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DESIGN OPTIMIZATION AND STRESS ANALYSIS OF MONO LEAF SPRING USING METAL MATRIX COMPOSITE

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ABSTRACT:

Weight is an important and contributing factor in an automobile in improving riding qualities. About ten to twenty percent of the weight of the system is provided by the leaf spring alone. Composite materials have the major advantage of high strength to weight ratio, with continuously decreasing travel cost in addition to other advantages like excellent corrosive resistance, superior fatigue strength and high specific strain energy storage capacity. The present work aims to evaluate the usage of composite material for the leaf spring of automobiles in order to reduce the effective weight of the suspension system, by this it is expected to improve the riding qualities of the automobile. The present work describes the design, material selection performance of the composite leaf spring under static and dynamic conditions. Many reinforcement and matrix resin materials have been considered under material selection, before the combination of glass fiber and epoxy in a symmetrically laminated composite was finally selected. A composite mono-leaf spring weighing about 3kgs is used to replace a steel leaf spring whose weight is about '12Kgs. The present study also aims to compare the performance of the composite leaf spring with that of the conventional steel leaf spring and to suggest the suitability of using composite materials in automobile industry. In this approach static and dynamic analysis were conduct. With the help of ANSYS 16 analysis software. The performance results are compared with steel leaf spring. Finally it is concluded that the composite leaf spring, which is 70, less in weight, is performing better than conventional steel leaf spring. It allows the traveler running leaf springs to be consistent night after night without having to constantly measure, monitor a. change their springs for loss of sagging. The initial cost is a value based on the incredible service life.

***Keywords*—ANSYS, CATIA**

I. INTRODUCTION

Originally called laminated or carriage spring, a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of springing, dating back to medieval times.

The advantage of leaf spring over helical spring is that the end of the springs may be guided along a definite path. Sometimes referred to as a semi-elliptical spring or cart spring, it takes the form of a slender arc-shaped length of spring steel of rectangular

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cross-section. The center of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in stiction in the motion of the suspension. For this reason manufacturers have experimented with mono-leaf springs. A leaf spring can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm. The shackle takes up the tendency of the leaf spring to elongate when compressed and thus makes for softer springiness. Some springs terminated in a concave end, called a spoon end (seldom used now), to carry a swivelling member.There were a variety of leaf springs, usually employing the word "elliptical". "Elliptical" or "full elliptical" leaf springs referred to two circular arcs linked at their tips. This was joined to the frame at the top center of the upper arc, the bottom center was joined to the "live" suspension components, such as a solid front axle. Additional suspension components, such as trailing arms, would be needed for this design, but not for "semi-elliptical" leaf springs as used in the Hotchkiss drive. That employed the lower arc, hence its name. "Quarter-elliptic" springs often had the thickest part of the stack of leaves stuck into the rear end of the side pieces of a short ladder frame, with the free end attached to the differential, as in the Austin Seven of the 1920s. As an example of non-elliptic leaf springs, the Ford Model T had multiple leaf springs over its differential that was curved in the shape of a yoke. As a substitute for dampers (shock absorbers), some manufacturers laid non-metallic sheets in between the metal leaves, such as wood. Leaf springs were very common on automobiles, right up to the 1970s in Europe and Japan and late 70's in America when the move to front wheel drive, and more sophisticated suspension designs saw automobile manufacturers use coil springs instead. Today leaf springs are still used in heavy commercial vehicles such as vans and trucks, SUVs, and railway carriages. For heavy vehicles, they have the advantage of spreading the load more widely over the vehicle's chassis, whereas coil springs transfer it to a single point. Unlike coil springs, leaf springs also locate the rear axle, eliminating the need for trailing arms and a Pan hard rod, thereby saving cost and weight in a simple live axle rear suspension. A more modern implementation is the parabolic leaf spring. This design is characterised by fewer leaves whose thickness varies from centre to ends following a parabolic curve. In this design, inter-leaf friction is unwanted, and therefore there is only contact between the springs at the ends and at the centre where the axle is Syambabu Nutalapati connected. Spacers prevent contact at other points. Aside from a weight saving, the main advantage of parabolic springs is their greater flexibility,

