Optimizing Weight of Mono Leaf Spring Using FEA Method

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Abstract: In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization, and better manufacturing processes. The main objective of this paper is the weight reduction of Leaf Spring and improving the performance of the vehicle. The reduce weight both Carbon/Glass Epoxy Leaf Springs and carbon fiber obtained using ANSYS Workbench 18.2. The total weight of the leaf decrease up to 2.8471.and total deformation decreases up to 7.02mm for the static case. And the Total efficiency of the vehicle increase due to lower weight.

Keywords: leaf spring, carbon, ANSYS, CAD.

I. INTRODUCTION

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the unstrung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. The introduction of composite materials was made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity and stiffness. Since, the composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, multi-leaf steel springs are being replaced by mono-leaf composite springs.

The composite material offer opportunities for substantial weight saving but not always are cost-effective over their steel counter parts. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential Energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system.

According to the studies made a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. Fortunately, composites have these characteristics. Fatigue failure is the predominant mode of in-service failure of many automobile components. This is due to the fact that the automobile components are subjected to variety of fatigue loads like shocks caused due to road irregularities traced by the road wheels, the sudden loads due to the wheel traveling over the bumps etc. The leaf springs are more affected due to fatigue loads, as they are a part of the unstrung mass of the automobile.

II. LITERATURE REVIEW

Chowdhury et al. [1] in this paper presented are the five leaf steel spring used in the rear suspension system of light vehicles is analyzed using Finite Element Analysis. Main consideration was to optimize the spring geometry to obtain a spring with minimum weight, capable of carrying given static external forces without failure. The design constraints are stresses and deformation where the design variables are cross section area and width at each point. Compared to the steel spring, the optimized composite spring has stresses that are much lower and the spring weight has been reduced.

Avinash Chander Sharma et al. [2] Overall Weight reduction of the vehicle is the main issue in automobile industries. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. In this paper main focus is to review all such work in which the weight reduction of the vehicle was achieved by considering leaf spring. Many of authors suggested that weight reduction can be achieved by using composite material having suitable properties and capable of carrying such heavy load of the vehicle.

D. Lydia Mahanthi1 et al. [3] in recent year automobile industries are mostly concentrating on weight reduction and in improving the riding quality. To reduce vehicle weight, three techniques have been studied rationalizing the body structure, utilizing lightweight materials for parts and decreasing the size of the vehicles. In this approach by introducing composite materials into automobile industries, which is having low cost, high strength to weight ratio and excellent corrosive resistance can fulfill the requirement.

Suresh Patil et al. [4] The Paper gives the brief look on the suitability of composite leaf spring on vehicles and their advantages. The objective of the present work is design, analysis and fabrication of composite leaf spring. The finite element results using ANSYS software showing stresses and deflections were verified with analytical and experimental results. Compared to the steel spring, the composite spring has stresses that are much lower, the natural frequency is higher and the spring weight is nearly 85 % lower with bonded end joint and with complete eye unit.

III. OBJECTIVES

1) Calculated the total deformation on mono leaf spring by using FEA method.
2) Identified the failure and stress contours for leaf spring by using ANSYS workbench.
3) The main objective of the study reduce the overall weight of the mono leaf spring by using ANSYS workbench.
4) Increase the total strength of the mono leaf spring by using ANSYS workbench.

IV. METHODOLOGY

A. FEA analysis on Leaf Spring.

Preparation of model: A CAD model is prepared in catia

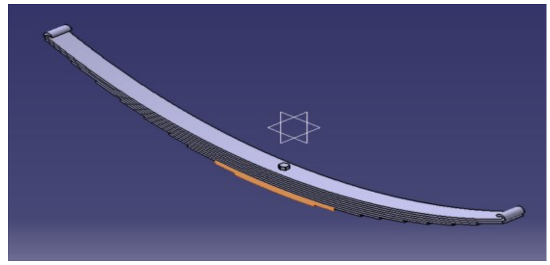


Fig.1 Catia model design of leaf spring

B. Steps of Working

Step 1: Collecting information and data related to leaf spring

Step 2: A fully parametric model of the leaf spring.

Step 3: Model obtained in Step 2 is analyzed using ANSYS 18.2.

Step 4: Finally, we compare the results obtained from ANSYS.

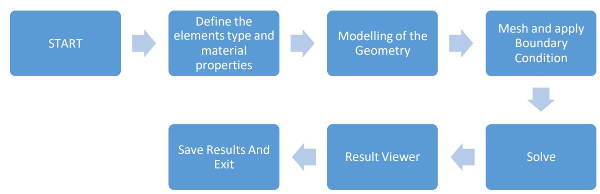


Fig. 2 Setup of working

C. Finite elements analysis

Finite elements analysis is a branch of fluid mechanics that uses numerical analysis and data structures to solve and analyze problems that involve solid structure. For the present work ANSYS 18.2 software used.

