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Analysis of Upper Control Arm of Suspension System

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Abstract:
Suspension system in automobile is always responsible for safety and driving comfort as the suspension carries the entire vehicle body and transmits all forces between road and body. Suspension system absorbs the vibrations due to rough terrains or road disturbances. Suspension system also provides stability under different conditions like accelerating, uneven road, cornering, braking, loading and unloading. Control arm is important part of suspension system as it joints steering knuckle to vehicle frame. In automotive industry structure optimization techniques was used for light weight and performance improvement of modern new cars. However, static load conditions could not represent all the various situations of automobile parts which subjected to complex loads those varying with time, especially for lower control arm of front suspension. This paper deals with transient structural analysis of the upper control arm of double wishbone suspension and modal analysis was carried out using ANSYS software.

Keywords: Double wishbone suspension, Modal analysis, Steering knuckle, Transient structural analysis, ANSYS software.

I. INTRODUCTION

Control arm is one of the most important part of the suspension system. Control arm is made from the materials like steel, iron or aluminium. Suspension arm is vital part for each vehicle on the road. Vehicle can results in annoying vibrations and undesirable driving irregularities that could sometimes cause to road accidents like collision with another vehicle or obstacle on road if there is no suspension arm. 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 which responsible for failure and twisting of lower arm at ball joint locations as well as control arm because of impact load. 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 of upper control arm finite element approach is used.

II. LITERATURE REVIEW

The different work to be carried out on control arm of suspension system in recent years. Jagwinder Singh et al. [1] works on ―Static Structural Analysis of Suspension Arm Using Finite Element Method‖. In this work the static structural analysis was done to find out the stress, deformation and safety factor of component and optimization approach is carried out to increase the structural strength of the component. Gurunath Biradar et al. [2] works on ―Life Estimation Of Double Wishbone Suspension System of Passenger Car‖. In this thesis focus was on the modal analysis and statically analysis of upper arm, lower arm and steering knuckle. Fatigue analysis of existing double wishbone suspension system and modify the design using software's namely Unigraphics, Hypermesh, Optistruct and nCODE. A. Rutci [3] works on ―Failure Analysis of a Lower Wishbone‖. Paper describes failure analysis of a lower wishbone in a light commercial vehicle has done which involved in service loading. To investigate reason of the failure, finite element analysis is done to evaluate stress distribution and reliability of wishbone. Furthermore, the metallographic and hardness evaluation were done on weld seam of the failed part. Finite Element Analysis and metallographic examination results showed that fatigue failure was occurred from highly stressed region in weld seam. Jong-kyu Kim et al. [4] paper describes shape of upper control arm was determined by applying the optimization technology. Study considers the static strength of arm in the optimization process. In this study, the kriging interpolation method is acquired to obtain the minimum weight satisfying the static strength constraint. The real experiments on 1/4 car is conducted to validate the FEM analysis. At last, the correlation of each case about durability life is obtained. B. Sai Rahul et al. [5] paper shows works that, ‖ Fatigue Life Analysis of Upper Arm of Wishbone Suspension System‖. In this characterization of the dynamic behavior and investigation of fatigue life of upper suspension arm is done. This study estimate the fatigue life of control arm. The results, thus obtained, can significantly reduce the cost and times to market improve product reliability. Prof. A. M. Patil et al. [6].This paper shows the stress strain analysis study of lower wishbone arm to improve and modify the existing design. The result obtained using finite element analysis approach. Lihui Zhao et al. [7] works on ―Dynamic Structure Optimization Design of Lower Control Arm Based on ESL‖. Lower control arm dynamic optimization was performed by incorporating traditional static load optimization techniques and multi-body dynamics by Equivalent Static Load (ESL) in this paper and the best draw-bead distribution of the stamped lower control arm was acquired. An optimized and existing result by comparison shows that the strength and stiffness was increased significantly while the mass was almost unchanged. N.A. Kadhim et al. [8] Fatigue life of lower suspension arm has been studied under different amplitude loadings. To obtain the material monotonic properties, tensile test has been carried out and to specify the material mechanical properties of the used material, a fatigue test under constant amplitude loading has been carried out using the ASTM standard specimens. Then, the results used in the finite element software to predict fatigue life has been evaluated later to show the accuracy and efficiency of the numerical models which they are appreciated. V.V. Jagirdar et al. [9] paper describes Wishbone structure for double wishbone front-independent suspension for a military truck. A double wishbone, double coil spring with twin damper configuration was employed for military truck application. MBD Analysis was done using ADAMS software. For the front axle of the vehicle double wishbone independent suspension has been designed. Y. Nadot et al. [10] an experimental device has been developed to study fatigue phenomena for nodular cast iron automotive suspension arms. A methodology is proposed to define the maximum defect size allowable in a casting component. It correlates the empirical method proposed by Murakami to determine the evolution of the fatigue limit with defect size and a multi axial endurance criterion based on the Dang Van model. Validation of the proposed approach gives encouraging results for surface defects and constant amplitude proportional loading.

