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Investigation of Critical Regions on Automotive Lower Suspension Arm Using Analytical Approach

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Abstract – *This paper focuses on investigating the critical locations of Automotive Lower Suspension of car front suspension to study the stress condition and to select the suitable materials for the front suspension lower arm. In this paper first upon the modeling of Automotive Lower Suspension Arm is done using Creo parametric 2.0. Then solid geometry of the component was imported in to ANSYS software version 18.1 to perform Finite Element Analysis prior to that information is collected regarding various boundary conditions to be applied on the component. Critical locations of lower suspension arm was studied with the existing material then comparative analysis were performed using other material to suggest suitable material for Automotive Lower Suspension Arm.*

Keywords- *Lower Suspension Arm, Finite Element Analysis, Modeling.*

INTRODUCTION

The suspension system is one of the most important components of vehicle, which directly affects the safety, performance, noise level and style of it. The vehicle suspension system is responsible for driving comfort and safety as the suspension carries the vehicle-body and transmits all forces between body and road. Positively, in order to influence these properties, semi-active or active components are introduced, which enable the suspension system to adapt to various driving conditions. From a design point of view, there are two main categories of disturbances on a vehicle namely the road and load disturbances.

Suspension arm is one of the main components in the suspension systems. It can be seen in various types of the suspensions like wishbone or double wishbone suspensions. Most of the times it is called as A-type control arm. It joins the wheel hub to the vehicle frame allowing for a full range of motion while maintaining proper suspension alignment. Uneven tire wear, suspension noise or misalignment, steering wheel shimmy or vibrations are the main causes of the failure of the lower suspension arm. Most of the cases the failures are catastrophic in nature. So the structural integrity of the suspension arm is crucial from design point of view both in static and dynamic conditions. As the Finite Element Method (FEM) gives better visualization of this kind of the failures so FEM analysis of the stress distributions around typical failure initiations sites is essential. Therefore in this project it is proposed to carry out the structural analysis of lower suspension arm of light commercial vehicle using FEM.

LITERATURE REVIEW

The lower Suspension arm is the most vital component in a suspension system. There are two Suspension arms, lower Suspension arm and upper Suspension arm. Lower Suspension arm allows the up and down motion of the wheel. It is usually a steel bracket that pivots on rubber bushings mounted to the chassis. The other end supports the lower ball joint. Significant amount of loads are transmitted through the Suspension arm while it serves to maintain the contact between the wheel and the road and thus providing the precise control of the vehicle. There are many types of Suspension arms are available. The selection of the arm is mainly based on the type of suspension system.

Fig. 1- Lower Suspension Arm

OBJECTIVES

I. The main aim is to investigate the failure of the lower arm.
II. To describe a computer-based approach to the car front suspension design problem.
III. To identify the critical regions on automotive lower suspension arm where stress and strain occurs.
IV. To analysis of the suspension arm using ANSYS Software.
V. Recommend the new Material for manufacturing of automotive lower suspension arm

METHODOLOGY

Chassis parts are a critical part of a vehicle, leaving no room for error in the design and quality the present process relates to a computer-aided structure analysis and design graphic display device and method, and more particularly, to a computer-aided structure analysis of Lower Suspension Arm and which is analyzed and designed, thereby to meet the customer requirements of Lower Suspension Arm. For finding the stress concentration areas in Lower Suspension Arm, we can use the ANSYS software. First upon we create the model in PRO-E software. ANSYS and PRO-E both are design software. In this we can find out lot of various result related with design phenomenon.

Model Formulation

Analytical Calculation

Software Analysis

DESIGN

By the wheel of the car (if driving) torque applied *Tк* and it rotates with angular velocity *ωк* . Wheel of the car with the help of independent suspension is related to the car body and has an angular stiffness *Cβp*, and stiffness *Cp* compression springs.Some numerical results are by definition a number of parameters that characterize the work areas 1 and 2 rod stabilizer which has the following kinematic and geometric source parameters.

