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Structural Analysis and Comparison of control Arm using SAE J2340 and Kevlar 49/Epoxy Fabric

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Abstract - *Control arms are used to manage the motion of the wheels by pivoting and keep it relative to the body of the vehicle. In this project work mainly focused on structural analysis of control arm using Kevlar and SAE J2340. CAD model was prepared using CATIA V5 software and finite element analysis was done using ANSYS 18.1 software tool. To analyse behaviour of SAE and Kevlar composite material of control arm by applying boundary condition at circular bushing all 3 transitional (x, y and z) DOF are fixed and rotational DOF (Rx, Ry, and Rz) are free. The boundary condition at end bushing given that all 3 transitional (x, y and z) DOF are fixed and rotational DOF (Rx, Rz) are fixed but rotation about (Ry) is free as the control arm tends to rotate about an axis with respect vehicle body frame. The control arm subjected to lateral and longitudinal loads from the tire and exhibits a combined load which acts along x and z directions. For static analysis, the load is calculated and applied on the ball joint holder location. Result obtained from the analysis were studied to check whether design is safe or not. The comparison is carried out based on the structural analysis of control arm made up of composite and SAE J2340 material. Comparison dictates that the control arm made of composite material (Kevlar 49) is best suitable material under normal conditions. Based on the strength to weight ratio, used composite material (Kevlar 49) exhibited good behavior than that of SAE J2340.*

Key Words: **Control Arm, Structural Analysis, Kevlar 49/Epoxy Fabric, SAE J2340, ANSYS 18.1.**

1. INTRODUCTION

The automobile suspension systems are the most important components of vehicle, the function of suspension system is to manage the vehicle body from road irregularities and to maintain contact of wheels for better riding and comfort. The Double wishbone and MacPherson types of suspension system are generally used for all vehicles. Suspension includes shock absorbers, control arms, links, springs, anti-roll bars, ball joint and bushings. They provide good ride and handling performance ensuring that the wheels follow the road profile.

Control arms are used to manage the motion of the wheels by pivoting and keep it relative to the body of the vehicle. It is connected between the steering knuckle/wheel hub assembly and vehicle chassis through flexible rubber bushings [7]. They assist the wheels to responds for varying load conditions by allowing the wheels to lift and descend as the wheel encounters bumps, potholes and uncertain road surfaces. Due to different types of forces exerted on the wheels, affect the suspension system that causes poor ride quality, wobbling of steering, clunking noise over bumps, roll over of vehicle, tire wear and failure of control arm.

Sagar Darge et. al [1] focuses on Finite Element Analysis of lower control arm of double wishbone suspension system that includes stress optimization under static loadings. In the first stage, the CAD model was prepared by using Unigraphics. The maximum stress was identified and analysed using Abacus software after meshing in Hyper Mesh software.

Lihui Zhao et. al [2] investigates structural optimization of lower control arm by using the static equivalent load method. In this study, the best draw-bead distribution of control arm under dynamic load conditions was determined and is used for optimization of control arm. The dynamic simulation was performed under different road conditions namely steering on smooth road, washboard road, and steering on torsion road to determine the strength and stiffness of the control arm.

S. Abdullah et. al [3] focuses on dynamic analysis of lower suspension arm. Initially, static analysis was performed under individual unit load to obtain distribution of strain along the arm. Modal analysis was performed to determine the natural frequency, damping and mode shape parameters of a component. These results were used for the frequency response analyses.

2. VEHICAL SPECIFICATION

In this present study McPherson strut suspension system of Maruti Suzuki Swift car is used. In this suspension system the Lower control arm is used for dissertation work to carryout study on structural analysis of control arm.

Table 1. Specification of vehicle [12]

Specification	Dimensions
Length	3,850 mm
Width	1,695 mm
Height	1,530 mm
Wheelbase	2,430 mm
Gross weight	1500 kg
Kerb weight	1065kg
Fuel tank Capacity	42 litres
Turning radius	4.8 meters

3. ANALYTICAL CALCULATION

Load calculation of suspension control arm:

In this study, Maruti Suzuki Swift car front suspension system is taken as reference and the dimensions are measured for calculating forces acting on the control arm. The problem is solved analytically and forces are calculated.

