Topology Optimization of Student Car Steering Knuckle

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Abstract - *In the era where using less material more effective products being created , topology optimization plays important role . Due to advance manufacturing processes like 3D printing ,optimized model can be made more efficiently and accurately . Current paper describes research work carried out to perform topology optimization of front knuckle of two sitter student car . Knuckle is optimized by controlled deformation . Optimized knuckle reduces overall weight by keeping deformation minimal . The methodology is also applied to optimize structural elements utilized in applications wherever the quantitative relation of desired properties to the price, typically in terms of weight, is to be optimized. Within the case of cars, strength to weight quantitative relation should be maximized. New researchers operating within the space can have associate degree understanding of the procedures, and more, the techniques is also applied to style normally.*

Keywords—car, knuckle , 3D printing, topology, topology optimization

1. INTRODUCTION

Topology Optimization is a mathematical technique that improves material layout in between a specified design area, for a predetermined set of loads, boundary conditions, and constraints with the goal of accumulating the efficacy of the system. TE is completely different from form Improvement and filler Optimization within the sense that the planning will attain any form at intervals in the planning area, rather than addressing predefined configurations styles are provided. The formatter will need to create these components, featuring the applicable criteria that follow.

The conventional TE formulation uses a finite component technique (FEM) to judge the planning performance. The plan is to optimized victimization either by gradient primarily based mathematical programming techniques like the optimality criteria rule and also the technique of moving asymptotes or non-gradient-based algorithms like genetic algorithms. Topology Optimization features a big selection of applications in part, mechanical, biochemical, and technology. Currently, engineers largely use TO at the construct level of a styling method. Thanks to the free forms that naturally occur, the result's is usually tough to manufacture. For that reason, the result rising from TO is commonly fine-tuned for manufacturability. Adding constraints to the formulation so as to extend the manufacturability is a vigorous field of analysis. In some cases results from TO are often directly factory-made victimization additive producing; TO is so a key part of style for additive manufacturing. The traditional solutions for structural Optimization issues in buildings were determined by the utilization of direct search ways on isotropous Solid and Empty topology. In topology, the weather square measure is either crammed by a given isotropous material or doesn't contain any material. However, thanks to the massive range of parts, the appliance of direct search ways on AN ISE topology was found to be computationally extraordinarily expensive. Therefore, since the Eighties, the most focus during this space has been to develop additional economical ways to get quick solutions. within the scientific literature, there square measure various techniques to perform a topology optimization; the hottest ways square measure the Solid isotropous Material with punishment technique and also the biological process Structural Optimization technique. The SIMP technique relies on deciding the optimum structure by variable the fabric density at intervals in the predefined domain. The predefined domain is discretized in parts and a finite component analysis is applied to work out the structure performance. Conceptually, the SIMP technique includes a Analysis of the domain followed by an Optimization of the density of every element of the domain. Afterward, the configuration with the new component densities is analysed, and also the optimization is performed once more.

1.1 LITERATURE REVIEW

[1] Aurabh Srivastav ,Sachin salunkhe ,Sarangp and Bhavin kapadiya ,(topology optimization of steering knuckle system) et.al [2019] This paper aims to reduce the mass of steering knuckles used in vehicles by applying the principles of Finite Element Analysis, CAD modeling and calculating the various forces acting on steering knuckle, and developing a topologically optimized version of the steering knuckle . Generally, knuckle in a steering structure is overdesigned. So, the strategy of using the topology enhancement technique as a tool to design the shape of the knuckle joint, in order to make it lightweight has proven to be successful. A reduction of up to 19% in original weight was obtained without compromising its initial performance of steering knuckle.

[2] A.W. Gebisa and H.G. Lemu ,(case study on topology optimized design for additive manufacturing) et. Al [2017] The paper explores the role of topology optimization in additive manufacturing to design a lightweight product. Here, a case study on a jet engine bracket is considered to show the potential of Topology optimization in reducing the weight of a product when coupled with additive manufacturing. The

engine bracket is redesigned considering four loading conditions, while also satisfying the design requirements. The reduction of weight saves a huge amount of material and processing energy, thus also economically efficient at the same time. Results showed that additive manufacturing coupled with topology optimization provides powerful means of reducing the weight without any hindrance of the conventional methods. A weight reduction of 65% was achieved reducing the mass of the components from 2.067 kg original part to 0.72 kg final one.

