

COMPARISON STUDY OF LOWER CONTROL ARM WITH DIFFERENT MATERIAL

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Abstract –Lower control arm is a component used in a suspension system of a car. It plays an whittle role in managing the motion of the wheel during bump, turning, and breaking. There are so many shapes of control arm like L-shape, and U-shape. The scope here in this project is to optimize the L-shape control arm with respect to weight with two different materials (steel & aluminium).

Keywords:-Suspension system, Automobile lower control arm, Suspension bushes, Static and dynamic FEA analysis.

1. INTRODUCTION

In suspension system, the control arm is very important component .the double wishbone suspension system contains lower control arm and upper control arm. The McPherson structural suspension system contains only lower control arm. Between wheel assembly and vehicle chassis the control arms are rigidly placed. The control arm is connected to the chassis with the help of bush which is placed in pivot joints. Rear and front bushes are used in control arms. it has U-shaped configuration. At the apex of the control arm a ball joint receptacle is formed. The ball joint receptacle is adapted to cooperate with a ball joint assembly and may include a ball joint housing integrally formed with the control arm. Typical modern control arm incorporate a separate ball joint housing which is inserted in to the apex of control arm. The bushing apertures are designed to retain pipe housings for mating engagement with a pivot bar assembly forming a portion of the vehicle suspension system. The pivot bar typically extends through both bushing apertures allowing the control arm to pivot about the assembly in response to road conditions affecting the vehicle suspension system. For the construction of control arm high strength alloy steel is used. Control arm consist of modulus section which is between the apex and pivot points.



Fig- 1: McPherson suspension Assembly

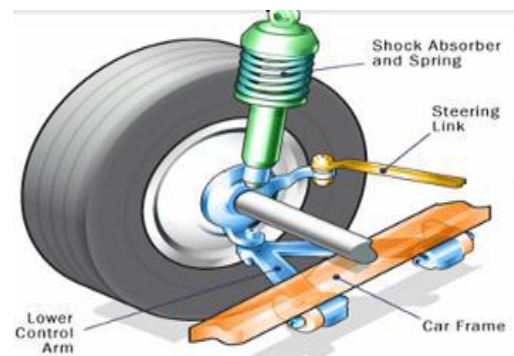


Fig - 2:General suspension system

2. OBJECTIVES AND SCOPE OF PRESENT WORK

2.1 OBJECTIVES

- To study the structural stability of lower control arm under turning conditions.
- To study the behavior of the structure with different material properties.
- To compare the weight to strength ratio under different materials.

2.2 SCOPE OF PRESENT WORK

Due to the various functions of control arm it is one of the important components in suspension system. When vehicle takes turn various types of forces are acting on the wheels which are transmitted to the control arm through attachments such as ball joint assembly and so on, to the wheel. These torque and force values can be mentioned in the load case. Here in this analysis the main concern is to find out the maximum stress region and stress values in control arm and compare this values with yield strength of materials and the result of experimental testing of control arm at the same load are mentioned in the load case of the control arm.

3. METHODOLOGY

3.1 METHODOLOGY FOR FINITE ELEMENT SOLUTION

In order to solve this problem, we use the following method mentioned in the below flow chart.