III. PROBLEM DEFINITION

In suspension system control arm is vital component. As the vehicle goes through bumps, speed breaker etc. some kinds of forces are to be transmitted from car wheels which get transferred to control arm via ball joint assembly to wheel. Control arms can bend or break when driving over large potholes, bumps while brushing can also wear out. Sometimes due to combination of forces like pitching, rolling, acceleration breakdown occurs due to large stress. Transient structural analysis to find out stress and deformation and modal analysis to find natural frequency

- ***Objective:***
  1. Upper control arm Transient Structural Analysis for Finding stress and deformation.
  2. Modal analysis is performed to study the Natural Frequencies of control arm.

IV. FORCE CALCULATION

***Condition I: Static Condition**:*
The earth's gravitational pull (mg=W) acts through the centre of gravity and the reaction acts through the contact patches between the tyres and the road. To every action there is an equal and opposite reaction Figure shows the forces on a stationary car. The vectors shown represent the combined reactions at both front wheels (R_f) and both rear wheels (R_r).

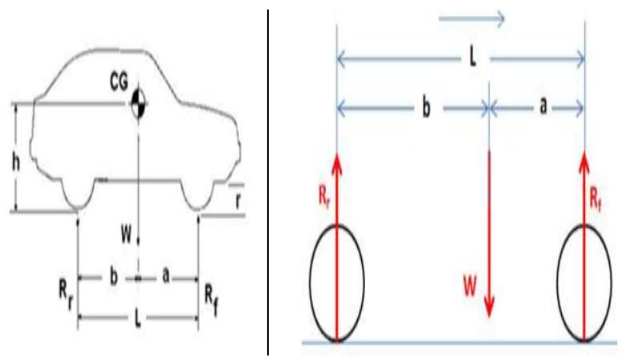

Figure.1. Forces on Stationary Car

Total weight of the car = 2300 kg = 22563 N
Weight must be divided into front axle weight and rear axle weight. 52% of total weight is taken by front axle and 48% of total weight is taken by rear axle.

Weight on Front axle = 2300 * 0.52 = 1196 kg = 11732.76 N
Weight on Rear axle = 2300 * 0.48 = 1104 kg = 10830.24 N