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which translates into vehicle ride quality that approaches that of coil springs. There is a trade-off in the form of reduced load carrying capability, however. The characteristic of parabolic springs is better riding comfort and not as "stiff" as conventional "multi-leaf springs". It is widely used on buses for better comfort. A further development by the British GKN company and by Chevrolet with the Corvette amongst others, is the move to composite plastic leaf springs.Typically when used in automobile suspension the leaf both supports an axle and locates/ partially locates the axle. This can lead to handling issues (such as 'axle tramp'), as the flexible nature of the spring makes precise control of the unsprung mass of the axle difficult. Some suspension designs which use leaf springs do not use the leaf to locate the axle and do not have this drawback. The Fiat 128's rear suspension is an example.A leaf spring is a long, flat, thin, and flexible piece of spring steel or composite material that resists bending. The basic principles of leaf spring design and assembly are relatively simple, and leafs have been used in various capacities since medieval times. Most heavy duty vehicles today use two sets of leaf springs per solid axle, mounted perpendicularly to support the weight of the vehicle. This Hotchkiss system requires that each leaf set act as both a spring and a horizontally stable link. Because leaf sets lack rigidity, such a dual-role is only suited for applications where loadbearing capability is more important than precision in suspension response.

II. LITERATURE SURVEY

LEAF SPRING

Semi-elliptic leaf springs are almost universally used for suspension in light and heavy commercial vehicles. For cars also, these are widely used in rear suspension. The spring consists of a number of leaves called blades. The blades are varying in length. The blades are us usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaf spring is based upon the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf, the remainingblades are called graduated leaves. All the blades are bound together by means of steel straps. The spring is mounted on the axle of the vehicle. The entire vehicle load is rests on the leaf spring. The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link which connects between leaf spring rear eye and frame. When the vehicle comes across a projection on the road surface, the wheel moves up, this leads to deflecting the spring. This changes the length between the spring eyes.

SUSPENSION SYSTEM

The automobile chassis is mounted on the axles, not direct but some form of springs. This is done to isolate the vehicle body from the road shocks, which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame anybody. All the part,

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which performs the function of isolating the automobile from the road shocks, is collectively called a suspension system. It includes the springing device used and various mountings for the same. Broadly speaking, suspension system consists of a spring and a damper. The energy of road shock causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper which is more commonly called a shock absorber

OBJECTIVE OF THE SUSPENSION SYSTEM

To prevent the road shocks from being transmitted to the vehicle components. To safeguard the occupants from road shocks To preserve the stability of the vehicle in pitting or rolling, while in motion Basic consideration for vertical loading

When the rear wheel comes across a bump or pit on the road, it is subjected to vertical forces, tensile or compressive depending upon the nature of the road irregularity. These are absorbed by the elastic compression, shear, bending or twisting of the spring. The mode of spring resistance depends upon the type and material of the spring used. Further when the front wheel strikes a bump it starts vibrating. These vibrations die down exponentially due to damping present in the system. The rear wheel however, reaches the same bump after certain time depending on the wheel base and the speed of the vehicle. Of course, when the tear wheel reaches the bump, it experiences similar vibrations as experienced by the front wheel some time ago. It is seen that to reduce pitching tendency of the vehicle, the frequency of the front springing system be less than that of the rear springing system. From human comfort point also it is seen that it is desirable to have low vibration frequencies. The results of the studies of human beings have shown that the maximum amplitude which may be allowed for a certain level of discomfort decreases with the increase of vibration frequency.

Rolling:

The centre of gravity of the vehicle is considerably above the ground. Due to this reason, while taking a turn, the centrifugal force acts outwards on the C.G of the vehicle, while the road resistance acts inward at the wheels. This gives rise to a couple turning the vehicle about a longitudinal axis. This is called rolling. The manner in which the vehicle is sprung determines the axis about which the vehicle will roll. The tendency to roll is checked by means of a stabilizer.

