Design and Analysis of Independent Suspension System using FEA

(Chassis Mechanism)

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Abstract- **Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. More efforts are taken in order to increase the comfort of user. Appropriate balance of comfort riding qualities and economy in manufacturing of independent suspension becomes an obvious necessity. To improve the suspension system, many modifications have taken place over the time. Inventions of individual suspension system using chassis mechanism that is some of these latest modifications in suspension systems. This study mainly focuses on the implementation of chassis mechanism by replacing conventional suspension system. Automobile-sector is showing an increased interest in the area suspension where independent suspension systems are widely used. Therefore, analysis of chassis mechanism has become essential in suspension system. And elastic strain energy per unit spring weight Stored in a coil is greater and Unsprung weight is reduced, which reduced tyre scrub and increases tyre life .This is the reason why individual suspension are widely used in a variety of automobiles to carry axial loads, lateral loads and brake-torque in the suspension.**

Keywords— Chassis mechanism, individual suspension, Unsprung weight , axial loads, lateral loads, torque, comfort riding strain energy.

I. INTRODUCTION

The demand in different branches of engineering is to form comfort zone, regarding their creations likewise in vehicle. We use suspension system to support the load and protect the passenger from the shock and vibration arising from tire and road interaction to provide the direction stability and yaw control of vehicle. The vibration caused because road irregularities and other disturbance the performance of the suspension system can be improved by reducing an impact of vibration of system which are caused by various factor as discussed earlier.

Now a day's different suspension systems are available in an Automobile, and those suspension system having some deviations and limits like degree of freedom, cost, heavy weight materials of suspension, lubrication, space limitation. To overcome these we will introduce a individual independent suspension. In independent suspension system one can accurately describe the dynamic behavior of vehicle in suspension are obtained desirable. Free movement of wheels with each other which reduces body movement, these prevent the other wheel being affected by moment of the wheel on the opposite side. So now lat us consider in improving the performance of active (full suspension) system by a performing an analysis on springs (helical compression spring and half conical tension spring) which are the major component of suspension system. The appropriate chosen independent suspension technology can offer significant enhancement of structural system performance in terms of effectiveness, reliability, safety, and other design criteria. The prime objective of using suspension system is to improve the ride quality, direction stability and handing of vehicle.

This study involves that analysis of different suspension component and also the behavior of independent suspension system under different loading condition, this result of failure condition and effect of different loading condition will be compared between FEM & experimentation in laboratory

II. SUSPENSION DETAILS

A. Principles of Suspension

The suspension system damps road shocks or vibrations which would otherwise be transferred to the passengers as it is. It also must keep the tires in contact with the road. When a tyre hits an obstruction, there is a reaction force. The size of this reaction force depends on the unsprung mass at each wheel assembly

The sprung mass is that part of the vehicle supported by the springs - such as the body, the frame, the engine, and associated parts. Unsprung mass includes the components that follow the road contours, such as wheels, tires, brake assemblies, and any part of the steering and suspension not supported by the springs. Vehicle ride and handling can be improved by keeping unsprung mass as low as possible. When large and heavy wheel assemblies encounter a bump or pothole, they experience a larger reaction force, sometimes large enough to make the tire's lose contact with the road surface.

Wheel and brake units that are small, and light, follow road contours without a large effect on the rest of the vehicle. At the same time, a suspension system must be strong enough to withstand loads imposed by vehicle mass during cornering, accelerating, braking, and uneven road surfaces.

A.1. Unsprung Weight

Mostly of a vehicle's weight is supported by its suspension system. It suspends the body and associated parts so that they are insulated from road shocks and vibrations that would otherwise be transmitted to the passengers and the vehicle itself. Un-sprung weight is the weight of vehicle components between the suspension and then road surface.

This includes rear axle assembly, steering knuckle, and front axle in case of rear drive rigid suspension, wheels, tires, and brakes. The sprung weight i.e. the weight supported by the vehicle suspension system, includes the frame, body, engine, and the entire transmission system. When the wheels strike against a bump, they vibrate along with other unsprung parts which store the energy of the vibrations and then further transmit it to the sprung parts via the springs. Thus it is seen that greater the weight of the unsprung parts, greater will be the energy stored due to vibrations and consequently greater shocks.

