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STRUCTURAL DESIGN AND ANALYSIS OF SUSPENSION SYSTEMS UTILIZING FEM METHODOLOGY

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Abstract: Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. Suspension systems serve a dual purpose contributing to the vehicles handling and breaking for good active safety and driving pleasure, and keeping occupants comfortable and reasonably well isolated from road noise and vibrations. The leaf spring suspension also protects vehicle itself and any cargo or luggage from damage and wear. In this project a leaf spring system is designed in Catia V5 tool and then finite element analysis is used to estimate the load that acts on the suspension and stresses and deflections in the suspension under the load is analyzed .These values vary as the boundary conditions of the tests are changed and are compared to a predetermined value from a reliable source. In analysis, the model is carried out in Ansys tool to determine the natural frequencies and corresponding node shapes. And load analysis is also performed to estimate the frequency response to see the stability of the suspension. A static analysis is also carried out to estimate the deflection and stresses due to working conditions .the design safety is ensured based on strength and rigidity.

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I- INTRODUCTION

Leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi-elliptical spring or cart spring, it is one of the oldest forms of springing, appearing on carriages in England after 1750 and from there migrating to France and Germany. A leaf spring takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. In the most common configuration, the center of the arc provides location for the axle, while loops formed at either end provide for attaching to the vehicle chassis. 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, some manufacturers have used 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 swiveling member.

The leaf spring has seen a modern development in cars. The new Volvo XC90 (from 2016 year model and forward) has a transverse leaf spring in high tech composite materials, a solution that is similar to the latest Chevrolet Corvette. This means a straight leaf spring that is tightly secured to the chassis and the ends of the spring bolted to the wheel suspension, to allow the spring to work independently on each wheel. This means the suspension is smaller, flatter and lighter than a traditional setup.

Leaf springs were very common on automobiles, right up to the 1970s in Europe and Japan and late 1970s 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 Panhard rod, thereby saving cost and weight in a simple live axle rear suspension. A further advantage of a leaf spring over a helical spring is that the end of the leaf spring may be guided along a definite path.

II - LITERATURE SURVEY

The literature review is carried out to understand and assess the current status of the above areas.
Ersoy and Vardar (2000) analyzed the residual stresses by compliance method in the thickness direction of laminates used in heavy-duty structures. However, their costs are high and their properties are not uniform due to uneven curing cycles, especially in the thickness direction. Liu et al (2000) has made a study on assembling thin composite laminates together to form thick composite structures was found to be feasible in reducing cost and achieving property uniformity. Techniques such as adhesive bonding, riveting and clamping were presented. Al-Qureshi (2001) has presented a general study on the design, analysis and fabrication of composite springs. His work has shown that composite leaf spring has a better fatigue strength than the steel leaf spring.

Rajendran and Vijayarangan (2001, 2002) studied the application of composite structures for automobiles and design optimization of a composite leaf spring. Mohamood shokreich (2003) has made a study onfour-leaf steel spring used in rear suspension system of light vehicles using ANSYS software. Using the results of the steel leaf spring, a composite one made from fiberglass with epoxy resin is designed and optimized using ANSYS. Main consideration is given to the optimization of spring geometry. He further showed that an optimum spring width decreases hyperbolically and the thickness increases linearly from the spring eyes towards the axle seat. The optimized composite spring has stresses that are much lower and the spring weight with eye unit is nearly 80% lower.