Brake-dip

On braking, the noise of the vehicle has a tendency to be lowered or to dip. This depends upon the position of centre of gravity relative to the ground, the wheelbase, and other suspension. In the characteristics the same way, torque loads during acceleration end the front of the vehicle to be lifted. These forces on account of braking and driving are carried directly by deflecting the springs, by wishbone arms or by radius rods.

Side Thrust

Centrifugal force during cornering, cross-winds, cambering of the road etc, cause a side-thrust to be applied to the vehicle, such forces are usually absorbed by the rigidity of the leaf springs or by fitting pan hard rods.

Unsprung Weight:

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. When a small shock results in the large movements of the wheel, the suspension is said to be soft, such a soft suspension is more comfortable to the occupants. However, excessively soft suspension will result in the loss of braking efforts are decreased. Thus a good suspension system should be an optimum compromise between softness and hardness.

Types of Suspension systems

Plastic Suspension

Has developed a new type of suspension based upon the use of resilient plastic rings in compression. The suspension consists of a cylindrical container secured to the chassis, a shaft attached to the axle and free to slide within the plastic rings contained in the cylinder, there are two cantering rings, the bottom one fixed to the lower end of the cylinder and the upper one is arranged as high as possible keeping in consideration that in the rebound position shaft must remain supported by it by the plastic rings and absorb the vertical dynamic load.

Independent Suspension

When a vehicle with rigid axle suspension encounters road irregularities the axle tilts and the wheels no longer remain vertical. This causes the whole of the vehicle to tilt on one side. Such a state of affairs is not desirable. Apart from causing rough ride, it causes ‘wheel wobble’. The road adhesion is also decreased. To avoid this, the wheels are sprung independent of each other, so that tilting of one does not affect the other. Besides the independent suspension also have the following advantages over rigid able type suspension.

Front Wheel Independent Suspension

Independent suspension has become almost universal in the case of front axle, due to the simplicity of such a suspension system.

Rear Wheel Independent Suspension:

Though the rear wheels are not to be steered, yet there is a considerable difficulty in the rear wheel springing if the power has to be transmitted to the rear wheel. But even the rear wheel independent springing is coming into prominence because of its distinct advantages over the rigid axle type.

Wishbone type suspension:

The use of coil springs in the front axle suspension of car is now almost universal. It consists of upper and the lower wishbone arms pivoted to the frame member. The spring is placed in between the lower wishbone and the underside of the cross member. The vehicle weight is transmitted from the body and the cross member to the coil spring through which it goes to the lower wishbone member. A shock absorber is placed inside the coil spring and is attached to the cross member and the lower wishbone member. The wishbone type is the most popular independent suspension system

Mac Pherson Strut Type of Suspension:

In this layout only lower wishbone are used. A strut containing shock absorbing and the spring carriers also the stub axle on which the wheel is mounted. The wishbone is hinged to the cross member and positions the wheel as well as resists accelerating, braking and side forces. This system is simpler than double wishbone type described above and is also lighter, keeping the unsprung weight lower. This type of suspension gives the maximum room in the engine compartment and is, therefore commonly used on front wheel drive cars. In India this system has been used in Maruti (Suzuki) 800 cars. This type of suspension with anti-roll bar as employed in Volkswagen Jetta and Passat cars. This is claimed to provide increased road safety, improve ride comfort and light and self-stabilizing steering which means that car continues along its chosen line of travel when the brakes are applied even though the road surface may vary.

Vertical guide suspension

The king pin is attached directly to the cross member of the frame. It can slide up and down, corresponding to the up and down motions of the wheel, thus compressing or elongating the springs. In this the track, wheel base and wheel attitude remain unchanged, but the system is having disadvantages of decreased stability

Trailing Link Suspension

In this type of suspension, a coil spring is attached to the trailing link which itself is attached to the carrying the wheel hub. When the wheel moves up and down, it winds and unwinds the spring. A torsion bar has also been used in certain designs in place of the coil spring. The system does maintain the camber and the wheel track constant. However, the distance between the front and the rear wheels does change. Difficulty to remedy this defect is the main reason for its very limited use in actual practice.

