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Research paper

Stress Analysis of Automobile Steering Knuckle Using Finite Element Method

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Abstract

This paper aims in identifying effect of constraint point against critical area of 1300 cc national car steering knuckle using finite element method. The material of this steering knuckle is cast iron ASTM A536. The steering knuckle is modeled using a computer aided design software and the dimensions is assigned according to 3D scanning files. Meanwhile, steering knuckle is simulate using commercial finite element software where the load is assigned based on three conditions of constraints. The three conditions are fixed at hub, fixed hub and brake clamp and fixed at hub, brake clamp and steering arm of steering knuckle. Result shows that the positions of constraint points are significantly effect on stress value of steering knuckle. By acknowledging the presence or absent the effect of constraint on steering knuckle will aid in detecting critical area on this steering knuckle. Thus, approach could be conducted to optimize and enhance the life cycle of a steering knuckle. The data will be further utilized in testing the steering knuckle under variable amplitude strain signal.

Keywords: *Critical area; Finite element method; Steering knuckle; Stress analysis.*

1. Introduction

Steering knuckle is one of the part in automobile system which is the linking parts of the steering system and the suspension system of automobiles. It has direct impact on the performance of the vehicle's ride, durability and steer ability. This part is one of important component of vehicle which is connected to the parts of the steering system and the suspension system with the function of the adjusting the direction of a rotation through its attachment to the wheel [1, 2].

Strut mount of steering knuckle is the part where it is connected to suspension system and withstands the weight of the automobile. Meanwhile, lower ball joint comprehends road condition as the automobile is drive and steering arm control the movement of automobile direction as it translate linear motion of tie road to angular motion of the front tyre. These three parts are the vital part of steering knuckle and where the force is mainly subjected.

Finite element analysis (FEA) is conducted based on a non-braking condition. Therefore, the brake force on the brake clamp will be negligible. This situation is similar with a study performed by Kamal et al. whom conducted multibody simulation for fatigue life simulation of steering knuckle as the simulation is modeled based on automobile with a constant speed of 60km/h on a gravel road [3]. The loads are subjected at strut mount, lower ball joint and steering arm and constraint at hub of steering knuckle. The result shows the highest stress distribution is at the neck of strut mount with maximum principle stress of 333 MPa, von Mises of 324 MPa and Tresca stress of 332 MPa.

The finite element result can be used to determine critical area of automobile component [4]. Azrulhisham et al. was performed the stress analysis on steering knuckle made from graphite cast iron FCD500-7 [5]. The loadings are applied on the strut mount, lower ball joint and steering arm and the hub and brake clamp is constrained during the simulation. They found that critical stress location is obtained at the neck of strut mount.

In service, most of engineering components are subjected to variable amplitude loadings. Relevant cases often refer to the field of automotive study, such as an automobile axle that experiences many repetitions or reversals of applied stress during the service life of the vehicle [6]. The steering knuckle also may exposed to fatigue failure and breakdown possibility as it is subjected to variable amplitude loading. It is important to identify its critical area for further research that can be conducted to improvise and enhance the design of steering knuckle.

It is known that fatigue test is tedious to be conducted; by having an alternative such as simulating stress analysis, it could save cost and time [7]. Therefore, this paper aims in identifying the effect of constraint point against critical area of 1300 cc national car steering knuckle using finite element method. In this study, the applied load is determined from the weight of an automobile and the constraint points were set at three different conditions. It is expected that different cases of constraint will give significant results of the stress distribution on steering knuckle.

2. Methodology

In this study, the steering knuckle is obtained from 1300cc national car as shown in Figure 1. The whole body of steering knuckle is made from the same material. Portion of steering knuckle is saw using a bend saw and tested using Scanning electron microscope (SEM) to identify their material composition. The material composition is tested for material identification of steering knuckle used.

Fig. 1: Actual steering knuckle of 1300 national car.

Since the steering knuckle is a complex component, a 3D scanner is used to obtain an accurate measurement of dimension and construct the correlative renderings drawing of steering knuckle. The computational aided design (CAD) software is used to produce a 3D model as shown in Figure 2. The finite element model consist of tetrahedral noded element with global size of 3.7 mm and local size element of 0.37 mm.

