iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** XI **Month of publication:** November 2020

DOI: https://doi.org/10.22214/ijraset.2020.31413

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue XI Nov 2020- Available at www.ijraset.com

Static and Fatigue Life Analysis of Steering Knuckle using FEM

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Abstract: This work describes a methodology for study the multiaxial loads acting on a steering knuckle and the possibility of increasing its performance under operating conditions. Steering Knuckle is the most critical component of a car and he is subjected to various loads at different conditions. The solid model and static analyses of steering knuckle was performed using Autodesk Inventor and for the fatigue analyses it was used specialized software for finite element analysis Autodesk Simulation Mechanical. Was investigated two materials, Gray Cast Iron which is the most used material and Aluminum Alloy. The FEM analysis showed that the maximum value of von Misses Stress are registered, for both models, at arm for mounting.
Keywords: Steering Knuckle, Static Analysis, Fatigue Analysis

I. INTRODUCTION

An important component of vehicle is steering knuckle which connects to the chassis, the wheel hub, brake, suspension and steering system. This component is subjected to different time-varying loadings during its service life and is important while not affecting the performance of vehicle. The important role of steering knuckle is to convert linear motion of the tie rod into the angular motion of the stub axle.

Kulkarni V. R. [1] and Dumbre P. [2] made static structural and modal analyzes to reduce the mass of the steering knuckle using OptiStruct software without reducing its performance by managing a 5% decrease in mass.

Razak I. H. A. et al. [3] studied the static analysis of the steering knuckle by FEM analysis using the SolidWorks software using Aluminum 6061-T651.

Sanjay Yadav et. al. [4] uses the Forge steel EN 47 material for steering knuckle and analysed, using Ansys Workbench 15.0, the various parameters such as Maximum Shear Stress, principal stress, total and directional deformation.

II. STEERING KNUCKLE DESIGN

The 3D steering knuckle model used for Dacia Duster was made, using Autodesk Inventor, in concordance with the specification given in specialized literature books and machine design. The steering knuckle solid model is presented in Fig. 1.

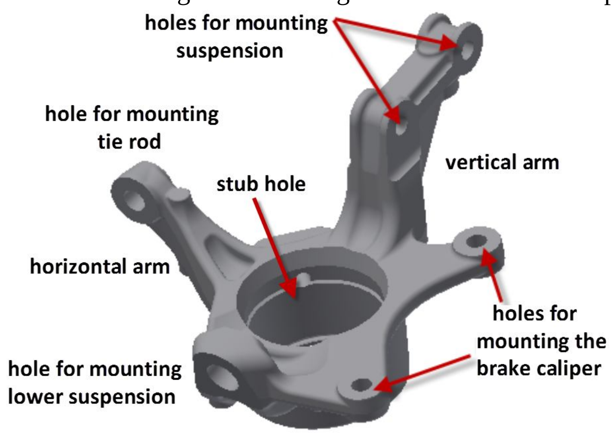

Fig. 1 A geometrical model of the steering knuckle

III.STATIC ANALYSIS

The static analysis of steering knuckle is used to determine the Von Mises stress, maximum value of displacements and minimum value of safety factor, caused by loads that do not induce significant inertia and damping effects. The geometry of steering knuckle is in concordance of the vehicle weight because vertical load of the vehicle is directly act on it.

The static analysis of steering knuckle component is done in Autodesk Inventor, following the steps presented below.

A. Choosing Material

Knowing that the materials from which the steering knuckle are made have to meet certain stress resistance conditions Iron, Gray Cast ASTM A-48 Grade 30 and and Aluminum Alloy 6061-O have been chosen for this study. The material properties of the Aluminum Alloy 6061-O and Iron, Gray Cast ASTM A-48 Grade 30 are presented in Table 1.

