# Static Analysis of Leaf Spring for Light Commercial Vehicle

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**Abstract:-Even being one of the oldest suspension components, leaf springs are still frequently used, especially in commercial vehicles. The advantage of leaf spring over a helical one is that the ends may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. The main function of this is not only to support vertical load but also to isolate the road induced vibrations. It is subjected to millions of load cycles thus leading to fatigue failure. The present work attempts to describe the theoretical design considerations that are used during the design and analysis of leaf springs and also to analyse the theoretical safe stress value and its corresponding pay load for a typical leaf spring configuration of TATA-407 (Light Commercial Vehicle). Hence, the calculated outcomes are described in the later part.**

**Keywords:** Leaf Springs, Deflect, Fatigue failure, Analysis, Safe Stress Value, Payload.

## I. INTRODUCTION

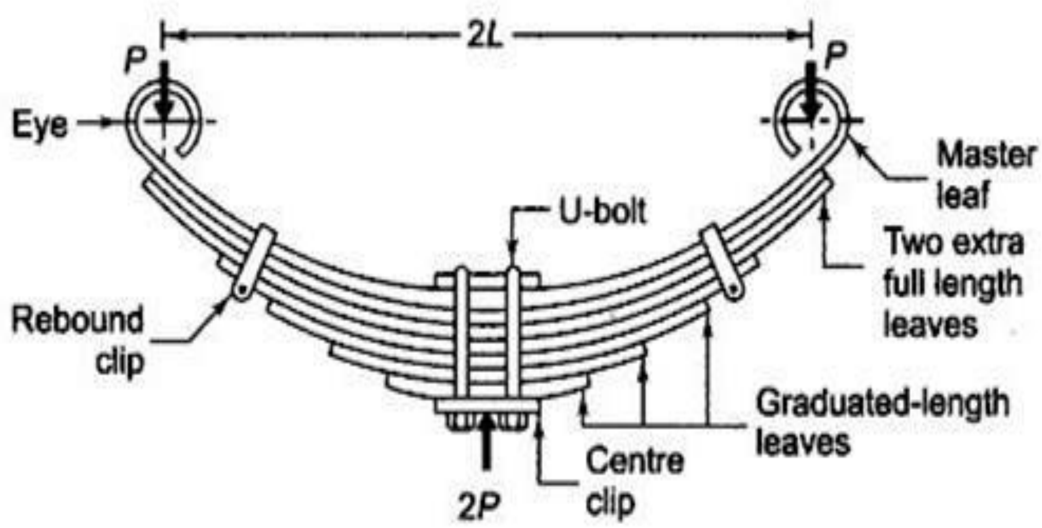


Figure 1: Components of a leaf spring

A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. Leaf springs absorb the vehicle vibrations, shocks and bump loads (induced due to road irregularities) by means of spring deflections, so that the potential energy is stored in the leaf spring and then relieved slowly. Ability to store and absorb more amount of strain energy ensures the comfortable suspension system. 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 remaining blades 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 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, leading to deflection of the spring. This changes the length between the spring eyes. If both the ends are fixed, the spring will not be able to accommodate this change of length. So, to accommodate this change in length shackle is provided at one end, which gives a flexible connection. The front eye of the leaf spring is constrained in all the directions, whereas rear eye is not constrained in X-direction. This rare eye is connected to the shackle. During loading the spring deflects and moves in the direction perpendicular to the load applied.

