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STATIC ANALYSIS OF FRONT AXLE INDEPENDENT CAR SUSPENSION USING FE ANALYSIS

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Abstract: Suspension system is the base for reduction of vibration and load transfer. Suspension system is designed to take structural loads and dynamic loads resulting from motion of the vehicle. Due to the advances in computer based CAD and CAE Software's, design simulation helps in proper design of the suspension system which is difficult with complex theoretical formulations. The finite element software's are developed to consider linear to nonlinear material behaviour along with simple static to complex spectrum loads. Generally front axle is made independent for smoother steering and along for traversing the curves. In the present work, a front axle suspension used for a new design is considered for finding the structural stability.

***Index Terms* – Suspension system, Wishbone suspension, Static Analysis, FEM.**

I. INTRODUCTION

Double-wishbone suspension incorporates two wishbone-shaped arms, also called A-arms, placed in parallel on each side of the axle for each wheel. One end of the wishbone arm connects two joints to the chassis, while the other single joint connects at the steering knuckle, or wheel pivot point. A coil spring and shock mounts to the wishbone arms, to control vertical movement. Double-wishbone suspension allows independent wheel travel in several smaller axes. The suspension is the prime mechanism that separates vibration from the road. It also prevents the car from shaking itself to pieces.

Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. Suspension systems serves a dual purpose – contributing to the car's road holding /handling and braking for good active safety and riving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps and vibrations etc. These goals are generally at odds, so the tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible because all the force acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different.

Suspension function :

II. Attached the wheel/tire to the vehicle and dictate wheel motion geometry

III. Carry vehicle sprung weight and payload

IV. Absorb road bumps, provide comfort ride

V. Provide safe and predictable cornering, braking and acceleration (good handling)

Types of Suspensions:

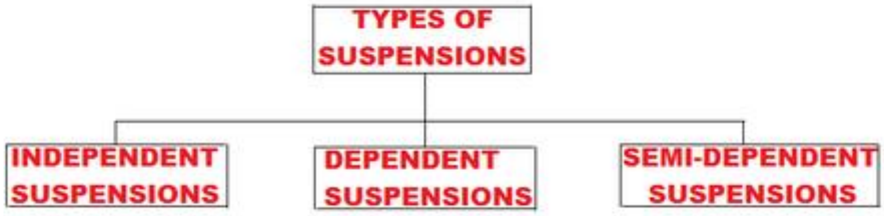


Fig: Types of Suspension

II. Literature on Suspension:

The primary goal of the front suspension in car applications is to keep the largest contact patch of both steering tires on the ground in order to maintain the most traction possible. In the world of fast moving cars, there are a few different front suspension design types. The first design type is known as the short long arm (SLA) suspension whereas the second design type is known as the MacPherson strut suspension [1]. Variations of the SLA suspension include those with parallel control arms or non-parallel control arms. The final front suspension type resembles the SLA suspension but instead of having different length control arms this type has equal length control arms. This suspension design is known as the equal length wishbone suspension and can be configured to have parallel or non-parallel control arms [2]. Each suspension type has several variations. As the name indicates the control arms of an SLA suspension are of different lengths and can be parallel or non-parallel in relation to each other [2]. In general, this type of suspension is widely used that there is much more freedom of upright design choice[3] . This suspension type is popular due to the fact that during the suspension travel there is a camber change[4]. This camber change can be used to maintain traction between the wheels and the ground during a tight corner. In the SLA, suspension traction is maintained because the upper control arm, which is shorter, will move toward the center of the car sooner than the lower control arm will when the car corners [5].

The MacPherson strut front suspension was used in earlier fast cars and has since then become less popular [2]. This strut type suspension is a variation in some ways of the SLA system. There is a lower control arm paired with a strut which replaces the upper control arm [4]. With this particular type of suspension brings many drawbacks to racing cars.

Literature on spectrum

A response spectrum is simply a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency, that are forced into motion by the same base vibration or shock. The resulting plot can then be used to pick off the response of any linear system, given its natural frequency of oscillation.

If the input used in calculating a response spectrum is steady state periodic, then the steady-state result is recorded. Damping must be present, or else the response will be infinite. For transient input (such as seismic ground motion), the peak response is reported. Some level of damping is generally assumed, but a value will be obtained even with no damping.

