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DESIGN AND ANALYSIS OF TUBULAR LOWER CONTROL ARM FOR MACPHERSON STRUT SUSPENSION

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Abstract : CAE analysis is a process used to compare the performance of a conventional lower control arm with that of a tubular lower control arm. The baseline lower control arm is made out of sheet metal and is measured for all its critical dimensions. Analytical calculations are performed to calculate the performance parameters such as stress, deflection, stiffness and mode frequency. Results obtained by analytical methods are compared with those of CAE analysis and it is found that both results are close to one another. Weight reduction due to the tubular lower control arm against the conventional sheet metal lower control arm is checked.

I. INTRODUCTION

The Lower control arm, also known as suspension arm, is a part of an automobile suspension system that connects the wheel to the vehicle subframe assembly. It provides stiffness (resistance to twist) to the vehicle dynamics response, improving ride comfort, handling and road holding. It is made of steel and helps to protect the vehicle and its occupants from vibrations and shocks caused by the road surface.

When designing cars, attention is given to the comfort and safety of the passengers. Control arm is one of the most important parts of the suspension system and is made from materials like steel, iron or aluminum. Suspension arm is fitted in different types of suspensions such as wishbone or double wishbone, Macpherson strut suspension. In Macpherson strut system maximum load is transferred tire to ball joint and in double wishbone maximum load is transferred from upper to lower arm. To develop and changes in existing design of control arm, it is mandatory to focus on stress and deformation study of upper control arm. For transient structural analysis, modal analysis, optimization of upper control arm finite element approach is used.

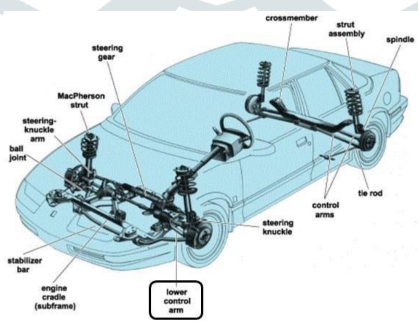


Fig 1. Passenger car suspension

II. LITERATURE REVIEW

SAE International by Imperial College London, Thursday, August 09, 2018 "Lightweight MacPherson Strut Suspension Front Lower Control Arm DesignDevelopmen

- Hannes Fuchs, Richard Salmon

This project aimed to develop lightweight sheet and forged steel front lower control arm (FLCA) proof-of-concept designs that achieve equivalent structural performance and function at a reduced cost relative to a baseline forged aluminum FLCA assembly. CAE structural optimization methods were used to determine the initial candidate designs. The manufacturing cost was estimated for the sheet steel designs relative to the baseline design for production volumes ranging from 30,000 to 250,000 vehicles per year. The study used optimization strategies to meet load requirements while minimizing the overall mass. Shape optimization was used to develop the component geometry and iterations were conducted to fine tune the material selection, thickness, and local geometry to meet strength and durability requirements.

Finite element (FE) analysis methods were used to predict the structural performance of each design. Opti struct, ABAQUS Standard, and Code software products were used to optimize and assess the structural performance of designs. A table summarizing the A/SP Team recommended sheet materials is provided. Hot dipped galvanized sheet steel products are recommended for clamshell and I-beam designs, and an E-coat finish is also recommended. The stiffness of all designs exceeded the baseline performance by a minimum of 10%, with the exception of the lateral stiffness of the clamshell. Durability life performance is compared for all designs, with the minimum life values shown for the worst case load cases. An iterative optimization strategy was used to develop two sheet steel FLCA designs and one forged steel FLCA design. The mass of each design was minimized based on stiffness, durability, extreme load, and longitudinal buckling strength requirements.

Manufacturing studies were recommended to assess the ability to meet the minimum forging gage target and to develop associated manufacturing costs. Results showed a 34% reduction in manufacturing cost for Clamshell Design based on DP780 steel sheet, a 2% increase in manufacturing cost for I-beam Design based on DP780 sheet, and a 4% increase in manufacturing cost for Forged Design based on AISI 15V24 grade material.

International Journal For Technological Research In EngineeringVolume 5, Issue1, September-2017

"Analysis and optimisation of upper control arm of suspension system"

- Bhushan S. Chakor, Y.B.Choudhary

Suspension system is essential for safety and driving comfort, absorbs vibrations, provides stability, and joints steering knuckle to vehicle frame. This paper analyzes the upper control arm of double wishbone suspension using ANSYS software and modal analysis. Testing was done on Universal testing machine to validate the results.

Control arm is an important part of the suspension system, made from steel, iron or aluminum. It is fitted in different types of suspensions, such as wishbone or double wishbone, Macpherson strut suspension. To develop and changes in existing design, stress and deformation study of upper control arm is necessary. Transient structural analysis, modal analysis, optimization of upper control arm finite element approach is used. Modal analysis is obtained with different mode sets and their respective deformation.

If a structure's natural frequency matches a component's frequency, the structure may continue to resonate and experience structural damage. The upper control arm of a suspension system is optimized based on material, transient structural analysis, modal analysis, and experimentation. Iterations are made based on stresses generated in the UCM and at lower stress regions material is removed. The maximum von Mises stress and deformation are found to be 146.14MPa and 0.37741 respectively. The best suited material is selected based on profile and iterations.

Optimized upper control arm has a lower stress and deformation value than existing, and is capable of handling loading conditions under safe limit. Stainless steel 321 is the best alternative material, and optimization shows 11.58% weight reduction.

IOSR Journal of Mechanical and Civil engineering

"Experimental & finite element analysis of left side lower wishbone arm of independent suspension system"

-Prof. A. M. Patil, Prof. A.S. Todkar, Prof. R. S .Mithari

Wishbone control arms are an independent suspension used in motor vehicles to keep the wheels from uncontrollably swerving. They consist of upper and lower arms, with the lower arm being the better shock absorber due to its position and load bearing capacities. Wishbones can be used in an all-wheel independent suspension setup, and can be easily adjusted for optimal wheel movement.

The present study focuses on the stress strain analysis of lower wishbone arm to improve and modify the existing design. It uses finite element analysis to compare the deflection and stresses of steel and composite lower wishbone arms under static load conditions. Carbon fiber suspension control arms meet the same static requirements as the steel ones they replace, and the natural frequency of composite lower wishbone arm is higher than steel.