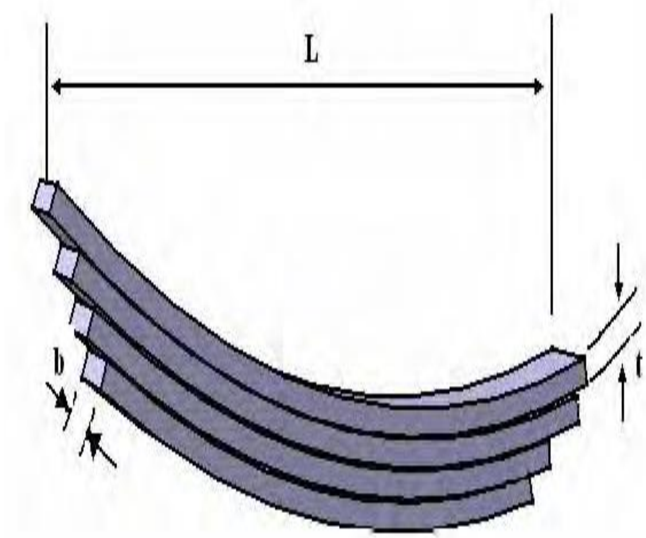


Figure 2: Terminology of leaf spring

When the leaf spring deflects, the upper side of each leaf tips slides or rubs against the lower side of the leaf above it. This produces some damping which reduces spring vibrations, but since this available damping may change with time, it is preferred not to avail of the same. Moreover, it produces squeaking sound. Further if moisture is also present, such inter-leaf friction will cause fretting corrosion which decreases the fatigue strength of the spring, phosphate paint may reduce this problem fairly. The elements of leaf spring are shown, where **t** is the thickness of the plate, **b** is the width of the plate and **L** is the length of plate or distance of the load **W** from the cantilever end.

As this work being an attempt to analyse the various terms related to the leaf spring, we summarize the nature of problem below. The objectives hence of this work are:

- To find the desired dimensions of a semi elliptical leaf spring along with the proper materials to be used according to their various properties for the vehicle TATA-407.

- To study the fatigue failure under the FEA approach and hence calculate the safe working stress and the corresponding payload.

This work being a general analysis, as most of the cases, it also has certain limitations which are to be compensated by stating some assumptions. The required modifications are mentioned below:

- The design considerations and calculations are completely theoretical and as the work being based on assumptions, reliability of results to be obtained accurately is not optimum.
- The automobile is assumed to be stationary.
- Analysis is carried out on one rear leaf spring even when the vehicle has four of them.
- Numerous other factors also affect the actual working of the component which are neglected in this present work.
- To compensate the errors occurred in calculations due to the above reason, the factor of safety for the component is considered higher than desired.

## II. LITERATURE SURVEY

*A. Ashish Amrute, "design and assessment of multi leaf spring", International journal of research in aeronautical and mechanical engineering ISSN (online): 2321-3051*

Leaf springs are one of the oldest suspension components they are still frequently used, especially in commercial vehicles. The automobile industry has shown increased interest in the replacement of steel spring with fiber glass composite leaf spring due to high strength to weight ratio. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. This work is carried out on multi leaf spring consist three full length leaves in which one is with eyed ends used by a light commercial vehicle. This work deals with replacement of conventional steel leaf spring of a light commercial vehicle with composite leaf spring using E-glass/Epoxy. Dimensions of the composite leaf spring are to be taken as same dimensions of the conventional leaf spring. The objective is to compare the load carrying capacity, stresses and weight savings of composite leaf spring with that of steel leaf spring. The finite element modeling and analysis of a multi leaf spring has been carried out. The CAE analysis of the multi leave leaf spring is performed for the deflection and stresses under defined loading conditions. The Theoretical and CAE results are compared for validation.

*B. G. Harinath Gowd, "static analysis of leaf spring", international journal of engineering science and technology (IJEST) ISSN: 0975-5462 Vol:4 .*

Leaf springs are special kind of springs used in automobile suspension systems. The advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. The main function of leaf spring is not only to support vertical load but also to isolate road induced vibrations. It is subjected to millions of load cycles leading to fatigue failure. Static analysis determines the safe stress and corresponding pay load of the leaf spring and also to study the behavior of structures under practical conditions. The present work attempts to analyze the safe load of the leaf spring, which will indicate the speed at which a comfortable speed and safe drive is possible. A typical leaf spring configuration of TATA-407 light commercial vehicle is chosen for study. Finite element analysis has been carried out to determine the safe stresses and pay loads.

