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DESIGN AND TOPOLOGY OPTIMISATION OF A STEERING KNUCKLE JOINT USING FEA

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Abstract- Weight reduction is now the main issue in automobile industries. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The weight of the vehicle is going on increasing due to additional luxurious and safety features. Steering Knuckle is one of the critical components of vehicle which links suspension, steering system, wheel hub and brake to the chassis. It undergoes varying loads subjected to different conditions, while not affecting vehicle steering performance and other desired vehicle characteristics.

This project focuses on optimization of steering knuckle targeting reducing weight as objective function with required strength, frequency and stiffness. In automotive suspension, a steering knuckle is that part which contains the wheel hub or spindle, and attaches to the suspension 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.

Here the optimisation refers to different cases in the shape optimisation and also the topology optimisation. The modeling of this project is done in Creo Parametric 2.0 and the analysis is carried out in Ansys 15.0.

Index Terms- *Creo parametric 2.0, design optimization, stable plane motion, weight reduction.*

I. INTRODUCTION

In automotive suspension, a steering knuckle is that part which contains the wheel hub or spindle, and attaches to the suspension 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 steering knuckle carries the power thrust from tie rod to the stub axle and hence it must be very strong, rigid and also as light as possible. In the case of automobile vehicle, during steering and turning the steering knuckle is subjected to compressive and tension loads and due to the wheel rotation it is also subjected to torsional load. Steering knuckle for automobile applications is typically manufactured either by forging or from casting. However, castings could have blow-holes which are detrimental from durability and fatigue points of view. The fact that forgings produce blow-hole-free and better parts gives them an advantage over cast parts.

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturer in the present scenario. The introduction of composite materials has made it possible to reduce the weight of the steering knuckle without any reduction on load carrying capacity and stiffness. So, composite materials are now used in automobile industries to take place of metal parts.Since the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel. Composite materials offers opportunity for substantial weight saving.

II. PROBLEM IDENTIFICATION

Due to its large volume production, it is only logical that optimization of the steering knuckle for its weight or volume will result in large-scale savings. It can also achieve the objective of reducing the weight of the vehicle component, thus reducing inertia loads, reducing vehicle weight and improving vehicle performance and fuel economy.

So considering automobile development and importance of relative aspect such as fuel consumption, weight, riding quality, and handling, hence development of new material is necessary in the automobile industry.

In spite of different configurations of the steering knuckle/spindle assembly for each type of vehicle suspension, the assembly is intended to play a common role in all type, and that is to accommodate the service loading.Mass or weight reduction is becoming important issue in car manufacturing industry. Weight reduction will give substantial impact to fuel efficiency, efforts to reduce emissions and therefore, save environment. Weight can be reduced through several types of technological improvements, such as advances in materials, design and analysis methods, fabrication processes and optimization techniques, etc.There are four disciplines for optimization process:

a. Topology optimization:
It is an optimization process which gives the optimum material layout according to the design space and loading case.

b. Shape optimization:
This optimization gives the optimum fillets and the optimum outer dimensions.

c. Size optimization:
The aim of applying this optimization process is to obtain the optimum thickness of the component.

d. Topography:
It is an advanced form of shape optimization, in which a design region is defined and a pattern of shape variable will generate the reinforcements.

III. MODELING OF STEERING KNUCKLE JOINT

The modeling of the steering knuckle is done in Creo Parametric 2.0.

Introduction to Creo Parametric:

Creo Parametric is a computer graphics system for modeling various mechanical designs and for performing related design and manufacturing operations. The system uses a 3D solid modeling system as the core, and applies the feature-based, parametric modeling method. In short, Creo Parametric is a feature-based, parametric solid modeling system with many extended design and manufacturing applications.

Creo Parametric is the first commercial CAD system entirely based upon the feature-based design and parametric modeling philosophy. Today many software producers have recognized the advantage of this approach and started to shift their product onto this platform.