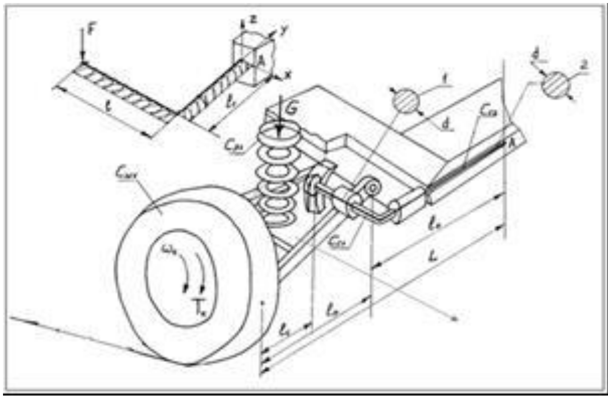


Fig. 2-The geometric parameter of wheel axle and arms

L=682.5mm, lп=350mm lo=325mm, l1=320mm, lc=230mm, l=210mm, 2Cp1=26kgs/cm, 2Cp2=30kgs/cm, 2Cш1=2Cш2=204 kgs/cm

The angular stiffness front suspensions (Cβp1) :

$C\beta p1 = 2Cp1 * L2$

$=26 * 68.252$

$C\beta p1 = 121109.62$ kgs·cm

The angular stiffness rear suspensions (Cβp2) :

$C\beta p2 = 2Cp2 * L2$

$= 30 * 68.252$

$C\beta p2 = 139741.87$ kgs·cm

We also calculate the angular stiffness of the tire:

$C\beta\text{ш}1 = C\beta\text{ш}2 = 2C\text{ш} * L2$

$= 204 * 68.252$

$C\beta\text{ш}1 = C\beta\text{ш}2 = 950244.75$ kgs·cm

Find given angular rigidity front suspensions (Cβ1) :

$$C\beta 1 = \frac{C\beta p1 * C\beta\text{ш}1}{C\beta p1 + C\beta\text{ш}1}$$

$$= \frac{121109.62 * 950244.75}{121109.62 + 950244.75}$$

$C\beta 1 = 107418.96$kgs·cm

Find given angular rigidity rear suspensions (Cβ2):

$$C\beta 2 = \frac{C\beta p2 * C\beta\text{ш}1}{C\beta p2 + C\beta\text{ш}1}$$

$= \frac{139741.87*950244.75}{139741.87+950244.75}$

$C\beta2$=121826.24kgs·cm

Effective roll arm (h3) :

h3 = hg – h2 *

h3 = 580 – 320 *

h3 = 420 mm

h3 = 42 cm

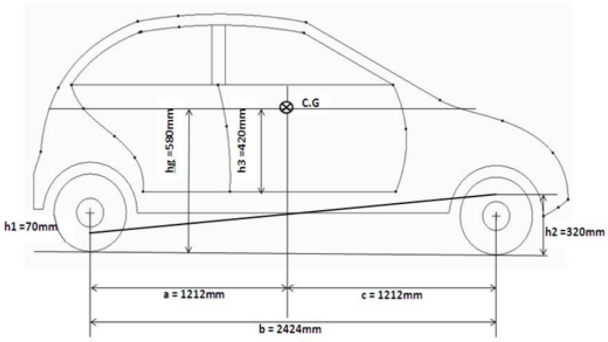


Fig. 3- Centre of gravity and parameters of car base

We define the angle of heel corresponding parameters calculated from the dependence :

$\beta = \frac{\mu*Ws*h3}{C\beta1+C\beta2-Ws*h3}$

when, μ -Specific lateral force applied at the center of gravity of the body and can be taken as 0.4,

Ws -Weight acting on one side of suspension = 1200 kg

$\beta = \frac{0.4*1200*42}{107418.96+121826.24-1200*24}$

$= \frac{20160}{178845.2}$

β = 0.112rad

β = 6°41ʹ

With the effective rolling arm h3 defined, it is possible to calculate the roll moment (Troll) applied to the vehicle due to the lateral acceleration imposed:

Troll = M * aL * h3

where, Troll= Vehicle Roll moment

M = Vehical mass, kg ; Maruti 800 M = 1000 kg

aL = lateral acceleration, m/s

h3 = effective roll arm, m

Troll = M * aL * h3

Troll = 1600 * 22.22 * 0.42

Troll = 14931.84 Nm

Then calculate the roll gradient (Kroll) :

Kroll = $\frac{T_{roll}}{K_t}$

where, Kroll = Roll gradient

Kt = Cβp1 = Vehicle's total roll stiffness

Kroll = $\frac{T_{roll}}{K_t}$

Kroll = $\frac{14931.84}{121109}$

Kroll = 0.12

The forces per axle can be calculated as follows:

Front axle force (Ffront) :