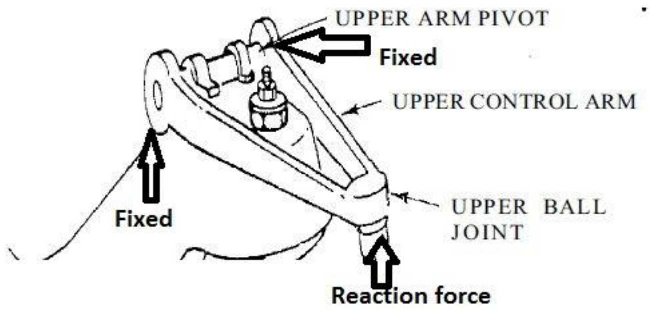

Figure.2. Boundary forces for Static Condition

Condition II: Static and Dynamic loads

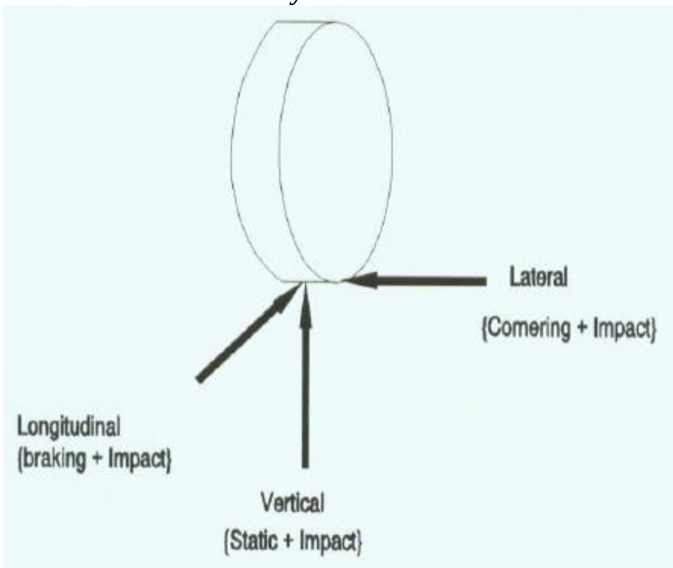

Figure.3. Wheel Loads and Directions

Table.1. Input parameters for load calculations:

Description	Symbol	Value
Total Weight of vehicle	W = F	22.563 KN
Weight on front axle	F1	11732.76 N
Weight in rear axle	F2	10830.24 N
Tyre rod coefficient	μ	1.45
Wheel Base	l	2680 mm
Average acceleration	ā	2.0 m/s^2
Vehicle mass	m	1680 kg
Centre of gravity height	hcg	880 mm

Front Axle Breaking Force (FB) per Wheel:
We have to find the term bcg, consider a simply supported beam, where force F=22.56 KN which acts at a distance X from point A (Front end)

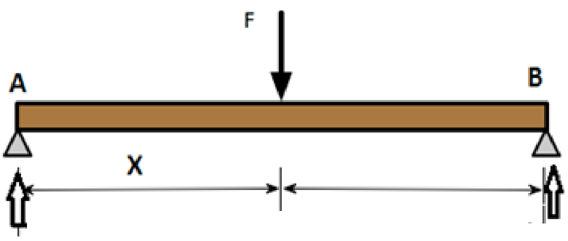

Figure.4. Force on the Axle Simply supported beam
Taking moment at point A:

ΣmA = 22.56 * X – 10.83 * 2680 = 0
X = 1286.54 mm.
bcg = 2680 – X = 1393.46 mm

$FB = \mu/2[\text{Static+ dynamic load}]$
$= \mu/2[W^* bcg/l + m^* \bar{a} *hcg/l]$
$= \mu/2\ W\ [bcg/l + \bar{a}/g\ hcg/l]$
Breaking Force FB = 9.60 KN

Vertical Force (FV):

$FV = 3/2\ [\text{Static+ dynamic load}]$
$FV = 3/2\ [W *bcg/l + m^* \bar{a} *hcg/l]$
$= 3/2\ W\ [bcg/l + \bar{a}/g *hcg /l]$
Vertical Force FV= 19.86 KN

Lateral Force (FL):

$FL = W\ [\text{Static+ dynamic load}]$
$FL = W\ [bcg/l + \bar{a}/g^* hcg / l]$
Lateral Force FL= 13.24 KN

Existing Material Properties:

Table.2. Structural steel properties

Properties of Material	Value
Young's Modulus E	212 GPa
Poisson's Ratio ν	0.3
Density ρ	7865 kg/m^3
Yield Strength σ_{yield}	440 MPa
Ultimate Tensile Strength σ_{uts}	540 MPa

ANALYSIS OF EXISTING UPPER CONTROL ARM OF SUSPENSION SYSTEM

Transient Structural Analysis:

Transient dynamic analysis is a technique used to determine the dynamic response of a structure under the action of any general time dependant load. This type of analysis is used to determine the time-varying displacement, stress. For the analysis of existing upper control arm firstly drawing with a evaluated dimensions is made in CATIA. After this model imported in ANSYS. Forces and boundary condition applied to the model then meshing of arm using tetrahedral element is done and the result of the analysis shows stresses and deformation of upper control of existing material. The result obtained in analysis shown below:

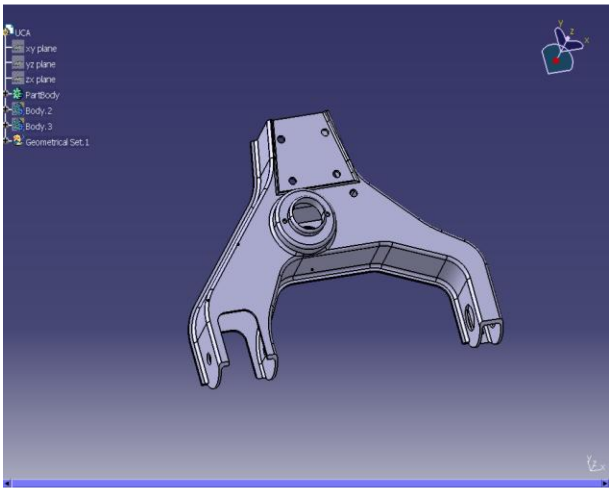

Figure.5. CATIA model of Upper Control Arm

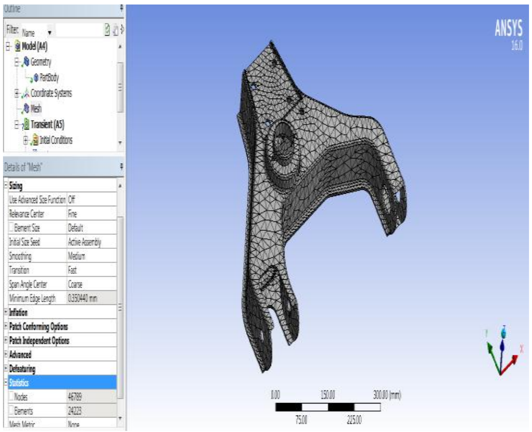

Figure .6. Meshing of Upper Control Arm using Tetrahedral Element

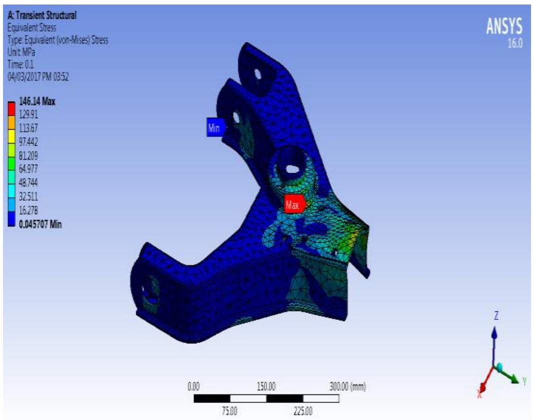

Figure.7. Von Misses Stresses on Upper Control Arm

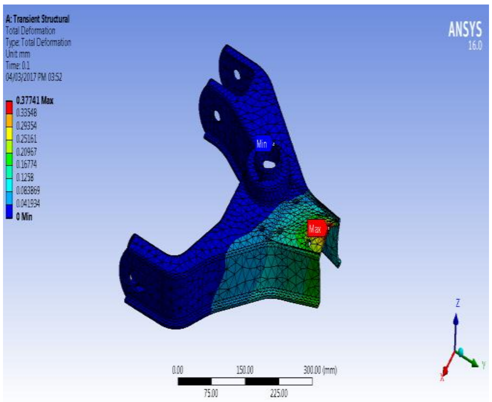

Figure.8. Deformation of Upper Control Arm

The maximum deformation 0.37741mm and von mises stress is 146.14 MPa obtained.

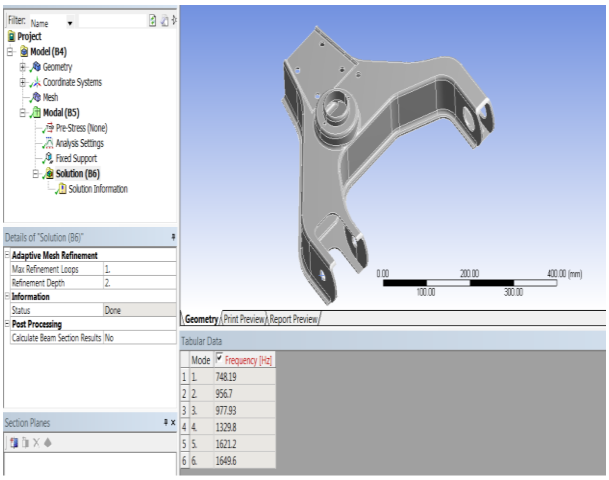

Figure.9. Natural Frequency of Upper Control Arm

Modal Analysis:
The study of the dynamic properties of structures under vibrational excitation is Modal analysis. The modal analysis is obtained with different mode sets and their respective deformation. Each mode gives the vibration range in the form of frequency and maximum deformation at that frequency level.. If a structure's natural frequency matches a component's frequency, the structure may continue to resonate and experience structural damage. 1649.6Hz maximum frequency above which chances of structural damage to the arm.

