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# Design of Mono Composite Leaf Spring for Four Wheeler Light Weight Vehicle

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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 Betweenthe chassis using bolts. The loads coming from the floor and the chassis are taken by the suspension. The model is designed in PRO- E and translated to Ansys 10.0. The model is simplified in Ansys by using the preprocessor. Constraint equations and couples are used to connect various regions of the suspension system. The loads are applied on the top flange of the suspension system. Static analysis is made to study the deflection of the suspension system. 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.

## INTRODUCTION

The complete suspension system is to isolate the vehicle body from road shocks and vibrations which would otherwise be transferred to the passengers and load. It must also keep the tires in contact with the road, regardless of road surface. A basic suspension system consists of springs, axles, shock absorbers, arms, rods, and ball joints.The spring is the flexible component of the suspension. Basic types are leaf springs, coil springs, and torsion bars.

Modern passenger vehicles usually use light coil springs.Light commercial vehicles have heavier springs than passenger vehicles, and can have coil springs at the front and leaf springs at the rear. Heavy commercial vehicles usually use leaf springs, or air suspension.

Solid, or beam, axles connect the wheels on each side of the vehicle. This means the movement of a wheel on one side of the vehicle is transferred to the wheel on the other side. With independent suspension, the wheels can move independently of each other, which reduces body movement. This prevents the other wheel being affected by movement of the wheel on the opposite side, and this reduces body movement.

## PRINCIPLE OF SUSPENSION SYSTEM

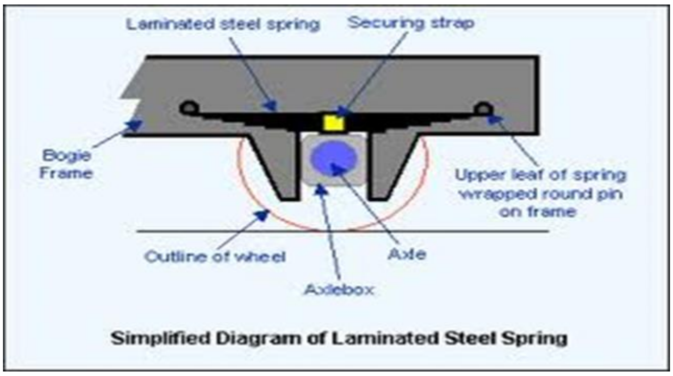



Figure : Principle of suspension system

The suspension system isolates the body from road shocks and vibrations which would otherwise be transferred to the passengers and load. It also must keep the tires in contact with the road. When a tire 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 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.

When a wheel strikes a bump, there is a reaction force, and energy is transferred to the spring which makes it oscillate. Oscillations left uncontrolled can cause loss of traction between the wheel and the road surface. Shock absorbers dampen spring oscillations by forcing oil through small holes. The oil heats up, as it absorbs the energy of the motion. This heat is then transferred through the body of the shock absorber to the air.

When a vehicle hits an obstruction, the size of the reaction force depends on how much unsprung mass is at each wheel assembly.Sprung mass refers to those parts of the vehicle supported on the springs. This includes the body, the frame, the engine, and associated parts.

Unsprung mass includes the wheels, tires, brake assemblies, and suspension parts not supported by the springs. Vehicle ride and handling is improved by keeping unsprung mass as low as possible. Wheel and brake units that are small and light follow the road contours without a large effect on the rest of the vehicle.

CLASSIFICATIONS OF SUSPENSION SYSTEM

INDEPENDENT SUSPENSION

Figure: Independent suspension system

One of the main benefits claimed for independent suspension is that unsprung mass can be kept low.Also, if a wheel on one side hits a road irregularity, it won't upset the wheel on the other side on the same axle. And it allows wheel camber to be adjusted individually, when provided for by the manufacturer.One of the simplest, and most common, independent suspension systems is the McPherson strut type. It can be used on the front and rear of the vehicle.

It consists of a spring and shock absorber unit called a strut. The lower end of the strut is located by a ball joint, fitted to the end of the suspension control arm. Its upper end is located in a molded rubber mounting. If the unit is on the front, the upper mounting includes a bearing to allow the complete strut to rotate with the steering. A tension rod, or stay bar, extends from the body sub-frame, to the outer end of the control arm.This maintains the location of the control arm during braking, and accelerating.

In this front-wheel-drive suspension, the control arm is a wishbone shape with 2 widely-spaced mounting points. This prevents backward and forward movement, so a tension rod is not needed. Wishbones can also be used in a parallel link system. They can be used in pairs with the coil spring between the lower wishbone, and the suspension cross-member. Alternatively, the upper link may be a wishbone, with the coil spring mounted above, combined with a single-pivot lower link, located by a tension rod. On some vehicles, a torsion bar provides the springing medium. The torsion bar is attached at the inner fulcrum point of the wishbone, or control arm. As the suspension is deflected, it twists around its center. It can be fitted to the upper, or the lower link, depending on the type of vehicle. The upper link is shorter than the lower one - irrespective of the springing method used. When the suspension is deflected, the unequal lengths allow the track of the vehicle to be maintained near constant, but with some changes to camber angle. Generally, when the car leans during cornering, the inner wheel leans outwards at the top, and the outer wheel leans inwards. This helps to maintain maximum tire contact with the road surface.

REAR INDEPENDENT SUSPENSION Figure: Rear independant suspension system


The kind of independent suspension used on the rear of a vehicle depends in part on whether it is front-wheel-drive, or rear-wheel-drive. If it is front-wheel-drive, it may use a McPherson strut system at the rear, similar to the front suspension system. There is normally no steering on the rear wheels, so there is no need for the bearing in the upper mounting. On rear-wheel-drive vehicles, the suspension arrangement has to allow for the external drive shafts to transfer the drive to the wheels.

The final drive assembly is normally fixed to a cross-member, and since it must absorb the torque reaction, it must be secure. Drive shafts, either with conventional or constant velocity joints, transmit the drive to the wheels. When conventional universal joints are used, each drive shaft may have a splined-section to accommodate changes in shaft length, due to changes in wheel camber, with suspension action. However, the drive shaft itself can be used as the upper link of the suspension, providing the pivot point. The splined-section is unnecessary, and the shaft can be made as a one-piece. As with the front suspension, the lower link has widely-spaced pivots to provide stability, and the unequal-length links maintain the track nearly constant, although, with deflection, some camber change does occur.

In some designs, the wheel units are located at the outer ends of semi-trailing arms. The arms are attached to their cross-member pivot-points by rubber bushes, and constant-velocity joints are used at each end of the external drive shafts.

TYPES OF SUSPENSION SYSTEM AND COMPONENTS

- Coil springs
- Torsion bars
- Rubber springs
- Leaf springs

COIL SPRINGS

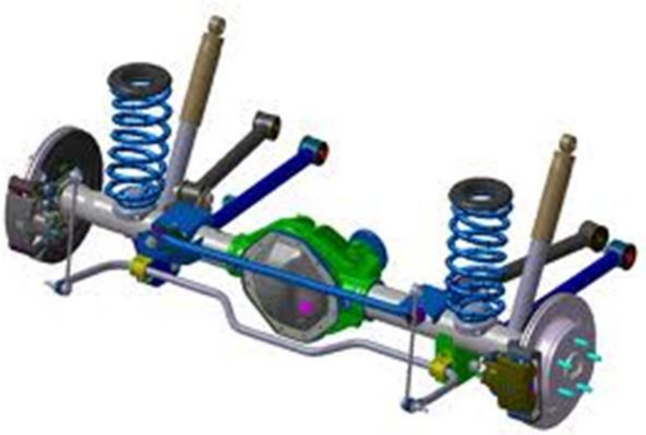


Figure: Coil springs

Coil springs are used on the front suspension of most modern light vehicles, and in many cases, they have replaced leaf springs in the rear suspension. A coil spring is made from a single length of special wire, which is heated and wound on a former, to produce the required shape. The load-carrying ability of the spring depends on the diameter of the wire, the overall diameter of the spring, its shape, and the spacing of the coils. And this also decides which vehicle it is suitable for. A light commercial vehicle has springs that are robust and fairly stiff.

