

Tensile Stress Analysis of Steering Knuckle of an Automobile under Static Load

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Abstract:

Steering knuckle is one of the critical components of four wheel vehicle which links suspension, steering system, wheel hub and brakes to the vehicle chassis. During the motion of the vehicle the steering knuckle undergoes varying load under different conditions, but it doesn't affect the steering performance and other desired vehicle characteristics. The Steering Knuckle used for the experimentation is made of SG Cast Iron. For the experimental analysis Instron UTM of 100 KN load cell was used and the results validated in Finite Element Analysis (FEA). The results obtained from the virtual analysis and experimental analysis has been compared and validated for SG iron steering knuckle. Design solution was provided with the ANSYS Workbench 14.5 using Austempered Ductile Cast Iron Steering Knuckle.

Keywords: Steering Knuckle, SG Cast Iron, Static Analysis, UTM, Finite Element Analysis and Experimental Analysis, ADI Steering Knuckle.

INTRODUCTION:

Steering knuckle is main important part in the vehicle because that requires lots of attention in selection because once it is damaged then it have to replace with the new one. Structural components such as a steering knuckle must be strong enough to withstand a single applied load. Steering knuckle is one of automotive component that frequently carries load from several directions.[3] The Steering knuckle has a strut mount at the top, ball joint at the bottom, and a steering arm on the side. The wheel spindle fits through a hole in the center. Each circumstances of the road give the different impact to the steering knuckle. Failures, or fractures, take place when cracks get so large that remaining material can no longer endure stresses and strains.[5] In classic structural analyses, failure predictions are based solely on material strength or yield strength. Durability analysis goes beyond this, evaluating failure based on repeated simple or complex loading. The assumption that loads tug in one direction is a simplification that works well, to a point. In the real world, however, loads are simultaneously applied in several directions, producing stresses with no bias to a particular direction.

Material Testing: The testing of specimens for tensile test as per ASTM E 8 standard [1] has been taken from knuckle arms as shown in Fig. 1. The stress strain relation data were

collected and the graph has been generated. Fig. 2 shows the stress strain relation of the steering knuckle material. The micro structure of a component found out by the optical microscope is shown in Fig. 3. The graphite's are in spherical shape and the ferritic matrix formation is also observed from the microstructure.[2]

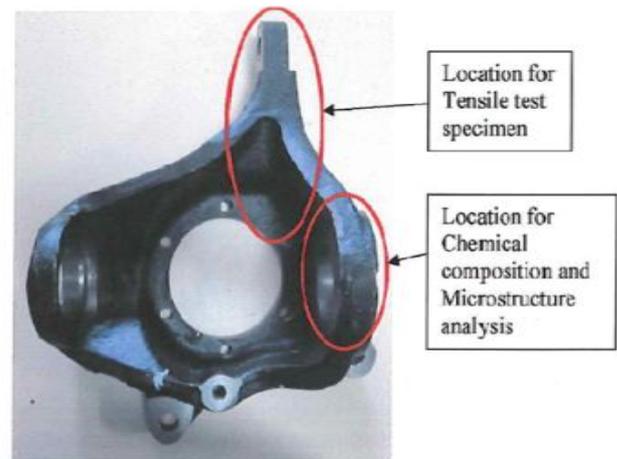


Figure 1. Showing location of Tensile Test Specimen and chemical composition and Microstructure analysis

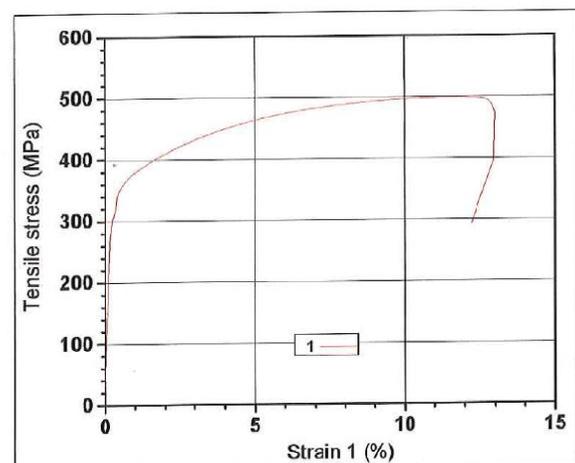


Figure 2: Show the stress- strain relationship

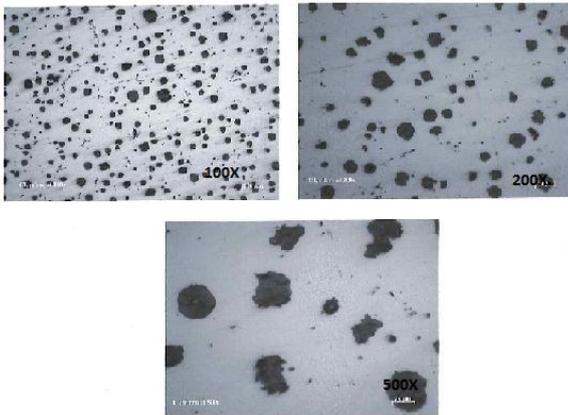


Figure 3: Showing the microstructure of steering Knuckle at Magnification 100X, 200X and 500X

Analysis and Testing: CAD model of the steering knuckle was completed in the CATIA V5R20 software and was imported through IGES file to ANSYS Workbench 14.5 for meshing the CAD model. ANSYS Workbench 14.5 software is used to mesh the model.