The model is as shown in the figure 1 as shown below:

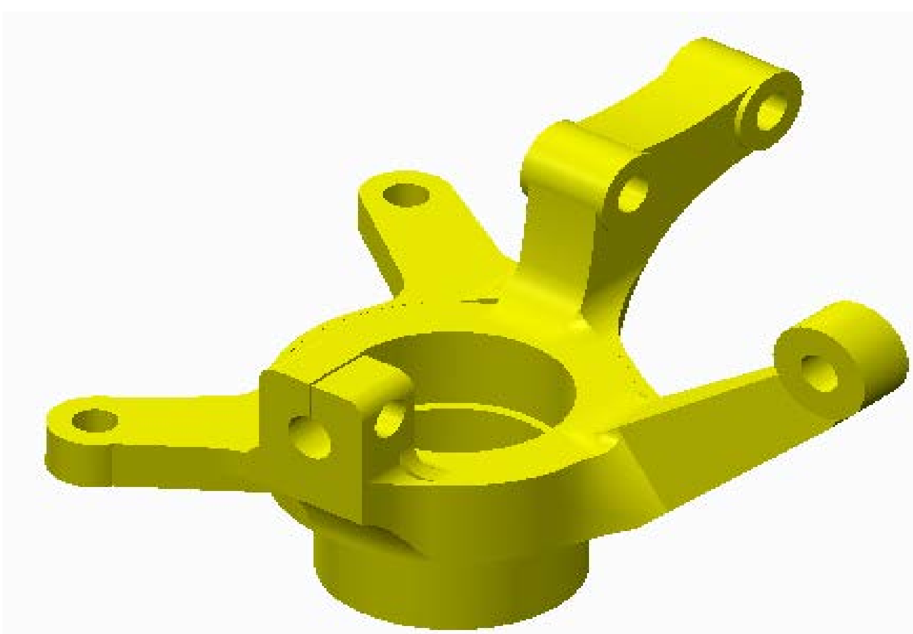


Fig 1.Steering Knuckle Joint Model

Creo Parametric was designed to begin where the design engineer begins with features and design criteria. CreoParametric's cascading menus flow in an intuitive manner, providing logical choices and pre-selecting most common options, in addition to short menu descriptions and full on-line help. This makes it simple to learn and utilize even for the most casual user. Expert users employ CreoParametric's "map keys" to combine frequently used commands along with customized menus to exponentially increase their speed in use. Because Creo Parametric provides the ability to sketch directly on the solid model, feature placement is simple and accurate.

IV. ANALYSIS OF STEERING KNUCKLE JOINT

The analysis of the steering knuckle joint is done in Ansys 15.0 and the analysis reports are as shown below.

The geometry and the mesh model in Ansys are as shown in the Fig.3 and Fig. 4 below respectively.

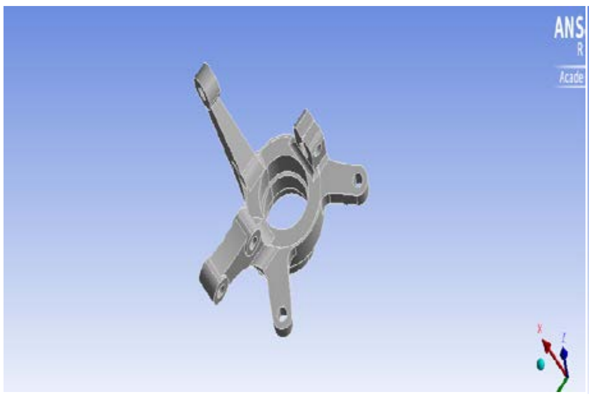


Fig. 3 Geometry of the steering knuckle joint

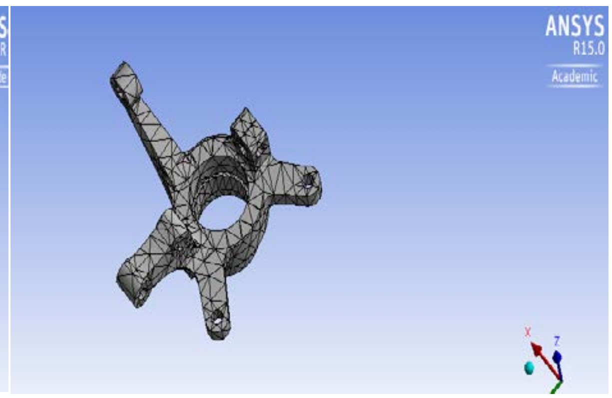


Fig.4 Mesh of the steering knuckle joint

The analysis is carried out for the Cast Iron material, Aluminium material and the composite material for the steering knuckle joint.

Analysis of Steering knuckle joint:

The Boundary Conditions are given as the force of 4358N with a moment of 36375 N-mm at two supports and fixed at the three supports of the knuckle. The base material is Cast Iron. The deformation and Equivalent Stress reports for the steel steering knuckle joints are are as shown in the Fig. 5 and Fig. 6 respectively.

