Finite Element Analysis of Mono Leaf spring by using Hybrid composite Material

Vinod Sheshkar[1], Yogesh Yadav[2]

[1]M.Tech. Research Scholar MGI Bhopal

[2]Asst. Prof. MGI Bhopal

Abstract- **Leaf springs are made out of flat plates. 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. Reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. The attempt is made in the present work to design and analysis of Hybrid composite leaf spring. The design constraint is stiffness with variable thickness and width of leaf spring. The main objective of this work is to analyze the principal stress, Deformation, and weight optimization of leaf spring by using a material Hybrid composite.**

Index Terms- **Leaf Spring, Hybrid composite material, equivalent stress, deformation, principle stress, finite element analysis.**

1. INTRODUCTION

Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. It carries lateral loads, brake torque, driving torque in addition to shock absorbing. 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 unsprung 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. For weight reduction in automobiles as it leads to the reduction of un-sprung weight of automobile. The elements whose weight is not transmitted to the suspension spring are called the un-sprung elements of the automobile.

The dimension of mono leaf spring shown in table 1.

Table 1.Dimensions of composite mono leaf spring

Parameters	Value
Total Length of the spring (Eye to Eye)	1165mm
Free Camber (At no load condition)	165mm

Parameters	At center (mm)	At eye end (mm)
Width	42	22
Thickness	28	16

2. LITERATURE REVIEW

Fuentes et al (2006) described the effective way of preventing fatigue failure by minimizing stress concentrators resulting from design, metallurgical or manufacturing factors. The specific measures to be adopted for lengthening spring life begin with the selection of clean steel, free of surface defects.

The three eye-end designs of a double GRP leaf suspension by finite element analysis and static and fatigue testing were evaluated by Hou et al (2007). The first two designs consisted of integral eye ends where the skin tape layers went around the eye and along the leaf body. These layers were then maintained in place via a transverse wrap using woven GRP tape. The third design consisted of open eye ends. FEA and static test results show that the stress concentration at the tip of the fibres coming back along the leaf body for the first two designs led to a local delamination.

A new concept for designing composite panels with improved performance under compression was

suggested by Christos Kassapoglou (2008). In this concept, the panel consists of two different concentric layups. A Rayleigh–Ritz-based approach to model such rectangular panels under compression is presented. The buckling load and the in-plane stresses everywhere in the plate are determined using an energy minimization approach. The results are compared to detailed finite element models and, for special cases, to other published finite element solutions and are shown to be in good to excellent agreement except for cases where twisting–bending coupling (not accounted for by the present method) is significant.

Demosthenis Rizos et al (2010) inferred the modern slender light weight structures (bridges) exhibit time varying resonant frequencies due to fluctuating loads and environmental conditions. In order to mitigate these vibrations effectively, a TMD device capable of tracking the structural modifications and adapting (tuning) its resonance frequency to that of the structure is highly desirable.

Thippeswamy Ekbote et al. (2012) optimal design and analysis of mono leaf composite spring by finite element analysis. Compared to steel spring, the optimized composite mono leaf spring has much lower stress and the spring weight without eye units is nearly 65% lower than steel spring.

Dixit et al (2013) reviewed to identify the modelling strategies for predicting the mechanical behavior of woven-fabric textile composites. The models reviewed can be classified in two categories, 1. analytical and 2. Numerical ones. The analytical models, sometimes providing instantaneous results, are usually based on various assumptions related to stress and strain fields, while the numerical models, which depend upon the FE mesh, are free from such assumptions.

Y.S. Kong et al. (2014) Fatigue life prediction of parabolic leaf spring under various road conditions. The road VALs has provided even more realistic fatigue life estimation of parabolic leaf spring design when compared to traditional controlled laboratory method.

Sagar Manchanda et al. (2015) Design and Finite Element Analysis of Leaf Spring Using Different Material Properties. E-glass/E-poxy has been found to be suitable for mass reduction of 6.1 kg (approx. 80% than steel) moreover, stress, strain and deformations observed are almost similar which

shows that the vehicle is light weight and can generate more torque and power.

Cristianah O et al. (2016) Design and simulation of fatigue analysis of vehicle suspension system and its effect on global warming. The fatigue life and static analysis of VSS adopting FEA technique provided a reliable design that can be employed in VSS design.