[3] P. Chaudhari , R. khairnar ,(Weight optimization of hub and knuckle) et al June 2020 – This paper presents systematic weight optimization of hub and knuckle using Topology Optimization technique. The purpose of this research paper is to design a Knuckle and wheel Hub having a minimum weight and maximum strength using Topology optimization. Results obtained show a weight reduction of 24.09% for Hub and 16.30% for Knuckle after weight Optimization. Aluminium 6061-T6 alloy and ENS were found best material due to its better physical and Mechanical properties also it is light in weight. Results also show that Knuckle and Hub are having below stress value and less deflection under given applied Load.

[4] S.R. gore , K.K Gund , Pm Patane , Nv Mohite , C.V chimote(topology optimization of automotive steering knuckle using finite element method) et al,March 2017 – The aim of this paper is to perform a Finite Element analysis on Steering Knuckle. While analyzing steering Knuckle three cases are to be considered Bumping, Braking, and Steering combined loading after analysis is to be optimized. Optimized Knuckle analysis shows that the maximum stress value occurs for combined loading conditions at the inner side of suspension and arm near Hub. The existing knuckle is reduced from 5.320 kg to 4.60 kg giving a mass reduction of about 13.20%.

1.2 OBJECTIVE

After enhancement by planning and analysis exploitation FEA convergent thinker , a 9.8% reduction of weight and volume obtained while not compromising the initial performance of steering knuckle. Topologically, optimization of management arm is employed in Associate in Nursing automobile to cut back its weight and improve Performance Enhancement. Optimal topologies and their corresponding essential buckling hindrances were obtained. Through the 3D approach, the study has conjointly been carried out to find incontestable variations in bending and shear on the length of a column that leads to a non-uniform cross-section. The goal is to style a knuckle that has an Associate in Nursing optimum weight. Here, the knuckle is redesigned in SOLIDWORKS by considering different loads acting on knuckle, followed by hand calculations and performing the Finite Element Analysis in Ansys Discovery by considering various Iterations .Topology Enhancement ends up the uneven surface of boundaries that is to be changed manually in step with sensible necessities. Topology optimization is often administrated to cut back the load of the structure while not compromising the meant performance. Thus, the general potency of a vehicle is hyperbolic. The application of TE is chosen as a tool to style the form of the knuckle joint, creating it lightweight.

2. THEIROTICAL DESIGN

A. Steering calculations

- Turning radius (Ro) = 45824.25mm
- Outer wheel angle= 28.6
- Tie rod length = 460.53mm
- Rack travel= 56.07mm
- Number of teeth on pinion =16
- Rack length=152.60mm

B. Suspensions

- Front bulk head = width= 650mm, height =350mm
- Ground clearance = 10 inches
- Wheel = 24 inches
- Track width= 1400mm
- Rim consideration= 9 inches
- Wheel offset = +45 mm
- KPI=7degree
- Length of knuckle = 150mm
- CG= 431.80
- Weight distribution is 45 in front and 55 in rear
- Antidive =60%
- Crossoverhead =300mm

C. Suspensions

- Initial velocity of car = 60 kmph
- Mass pf vehicle = 250kg
- Piston diameter = 200 mm
- Disc diameter = 27.5mm
- Force on calliper mount =10528.6n

2.1 CAD DESIGN

A. Steering design

To design a knuckle we have to design steering geometry following fig.[1] shows steering system design which is done by considering steering calculations. By using SOLIDWORKS

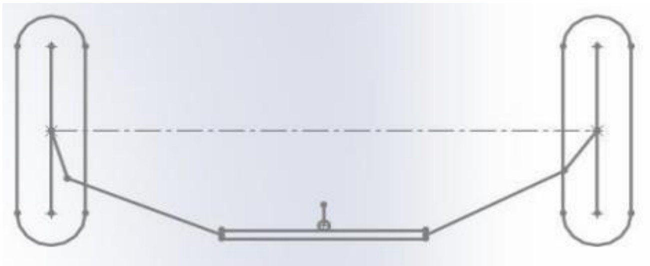


Fig.[1]

B. Suspension

After steering system design we have to design suspension system for that we have to design front view of system by using SOLIDWORKS as shown in Fig[2]