Total weight of the vehicle[10]:

Total gross weight = 1500 kg

Total kerb weight = 1065 kg

For conducting static analysis the front weight distribution is taken as 40% and rear weight distribution is taken as 60% gross weight of the vehicle.

Front axle load:

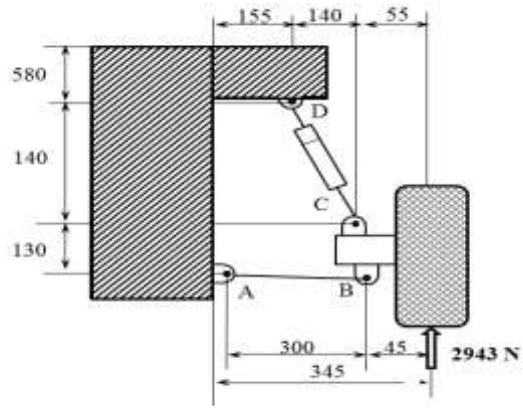
$$Fzf = \frac{(m * g * Wd)}{2} = \frac{(1500*9.81*0.40)}{2}$$

Fzf = **2943 N**

Rear axle load:

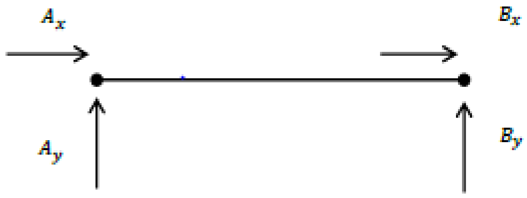
$$Fzr = \frac{(m * g * wd)}{2} = \frac{(1500*9.81*0.60)}{2}$$

Fzr = **4414.5 N**



Moment about point "B &C"

$$\propto = \tan^{-1}(\frac{140}{580}) = 13.57°$$



$\sum \boldsymbol{MB} = 0$

$(2943 * 45)$ $-\mathbf{C_D} * \cos(13.57) * 171 + \mathbf{C_D} * \sin(13.57) * 5,$ $\mathbf{C_D} = \mathbf{802.37}\ \boldsymbol{N}$

$$\sum \boldsymbol{FX} = 0$$

$$B_x + C_D * \cos(\propto) = 0$$

$$B_x = - C_D * \cos(\propto) = 0$$

$$B_x = (- 802.37) * \cos(13.57)$$

$$\mathbf{B_x = - 780.13}\ \boldsymbol{N}$$

$$\sum \boldsymbol{FY} = 0$$

$$B_y + C_D * \sin(\propto) + F_y = 0$$

$$B_y = F_y + C_D * \sin(\propto)$$

$$B_y = 2943 + (802.54) * \sin(13.57)$$

$$\mathbf{B_y = - 3130.30}\ \boldsymbol{N}$$

By considering both forces in X and Y directions, the resultant force is given by:

$$B_{xy} = \sqrt{(Bx)2 + (By)2}$$

$$= \sqrt{(-780.13)2 + (-3130.30)2}$$

$\mathbf{B_{xy} = 3227.10}$

4. PROPERTIES OF MATERIALS

The properties of the materials which were considered SAE J2340 and Kevlar 49/ Epoxy Fabric is as below.

