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Effect of Loading on Various Point of Steering Knuckle

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Abstract*—This study was aimed at developing general procedures for fatigue analysis and optimization of safety-critical automotive components with manufacturing considerations. A literature survey was conducted, specimen and component tests were performed, and optimization evaluations of similar components produced by different manufacturing material were made to achieve the objectives. The typical example component chosen was a vehicle steering knuckle made of six competing materials and manufacturing processes including forged steel, cast aluminum and cast iron. In the literature survey, manufacturing processes were studied and compared with focus on mechanical behavior. The methods used in the literature for fatigue life evaluation and prediction of automotive components, as well as for optimization studies with respect to geometry, material and manufacturing aspects were also reviewed. Comparisons of materials and properties, along with components' behaviors were made for competing material and manufacturing processes. In terms of structural performance and durability, based on both material testing and component evaluation, forged steel was found superior to cast iron which in turn was found superior to cast aluminum*

Keywords*- Steering knuckle; Structural Components; Fatigue; Durability; Analysis.*

I. INTRODUCTION

Suspensions use various links, arms, and joints to allow the wheels to move freely up and down; front suspensions also have to allow the front wheels to turn. All suspensions must provide transverse as well as longitudinal wheel support. Steering knuckle/spindle assembly, which might be two separate parts attached together or one complete part, is one of these links. Its geometry depends on the type of suspension.

Figure shows the assembly of the steering knuckle and spindle on an SLA, which is the typical rear-wheel-drive car's front suspension. The steering knuckle for a MacPherson Strut Suspension, which has no upper control arm or upper ball joint,. In the Solid Axle Suspension, a beam of steel is connected to the steering knuckle, 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.

In automotive industry, designers have a wide range of materials and processes to select from. Steel and aluminum forgings and castings, cast irons, and powder forgings have found broad applications in automotive safety-critical systems. The competition is particularly acute in the chassis, and it is not unusual to find a range of different materials and manufacturing technologies employed within modern chassis components.

Many safety-critical components in the vehicle experience static as well as time varying loadings, and obviously they undergo the latter during a major portion of their service life. The steering knuckle also provides an attachment point for the upper and lower ball joints in conventional A frame suspension system. The spindle of a rear wheel drive vehicle is supported and attached by the steering knuckle. With a front wheel drive vehicle, the front hub and bearing assembly is attached to the steering knuckle. Disc brake systems also use the steering knuckle as a mount for the brake caliper. The components attached to the steering knuckle will usually wear out before the steering knuckle itself. In fact, most of the damage to a steering knuckle will occur from collision damage.

The steering wheel is connected to the suspension and wheels via the steering knuckles. The knuckle connects the steering wheel to the rest of the car, allowing the driver to direct the vehicle. Two control arms link the chassis and the front suspension, while trailing arms connect the chassis to the rear suspension.

II. PROBLEM DEFINITION

When performing steering angle diagnostics, it is not easy to verify if a steering knuckle is damaged. Due to their size and design, even when they are bent, it is not typically obvious. Steering knuckles are heavy cast parts made of steel or aluminum. They are not repairable and should be replaced if damaged. A damaged steering knuckle could be discovered anytime during the collision repair process. For that reason, many times a damaged knuckle escapes replacement up to the point of the vehicle getting an alignment.

So for this we have to take care about the steering knuckle. The damage in steering knuckle is done by several reasons like due to more axial load on steering knuckle or due to less suspension between the tire and the axial hub where the steering knuckle is attached. When the car goes from the up and down roads and on the mantels or on bad road it effect on the steering knuckle and when the sudden turn or change in direction is there it also effect on the steering knuckle.

So the purpose of a study is to reduce the stresses acting on a knuckle with better material property whose weight is less and which can increase the life of a steering knuckle.

III. EXPERIMENTAL ANALYSIS

There are four types fatigue life prediction models are commonly used. These include the Stress-life model, the strain-life model, the fatigue crack growth model, and a combination of fatigue crack growth and strain-life models. Strain-based approaches are very common in life prediction of notched components.

In these cases, the behaviour of the material at the root of the notch is best described in terms of strain. The approaches pursued here are nominal stress approach, local strain approach using nominal stresses, and local stress and strain approaches using finite element analysis (FEA) results Hear in our analysis we have consider the standard force that is 1000 N and from that we have calculated the data .