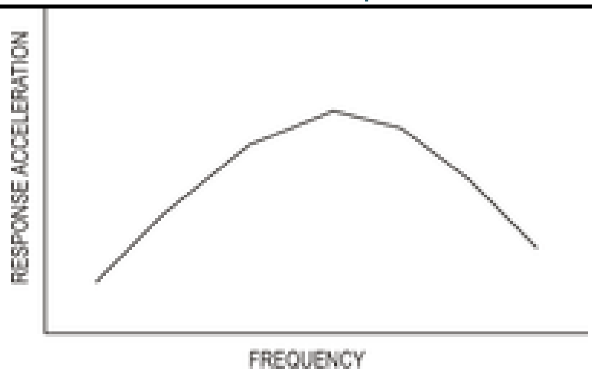


Fig : 2 Spectrum response plot

Engineers must anticipate transportation and shipping shock. The tank is fitted on a truck which runs over a speed bump or a railroad track at an imprudent speed face a half-sine shock pulse. This type of pulse can be readily represented in the time domain by its duration and peak amplitude. The tank must now withstand a series of shock pulses Atypical pulse is shown in Figure 1.3

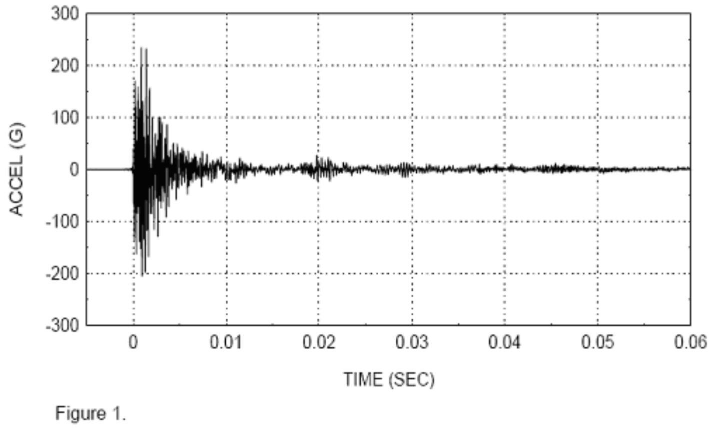


Fig: 3 Typical Space Vehicle Pyro-technique shock

III. Theoretical framework

Newton’s law can be applied to a free-body diagram of an individual system, as shown in

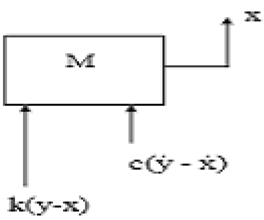


Fig:4 Free body diagram

A summation of forces yields the following governing differential equation of motion:

$$m\ddot{x} + c\ddot{x} + kx = c\dot{y} + ky \quad \ldots\ldots\ldots\ldots\ldots\ldots (1.1)$$

A relative displacement can be defined as z = x-y. The following equation is obtained by Substituting this expression into equation (1):

$$m\ddot{z} + c\dot{z} + kz = -m\ddot{y} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1.2)$$

Additional substitutions can be made as follows,

$$\omega_n^2 = \frac{k}{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.3)$$

$$2\zeta\omega_n = \frac{c}{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1.4)$$

Note that ζ is the damping ratio, and that ω_n is the natural frequency in radians per second.

Further more ,ζ is often represented by the amplification factor Q, where Q=1/ (2ζ).

Substitution of these terms into equation (2) yields an equation of motion for the relative Response

$$\ddot{z} + 2\zeta\omega_n \dot{z} + \omega_n^2 z = -\ddot{y}(t) \ldots\ldots\ldots\ldots\ldots\ldots (1.5)$$

Equation (1.5) does not have a closed-form solution for the general case in which y(t) is an arbitrary function. A convolution integral approach must be used to solve the equation. The convolution integral is then transformed into a series for the case where y(t) is in the

Form of digitized data. Furthermore, the series is converted to a digital recursive filtering relationship to expedite the calculation. The resulting formula for the absolute acceleration is

$$\begin{aligned}\ddot{x}_i = & +2\exp[-\zeta\omega_n \Delta t]\cos[\omega_d \Delta t]\,\ddot{x}_{i-1} \\ & -\exp[-2\zeta\omega_n \Delta t]\,\ddot{x}_{i-2} \\ & +2\zeta\omega_n \Delta t\,\ddot{y}_i \\ & +\omega_n \Delta t \exp[-\zeta\omega_n \Delta t]\left\{[\omega_n / \omega_d (1-2\zeta^2)]\sin[\omega_d \Delta t] - 2\zeta\cos[\omega_d \Delta t]\right\}\ddot{y}_{i-1}\end{aligned} \quad \ldots\ldots (1.6)$$