On a small passenger car, they are lighter, and more flexible. The coils may be evenly spaced, or of uniform pitch, or unevenly spaced. The wire can be the same thickness throughout, or it may taper towards the end of the spring. The spring itself may be cylindrical, barrel-shaped, or conical. Generally, a cylindrical spring, with uniform diameter wire, and uniform pitch, has a constant deflection rate. Its length reduces in direct proportion to the load applied.

When the pitch is varied, the deflection rate varies too. The spring is then said to have a progressive rate of deflection. Similarly for varying wire diameter and the shape. A spring with a progressive rate deflects readily under a light load, but increases its resistance as the load increases. This gives a softer ride. As conical and barrel-shaped springs compress, they collapse into themselves. This gives a longer suspension travel for the length of the spring, than for a cylindrical spring. This gives a softer ride for light-load situations, and a harder ride for heavy load situations.

As a cylindrical coil compresses, it can become coil-bound, which limits its travel. Coil springs can look alike but give very different load ratings, which are often color coded for identification. They normally use rubber pads to prevent transmission of noise and vibration

TORSION BARS

Figure : Torsion bars

A torsion bar is a long, alloy-steel bar, fixed rigidly to the chassis or sub-frame, at one end, and to the suspension control arm at the other. The bar is fitted to the control arm in the unloaded condition, and as the control arm is raised, the bar twists around its center, which places it under a torsion load. When the vehicle is placed on the road, with the control arm connected to the suspension assembly, the bar supports the vehicle load, and twists around its center, to provide the springing action. Spring rate depends on the length of the bar, and its diameter. The shorter and thicker the bar, the stiffer its spring rate. Torsion bars can be used across the chassis frame on the same principle, in a trailing arm suspension, or as part of the connecting link between two axle assemblies, on a semi-rigid axle beam. After a lot of use, a torsion bar can sag. On many vehicles, it can be adjusted to allow for this. It is used in light vehicles as a stabilizer, or anti-roll bar, connected between each side of the suspension on the front, and sometimes the rear.

When the vehicle is turning, centrifugal force acts on the body, and tends to make it lean outwards. The anti-roll bar, or stabilizer, tries to use its connections to each side of the suspension, to resist this roll tendency.

RUBBER SPRINGS

Figure : Rubber springs

Rubber is used in most suspension systems as bump and rebound stops. If the suspension reaches its limit of travel, these stops prevent direct metal-to-metal contact, which reduces jarring of the body of the vehicle. The stops can also be shaped to provide an auxiliary springing function, increasing their resistance progressively with suspension contact. Some vehicles use rubber as the main springing medium. This rubber cone is this vehicle's main suspension member.

Increasing the load on the suspension causes the cone to act like a spring being deformed. When the load is removed, the rubber's elastic properties tend to return it to its original state. Rubber has a number of advantages. It doesn't need to be lubricated, it can be made into any shape, as required, and it's silent during use

LEAF SPRING

Figure : leaf spring

The leaf spring is one of the oldest forms of springing. It is usually used on rear-wheel-drive vehicles because its simplicity. They can be mounted longitudinally. Leaf springs consist of one or more flat springs, made of tempered steel. A number of leaves of different length are used to form a multi-leaf spring. They are held together by a center bolt that passes through a hole in the center of each leaf. It is also used to locate the axle on the spring. The axle is then clamped to the spring by U-bolts that wrap around the axle housing, and through a spring plate underneath the spring.

Rebound clips are formed at intervals around the leaves. They prevent excessive flexing of the main leaf during rebound, and also keep the leaves in alignment. The longest leaf called the main leaf, is rolled at both ends to form eyes. These eyes are used to mount the spring to the frame of the vehicle. Some springs have the ends of the second leaf rolled around the eyes of the main leaf, as reinforcement. This leaf is called the wrap leaf.

The front of the spring is attached to a rigid spring hanger on the vehicle frame. The rear is connected to the frame by a swinging shackle, which provides a link between the spring eye and a bracket on the sub-frame. This swinging link is needed, because, as the spring flexes, and flattens out under load, the distance between the spring eyes increases.

Some springs have inserts between the leaves, of plastic, nylon, or rubber. They act as insulators, to reduce noise transfer, and friction as the leaves move under load. Some older vehicles completely enclose the leaf springs in grease. The spring eyes are fitted with bushes, usually with a rubber, flexible section, but nylon and urethane bushes are also used, and sometimes bronze for heavy duty applications. Rubber insulating pads between the spring mounting pad and the spring also act as insulators and similarly, between the spring plate and the spring.

The spring forms a flexible suspension unit that locates the axle housing longitudinally and laterally. It can sustain the torque reaction on acceleration and the braking torque during deceleration, and the driving thrust is transferred through the front half of the spring to the fixed shackle point.

TYPES OF LEAF SPRING

Several designs of leaf springs are employed on automobiles. They are

- Semi-elliptic and quarter-elliptic (or cantilever) type leaf springs.
- Longitudinally and transversely located type leaf springs.
- Tapered and progressive (or helper) type leaf springs. Among these, the semi-elliptic leaf springs are most common

SEMI-ELLIPTICAL LEAF SPRING

A semi-elliptic leaf spring along with its connections is shown in below figure. As the name itself implies, the leaf spring is made-up of a number of steel leaves. Each leaf is of different length but of equal width and thickness. The uppermost longest leaf having bushes at its two ends is called master leaf. One of its ends is directly connected to a side member of the frame through a gusset plate. While the other end is attached on the frame via a shackle. This end of the master leaf is known as spring eye end

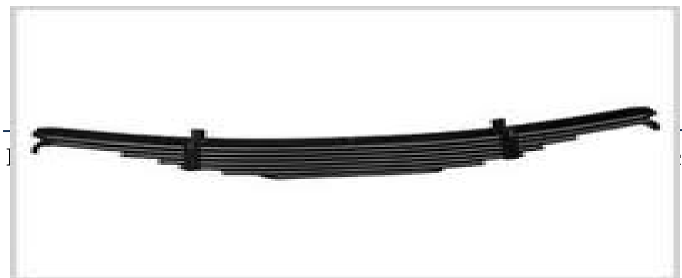


Figure: semi elliptical leaf

QUARTER-ELLIPTIC LEAF SPRING

This is also known as cantilever type leaf spring since its one end is fixed on the side member of the frame, and the other end is freely connected to the front axle. In such springs the camber is provided in upward side so that the leaves tend to straighten when the front axle beam is subjected to shock load.

Figure: Quarter-elliptic leaf spring

TRANSVERSELY MOUNTED SEMI-ELLIPTIC INVERTED LEAF SPRING

In this arrangement, a semi-elliptic leaf spring is mounted transversely i.e. along the width of the vehicle. The springs are placed inverted such that the longest leaf is located on the bottom. The specialty of this arrangement is the use of two shackles. This arrangement could not become popular due to increased rolling tendency produced in the vehicle. This tendency is more when the vehicle runs faster at the sharp turns.