Table 2 Material Properties of SAE J2340 [11]

MATERIAL	PROPERTIES	
SAE J2340	Poisson's ratio	0.3
	Young's modulus	210*10^3 N/mm^2
	Yield strength	555 Mpa
	Tensile strength	609 Mpa

Table 3 Material Properties of Kevlar 49/ Epoxy Fabric [13]

Property	Kevlar 49/ Epoxy Fabric
Density	1384
Longitudinal Modulus (GPa)	29.0
Transverse In Plane Modulus (GPa)	29.0
In-Plane Shear Modulus (GPa)	17.9
Poisson's Ratio	0.05
Longitudinal Tensile Strength (Mpa)	368.9
Transverse Tensile Strength (MPa)	368.9
Longitudinal Compressive Strength (Mpa)	128.9
Transverse Compressive Strength (Mpa)	128.9
In plane Shear Strength (Mpa)	113.1

5. FINITE ELEMENT ANALYSIS

The dimensions are measured with the aid of measuring instruments for generation of CAD model. The CAD modelling is done by using CATIA V5 R21 CAD software for developing a control arm. The CAD model is exported to meshing software in IGES format for further operations.

Figure 1 CAD Model of control arm

After importing the geometric model to pre-processor software, the control arm meshing is done by using three dimensional second order tetrahedral elements of element size 4. The FE model of a control arm is shown in Figure 2

Figure 2 Meshed model of control arm

A. Boundary conditions

At circular bushing all 3 transitional (x, y, and z) DOF are fixed and rotational DOF (Rx, Ry, and Rz) are free and at end bushing all 3 transitional (x, y and z) DOF are fixed and rotational DOF (Rx, Rz) are fixed but rotation about (Ry) is free as the control arm tends to rotate about an axis with respect vehicle body frame.

Table 4 Boundary Conditions of control arm

Location	Transitional			Rotational		
	X	Y	Z	R_x	R_y	R_z
Circular bushing	0	0	0	F	F	F
End bushing	0	0	0	0	F	0
	Fixed = 0, Free = F					

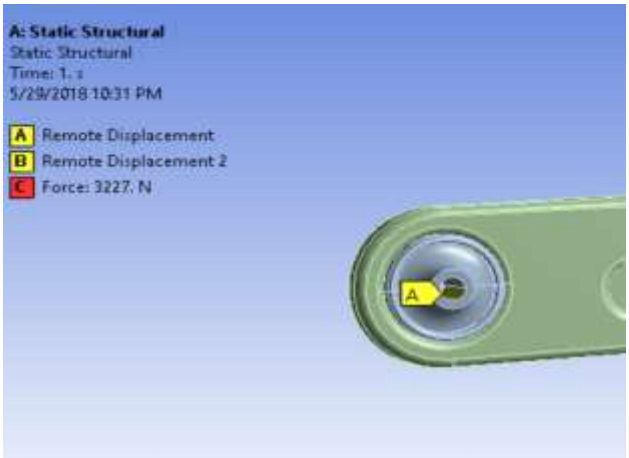


Figure 3 Circular bushing

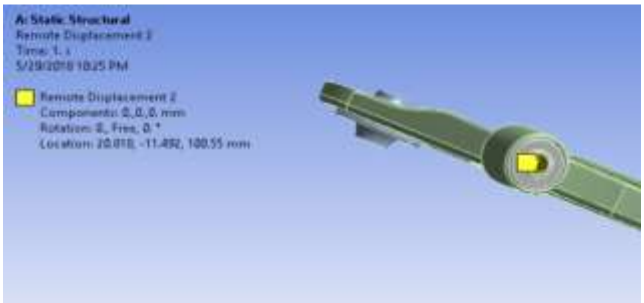


Figure 4 End bushing

B. Loads

The control arm subjected to lateral and longitudinal loads from the tire exhibits a combined load which acts along x and z directions.