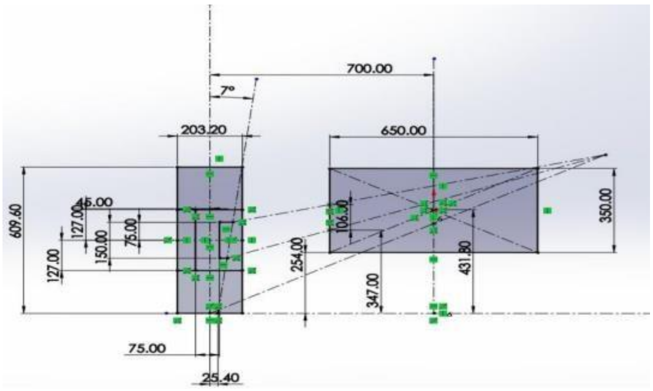


Fig.[2]

After designing front view of suspension system we have to design side view of suspension system by considering front view of suspension system , steering system and suspension calculations by using SOLIDWORKS as shown Fig.[3]

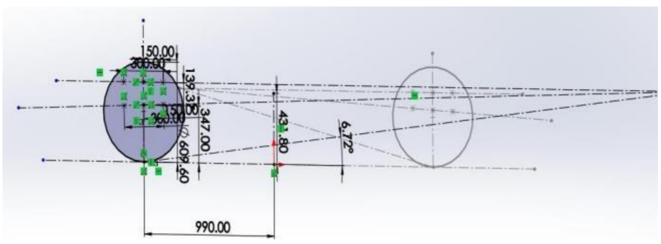


Fig.[3]

C. Chassis design

After completing suspension system and steering system by taking both system into account we have to design chassis by using SOLIDWORKS as shown in Fig.[4]

We have used circular pipes as structural members for more strength of structure.

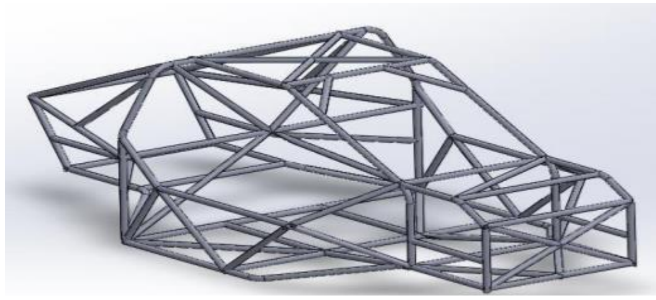


Fig.[4]

D. Merging of suspension and steering geometry into chassis

After designing of chassis we have to assemble suspension system and steering system into chassis to get positioning of A arms position of suspension system length of tie rod, and then to find hard points in SOLIDWORKS as shown in Fig[5]

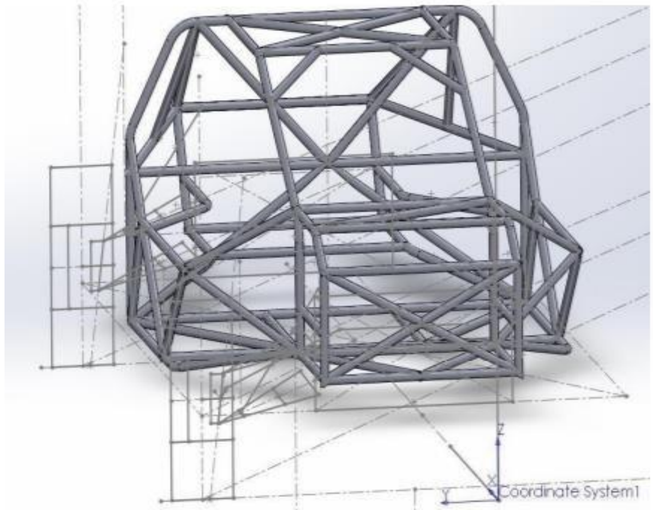


Fig.[5]

E. Analysis of suspension system on lotus shark

After assembling suspension system and steering system with chassis we get the coordinates of suspension system, after that we import those coordinates into lotus shark and perform bump analysis, steer analysis and roll analysis. Finally ,we confirm the coordinates of suspension system.

F. Analysis of suspension system on lotus shark

After design and analysis of suspension system by taking into consideration of steering and suspension system along with chassis we have to design a knuckle by using using SOLIDWORKS as shown in Fig.[6]

By considering KIP , camber , caster , positions of upper and lower ball joints , rim clearance , hub positioning, ackermann arm length , ackermann arm position we have to design knuckle.

In the Knuckle design , knuckle has caliper mounted so we have to take into consideration the caliper mountings by selecting caliper.