Analysis and Testing of Adhesively Bonded Joints

Over the recent decades, fiber reinforced composites have found several applications as load-carrying components, particularly in the realms of aeronautical and marine industries. A typical aerospace structure may consist of thin composite panels or skins, adhesively bonded to stiffeners, webs, spars or frames. Stiffened panels are typically subjected to large in-plane and out of-plane loads. As a result, considerable bending and shear stresses are produced at the skin stiffeners interfaces. Many workers have studied the single-lap adhesively bonded joints analytically, numerically

Goland–Reissner (1944) performed investigations on the cylindrical bending plate analysis of a single-lap joint. Erdogan and Ratwani (1971) studied on Adhesive-bonded joints. He discussed the effect of stress concentration occurs at the edge of overlap area in adhesively bonded joints. Wooley (1971) conducted a stress analysis on single-lap joints by using quadrilateral elements. Hart-Smith (1973) developed a layered beam model to solve the single-lap joint problem. He also discussed the three possible failure modes in the bonded joint, which are:

(1) Failure of adhered just outside the joint due to in-plane stresses resulting from the combination of direct load stresses and bending stresses resulting from eccentricity in the load paths,
(2) Failure of the adhesive layer in shear, and
(3) A failure mode that may be manifested in either of the two forms and is associated with the adhesive peel stresses. He showed that both adhered bending moment and peak peel stresses are intensified at the end of the joint from which the thinner adhered extends and stiffness imbalance in the joint results in a reduction of adhered bending strength.

III - WORKING METHODOLOGY

Leaf springs are a basic form of suspension made up of layers of steel of varying sizes sandwiched one upon the other. Most leaf spring setups are formed into an elliptical shape through the use of spring steel which has properties that allow it to flex as pressure is added at either end, but then returning to its original position through a damping process. The steel is generally cut into rectangular sections and then once held together by metal clips at either end or a large bolt through the centre of the leafs. It is then mounted to the axle of the vehicle using large U-bolts, securing the suspension in place.

The elasticity of the spring steel allows for pliancy within the suspension for comfort and control of a car while moving, and a leaf spring setup has been proven as a viable option for cars for many decades, despite only really being found on HGVs and Military vehicles these days.

THE ADVANTAGES

Due to the sheer amount of metal layered together, leaf springs offer a large amount of support between the wheels, axles and the car's chassis. They can take huge vertical loads being applied to them due to their tight-knit structure, hence why heavy duty industries still use them. Vertical loading is also distributed throughout the length of the leaf spring rather than acutely through a small spring and damper, which can potentially create a concentrated force too large for the suspension to handle.

In a car, damping can be an extremely important characteristic. If the suspension is under-damped, the car will wallow and bounce around well after hitting any bump or pot hole in the road. This was a significant characteristic in cars that used helical springs before the dawn of the shock absorber and was disadvantageous to cars when driven at any real pace. Leaf springs coped much better with vehicle damping due to the friction between each plate of steel which made the response time after a vertical flex in the suspension much quicker, thus making for a much more controllable car.

The disadvantages

A big downside of leaf setups is they aren't brilliant when it comes to suspension tuning. In racing and performance car applications, it is vital to be able to manipulate a suspension setup for the driving conditions and for different driving styles, something that is much easier nowadays through adjustable coilovers. This lack of adjustability of leaf setups is emphasized by the fact that the ends of the leaf springs are attached to the chassis, which leaves very little scope for shortening or lengthening of the leafs.

Adjustments can therefore only really be made through the strength and flexibility of the material used to make up the leaf springs.

Leafs also allow very few directions of motion and are only really designed to move vertically, while a spring and damper combination can be manipulated into a much larger range of motion. Leaf springs are firmly clamped together and bolted to the chassis as well as clipped to the axle, thus giving little to no scope for any other direction of motion which can lead to heavy wear on the joints and connections holding the setup together.

IV - DESIGN METHODLOGY OF AUTOMOBILE SUSPENSION SYSTEM

Introduction to CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

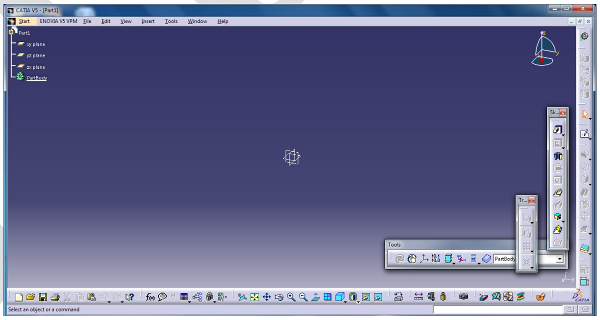


Fig: 4.1: Home Page of CatiaV5

Modeling of Automobile Suspension System in CATIA V5

This Automobile Suspension System is designed using CATIA V5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design.