Winging Half Axle Suspension

In this wheels are mounted rigidly on the half axles, which are pivoted on their ends to the chassis member at the middle of car. The main disadvantage of this system is that up and down movement of the wheel causes the camber angle to vary

Interconnected Suspension Systems:

In these systems, the front and rear suspension units or else the units on the two sides of the automobile are connected together. These are also called ‘linked system’. Te major advantage of such a system is that tendency of the vehicle to bounce, pitch or roll is reduced and a constant desirable attitude of suspension. The other systems in current use are the Hydro elastic suspension, the Daimler – Benz suspension and the Hydra gas suspension system.

Air Suspension

Air suspension systems are coming into prominence because of certain advantages they possess over the conventional metal springs. The advantages are: A vehicle space for wheel deflection is put to optimum use by virtue if the automatic control devices. Because of the vehicle is also constant, changes in headlamp alignment due to varying loads are avoided. The spring rare varies much less between the laden and unladen conditions, as compared with that of conventional steel springs. This reduces the dynamic loading.The improved standard for ride comfort and noise reduction with air springs reduces both driver and passenger fatigue.The four air springs, which may be either the bellows type or the piston type, are mounted in the same position where generally the coil springs are mounted. An air compressor takes the atmospheric air through a filter and compresses it to a pressure of 240 MPa, at which pressure of air in the accumulator tank is maintained, which is also provided with a safety relief. The high pressure air goes through lift control valve and the levelling valves, to the air springs. The control valve is operated manually by means of a handle on the control panel, through a cable running from the valve to the handle.

Hydro elastic Suspension

In this system a displacer unit is fitted at each of the four wheels. The displacer units are all interconnected by means of fluid. In the displacer unit, rubber (under compression and shear) is used as a spring where as fluid rubber pressure acts as damping medium. The stem is connected to the wheel through suitable linkage so that its movement is proportional to the up and down movement of the wheel. A two way valve assembly controls the up and down flow of the fluid. The upper valve opens when the fluid pressure below rises sufficiently.

III. MODELING

As the world's one of the supplier of software, specifically intended to support a totally Integrated product development process. Dassault Systems (DDS) in recognized as a strategic partner which can help a manufacturer to the turn a process into competitive advance, greater market share and higher profits and industrial and mechanical design to functional simulation manufacturing and information management. CATIA Mechanical design solution will improve our design productivity. CATIA is a suit of programs that are used in design, analysis and manufacturing of a virtually unlimited range of the product.

"Feature based" means that we create parts and assemblies by defining feature like extrusion sweeps, cuts, holes, round and so on instead of specifying low level geometry like lines, areas circles. This means that the designer can think of the computer model at a very high level and leave all low geometry detail for CATIA to figure out.

"Parametric" means that the physical shape of the part as assembly is driven by the value assigned to the attributes of its features. We may define or modify a feature dimension or other attributes at any times. Any changes will automatically propagate through the model.

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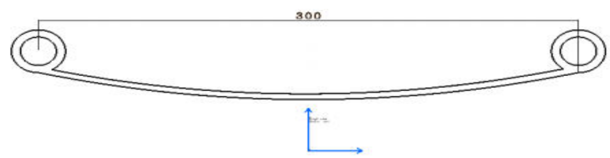
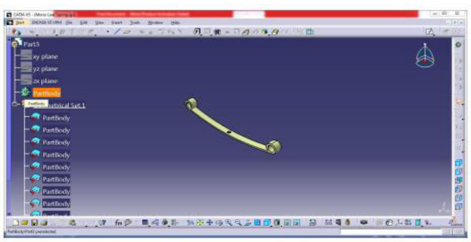
"Solid Modelling "means that the computer model we create is able to contain all the information that a real solid object would have. It has volumes and therefore, if you provide a value for the density of the material it has mass and inertia.