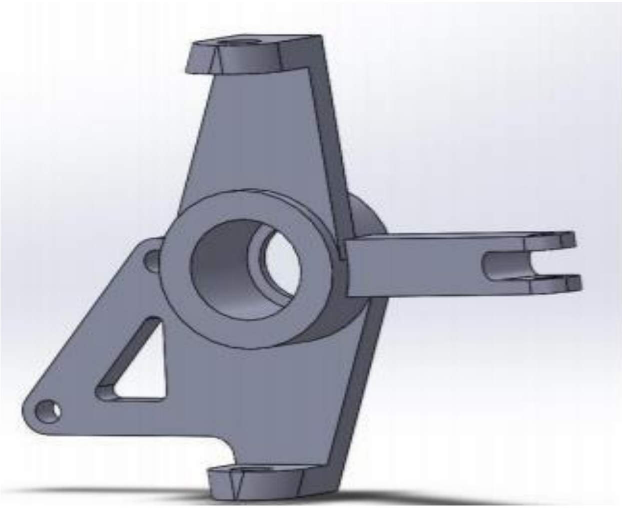


Fig.[6]

Fig.[7] shows loads acting on knuckle each color arrow demotes different forces.

- F_{us}=2200N
- F_{uch}=970N
- F_{ucv}=1706.2N
- F_{ls} =3683.16N
- F_{lch}=1066.6N
- F_{lcv}=182N
- F_{sb}=328.66N
- F_{b}=10582.6N

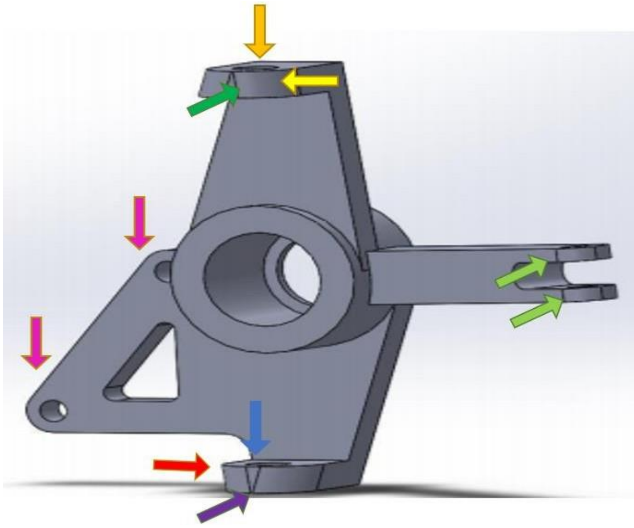


Fig.[7]

2.2 MATERIAL

We have decided AL7075-t6 material for knuckle this material is widely used to manufacture to manufacture knuckle due to its strength and light weight properties. following are properties of AL 7075-t6

- Yong's modulus -7.20e+04
- Shear modulus – 26.9e+03
- Yield strength – 5.03r+02
- Poisson's ratio – 0.33
- Density – 2.81g/cm^3
- Elastic modulus- 72.0 Gpa

2.3 BOUNDARY CONDITIONS

After calculating loads on knuckle we have to apply these loads as boundary conditions and by applying cylindrical support in place where bearing is going to be fixed.

2.4 RESULTS

By taking boundary conditions into account and using ANSYS Discovery we have to perform stress analysis and topology optimization. Following are results of iterations initial weight of knuckle is 4,302.51 grams

A. 3% of weight reduction

After applying all the boundary conditions in ANSYS Discovery we have achieved 3% of weight reduction without any discontinuity.

3% weight reduction	***maximum***	***minimum***
Stress (Mpa)	209	0.343
Deformation (mm)	0.504	0

Table.[1]

5% weight reduction	*maximum*	*minimum*
Stress (Mpa)	205	0.233
Deformation (mm)	0.489	00

Table.[2]

We achieved 129.07 grams of weight reduction. Final weight of knuckle becomes 4,173.43 grams

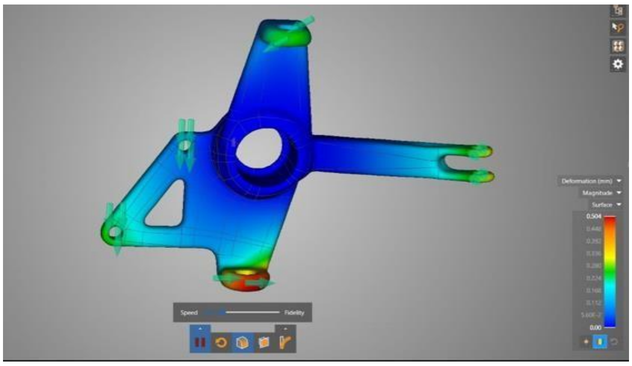


Fig.[8]