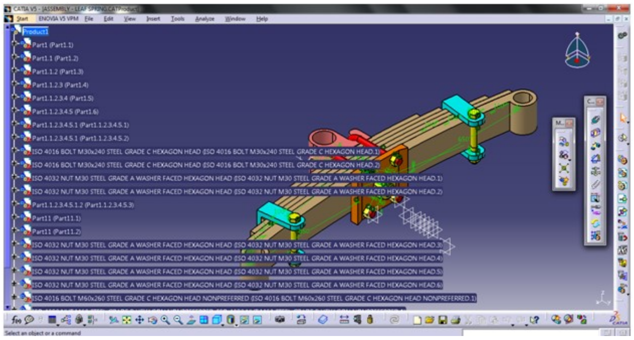


Fig: 4.2: Model design of Automobile Suspension System in CATIA-V5

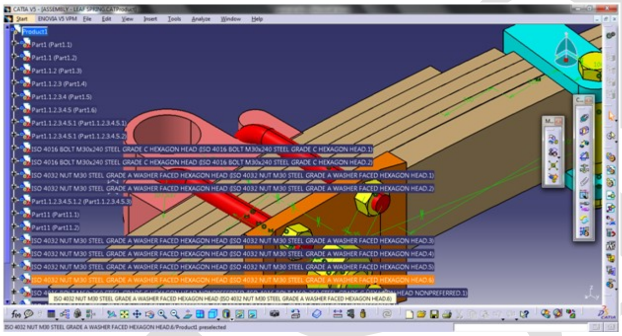


Fig: 4.3: Model arrangement in CATIA-V5

V - ANALYSIS OF AUTOMOBILE SUSPENSION SYSTEM

5.1 Procedure for FE Analysis Using ANSYS:

The analysis of the Automobile Suspension System is done using ANSYS. For compete assembly is not required, is to carried out by applying moments at the rotation location along which axis we need to mention. Fixing location is bottom legs of rod assembly machine.

5.2 Preprocessor

In this stage the following steps were executed:

- **Import file in ANSYS window**

  File Menu > Import> STEP > Click ok for the popped up dialog box > Click Browse" and choose the file saved from CATIAV5R20 > Click ok to import the file

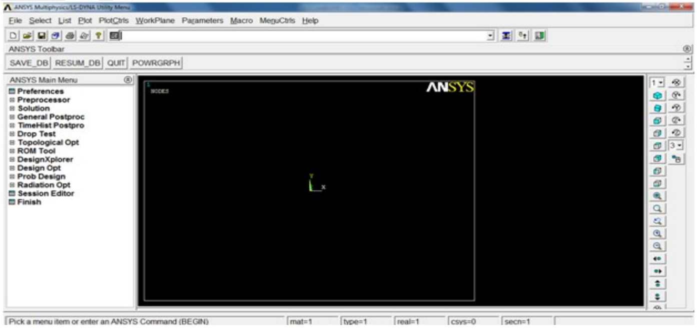


Fig.5.1: Import panel in Ansys.

Rod is modeled with 1d element and shown as above and assembled with adjacent components. Few components are solved using Thermal Analysis for checking the stress and displacements while flowing the fluid.

After completing the meshing of each assembly components next is to do analysis based on the OEM (Original Equipment of Manufacturer) application. So all the models which are analyzed, we need to mention in the Ansys software to get accurate results as per the original component. Some of the components are needed to be solved using thermal analysis.