Chen Qian et al. (2017) Fatigue Reliability Design of Composite Leaf Springs Based on Ply Scheme Optimization. The production of composite leaf spring samples, on which the fatigue bench test was conducted, was based on the optimized ply scheme. Results indicate that the fatigue life of composite leaf springs can be improved by using the proposed ply scheme design method.

K.Ashwini et al. (2018) Design and Analysis of Leaf Spring using Various Composites –An Overview. This review is designed to be a comprehensive source for designing a leaf spring using various composites as the Automobile industries are showing keen interest for replacing steel leaf spring with that of a composite leaf spring to obtain reduction in weight, which is an effective measure for energy conservation as it reduces overall fuel consumption of the vehicle.

3. PROBLEM FORMULATION AND RESEARCH OBJECTIVES

According to the brief study of research paper the fallowing point have been observed:

- Maximum deformation results in the form of failure of leaf spring. Minimize the deformation of leaf spring for long life of suspension system.
- Heavy weight is the major issue in the suspension system. Minimize the weight of leaf spring for good suspension.
- Higher stresses will results in failure of suspension system. Reduce the stresses on leaf spring.

4. METHODOLOGY

The steps involved in creating a model of the spring. A model of the spring is first created using Design Modular software. Then the model is imported to ANSYS to complete static structural analysis; the finite element analysis and analytical result of leaf springs has been compared. The entire section deals

with the methodology adopted for the analysis of leaf spring for comparison of stress and deflections. The basic objective of design here is to determine the stress and deflection and comparison of analytical and FEA results. The results obtained from analytical method gives very close results as obtained from FEA. The model of the leaf spring has been analyzed using finite element static analysis under the boundary and loading condition. The FE analysis has been done to obtain the safe design for static loading condition. The design modular models of leaf spring are shown below:
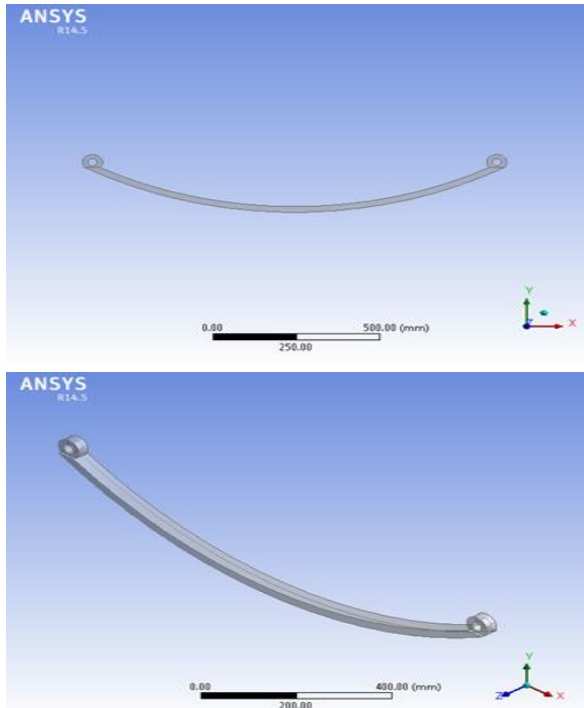
Fig. 1. Model of Leaf spring

4.1 Meshing

The meshing type have been done is quardcore type. The number of node on the meshing are 20681 and the number of elements are 12572. The meshing diagram has shown below
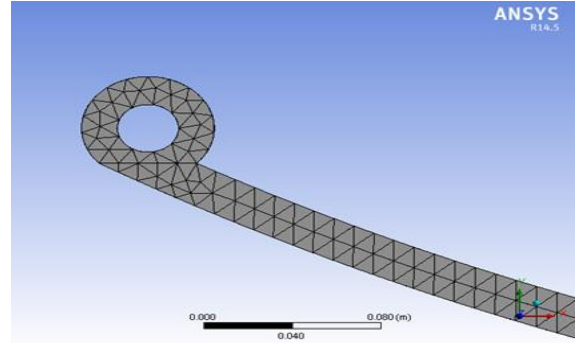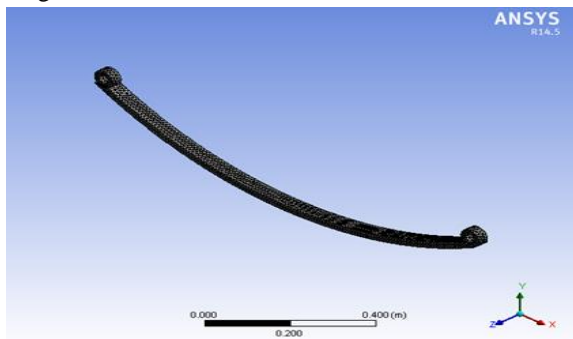
Fig.2 Meshing diag. of leaf spring