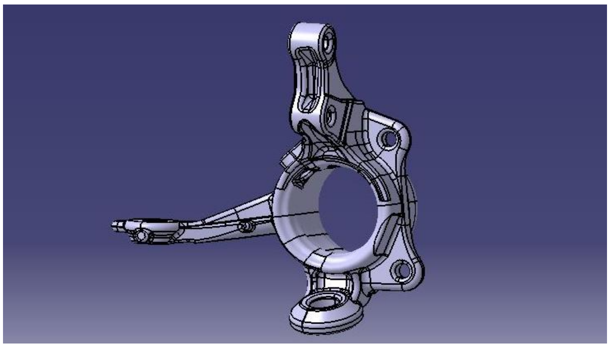
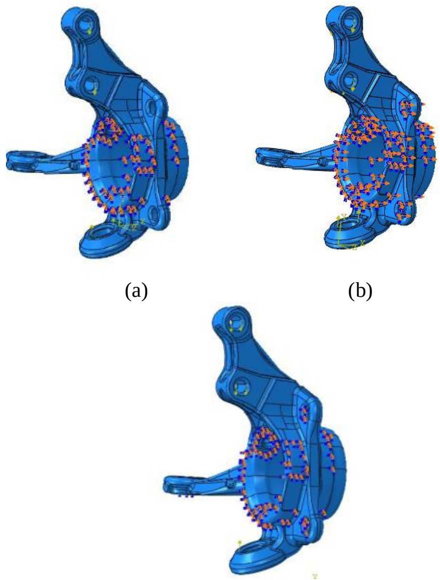


Fig. 2: Steering knuckle model.

In this study, the finite element model is subjected to applied load and constrained at three different cases in order to study the effect of constraint point to the stress distribution. The load is applied on strut mount and lower ball joint with 2500 N and 2250 N, respectively. The loads applied are based on dividing the weight of the automobile on the four wheel. The weight of the automobile is identified as 1000kg. The lower ball joint comprehends 90% of the total force acting on strut mount [8]. Since the automobile is driven in a straight route the force on the steering arm is not considered. The steering knuckle was constraint at hub only, for the case 1; at hub and brake clamp, for the case 2; and at hub, brake clamp and steering arm for the case 3. These three cases of constrained are shown in Figure 3 (a) to (c).



(a) (b) (c)

Fig. 3: Finite element model with three different point of constraint for (a) Case 1, (b) Case 2 and (c) Case 3 respectively

3. Results and Discussion

Figure 4 shows surface condition of steering knuckle image taken from SEM. Their chemical compositions are presented in the Table 1. From this table, the main composition of steering knuckle are iron (93.59%), carbon (3.80%), chromium (0.07%), copper (0.035%), nickel (0.04%), phosphorous (0.045%), silicon (2.40%) and sulfur(0.02%). Based on this chemical composition analysis, the grade for the alloy steel was ASTM A536.

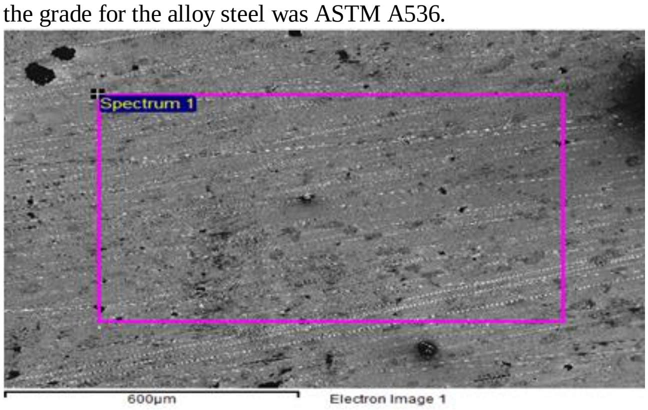


Fig. 4: Sample surface using SEM.

The result obtained was compromise with the previous research done by Zoroufi and Fatemi that compared the fatigue life of steering knuckle made from forged steel SAE grade 11V37, cast aluminium A356-T6 and cast iron ASTM A536 [8]. The cast iron ASTM A536 properties can be referred in Table 2 [8]. Mechanical properties [9] is verified using tensile test which are conducted on the specimen according to ASTM E8 standard with slight different as can be seen in Table 2 and Figure 5.

Table 1: Material composition of steering knuckel

Component Element Properties	Carbon, C	Chromium, Cr	Copper, Cu	Nickel, Ni	Phosphorous, P	Silicon, Si	Sulfur, S	Iron, Fe
Percentage (%)	3.80	0.07	0.035	0.04	0.045	2.40	0.02	93.59

Table 2: Mechanical properties of steering knuckle

Name	Cast Iron ASTM A536	Experimental Cast Iron ASTM A536
Yield Strength	300 MPa	322 MPa
Ultimate Tensile Strength, UTS	471 MPa	462 MPa
Elastic Modulus	193 GPa	189 GPa