Table I
Material Properties

Parameters	Aluminum Alloy 6061-O	Iron, Gray Cast ASTM A-48 Grade 30
Elastic Modulus	68947.57 [N/mm^2]	101490.8 [N/mm^2]
Poisson's Ratio	0.33	0.253
Shear Modulus	26000 [N/mm^2]	50000 [N/mm^2]
Mass Density	2700 [kg/m^3]	7200 [kg/m^3]
Tensile Strength	124.1056 [N/mm^2]	275.7903 [N/mm^2]
Compressive Strength	55.1485 [N/mm^2]	572.165 [N/mm^2]
Thermal Expansion Coefficient	2.4e-005 [/K]	1.2e-005 [/K]
Thermal Conductivity	170 [W/(m·K)]	45 [W/(m·K)]
Specific Heat	1300 [J/(kg·K)]	510 [J/(kg·K)]

B. The Boundary Condition

In scope of calculating breaking force, who action on one wheel, we have to distribute mass of vehicle for four wheels, for small vehicles the distribution is uniform on the two axles of the vehicle. The moment who acting on steering knuckle where break caliper is mounted was calculated as the product of breaking force and perpendicular distance.

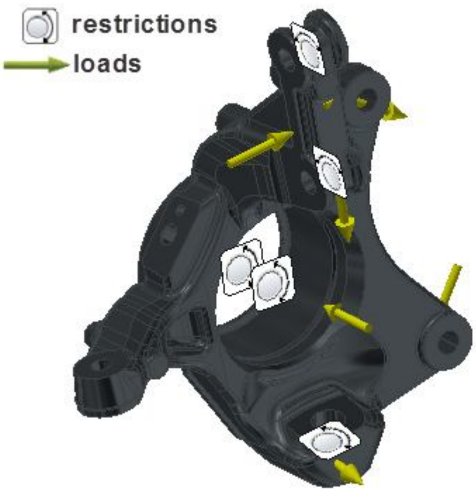

Fig. 2 The boundary condition of the steering knuckle

In the specialized literature is specified that the maximum braking force applied is not greater than 1.5·m·g, and the forces on steering knuckle in X, Y direction are m·g and in Z direction are 3·m·g (e.g. [5], [6]).
where m - distributed mass on each wheel, (maximum authorized weight m = 1875 kg)
g - gravitational acceleration.

1) Initial Condition

a) Radial and axial fixation on the vertical arm.

b) Radial and axial fixation on the stub hole.

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2) Loading Condition

a) Bearing load on upper suspension caused by weight of the car.
b) Bearing load on brake caliper caused by brake force.
c) Distributed force on upper suspension mount caused by mass and speed of the car.
d) Bearing load on horizontal steering mount caused by steering movement.
e) Bearing load on balance caliper caused by car balance.
f) Distributed force on axis wheel hub caused by axial car load.

The initial condition and loading condition of the steering knuckle are presented in Fig. 2.

C. Generate Meshing

To generate the mesh of the steering knuckle the automatic tetrahedron elements generation was used and the solid model of the steering knuckle being meshed into 75873 elements and 118572 nodes. The steering knuckle after mesh generation shows in Fig. 3.

