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DESIGN AND LOAD ANALYSIS OF COMPOSITE LEAF SPRING FOR HEAVY LOAD VEHICLES USING ANSYS

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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

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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.

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II - LITERATURE SURVEY

The literature review is carried out to understand and assess the current status of the above areas.

Mahmoud Omar et al. [1] (2017) were represented the active performance compared against the passive is performed experimentally and numerically utilizing SIMULINK's Simscape library. Both systems are modeled as single degree-of-freedom to simplify the validation process. Economic considerations were considered during the rig's implementation. The rig consists of two identical platforms fixed side by side allowing testing two independent suspensions simultaneously. Position sensors for sprung and un sprung masses on both platforms are installed.

Tian Mi, Gabor Stepan et al. [2] (2017) was presented to study the shimmy problem of the electric vehicle with independent suspensions, a 5 DoF model is established using the Lagrange Equation. Gyroscopic moment and tire nonlinearity are both considered, and tire-road constraint equations are derived on the non-slip assumption. Stability charts are conducted with the linearized model, while the numerical simulation is also made so that these two methods can verify each other. The results show that bifurcation occurs at certain vehicle forward speeds. Suspension structural parameters, such as caster angle, affect wheel shimmy. Furthermore, the presented model enables the analysis of any parameters in the system, and as an example, the influence of dampings on shimmy is investigated.

Carlos Arana et al. [3] (2017) had represented the potential of the Series Active Variable Geometry Suspension (SAVGS) for comfort and road holding enhancement. The SAVGS concept introduces significant nonlinearities associated with the rotation of the mechanical link that connects the chassis to the spring-damper unit. Although conventional linearization procedures implemented in multi-body software packages can deal with this configuration, they produce linear models of reduced applicability.

Jan Dizo et al. [4] (2017) had focused on the vibration analysis of the coach, which wheel is damaged by the wheel-flat. Analyses are carried out in multibody software and results are evaluated in terms of influencing suspension parameters to change on accelerations output signals. The article consists of two parts. The first part is aimed at the problem of the damaged wheel's origin and its consequence during rail vehicles running on tracks during real operation. There is also included the system of forces and accelerations measurement during rail vehicles running on the given track section. The secondpart is focused on the assessment of selected measured parameters of a rail vehicle with wheel-flat which are

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obtained from computer simulations. As evaluation parameters signals accelerations in the selected location during passenger car running on the straight track for various stiffness of coil spring of the primary and secondary suspension were assessed.

Anirban. C. Mitrab et al. [5] (2016) had represented one of the challenging tasks for engineers. The main function of any suspension system is to reduce or eliminate the road excitations transmitted to the vehicle body. An effort has been made in this paper for a passive suspension system by using an optimization technique called the Genetic algorithm to absorb vibrations as per ISO 2631-1: 1997 standards. The spring stiffness (ks), damping coefficient (cs), sprung mass (ms). unsprung mass (mu), tire stiffness (kt) are optimized in such a way that ride comfort is increased. The quarter car and driver seat with the driver's body is simply modeled together as four degrees of freedom (DOF) system by using SIMULINK for analyzing the ride comfort.

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.

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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.

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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).

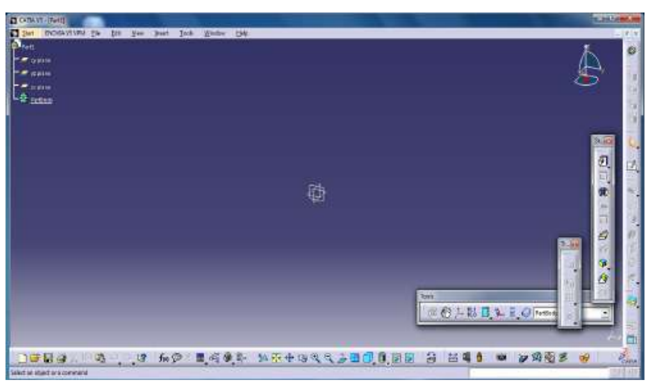

Fig: Home Page of CatiaV5

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.