Leaf springs consist of one or more flat strips of material loaded as cantilevers or simple beams. They can be designed to provide a compressive or tensile force as they are deflected from their free condition. Leaf springs are capable of exerting large forces within comparably small spaces. Particular force-deflection characteristics can be achieved for a spring by careful dimensioning of the strips and nesting of a number of components. If it is desired to maintain uniform bending stresses over the length of the beam, then the width of the cantilever needs to vary linearly with location. The Maximum stress and deflection of a non uniform width leaf spring is given by
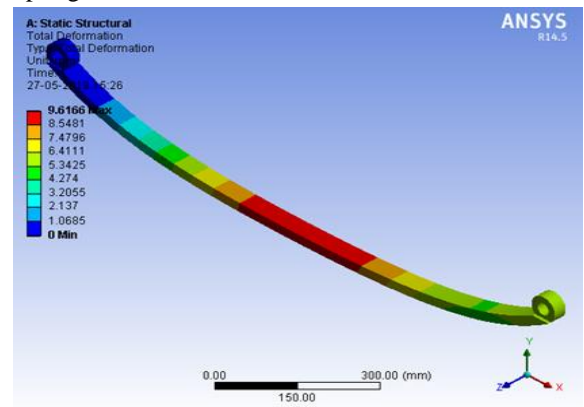
$$\Sigma_{\text{Max}} = \frac{6FL}{bh^2} \quad \& \quad \delta_{\text{Max}} = \frac{6FL^3}{Ebh^3}$$

Where F is the force (N), L is the length (m), E is Young's modulus (N/m2), and b is width in (m) and h is the thickness of leaf in (m).

5. RESULT & DISCUSSION

From the FEA simulation of Hybrid composite mono leaf spring, the various results that obtained are as fallows:

Deformation of Steel and Hybrid Composite leaf spring at load 15 KN
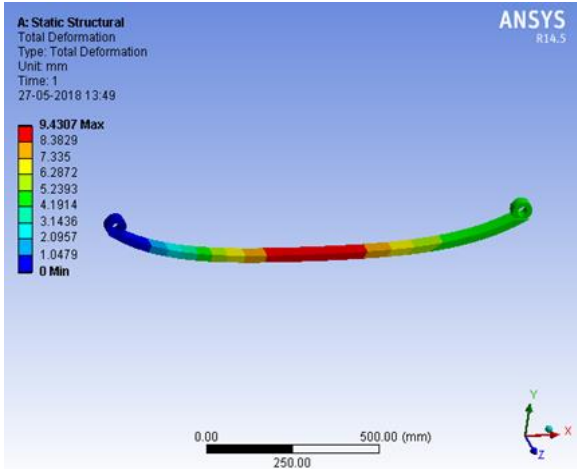
Fig. 3 Deformation of Steel and Hybrid Composite leaf spring at load 15 KN