So another part of the data is

Apply maximum load and moments are

Pmax =1500 N and	M max =463.5Nm
Pmin =500N	M min =154.5Nm
p a =1000N	Ma =309 Nm
Pm=1050 N	Mm=344.5 Nm

Apply Pm =1050 N to find the Sm

$$Sm = \frac{Pm}{Kt} = 477.27 \text{ MPa}$$

Like that Pmin =500N find the Smin

$$Smin = \frac{Pmin}{Kt} = 227.27 \text{ MPa}$$

Apply Pmax =1500 N to find the Smax

$$Smax = \frac{Pmax}{Kt} = 681.81 \text{ MPa}$$

Apply Pa =1500 N to find the Sa

$$Sa = \frac{Pa}{Kt} = 454.54 \text{ MPa}$$

For maximum load the equitation

$$\frac{Ktq^2S^2}{E}\frac{E\ e^*}{S^*} = \varepsilon\sigma = \frac{\sigma^2}{E} + \sigma\left(\frac{\sigma}{K}\right)^{\frac{1}{n}}$$

Will be the max

$$\frac{Ktq^2S^2}{E}\frac{E\ e^*}{S^*} = \varepsilon\sigma max = \frac{\sigma max^2}{E} + \sigma max\left(\frac{\sigma max}{K}\right)^{\frac{1}{n}}$$

Here, the and*Mp*= 2028 N.m (equivalent to 1470 lbf load at the actuator).

Thus:

$$S^* = \frac{M}{Mp}Sy = 415.5 \text{ MPa}$$

$$\frac{415.15}{201500} = 0.0235$$

So now put all this value and find max from the equitation

$$\frac{Ktq^2S^2}{E}\frac{E\ e^*}{S^*} = \varepsilon\sigma max = \frac{\sigma max^2}{E} + \sigma max\left(\frac{\sigma max}{K}\right)^{\frac{1}{n}}$$

$$\frac{1.9^2 90.11^2}{201500}\frac{201500 * 0.0235}{415.5} = \varepsilon\sigma max = \frac{\sigma max^2}{201500} + \sigma max\left(\frac{\sigma max}{1269}\right)^{\frac{1}{n}}$$

$$0.016944 = \frac{\sigma max^2}{201500} + \sigma max$$

Solving this equitation we got the value of the it is 304 MPa

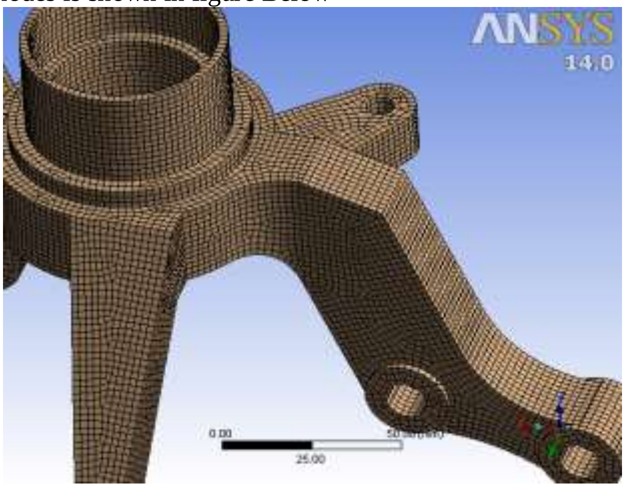
IV. SOFTWARE ANALYSIS

Hear we come with the analytical software Ansys-14. ANSYS offers engineering simulation solution sets in engineering simulation that a design process requires. Companies in a wide variety of industries use ANSYS software with the help of this software we will do our remaining work

Geometric modeling and meshing of this Steering Knuckle with suitable elements (Hex Dominant Method) and optimum degrees of freedom was an iterative and challenging process, First, a coarse Hexa mesh was made and the overall response of structure was evaluated. Modeling was done using CATIA, meshing was done using the preprocessor in ANSYS

Modeling of Steering Knuckle is done by CATIA, Discretization of Model is 1st done by coarse meshing and after interpretation of results the mesh was refined. All the load cases were solved on the complete model.

The discredited geometry with 47386 elements and 185021 nodes is shown in figure Below