Fig.[8] shows deformation analysis on 3% weight reduced knuckle

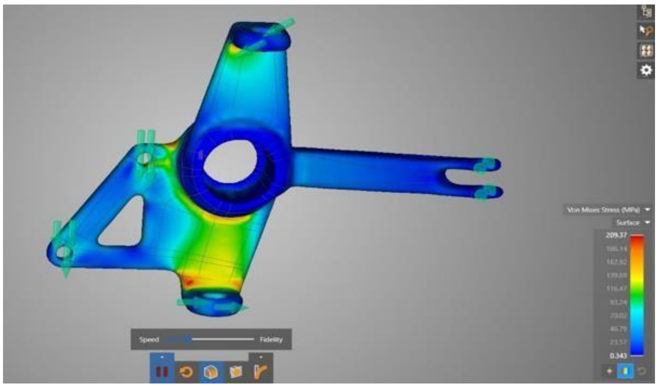


Fig. [9]

Fig.[9] shows stress analysis of 3% weight reduced knuckle.

B. 5% of weight reduction

After applying all boundary conditions in ANSYS Discovery we have achieved 5% of weight reduction without any discontinuity.

We have achieved 215.12grams of weight reduction .To reduce knuckle to 4,087.38 grams

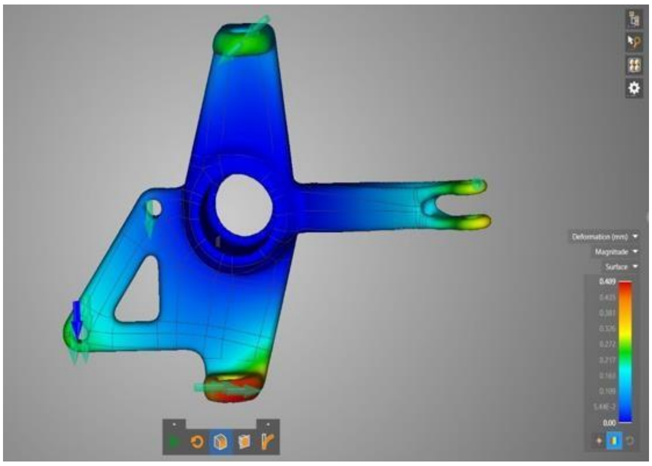


Fig.[10]

Fig.[10] shows deformation analysis on 5% weight reduced knuckle

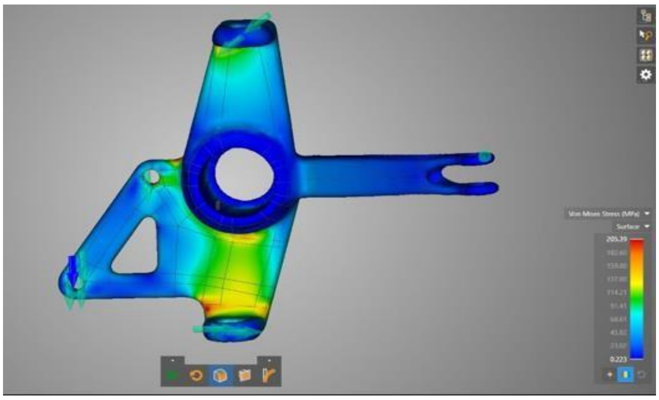


Fig.[11]

Fig.[11] shows stress analysis of 5% weight reduced knuckle.

C. 8% of weight reduction

After applying all boundary conditions in ANSYS Discovery we have achieved 8% of weight reduction without any discontinuity.

8% weight reduction	*maximum*	*minimum*
Stress (Mpa)	231.55	0.230
Deformati on(mm)	0.494	00

Table.[3]

Table.[1]

We have achieved 344.20grams of weight reduction. Final weight of knuckle becomes 3,958.31 grams .