International Research Journal of Engineering and Technology (IRJET)e-ISSN: 2395 -0056 Volume: 03 Issue: 10 | Oct -2016

"Comparison study of lower control arm with different material"

-Gururaj Dhanu, R. S. Kattimani

This project aims to optimize the L-shape control arm with respect to weight with two different materials (steel & aluminum). The control arm is connected to the chassis with bushings and a ball joint receptacle at the apex. The bushing apertures are designed to retain pipe housings for mating engagement with a pivot bar assembly, and the modulus section is between the apex and pivot points. High strength alloy steel is used for the construction of the control arm.

The control arm is an important component of a suspension system, and its main concern is to find out the maximum stress region and stress values in the control arm. Abaqus is a pre-processor solver and post processing software used to solve static, dynamic and impact analysis. The current study involves study of mechanical properties of the material, including static analysis and dynamic analysis. Quadratic tetrahedron is a second complete polynomial adherent of the isoparametric tetrahedron family, and its stress calculation is considerably better than the four nodes.

End A is connected to the ball joint and moves in a vertical direction, while end B and end C are fixed in a z direction and can only rotate in the x direction. The loads on end B and end C are calculated and obtained during turning due to side force components. In this case, the lower control arm is made with aluminum alloy and the stress encountered is 470 Mpa. In the other case, the stress is almost below 350 Mpa, but it can be removed by shape optimization. Von-misses stress is the minimum stress required to accurately model the structure of a control arm.

The figures show the deflection of a lower control arm using aluminum alloy and steel, with steel being a better choice due to its greater compressive yield strength. The result summary sheet provides details of the stress and deflection of the control arm, with load case 1 considering steel and load case 2 considering aluminium material having similar stresses but different deflection results due to young's modulus. The weight of the component using steel is 7.6 kg and aluminium material is 2.6 kg, with a factor of safety equal to 1. The validation is carried out on the cantilever beam using a numerical formula.

International Journal of Science Technology & Engineering | Volume 2 | Issue 01 | July 2015

"Design, Modeling and Failure Analysis of Car Front Suspension Lower Arm"

-Mr.Sushilkumar P.Taksande, Dr. A.V.Vanalkar

This paper presents design, modeling and analysis of a car front suspension lower arm to study the stress condition and select the suitable materials. The main objectives are to determine critical locations and strain distributions of the component and complete Finite Element Analysis of the front suspension lower arm. The Wishbone lower arm is an independent suspension used in motor vehicles to keep the wheels from uncontrollably swerving when the road conditions are not smooth. The lower control arm is the better shock absorber than the upper arm due to its position and load bearing capacities.

The specific nature of attaching linkages and spring elements varies widely among automobile models. Independent suspension systems allow the wheels to move independently of each other, reducing the unsprung weight and minimizing front-wheel vibration problems. Suspension arm is one of the main components in suspension systems, joining the wheel hub to the vehicle frame. Uneven tyre wear, suspension noise or misalignment, steering wheel shimmy or vibrations are the main causes of failure of the lower suspension arm. Finite Element Method (FEM) analysis of the stress distributions around typical failure initiations sites is essential.

Modeling and simulation are indispensable when dealing with complex engineering systems, providing support in all stages of a project. Integrating them in the design and manufacturing process can improve product quality and reliability. This project investigated the maximum force transmitted by tyres to the body of a vehicle through the lower suspension arm. Stress analysis was performed using finite element method and further corrective actions will be carried on the basis of results analysis. Fe410 material was found to be better than EN 24 material in terms of deformation, von-Misses Stress and Max shear stress.

International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Finite Element Analysis and Topology Optimization of Lower Arm of DoubleWishbone Suspension using RADIOSS and Optistruct

-Vinayak Kulkarni , Anil Jadhav , P. Basker

This paper focuses on calculating the forces acting on the lower wishbone arm while vehicle is subjected to critical loading conditions. Lower arm suspension geometry and materials have been identified, and Von Mises stress-strain and modal analysis have been carried out to find out maximum induced stress and strain. Topology optimization analysis has been carried out in Hyperworks to optimize the shape.

The behavior of lower control arm with different material has been studied by using design parameters such as von mises stress, strain and total deformation, mode shapes and its frequencies. The maximum stress developed in the component is 72.4 Mpa for Mild Steel and 71.89 Mpa for Aluminum Alloy, which is lower than the maximum allowable stresses. The total deformation in the component is 0.43mm for Mild Steel and 1.3mm for Aluminum Alloy, which are less than the thickness of the component and deformation limit of the material. Modal analysis is important in situations where resonance is a potential problem. The results of a modal analysis in hypermesh will be the natural frequencies and the mode shapes. Modes are inherent properties of a structure and can be changed by changing the material properties or boundary condition.

Opti Struct is an optimization technique that can be used to create an optimum component within a given design space. Constraints on von Mises stress and buckling factor can be imposed, and a conceptual design can be imported into a CAD system using an iso-surface generated with Smooth. When the solution converges, the density pattern of the component will be like Figure 10. This project analyzed the forces acting on the lower control arm of a wishbone vehicle and found that aluminum alloy is better material than Mild Steel on strength and strain basis. Topology optimization generated an optimized material distribution for a set of loads and constraints, reducing weight, product design cycle time and cost.

III. METHODOLOGY

In this project, at stage 1, benchmarking of lower control arm is done. Also CAD modeling is done along with CAE analysis to estimate stiffness and stress under applied load. In same packaging boundary tubular Subframe will be designed to meet similar performance keeping minimum weight. This will help is weight & cost reduction of suspension assembly.

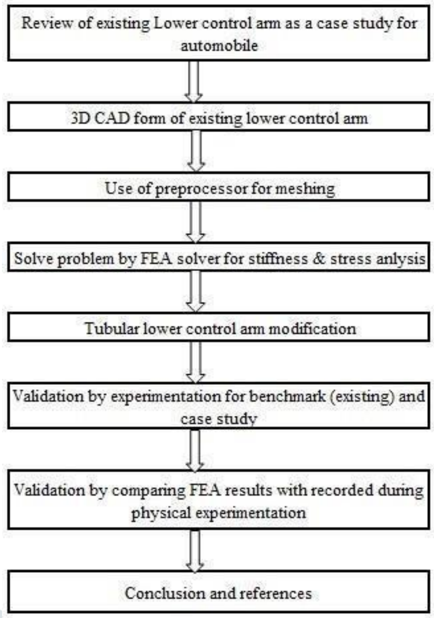


Fig 2. Flowchart of methodology

IV. THOERY

- **DETAILS OF LOWER CONTROL ARM & SUSPENSION**

➢ **Function of suspension systems**

The suspension system of a vehicle is responsible for absorbing road roughness, connecting the vehicle's body to the ground, and influencing its dynamic behavior.