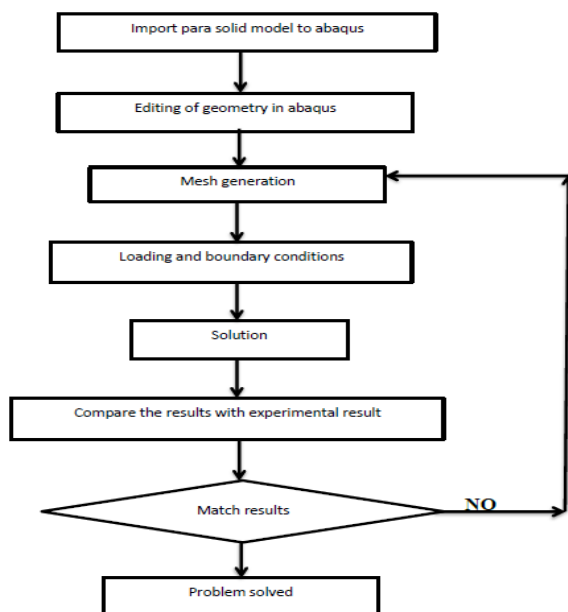


Fig -3.1.1: Flow chart of problem methodology

3.2 OVERVIEW OF HYPERMESH

Hyper mesh is a preprocessing tool which is used to discretize the structure surface in to small number of parts and each part are called as elements which collectively are connected by means of nodes. The group of elements and nodes is termed as mesh. And hyper mesh is commercially pre-processor software; which is developed by a Altair.

3.3 OVERVIEW OF ABAQUS

Abaqus is a pre-processor solver and post-processing software which is used to solve the static analysis, dynamic analysis and impact analysis by the use of numerical methods such as Newton’s rapson method, lanceoz method and time integration method and it is also a post processing software. This will help to interpret the results and take appropriate decision to design a part or a system.

4. GEOMETRY AND MATERIAL DETAILS

4.1 GEOMETRY OF SPECIMEN

The lower control arm is a important part of front suspension system. It is used to control wheel trace and transmits the load exerting on the wheel by the ground to the various parts of the car. When the car was in motion, the lower control arm is subjected to complex loads alternating with time. There may be different shapes of lower control arms are available.



Fig -4.1.1: Geometry of specimen

4.2 MATERIAL DETAILS

4.2.1 ALUMINIUM PROPERTIES

Density	$\rho=2.6898\text{g/cm}^3$
Yield strength	$S_y= 240 \text{ MPa}$
Young’s modulus	$E=7*10^5\text{MPa}$
Poisson’s ratio	$\nu = 0.34$

Table - 1: Properties of Aluminium

The above table-1 shows the properties of Aluminum such as Density, Yield strength, Young’s modulus, Poisson’s ratio.

4.2.2 STEEL PROPERTIES

Density	$\rho=7.85\text{g/cm}^3$
Yield strength	$S_y=415\text{ MPa}$
Young’s modulus	$E=2*10^5\text{MPa}$
Poisson’s ratio	$\nu = 0.34$

Table - 2:Properties of Steel

The above table-2 shows the properties of Steel such as Density, Yield strength, Young’s modulus, Poisson’s ratio.

5. FEA ANALYSIS

5.1 TYPE OF ANALYSIS

The software provides modules to carry out various types of analysis, such as structural analysis, thermal analysis, fluid analysis and computational fluid analysis.

The current study involves study of mechanical properties of the material. There are basically two types of analysis one is static analysis and second one is dynamic analysis. Here in this project implicit static analysis is carried out to obtain results

5.2 TYPE OF ELEMENT

Quadratic tetrahedron is also called ten node tetrahedron. It is second complete polynomial adherent of the isoparametric tetrahedron family. In this element the stress calculation is considerably better than the four nodes. This element proceeds the compensations of the existence of fully automatic tetrahedral mashers.