D. ANSYS Capabilities:

In finite element analysis ANSYS software is used that helps engineers for performing thefollowing tasks:

- To build computer prototype, components, transfer CAD models of structures in a system products.
- Enhances the profile of structural member with shape optimization.
- Physical responses, such as stress levels, temperature distributions, or electromagnetic fieldscan be studied.
- To reduce production costs optimization of design is done early in the development process.

- Testing of prototypes is done in environments where it otherwise would be undesirable or impossible (for example, biomedical applications).

Graphical user interface (GUI) in ANSYS gives users an easy, interactive approach to documentation, program functions, commands, and reference material. To navigate through the ANSYS program an intuitive menu system is used by users. Input data can be given using a mouse, a keyboard, or a combination of both.

E. Steps of Ansys Analysis

The different analysis steps involved in ANSYS are mentioned below.

1. Preprocessor

The model setup is basically done in preprocessor. The different steps in pre-processing are

- Build the model
- Define materials
- Generation of element mesh

2. Building The Model

- Creating a solid model within Catia
- Leaf Spring Design Specifications

Leaf Spring is designed for parameters taken from Mahindra Commander 650 Di Jeep

Table 1 Design Parameters

Design Parameters	Value
Length of Master Leaf (2L)	1151mm
Effective length (L)	526 mm
Radius of Master Leaf (R)	1398 mm
Number of Full Leaves	2
Number of Graduated Leaves	8
Leaf Width (b)	50 mm
Thickness (t)	6 mm
Deflection of Leaf Spring	117 mm
Camber Length	58.5 mm
Eye Diameter	9 mm
Center Bolt Diameter	10 mm
Thickness (t)	6 mm

3. Meshing

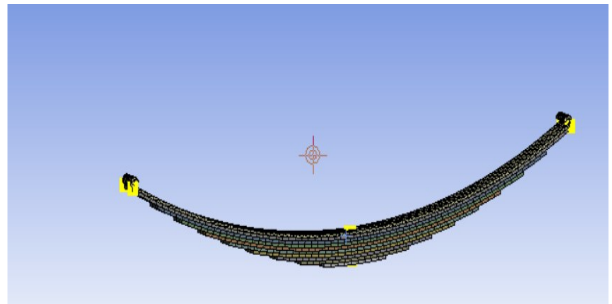


Fig. 3. Mesh model (Nodes:13119 Elements:2646)

4. Defining Material Properties

➢ Mechanical Properties of Carbon/Glass Epoxy Composite

Table 2 Mechanical Properties of Carbon/Glass Epoxy Composite

Properties	Value
Density (kg/m^3)	1672
Poisson's Ratio	0.275
Young modulus	1.34×10^5

➢ Mechanical Properties of Kevlar Fabric.

Table 3 Mechanical Properties of Kevlar Fabric.

Properties	Value
Density (kg/m^3)	1400
Poisson's Ratio	0.2
Young modulus	0.3×10^5

➢ Mechanical Properties of low density carbon fiber

Table 4. Mechanical Properties of low density carbon fiber

Properties	Value
Density (kg/m^3)	1298
Poisson's Ratio	0.32
Young modulus	1.13×10^5

F. Boundary Condition

1. Define boundary conditions.

Finite element analysis of Hybrid Composite Leaf Spring is done using ANSYS 16.2. Both Static and Dynamic Structural Analysis are done for both Steel and Hybrid FRP Composite. In ANSYS Workbench 18.2, before solving the analysis, we have to provide proper fixtures to simulate component in near exact environment. Regarding the Constraints, both the eye ends are constrained with remote displacement shown in Figure 4 and 5 In fixed end, all translations are constrained as well as rotations except z-axis. In Shackle end, translation along x-axis and rotation along z-axis are released while all other DOFs are arrested.