Bearing Base

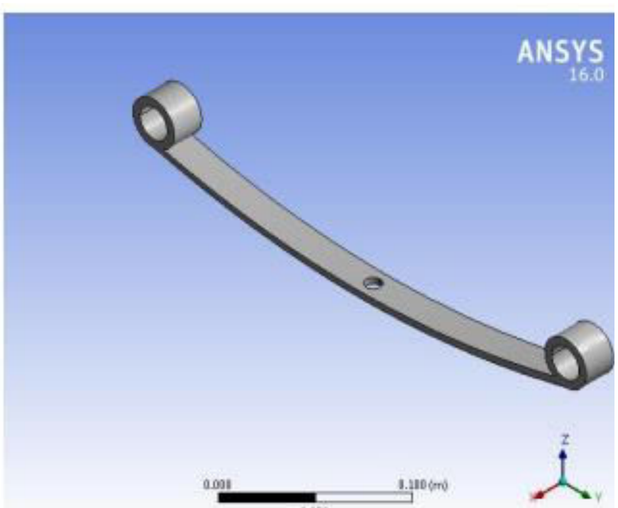


Roller

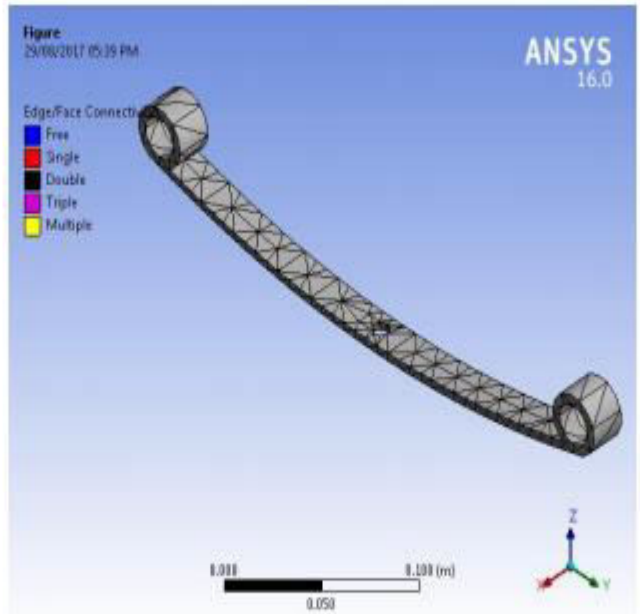


IV. RESULT AND ANALYSIS

3D CAD Model

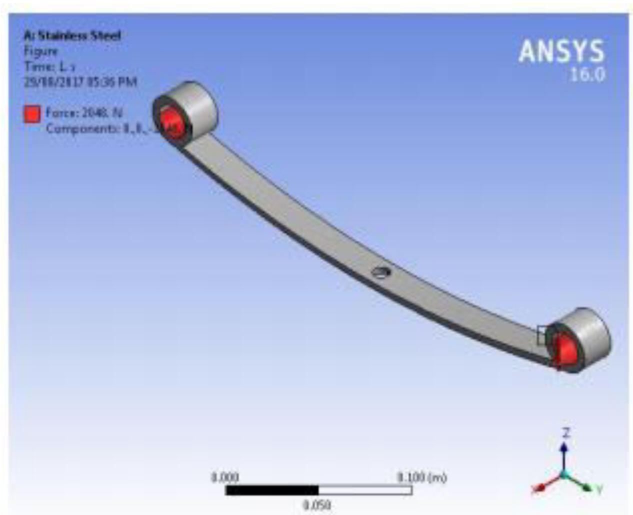


Mesh



Static Structural For Stainless Steel

LOAD



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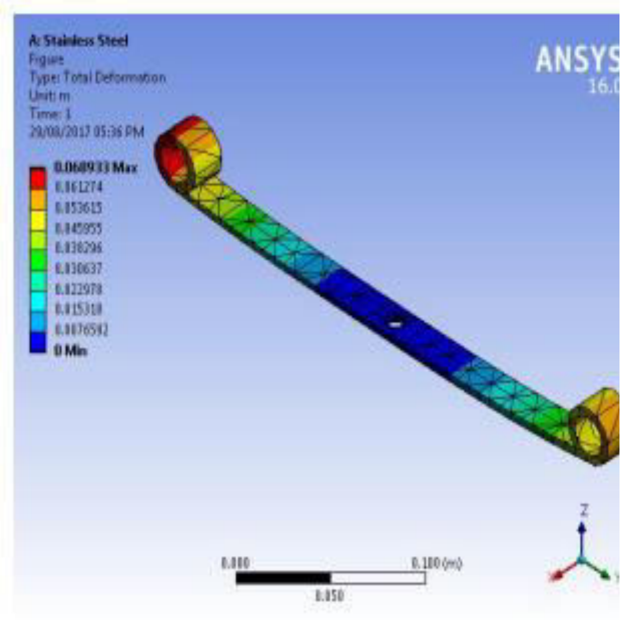
TOTAL TRANSFORMATION