The most important details of a suspension system are ride comfort, road holding, handling, structural efficiency,isolation, and low weight. Ride comfort is determined by the passenger compartment's level of vibration, while road holding is determined by the forces on the contact point between a wheel and the road. Handling is determined by the vehicle's response to the driver's inputs, and isolating road roughness is one of the most important tasks of a suspension system. Low weight is achieved by minimizing the vehicle's roll and pitch motion, controlling the wheels' angles, and decreasing the lateral load transfer during cornering. The most important details are that the suspension system should be optimized to minimize its mass, be durable, and be affordable. Other features such as anti-dives and anti-squats are also needed to improve the ride quality, noise isolation, and performance of the system.

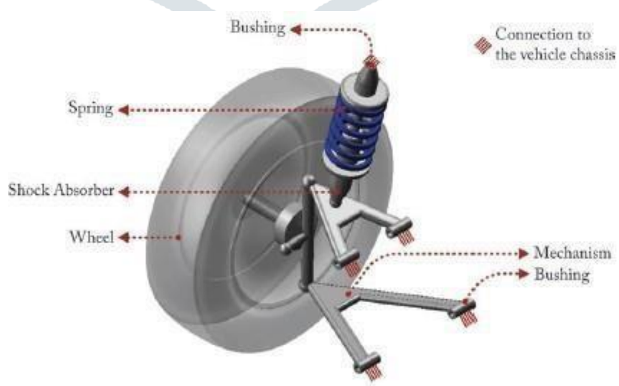
- **Main components of suspension system**

Fig:3. Main components of suspension systems

A vehicle suspension system is made of four main components-mechanism, spring, shock absorber, and bushings-as shown above figure.

➢ **MECHANISM**

Suspension mechanisms transfer forces and moments between the vehicle body and the ground, determining the suspension geometry and wheel angles. Variation in wheel angles during suspension travel affects the vehicle's road holding and handling. The main weight of a suspension system is determined by its mechanism, with heavy materials reducing ride quality and light materials improving it.



○ **Spring**

The spring is a winding wire or strips of metal that support the vehicle's weight and make it tolerable for passengers. However, when using high stiffness springs, the vehicle exhibits good road holding and handling, but with decreased ride comfort. This creates a condition of limitation when choosing an appropriate spring stiffness.

○ **Shock absorber**

The shock absorber is a mechanical or hydraulic device to dampen impulses. A high damping shock absorber compromises the vehicle’sride quality inorder to immediately dampen impulses to improve handling and road holding

○ **Bushings**

Bushings are vibration isolators used to connect moving components to the vehicle body or suspension frame. They are classified by the number of DOF between the two connected parts they support. Revolute joints are the most common type, while ball joints allow rotational relative motion in all directions. Bushings are expensive parts in a suspension system.

➢ **Weight transfer**

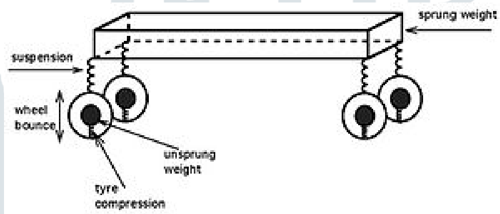
Weight transfer during cornering, acceleration or braking is usually calculated per individual wheel and compared to static weights. The total amount of weight transfer is only affected by four factors: the distance between wheel centers, the height of the center of gravity, the mass of the vehicle, and the amount of acceleration experienced. The speed at which weight transfer occurs and through which components it transfers is complex and determined by many factors. Elastic weight transfer occurs through intentionally compliant elements, while geometric weight transfer occurs through more rigid suspension links.

○ **Unsprung weight**

Unsprung mass is the mass of suspension, wheels or tracks, and other components directly connected to them, rather than supported by the suspension. It includes the mass of components such as wheel axles, wheel bearings, wheel hubs, tires, and a portion of the weight of driveshafts, springs, shock absorbers, and suspension links. Unsprung weight transfer is calculated based on the weight of the vehicle's components that are not supported by the springs. The weight transfer for cornering in the front is equal to the total unsprung front weight times the G-Force times the front unsprung center of gravity height divided by the front track width.

○ **Sprung weight**

Sprung mass (or sprung weight) is the portion of the vehicle's total mass that is supported by the suspension, including in most applications approximately half of the weight of the suspension itself. The larger the ratio of sprung mass to unsprung mass, the less the body and vehicle occupants are affected by bumps, dips, and other surface imperfections. Sprung weight transfer is the weight transferred by only the weight of the vehicle resting on the springs, not the total vehicle weight. Calculating this requires knowing the vehicle's sprung weight, the front and rear roll center heights, and the sprung center of gravity height. The roll couple percentage is the line through the front and rear roll centers that the vehicle rolls around during cornering.



The total sprung weight transfer is equal to the G-force times the sprung weight times the roll moment arm length divided by the effective track width. The front sprung weight transfer is calculated by multiplying the roll couple percentage times the total sprung weight transfer. The rear is the total minus the front transfer.

Fig4: Sprung & Unsprung weight in car

➢ **MATERIAL**

A) High-strength low-alloy steel (HSLA)

High strength low alloy steel (HSLA steel) is an alloy that provides improved mechanical properties and greater atmospheric corrosion resistance than traditional carbon steel. Its chemical composition consists of a low carbon content of between 0.05% - 0.25% and a manganese content of up to 2%. The remaining chemical constituents can vary depending on the product thickness and mechanical property requirements. Strength is added with the addition of vanadium, niobium, copper, and titanium. Increased corrosion resistance is given by the addition of silicon, copper, chromium, and phosphorus. Formability is improved with the inclusion of zirconium, calcium, and other rare earth elements.

HSLA material has improved low temperature toughness, fatigue resistance, creep resistance, corrosion resistance, notch toughness, weld ability, and decarburization resistance.

E34, E46, and SAPH590 are HSLA type steels with different chemical compositions and mechanical properties. E34 has a tensile strength of 390-510 MPa, while E46 has a yield strength of 450-460 MPa and a elongation of 23%. SAPH590 has a tensile strength of 590 MPa and a yield strength of 420 MPa.

b) Composite material

Composite fibre is being used in manufacturing due to its high strength to density ratio. Cold drawn seamless steel (CDS) tubes are made by cold drawing a larger mother seamless pipe without any welding seam. There are various types of CDS tubes, such as CDS1, CDS2, CDS3, and CDS4. CDS1 has a yield strength of 370 Mpa and a tensile strength of 430 Mpa. CDS4 has a yield strength of 460 Mpa and a tensile strength of 570 Mpa..