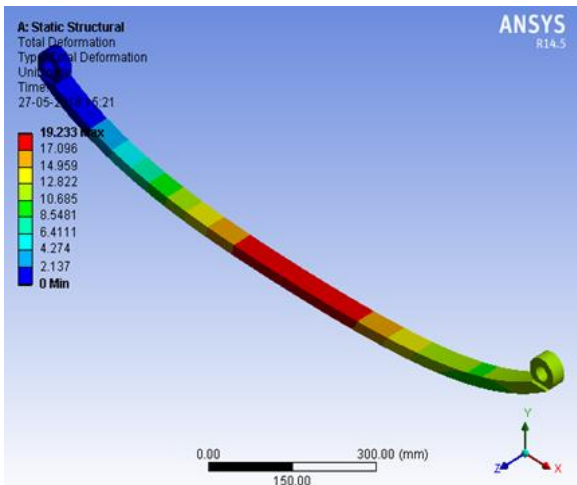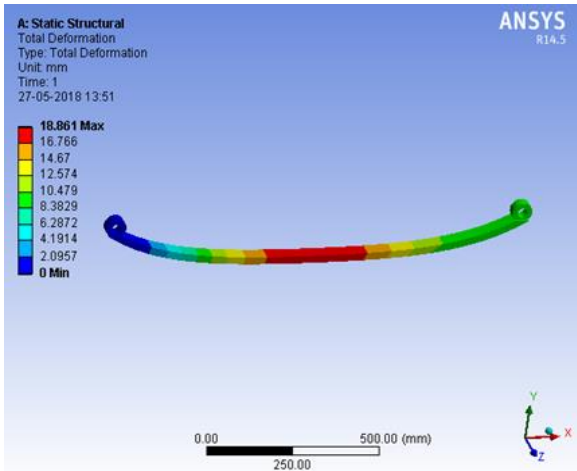Deformation of Steel and Hybrid Composite leaf spring at load 30 KN

Fig. 4 Deformation of Steel and Hybrid Composite leaf spring at load 30 KN

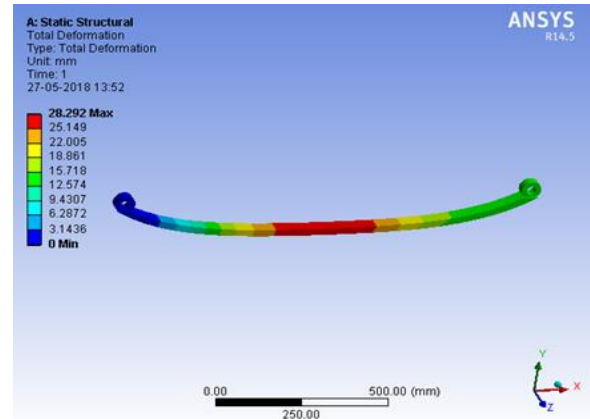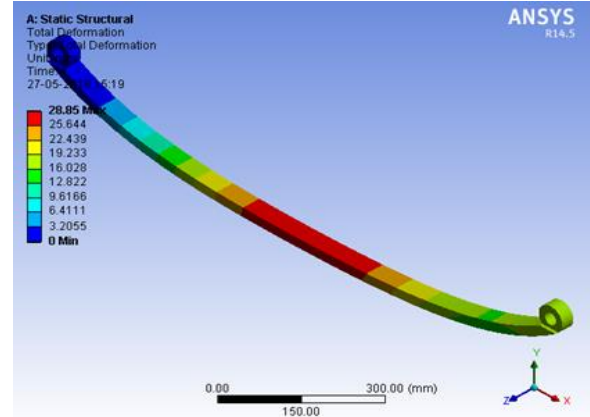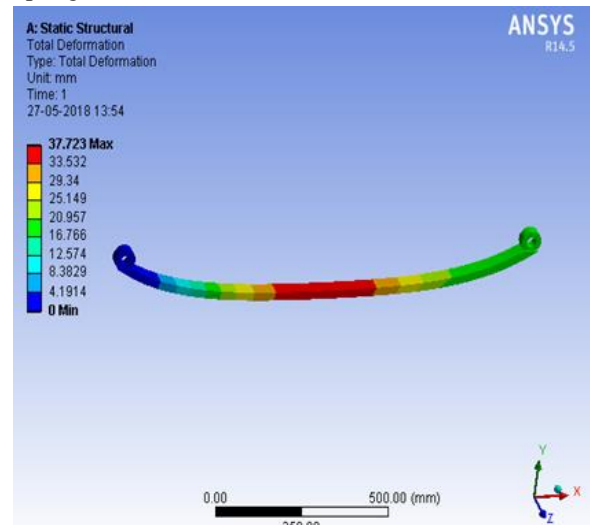Deformation of Steel and Hybrid Composite leaf spring at load 45 KN

