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Design and Analysis of Automated Truck Cabin Suspension System

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ABSTRACT

The suspension system is used to isolate the chassis from the shock loads due to irregularities of the road surface. This must be handled without impairing the stability, steering or general handling of the vehicle. Suspension system for the cab is placed between the chassis using bolts. Leaf springs are unique kind of springs used in automobile suspension systems. The benefit of leaf spring over helical spring is that the ends of the spring may be leaded along a definite path as it deflects to act as a structural member in addition to energy absorbing device. The main work of leaf spring is not only to give support to vertical load but also to isolate road induced vibrations. It is subjected to millions of load cycles leading to fatigue failure. Static analysis gives the safe stress and with corresponding pay load of the leaf spring and also to research the behavior of structures under practical situations. The loads coming from the floor and the chassis are taken by the suspension. Constraint equations and couples are used to connect various regions of the suspension system. The loads are applied on the leaf spring of the suspension system. Static analysis is made to study the deflection of the leaf spring. Modal analysis is made to check the natural frequencies. Harmonic analysis is also done to plot various graphs between frequency and amplitude. Results and discussions are made from the results obtained from the Ansys and conclusions are given and scope for future work is also given.

Keywords: Suspension system, Catia V5, Leaf spring, Analysis

INTRODUCTION

A spring is explored in the form of elastic body, where the working criterion alters when it is loaded then used for recovering its original shape and then load is flushed out. Leaf springs absorb the vehicle vibrations, shocks and bump loads by means of spring deflections, so that the potential energy is kept in stock in the leaf spring and then explored slowly. Capability to store and absorb more amount of strain energy ensures the availability suspension system. Semi elliptic leaf springs are most universally used for break in all type of vehicles. In case of cars also, these are widely used in rear suspension. The spring consists of a number of leaves known as blades. The blades are differs in length. The blades are normally given an initial curvature then it will be set to straight. The leaf spring is based on theory of a beam of uniform strength. The largest blade has eyes on its ends. This blade is referred master leaf; the rest are known as graduated leaves. All the blades are bound together by means of steel straps. The spring is placed on vehicle's axle. The complete vehicle load rests on the leaf spring. The front end of the spring is attached to the frame with a simple pin joint, while the rear end of the spring is attached with a shackle. Shackle is the flexible link one that which connects between leaf spring rear eye and frame. And when vehicle comes across a projection on the road surface, the wheel moves up, leading to deflection of the spring. If two ends are fixed, the spring will not be able to accommodate this change of length. So, to accommodate this change in length shackle is given at one end, which gives a flexible connection. The leaf spring's front eye is constrained in every direction, where as rear eye is not in X-direction. This rare eye is linked to the shackle. While loading the spring deflects and moves in the direction perpendicular to the load applied. This gives some damping which reduces spring vibrations, but since this available damping may change with time, it is not advised to avail of the same. Moreover, it produces squeaking sound. In any further if moisture is also present, such inter-leaf friction will gives fretting corrosion which reduces the fatigue Strength of the spring, phosphate paint may reduce this problem fairly of the load W from the cantilever end.

Truck Suspension

Truck Suspension is the suspension system which allows relative between both a truck frame and wheels. A suspension system provides a number of tasks like as stabilization, cushioning, road holding, road handling and ride quality. Truck`s Suspension consists of tires, springs, spring leafs, shock absorbers and linkages. Here is more information about Truck Anatomy.