IV RESEARCH METHODOLOGY

Cad Design and Analysis of Front axle independent suspension system to with stand structural and dynamic loads for structural integrity for wishbone system. Also to estimate the factor of safety in the different components. Here the objectives include

1) Literature on Spectrum analysis and Loads on Suspension systems
2) Cad drafting and three dimensional modelling of the Suspension system
3) Meshing and Importing to Ansys for analysis
4) Analysis for the given loads to check the structural integrity
5) Spectrum response analysis

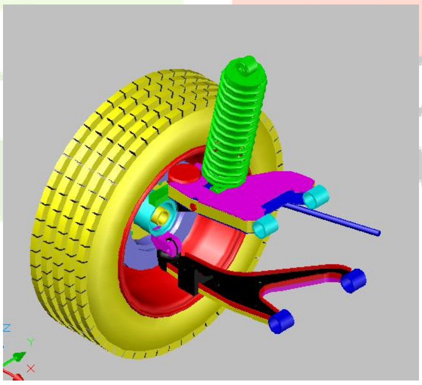


Fig:5 New design of Suspension

4.1 Requirements of the work

Suspension is a very important component in the automobile design. Proper suspension helps in reducing the stresses developed in the chassis and body of the automobile. Also human comfort is decided by the level of suspension. Since suspension connects the chassis to the axle structure, any failure of suspension is very critical. So present analysis is carried out for finding the structural integrity of a new design of car.

4.2 Material

Material : St42

Yield stress: 420N/mm^2.

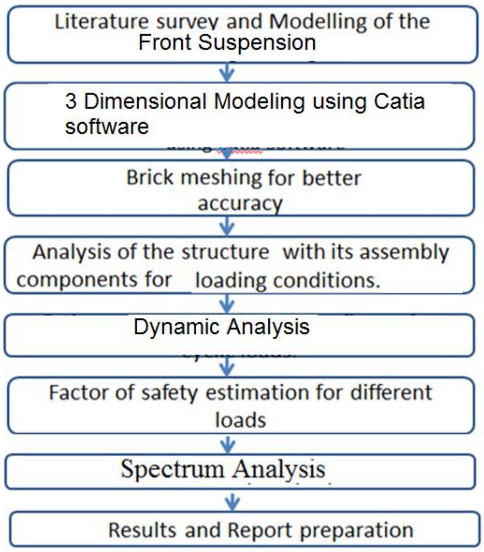
Poison's ratio=0.3

Allowable stress: 140N/mm^2.

4.3 Design Specifications

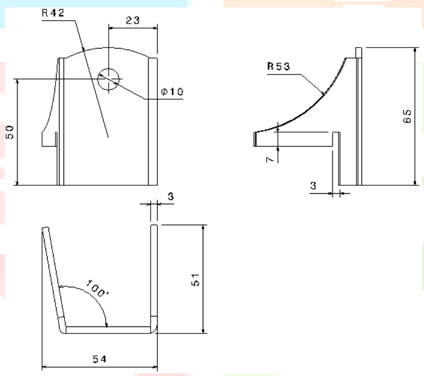
1) Stresses should be within the Yield Stress(Factor of Safety should be more than 3)
2) Maximum deflection should not cross 0.937*mm.
3) As per IS standards allowable deflections for the beam is 1mm for 350mm span.

4.4 METHODOLOGY



4.5 Cad Models

The problem specification Cad modeling is done and draft model is as represented as follows. The structure comprises two wishbone(Upper and bottom), damper arrangement.