TAPER LEAF SPRING

The leaf springs discussed till now are equipped with leaves of constant cross-sectionthroughout their lengths. Such leaves may be called conventional leaves and the springs asconventional leaf springs. Different from them is the development of a new kind of leaf spring whichconsists of a single leaf having varying cross-section. Such spring is termed as tapered leaf spring or taperlite spring. These are of parabolic profile. They are prestressed before use, therefore they canwithstand higher than normal stresses

Figure : Taper leaf spring

HELPER SPRING (PROGRESSIVE SPRING)

Many heavy commercial vehicles are provided with an auxiliary leaf spring in addition to the main leaf spring. It is done so as to combine the soft suspension with adequate resistance to heavy loads. It is mounted above the main leaf spring. The helper spring is cambered while the main spring is of flat type.

Figure : Helper spring

The helper spring performs no functions until the main spring is loaded beyond the flat stage(i.e. it acquires negative camber). When the vehicle is lightly loaded, the load is shared by mainspring only. But in case of heavy load, the helper spring comes into operation and shares the load on the vehicle. In that case, the upward deflection of the main spring is transfers load to the helper spring. The combination of helper spring and main spring is known as progressive spring.

THREE QUARTER( FULL ELLIPTIC TYPE) LEAF SPRING

The three quarter elliptical spring is clamped to the axle in the usual manner. One end is bolted to the frame, the other being rigidly held by spring clips to the frame. A spring shackleholds the two members of the spring together, allowing enough movement to compensate for theelongation of the main leaves when the spring is compressed. The full elliptical spring is attachedrigidly to both : the axle and the frame in usual manner. Spring shackles are not necessary, since bothtop and bottom members will elongate by the same amount when compressed

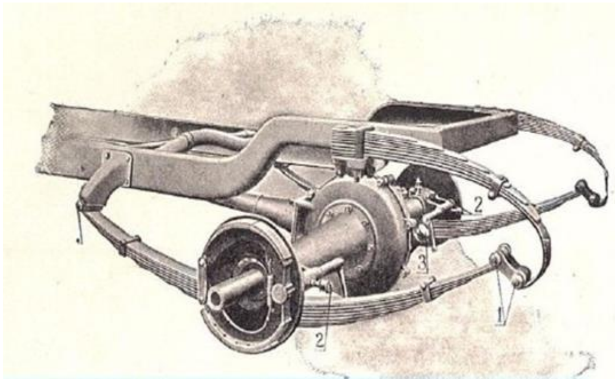


Figure: Three quarter, full elliptic type leaf spring

MATERIALS FOR LEAF SPRING

Materials for leaf spring are not as good as that for the helical spring. Plain carbon steel, Chromium vanadium steel, Chromium- Nickel- Molybdenum steel, Silicon- manganese steel, are the typical materials that are used in the design of leaf springs

LEAF SPRINGS MANUFACTURING PROCESS

With years of experience in the industry, Leafsprings.co.uk has gained the much required proficiency to guide you in your selection of the appropriate leaf springs for your vehicle. No matter, whether you want leaf springs for heavy or light goods vehicles, Trucks, Locomotives, Lorry and Bus leaf springs, Vintage car leaf springs or Farm trailer

Leaf springs, you will find it all at Leafsprings.co.uk, at quite affordable prices.

MANUFACTURING PROCESS OF LEAF SPRINGS

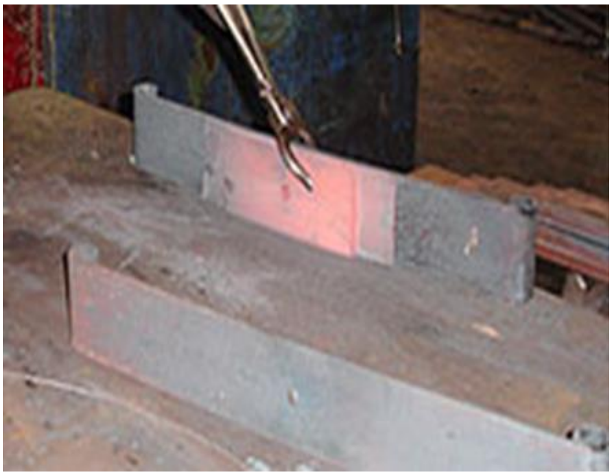


Figure: manufacturing process heating

Step-1: By identifying your specific requirements, our sales department firstly picks up the appropriate specification sheet, which is then issued to the production team to proceed with the manufacturing process. We give a unique reference number to each specification sheet so that we can track the process all through the working life cycle of sundry item or spring.

Figure: Shaping

Step – 2: Spring steel to BS970 is then cut off along the length and made to go through required operations incorporating eye-forming, nibbing, beating, taper-rolling and wrapping. Then, the leaves are heated up at temperature 1000 to 1, 0500 C, oil quenched in order to provide the temperature 8900C, or above. Once the draining is done, they are re heated at about 500 to 5600C so as to obtain the Brinell solidity reading of 356 to 440 HBS 10/3000, before the closing alterations are made to give adequate arc and shape.

Figure: manufacturing process

Step – 3: When assembling the entire unit, the required components including center bolts, clips and bushes are added. The final unit manufactured is again evaluated against the specifications given in specs sheet. To complete the spring, it is coated with a protective covering, and then goes through final inspection according to quality control standards

Figure: Assembly

Step – 4: The Locomotive Springs also implement the similar manufacturing course, but are made according to BR 148 and BR 166.

SPRINGS TERMS

- Axis: It is a straight line that traverses the central point of any object.
- Active Coil: It is a coil in the coil-spring that deflects or moves under load
- Beam Spring: A simple type of spring that is made of a flat, smaller metal piece and is mainly put into use in several automotive applications including suspension system. It is sometimes also known as leaf springs or flat springs.