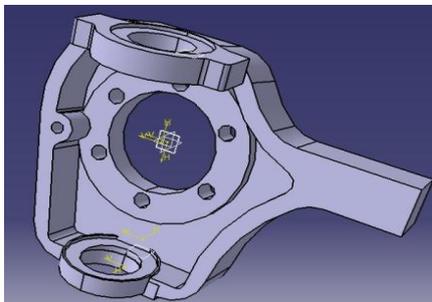


Figure 4. CAD model in Catia V5R20

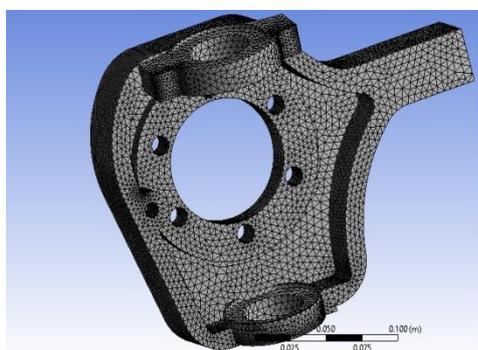


Figure 5 Meshed Model in ANSYS Workbench

Static Analysis: The static analysis has been performed by using ANSYS Mechanical Workbench 14.5. In the preprocessor, the model is meshed with solid187 element is a higher order 3-D, 10-node element. The linear static analysis of steering knuckle is carried out. The material properties young's modulus (E) is $2E5 \text{ N/mm}^2$ and the Poisson ratio is 0.3.

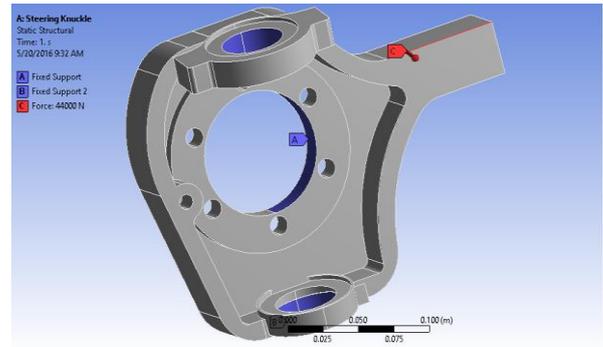


Figure 6 Boundary Conditions

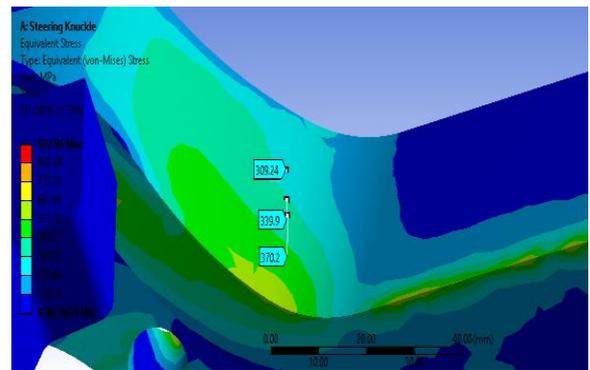


Figure 7 Stress Analysis of Steering Knuckle

Experimental Static Test: The INSTRON UTM 5538 capacity of 100 KN and extensometer with original gauge length 25 mm was used in the static test. The facility is available at ARAI, Pune. The actuator is automated (PLC) which was connected to the computer. The software RS console was used as an input to the actuator. The static load was applied to the component break. The test specimen was held in two clamps as shown in the fig. 8 and pull load was applied.

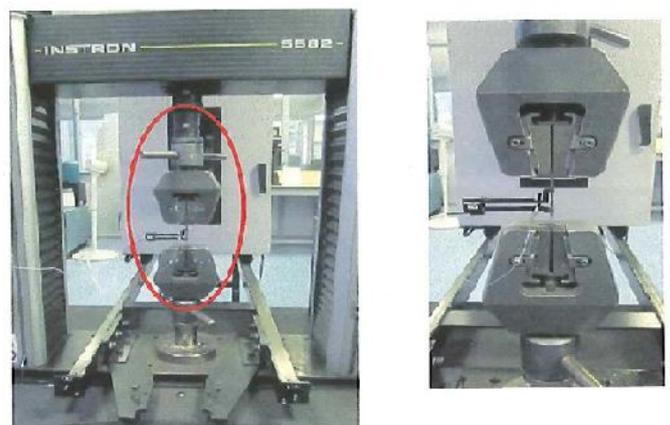


Figure 8. Set up photograph of Tensile Test

EXPERIMENTAL STATIC ANALYSIS RESULTS

The result obtained in the tensile test through the use of UTM is tabulated in the Table 1.