Fig. 5 Deformation of Steel and Hybrid Composite leaf spring at load 45 KN

Deformation of Steel and Hybrid Composite leaf spring at load 60 KN
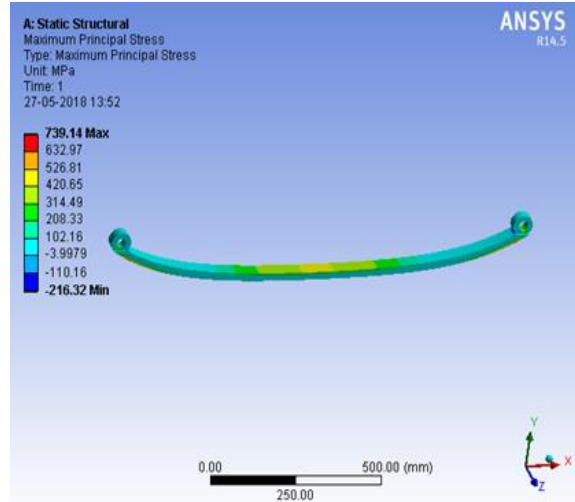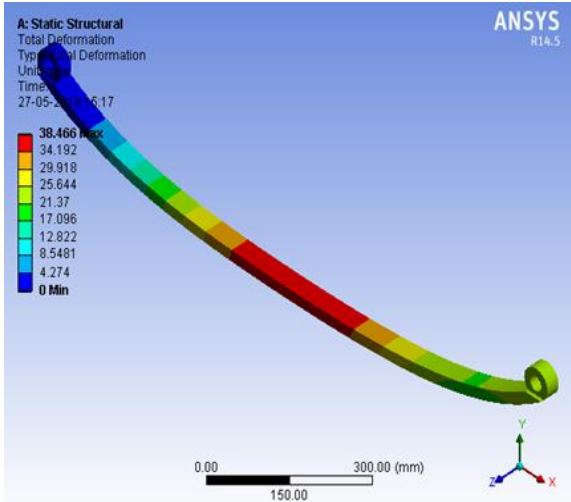
Fig. 6 Deformation of Steel and Hybrid Composite leaf spring at load 60 KN

Principal stress act on steel and Hybrid Composite leaf spring at load 15 KN

Fig. 7 Principal stress act on steel and Hybrid Composite leaf spring at load 15 KN

Principal stress act on Steel and Hybrid Composite leaf spring at load 30 KN
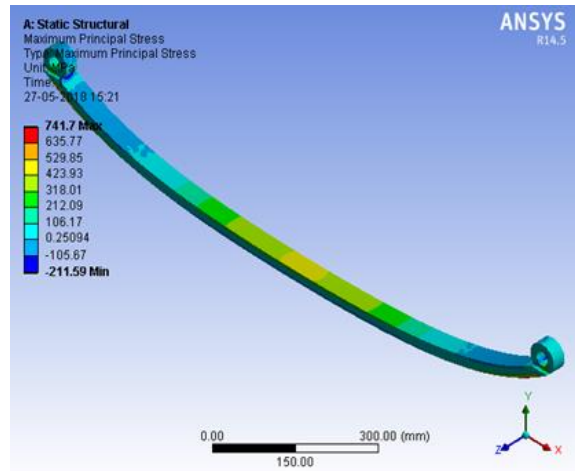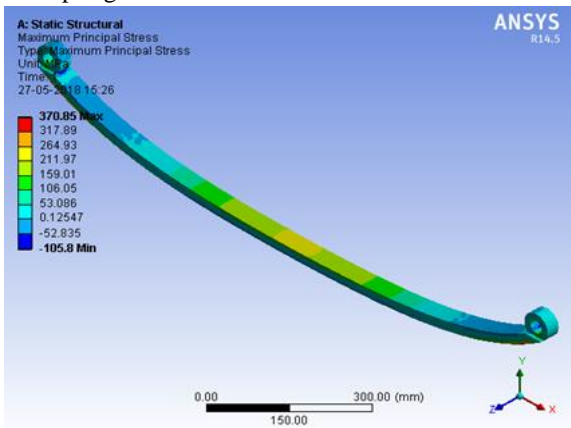