Ffront = $\frac{c}{b}$* M * aL

Ffront = $\frac{1.212}{2.424}$* 1000 * 22.22

Ffront = 11110 N

FINITE ELEMENT ANALYSIS

Finite Element Analysis (F.E.A) is a powerful technique used for solving complicated mathematical problem of engineering and physics such as structural analysis, heat transfer, fluid flow, mass transport and electromagnetic potential. Modem F.E.A. generated by computer software allows engineer to subject a computer model of structure to various loads to determine how it will react. The environment is defined through a combination of loads and constraints and the decisions or assumptions that about those loads and constraints are very important to the overall accuracy of the simulation. It also enables designs to be quickly modeled, analyzed, changed, checked for feasibility and structural integrity, redesigned or discarded if they do not work.

FEA is used in problems where analytical solution not easily obtained Mathematical expressions required for solution not simple because of complex geometries loadings material properties.

Material Properties:

We have used three types of material which are as :

1) EN 24

2) Fe 510

3) Structural Steel

1) EN 24:

Density = 7850 kg/mm3 , Young's Modulus = 2.1 x 10^5 Mpa

Poisson's Ratio = 0.3, Yield Tensile Strength = 680 Mpa

Yield Compressive Strength = 680 Mpa

Ultimate Tensile Strength = 850 Mpa

Ultimate Compressive Strength = 0 Mpa

2) Fe 510:

Density = 7850 kg/mm3, Young's Modulus = 2 x 10^5 Mpa

Poisson's Ratio = 0.3, Yield Tensile Strength = 490 Mpa

Yield Compressive Strength = 490 Mpa

Ultimate Tensile Strength = 590 Mpa

Ultimate Compressive Strength = 0 Mpa

3) Structural Steel:

Density = 7685 kg/mm3 , Young's Modulus = 2.1 x 105 Mpa

Poisson's Ratio = 0.285

Yield Tensile Strength = 290 Mpa

Yield Compressive Strength = 290 Mpa

Ultimate Tensile Strength = 510 Mpa

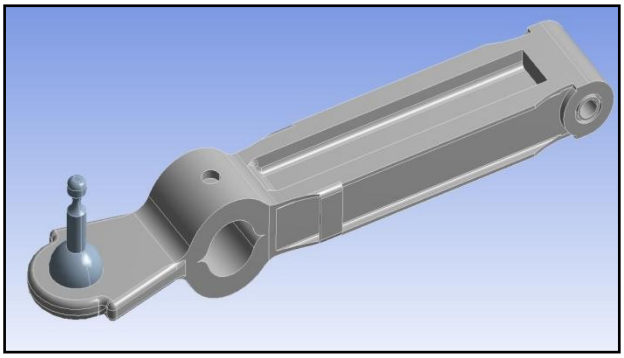


Fig. 4- Solid Model of Lower Suspension Arm

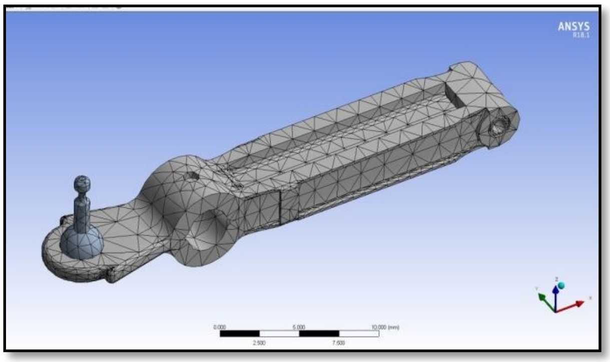
Mesh Generation:

ANSYS meshing technologies provide physics preferences that help to automate the meshing process. For an initial design, a mesh can often be generated in batch with an initial solution run to locate regions of interest. Further refinement can then be made to the mesh to improve the accuracy of the solution. There are physics preferences for structural, fluid, explicit and electromagnetic simulations. By setting physics preferences, the software adapts to more logical defaults in the meshing process for better solution accuracy.