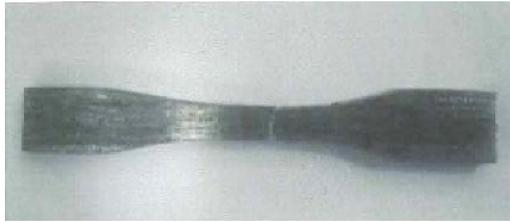


Figure 9 Photograph of Failed Specimen

Sample No.	0.2% offset Yield Stress (MPa)	Ultimate Tensile Stress (MPa)	Elongation (%)
1.	343.0	499.0	13%

STATIC FAILURE CALCULATION:

The block diagram of steering arm is shown in Fig. 11. The arm was assumed to be in uniform rectangular cross section. It has breadth $B = 24$ mm and depth $D = 34$ mm and length $L1 = 75$ mm and $L2 = 32$ mm. The critical section in the steering arm was measured as a length of $L1$ from steering arm ball center. Force acting on the steering ball was at 70° angle. For right hand steering knuckle component, let's take $F = 44$ KN from Table 1. The vertical force $F1$ and horizontal force $F2$ values can be calculated as below,

$$F1 = F \sin 83^\circ = 44 \times 1000 \times \sin 83^\circ = 43.672 \text{ KN}$$

$$F2 = F \cos 83^\circ = 44 \times 1000 \times \cos 83^\circ = 5.362 \text{ KN}$$

Stress at critical section was calculated as below,

Principal stresses on x-axis σ_x and y-axis σ_y ,

$$\sigma_x = \frac{MY}{I}$$

$$\text{ie, } \sigma_x = \frac{F2 \times L1 \times D/2}{BD^3/12}$$

$$\text{Therefore } \sigma_x = 77.88 \text{ N/mm}^2$$

$$\text{Similarly } \sigma_y = \frac{F1 \times L1 \times D/2}{BD^3/12}$$

$$\text{Therefore } \sigma_y = 373.63 \text{ N/mm}^2$$

$$\text{Shear stress } S_{xy} = \frac{T_r}{J} = \frac{T(D/2)}{BD(B^2 + D^2)/3}$$

$$\text{I.e., } S_{xy} = 45.16 \text{ N/mm}^2$$

Then the Von mises stress can be calculated by

$$\Sigma \text{vm} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3S_{xy}^2}$$

$$\text{ie, } \sigma_{vm} = 342.3466 \text{ N/mm}^2$$

Test Results:

Design Solution:

To increase the strength of steering knuckle made of ductile cast iron is heated at austenitic temperature which results in the formation of austempered ductile cast iron having strength more than the original ductile cast iron. The analysis of the steering knuckle is carried out in ANSYS Workbench 14.5 using the properties of ADI

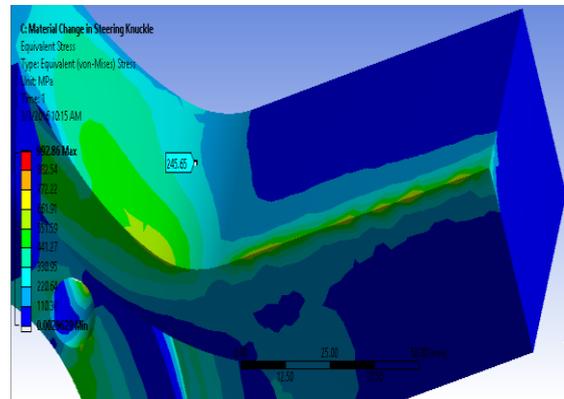


Figure 10 Stress Analysis of ADI Steering Knuckle

The meshing and loading condition were the same as for the ductile cast iron. The stress i.e. von mises stress developed was 245.65 MPa which is much less than the stress in Ductile Cast Iron.

CONCLUSION:

The method used for stress analysis of steering Knuckle is used as the foundation for structural analysis of steering Knuckle. The static analysis is the base for weight reduction, strength analysis and then for fatigue analysis. Steering Knuckle being a structural member is heavier and should be replaced by a strong but having less mass density. From the study carried out on steering Knuckle of tensile strength following conclusions can be drawn. They are as follows.

1. The tensile strength analysis is within the range of material used for Knuckle which suggest ultimate tensile strength, yield strength and elongation result obtained from this test are without error due to use of pure material.
2. The stress- strain graph obtained from the experimental analysis contains ultimate tensile strength and yield strength point that can be used further for fatigue analysis of the steering Knuckle.
3. The value obtain through the finite element analysis is exactly similar to the experimental analysis with an error of 1 % for the Knuckles which suggest that the experimental analysis carried out is in correct direction.
4. The fracture of the specimen of the steering Knuckle is at the centre which reflects that the impurities present are within limit.

5. The stress induced in the knuckle can be reduced by changing material to Austempered Ductile Iron. It was found that the stress induced are much less (290 N/mm^2) than Spheroid Cast Iron knuckle.
6. From the fore going study, it can be concluded that there is scope for improvement in the steering Knuckle design and material used which becomes a pivotal part of the automobile.

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