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Design and Analysis of Steering Knuckle for Fatigue Loading

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Abstract
The steering knuckle is made of cast iron which is heavy in weight. Due to more weight, moment of inertia is increased. So it requires a high force to perform the work. We have to reduce weight to improve the efficiency. Hence the steering knuckle is made out of aluminum alloy which will be light in weight. Fatigue analysis is performed in order to find fatigue failures and estimate the fatigue life of an automotive steering knuckle, which is very critical for vehicle safety. Solid works is used to determine local stress and strain distributions of the Steering knuckle. The results obtained from software analysis and experimental testing encouraged using particulate 6063 aluminium alloy for critical component steering knuckle with a weight saving about 60% when compared with currently used gray cast iron.

Keywords
Steering Knuckle, Aluminum, Fatigue, Weight.

I. Introduction

The steering knuckle is the connection between the tie rod, stub axle and axle housing. Steering knuckle is connected to the axle housing by using king pin. Another end is connected to the tie rod. The wheel hub is fixed over the knuckle by using a bearing. The function of the steering knuckle is to convert linear motion of the tie rod into angular motion of the stub axle. The lighter steering knuckle which results in greater power and less vibration because of the decreased inertias. 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 weight. In this case, during 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 casting. However, castings would 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 this investigation, steering knuckle was used as component for study. Suspension system in any vehicle uses different types of links, arms, and joints to let the wheels move freely; front suspensions also have to allow the front wheels to turn. Steering knuckle/spindle assembly, which might be two separate parts attached together or one complete part, is one of these links 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.
The following table shows the properties of materials.

Table 1 .Properties of material

Properties	Aluminium 6063	Gray cast iron
Density (g/m^3)	2.7	7.2
Tensile Strength (MPa)	90	151
Yield Strength (MPa)	50	0
Poisson’s Ratio	0.33	0.27
Elastic Modulus (N/m^2)	6.9e10	6.62e10

II. Literature Survey

S.Vijayarangan, (2013) The steering knuckle is one of the critical component. The aluminum alloy reinforced with titanium carbide is replaced with SG iron and analysis is done using ANSYS software. In this method up to 55% weight reduction is achieved.
W.S.Miller(2015) focus on the properties of aluminium related to automotive industry. 5000 alloy for inner panel and 6000 alloy for outer panel. This can reduce 50% of weight when compared with steel or copper.
PurushottamDumbre (2014) used a topology optimization method to reduce the weight of the steering knuckle. HYPERMESH is used as a modeling and RADIOSS used as a solver. OPTISTRUCT software is used for optimization.
Razak I.H.A (2014) derived an optimized design to reduce the weight of steering knuckle. Solidworks software is used for analyzing. The improved design achieved 45.8% of mass reduction while meeting the strength requirements.

III. Methodology

The 6063 aluminium alloy was selected as a suitable material for steering knuckle. Several tests such as Tensile, Hardness, Impact and fatigue test were performed and the parameters are noted. Then the Steering knuckle was modeled using Solid works. The required boundary and loading conditions are applied. The Steering Knuckle was solved using both aluminum alloy and gray cast iron under static and fatigue analysis using solid works. The results from the analysis are compared.

IV. Designing A Model

Model of steering knuckle was developed in 3D modeling software SOLIDWORKS. It consists of stub hole, brake caliper mounting points, steering tie-rod mounting points, suspension upper and lower A-arm mounting points, Knuckle design mainly depends on suspension geometry and steering geometry.

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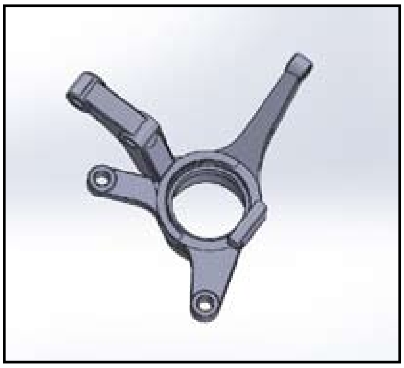


Fig 1.

V. Meshing

The meshing process was done based on the material parameters. Fig.2 shows the meshing result of the steering knuckle.

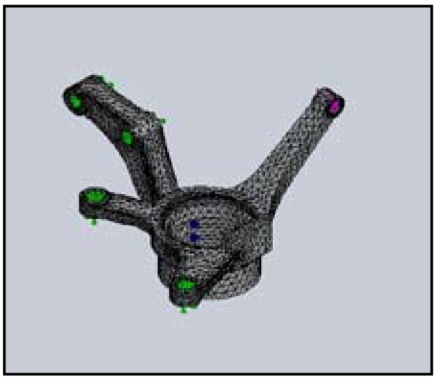


Fig. 2.