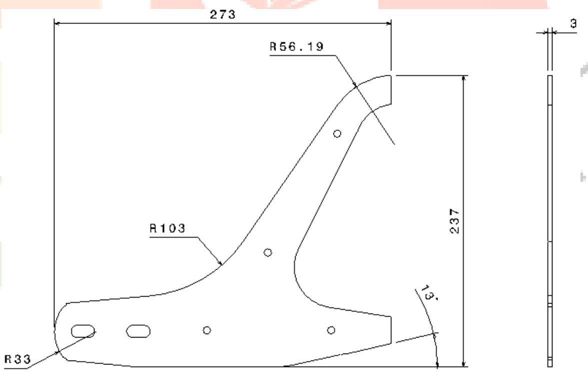


Fig:6 Dimensional view of the Component Fig:7 Bottom wishbone Dimensions

The figure 6&7 shows component dimensions of the problem. All dimensions are represented in mm. Bend radius of the pipe is given as 380mm. Sleeve length is around 300mm to accommodate the hanger flange. Rib dimensions are increased towards the bottom to increase the strength of the joint at the base.

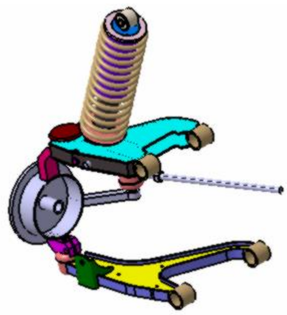


Fig:8 Dimensional view of the problem

The three dimensional view of the Suspension system is shown in the fig3.5. Initially using sketcher front views are represented and later part modeling is done using Catia part modeling module. Later the parts are assembled to create independent front suspension assembly.

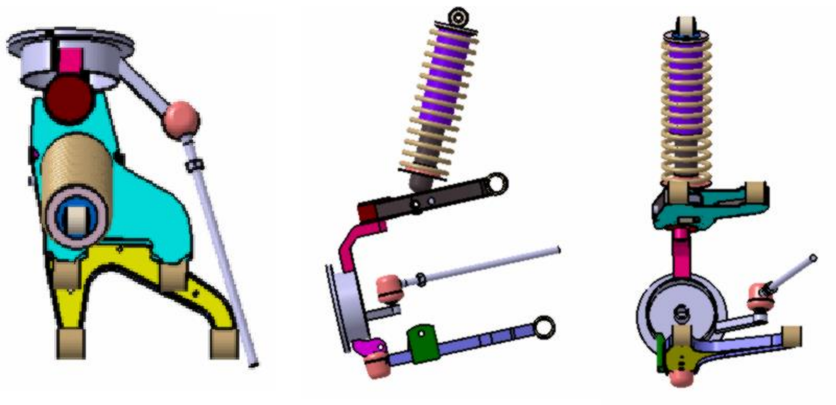


Fig: 9 Front Independent Suspension System for Car

The three dimensional views shows (Fig 9)Suspension system cad design with part details. The ribs are used to improve the strength of the structure. The components like coil spring, strut, upper and lower wishbone and torsion arm is shown in the figure. Individual parts are separated and figures are captured for representation and shown in the drafting views.

4.6 Load cases:

Totally 3different load cases are carried out to analyze the suspension. Each load case with its load considerations are represented as follows.

Table: Different Load cases

S.No	Load case no
1	Only Self Weight
2	Self Weight + Chassis Loads
3	Spectrum load in Vertical Axis

The table represents applied boundary conditions on the problem. Various load cases are considered based on the loads coming in the operational and working conditions. The spectrum loads are generated due to road vibration.

V.RESULTS FOR ANALYSIS

Structural stress estimations are very important to find the stress distribution and safety of the problem. The advantage of Finite element method is its ability to view the results on individual components and also at the place of interest. Only the requirement here is the finer mesh for better results. Since the suspension is very critical component, the mesh is imported to ansys and appropriate properties are assigned before going for actual execution.

The design of new suspension is analyzed for the given structural loads and dynamic loads. The results are presented for stress and deformation conditions. Following load cases are represented for the problem