VI - DISCUSSION ON ANALYSYS RESULT

DISPLACEMENT

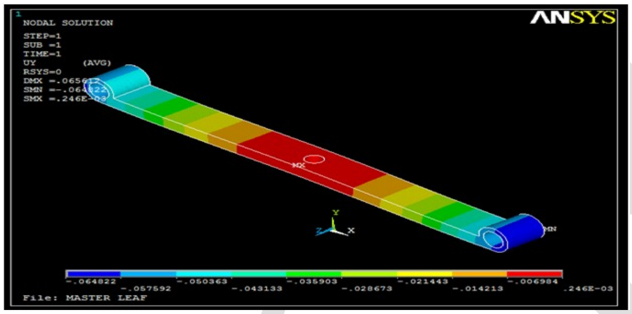


Fig: MASTER LEAF

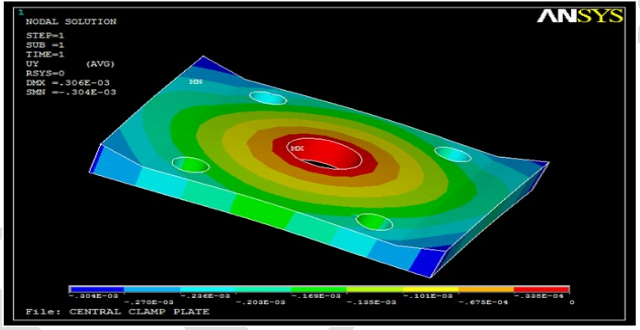


Fig: CENTRAL CLAMP PLATE

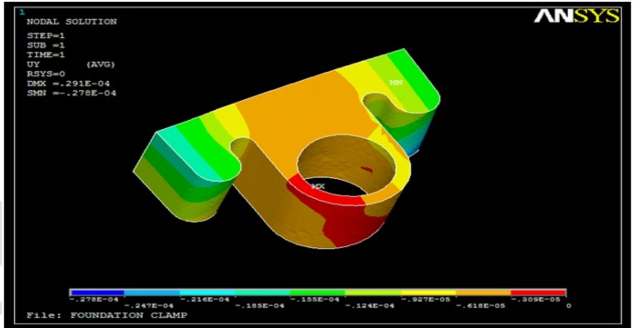


Fig: FOUNDATION CLAMP

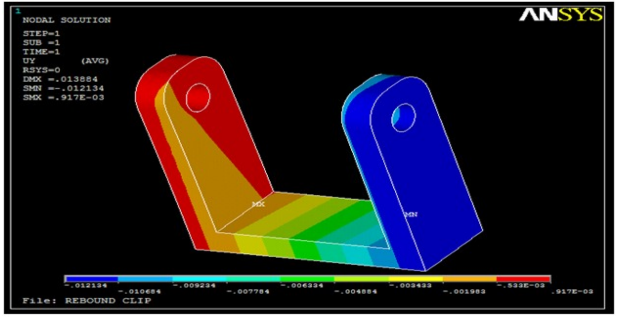


Fig: REBOUND CLIP

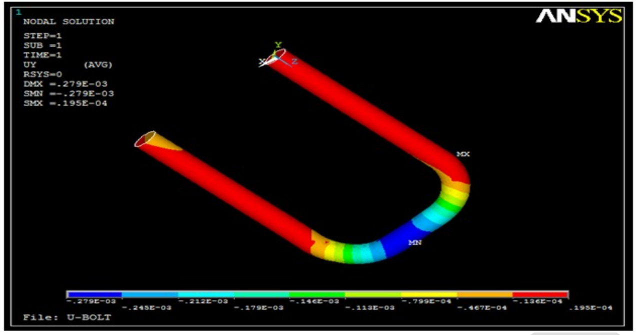