## III. METHODOLOGY

- *Modeling and analysis of the leaf spring*

Bending stress for the leaf spring is calculated by considering the leaf spring to be a cantilever beam of uniform strength. Thus the results achieved are.

Let

t = Thickness of plate,

b= Width of plate, and

L= Length of plate or distance of the load from the cantilever end.

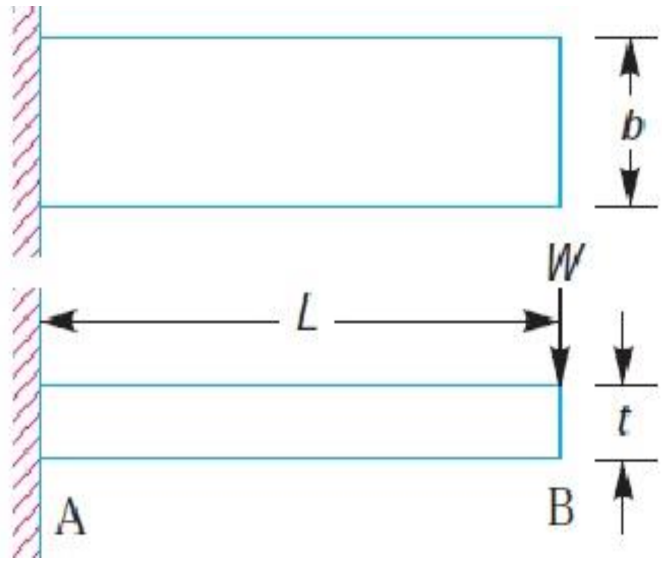


Figure 3: Leaf Spring as a cantilever beam

Thus the stress $\sigma = \frac{6WL}{nbt^2}$

And the deflection $\delta = \frac{4WL^3}{nEbt^3} = \frac{2\sigma L^2}{3Et}$

Bending stress for full length leaves

$$\sigma_f = \frac{18WL}{bt^{2(2n_g+3n_f)}}$$

And since $\sigma_G = \frac{2\sigma_F}{3}$,

Bending stress for graduated leaves where E is the Young's

Modulus $\sigma_G = \frac{\frac{12WL^3}{Ebt^3}}{2ng+3nf}$

The master leaf of a laminated spring is hinged to the supports. The support forces induce, stresses due to longitudinal forces and stresses arising due to possible twist. Hence, the master leaf is more stressed compared to other the graduated leaves.

- *Methods to reduce additional stresses could be:*

  - Master leaf is made of stronger material than the other leaves.
  - Master leaf is made thinner than the other leaves. This will reduce the bending stress as evident from stress equation.
  - Another common practice is to increase the radius of curvature of the master leaf than the next leaf.

Since, the main leaf takes upon most of the load and stress applied on the leaf spring, the graduated leaves in this present work case are approximately considered to be evenly decreasing in length from the main leaf to the end leaf.

- *The materials most commonly used for leaf springs' manufacturing are:*

Table 1: Materials used for leaf spring

| MATERIAL | CONDITION | ULTIMATE TENSILE STRESS (MPa) | TENSILE YEILD STRENGTH (MPa) | BRINELL HARDNESS NUMBER |
|---|---|---|---|---|
| 50 Cr 1 | Hardened and Tempered | 1680-2200 | 1540-1750 | 461-601 |
| 50 Cr 1 V 23 | | 1900-2200 | 1680-1890 | 534-601 |
| 55 Si 2 Mn 90 | | 1820-2060 | 1680-1920 | 534-601 |

The physical properties of the material used in this present work, 'Manganese Silicon Steel' are:

1. Young's Modulus (E)= 2.1E5 N/mm$^2$
2. Poisson's Ratio= 0.3
3. Density= 7.86E-6 kg/mm$^3$
4. Yield Stress= 1680 N/mm$^2$
5. Factor of Safety= 3
6. $Length\ of\ Master\ Leaf\ = 2L1 + \pi(d + t) * 2$

- *Calculated Geometric Dimensions of the Leaf Spring:*

1. Camber= 80mm
2. Span= 1220mm
3. Thickness= 7mm
4. Width= 70mm
5. Number of Full Length Leaves= 2
6. Number of Graduated Leaves= 8
7. Total number of leaves= 10

- *Standard procedure for leaf spring in 3-D solid modeling:*

1. First of all design the required component properly and note down the dimensions.
2. Now draw the front view of main leaf with the help of commands like ellipse, circle, tangent, mirror and trim.
3. Now, extrude the drawing upto the required depth.
4. Similarly, prepare the leaves as per corresponding dimensions.
5. Save all the leaves in separate component files.
6. Open assembly in CATIA so as to import all the components and align them together to form a single product.
7. Assemble all the leaves together and align as per the planes so as to create a whole new component made up of all the leaves which are then restricted to act separately.
8. Check the structure and save the assembly as .iges file.
9. This file is important as being used in ANSYS further after importing the same for inserting geometry for analysis purpose.

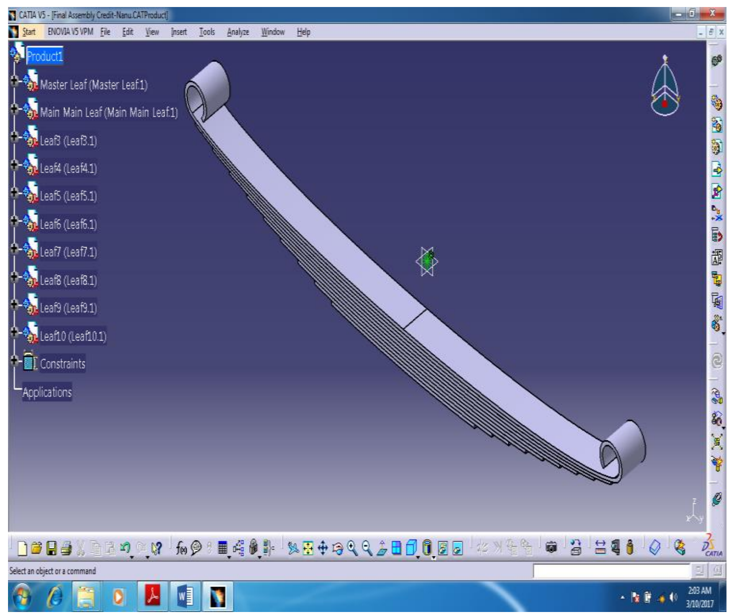


Figure 4: Assembly of the leaf spring

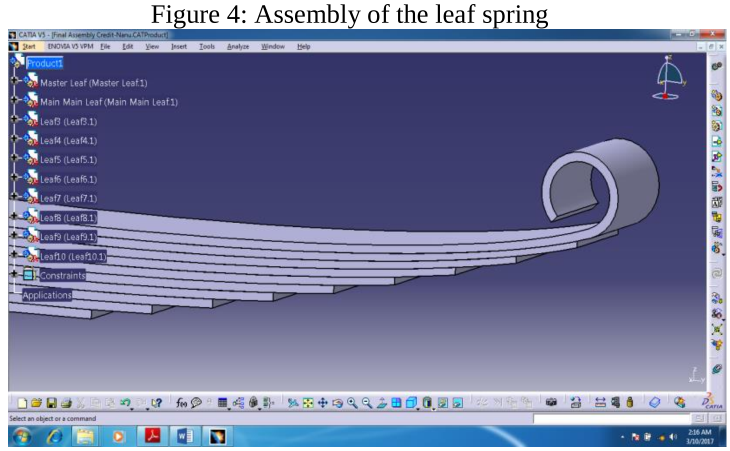

Figure 5: Right half of leaf spring assembly (Front view)

- *Static structural analysis of the leaf spring in ANSYS 16.0:*

1. We use static structural analysis mode of calculation to start with.
2. Now, we insert the predetermined values of the properties into the Add New Material section.