Material Properties

1. Composite of Iron with Following Properties (For Case 1)

Element	C	Cr	Si	Mn	Fe	Cu
Max %	3.8	0.07	2.8	1.00	94.16	1.0

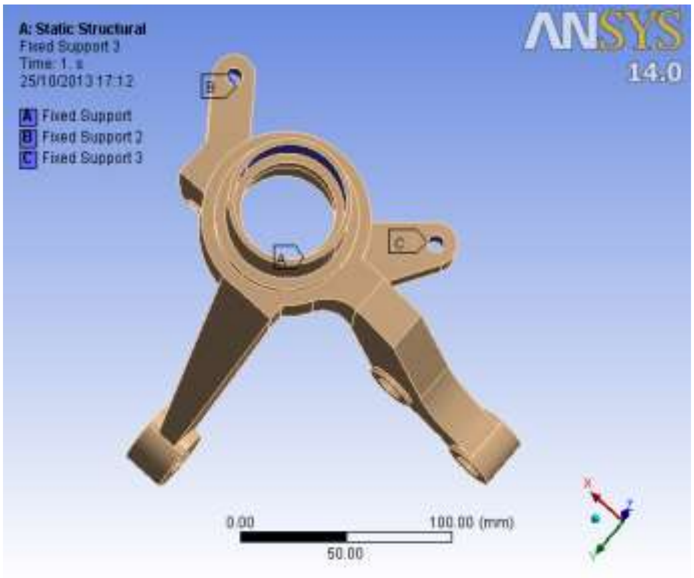
a. Yield strength 360MPa
b. Ultimate tensile strength 520MPa
c. Elastic modulus 170GPa
d. Density 7.14*E*−06 kg/mm3

2. Composite of iron with Following Properties (For Case 2)

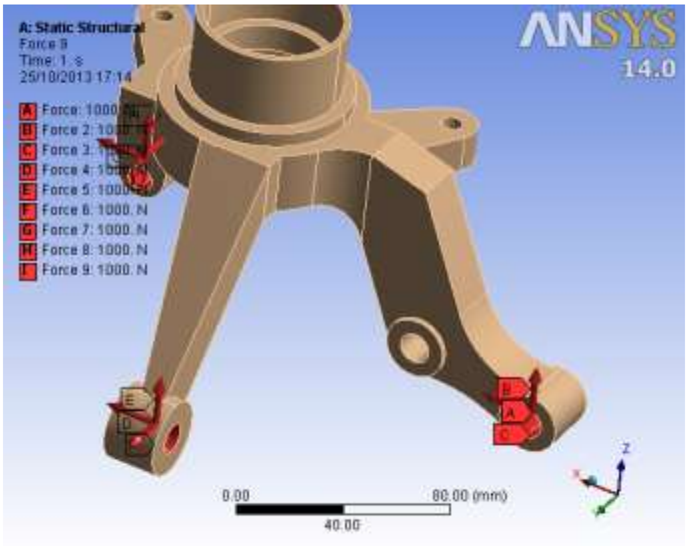
a. Young Modulus 207000 MPA

b. Poison Ratio 0.29
c. Density 7.85E-9 ton/mm3
d. Ultimate Tensile Stress 522 MPA
e. Yield Stress 391.5 MPA

The steering knuckle model was constrained at the wheel centre and 12 load cases were applied, including three forces (1,000N in *X*, *Y*, and *Z*) at the lower ball joint,steering arm and strut mount, and three moments (1,000Nmm)at the strut mount.
Different Boundary Conditions and Loading Conditions are shown below.



Fix Support of steering knuckle



Different Forces Acting on Steering Knuckle

4.1 Summary of Assumption in the Analysis of the Steering Knuckle

- The actual loading in the Steering Knuckle was idealized using statically equivalent loads
- Perfect Welding was assumed between the structural components.
- The Geometry of the Steering Knuckle was simplified to accommodate the analysis within the limitations of the ANSYS University High option.
- There may be some error due to linear Analysis.

4.2 Analysis with Different Material

But still our purpose is not satisfied so here now we are going to conduct one more experience
Here so far we have discussed about the design parameter of steering knuckle, now move to the our purpose to reduce the weight of the steering knuckle and increase the strength of it and also to reduce the deformation of the former arm .
So to fulfill our purpose we have consider six different type of material and they are below.

DIFFERENT MATERIAL PROPERTY

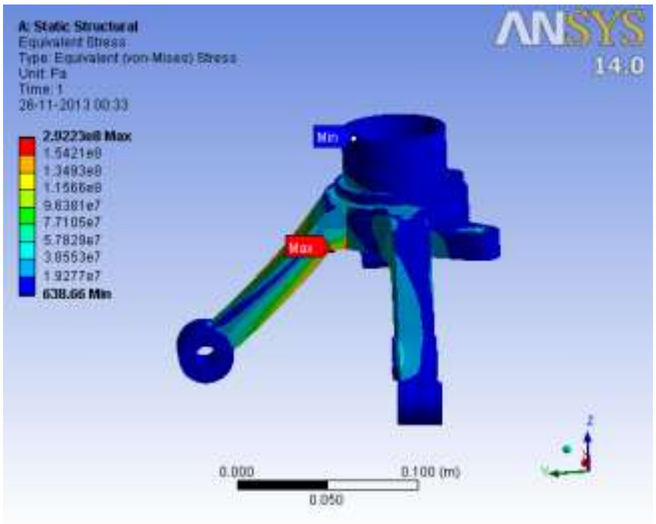
Material	**Density(g/cc^3)**	**Young modulus(GPa)**	**Poisons ratio**
Structural steel	7.85	200	0.30
Cast iron	6.8	169	0.275
Cast al component	7.14	170	0.31
ASTM CA 40	7.6	200	0.41
Sand cast zinc aluminum	6	83	0.30
Cast grade 5 titanium	4.4	115	0.36