- Buckling: It is a kind of damage to coil-compression spring in which the unit is distorted permanently after attaining rock-hard compression on account of working under heavier loads than it is able to hold out. Buckling actually appears just like side ¬-ways deflection.
- Clash Allowance: This term refers to the amount of room available between the unit's solidity height under maximum loads and solid-compression height. Coil-compression springs are usually designed with ten percent difference between solid compression and maximum load-height to evade coil clash.
- Chassis: It actually refers to the framing of equipment, such as clothes or car washer.
- Deflection: It is the degree of adjustments in shape on the application of the force. Springs turn aside and alter their shape so as to take up forces.
- Dampen: Dampen means lessening the application of force. Spring units in auto suspension systems damp forces when vehicle runs into road bumps.
- End Coils: These are end coils in coil spring units that are utilized to fasten springs to machine. They can also be squared to increase the strength.
- Flat Spring: It is a simple spring unit made of flat, small piece of metal, and is utilized in automotive applications. Flat spring is also called leaf springs and beam springs.
- Foot pounds: It is basically a torque measuring unit, used in the English system.
- Free Length: It is a variable required when placing order for springs, and represents the length of spring under no-load.
- Inch Pounds: It is also a unit that is employed to gauge torque.
- Kinetic Energy: The energy which is in motion is usually called kinetic energy. In relation to springs, it is the energy which the spring discharges when coming back to original shape, upon deflection.
- Load/Load rate: The force which is applied to any structure or material is called load. Springs take up and release energy from load. The rate at which force is applied to a module is called load rate.
- Mechanical device: This is the device that works by producing motion and force. Springs are considered mechanical devices as they exert and react to a motion and force.
- Mechanical system: It refers to the grouping of many components working together so as to do useful work. Leaf springs are often employed in 'mechanical systems' for storing energy or humidifying forces.
- Multi Leaf Springs: These springs are made by grouping several metal pieces. They can humidify friction, but are able to accept force in one-direction only.
- Overload stop: It is basically a circumstance in which end-coils of compression spring stop supporting machine because the unit is overloaded and cannot operate. Overload stop is an imperative safety measure because it can evade machine damage and injury.
- Pre-loading: The method utilized by manufacturers to improve the operating abilities of coil springs is called preloading. It incorporates creating a relatively longer spring and applying a certain amount of force before being delivered to customers.
- Set: It is a kind of permanent distortion and occurs when springs are subjected to unacceptable high-load conditions. A compression spring must not experience more than 2% set.
- Shear strength: It refers to the ability of a material to stop forces that try to make it deformed permanently. Too much sheer twist can even cause the spring to break down.
- Shearing: The damages that occur when springs break due to the application of heavy loads causing upright strain or excess transverse are called shearing.
- Shock Load: This load characterizes a huge amount of load and extreme speed.
- Shot Peening: It is a method utilized by spring manufacturers to augment the capabilities of metal employed in the components. In this procedure, the metal surfaces are blasted, which ultimately boosts the material's capability to withstand many kinds of damages.

- Spring: It is a device employed to moisten and apply load, store energy, and control vibration and motion.
- Spring Rate: It can be defined as the amount of load required to condense a spring.

INSTALLING LEAF SPRINGS

Leaf springs are positioned behind the wheel -- you can't see them clearly when they're attached unless you crawl under the trailer -- so the wheel needs to be taken off completely before installation begins. Once the wheel is off, you should notice a pair of hangers on either side of the axle. The hangars are usually small, extended pieces of metal with holes that hang down from the frame of the trailer. Between the holes of these hangers is where you line up the eyes of a leaf spring, securing them with the proper hardware. If the leaf spring is a double-eye, one hanger will have a shackle link. Once the leaf springs are bolted into the hangers, the next step is to install a pair of U-bolts, two horse shoe shaped metal rods.

The leaf springs can be over lung (placed over the axle) or under lung (placed under the axle). Either way, the U-bolts fit around the axle and secure to a metal plate that rests against the leaf springs. The purpose of the U-bolts is to keep the leaf springs flush against the axle so they take the weight of the cargo and don't move around too much during driving. It's always important to check leaf springs and their accessories for wear -- a worn or cracked leaf spring can cause untold damage to a trailer and its contents. When taking leaf springs off, it's a good idea to check the shackle links for wear.

A round ring of wear that matches the shape of the nut is OK, but once the shape becomes an oval, it's time to replace the shackle link. Proper care of leaf springs will ensure a safe ride while towing by keeping the trailer's wheels on the ground and its cargo in place

SOURCING OF RAW MATERIAL

An important Factor for Leaf Spring Manufacture Raw material :

The basic requirement for spring steel is that it should have sufficient hardening ability relative to leaf thickness to ensure a fully martensitic structure throughout the entire cross section of the leaf spring. Leaf springs are made of various fine grade alloy steel. The most commonly used grades of spring steel are 55 Si 7, 60 Si Cr 7, 50 Cr V4. We at UAW manufacture springs using EN 45A, 55 Si 7, 60 Si 7, 65 Si 7, 55 Si Cr 7, 60 Si Cr 7 & 65 Si Cr 7 grades of steel, however we offer other grades based on customer requirement. The spring steel flats should be reasonably straight and straightness to the extent of 2 mm per meter length is allowed.

The flats should be free of defects like Piping, Seams, Edge Cracks, End Kinks, Rust pitting and other Rolling Defects. Flats shall usually be with round edges. The edges shall be rolled convex with the radius of curvature of the edge approximately equal to the thickness of the flat or as agreed between the purchaser and supplier. Different cross sections of steel are used for the manufacture of leaf springs depending on the design.

Composite Leaf Springs:

Composite leaf springs are a fairly new product in racing that have been further refined recently. They're made of fiberglass instead of steel. The mounting portions are composed of steel that is bolted to the fiberglass leaf. These leaves come in various rates and, with the lower rates, may need additional coil springs to support the weight of the car.

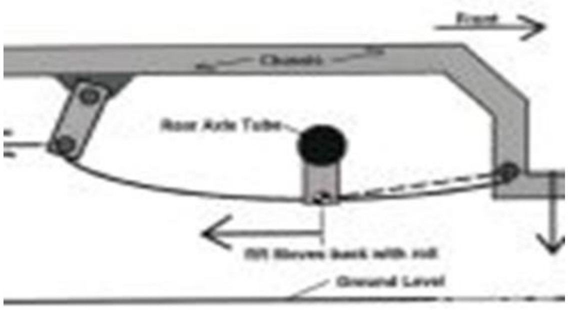



Figure: composite leaf spring Epoxy

The most widely used polymer matrix for carbon fibers is epoxy. The material is common in high performance continuous fiber composites. According to their use in different environments depending on temperature and moisture variations epoxy has classify into two categories, which are used in. those that are cured at lower temperature (120°C) and used in components exposed to low or moderate temperature variations, e.g. sports equipment, and those that are cured at higher temperature (175°C). And the other are used in high performance components and are exposed to high temperature and moisture variations.

The curing process involves by addition of hardener and an accelerator, and the temperature ranges are between 600C and 180°C. Epoxy has the combination of mechanical properties like, corrosion resistance, dimensionally stable, exhibits good adhesion and relatively inexpensive that gives the composite material good properties. When compared epoxy with polyester mechanical properties and water resistance of epoxy is superior, and the shrinkage property of polyester is minimum during curing.

There are several types of epoxy, and commonly epoxy for many commercial composite matrix systems are DGEBA (diglycidyl ether of Bisphenol A) and TGMDA (tetraglycidyl methylene dianiline) also known as TGGDM (tetraglycidyl-4,4”-diaminodiphenymethane). Their uses are common within aerospace applications. DGEBA is the most widely used epoxy type, which is often used for filament winding and pultrusion because it is found as a liquid at several viscosities, and can be either a solid or a liquid. TGMDA is the base resin used in a majority of the commercial epoxy matrix systems. It has high strength, high rigidity and elevated temperature resistance. It is also available in a variety of viscosity, and is sold commercially as MY-720 and MY-721. In adhesive systems, where toughness is an important factor, mix suppliers DBEBA and TGMDA to help provide more flexibility in the cured adhesive.

Basically epoxies are added to provide viscosity control, improve high-temperature properties, lower moisture absorption and improve toughness. Epon, Epi-rez, D.E.R., Epotuf and Araldite are all trade names of epoxy

About Pro/E

Pro/Engineer was the system that introduced parametric 3D modeling to the market and turned it mainstream. Since the early days it has always had a reputation for being difficult to use. The complex user interface (UI) interaction model was never the easiest to use, and the process of building parametric models of any complexity was never much fun. During the twenty years that the system has been around, the world has changed and parametric modeling has become a whole lot easier or, more accurately, less strict in its requirements.