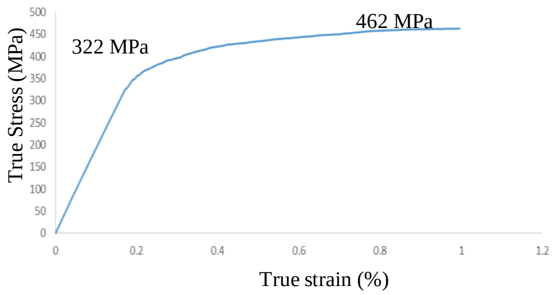


Fig. 5: Stress-strain curve experimental test ASTM A536

Figure 6 showed the stress distribution on steering knuckle for the case (1). Result showed that the maximum stress is occurred at point under the strut mount with magnitude of 335. 3 MPa. Therefore, this area is identified as a critical area for the steering knuckle since fatigue failure may occurred starting from this location. Similarly, for cases (2) and (3), their critical is at the same point as shown in Figure 7 and 8, respectively. The maximum stress for case (2) and (3) are 326.7 MPa. Maximum stress for all cases are lower than ultimate strength of ASTM A536. Since the maximum stress of case (1), case (2) and case (3) is not much different, the stress gradient is distinguishable apart of each case.

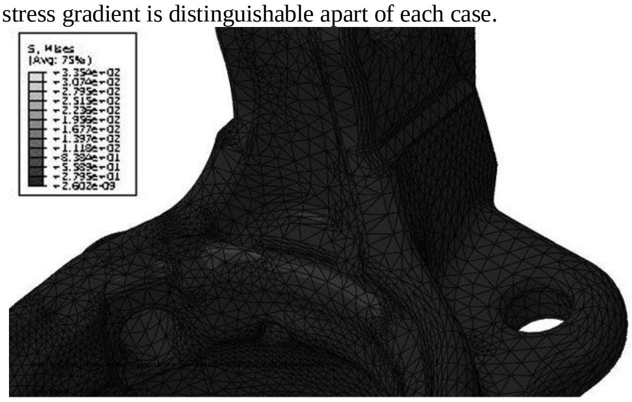


Fig. 6: Stress distribution for constraint at hub only.

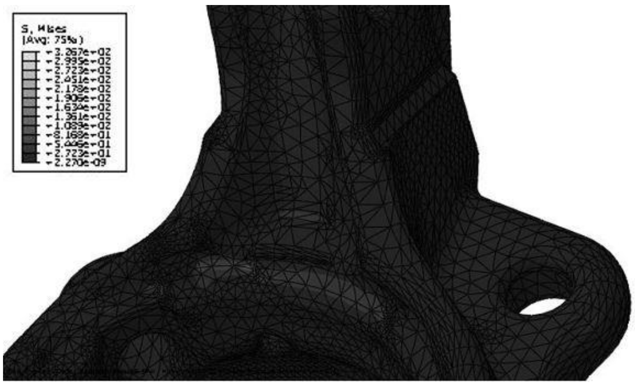


Fig. 7: Stress distribution for hub and brake clamp.

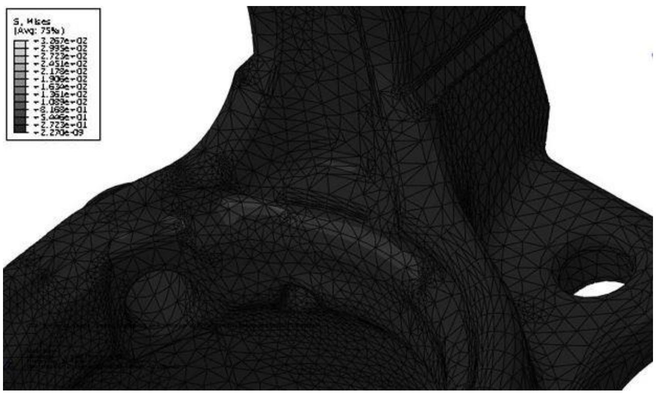


Fig. 8: Stress distribution for hub, brake clamp and steering arm

By comparing the three case of these constraint, it shown that the location of this constraints are not much effect the magnitude of the maximum stress. By conducting studies on constraint location it can be confirm that the critical area of cast iron ASTM A536 steering knuckle is on the neck of strut mount. It is important for further study on steering knuckle to take into consideration of this particular area in developing new ideas and theories of steering knuckle. Moreover, the magnitude of maximum stress is more influenced by the applied load on the steering knuckle.
From the observation, it was noticed that the strut mount connected to shock absorber that support the weight of the car. Other than that, automobile works under vast range of friction situations and conditions of uneven road surface will causes uncertainty in dynamic modelling safety [10] and could induce variable amplitude loading on the steering knuckle, which will further studied and discussed in future.

4. Conclusion

The steering knuckle was model using model using finite element method. Results showed that maximum stress for all three cases of constraint occurred under the strut mount with the magnitude range from 326 to 335 MPa. Therefore, it can be conclude that the most critical point of steering knuckle is at strut mount in all the three cases of different constrain in static analysis of the steering knuckle. The magnitude of stress range is not much influenced by the constraint point used in this study compared to the magnitude of applied load. Further study will be done on this steering knuckle using variable amplitude loadings.

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