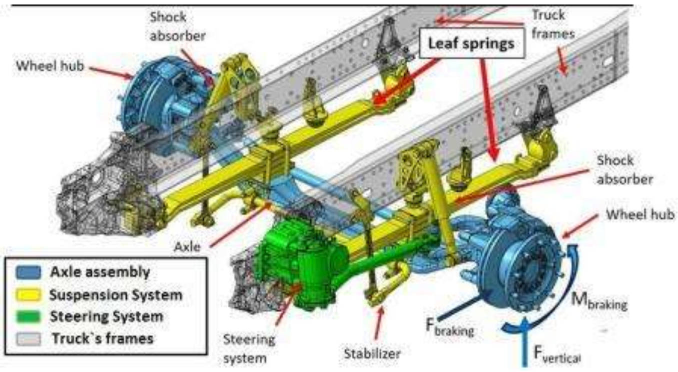

Fig. 1 – Truck Suspension

Truck Suspension Parts

A. Leaf Springs

Leaf spring is an integral part of your vehicle's suspension system. They are installed to help support the entire weight of your car or truck. Leaf springs also help to maintain the tyres grip on the road and regulate the wheelbase lengths when it is speeding up or slowing down. To control the height of the ride and axel damping leaf springs are very important. These parts are susceptible to wear and tear which is why people would want to have them replaced. Either the leaf springs wear out and begin to sag; lowering the chassis of the vehicle or the leaf spring is cracked and broken. Oftentimes people also prefer to upgrade their leaf springs to one that is heavy duty to help increase the support and keep the vehicle safer. However, leaf spring replacement is not something anyone can do. It is always best to take your vehicle to a professional. Often you will not have to change your whole suspensions when you are repairing it, but it readies to understand exactly what needs to be replaced. When you are making that choice, it is important that you examine all parts for extreme wear and damage so that you can make the proper decision.

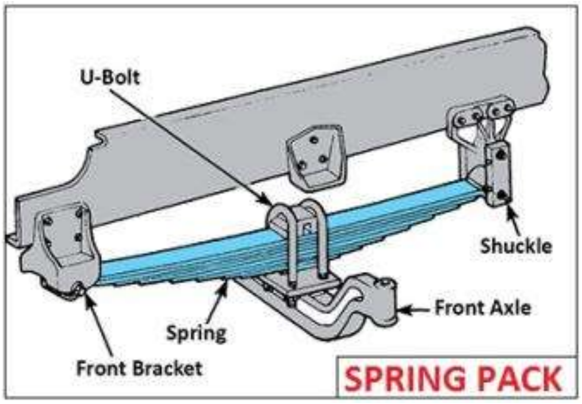

Fig. 2 – Leaf Spring

B. Torsion bar

A torsion bar is a type of suspension system in an automobile that is used in vehicles such as cars, trucks, and vans; A torsion bar suspension system is a significant and acute element of a vehicle's design. Irrespective of the design, all suspension systems do the same functions. They keep the tires in contact with the surface of the road, uphold the weight of a vehicle, and absorb the forces produced by the movement and motion of the vehicle.

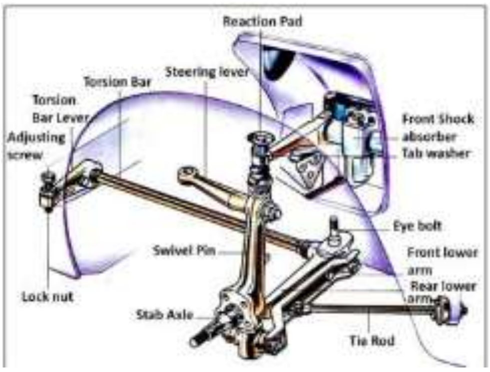

Fig. 3 – Torsion Bar

C. Equalizer beam

An equalizer for a suspension system for a trailer is configured to absorb or dampen the harsh shocks or vibrations coming off of the leaf springs proximate to a center frame hangar, thus allowing for a “softer” ride. The equalizer utilizes two independent equalizer arm assemblies which are each rotatably secured within the equalizer. Each equalizer arm assembly is operatively associated with one of the front or rear leaf springs such that upon upward movement of the front or rear leaf spring, the associated equalizer arm assembly is forced to rotate within the equalizer and to deform a shock absorber provided within the equalizer. The shock absorber, upon the deformation thereof, absorbs the harsh shocks or vibrations which would otherwise normally be transferred from the leaf springs, to the equalizer, and thus to the frame of the trailer.