A.2. Types of Independent Suspension Systems

Following are the major suspension (Independent) system types.

1) Wishbone type

2) Macpherson type

3) Vertical guide type

4) Trailing link type

5) Swinging half-axle type.

A.3 *Objectives of Suspension*

I. To prevent the road shocks from being transmitted to the vehicle components.

II. To safeguard the occupants from road shocks.

III. To preserve the stability of the vehicle in pitting or rolling, vehicle in motion.

B. Design of Independent Suspension System (Chassis Mechanism)

Considering several types of vehicles (off-road) that have independent suspension and different loading on them, various kinds of independent suspension system have been developed. But in independent suspension the limit of degree of freedom or deflection of wheel (Vertically) is up to 228 cm (Considering positive and Negative obstacles).And it has the maximum limit is up to 228 and we have to improve the limit of same. So it has to be studied carefully. In this study, Chassis Mechanism with varying load condition and dimension is designed and analyzed using catia and Ansys 15. Newly introduced chassis mechanism is designed using different graphics packages. The results showed that a use of chassis mechanism is causing to increases the limit up to 8 cm by providing different angle.

B.1 ParametersfFor Mechanism

TABLE-1 Parameter for Mechanism

Sr No	Parameters	Dimension	Units
1	Wheel Base	2510	mm
2	Frontal Track	1486	mm
3	Cross Member	1070	mm
4	Overall Length	3900	mm

B.2 Materials For Chassis

The different chassis materials can reduce the weight of the vehicle, improving the vehicle power to weight ratio. The material used for chassis is usually is Aluminum Alloy, mild steel, Carbon Sheet Steel and Nickel Alloy Sheet Steel an AISI 1018 to 4130 form Standard Catalogs. According to Indian standards, the recommended materials are For automobiles: AA1050A and AA3103 all used in Forged state physical properties of some of these materials are given in the following table.

TABLE-II Material properties of Aluminum Alloy

Sr. No	Properties	Value	Units
1	Young's Modulus	7.1 E+10	(Pa)
2	Poisson's ratio	0.33	-
3	Bulk Modulus	6,9608 E+10	(Pa)
4	Shear Modulus	2.6692 E+10	(Pa)
5	Yield Tensile Strength	2.8 E+8	(Pa)
6	Yield Compressive Strength	2.8 E+8	(Pa)
7	Ultimate Tensile Strength	3.1 E+8	(Pa)
8	Compressive Strength	0	(Pa)
9	Density	2770	(Kg/m^3)

III. DESIGN DETAIL

C. DESIGN

As concerning the above materials and dimensions we are going to design a chassis mechanism. Following design shows the individual component design and assembly design

C.1 DESIGN CONSIDERATION

- 1. Weight of body 2. Vertical load
- 3. Driving trust 4. Side trust
- 5. Rolling trust 6. Road Holding
- 7. Ride handling 8. Sprung Weight
- 9. Unsprung weight 10. Miscellaneous
- 11. Break drift and squat

C.2 DIFFERENT FORCES ON DESIGN

- 1. Tensile 2. Shear 3. Bending 4. Twisting

C.3 SHOCK TYPE

- 1. Rolling 2. Pitching 3. Bouncing 4. Sway

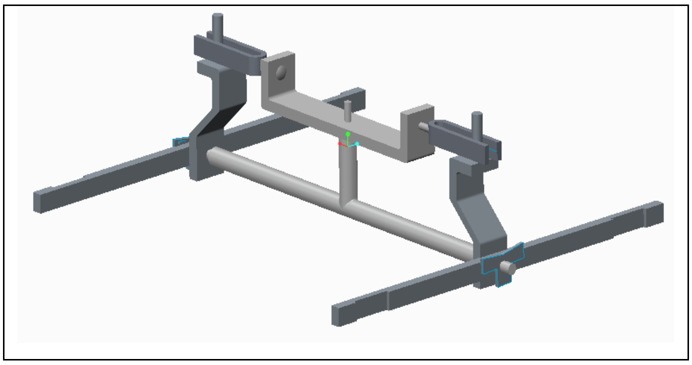

Fig1.1 Assembly of Chassis Mechanism

Above diagram is self explanatory we used the two side member with only one cross member in between them at the end of T-section side member is located. In above fig the side member and the deflection member is rigidly attached to the each other and it is freely rotating over the T- section end .and the moment form by the both of them is angular moment.