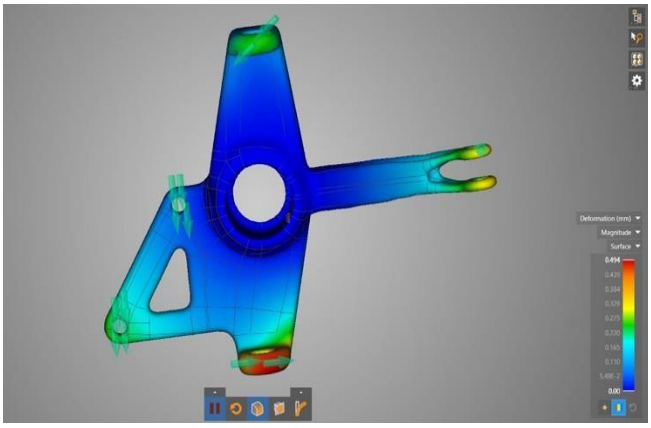


Fig [12]
Fig.[12] shows deformation analysis on 8% weight reduced knuckle

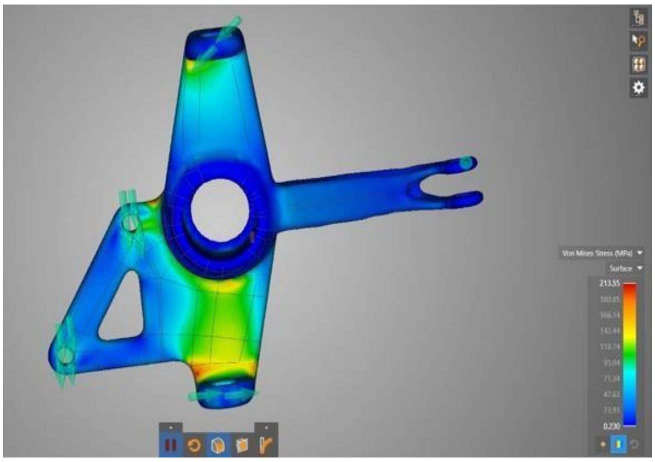


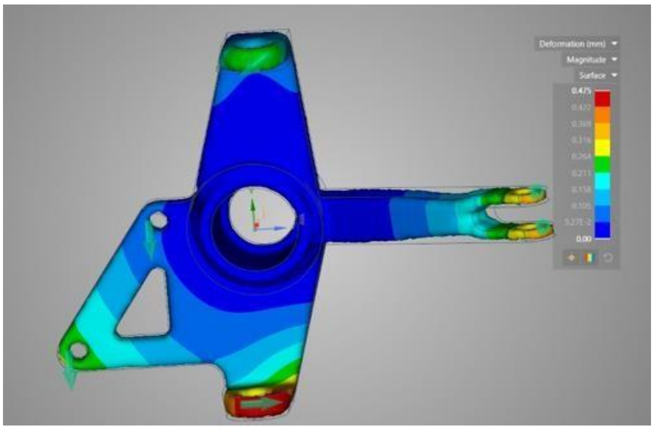
Fig.[13]
Fig.[13] shows stress analysis of 8% weight reduced knuckle.

D. 9.8% of weight reduction

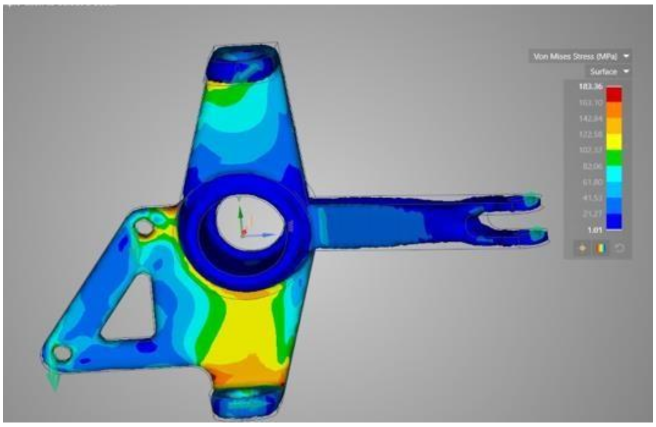
9.8% weight reduction	***maximum***	***minimum***
Stress (Mpa)	18.36	1.01
Deformation (mm)	0.475	00

Table [4]

We have achieved 421.64 grams of weight reduction Final weight of knuckle becomes 3,880.86 grams .



Fig[14]
Fig.[14] shows deformation analysis on 9.8% weight reduced knuckle .



Fig[15]
Fig.[15] shows stress analysis of 9.8% weight reduced knuckle.

3. CONCLUSION

After taking iterations up to9.8%percent weight reduction deformation and stress values were in acceptable amount and after 9.8% of weight reduction there was discontinuity in Ackermann arm so that we have to finalize 9.8% of reduction of weight as our final Iteration . Initial weight of knuckle was 4,302.51 grams after 9.8% of weight reduction final weight of knuckle become 3,880.86 grams.

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