Since the initial release of Pro/Engineer Wildfire back in 2001, PTC has been working on modernizing the software and presenting a less restrictive way of working. The introduction of the dashboard-driven command control made life much easier and presented the command options in a logical manner directly on screen. In the subsequent releases this has been extended deeper and deeper into the application, so now the vast majority of modules and areas within the system are now using the same user interaction methods. During this transition period some commands were still controlled by the menu manager, which seemingly popped up at random.

New pervasive fuzzy search which uses ProductView-based dynamic thumbnails to help make finding data much easier. This is then backed up with tools to make loading large datasets more efficient

For the Wildfire 5.0 release, this transition continues, but the real bulk of UI work is in other areas. For example, the software now uses ProductView technology to give 3D previews that users can interact with and inspect, prior to opening the data in full. There are pervasive fuzzy search tools for quickly locating parts and, depending on the type of data management method deployed (file system, ProductPoint or Wind-chill Interlink) it searches not only file or part name, but a larger range of metadata and part attributes. This makes finding data much easier.

In terms of user experience the big news for this release is Dynamic Feature Editing. This dramatically reduces the time taken to edit feature-based models by removing much of the recalculation time. It should be made clear that this is an acceleration of the time taken to recalculate a model's history tree, and not a history-less approach that is being introduced into other systems. This, we have been told, is coming in Wildfire 6.0.

The big news for this release is Dynamic Feature Editing which dramatically reduces the time taken to edit feature-based models by removing much of the recalculation time

In use, Dynamic Feature Editing enables users to grab the feature entity either from the right mouse button menu or the model tree. The sketch can then be edited and as it is dragged it into its new position, the system recalculates the history that follows on from it in real-time. Using the phrase 'real-time' may be a little misleading because no matter how quick the workstation is, editing an early stage feature in a typical complex part always means a lag. However, it should only take a matter of seconds, rather than the minutes typically required for standard model regeneration.

When using Dynamic Feature Editing, because the system maintains the history, there's the distinct possibility that the parameters and inter feature links that add the intelligence to the part may be broken. This is where another key new capability comes in. It's now possible to break the history within a part, flag up the 'broken' features and defer the updates, rather than having to deal with them there and then. This should make life much easier when making dramatic changes to the structure of both parts and inter-linked assemblies.

Another update is the change made to the reuse of User Defined Features (UDF). While the definition stage hasn't changed, the placement of UDFs has. When starting to place new standardized features, a wireframe preview is shown on screen. This means the initial placement can be seen and all of the placement requirements and inputs are clearly shown as the users locates the feature and adapts it to the new use case.

The system also takes advantage of the new co-ordinate system on surface tools that allows users to place a co-ordinate system onto any surface and then constrain it using drag handles. When used in the context of UDFs, it's very powerful as the user simply matches up co-ordinate systems. Now, let's move onto the fun stuff, that of the new modeling tools.

## II. METHODOLOGY

The vehicles must have a good suspension system that can deliver a good ride and good human comfortsuspension system separate the axle from the vehicle chassis, so that any road irregularities are not transmitted directly to the driver and the load on the vehicle. This is not only allows a more comfortable ride, and protection of the load from possible damage, but it also helps to prevent distortion and damage to the chassis frame.

### Modeling of leaf spring

Modelling and numerical simulation are essential aspects of today's automotive sector. They are necessary in order to reduce the time-to-market for new products and the costs associated with experimental testing. A good modeling and simulation in design and analysis give many benefits such as: minimizing product manufacturing time, material scrap and material cost. In vehicle structure design, the automotive sector has been undertaking structural analyses (static, dynamic, safety, noise and vibration, handling, etc.) for many years. Gradually, the precision and accuracy of models increase in its quality, but until now except metals and a few polymer components composite materials does not involved. The polymer components, in the majority of cases, have only been modelled as isotropic materials.

However, as the use of structural composite materials in the automotive sector increased, it has now become necessary to model composites more rigorously.

It is also desirable to integrate design and analysis processes to verify a product's performance in relation to its manufacturing and vice versa. Light weighting is one of the major drivers for the use of composites in the automotive industry. However, the benefits of light weighting are different for different categories of vehicle. Light weighting in trucks allows for payload increases whilst maintaining the same overall mass. In mass production vehicles, the most important driver for light weighting is the reduction of fuel consumption and the associated reduction of CO2 and other emissions in order to reduce environmental hazards

2D sketching and 3D Modeling of Leaf Spring

The 3D Modeling is a geometrical representation of a real object without losing information which the real object has. Various mechanical design and manufacturing operations modeled using CREO. This software allows the user to make changes very easily without having to go to back at the beginning and update all the drawings and assemblies. Generally CREO is easy to use and feature based parametric solid modeling software with many extended design and manufacturing applications.

In this specific research, based on the dimension obtained from theoretical calculation and direct measuring data 3D modeling and 2D sketching of the leaf spring was created with the help of CATIAV5 R19 solid modeling software and analysis is done by using ANSYS 16 workbench for stress and deflection.

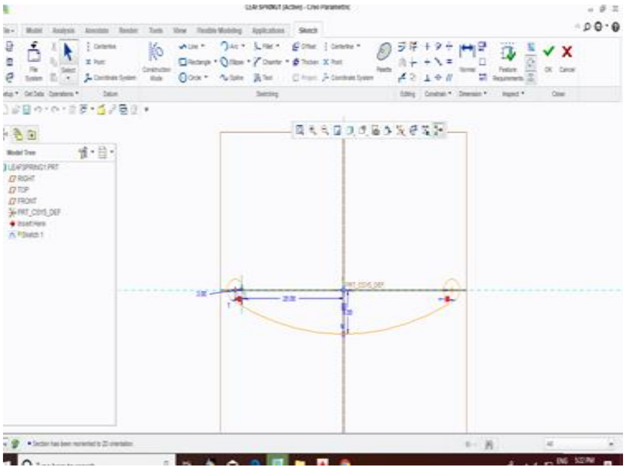


Figure: 2D sketch of mono leaf spring

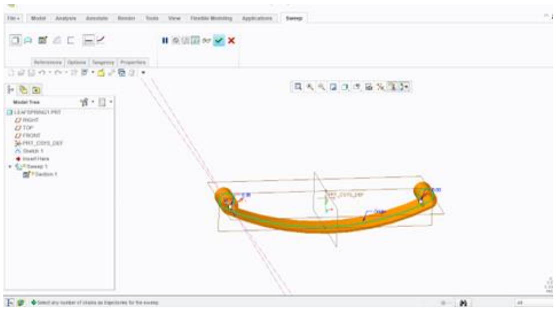


Figure: 3D modeling of mono leaf spring

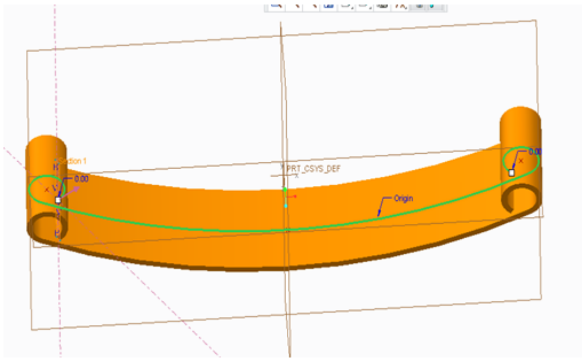


Figure: 3D modeling of mono leaf spring

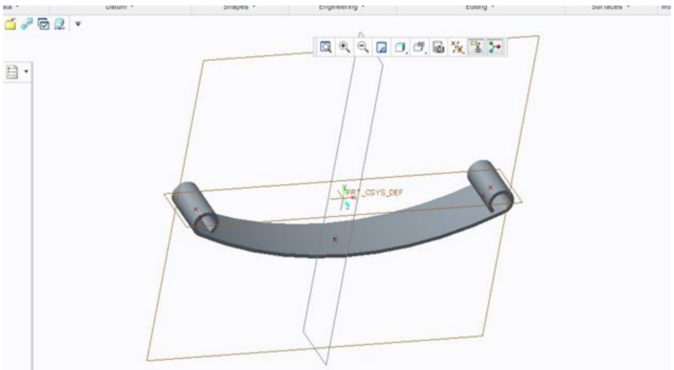


Figure: mono leaf spring Isometric view

Weight Calculations

From the mass, density and volume relation the weight of the leaf spring can be calculated as: Density = $mass/\ volume$