At the end of T-section end there is angle adjuster that gives the free moment for the side member. And it is rigidly attached to the T-section end. And in other end it is same as that of the end.

Deflection member have the free moment in between the U-section provided on the top of deflection member. And that U- member is connected rigidly to the C-section provided on the top of the T-section. And it has pivoted at center top of the T- section.

C.4 DESIGN LOAD

3990 N is considered as the design load with different factor regarding static condition

Consider the reaction load

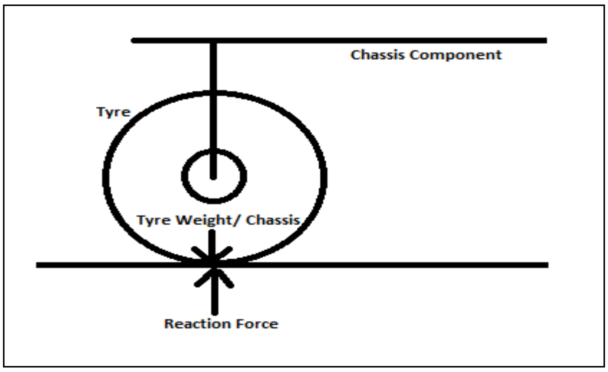

Fig. 1.2 Design Load/Reaction Load

Weight of tyre = 50 Kg

And weight of other chassis component without roof on tyre is = 51.68 Kg

So, total weight is equal to the

= (Weight of Tyre) + (Weight of other chassis component without roof)

= (50 Kg) + (51.681 Kg)

= 101.681 Kg

Convert in to Newton =

= 101.681 Kg *9.81

= 997.5 N

The reaction force on each tyre is 997.5 N

Then total force acting at center of vehicle is the sum of four wheels

The vertical force acting on vehicle at center is equal to

= 997.5 * 4

= 3990 N

And this force is taken as a design force for chassis

D.ANGLE ADJUSTER

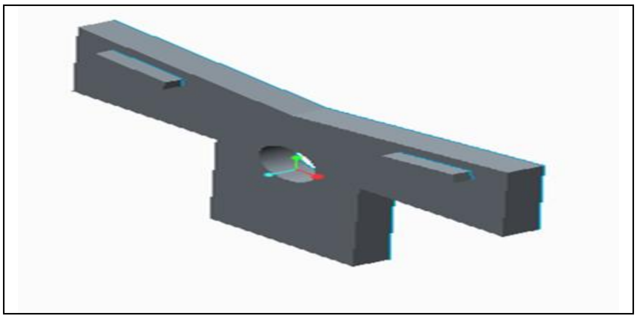

Fig. 1.3 Angle Adjuster

This element introduced where the side member and deflection member connected rigidly attached at point and both the above element is pivoted at the center using T-section end and the angle adjuster/ stopper is rigidly connected to the T- section end so that it will give the freedom to the moving side member and deflector. Following fig shows the detail how it works.

Its moment is very small as the T-section moves circular then only it works otherwise it will not.

Following fig shows the details about the Angle adjuster .And working principles of the angle adjustor.

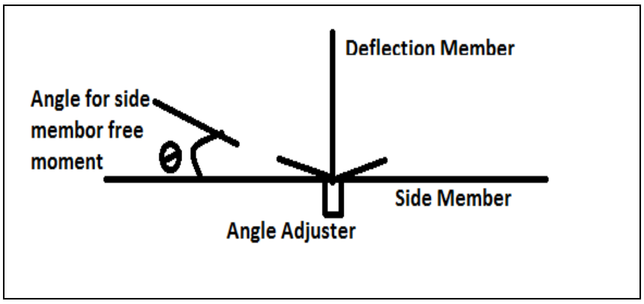

Fig. 1.2 Principle of Angle Adjuster

The maximum deflection we obtained from such suspension system is up to the 228 mm i.e. 8.97 Inches and 22.8cm including positive and negative obstacle on the road