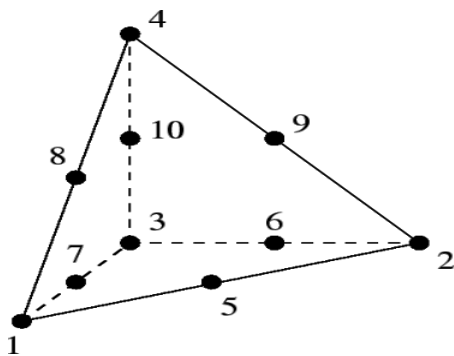


Fig -5.2.1: 2nd order 10 noded tetrahedral element

5.3 DEVELOPMENT OF CAD

MODEL

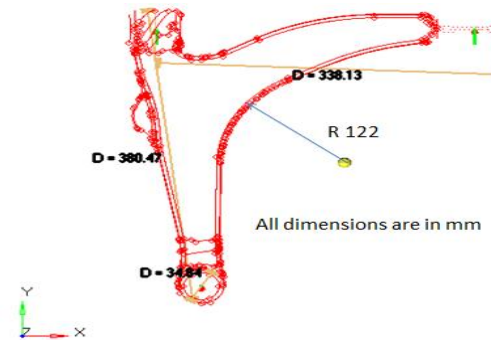


Fig -5.3.1: LCA with dimensions

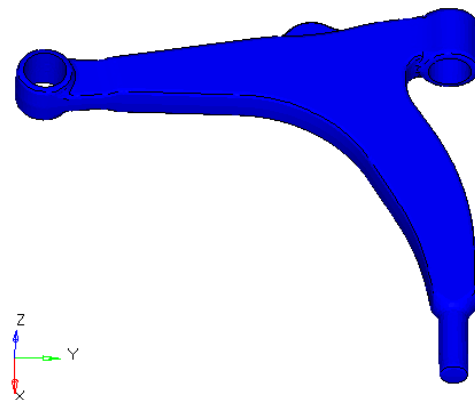


Fig -5.3.2: Designed LCA cad model

This is a cad model which can be analyzed to determine structural the stability during turning, to study the behavior of material under different material properties and to compare weight to strength ratio under different material conditions.

5.4 LOAD AND BOUNDARY CONDITIONS

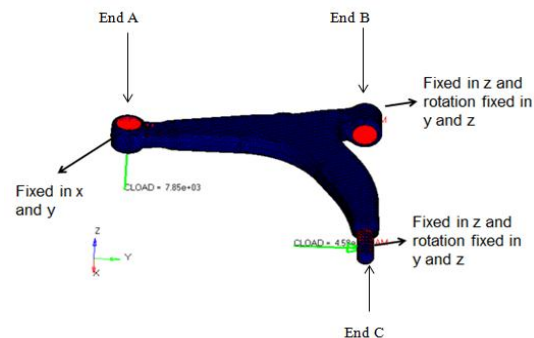


Fig -5.4.1: Applied boundary conditions

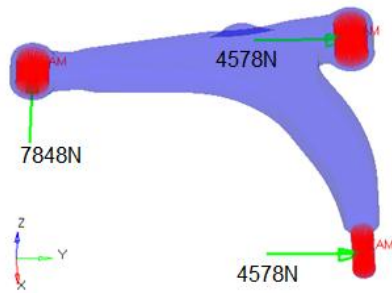


Fig -5.4.2: Loads generated on LCA

Here, End A is connected to the ball joint where it is move in a vertical direction i.e z and this vertical load is from ground and it can be calculated as shown below .it is fixed in a X and Y direction, such that there is no motion in x and y direction. Where end B and end C are fixed in z direction so that it cannot move in vertical direction. And it can rotate only in x direction but rotation is fixed in y and z direction. The loads which are shown are given by calculation. The loads on end B and end C are obtained during turning due to side force components.

5.5 MAX VON-MISES STRESS: 470 MPa(FOR ALUMINIUM)

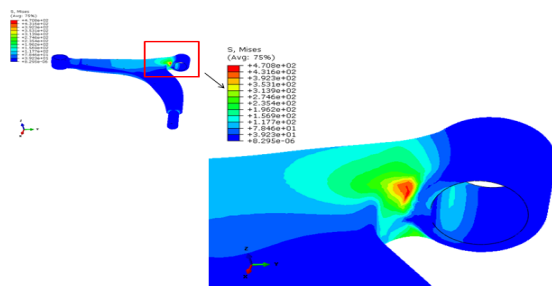


Fig - 5.5.1: Lower control arm made from aluminum

Here I have considered the lower control arm with aluminium alloy. The stress encountered using this alloy is 470 Mpa which is a very small, so this shows the stress distribution with a small area(red) i.e 470 Mpa and in rest of the cases , the stress is almost below 350 Mpa (yellow) but it can be removed by shape optimization but here my scope is only to topology optimization.