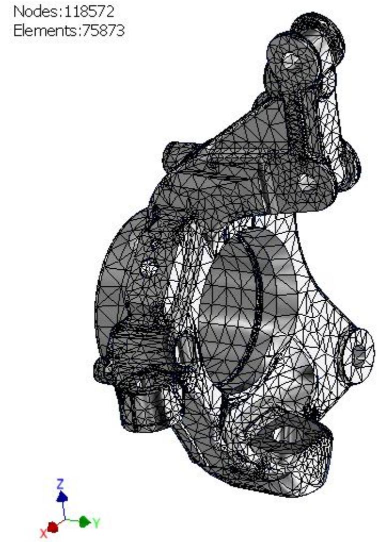
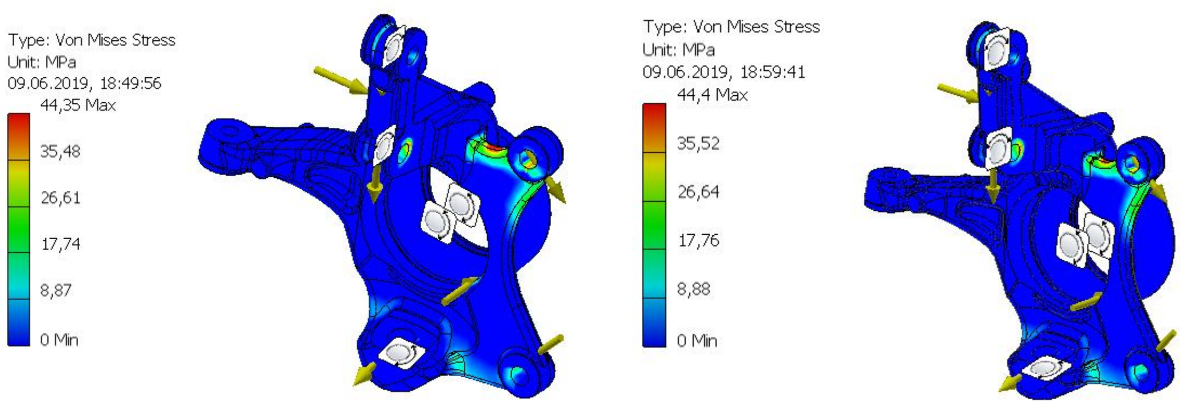


Fig. 3 The steering knuckle meshing

D. Results of Static Analysis

After the material was assigned and the boundary conditions have been specified we proceed to the running of the simulation for both materials.

Figure 4 presents the results for Von Mises Stress obtained in both situation, a) Aluminum Alloy 6061-O and b) Iron, Gray Cast ASTM A-48 Grade 30. The maximum deformation for steering knuckle as shown in Fig. 5, a) Aluminum Alloy 6061-O and b) Iron, Gray Cast ASTM A-48 Grade 30.



a) Aluminum Alloy 6061-O b) Iron, Gray Cast

Fig. 4 Von Mises stress

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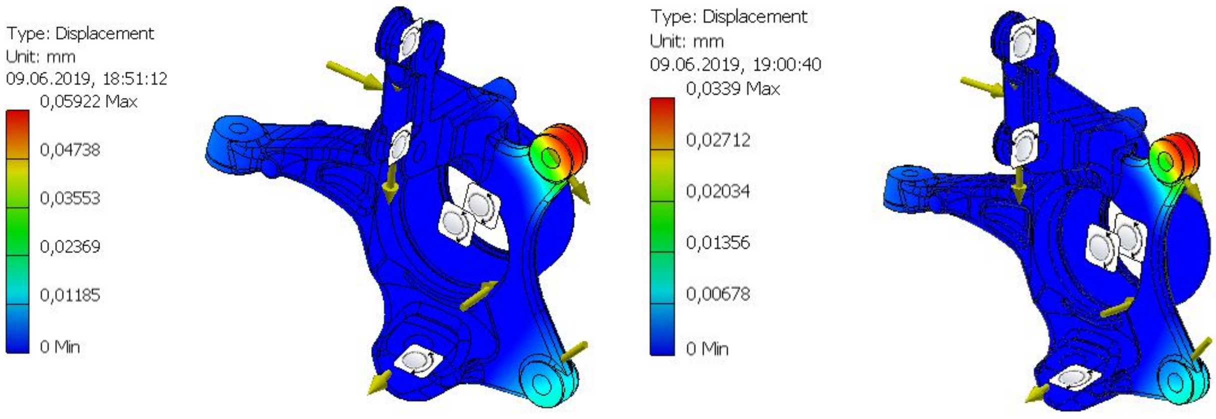