So that angle obtained from the angle adjuster is to 2^0 to 4^0

Let following calculation for the 4^0 angle

$$\tan(4^0) = (A)/(185 \times 10 \text{ mm})$$

185cm = distance of side member from vertical load carrying member to the pivoted center

$$A = 129.36 \text{ mm}$$

For different angle different ratios are obtained

So the final output we gate is the increase the limit of deflection by 64.60 mm to 129.36 mm

So the total deflection increase is the

= (Conventional limit 228mm) + (Increased limit 129.36)

= 357.36 mm this is our objective

= 35.73 cm

TABLE-III Increased Degree of limit

Sr. No	Angle	Increased Limit(mm)	Conventional Limit (228mm) + Increased Limit(mm)
1	0.1^0	3.22	231.22
2	0.5^0	16.14	244.14
3	1^0	32.29	260.29
4	2^0	64.60	292.60
5	3^0	96.95	324.95
6	4^0	129.36	357.36

Above Table shows the different ratios are obtained by applying different angle.

IV. ANALYSIS DETAIL

E.FINITE ELEMENT ANALYSIS

E.1 Introduction To F.E.A

The name finite element is of recent origin, though the concept has been used for centuries. The basic philosophy is to replace the actual problem into a simpler model, which will closely approximate the solution of the problem at hand

A continuum is divided into a mesh; two adjacent regions placed side by side will have a common edge. It is assumed that the elements are connected at nodal points and it is only there that the continuity requirements are to be satisfied. Once the discretization is made, the analysis follows a rather set procedure. The stiffness matrix of the individual element is formulated. The forces distributed in the real structure are transformed to actually distribute in the real structure to act at the nodal lines. Assembly of individual elements is carried out to obtain stiffness matrix of the whole structure. In the finite element analysis, therefore the continuum is divided into a finite numbers of elements, having finite dimensions and reducing the continuum from infinite degrees of freedom to finite degrees of unknowns. The problem to be solved by the finite element method is done in two stages-

1. The element formulation
2. The system formulation

E.2 Steps In Finite Element Analysis

1. *FEA Pre-processor*- Creating the model Defining the element type Applying a mesh: Assigning material properties Apply loads Applying boundary conditions:

2. *Solution*-The Finite Element solver can be logically divided into three mains parts, the pre-solver, the mathematical engine & the post solver. The pre-solver reads the model created by the pre-processor & formulates the mathematical representation of the problem. All parameters defined in the pre-processing stage are used to do this, so if something is left out, pre-solver will complain to form the element stiffness matrix for the problem & calls the mathematical engine which calculates the results (displacement, temperature & pressure etc.). The results are returned to the solver & the post-solver is used to calculate strains, stresses, heat fluxes, velocities etc. for each node within the component or continuum. All these results are sent to a result file which may be the post-processor.

3. Post-processor

Here the results are read & interpreted. They can be presented in the form of table, a contour plot, deformed shape of the component or the mode shapes & frequencies if frequency analysis is involved. Most post-processors provide an animation service, which produces an animation. Slices can be made through 3-D models to facilitate the viewing of internal stress patterns.

E.Structural Analysis

In the broad sense, design of structure consists of two parts. The first parts deals with determination of forces at any point (or) member of the given structure and second part deals with the selection and design of suitable sections to resist these forces so that the stresses and deformations developed in the structure due to these forces are within permissible limits. Structural analysis can be broadly divided as Static Analysis, Modal Analysis, Harmonic Analysis, Transient Dynamic Analysis, and Buckling Analysis.