➢ **GEOMETRY**

Lower control arm outer profile is critical, as it must be designed to ensure no fouling in all operating conditions of the tyre. The inboard side profile must be designed to ensure the lower link will not foul with the Subframe in all bump & rebound conditions. The front side must have sufficient clearance with surrounding parts, and the principle locating holes must be designed to tighten the Subframe to the body. The outboard edge should not foul with the brake disc.

Fig 5. Typical design of Lower control arm

○ **CHILD PARTS OF LOWER CONTROL ARM ASSEMBLY**

Lower control arm assembly consist of Lower control weldment, bushes,and ball joints. Lower link weldment consist of welding top shell , bottom shell,front pivot sleeve& rear pivot sleeve. Front pivot bush and rear pivot bushes are press fitted inside the lower link weldment. Lower ball joint is also press fitted inside the lower link weldment, however for positive or fail safe arrangement, ball joint is also secured with help of circlip.

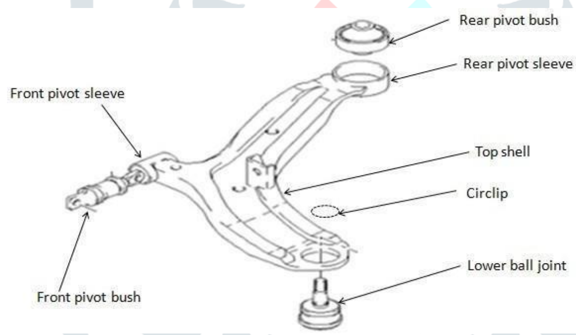


Fig 5. Exploded view of Lower control arm

➢ MANUFACTURING PROCESS OF LOWER CONTOL ARM

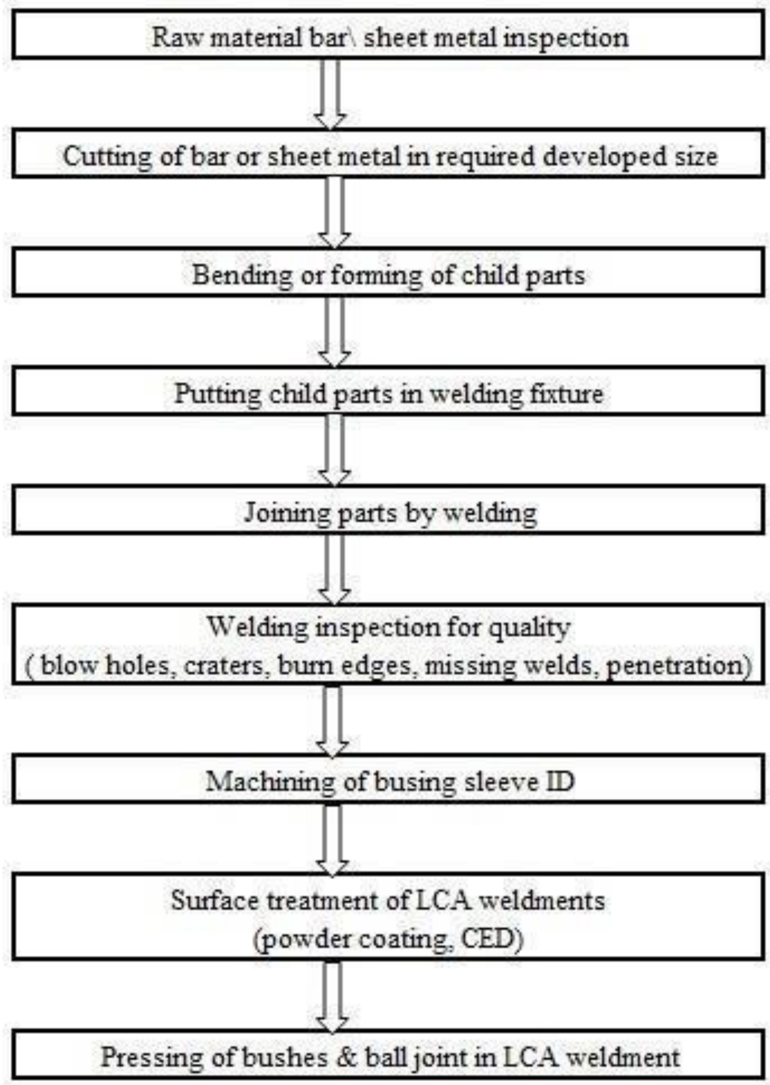


Fig 7: Manufacturing process of Lower control arm

➢ WORKING PRINCIPLE OF LOWER CONTROL ARM

Lower control arms are part of a suspension system that attach suspension members to the chassis and manage the motion of the wheel so that it synchronizes with the body of the car. They are connected to the chassis with bushings, which reduce friction and restrain the auto parts from going every which way. At the apex of the control arm is a ball joint receptacle, which is adapted to cooperate with a ball joint assembly and may include a ball joint housing integrally formed with the control arm. The control arm plays an important role in every vehicle, as it allows the suspension steering parts to rotate whenever the car is cornering and makes the coil springs respond to the axle and wheel assembly when travelling through bumps and potholes on road. It also allows for up and down motion of the coil springs, helping them to absorb the shocks during driving.

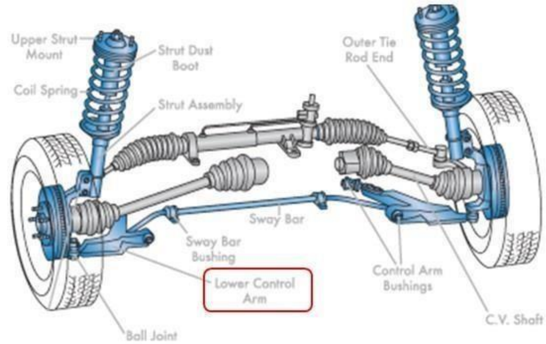


Fig 8: Lower control arm with front suspension assembly

Braking, acceleration, and cornering forces come from the Lower control arm in longitudinal, longitudinal, and lateral directions.