5.6 MAX VON-MISES STRESS: 471MPa (FOR STEEL)

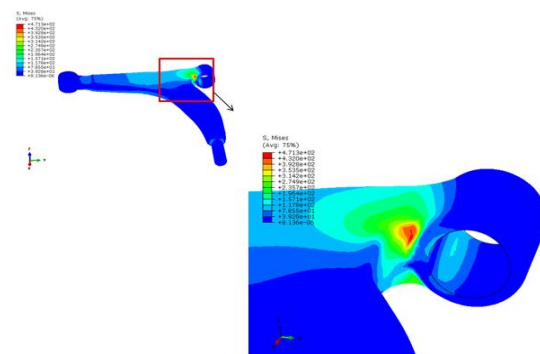


Fig -5.6.1: Lower control arm made from steel

In this the lower control arm is made with steel material. The stress encountered using this alloy is 471 Mpa which is a very small, so this shows the stress distribution with a small area(red) i.e 470 Mpa and in rest of the cases , the stress is almost below 350 Mpa (yellow) but it can be removed by shape optimization but here my scope is only to topology optimization.

5.7 MAX AND MIN PRINCIPLE STRESSES

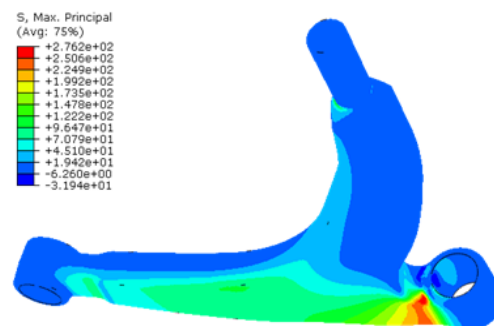


Fig -5.7.1: Max principle stress: 276MPa (for aluminum)

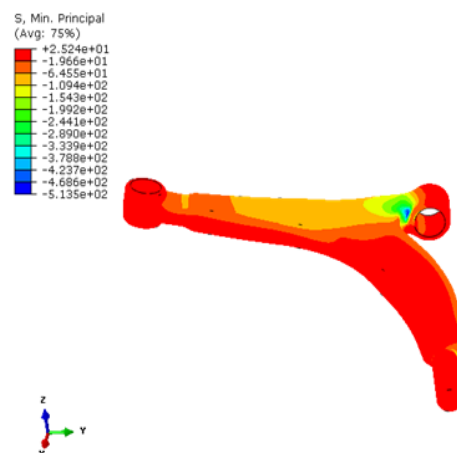


Fig - 5.7.2: Min principle stress: -513MPa (for aluminium)

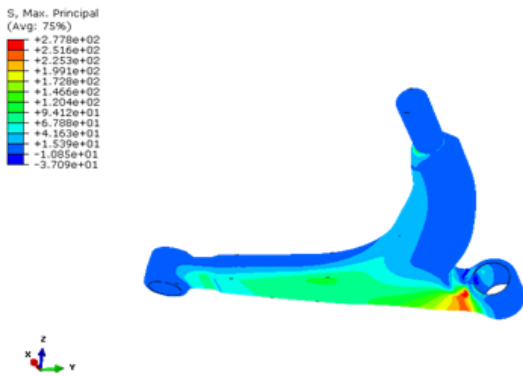


Fig -5.7.3: Max principle stress: 277 MPa (for steel)

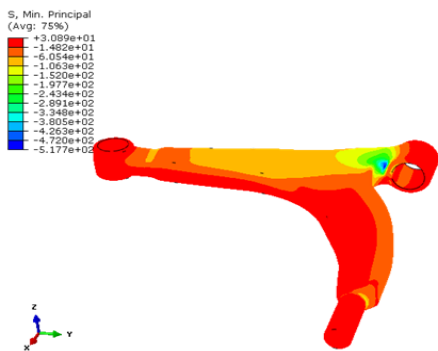


Fig -5.7.4: Min principle stress: -517MPa (for steel)

These are the principle stresses, so these stresses well within the von-misses stress and this is the minimum stress and it showing around 513Mpa as compressive, since compressive yield strength is more compare to tensile stress so I am not considering this for my result discussion And considering only von-misses stress.