C. Air spring Suspension

Air suspension systems essentially replace a vehicle's coil springs with air springs. The air springs are simply tough rubber and plastic bags inflated to a certain pressure and height to mimic the coil springs. But the similarities end there. By adding in an on-board air compressor, sensors and electronic controls, today's air suspension systems provide several advantages over all-metal, conventional springs, including near-instant tuning, and the ability to adapt handling to different situations and vary load capability.

Literature Review

An extensive literature study is first performed on the topic of passive and semi-active automotive suspension systems. Since the amount of publications on cabin suspension systems is very limited, suspension concepts applied in primary vehicle suspensions are also regarded. From this literature study, several passive and semi active suspension concepts are selected. The performances in terms of driver comfort of the selected suspension concepts, applied to a truck cabin suspension, are compared. Therefore a 4 degree-of-freedom quartervehicle model is used to describe the dynamics in vertical direction of a truck with axle suspension, cabin suspension and engine suspension.

Bharwad Jayesh Melabhai [1] published paper on Design and Analysis of Suspension System for Light Weight Vehicle and they concluded that less value of total deformation happened in spring made of copper alloy for all the values of the load. The deformation reduced by 20% in copper alloy comparing with the deformation in the steel. The deformation, strain, and stress increased by increasing the load in case of steel material. It could be concluded that the copper alloy is the suitable material to fabricate the tapered spring in the suspension system in automobiles.

Udhav U.Gawandalkar [2] worked on Design, Analysis and Optimization of Suspension System for an Off Road Car According to their research work Analysis of wishbones helped to structurally strengthen them without using excess material. The designed suspension was found to give satisfactory wheel travel in the front. The steering system was responding very well and turning radius of around 2.6m was obtained easily. The Unique design of the rear wishbone was well appreciated as it gave good performance satisfying all the aims we had at the back of our minds while designing it.

K. Chinna Maddaiah [4] published paper on Design and Analysis of Automated Truck Cabin Suspension System and according to their study the deflection in the composite leaf spring was almost equal so that composite spring had the same stiffness as that of steel spring. It was observed that the composite leaf spring weighed only 39.4% of the steel leaf spring for the analyzed stresses. Hence the weight reduction obtained by using composite leaf spring as compared to steel was 60.48 %. By analyzing the design, it was found that all the stresses in the leaf spring were well within the allowable limits and with good factor of safety.

Sainath Kasuba [5] worked on Design and Analysis of Automated Truck Cabin Suspension System and they concluded that the automobile chassis is placed on the axles, which is not direct but with some form of springs. This is to isolate the vehicle body from the road shocks which might be in the form of bounce, pitch, etc. These tendencies give rise to an uncomfortable ride and also cause extra stress in the automobile frame and body. Every part which performs the function of isolating the automobile from the road shocks are bunch of collection referred as a suspension system.

Objectives:

Study the static and dynamic parameters of the chassis.

Workout the parameters by analysis, design, and optimization of suspension system.

Study of existing suspension systems and parameters affecting its performance.

Determination of design parameters for cabin suspension system.

3. Design and Analysis of Leaf Spring

5.1 Design of Suspension System

The design of the leaf spring is done in CATIA V5 R20. All the leaves, clamps and bolt are designed separately in the part drawing and are assembled in the assembly drawing section in CATIA. The leaves are assembled by giving surface contact between the bottom surfaces of one leaf to the top surface of the other leaf. In this way all the 10 leaves are assembled in the CATIA, after that the clamps and bolts are assembled in the leaf spring.