Case 1 : Self Weight analysis

Case 2 : Self weight + Structural loads

5.1 Self Weight Analysis:

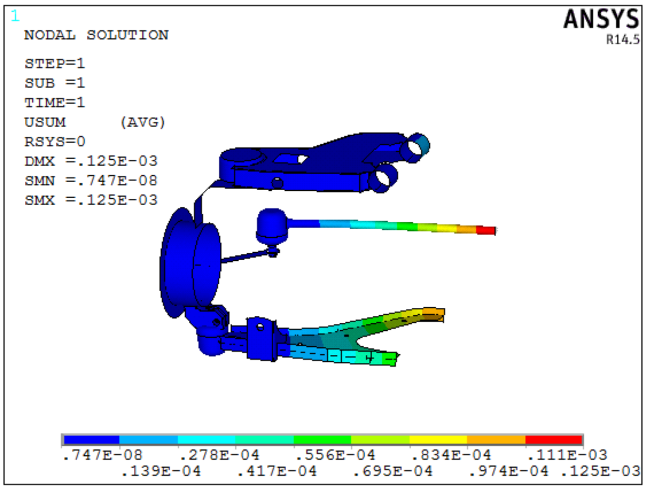


Fig: 10 Deflection plot

The figure 10 shows maximum displacement of 0.125mm (0.149e-03m). Since problem is represented in the meters results values are in meters. Maximum deflection can be observed at torsion bar. The status bar at the bottom shows variation of displacement in the structure.

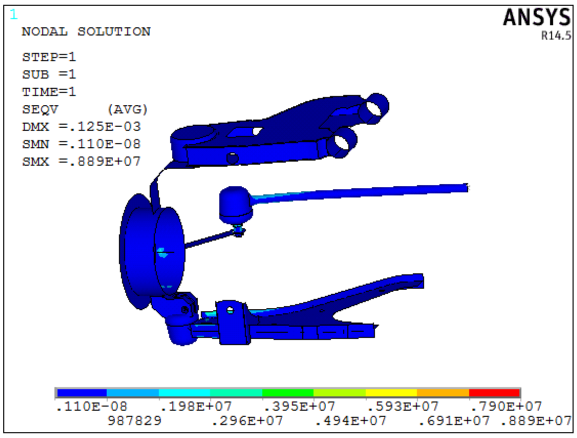


Fig:11 Vonmises stress due to self weight

The figure 11 shows Vonmises stress in the structure. Maximum Vonmises stress is around 8.89Mpa or 8.89N/mm^2. This stress is small compared to the allowable stresses specified for the material. So structure is safe for self weight. Maximum stresses are observed at the constrained ends. The blue region indicates minimum stress in the structure.

5.2 Load Case 2(With Structural Loads)

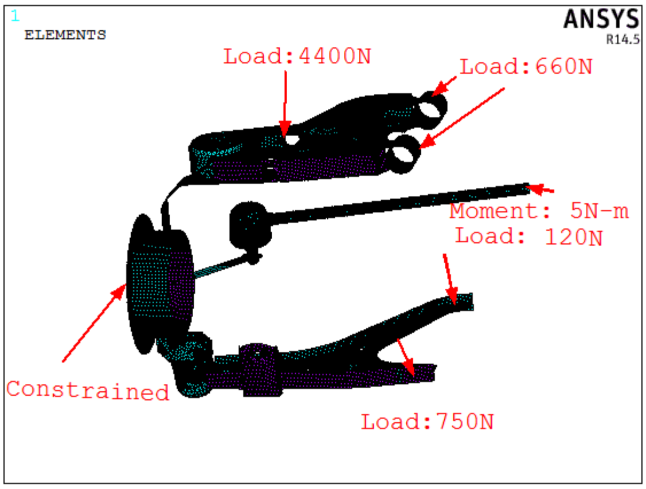


Fig: 12 Boundary conditions for static load

The figure 12 shows applied static boundary conditions on the problem. The figure shows the load values applied at different location. The knuckle region connected to the wheel is constrained and other loads in its extreme condition are applied. The torsion load is applied through RBE3 element.

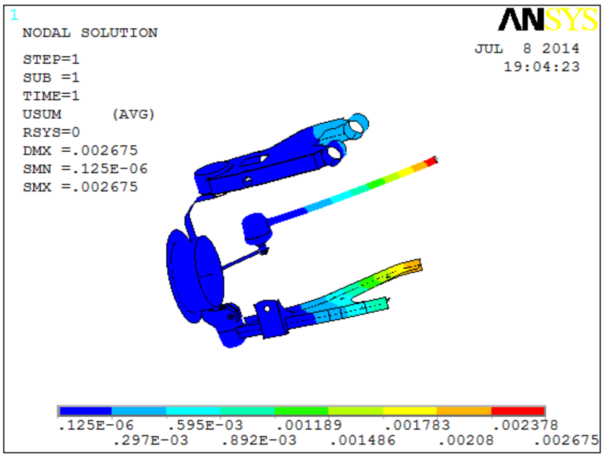


Fig: 13 Displacement plot

The figure13 shows deflection in the problem due to self weight and structural loads. Maximum deflection is moving towards the torsion bar. The deflection is increased to 0.002675m(2.675mm). But this deflection is less than the allowable deflection. So structure is safe for the given loads.