E.1 Structural Analysis

1. Static Analysis: Used to determine displacements, stresses, etc. under static loading conditions. Both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

In (X) Direction-

Static Analysis Result Acceleration In (X) Direction

Deformation of whole geometry is low in range

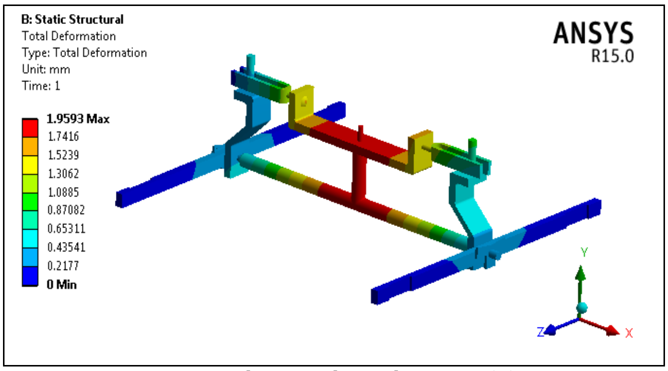

Fig 1.5 Static Analysis Result Acceleration In (X) Direction

Von-Mises Stress In (X) Direction

Stress distribution is properly distributed throughout the geometry.

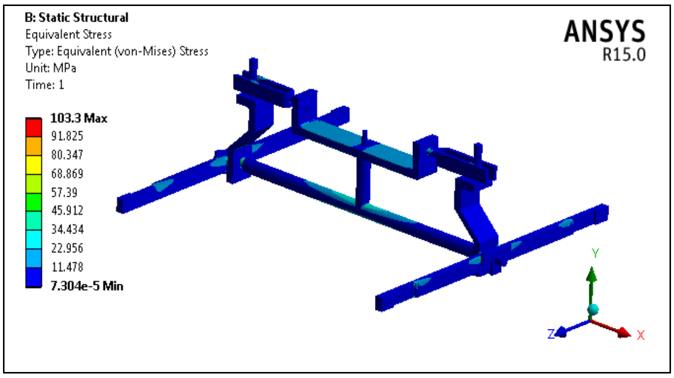

Fig 1.5 Von-Mises Stress In (X) Direction

Static Analysis Result Acceleration in (Y) Direction

Deformation of whole geometry is low in range

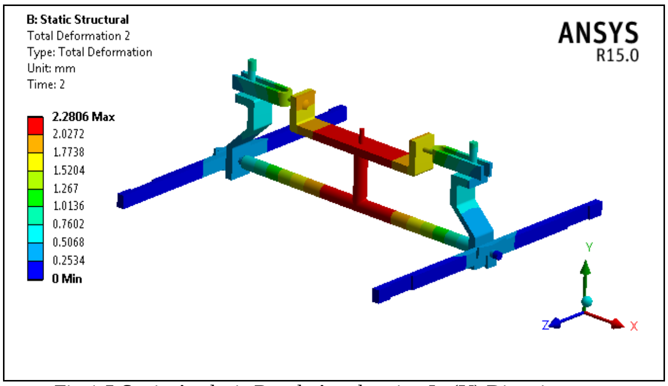

Fig 1.5 Static Analysis Result Acceleration In (Y) Direction

Von-Mises Stress In (Y) Direction

Stress distribution is properly distributed throughout the geometry.