Table 5 Load acting on control arm

TOTAL LOAD	DIRECTIONS		
	FX	FY	FZ
3227 N	0	-3131.3N	-780.13N

Figure 5 Force acting at ball joint holder location

6. RESULTS AND DISCUSSION

A. Numerical Results of control arm using SAE J2340

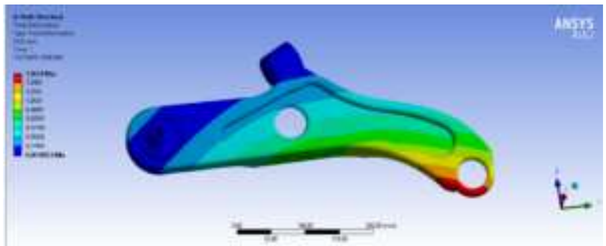


Figure 6 Deflection of Control Arm

The deformation across the control arm is shown in the Figure 6. It indicates maximum deformation at the ball joint portion; this deformation is due to direct application of load at this point and is been free. At other two points deformation is negligible because it is constrained as the circular bushing portion is held rigid and end bushing is allowed to rotate about Y-axis.

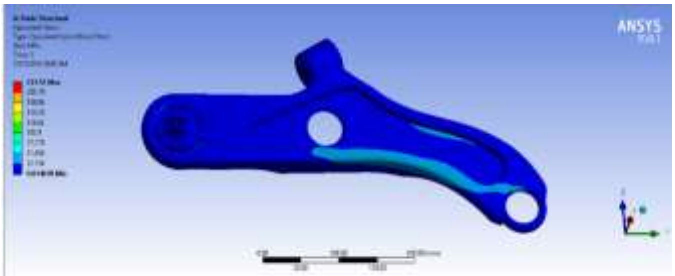


Figure 7 Von misses Stress of Control Arm

The above contour plot represents the equivalent stress distribution over the control arm. The middle curvature and regions of circular bushing is subjected to high stress level as indicated by red zone. Whereas the remaining portion is subjected to lower stress level and it is indicated by blue zone.

B. Numerical Results of control arm using Kevlar 49/Epoxy Fabric

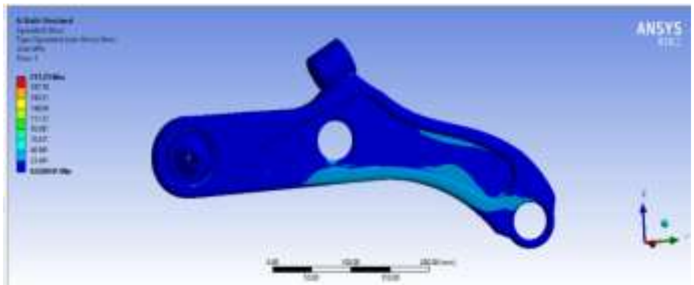


Figure 8 Deflection of control Arm

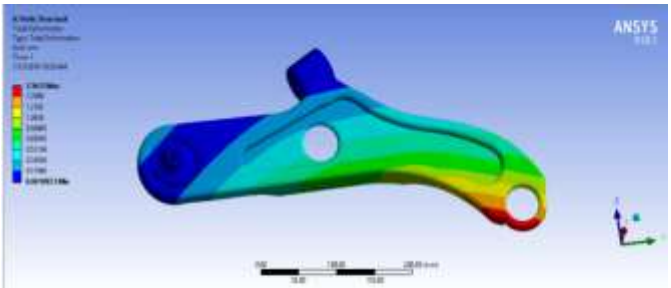


Figure 9. Von misses Stress of Control Arm

Results

Table 5 Stress and Deformation Results

Materials	Deformation (mm)	Von Misses Stress (Mpa)	Yield Strength (Mpa)
SAE J2340	1.56	231.51	555
Kevlar 49/ Epoxy Fabric	1.38	211.25	368.9

7. CONCLUSION

1) Strength wise comparison of two different materials namely SAE J2340 and Epoxy Fabric are safe under the applied loadings. But stress obtained in Kevlar 49/Epoxy Fabric is less than SAE J2340. Therefore epoxy is best for the application.

2) The comparison based on the deformation prospective, both the structures can carry the loads but deformation obtained in Kevlar 49 is less than that of SAE J2340. Therefore the Kevlar 49 fabric is best suitable material.

3) The comparison based on the strength to weight ratio of SAE J2340 and Kevlar 49, Kevlar 49/ Epoxy Fabric is best choice.

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