Fig. 8 Principal stress act on steel and Hybrid Composite leaf spring at load 30 KN

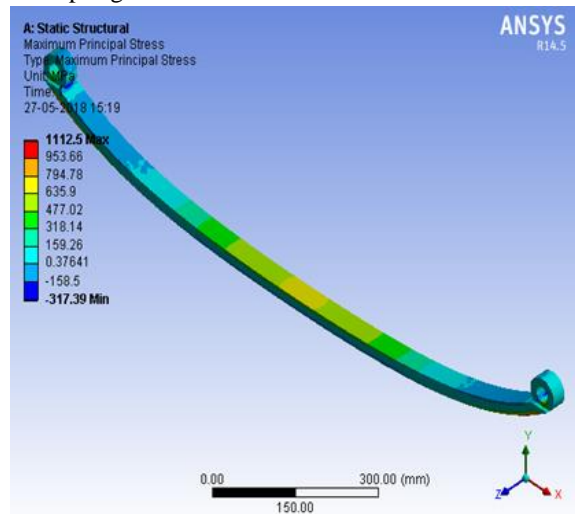Principal stress act on Steel and Hybrid Composite leaf spring at load 45 KN
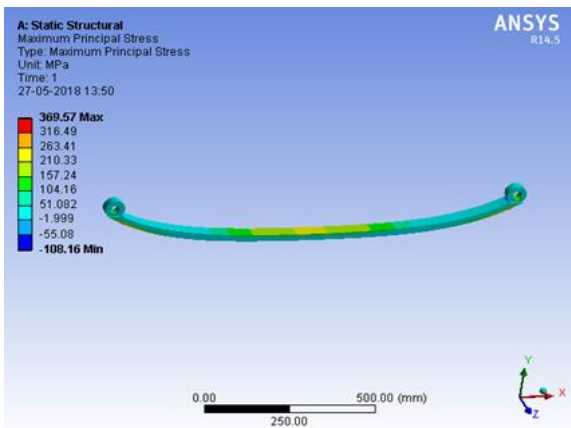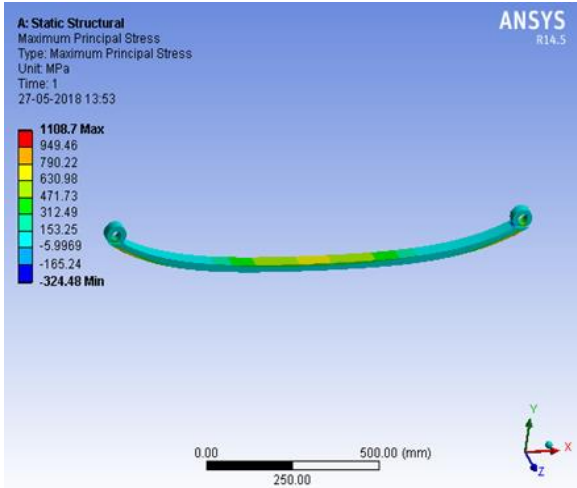
Fig. 9 Principal stress act on steel and Hybrid Composite leaf spring at load 45 KN

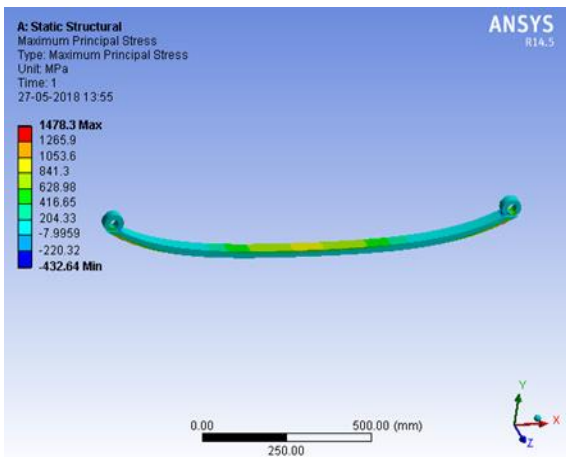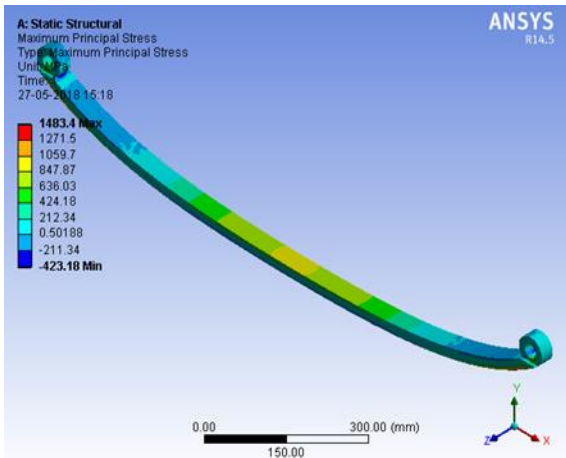Principal stress act on Steel and Hybrid Composite leaf spring at load 60 KN