5.8 DEFLECTION OF LOWER CONTROL ARM

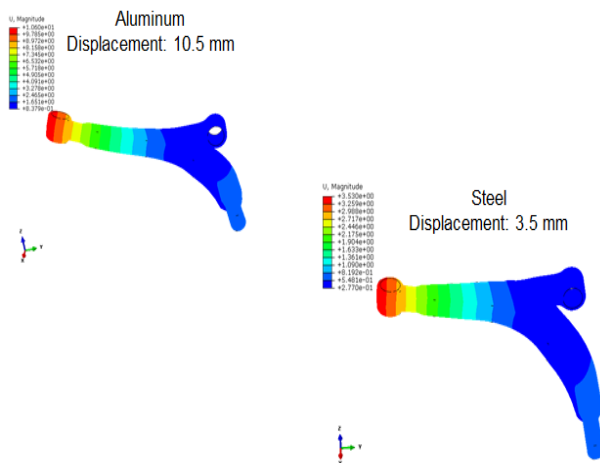


Fig 5.8.1: Deflection of LCA

The figures shows deflection of lower control arm using aluminum alloy and steel. In a deflection since, the young's modulus of aluminum alloy is less compared to the steel hence, the deflection will be more compare to steel in aluminum alloy. Hence deflection is the design criteria then steel is a better choice.

5.9 CALCULATION

Consider a car of 800 kg, which has length 2.8m , and its body has CG at a distance of 300mm from ground.

Therefore, vertical load can be calculated as;

$$\text{Vertical load} = \frac{800 \times 2G}{2}$$

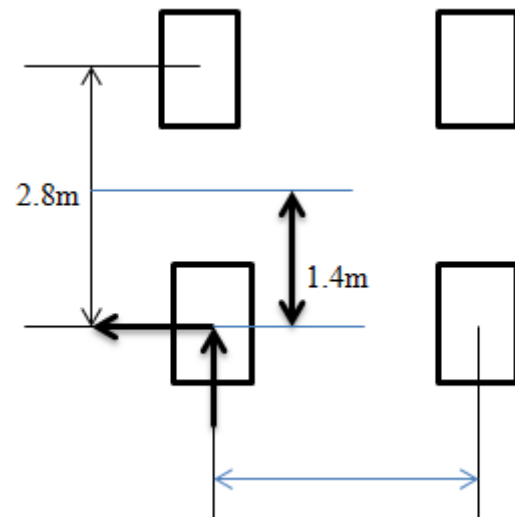
Where, 800= mass of car in kg

2= no of wheels on which max load is acting

G= gravity, which is taken two times, N/mm²

$$\text{Vertical load} = \frac{800 \times 2 \times 9.81}{2} = 7848 \text{ N (this force is on two wheels)}$$

Consider the car during turning, where two forces are acting on it. One is vertical force which is calculated and other is turning force. The representation of this forces is shown in below figure.



$$\text{Momentum} = \text{force} \times \text{perpendicular distance}$$

$$\text{Momentum} = F_z \times 1400 (\text{from CG})$$

$$F_z \times 1400 = 2 \times F_x \times 30 (\text{CG of car body from ground})$$

$$F_x = \frac{7848 \times 1400}{2 \times 300}$$

$F_x = 18312 \text{ N}$ (for 2 wheels)

$F_x = 9156 \text{ N}$ (for 1 wheel)

For two ends connected to the frame is given as $= \frac{9156}{2} = 4578 \text{ N}$

6. RESULT AND DISCUSSIONS

6.1 RESULT SUMMARY

Sl.No	Material	YS	Density	E	Weight	Volume	weight
		(Mpa)	(tons/mm3)	N/mm2	(tons)	mm3	Kg
1	Steel	750	7.85E-09	2.10E+05	7.64E-03	973120.2	7.6
2	Al	750	2.70E-09	70000	2.63E-03	973120.2	2.6
wt(kg)	c	g(m/s2)	tz(N)	fx(N)	fy(N)		
800	2	9.81	7848	18312	4578		

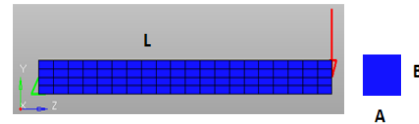
Sl.No	Material	Applied Force(N)			YS(MPA)	Max Stress	FOS
		X	Y	Z		Von-Mises	
LC1	Steel		4578	7848	550	471	1.2
	AL		4578	7848	550	470	1.2