Fig: U-BOLT

STRESS

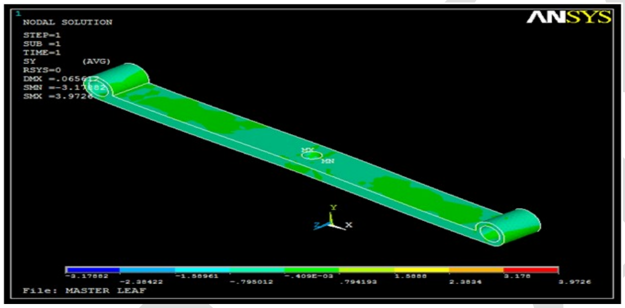
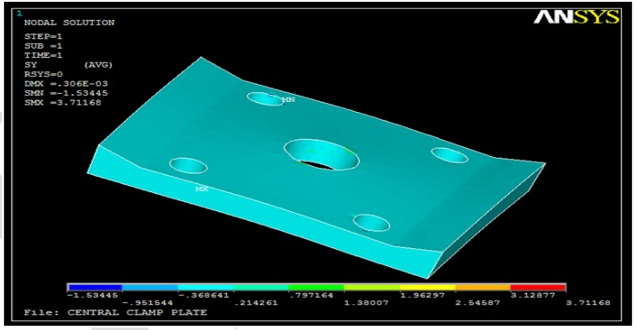


Fig: MASTER LEAF



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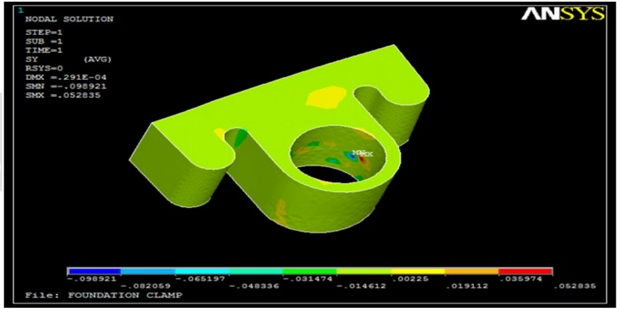

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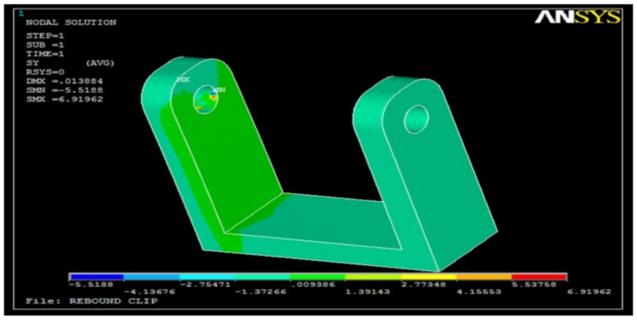