VI. Static Analysis

Static analysis, static projection, and static scoring are terms for simplified analysis wherein the effect of an immediate change to a system is calculated without respect to the longer term response of the system to that change. Such analysis typically produces poor correlation to empirical results. In this analysis 3.5KN is applied on the tie rod end of the steering knuckle.

1. Von Mises Stress

The von Mises yield criterion suggests that the yielding of materials begins when the second deviatoricstress invariant reaches a critical value. In materials science and engineering the von Mises yield criterion can be also formulated in terms of the von Mises stress or equivalent tensile stress. Fig.3 shows the result of von mises stress for 6063 aluminium alloy.

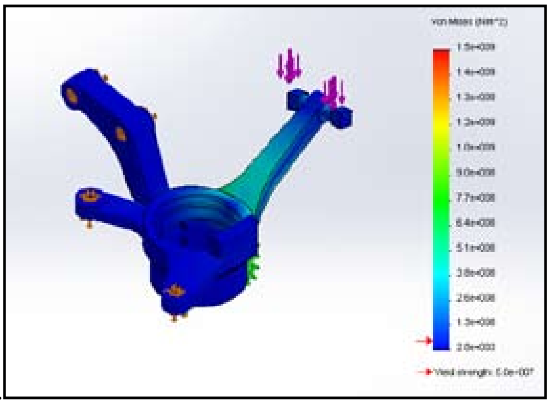
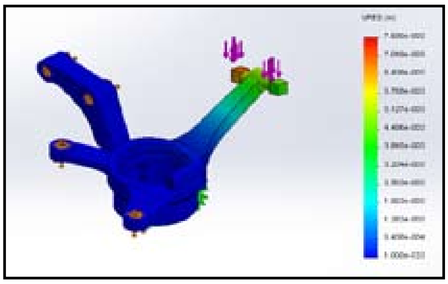


Fig.3

2. Displacement



A displacement is a vector that is the shortest distance from the initial to the final position of a point. It quantifies both the distance and direction of an imaginary motion along a straight line from the initial position to the final position of the point. A displacement may be also described as a 'relative position'. Fig.4 shows the displacement result for 6063 aluminium alloy.

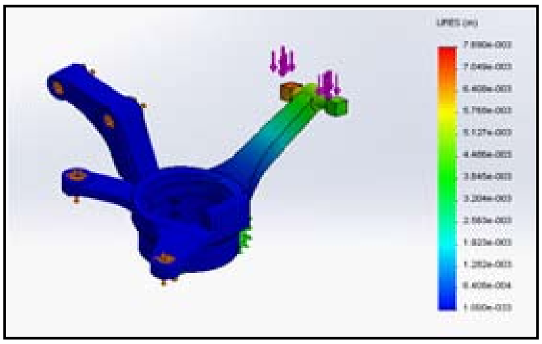


Fig.4

3. Strain

A strain is measure of deformation representing the displacement between particles in the body relative to a reference length.The below fig. shows the strain result for 6063 aluminium alloy.

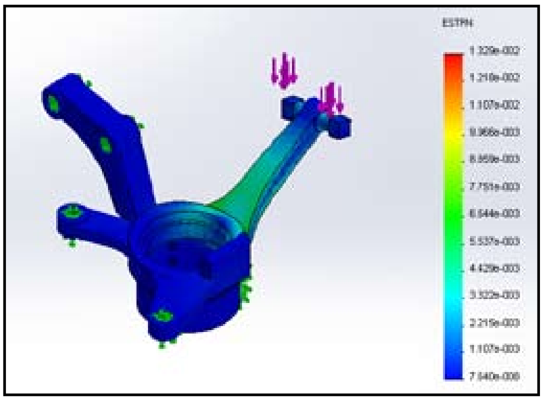


Fig.5

VII. Fatiguie Analysis

Fatigue analysis is to find the fatigue strength of the part. Fatiguestrength is a measure of the strength of a material or a component under cyclic loading, and is usually more difficult to assess than the static strength measures. Fatigue strength is quoted as stress amplitude or stress range ($\Delta\sigma = \sigma_{\mathrm{max}} - \sigma_{\mathrm{min}}$), usually at zero mean stress, along with the number of cycles to failure under that condition of stress.

In this fatigue analysis on the steering knuckle is analyzed for 1x10^6 cycles.

A. Damage

Damage is the deformation of the part under the maximum loading

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condition. Fig.6 shows the damage results for 6063 aluminium alloy.