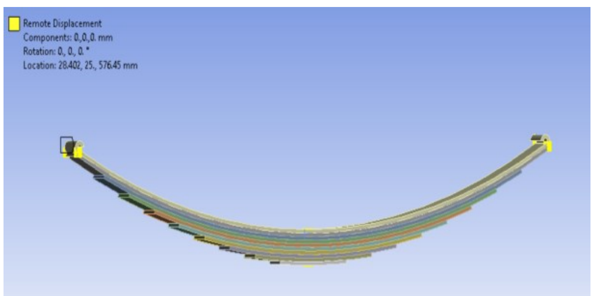


Fig. 4 Remote Displacement Fixed End

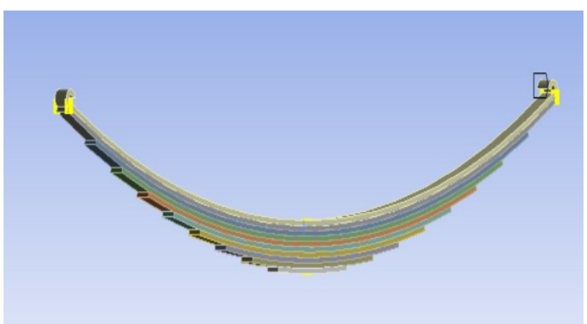


Fig. 5 Remote Displacement Shackle End

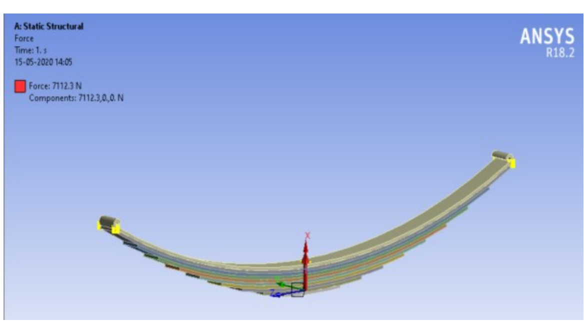


Fig. 6 apply force

G. Results Paper validations

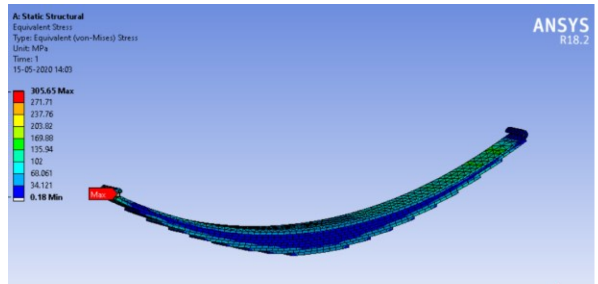


Fig. 7 Equivalent stress

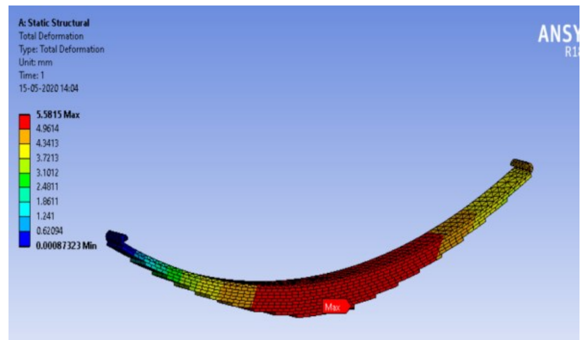


Fig. 8 total deformations

H. CASE-1 In case first aluminum alloy use as leaf spring material.

Static structural analysis:

Assume Leaf Spring is in static loading condition shown in Figure 9 (without speed factor) and analyze Total Deformation and Von-Mises Stress values of both Steel and Hybrid Composite Leaf Spring.

Load Calculation: Weight of Vehicle, W1= 2150 Kg, Additional Weight (Passengers and Luggage), W2= 750 Kg. Total Weight, W= 2900 Kg. Load Acting on Leaf Spring, F= m×a F= 2900×9.81 F= 28449 N (For all four-Leaf Springs): F= 7112.25 N (For one Leaf Spring)

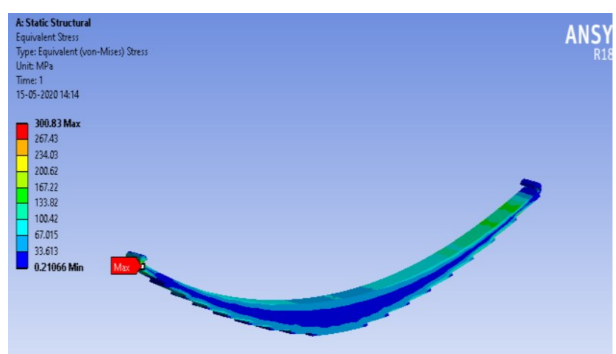


Fig. 9 Equivalent stress

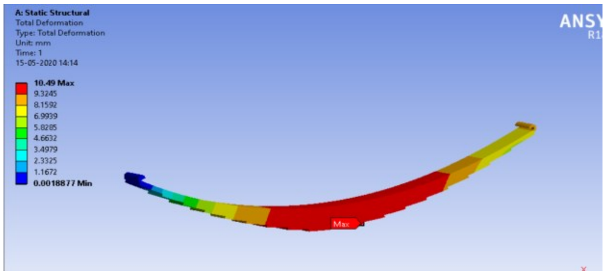


Fig. 10 Total deformations

Dynamic analysis.