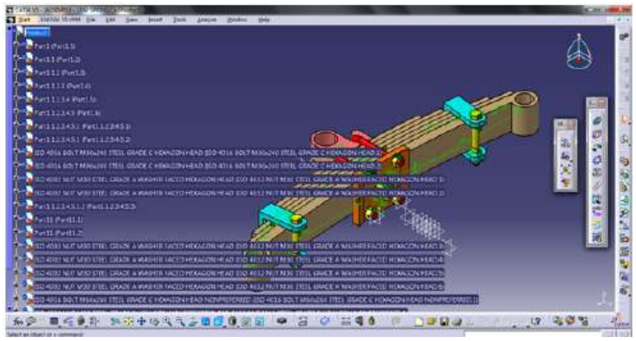

Fig: Model design of Automobile Suspension System in CATIA-V5

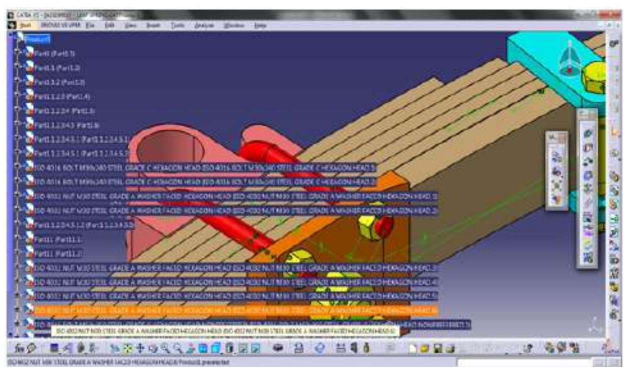

Fig: Model arrangement in CATIA-V5

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**

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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

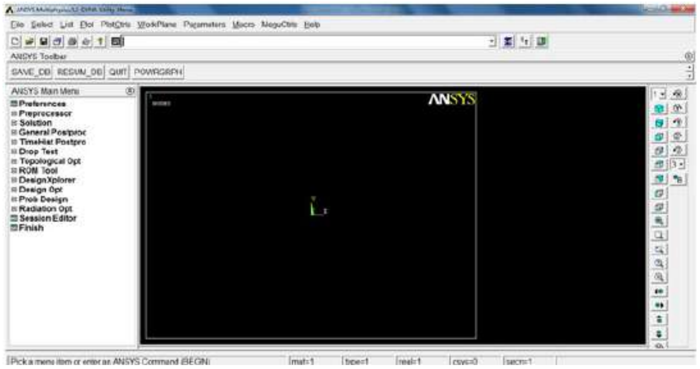

Fig: Import panel in Ansys.

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

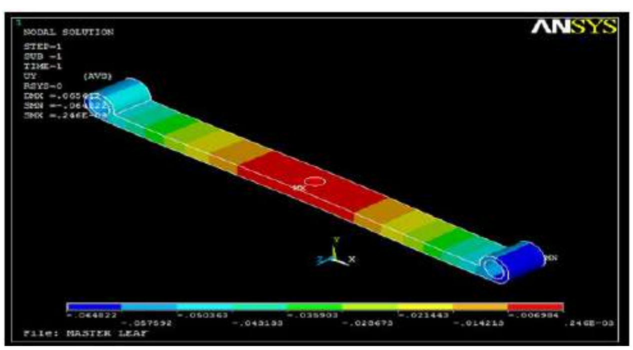

Fig: MASTER LEAF

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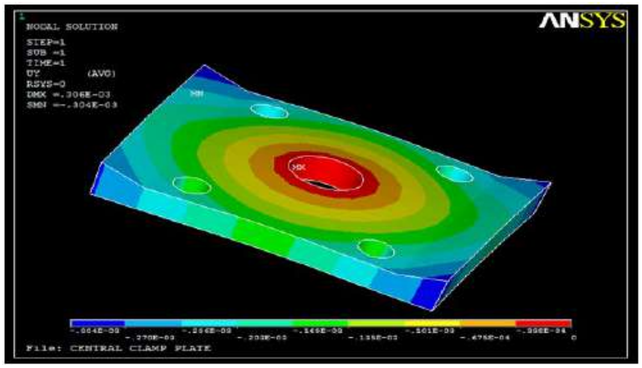