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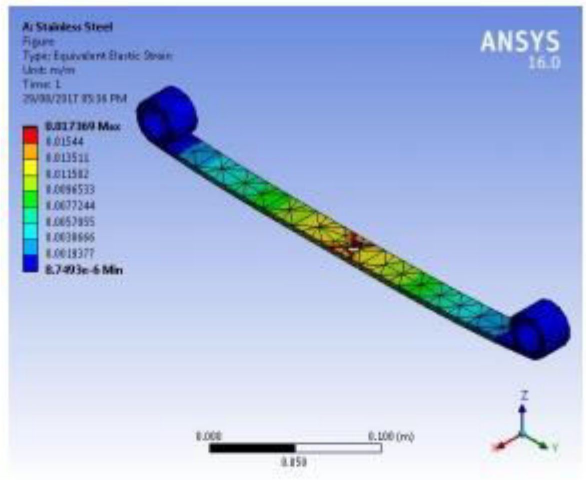
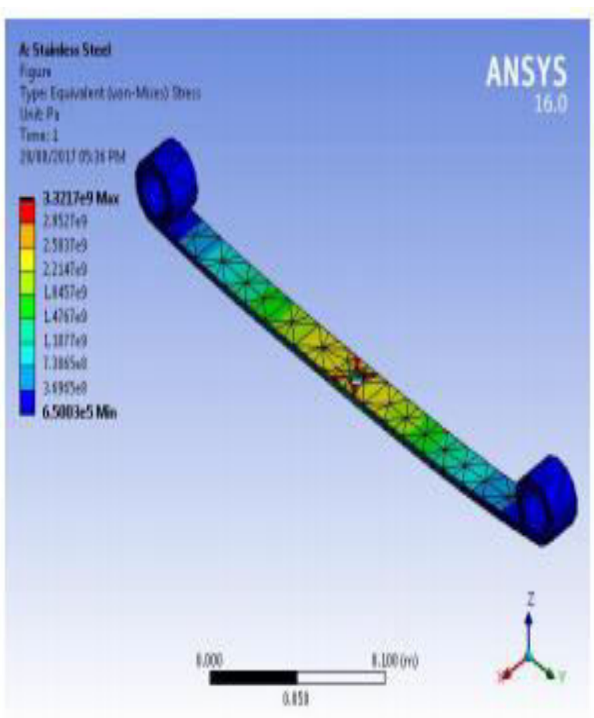
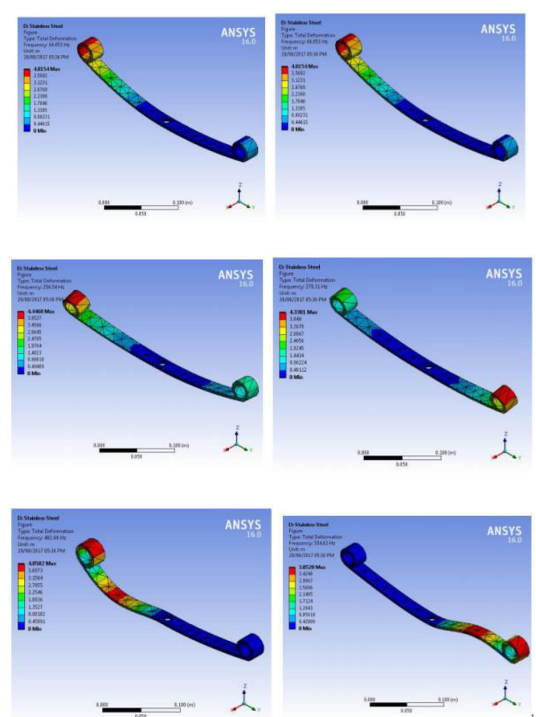