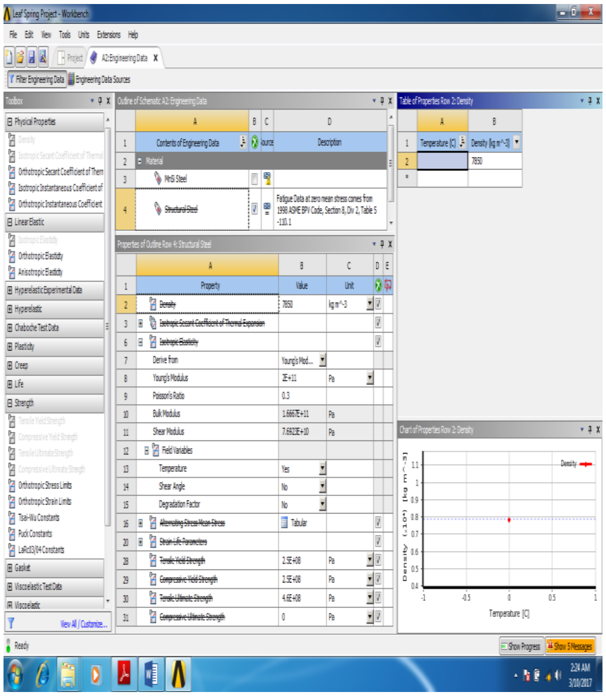

Figure 6: Material Selection

3. Then we move forward to the insertion of geometry and then we carry it forward to the modeling section of the ANSYS.

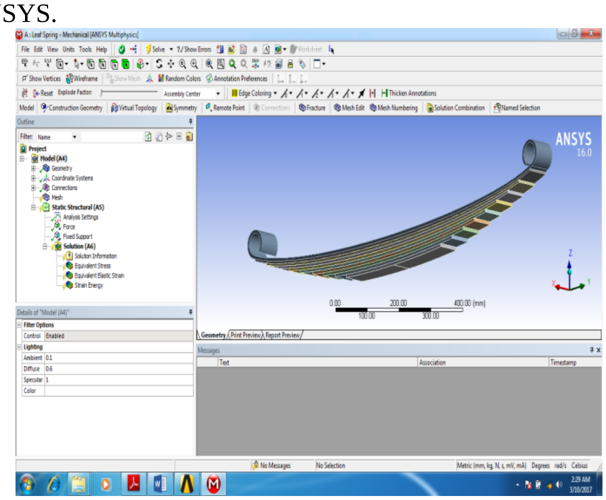

Figure 7: Insert Geometry

4. All surface contacts are considered to be bonded contacts for ease.
5. We now generate a mesh there with 5mm size for convenience.

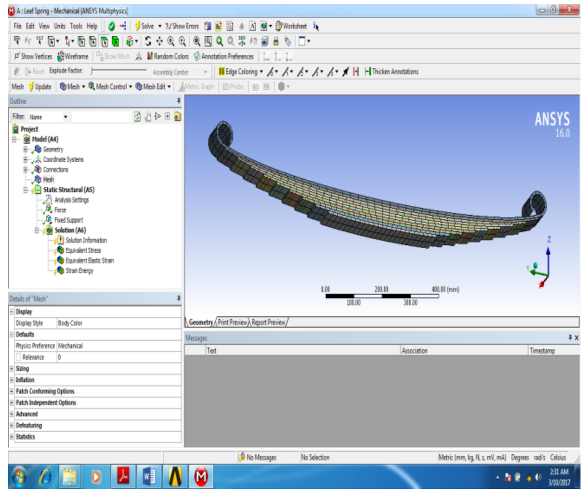

Figure 8: Meshing Process

6. We then apply a fixed support to the eyes of the leaf spring and a considerable force of 6000 N on the smallest leaf from below.