Fig: CENTRAL CLAMP PLATE

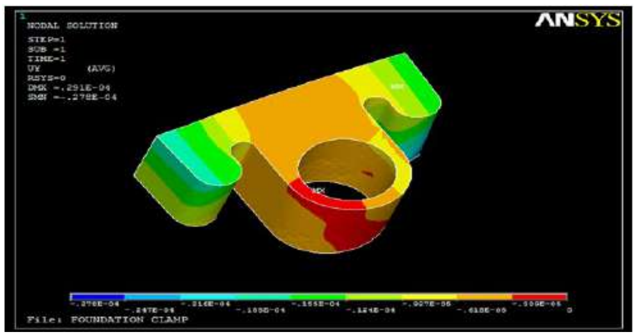

Fig: FOUNDATION CLAMP

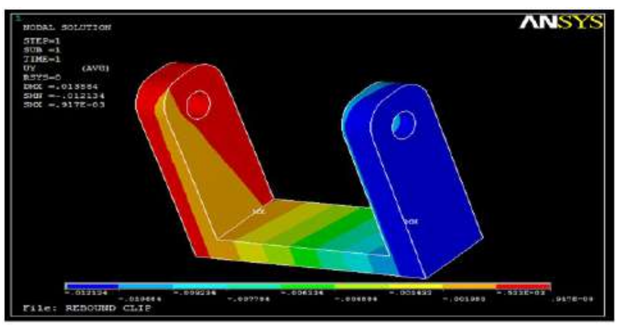

Fig: REBOUND CLIP

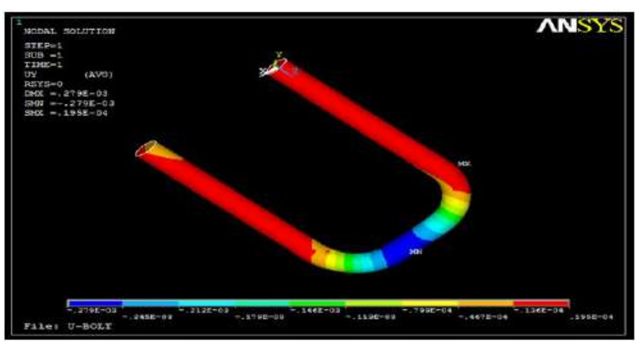

Fig: U-BOLT

STRESS

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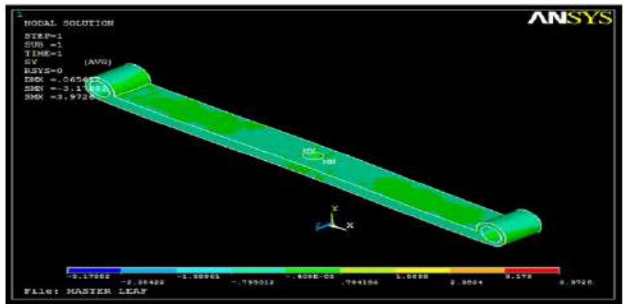
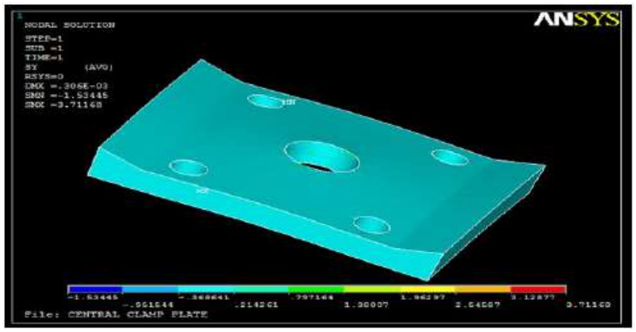


Fig: MASTER LEAF



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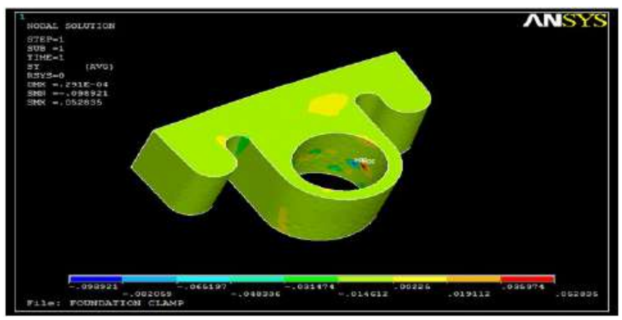

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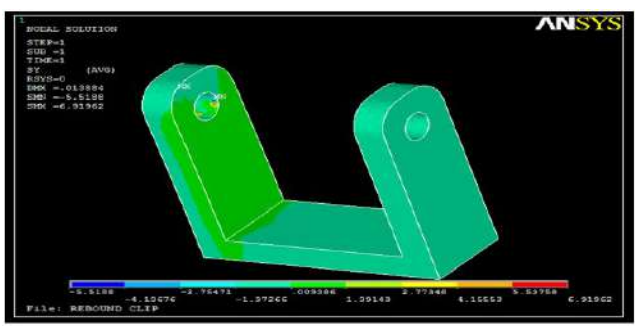