A. Design specifications of leaf spring

Table 1- Design specifications of leaf spring

Sr. No	**TOTAL LENGTH OF THE SPRING(EYE TO EYE)**	**1120 MM**
1	FREE CAMBER	180 MM
2	NO OF FULL LENGTH LEAVES	2
3	NO OF GRADUATED LEAVES	8
4	THICKNESS OF THE LEAF	6 MM
5	WIDTH OF THE LEAF	50 MM
6	YOUNG'S MODULUS OF THE STEEL	210 GPA
7	POISSON RATIO	0.3

A. Catia drawing of leaf spring

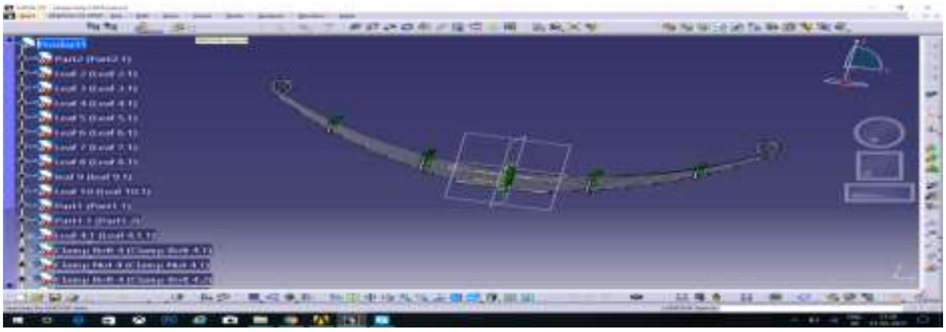

Fig. 4- Assembled diagram of Leaf spring in CATIA

5.2 Material Properties of Leaf Spring

In Analysis of Leaf spring, the authors are considered different materials to compare the conventional steel leaf spring. The selected materials are Epoxy glass, Epoxy carbon, Aluminum Alloy, and Titanium Alloy. The following are the material properties of selected materials are compared with the steel properties.

1) **Steel:**

The material used for leaf springs is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated after the forming process. The heat treatment of spring steel products has greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

2) **E-Glass/Epoxy:**

The main advantage of Glass fiber over others is its low cost. It has high strength, high chemical resistance and good insulating properties.

3) **Epoxy Carbon:**

The advantages of Epoxy carbon include high specific strength and modulus, low coefficient of thermal expansion and high fatigue strength.

4) **Aluminum Alloy:**

Aluminum is a very desirable metal because it is more malleable and elastic, corrosion resistant and less dense.

5) **Titanium Alloy:**

Titanium's material is a combination of high strength, stiffness, toughness, low density and good corrosion resistance provided by various titanium alloys. It is the most useful strongest metal available.

5.2 Analysis Procedure of Leaf Spring

1) Geometry:

First generate the geometric model of the leaf spring from CATIA into Ansys software.

2) Define Materials:

Define a library of materials for Analysis. In this Analysis of leaf spring, selected materials are steel, Epoxy glass, Epoxy carbon, Aluminum Alloy, Titanium Alloy. These materials can be selected from the engineering data available in Ansys software.

3) Generate Mesh:

Now generate the mesh. This divides the drawing into finite number of pieces. It will show the number of nodes and elements present in the drawing after meshing is completed.

4) Apply Boundary conditions:

Simply supported boundary conditions are considered for the leaf spring. In this case both the ends of the leaf spring are given fixed support and the load on the leaf spring is applied at the bottom leaf in upwards direction.

5) Obtain solution and generate results:

Now obtain the solution for the stress, deformation and elastic strain and generate the results.

5.2 Analysis of Leaf Spring

Now, let us check the results obtained in Ansys for stress, deformation, elastic strain and weight for the specified materials.