ρ = $M$/V

$M = \rho \times$ V

$W = M \times g$, $where$: $M = \rho \times$ V

Therefore, $W = \rho \times V \times$ g

Density of structural steel = 7.85 gm/cm3 and

Take acceleration due to gravity (g) = 10 m/s2

Now weight of the master leaf (W1) = ρ× $V1 \times$ g

V1 = $L1 \times t \times$ w

For carbon/epoxy composite material

For the carbon/epoxy composite leaf spring design, dimension of carbon/epoxy leaf spring is the same to that of the current steel leaf spring except the diameter of the eye. This is because, to differentiate the advantages and disadvantages of the two leaf spring materials and to know the best features of the materials. But some dimensions are selected from the standard size of automobile suspension springs tables

Following are the standard sizes for the automobile suspension springs

a. Standard nominal widths are: 32, 40*, 45, 50*, 55, 610*, 65, 70*, 75, 80, 90, 100 and 125 mm. (Dimensions marked* are the preferred widths)

b. Standard nominal thicknesses are: 3.2, 4.5, 5, 6, 6.5, 7, 7.5, 8, 9, 10, 11, 12, 14 and 16 mm.

c. At the eye, the following bore diameters are recommended: 19, 20, 22, 23, 25, 27, 28, 30, 32, 35, 38, 50 and 55 mm

The carbon/epoxy leaf spring is a mono leaf spring which have a uniform cross section. And the specification of the carbon/epoxy leaf spring becomes looks as below

Type of material = carbon/epoxy (Vf = 60% and Vm = 40%)

No. of leaves = 1

Length = 800 mm, this is because to minimize the extra buckling and deformation of the leaf spring, to with stand a heavy load without deformation and break during loading session

Width = 40 mm

Thickness = 24 mm,

Then according to the above specification the weight of the carbon/epoxy leaf spring becomes

$Wc = \rho c \times Vc \times$ g

=1.5 g /cm3 × 768 cm3 × 10 m/s

W = 11.52 N

Analysis of Leaf Spring Using ANSYS 16 Workbench

ANSYS is being used by designers across a broad spectrum of industries such as aerospace, automotive, manufacturing, nuclear, electronics, biomedical, and many more. ANSYS provides simulation solutions that enable designers to simulate design performance directly on desktop. In this way, it provides fast, efficient and cost-effective product development from design concept stage to performance validation stage of the product development cycle. ANSYS package help to accelerate and streamline the product development process by helping designers to resolve issues related to structural deformation, heat transfer, fluid flow, electromagnetic effects, a combination of these phenomena acting together, and so on.

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces called elements. The software implements equations that govern the behavior of these elements and solves them all creating a comprehensive explanation of how the system acts as a whole. These results then can be displayed in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system that is too complex to Analyze manually. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations

Static structure analysis

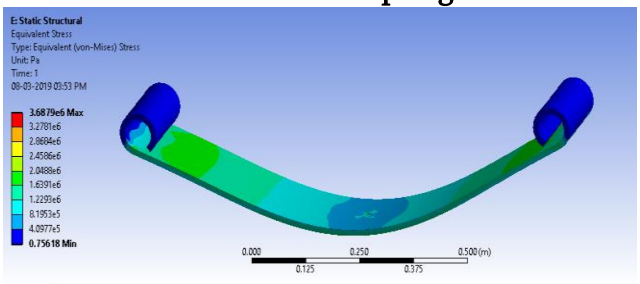
A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The types of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)

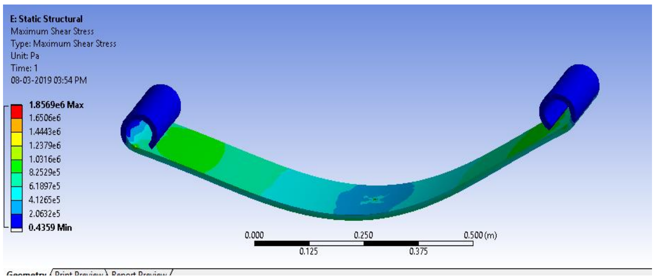
## III. RESULTS AND DISCUSSION

Static Structural Analysis:Figure: properties of carbon epoxy

### Results of Steel Mono Leaf spring




Von misses stress




shear stress

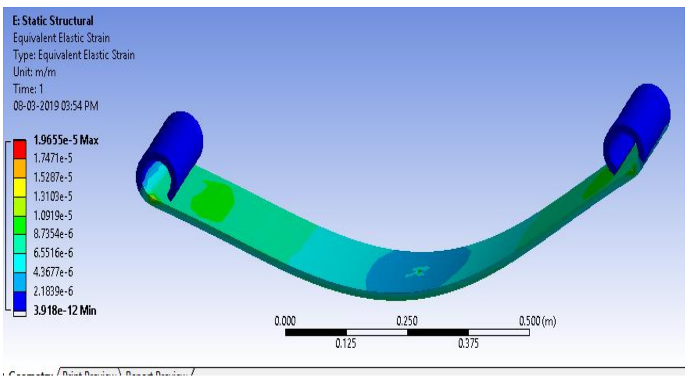



Figure: elastic strain

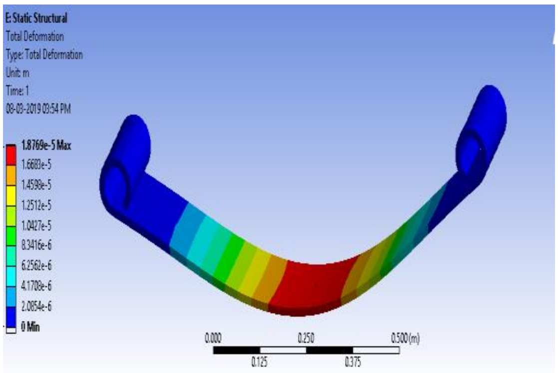



Figure : total deformation

Details of " MSBR"

| | |
|---|---|
| Thermal Strain Effects | Yes |
| + Bounding Box | |
| − Properties | |
| Volume | 3.3459e-003 m³ |
| Mass | 25.931 kg |
| Centroid X | 6.109e-010 m |
| Centroid Y | -8.036e-002 m |
| Centroid Z | 5.7264e-018 m |
| Moment of Inertia Ip1 | 0.1689 kg·m² |
| Moment of Inertia Ip2 | 3.6535 kg·m² |
| Moment of Inertia Ip3 | 3.6859 kg·m² |
| + Statistics | |