VON MISSES STRESS



DYNAMIC ANALYSIS FOR STAINLESS STEEL

TOTAL DEFFORMATION



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Static Structural For Epoxy Resin

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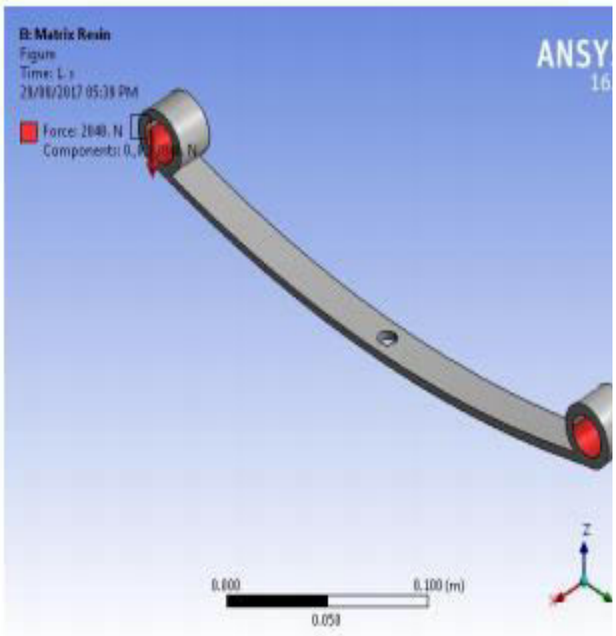

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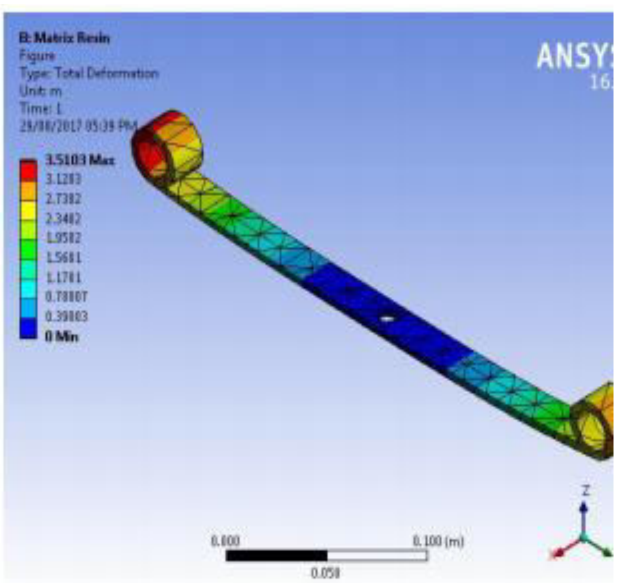

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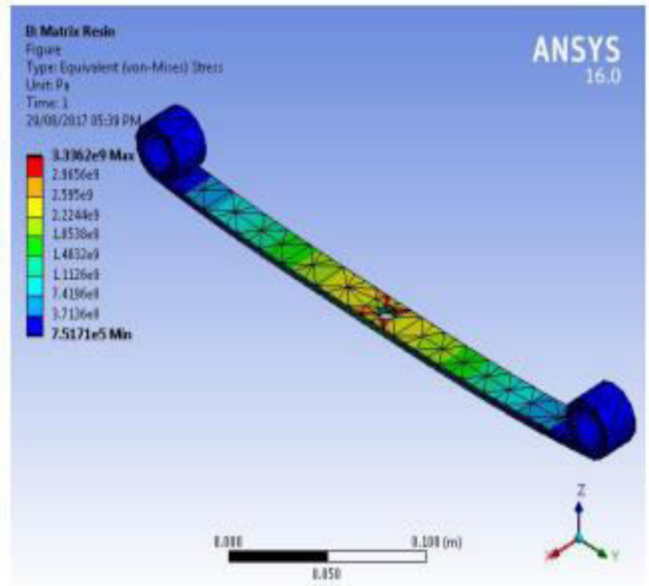