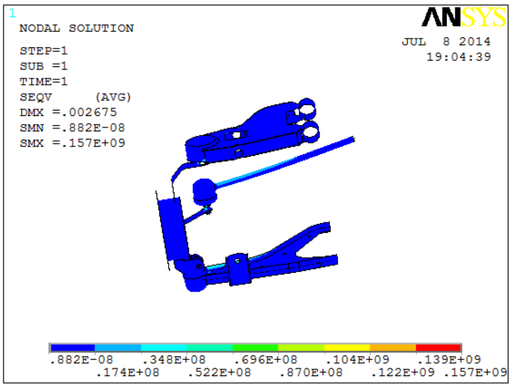


Fig:14 Vonmises Stress

The figure 14 shows Vonmises stress in the structure. Maximum stress is around 157 N/mm^2at the constrained ends. Even this stress is less than the allowable stresses of the structure. So structure is safe for the given loads.

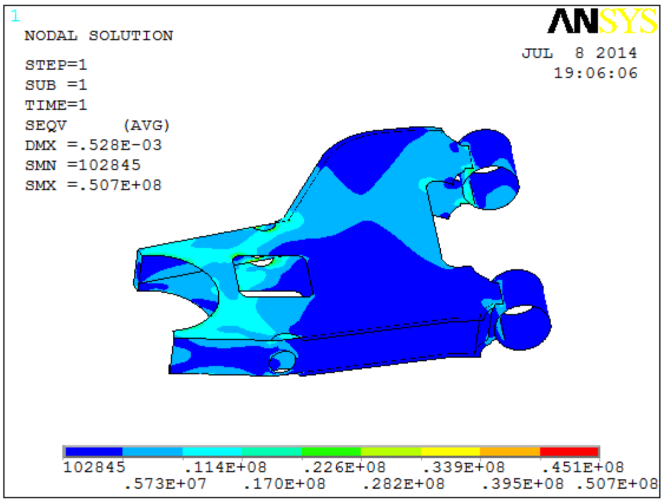


Fig:15 Upper Wishbone stress

The stress in the individual components are represented. The maximum stress in the upper wishbone is around 50.7Mpa. The stress is maximum at the connection regions and loading regions. The status bar at the bottom shows variation of stress in the upper wishbone.

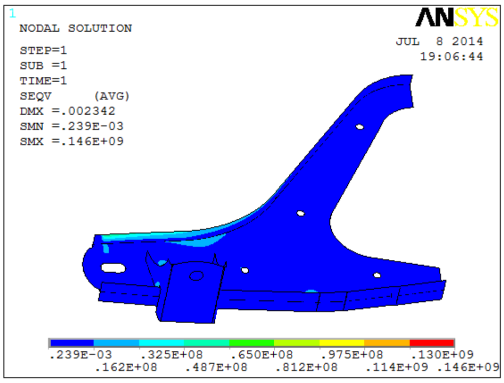


Fig:16 Lower Wishbone stress

The figure 16 shows stress development in the lower wishbone structure. Maximum stress is around 146Mpa. The stress is maximum in the outer part as the ribbing is less compared to the other side. Also moment effect is more due to higher length of the arm.

5.3 Result summary

Description	Deflection	Static Stress	Spectrum Stress				
			1 Sigma Stress (Mpa)	3 Sigma Stress (Mpa)	Total Stress	Yield Stress	Factor of Safety
Self Weight	0.125	8.89				550	61.86
Self Weight + Structural Loads	2.675	157	-	-	157	550	3.5

VI Conclusion

The front independent suspension used in an automobile system is analyzed for structural stability condition. Total 5 practical load cases are considered to check the safety of the structure. Here main objective is to find the load carrying capacity along with modal frequency conditions. Upper and bottom wishbone, torsion bar, connecting members are the main members in the suspension assembly. Solid and shell elements are used for meshing the suspension. Coupling and constraint equations are used for representing the connectivity in the members.

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