Dynamic Analysis of Leaf Spring is done using Transient Structural Module of ANSYS Workbench 16.2. The Leaf Spring Assembly is analyzed for dynamic conditions like Acceleration and Deceleration. [8,9]During Acceleration: Assume vehicle is moving from 0 km/h to 60 km/h. Distance covered by vehicle is assumed as 40m. Load Acting on a Leaf Spring: Vf2 = Vi2 + 2×a×d where, Vf = Final Velocity= 60 km/h = 16.67 m/s, Vi = Initial Velocity= 0 km/h = 0 m/s, a = acceleration, d = distance travelled by vehicle = 40m. (16.67)2 = 0 + 2×a×40, 277.78 = 80a, a = 3.47 m/s2. Accelerating Force, Fa = ma, Where, m = mass of the vehicle= 2900 kg, a = acceleration= 3.47m/s2, Fa = 2900×3.47,Fa = 10,069.44 N (For all four-leaf springs), For one leaf spring, Fa = 10,069.44/4, Fa = 2517.36 N. Total load acting on the leaf spring is Ft = F + Fa, Ft = 7112.25+2517.36, Ft =9629.63 N

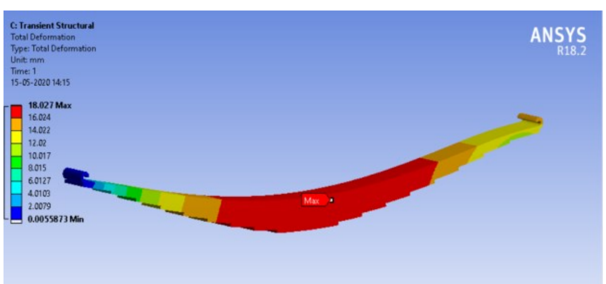


Fig. 11 Total deformations

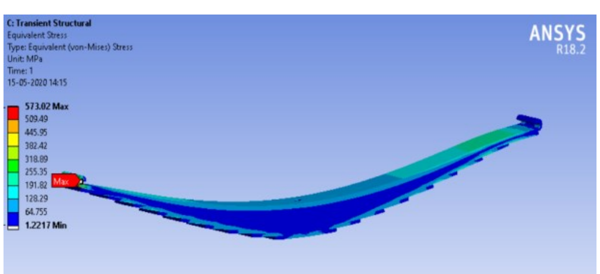


Fig. 12 Equivalent stress

During Deceleration:

Assume the vehicle is slowing down from 60 km/h to 30 km/h. Distance covered by vehicle during deceleration is assumed as 20 m. Load acting on a leaf spring:Vf2 = Vi2 + 2×a×d Where,Vf = Final Velocity = 30 km/h = 8.335 m/s, Vi= Initial Velocity = 60 km/h = 16.67 m/s,a = acceleration,d = distance travelled by vehicle = 20m.(8.335)2 = (16.67)2 + 2×a×20,208.42 = 40a,a = 5.208 m/s2. Decelerating Force, Fd = ma,Where,m = mass of the vehicle= 2900 kg, a = acceleration= 5.208 m/s2, Fd= 2900×5.208, Fd= 15110.21 N (For all four-leaf springs),For one leaf spring, Fd = 15102.32/4, Fd= 3775.58 N. Total load acting on the leaf spring is Ft = F+ Fd, Ft= 7112.25+3775.58,Ft=10887.83N.