Figure: Mass properties

### Results of Carbon/epoxy composite Mono Leaf spring

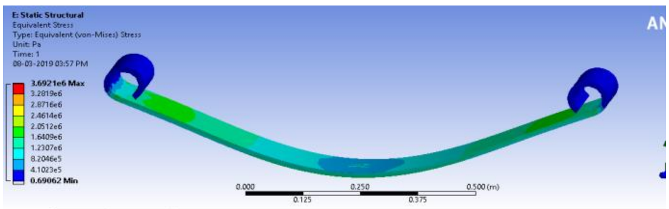



Figure: Von misses stress

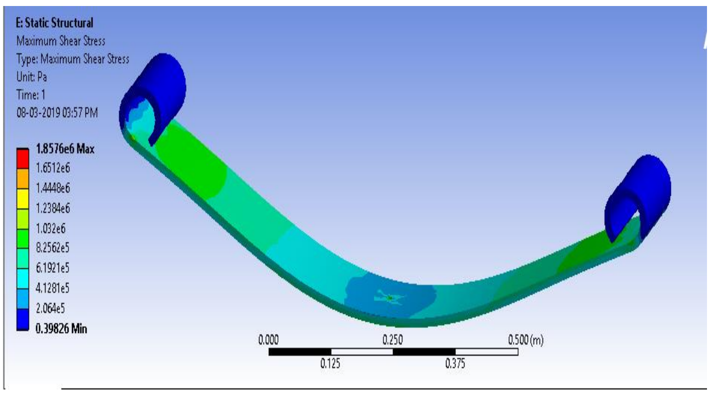


Figure: shear stress

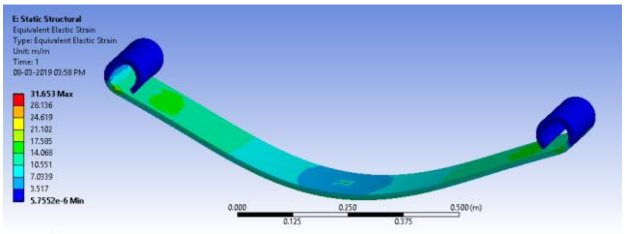


Figure: elastic strain

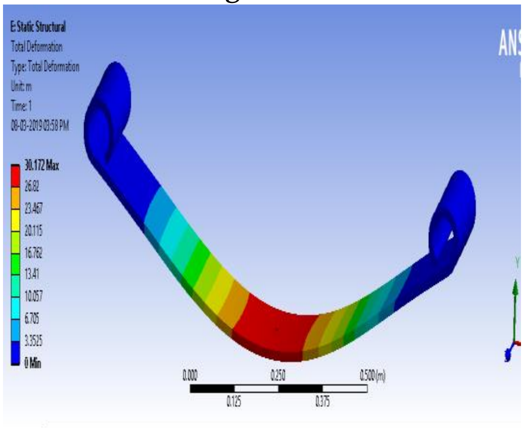


Figure: total deformation

| | |
|---|---|
| Thermal Strain Effects | Yes |
| Bounding Box | |
| Properties | |
| Volume | 3.3459e-003 $m^3$ |
| Mass | 5.3535 kg |
| Centroid X | 6.109e-010 m |
| Centroid Y | -8.036e-002 m |
| Centroid Z | 5.7264e-018 m |
| Moment of Inertia Ip1 | 3.4869e-002 $kg \cdot m^2$ |
| Moment of Inertia Ip2 | 0.75427 $kg \cdot m^2$ |
| Moment of Inertia Ip3 | 0.76097 $kg \cdot m^2$ |
| Statistics | |

Figure: Mass properties

## 4.2 Modal Analysis:

### 4.2.1 Results of Steel Mono Leaf spring

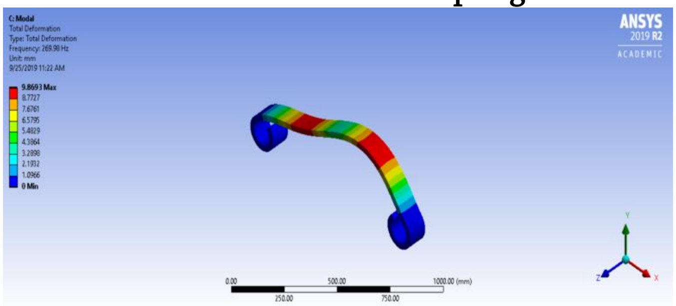


Figure: Natural frequency

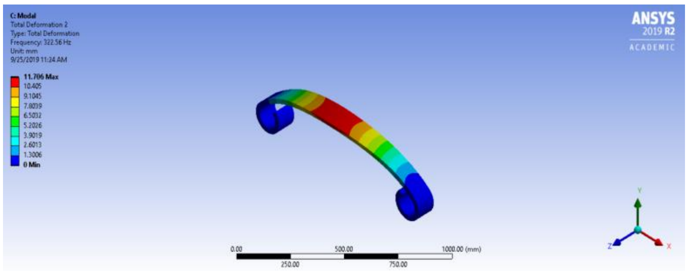


Figure: Natural frequency

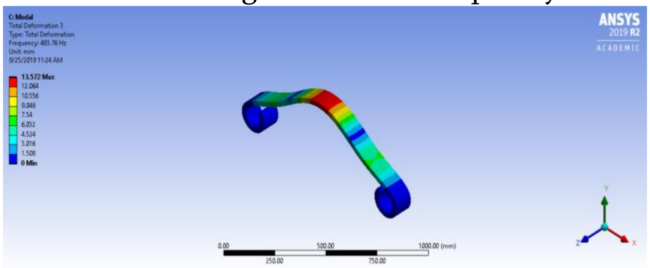


Figure: Natural frequency

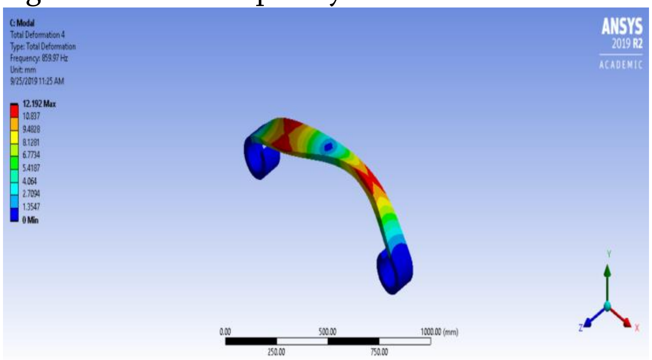


Figure: Natural frequency

**Properties of steel:**

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Property | Value | Unit | | |
| 2 | Material Field Variables | Table | | | |
| 3 | Density | 7850 | kg m^-3 | | |
| 4 | Isotropic Secant Coefficient of Thermal Expansion | | | | |
| 5 | Coefficient of Thermal Expansion | 1.2E-05 | C^-1 | | |
| 6 | Isotropic Elasticity | | | | |
| 7 | Derive from | Young's ... | | | |
| 8 | Young's Modulus | 2E+11 | Pa | | |
| 9 | Poisson's Ratio | 0.3 | | | |
| 10 | Bulk Modulus | 1.6667E+11 | Pa | | |
| 11 | Shear Modulus | 7.6923E+10 | Pa | | |