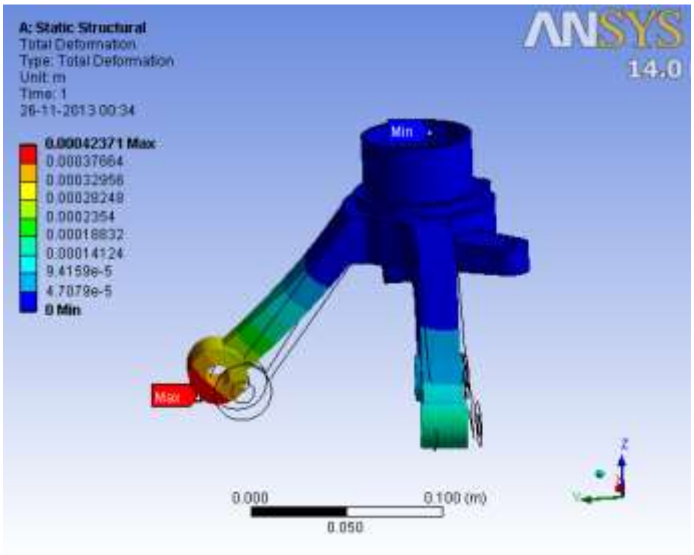
CASE 4

Material	Astm CA 40
Density	7.6
Young modulus	200
Poisons ratio	0.41

The material weight of steering knuckle is 2.0569 kg

Equivalent Stress & Total Deformation (Astm CA 40)





V. RESULT AND COMPARISON

Here we have seen six different analysis with different material , so hear if we compare the all result and see that which material is more stable and have less stress and less deformation in it And we also have to consider that material weight so which material is lighter in weight.

Now talk to different material first the structural steel , in this material the stress is almost same to all material but the deformation is less but the main factor is weight then the weight of the material is more compare to all other material so we cannot apply this material in our steering knuckle design though it have less deformation but the weight is more than it has to be so we will talk to the other case

In our second case we have consider the cast iron material , this is most commonly material used in the all component of the vehicle , hear in our case the stress is more compare to all other material and the deformation is at average point and the weight is better than the previous one, now we will discuss the third case

In the third case we have consider the material as Cast aluminum component , in this analysis the stress is less compare to the cast iron but the deformation is very less in the this component and the weight is little more than the cast iron so we can use this material in the design of steering knuckle .

Now move to forth case .it is the ASTM CA40 material. this is high carbon material, It has good stress result and it is less among the all component and the deformation is also less compare to the other material and the weight is less than the structural steel so it is good for the steering knuckle because as our point is getting fulfil in this material less stress and less deformation

Now move to the fifth and sixth case . In this fifth case the stress is more and the deformation is also more though it has the lower weight but we cannot consider this material

And In the sixth case the weight is less among the all because the titanium is the material with less weight but in this the deformation is more compare to other material so we cannot use this material in the manufacture of steering knuckle

So finally we have consider the material ASTM CA40 because it has less stress and the less deformation to compare to all and the weight is almost same to the cast component so as we are applying this material defiantly it has advantage then the older material composite of iron .

With the help of analysis result we can conclude that by using the ASTM A40 material we can reduce the weight the steering knuckle weight up to 10% as they are using now a days in the Maruti Suzuki car. and applying this material we can reduce the stress and also the deformation . And we can also prevent the crack so it will not damage .And it also with stand the more load and shock.

Comparison of Result

Material	Equivalent stress(MPa)	Total deformation(mm)	Material weight
Structural steel	297.27	0.4275	2.1245
Cast iron	298.56	0.506	1.8403
Cast al component	297.78	0.4137	1.9340
Astm CA 40	292.23	0.4237	2.0569
Sand cast zinc aluminium	297.247	1.0303	1.6238
Cast grade 5 titanium	294.39	0.74	1.1908

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