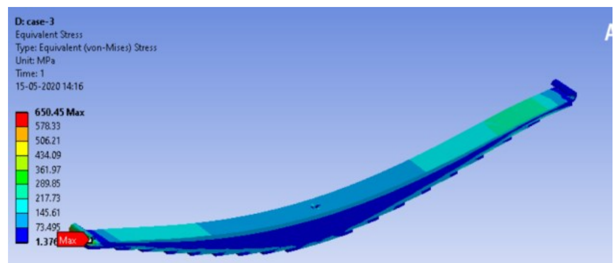


Fig.13 Equivalent stress

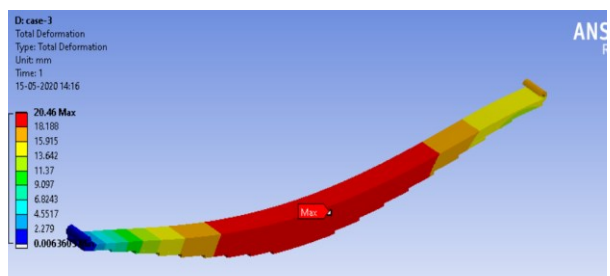


Fig. 14 total deformations

I. *Case-2 In case second kevlar fabric use as leaf spring material.*

Static analysis:-

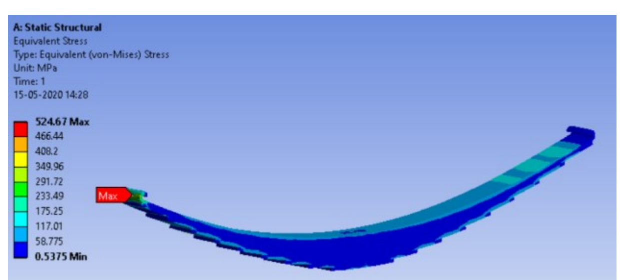


Fig. 15 Equivalent stress

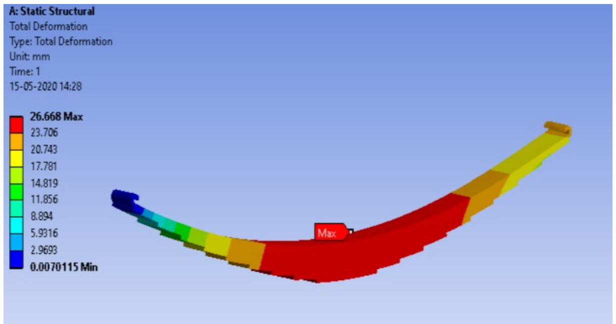


Fig. 16 Total Deformations

Dynamic analysis:-

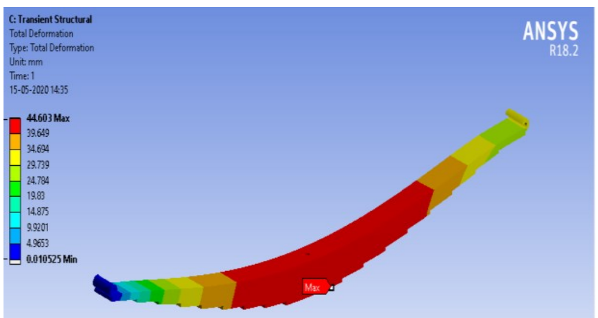


Fig. 17 Total Deformations

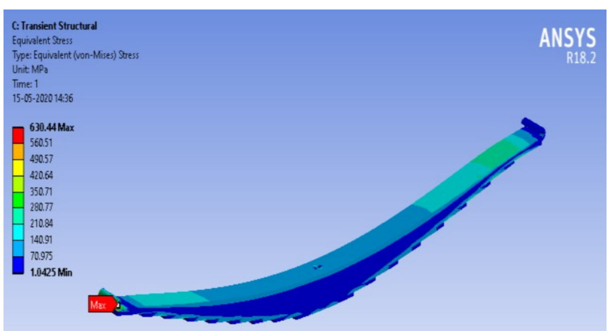


Fig. 18 Equivalent stress

During Deceleration:

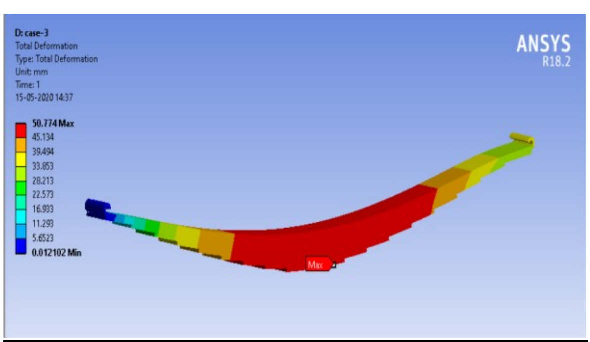


Fig. 19 Total Deformations

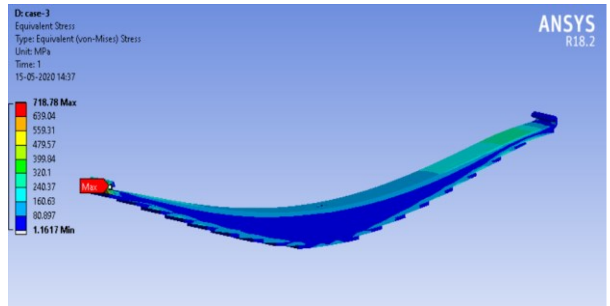


Fig. 20 Equivalent stress

J. *Case-3 In case second low density carbon fiber use as leaf spring material.*

Static Analysis:

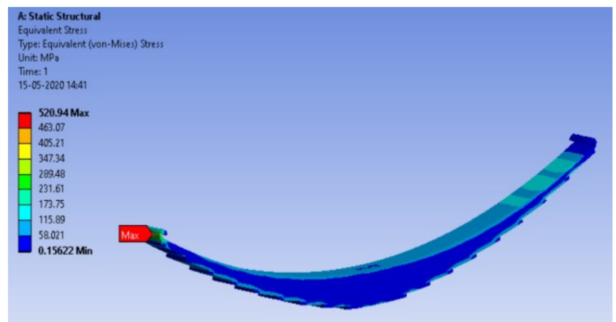


Fig. 21 Equivalent stress

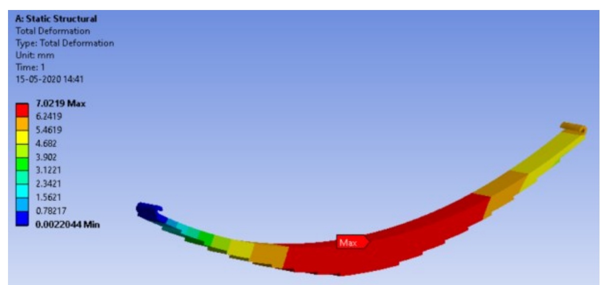


Fig. 22 Total Deformations

Dynamic Analysis:

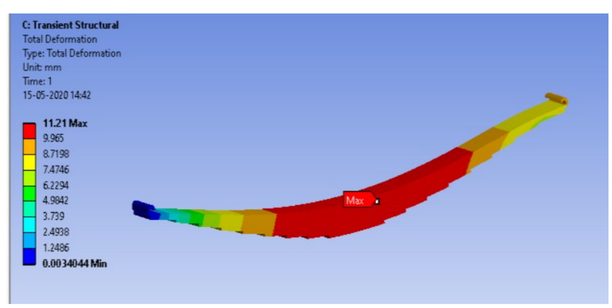


Fig. 23 Total Deformations

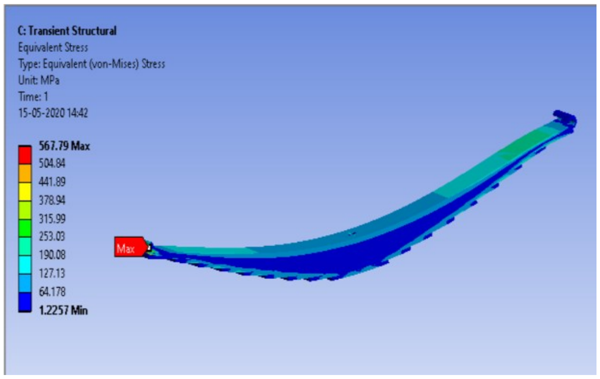


Fig. 24 Equivalent stress

During Deceleration

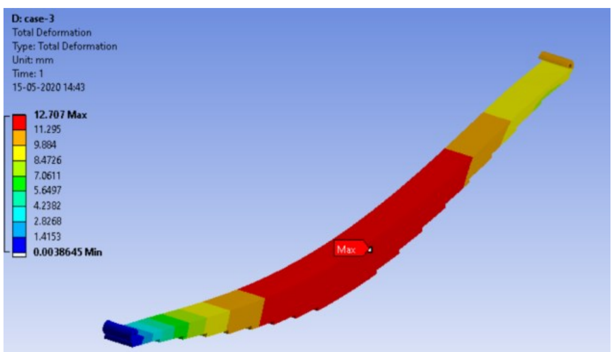


Fig. 25 Total Deformations

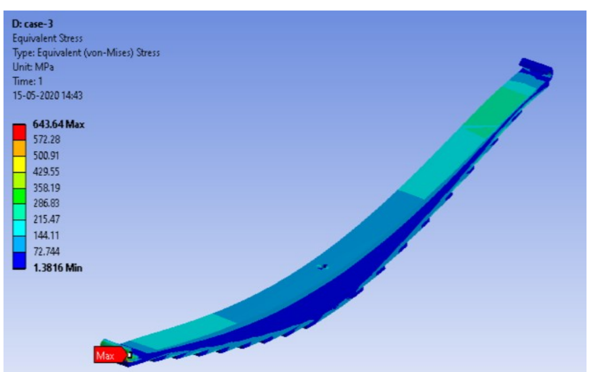


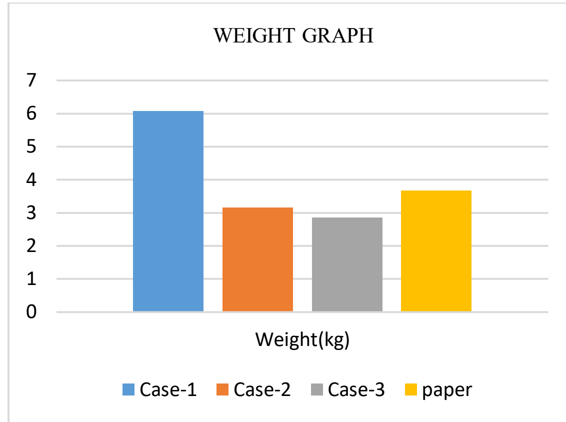
Fig. 26 Equivalent stress

V. Results

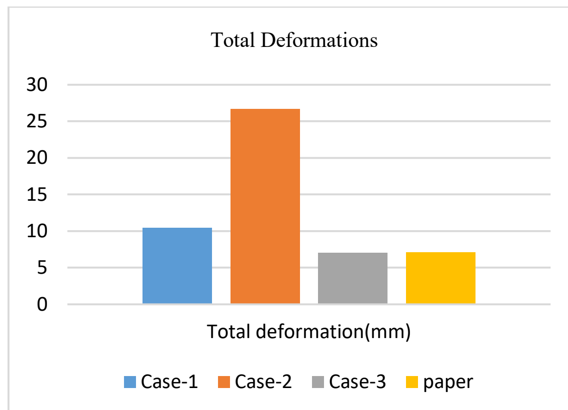
A. *FEA Analysis of leaf spring of static analysis result*

Table 1 Static Analysis Result

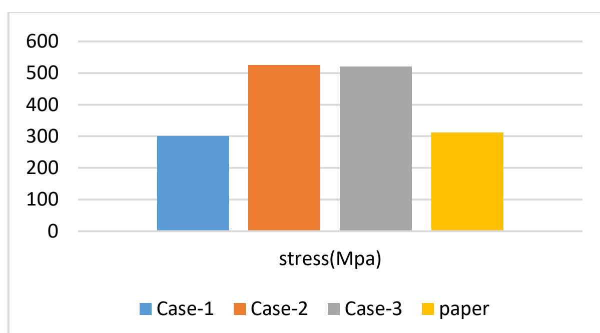
	Case-1	Case-2	Case-3	paper
Weight(kg)	6.075	3.165	2.8471	3.672
Total deformation(mm)	10.49	26.668	7.02	7.1042
stress(Mpa)	300.83	524.67	520.94	312.23