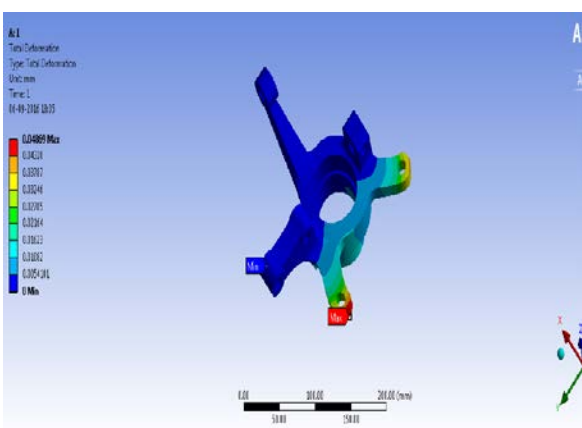


Fig. 5 Deformation of the steering knuckle joint

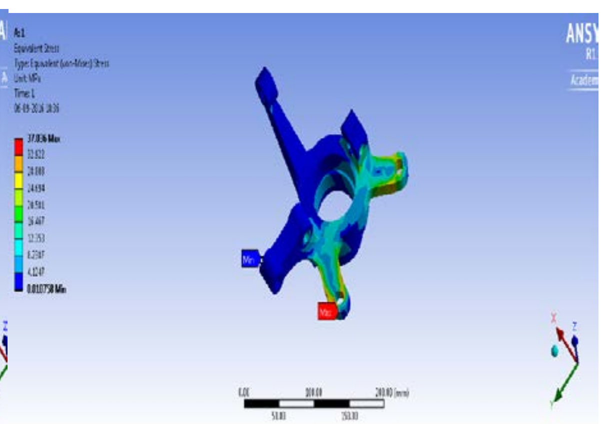
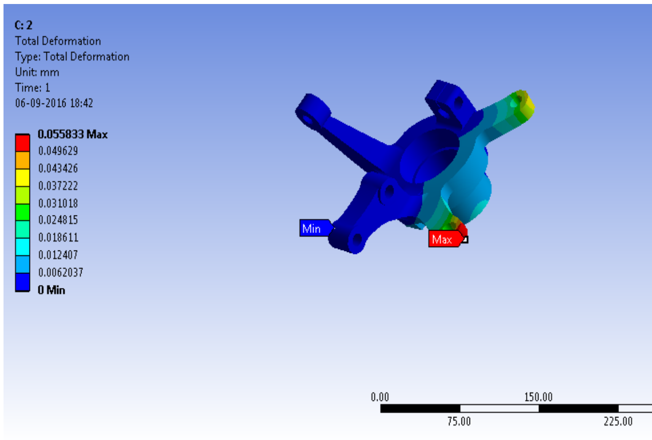


Fig.6 Equivalent Stress of the steering knuckle joint

The deformation and Equivalent Stress reports for the first optimisationsteering knuckle joints are are as shown in the Fig. 7 and Fig. 8 respectively.



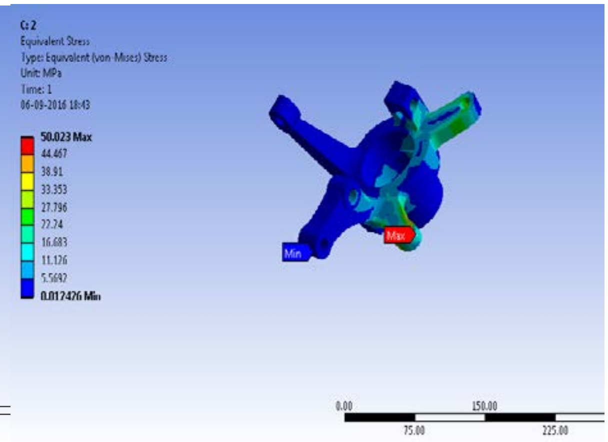
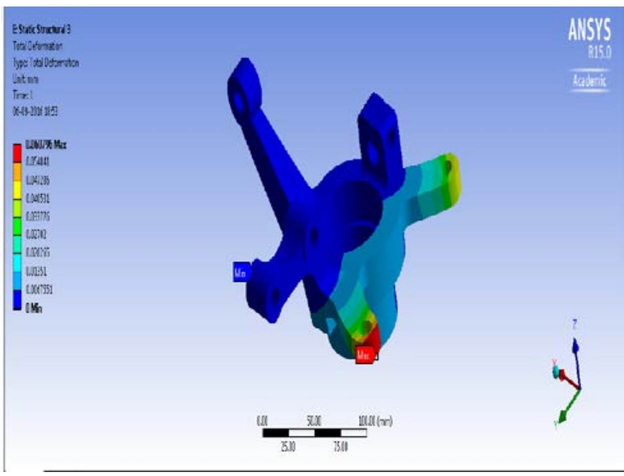


Fig. 7 Deformation of the 1st opt.steering knuckle joint

Fig.8 Equivalent Stress of the 1st optsteering knuckle joint

Also the analysis is carried out for the knuckle joint which consists of different shape optimisations. The deformation of and the Equivalent Stress reports for the last optimisedsteering knuckle joint are shown in the Fig. 9 and Fig. 10 respectively.