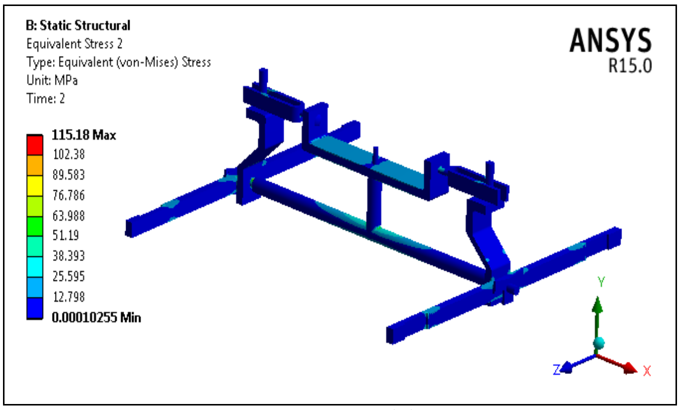

Fig 1.5 Von-Mises Stress In (Y) Direction

Static Analysis Result Acceleration In (Z) Direction

Deformation of whole geometry is low in range

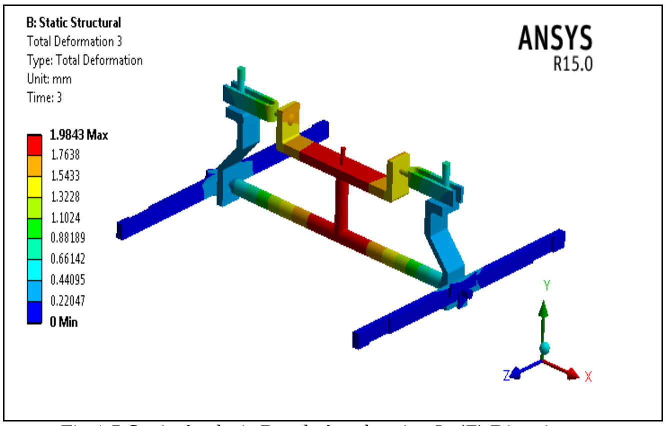

Fig 1.5 Static Analysis Result Acceleration In (Z) Direction

Von-Mises Stress In (Z) Direction

Stress distribution is properly distributed throughout the geometry.

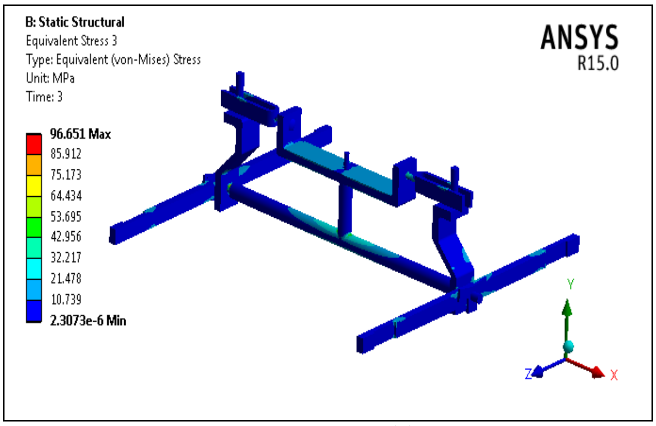

Fig 1.5 Von-Mises Stress In (Z) Direction

Summery

1. Structural Analysis shows assembly is safe from high deformation and Stresses.
2. Assembly is safe for selected material choice.

MODAL ANALYSIS

Used to calculate the natural frequencies and mode shapes of a structure. Several mode-extraction methods are available.

Model

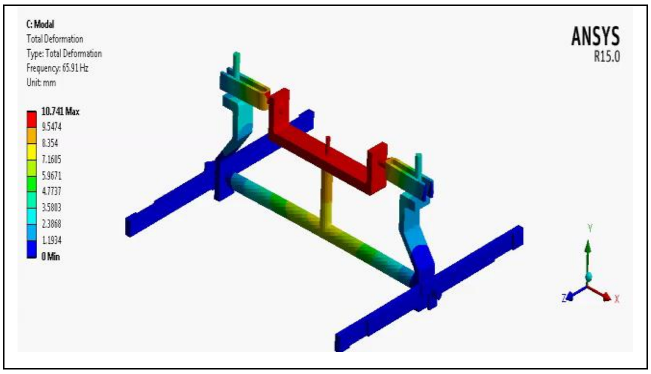

Fig 1.5 Model

Summery

From Modal Analysis the first fundamental frequency is quiet high than the operating frequency which dominates the problem of resonance.

Harmonic Analysis

Used to determine the response of a structure to harmonically time-varying loads.

Harmonic analysis is a technique to determine the response of a structure to sinusoidal (harmonic) loads of known frequency.

Input: Harmonic loads (forces, pressures, and imposed displacements) of known magnitude and frequency. Loads may be multiple loads, in-phase or out-of-phase, all at the same frequency.

Output: Harmonic displacements at each DOF, usually out of phase with the applied loads and other derived quantities, such as stresses and strains. Following fig shows the

Harmonic analysis is used in the design of supports, fixtures, and components of rotating equipment such as compressors, engines, pumps, and turbo-machinery. And structures subjected to vortex shedding (swirling motion of fluids) such as turbine blades, airplane wings, bridges, and towers.