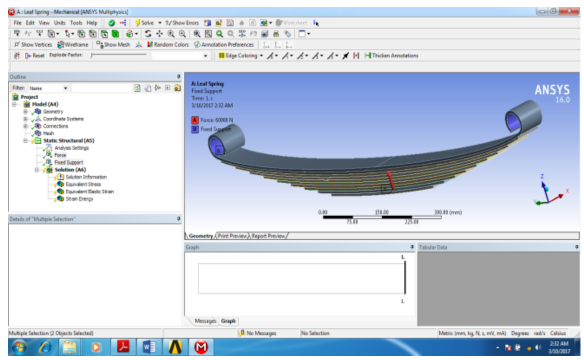

Figure 9: Addition of load, support and forces

7. We then apply for a solution through Von-Miss Equivalent Stress, Strain and Strain Energy.
8. We then tabulate the results for various loads and then find out the required Safe Stress and the corresponding Payload.

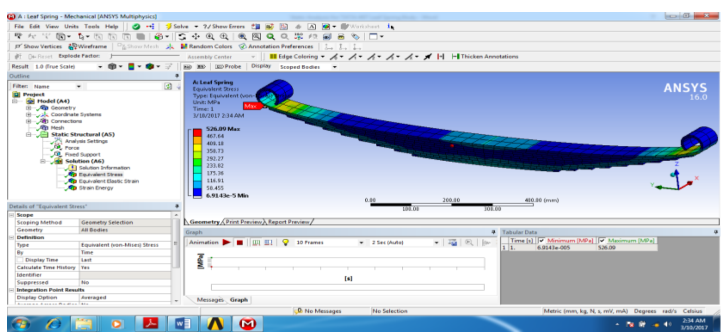

Figure 10: Stress developed in the leaf spring

| LOAD (N) | STRESS(N/mm$^2$) |
|---|---|
| **60000** | 562.09 |
| **65000** | 569.93 |
| **70000** | 613.77 |
| **75000** | 657.61 |
| **80000** | 701.45 |
| **85000** | 745.29 |
| **90000** | 789.14 |
| **95000** | 832.98 |
| **100000** | 876.82 |