Fig 9 .Various force acting on tire contact patch

VI . DESIGN OF LOWER CONTROL ARM

Calculation of Tubular lower control arm

Let, the weight of car be 1000kg. Load coming on front axle be 550kg.

So load per wheel in longitudinal direction because of braking be (550/2)x0.75x 9.81=2000N

Both tube of LCA are of diameter 34 mm with2 mm thickA= cross section area of link =907.9 mm^2

E= Young's modulus of elasticity =200 x 10^3 MPaLoad= P= 2000 N.

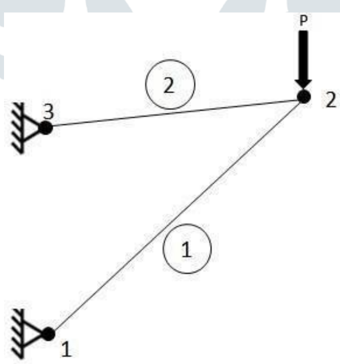
Co-ordinate of node 1 is (0,0)

Co-ordinate of node 2 is (274, 292)

Co-ordinate of node 3 is (0, 232)

Let u and V be the deflections of hard point in x &y direction.Length of element 1 & 2 be L1 & L2 Let Fx & Fy be load at node in x & y direction.

Let us simplify the lower control arm structure in links and nodes asshown in below figure.



For node 1:

(x1, y1)= (0, 0)

Since node 1 is fixed, u1=0, u2= 0F1x= 0, F1y= 0

For node 2 :

(x2, y2)= (274, 292)

u2=To bedetermined u2= Tobe determinedF2x= 0

F2y= -2X10^3 N

For node 3 :

(x3, y3)= (0, 232) For element 1:

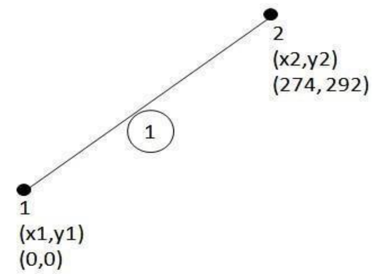


Fig 4.1.2: Simplified representation of element 1

$$L1 = \sqrt{(x2-x1)^2 + (y2-y1)^2}$$

= 400.4 mm

Let StIffness matrix for element 1= [K1]

$$[K1] = \frac{EA}{L1}\begin{pmatrix} (\cos\theta1)^2 & \cos\theta1 x \sin\theta1 & -(\cos\theta1)^2 & -\cos\theta1 x\sin\theta1 \\ \cos\theta1 x \sin\theta1 & (\sin\theta1)^2 & -\cos\theta1 x\sin\theta1 & -(\sin\theta1)^2 \\ -(\cos\theta1)^2 & -\cos\theta1 x\sin\theta1 & (\cos\theta1)^2 & \cos\theta1 x\sin\theta1 \\ -\cos\theta1 x \sin\theta1 & -(\sin\theta1)^2 & \cos\theta1 x\sin\theta1 & (\sin\theta1)^2 \end{pmatrix}$$

Since node 3 is fixed,u1=0, u2= 0F3x= 0 F3y= 0

$$[K2] = \frac{EA}{L2}\begin{pmatrix} (\cos\theta2)^2 & \cos\theta2 x \sin\theta2 & -(\cos\theta2)^2 & -\cos\theta2 x\sin\theta2 \\ \cos\theta2 x \sin\theta2 & (\sin\theta2)2 & -\cos\theta2 x\sin\theta2 & -(\sin\theta2)^2 \\ -(\cos\theta2)^2 & -\cos\theta2 x\sin\theta2 & (\cos\theta2)^2 & \cos\theta2 x\sin\theta2 \\ -\cos\theta2 x \sin\theta2 & -(\sin\theta2)^2 & \cos\theta2 x\sin\theta2 & (\sin\theta2)^2 \end{pmatrix}$$

$$\cos\theta2 = \frac{x3-x2}{\text{sq rt } [\,(x3-x2)^2+(y3-y2)\,]^2}$$

$$= \frac{(0-274)}{\text{sq rt } [(0-274)^2+(232-292)^2]}$$

$$= -0.976$$

$$\sin\theta2 = \frac{y3-y2}{\text{sq rt } [\,(x3-x2)2+(y3-y2)\,]^2}$$

$$= \frac{(232-292)}{\text{sq rt } [(0-274)^2+(232-292)^2]}$$

$$= -0.213$$

$$[K2]= \frac{200x10^3x907.9}{280.4}\begin{pmatrix} 0.952 & 0.207 & -0.952 & -0.207 \\ 0.207 & 0.045 & -0.207 & -0.045 \\ -0.952 & -0.207 & 0.952 & 0.207 \\ -0.207 & -0.045 & 0.207 & 0.045 \end{pmatrix}$$

$$[K2]=\begin{pmatrix} 266.6x10^3 & 24x10^3 & -266.6x10^3 & -24x10^3 \\ 24x10^3 & 15x10^3 & -24x10^3 & -15x10^3 \\ -266.6x10^3 & -24x10^3 & 266.6x10^3 & 24x10^3 \\ -24x10^3 & -15x10^3 & 24x10^3 & 15x10^3 \end{pmatrix}$$

Global stiffness matrix can be formed from matrix K1 & K2

$$[K]=\begin{pmatrix} 191x10^3 & 126.6x10^3 & -191x10^3 & -126.6x10^3 & 0 & 0 \\ 126.6x10^3 & 83.9x10^3 & -126.6x10^3 & -83.9x10^3 & 0 & 0 \\ -191x10^3 & -106.6x10^3 & (191+266.6)x10^3 & (126.6+24)x10^3 & -266.6x10^3 & -24x10^3 \\ -126.6x10^3 & -83.9x10^3 & (126.6+24)x10^3 & (83.9+15)x10^3 & -24x10^3 & -15x10^3 \\ 0 & 0 & -266.6x10^3 & -24x10^3 & 266.6x10^3 & 24x10^3 \\ 0 & 0 & -24x10^3 & -15x10^3 & 24x10^3 & 15x10^3 \end{pmatrix}$$