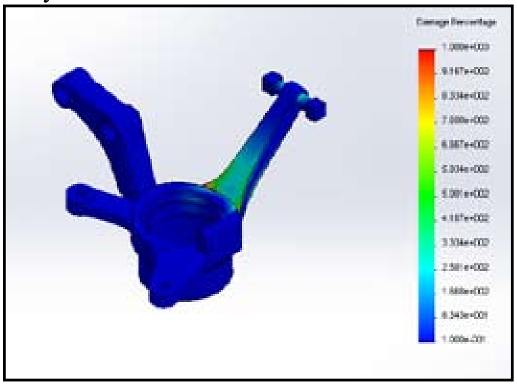

Fig 6.

B. Fatigue Life

The number of cycles of loading of a specified character that a given specimen of material can sustain before failure occurs; a measure of the useful life of the material. The final position of a point (Rf) relative to its initial position (Ri), and a displacement vector can be mathematically defined as the difference between the final and initial position vectors:

$$s = R_f - R_i = \Delta R$$

Fig.7 shows the fatigue life results for 6063 aluminium alloy.

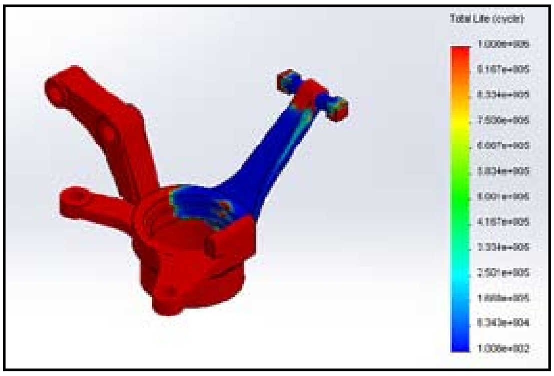

Fig.7

VIII. S-N CURVE

Well before a microstructural understanding of fatigue processes was developed, engineers had developed empirical means of quantifying the fatigue process and designing against it. Perhaps the most important concept is the S-N diagram, such as those shown in Fig. 8, in which a constant cyclic stress amplitude S is applied to a specimen and the number of loading cycles N until the specimen fails is determined. Millions of cycles might be required to cause failure at lower loading levels, so the abscissa in usually plotted logarithmically.

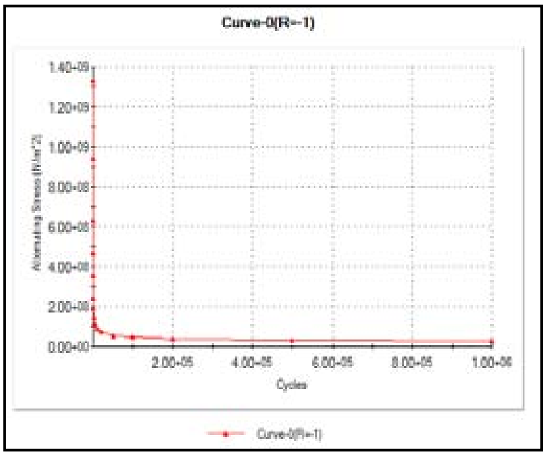

Fig.8

IX. Material Testing

1. Tensile Test

Yield load =10KN
Ultimate load =12KN
Breaking load =14KN

IX.2. IMPACT TEST

Charpy test =242 joules
Izod test =276 joules

IX.3. HARDNESS TEST

Rockwell hardness no. =B77
Brinell hardness no. =1017.378

X. Result and Discussion

Table.2 shows that the comparison of 6063 aluminium alloy and gray cast iron.

1. Static Analysis

S. NO	PERFORMANCE	6063 AL. ALLOY	GRAY CAST IRON
1	VON MISES STRESS	1.53824e+009 N/m^2	1.56671e+009 N/m^2
2	DISPLACEMENT	0.0076901 m	0.00795997 m
3	STRAIN	0.0132879	0.0132761

Table.2

2. Fatigue Analysis

S.NO	PERFORMANCE	6063 AL. ALLOY	GRAY CAST IRON
1	DAMAGE	10 CYCLES	100 CYCLES
2	FATIGUE LIFE	4.71E+08 N/m^2	1.33E+09 N/m^2

Table.3

Table.3 proves that the 6063 aluminium alloy suitable for replacing the gray cast iron material.

XI. Conclusion

Aluminium 6063 alloy can be used to reduce the weight of steering knuckle component by 60% while meeting the strength requirement. Hence less force is required to perform the work. It also increases the fatigue life of the steering knuckle and reduces the material cost.

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