a) Aluminum Alloy 6061-O b) Iron, Gray Cast

Fig. 5 Total 1deformation

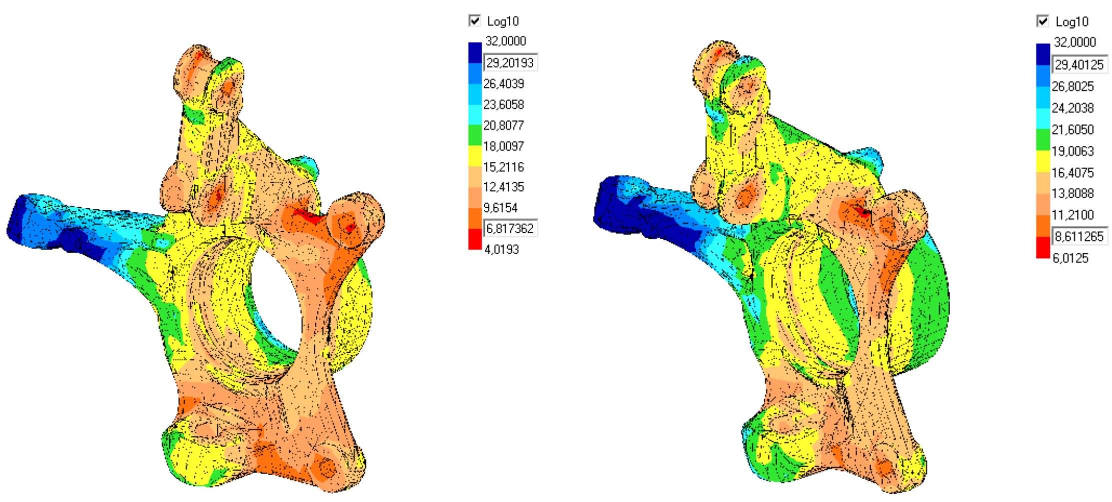
Result of the static analysis shows that the maximum Von Mises Stress of the steering knuckle, which occurs at the arm where the brake pads are mounted, is 44.35 MPa for Aluminum Alloy 6061-O and 44.4 MPa in the case of Iron, Gray Cast ASTM A-48 Grade 30 model. The maximum deformation for steering knuckle as shown also in the arm where the brake pads are mounted, is 0.059 mm for Aluminum Alloy 6061-O and 0.034 mm in the case of Iron, Gray Cast ASTM A-48 Grade 30 model.

IV. FATIGUE ANALYSIS

The fatigue is a process that involves several stages of deterioration. At each stage, there are various mechanisms of damage accumulation, following more or less known laws.

Researches on fatigue degradation have shown links between the different mechanical properties of the material, such as: flow limit, tensile strength, toughness and the fatigue life (e.g. [7]–[10]).

Loads have been defined so that they match as much as possible with real conditions. The simulation was performed using the same border conditions as the static analysis, imposing the 10000000 cycles. Fatigue simulation analysis requires the choice of a coefficient based on the degree of part surface machining, in this case was chosen forged.



a) Aluminum Alloy 6061-O. b) Iron, Gray Cast.

Fig. 6 Fatigue results

The fatigue simulation results for steering knuckle are shown in Fig. 6. The maximum number of fatigue cycles was recorded in the case of Gray Cast Iron steering knuckle, 1029241. In the case of the Aluminum Alloy steering knuckle, the maximum number of fatigue cycles was 10454.2.

V. CONCLUSION

Result of the static analysis shows that the maximum Von Mises Stress and maximum deformations of the steering knuckle, due to the applied load, occurs at the arm where the brake pads are mounted, regardless of the material used.

Based on the basics of fatigue analysis, this paper uses Autodesk Simulation Mechanical software for finite element analysis of steering knuckle two materials of Gray Cast Iron and Aluminum Alloy 6061.

From the comparative analysis of the results obtained for the two variants it can be noticed that the highest resistance to fatigue has the steering knuckle made from Iron, Gray Cast ASTM A-48.