Applying boundary conditions

[K] [u] = [F]

$$[K]= 10^3\begin{pmatrix} \cancel{191} & \cancel{126.6} & \cancel{-191} & \cancel{-126.6} & \cancel{0} & \cancel{0} \\ \cancel{126.6} & \cancel{83.9} & \cancel{-126.6} & \cancel{-83.9} & \cancel{0} & \cancel{0} \\ \cancel{-191} & \cancel{-106.6} & (191+266.6) & (126.6+24) & \cancel{-266.6} & \cancel{-24} \\ \cancel{-126.6} & \cancel{-83.9} & (126.6+24) & (83.9+15) & \cancel{-24} & \cancel{-15} \\ \cancel{0} & \cancel{0} & \cancel{-266.6} & \cancel{-24} & \cancel{266.6} & \cancel{24} \\ \cancel{0} & \cancel{0} & \cancel{-24} & \cancel{-15} & \cancel{24} & \cancel{15} \end{pmatrix}\begin{pmatrix} \cancel{u1=0} \\ \cancel{v1=0} \\ u2= \\ v2= \\ \cancel{u3=0} \\ \cancel{v3=0} \end{pmatrix}=\begin{pmatrix} \cancel{F1x=0} \\ \cancel{F1y=0} \\ F2x=0 \\ F2y=-2000 \\ \cancel{F3x=0} \\ \cancel{F3y=0} \end{pmatrix}$$

$$\begin{pmatrix} 457.6x10^3 & 150.6x10^3 \\ 150.6x10^3 & 98.9x10^3 \end{pmatrix}\begin{pmatrix} u2 \\ v2 \end{pmatrix}=\begin{pmatrix} 0 \\ -2000 \end{pmatrix}$$

$$\begin{pmatrix} u2 \\ v2 \end{pmatrix}=\begin{pmatrix} -0.68 \\ -0.86 \end{pmatrix}$$

Resultant deflection at node2 = 1.1 mmStress in element

$\sigma 1 = E \times \varepsilon 1$

$$\sigma 1 = E \begin{pmatrix} \frac{-\cos\theta 1}{L1} & \frac{-\sin\theta 1}{L1} & \frac{\cos\theta 1}{L1} & \frac{\sin\theta 1}{L1} \end{pmatrix} \begin{pmatrix} u1 \\ v1 \\ u2 \\ v2 \end{pmatrix}$$

$$\sigma 1 = 200 \times 10^{3} \begin{pmatrix} \frac{-0.68}{400.4} & \frac{-0.72}{400.4} & \frac{0.68}{400.4} & \frac{0.72}{400.4} \end{pmatrix} \begin{pmatrix} 0 \\ 0 \\ -0.68 \\ -0.86 \end{pmatrix}$$

$\sigma 1 = 223$ Mpa

Stress in element 2

$$\sigma 2 = E \times \varepsilon 2$$

$$\sigma 2 = E \begin{pmatrix} \frac{-\cos\theta 2}{L2} & \frac{-\sin\theta 2}{L2} & \frac{\cos\theta 2}{L2} & \frac{\sin\theta 2}{L2} \end{pmatrix} \begin{pmatrix} u2 \\ v2 \\ u3 \\ v3 \end{pmatrix}$$

$$\sigma 2 = 200\times 10^3 \begin{pmatrix} \frac{0.97}{280.4} & \frac{0.21}{280.4} & \frac{-0.97}{280.4} & \frac{-0.21}{280.4} \end{pmatrix} \begin{pmatrix} -0.68 \\ -0.86 \\ 0 \\ 0 \end{pmatrix}$$

$$\sigma 2 = 409 \text{ Mpa}$$

Summary of results obtained from above analysis for tubular lower control arm

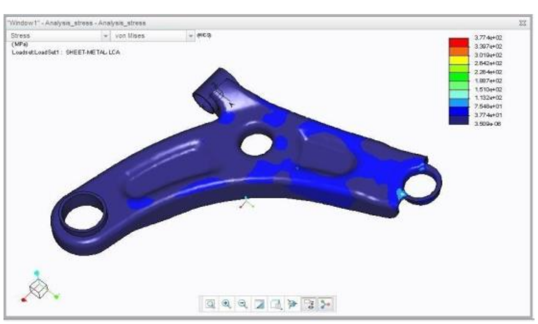
1) Mass of the Lower control : 1.5 Kg
2) Deflection: 1.1 mm
3) Max Von Mises Stresses: 409 N/mm^2
4) Longitudinal Stiffness= 2000/1.1= 1818.1 N/m

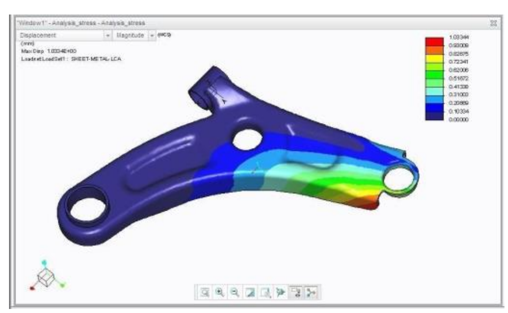
VII. ANALYSIS OF SHEET METAL LOWER CONTROL ARM

Lower control arm is modelled in CAD software, imported into simulation software, assigned material properties, meshed geometry, applied boundary condition, applied load, run CAE analysis, and plot stress & deflection