Figure: properties of steel

**Results of Steel Mono Leaf spring**

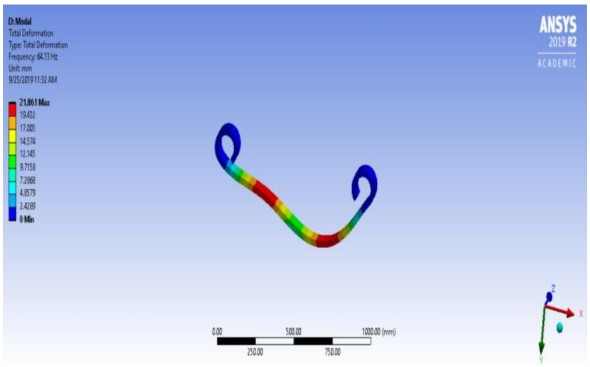


Figure: Natural frequency

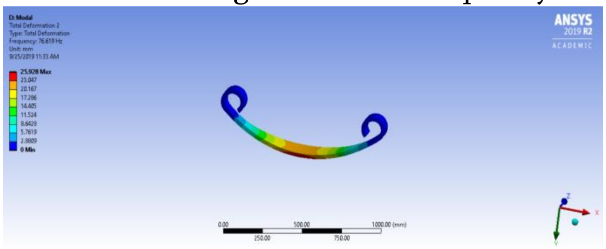


Figure: Natural frequency

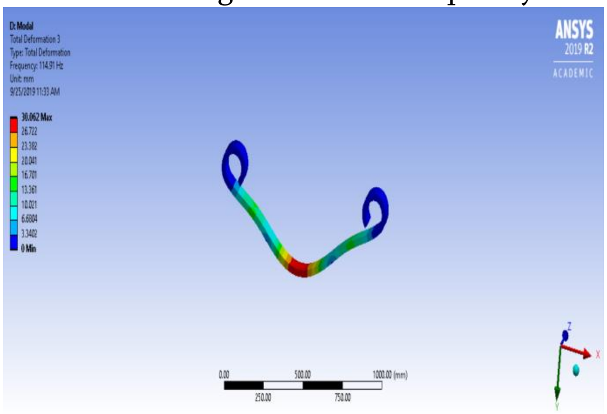


Figure: Natural frequency

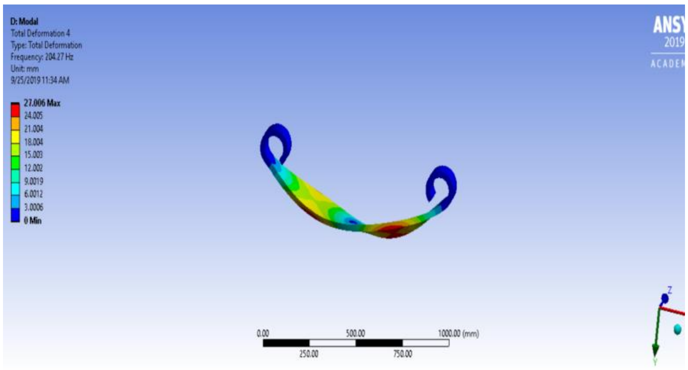


Figure: Natural frequency

**Properties of carbon epoxy material:**

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Property | Value | Unit | | |
| 2 | Material Field Variables | Table | | | |
| 3 | Density | 1.6 | g cm^-3 | | |
| 4 | Isotropic Elasticity | | | | |
| 5 | Derive from | Young's ... | | | |
| 6 | Young's Modulus | 2300 | MPa | | |
| 7 | Poisson's Ratio | 0.3 | | | |
| 8 | Bulk Modulus | 1.9167E+09 | Pa | | |
| 9 | Shear Modulus | 8.8462E+08 | Pa | | |

Figure: properties of carbon epoxy

**Comparison Results**

| Material | Von-misses stress (MPa) | Shear stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 3.6879 | 1.8569 | 25.931 |
| Carbon/epoxy | 3.6892 | 1.8573 | 5.3535 |

**Comparison plots For static structural:**

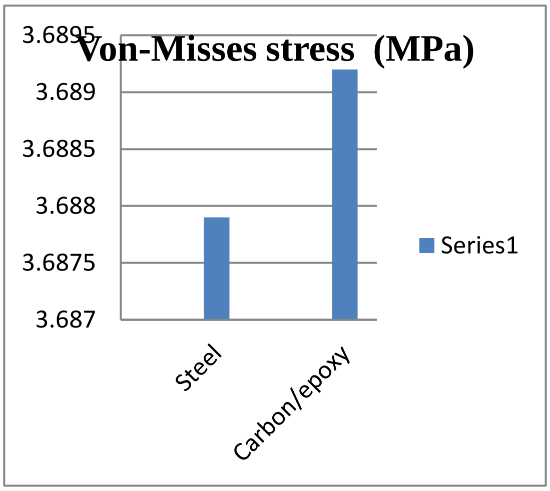



Figure: Comparison plot for Von-Misses stress

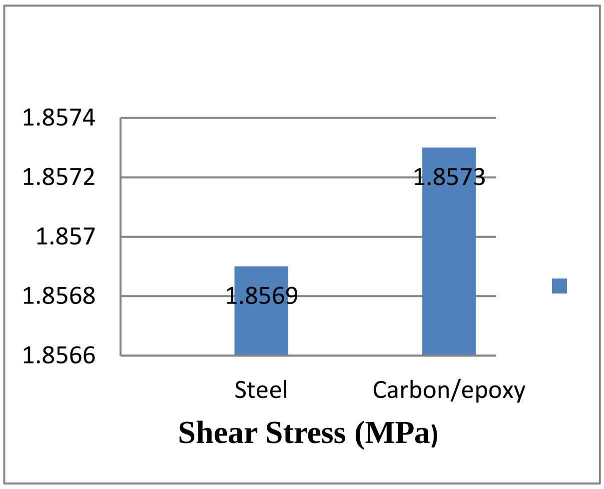



Figure: Comparison plot for shear stress

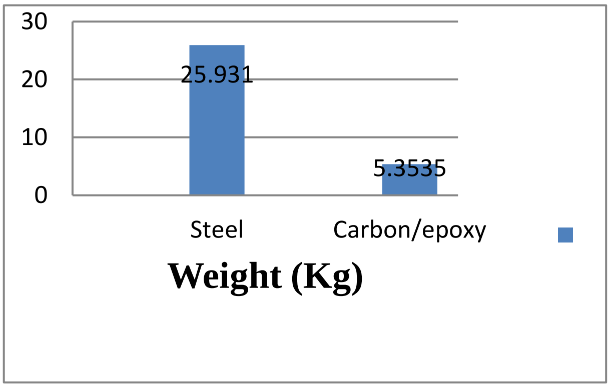



Figure: Comparison plot for Weight

From the above table comparing three materials steel and carbon epoxy materials are best suitable for mono leaf spring than the cast iron material. The steel and carbon epoxy material have almost same Von-misses stress and shear stress but when compare to the weight carbon epoxy almost 80% of weight is reduced. From the overall result for mono leaf spring the light weight carbon epoxy material is preferred

## Conclusion

As reducing weight and increasing strength of products are high research demands in the world, composite materials are getting to be up to the mark of satisfying these demands. In this project reducing weight of vehicles by 68.14% and increasing the strength of their spare parts is considered. A mono composite leaf spring for the vehicular suspension system was designed using E-Glass/Epoxy with the objective of minimizing weight of the leaf spring. And it is shown that the resulting design stresses are much below the strength properties of the material satisfying the maximum stress failure criterion. The deflection of the leaf spring along its transverse direction, which is very small compared to the considered maximum deflection.. This particular design is made specifically for the case study/Mahindra/light weight vehicles.

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