Fig: REBOUND CLIP

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Fig: U-BOLT

STRAIN

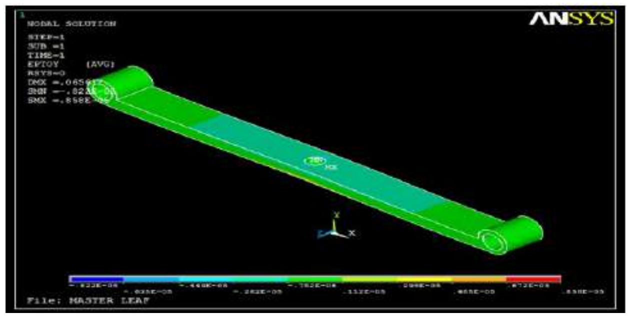
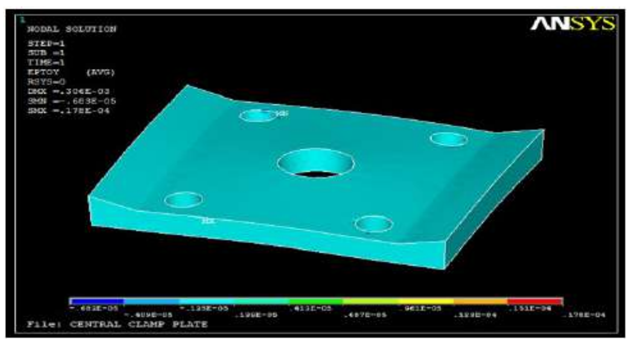


Fig: MASTER LEAF



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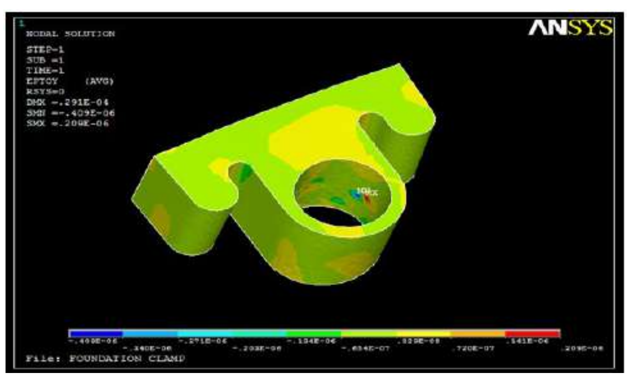

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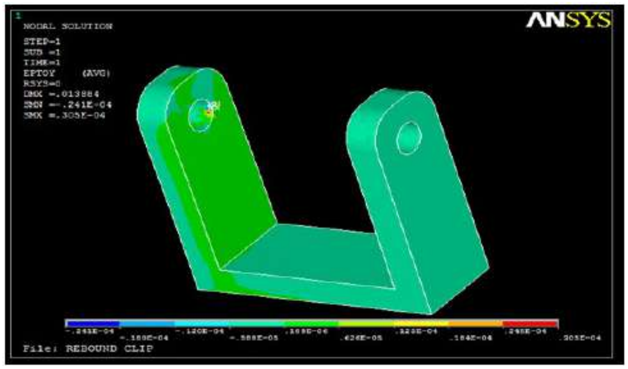

Fig: REBOUND CLIP

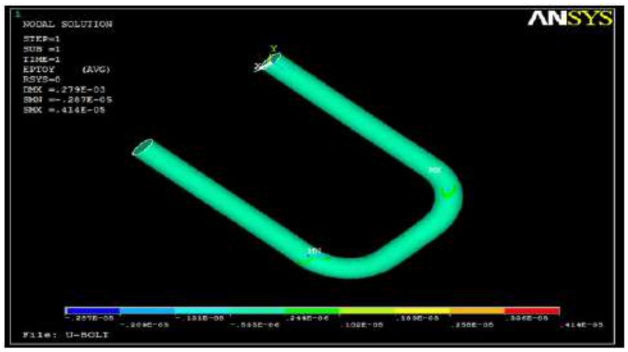

Fig: U-BOLT

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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