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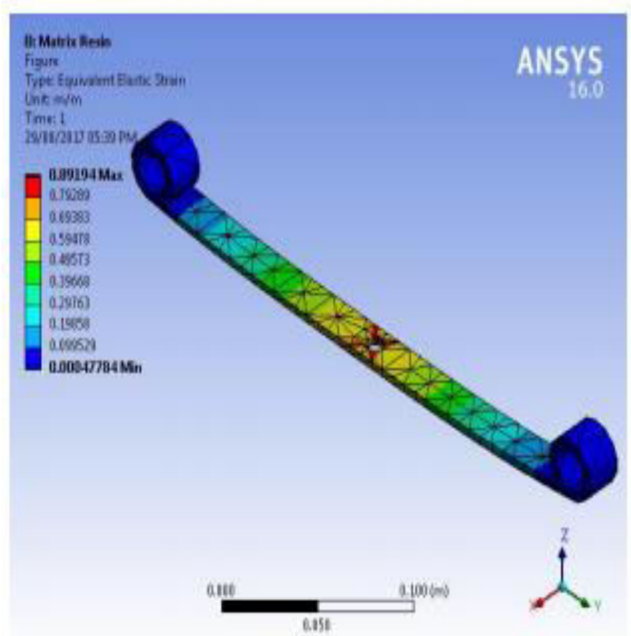

DYNAMIC ANALYSIS FOR STAINLESS STEEL

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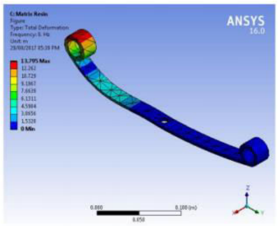
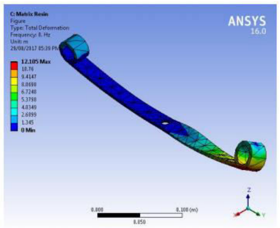
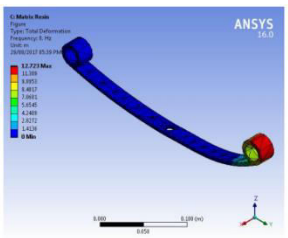
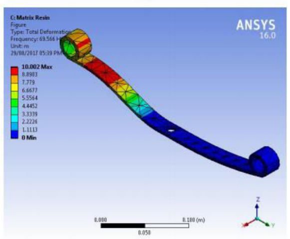
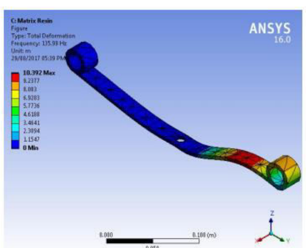
TOTAL DEFFORMATION

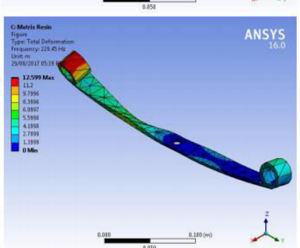








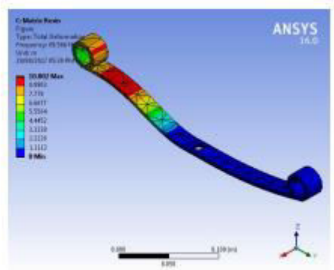


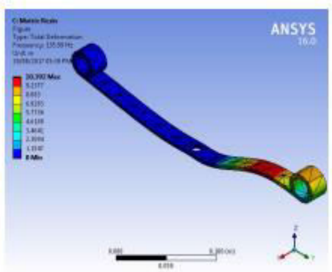


COMPARISON

Ansys Result Comparison

Material	Stress (Pa)	Deformation (m)
Stainless Steel	3.3217e9	0.068933
Epoxy Resin	3.3362e9	3.5103





Frequency and Deformation at mode 3 & 4

V. CONCLUSION

In this research we can conclude that with respect to conventional steel leaf spring composites having high strength to weight ration. Also composites having nearly 400% less weight than conventional steel leaf spring. And also from Modal analysis we can conclude that composite leaf spring is safe as its not showing resonance effect so it's safe in that manner.