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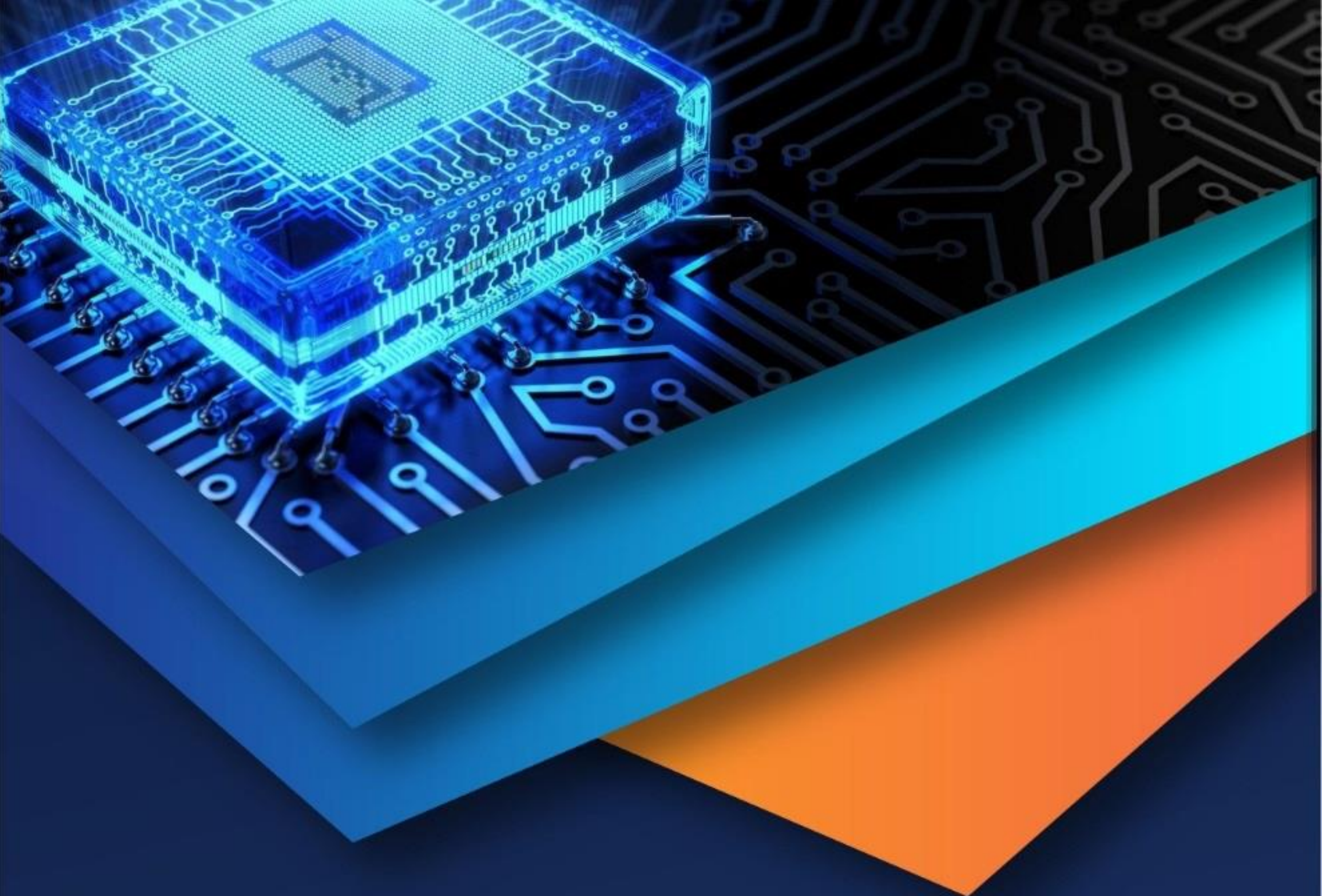

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