Harmonic Responses at the (C-1) Y-axis (Acceleration Output)

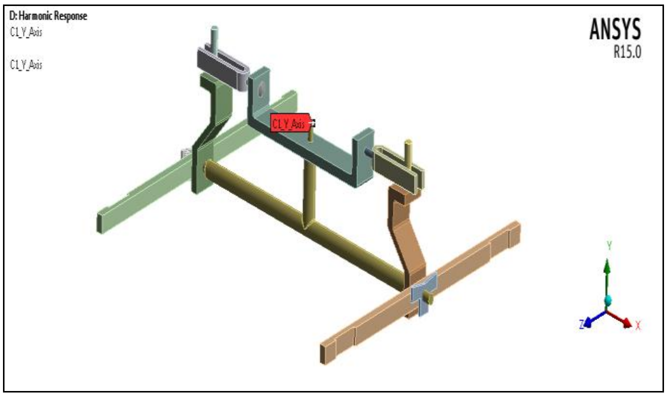

Fig 1.5 Harmonic Responses at the (C-1) Y-axis

Frequency Response (C-1) Y-axis

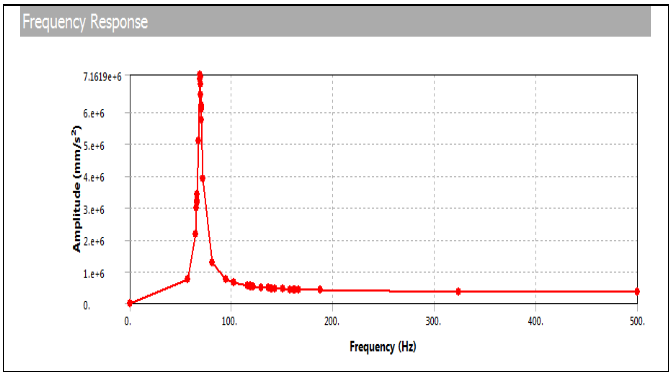

Fig 1.5 Frequency Response (C-1) Y-axis

Summery

Harmonic Analysis (Dynamic) is done and observed maximum Acceleration is observed at 72Hz which is quiet high from the operating frequency and for off-road vehicles minimum frequency should be 60Hz which indicates sufficient stiffness is there in design to handle worst situations while riding.

V. RESULTS AND CONCLUSION

Comparison/ Result

The objective of this project was to optimize the design and increase the degree of freedom of suspension and design new individual suspension system in automobiles by considering cost-effectiveness, riding comfort and strength. The comparison between conventional independent suspension limit/vertical deflection of wheel and newly introduced mechanism is show in table. And the design of new individual suspension system is made for the same requirements and loading conditions. The comparison is based on major aspects such as conventional limit of deflection of vertical load carrying member riding, And the FEM analysis.

The total deflection achieved in conventional vehicle is 228mm i.e. 22.8cm or 8.97 inches considering the negative and positive deflection. As the mechanism having angle adjustment so we put angles in between 0.20 to 0.30 angle in degree and in radian 11.45 and 17.18 following table shows the for different angle different ratios are obtained. By including our increased limit 234.45mm the limit of deflection of wheel vertically is increased by 14.70 % to 22.07 % is achieved. Thus the objective of increasing limit is achieved to a larger extent.

The Mechanism of chassis has to be designed in such a way that its natural frequency is maintained to avoid resonance condition with respect to road frequency to provide good ride comfort. The road irregularities usually have the maximum frequency of 55 Hz. Therefore, the chassis mechanism should be designed to have a natural frequency, which is away from 55 Hz to avoid the resonance (poor ride comfort zone). It is found that the first natural frequency of composite leaf spring is nearly 65.91 Hz i.e. maximum road frequency and therefore resonance will not occur. Therefore, it is obvious that Mechanism improved ride comfort.

And for static analysis Structural Analysis shows assembly is safe from high deformation and Stresses Assembly is safe for selected material choice. It is clearly shows that assembly mead is safe for high deformation.

For model analysis the first fundamental frequency (65.91 Hz) is quiet high than the operating frequency which dominates the problem of resonance

Harmonic Analysis (Dynamic) is done and observed maximum Acceleration is observed at 72Hz which is quiet high from the operating frequency and for off-road vehicles minimum frequency should be 60Hz which indicates sufficient stiffness is there in design to handle worst situations while riding

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