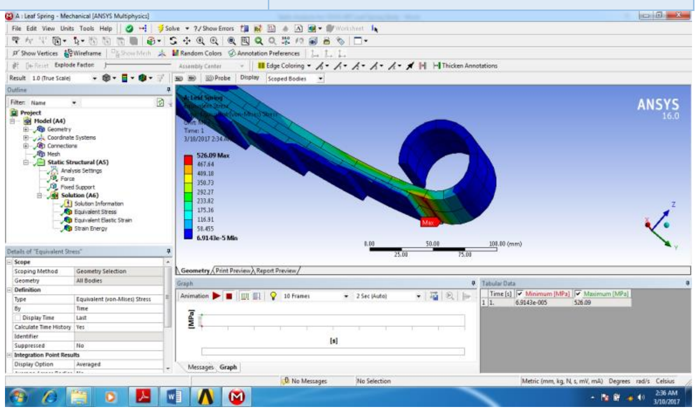

Figure 11: Maximum stress point at the eye of the leaf

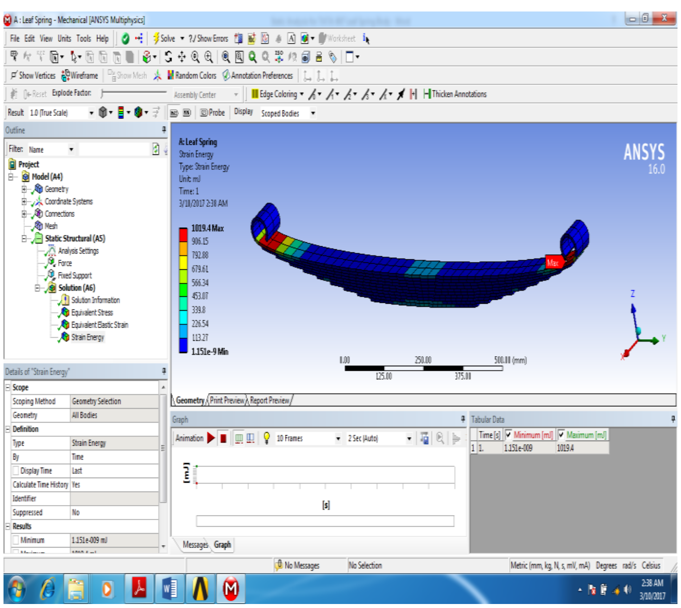

Figure 12: Strain developed in the leaf spring

## IV. RESULTS

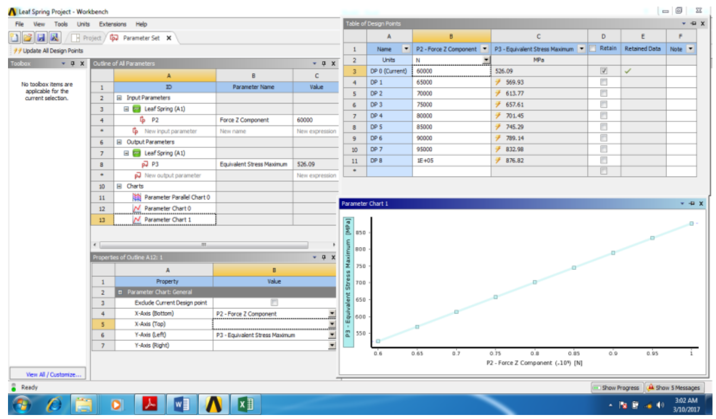

Figure 13: Tabulated results in ANSYS

Hence, the results are organized in a table form for convenience as follows:
Table 2: Stress developed in leaf spring for the corresponding loads

1. Considering the various factors, we take the factor of safety to be 2.5 to 3.
2. Hence, the yield stress allowable= 1680/2.5 to 1680/3 = 560 to 672 N/mm$^2$
3. It is seen that at load 80000N, it crosses the yield stress allowable. So the corresponding loads are 60000 to 80000 N. Therefore it is concluded that the maximum safe pay load for the given specification of the leaf spring is 70000N.
4. Hence, we get the maximum stress allowable as 613.77 N/mm$^2$.
5. Thus, for the same stress we have the maximum safest payload as 70000 N.
6. Hence approximately it can apparently withstand 7000 kg of load, i.e. 7 tones of load.
7. The self-weight of TATA-407 being 2.5 tones and considering the tire wear out, moisture and impact
8. Vibrations, we restrict loading by 1.5 tones, to get the practically allowed payload to be 3 tones (as prescribed by the manufacturer itself).
9. Hence, we get the maximum equivalent stress and corresponding payload by FEA approach and we also prove that the analysis thus recorded is correct.

## V. CONCLUSION

- The design procedure of leaf spring applied in various sectors is highly accurate and hence is universally accepted.
- The graph of Load vs. Stress is Linear, as per the rule.
- The max stress is generated at the eye, so care has to be taken to avoid any fracture there at the initial stage.

- The selected material must have good ductility, resilience and toughness to avoid sudden fracture for providing safety and comfort to the occupants.
- But, the FEA analysis values show some deflection from that ones obtained experimentally.
- Hence, all the retarding factors have to be considered for a highly accurate and reliable design.
- Still, FEA is a better approach to develop, test, analyse, modify and design any mechanical component working under any loading conditions.
- FEA has proved to be the most reliable source for any development till date and has opened the mankind a door to a whole new world.

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