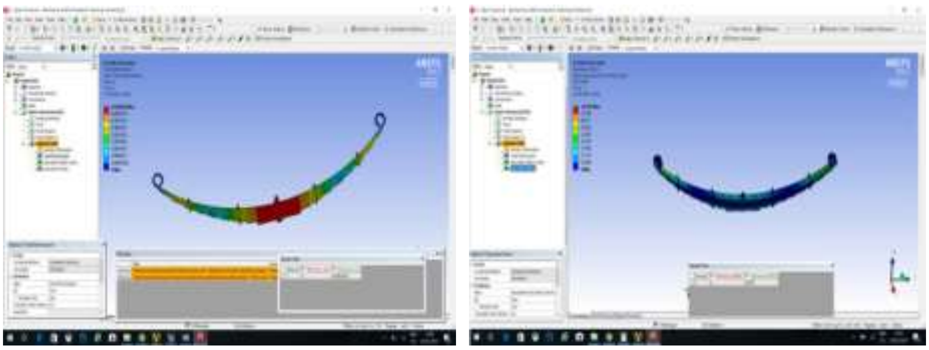

Fig. 5- Steel material

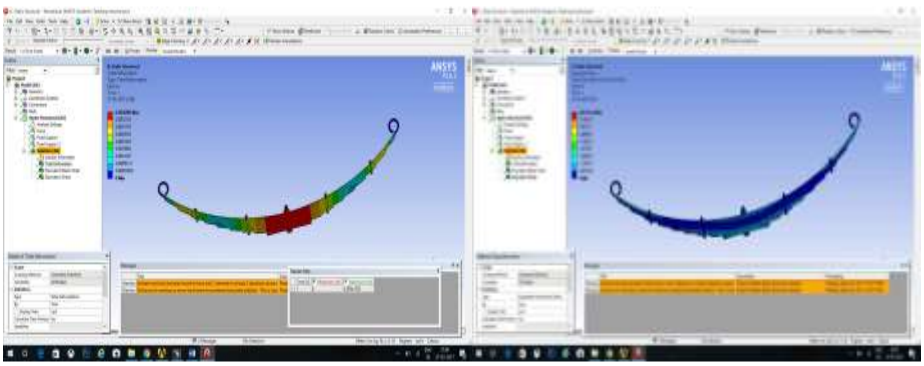

Fig. 6- E-Glass/Epoxy

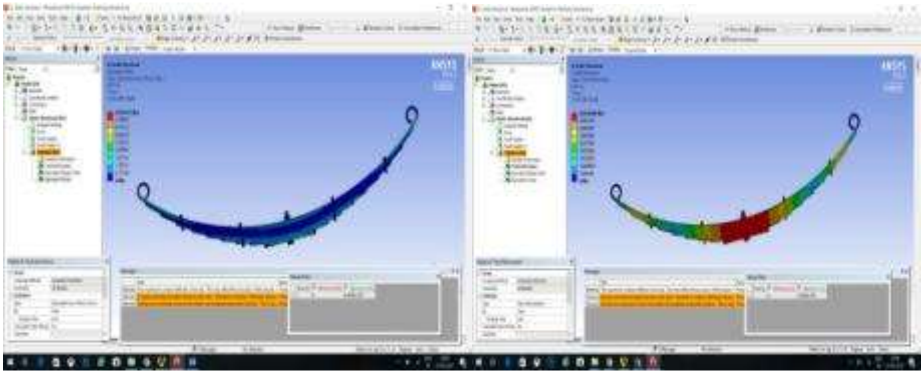

Fig. 7- Epoxy Carbon

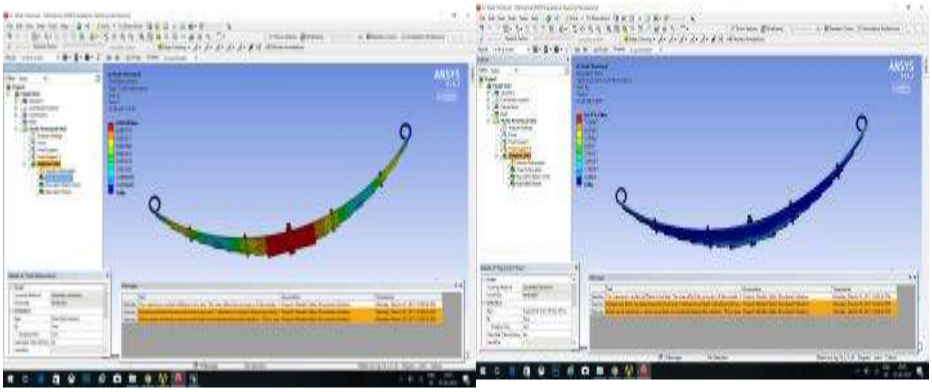

Fig. 8- Aluminum Alloy

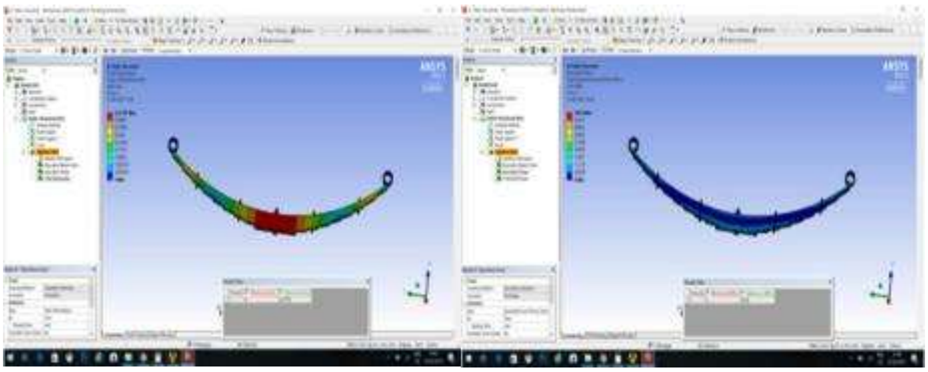

Fig. 9- Titanium Alloy

4. Result and Discussion

4.1 Comparison of Theoretical and Analysis Result

Comparison of theoretical stress, deformation and weight with that of the results obtained from the Ansys software:

Table 2- Comparison of Stress

SR.NO.	MATERIAL	THEORETICAL ((N/mm^2)	ANSYS (N/mm^2)
1	STEEL	60	59.38
2	E-GLASS/EPOXY	60	69.13
3	EPOXY CARBON	60	63.16
4	ALLUMINIUM ALLOY	60	59.64
5	TITANIUM ALLOY	60	59.93

Table 2 shows the comparison of stress in theoretical and computational for the steel and other composite materials, the theoretical stress is 60 N/mm2, where as the stress values obtained using Ansys for different materials are nearly to 60 N/mm2. Now the theoretical values are very close to the computational using ANSYS.

Table 3- Comparison of Deformation at 3200N

SR.NO.	MATERIAL	THEORETICAL ((MM)	ANYSYS (MM)
1	STEEL	0.141	0.135
2	E-GLASS/EPOXY	3.54	3.38
3	EPOXY CARBON	2.83	3.11
4	ALLUMINIUM ALLOY	0.39	0.375
5	TITANIUM ALLOY	0.295	0.277

Table 3 shows the comparison of the theoretical and Ansys results of deformation for various materials. The Ansys values are close to the theoretical values.

Table 4- Comparison of Weight

SR.NO.	MATERIAL	THEORETICAL	ANYSYS
1	STEEL	16.67	18.7
2	E-GLASS/EPOXY	4.27	3.62
3	EPOXY CARBON	3.18	3.55
4	ALLUMINIUM ALLOY	5.91	6.61
5	TITANIUM ALLOY	9.87	11

Table 4 shows the comparison of the theoretical and Ansys results of weight of the leaf spring for different materials. The ANSYS values are close to that of the theoretical leaf spring weight.

5. Conclusion

It was observed that the deflection in the composite leaf spring was almost equal so we can say that composite spring had the same stiffness as that of steel spring. It was observed that the composite leaf spring weighed only 39.4% of the steel leaf spring for the analyzed stresses. Hence the weight reduction obtained by using composite leaf spring as compared to steel was 60.48 %. By analyzing the design, it was found that all the stresses in the leaf spring were well within the allowable limits and with good factor of safety. It was found that the longitudinal orientations of fibers in the laminate offered good strength to the leaf spring. Ride quality is generally quantified as the natural frequency of a suspension system.

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