Kulkarni, "Mass Reduction for Steering Knuckle Arm in a Suspension System through Topology Optimization in CAE" International Journal of Advanced Engineering Research and Studies, December 2014.*

4. *Pilla Anitha , V. Hari Shankar, "Design and Topology Optimisation of a Steering Knuckle joint using FEA" Department of Mechanical Engineering. Visakha Technical Campus, Narava, November 2016.*

5. *Pooja Chavan, Dr. D.N. Kamble, "Design Optimization of Integrated Steering Knuckle" International Engineering Research Journal (IERJ), November 2015.*

6. *R.Prem Raj, K.Palpandi, "Static Analysis and Topology Optimization of Steering Knuckle by Using Finite Element Method" International Journal of Innovative Research in Science, December 2015.*

7. *Santosh Gowda K R, Dr. A R Anwar Khan & Mohammed Imran, "Topology Optimization of Steering Knuckle using Finite Element Analysis" International Journal for Ignited Minds (IJIMIINDS), September 2016.*