Graph 1 Weight graph



Graph 2 Static Analysis Total Deformations graph

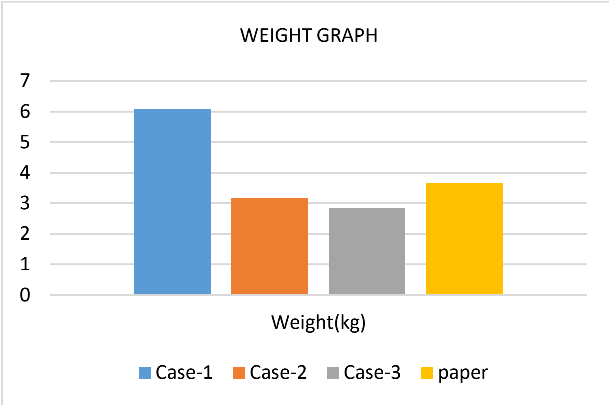


Graph 3 Static Analysis Equivalent stress graph

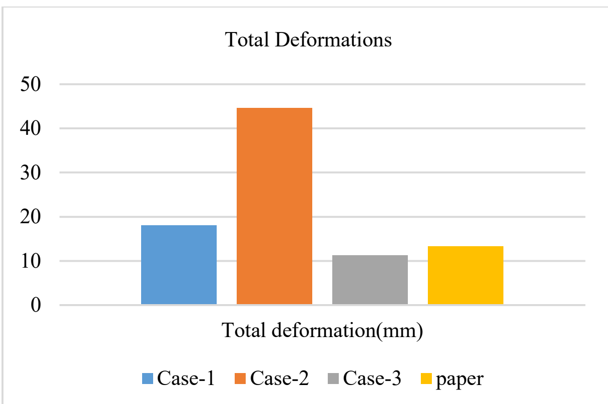
B. *Dynamic Analysis Result*

Table 2 Dynamic Analysis Result

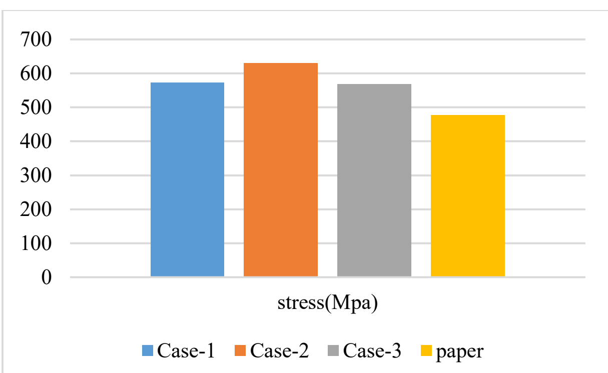
	Case-1	Case-2	Case-3	paper
Weight(kg)	6.075	3.165	2.8471	3.672
Total deformation(mm)	18.027	44.603	11.21	13.223
stress(Mpa)	573.02	630.44	567.79	13.233



Graph 4 Weight graph



Graph 5 Total Deformations graph

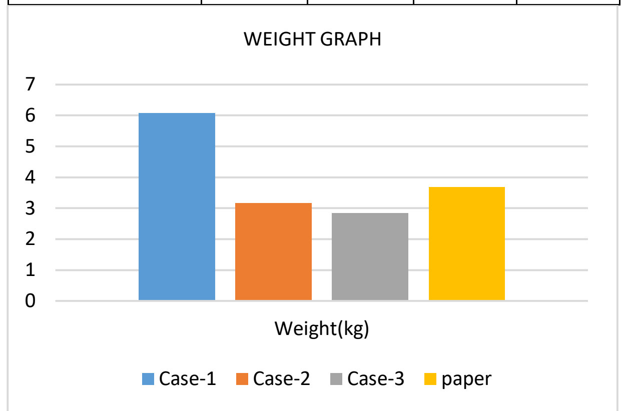


Graph 6 Equivalent stress graph

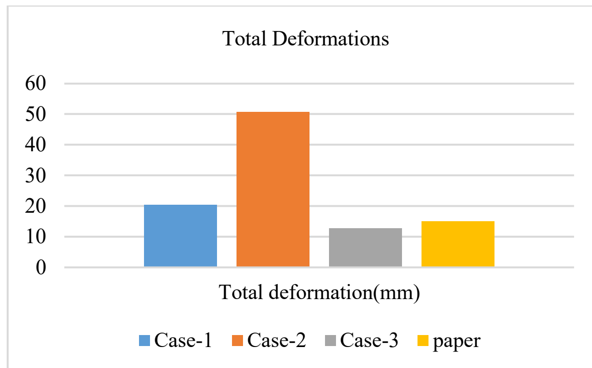
C. During Deceleration Result

Table 3 During Deceleration Result

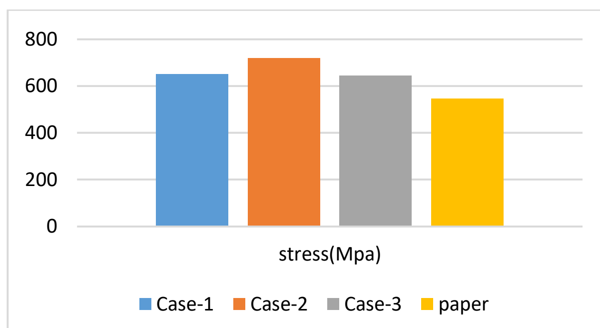
	Case-1	Case-2	Case-3	paper
Weight(kg)	6.075	3.165	2.8471	3.672
Total deformation(mm)	20.46	50.774	12.707	15.005
stress(Mpa)	650.45	718.78	643.64	545.53



Graph 7 Weight graph



Graph 8 Total Deformations graph



Graph 9 Equivalent stress graph

VI. CONCLUSION

The main objective of this paper is weight reduction of Leaf Spring and thereby improving performance of the vehicle. Weight of both Carbon/Glass Epoxy Leaf Springs and carbon fiber obtained using ANSYS Workbench 18.2.

- The total weight of the leaf decrease up to 2.8471.and total deformation decreases up to 7.02mm for static case.

- In dynamic analysis total deformation decreases up to 11.21mm.
- In during Deceleration analysis the total deformation decreases up to 12.707.
- Total efficiency of the vehicle increase due to lower weight.
- Weight reductions improve the performance of system and maintain the vehicle stability.
- Corrosion problem is eliminated.

VII. FUTURE SCOPE

Total weight of leaf spring is optimized by using carbon fibre material. And total strength of the leaf spring will also improve by change in the orientation of the composite fibre at different angle the composite mechanical strength decline with the increase of orientation fibers from 0° to 90°.the strength of the composite depend on the fibre orientations.

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