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Fig: REBOUND CLIP

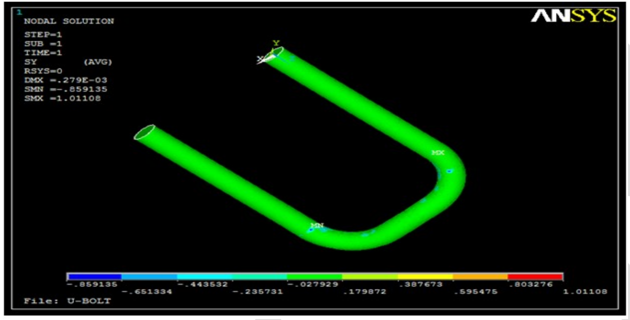

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Fig: U-BOLT

STRAIN

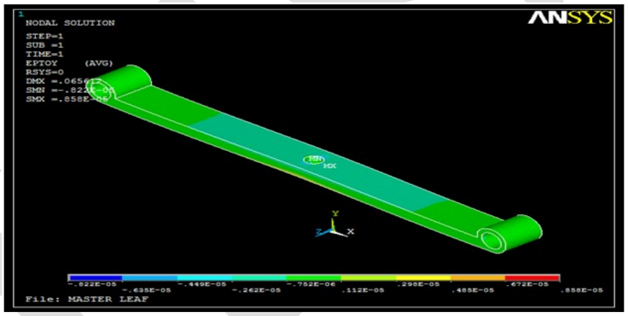

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Fig: MASTER LEAF

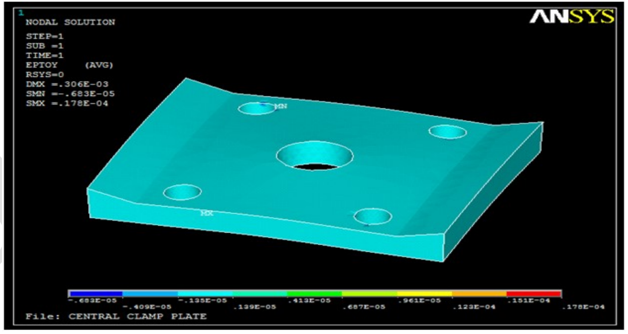

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Fig: CENTRAL CLAMP PLATE

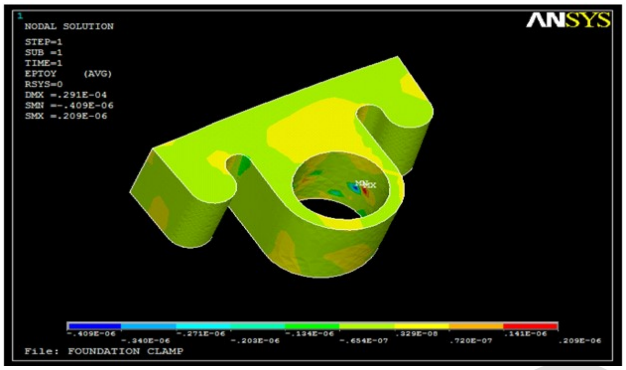

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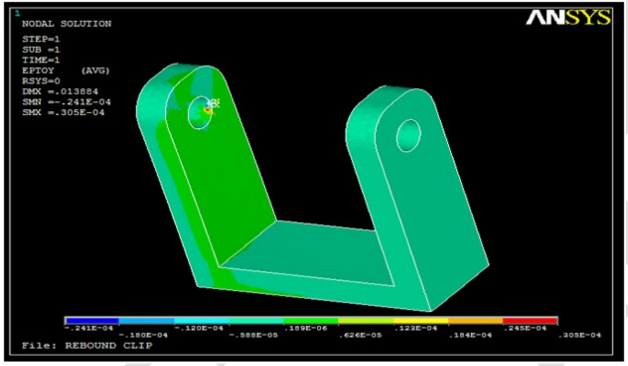
Fig: FOUNDATION CLAMP



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File: REBOUND CLIP
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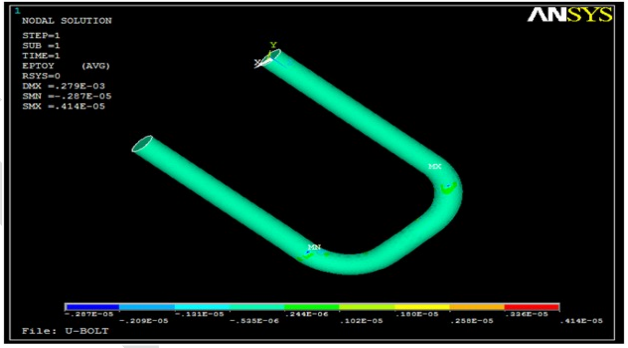
Fig: REBOUND CLIP



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SMX =.414E-05
File: U-BOLT
```

Fig: U-BOLT

VII - CONCLUSION

It can be seen from the above result that, our objective to increase the results of a leaf spring in a curve has been successful. As shown above figures the displacement of the complete design assembly is meshed and solved using Ansys and displacement is 0.246E-05mm which is very less. This is showing us that clearly each component in assembly is having minor displacement.

Stress is at the fixing location (Minimum Stress which is acceptable). The value is 3.972 MPa which is very less compared to yield value; this is below the yield point.

The maximum strain is coming, this solution solving with the help of Ansys software so that the maximum strain is 0.858E-05 MPa. So we can conclude our design parameters are approximately correct.

The design of the leaf spring is worked flawlessly in analysis as well, all these facts point to the completion of our objective in high esteem.

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