Fig: Cad model sheet metal Lower control arm

Fig 4 Von Mises Stress plot for sheet metal Lowercontrol arm





First mode frequency of Lower control arm

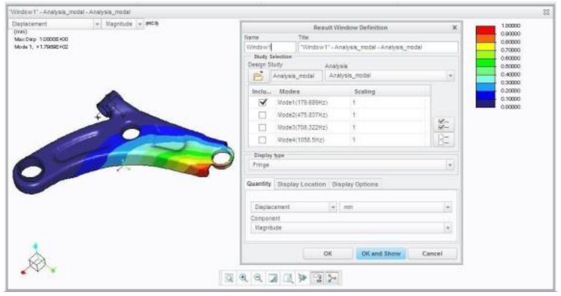


Fig .First mode frequency plot for sheet metal Lower control arm

Buckling analysis of Lower control arm

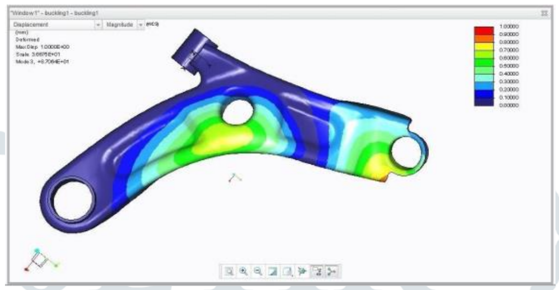
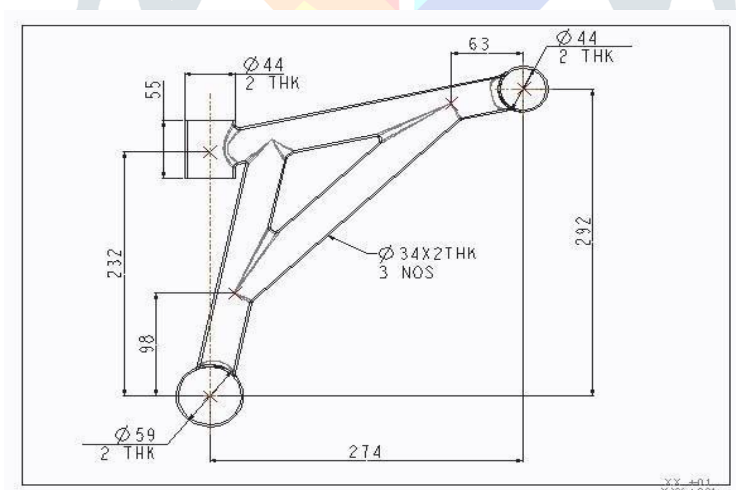


Fig .Buckling analysis plot for sheet metal Lowercontrol arm

The analysis showed that the bar had a mass of 2.2 Kg, a Deflection of 1.03 mm, Max Von Mises Stresses of 377 N/mm24, Longitudinal Stiffness of 2000/1.03, First mode frequency of 179 Hz, and Buckling load of 8534.7 N.