Table - 3: Result summary sheet

The result summary sheet gives details of the stress and deflection of the control arm. Analysis is conducted with a necessary load and boundary conditions that occurs during turning of the vehicle. The stresses in both the cases i.e load case1 considering the steel material and load case 2 considering aluminium material are almost same but deflection wise the result are different because of young's modulus. The weight of the component using the steel is 7.6 kg and aluminium material is 2.6 kg. Factor of safety is same for both the cases with respect to strength but not with the stiffness.

7. VALIDATION

7.1 VALIDATION



SL.NO	E(MPA)	P(N)	L(MM)	C/S(MM)		I(MM4)	DEFL(Y)	STRESS(f)
				A	B		MM	MPA
1	210000	1000	100	10	10	833.33	1.90	600

Bending stress is given by

$$f = \frac{M}{I} * Y$$

Deflection is given by

$$Y = \frac{P * L^3}{3 * E * I}$$

SLNO	SOFTWARE CALCULATION		HAND CALCULATION		DEFLECTION		STRESS	
	Deflection(mm)	Stress(mm)	Deflection(mm)	Stress(mm)	ERROR	ERROR	ERROR	ERROR
1	1.898	607	1.9	600	1%	1%		

Table - 4: Validation table

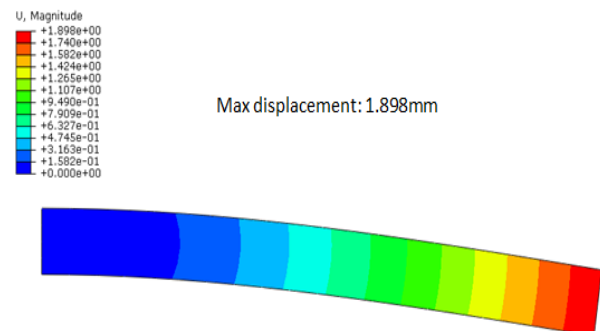


Fig -7.1.1: Beam displacement

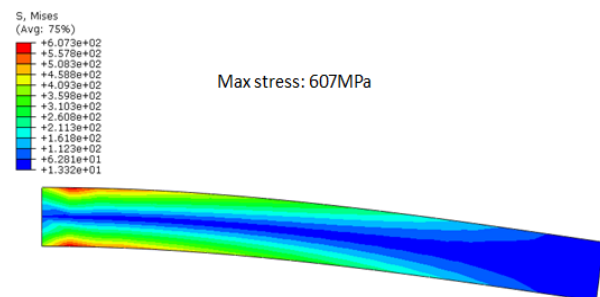


Fig -7.1.2: Max stress on beam(607 Mpa)

To validate the software a simple cantilever beam is considered for analysis with the following dimensions and considering steel as a material. Cantilever beam is subjected to vertical load of 1000N at the tip of cantilever and after submitting run, the results obtained from software are in correlating with the hand calculation. This is explained in above table.

The software results are matching with hand calculations and results with error percentage of 1 which is because of approximating the structure during the finite element modeling and which is acceptable. The validation is carried out on the cantilever beam because of the numerical formula available to calculate and validate.

8. CONCLUSION AND FUTURE SCOPE OF PROJECT

8.1 CONCLUSION

- To study the structural stability of lower control arm under turning conditions.
Structural strength of lower control arm is good and safe to manufacture with either steel or aluminium.
- To study the behavior of the structure with different material properties.
Strength wise both the materials are good but if the design is based on the elastic limit (i.e, if the deflection is design criteria) then steel is a better choice.
- To compare weight to strength ratio under different materials.
With respect to strength to weight ratio aluminium is a better choice.

8.2 FUTURE SCOPE OF PROJECT

Currently the analysis is done on the topology optimization but this will only reduce the weight of the component still there is chance of getting stress concentration. So in order to avoid this stress concentration we can do it in a shape optimization. We can conduct shape optimization for same kind of analyses which is a future scope.

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