After Meshing in ANSYS Software, find out Nodes and Element

Nodes : 13877

Element : 7619



Boundary Condition :

1 Force
2. Fixed Support
3. Frictionless Support

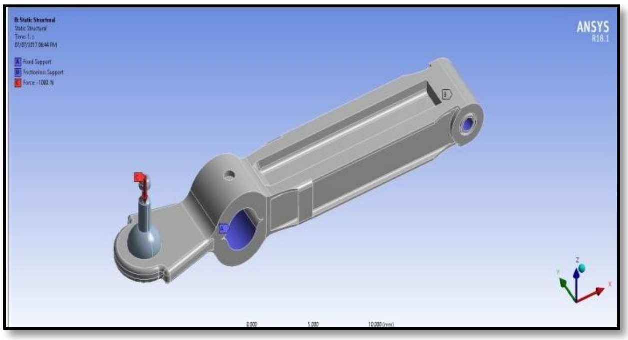


Fig.5- Shows Boundary Condition applied on Arm

The analysis of Automotive Lower Suspension Arm has been carried out for three materials which are EN 24, Fe 510 and Structural Steel (S355) for loads of 1000 N, 4500 N and 5500 N on the basis of following parameters

i. Total Deformation
ii. Von-Mises Stress
iii. Equivalent Elastic Strain
iv. Maximum Shear Stress

1) Material EN 24:

a) For 1000 N Force

i) Total Deformation Max.= 1.0845 mm

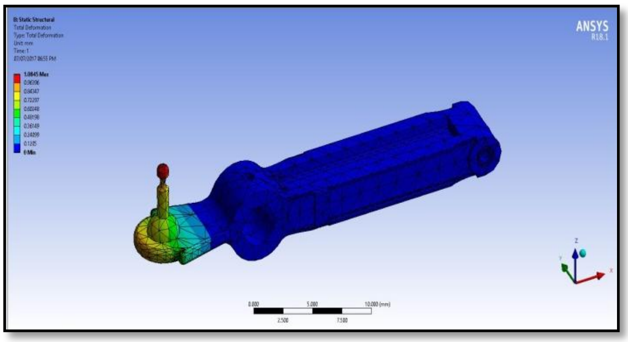


Fig. 6- Results of Total Deformation for 1000 N force

ii) Von-Mises Stress Max. = 7153.5MPa

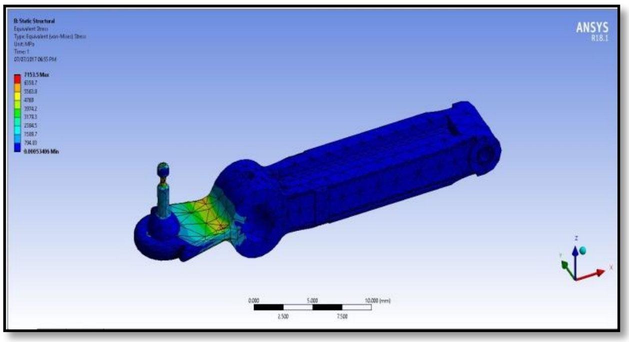


Fig. 7- Results of von-Mises Stress

iii) Max Shear Stress Max = 1030.6 Mpa

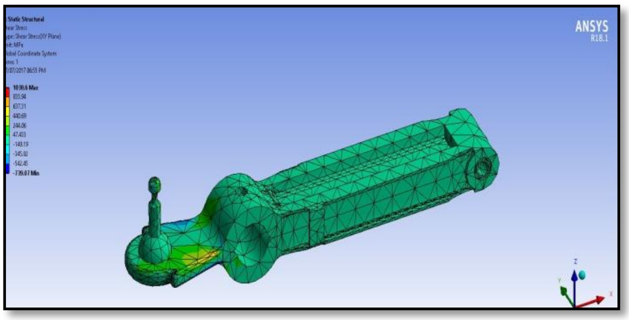


Fig. 8- Results of Shear Stress

iv) Equivalent Elastic Strain Max.= 0.03461

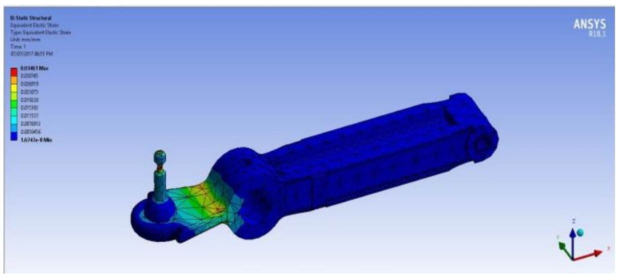


Fig. 8- Results of Equivalent Elastic Strain

Material EN 24:

b) For 5500 N Force

i) Total Deformation Max.= 5.9645 mm

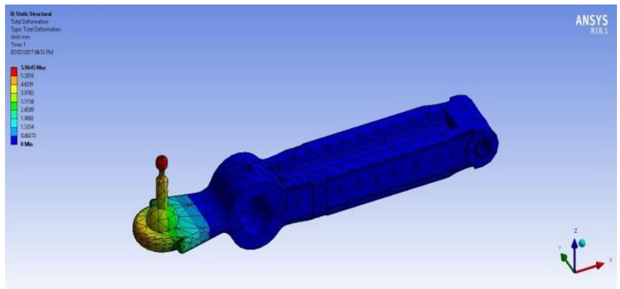


Fig. 9- Results of Total Deformation

ii) Von-Mises Stress Max. = 39344 MPa

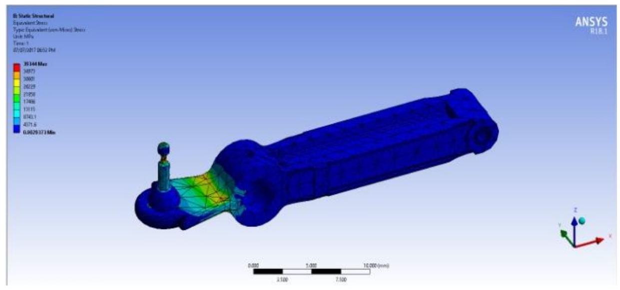


Fig. 10- Results of von-Mises Stress

iii) Maximum Shear Stress Max. = 5668.1 MPa

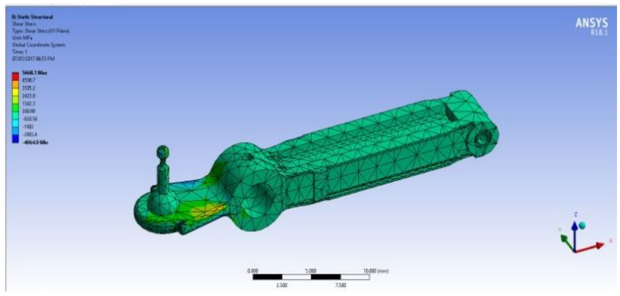


Fig. 11- Results of Shear Stress

iv) Equivalent Elastic Strain Max.= 0.19036

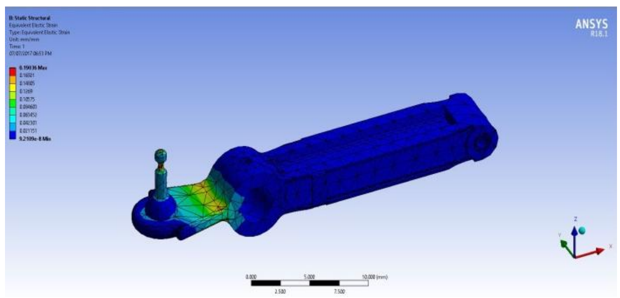


Fig. 12- Results of Equivalent Elastic Strain

Results of Software analysis:

All the results obtained by the FEA Software for analysis of Automotive Lower Suspension Arm on different load range by using different materials are given in the tabular form -Total Deformation, Von-Mises Stress, Maximum Shear Stress, Equivalent Elastic Strain

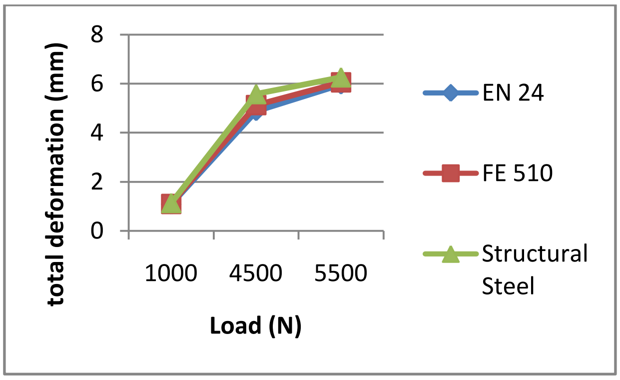
Table 1 - Results of Software analysis

Material	Force in Newton	Deform-ation in MM	Von-Mises Stresses in Mpa	Elastic strain in MM	Shear Stress in Mpa
EN 24	1000 N	1.0845	7153.5	0.03461	1030.60
	4500 N	4.8801	32191	0.15575	4637.50
	5500 N	5.9645	39344	0.19036	5668.10
FE 510	1000 N	1.1042	7153.5	0.03521	1030.60
	4500 N	5.1265	33029	0.16352	4852.20
	5500 N	6.0526	40809	0.19532	5825.30
Structural Steel	1000 N	1.1387	7153.5	0.036341	1030.60
	4500 N	5.5795	35052	0.17807	5049.80
	5500 N	6.2627	42221	0.19987	6026.60