VIII. DRAWING DETAILS FOR TUBULAR LOWER CONTROLARM



Analysis of tubular lower control arm

Modeling of Tubular Lower control arm

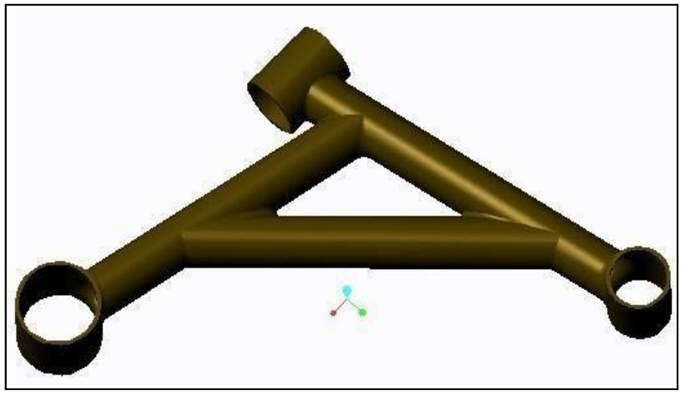


Fig: Cad model of tubular Lower control arm

Step 2-Application of material, load, & constraining Lower control arm

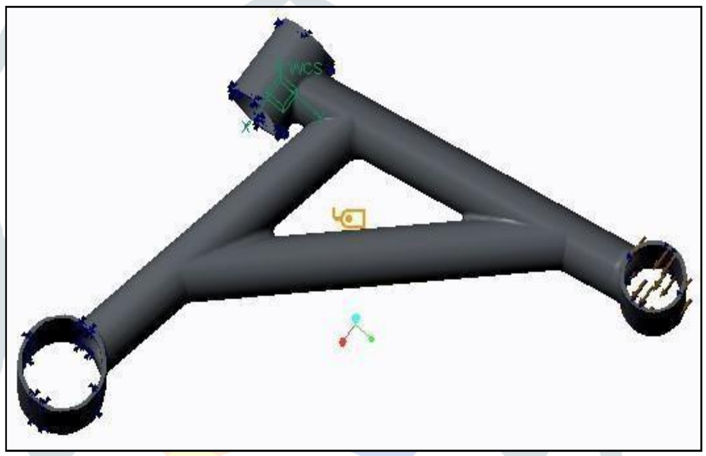


Fig .Constrained model of tubular Lower controlarm

Step 3 -Stress plot of Lower control arm

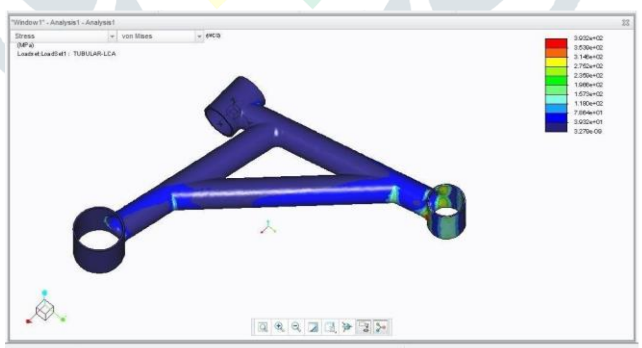


Fig: Von Mises Stress plot for tubular Lower control

Step 4-Deflection plot of Lower control arm

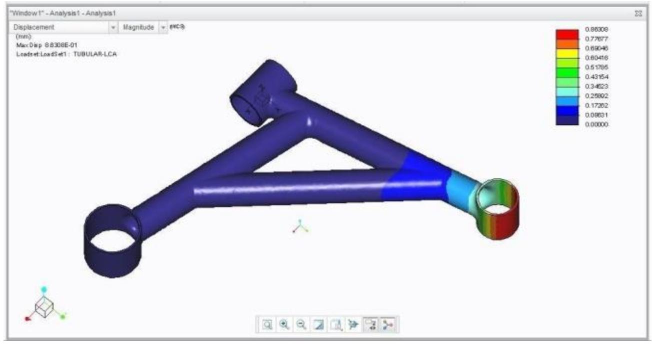


Fig : Deflection plot for tubular Lower control arm

Step 5-First mode frequency of Lower control arm

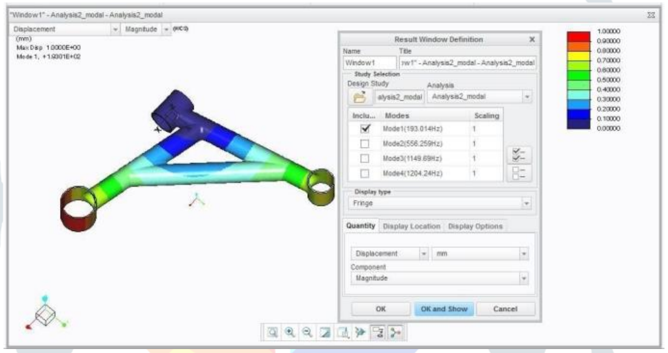


Fig .First mode frequency plot for tubular Lowercontrol arm

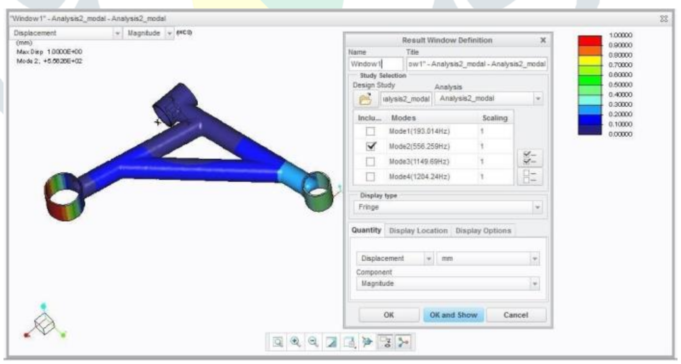


Fig : Second mode frequency plot for tubular Lowercontrol arm

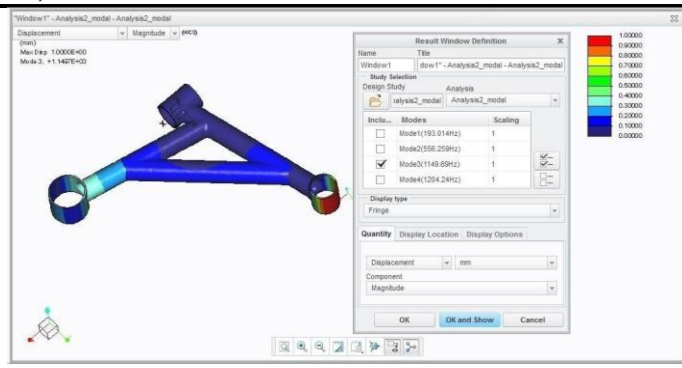


Fig: Third mode frequency plot for tubular Lowercontrol arm

Step 6-Buckling analysis of Lower control arm

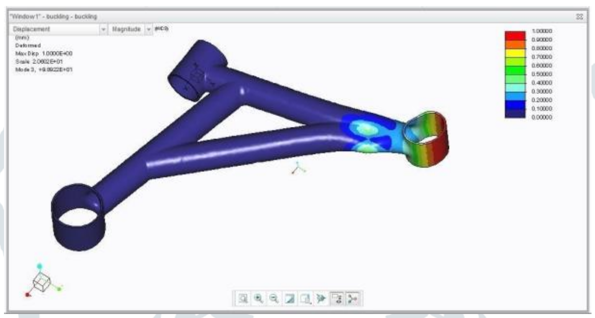


Fig. Buckling analysis plot for tubular Lowercontrol arm

Summary of results obtained from above analysis for tubular lower control arm

1) Mass of the Bar: 1.5 Kg
2) Deflection: 0.86 mm
3) Von Mises Stresses: 393 N/mm^2
4) Longitudinal Stiffness= 2000/0.86= 2325.5 N/mm
5) First mode frequency = 193 Hz
6) Buckling load = 989.2 Kg = 9702 N

IX. SUMMARY OF RESULTS

The design of the tubular lower control arm is carried by both analytical& digital analysis method. Performance of tubular lower control arm is compared with baseline sheet metal lower control arm.

Design	Baseline Sheet metal Lower control arm	Tubular Lower control arm (Analytical results)	Tubular Lower control arm (CAE results)
Deflection under applied load (mm)	1.03	1.1	0.86
Stiffness (N/mm)	1941.7	1818.1	2325.5
Max stress (N/mm)	377	409	393
First mode frequency (Hz)	179	-	193
Buckling load (N)	8534.7	-	9702
Weight of LCA (Kg)	2.2	1.5	1.5

Table 4.4.1: Result summary

We can see from above table that, performance of tubular lower control armis inline orbetter than base line sheet metal lower control arm.

As can be seen from above result that weight of tubular control arm is 0.7 kgless than that of sheet metal lower control arm. So per car weight reduction will be 0.7 x2= 1.4 kg.

X . FABRICATION AND EXPERIMENTAL TESTING

The most important details are that tubes of various grades are searched for their mechanical properties, then cut to the required size and angles, mounted on a position fixture for welding, and MIG welded at all joints. After welding, deburring is done to remove weld spatters and sharp edges, and tubular lower control arm assemblies or weldments are painted with epoxypaint for corrosion protection. Inspection and dimensional measurement is done by comparing sample withdrawing.

Lower control arm has three point mounting on vehicle. The three mounts are front pivot, rear pivot & ball joint. Front pivot & rear pivot bush areheld in brackets of Subframe assembly. Ball joint end is connected to steering knuckle thru ball joint. Duringsuspension articulation, front & rear pivot are stationary and only ball joint end ismoving. So while testing of lower control arm we have applied same boundary conditions to simulate vehicle level behaviour.

Front pivot and rear pivot are fixed on load actuator machine. Load is applied at ball joint end of control arm. Once load application starts, strains getdeveloped in assembly. Machine records load & deflection valuesof control arm. Load and deflection values are plotted on graphs. Slope of this graph gives the stiffness value of control arm assembly.

XI. DISCUSSION OF TEST RESULT

We did design of tubular control arm its performance parameters are checked in FEA.Stiffness is calculated based on FEA is compared with experimental method. In experimental method load is gradually applied atball joint location & corresponding deflection at ball joint is noted. Values of stiffness by both method are close. The difference in both values is because of various experimental , mechanical property variation.

Method	Stiffness(N\mm)	Buckling load(N)
CAE method	2325.5	9702
Experimental method	2218	9000

Table: Comparison of experimental result with CAE

XII. Conclusion

The design of the tubular lower control arm is carried with help of analytical method or calculation method, then the CAE analysis is carried. Various performance parameters of design such as Static stiffness, stress , modalanalysis & buckling analysis is carried out. Results of analytical & CAE analysis are much close to each other.

Performance of tubular lower control arm is compared with baseline sheet metal lower control arm. As seen in all types of analysisperformance of tubular lower control arm is inline with that sheet metal lower control arm. Weight of tubular control arm is 0.7 kg less than that of sheet metal lower control arm. So per car weight reduction will be 0.7 x 1.4 kg. As canbe seen from previous analysis that there is potential to reduce the weight of Lower control arm by using tubes instead of sheet metal.

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Modal and Stress Analysis of Lower Wishbone Arm AlongWith TopologyPratik S. Awati1 , Prof. L.M.Judulkar

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