Fig. 9 Principal stress act on steel and Hybrid Composite leaf spring at load 60 KN

Table 5.1 Tabular representation of results on varying load.

Load (KN)	Total Deformation (mm)		Maximum Principal Stress (Mpa)	
	Steel	Hybrid Composite	Steel	Hybrid Composite
15	9.6166	9.4307	370.85	369.57
30	19.233	18.861	741.7	739.14
45	28.85	28.292	1112.5	1108.7
60	38.466	37.732	1483.4	1478.3

The varying deformations of leaf spring on various loading conditions have been shown by graph below.
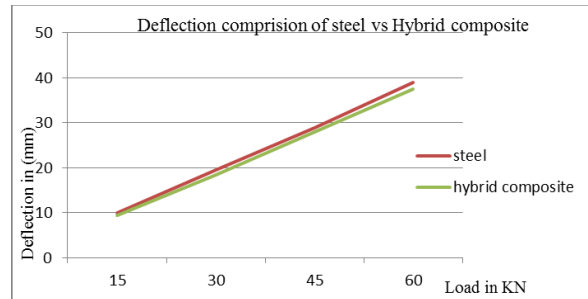
Fig. 11 Deformation of Steel and Hybrid Composite leaf spring at varying load.
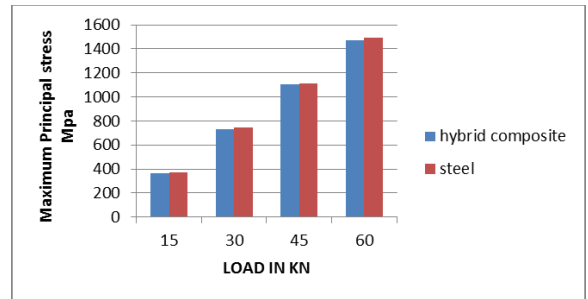

Fig. 12 Principal stress act on Steel and Hybrid Composite leaf spring at varying load.

Table 5.2 Results Compression of Total deformation of leaf spring

Load	Steel	Hybrid Composite	% Variation
15 KN	9.6166 mm	9.4307mm	2%
30 KN	19.233 mm	18.861 mm	2%
45 KN	28.85 mm	28.292 mm	2.12%
60 KN	38.466 mm	37.732 mm	3%

Table 5.3 Results Compression of Mass reduction of leaf spring

Material	Density (Kg/ m^3)	Mass (Kg)	mass reduction %
Steel	7850	10.75	
Composite	2550	3.49	40.68 (as composite)
Hybrid Composite	1510	2.07	80.76 as steel)

6. CONCLUSIONS

From the above analysis and results compression it can observed that the best suitable material for the suspension system like as leaf spring that are the part of our study have a better replacement of structural steel is available and known as Hybrid Composite. Hybrid Composite is better than steel and other composite material in fallowing criteria that are the deformation occurs on varying loading condition is less than steel which shows that the Hybrid composite is the best suitable material for suspension system. Principal stresses which are acting on the leaf spring are less than the stresses acting on the structural steel and other composite materials. Mass containing on the Hybrid composite Leaf Spring are nearly 40 % less as compare composite material and 80 % less than the structural steel. All the above points show that the Hybrid composite is the best suitable material for leaf spring.

Future Scope of work: It has observed from this study the Hybrid Composite is a best available material for leaf spring of suspension system. It's an ecofriendly material. The work that can be done in this field in future is experimental analysis.

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