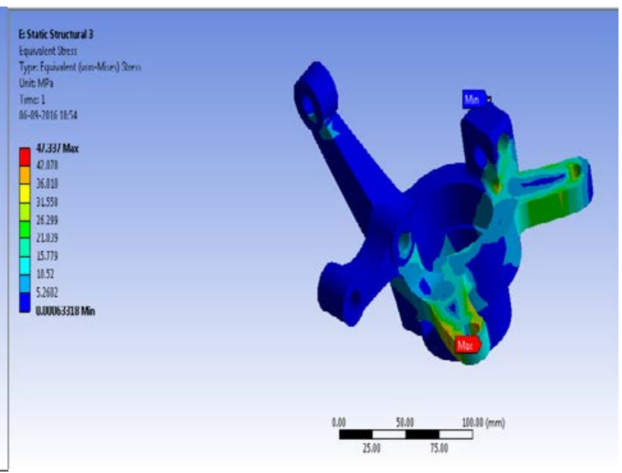


Fig. 9 Deformation of the opt.steering knuckle joint

Fig.10 Equivalent Stress of the opt.steering knuckle joint

The Glass Epoxy properties are as shown in the Fig. 11

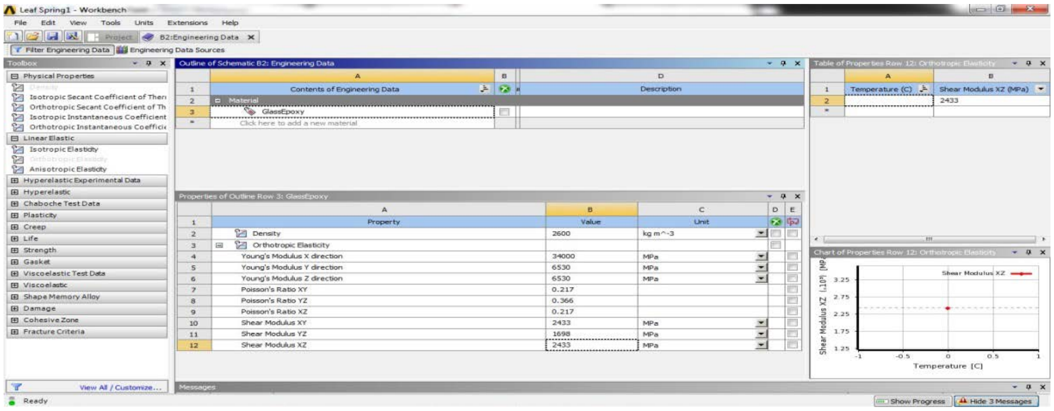


Fig. 11 Glass Epoxy material properties

V. RESULTS AND DISCUSSION

The analysis of Steel Steering knuckle joint with the composite steering knuckle joint is done. The shape optimization and material optimization is carried out in Ansys 15.0. The results for the steering knuckle for various considerations are as shown below:

Optimisation	**Base model**	**1**	**2**	**3**	**4**
TOTAL DEFORMATION (mm)	0.04869	0.05583	0.06079	0.058858	0.048036
STRAIN	0.00034	0.000456	0.000448	0.000453	0.000324
STRESS (MPa)	37.036	50.023	47.337	45.249	36.424

The results for the optimized material consideration are as shown below:

RESULTS	**STRESS (MPa)**	**STRAIN**	**TOTAL DEFORMATION (mm)**	**Optimised material with weight (kgs)**
1	53.81	0.00076	0.090	0.8755
2	76.12	0.00085	0.072	0.6321

VI. CONCLUSION

This project work involves the aim to reduce the weight of the steering knuckle joint while keeping the stress within the safe limits. Thus from the first results table it is very clear that the fourth model gives us optimized results i.e. less stress value and also less weight. The model is then analyzed Cast Iron and is optimized under different cases of material adding and material reduction.Then the optimized model is analysed for different materials such as Aluminum alloy and S- Glass Epoxy composite.The results table clearly indicate that there is a significant amount of weight reduction when we use S-Glass Epoxy material. The stress values are within the safe limits of their respective material properties.

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