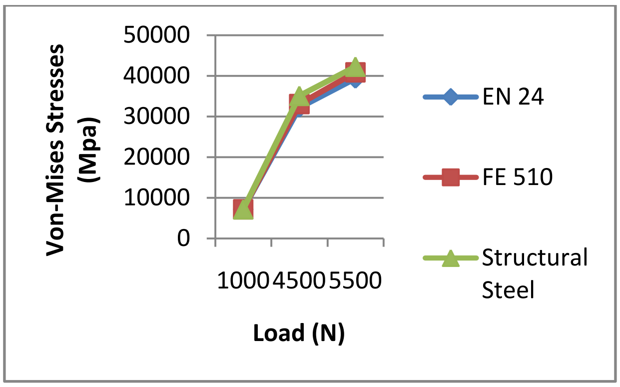
Graphical Representation of Software analysis results :

To understand the behavior of different materials used for Automotive Lower Suspension Arm on different loadings for different material the graphical representation is given.

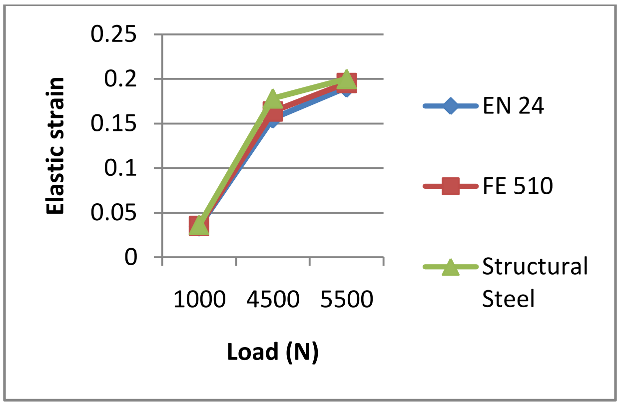
1) Load Range (N) Vs Total Deformation



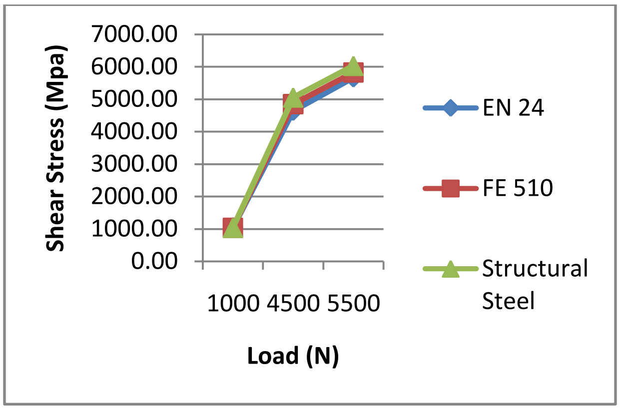
2) Load Range (N) Vs Von-Mises Stress



3) Load Range (N) Vs Elastic Strain



4) Load Range (N) Vs Shear Stress



From the above graph it can be concluded that for the load of 1000 N behavior of all the material is nearly same but as we consider the higher load of about 5500 N all parameters like total deformation, shear stress, elastic strain and von-mises stress are very less for material EN 24.

CONCLUSION

In this research it has been seen that the maximum value of force transmitted by tire to the body of vehicle through lower suspension arm. During braking and cornering the lower suspension arm is subjected to high stresses because of that Failure of lower suspension arm of vehicle was reported. Plastic deformation and cracks were observed frequently during on road running of vehicle. Stress analysis was performed using finite element method.

The aim of this study was to investigate the critical regions of Automotive Lower Suspension Arm where the stress concentration is maximum and to suggest a suitable material for Automotive Lower Suspension Arm as it is a very vital component of the suspension system and always subjected to variable amplitude loading. In this project, the stress analysis is done with the help of ANSYS 18.1 software. The stress and deformation effect on suspension lower arm was investigated under vehicle loading. The behavior of lower arm is very important parameters in stress distribution near loading and bush portion of the lower arm.

In this project, we conclude that the stress analysis for considering lower arm deformation, von-Misses Stress, Max shear stress, and Equivalent Elastic strain also using different lower arm materials were tested and it was observed that EN 24 Fe410 material was much better than the Fe510 material.

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