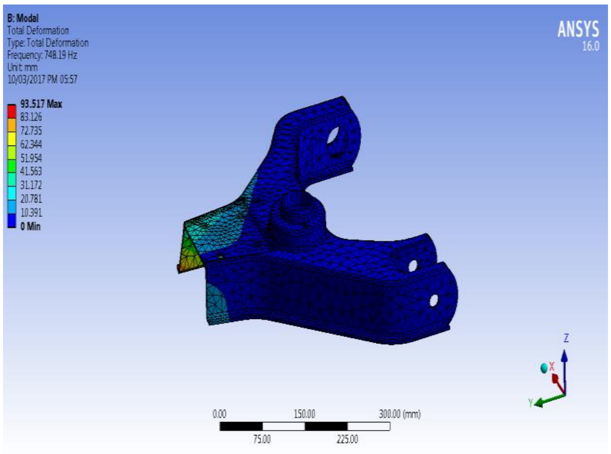

Figure.9a. Mode Shape1

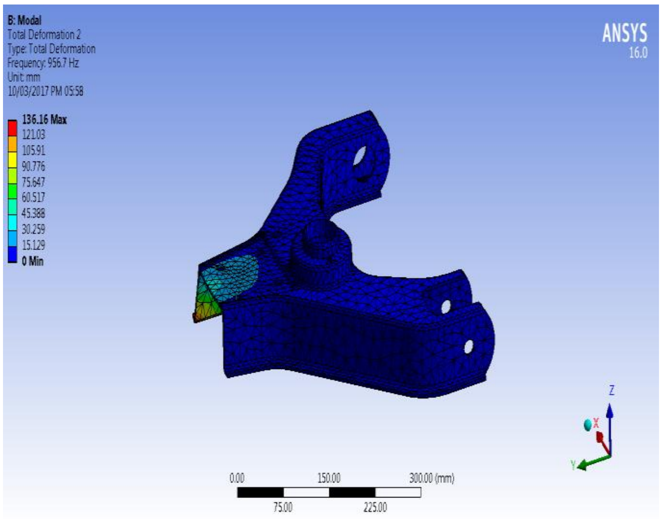

Figure.9b. Mode Shape2

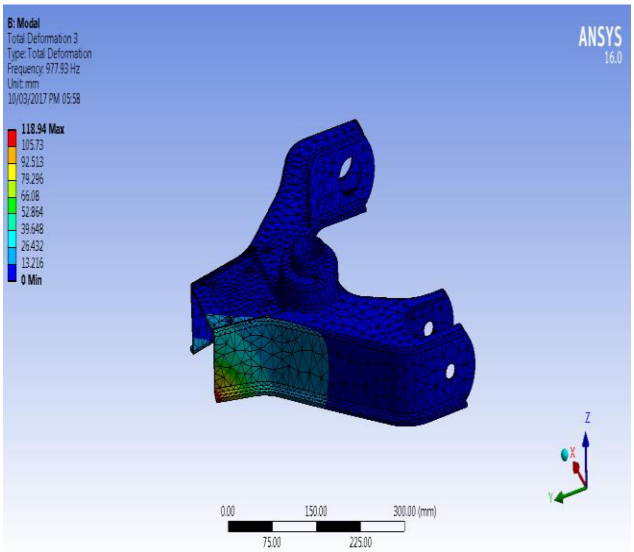

Figure.9c. Mode Shape3

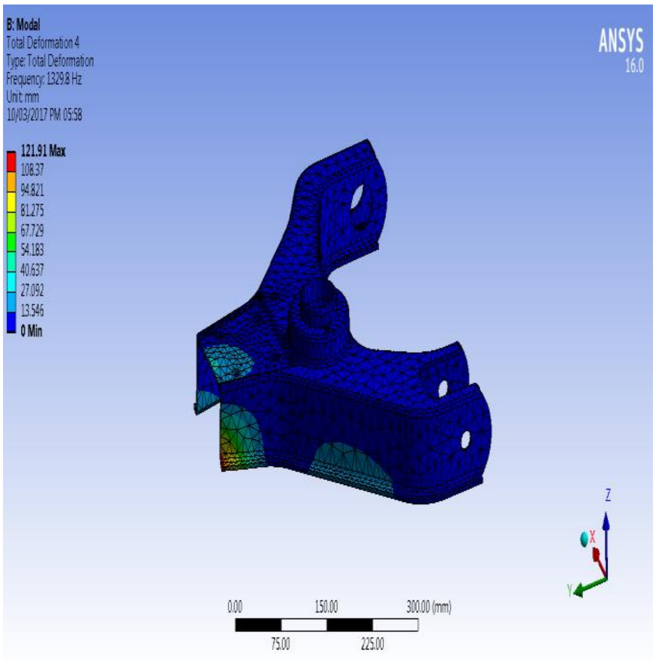

Figure.9d. Mode Shape

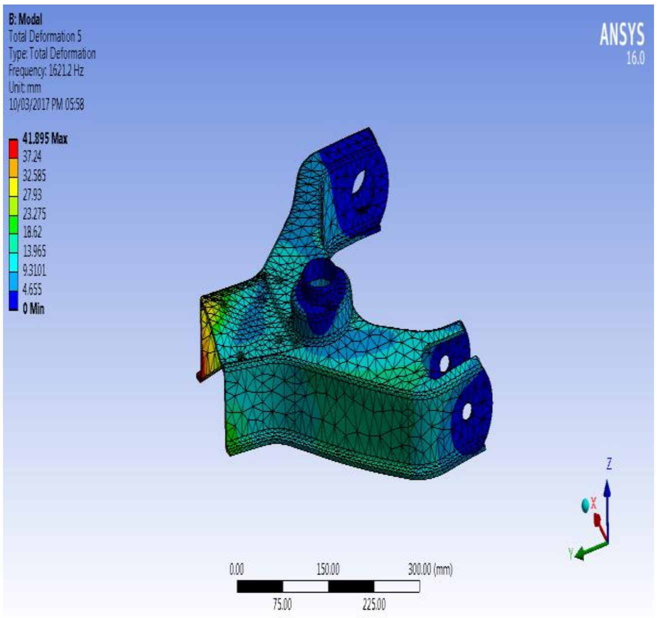

Figure.9e. Mode Shape5

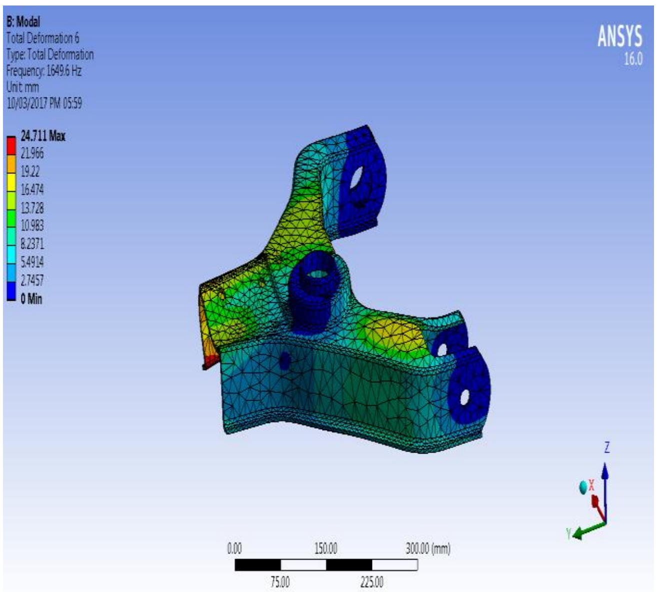

Figure.9f. Mode Shape6

Table.3. Natural frequency for existing upper control arm

Mode Shape	Natural Frequency Hz	Deformation mm
1	748.19	93.517
2	956.7	136.16
3	977.93	118.94
4	1329.8	121.91
5	1621.2	41.895
6	1649.6	24.711

V. RESULT AND DISCUSSION

Upper control arm existing model is analyzed stresses and deformations are found. Maximum von mises stress found to be146.14MPa and deformation found to be 0.37741. Modal Analysis shows natural frequencies of existing control arm for different deformation.

VI. CONCLUSION

Finite Element Analysis can be effective technique used to find out stress and deformation of upper control arm. Modal Analysis is done to find out natural frequency of arm using finite element analysis

VII. FUTURE SCOPE

1. Optimization of Upper Control Arm.
2. To find Natural Frequencies of Optimized arm.
3. To find best suited alternative material for upper control arm.

VIII. ACKNOWLEDGEMENT

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