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Design and Analysis of "Mahindra Bolero" Leaf Spring for Optimum Utilization of Material, using ANSYS

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Abstract:-- **In automobile, the suspension leaf spring is one of the potential icons for weight reduction as it accounts for ten to twenty percent of unsprung weight.While reducing weight, the strength has to be maintained by optimising cost. In this paper, the design and analysis is done by replacing material of steel leaf spring by Aluminium Reinforced with Boron Carbideand composite materials like E-glass Epoxy and 50% Kevlar fibre. The objective of the work is to compare deflection, stress,and stiffness of steel leaf spring with that substitute materials. The study aim's in the rear leaf spring analysis of "MahindraBolero". Comparative study of leaf spring made by steel and composite materials is tabulated in the paper. CAE Analysis is done in ANSYS.**

***Index Terms*:-- Leaf spring, Static Analysis, Composite materials, Aluminium Reinforced with Boron Carbide, Creo 2.0, ANSYS 14.5**

I. INTRODUCTION

The Automobile Industry has shown keen interest for replacement of steel leaf spring with that of composite leaf spring, since the composite material has high strength to weight ratio, good corrosion resistance and tailor-able properties [1]. In present study, the materials selected are E-glass/epoxy, Kevlar and Boron/Aluminium which are used against conventional carbon steel.

Semi-elliptic leaf spring is most commonly used for light and heavy commercial vehicles which have number of leaves whose length gradually decreases. The master leaf has eye on its both end and other graduated leaves are bound together by means of central bolt. The leaf spring is mounted on the rear axle on which the whole vehicle rests. Chassis is mounted on the axle with the help of this spring which isolates the vehicle from road shocks such as sudden bounce, sway, pitch etc. [2]. When sudden projection comes on the way, obstacle on the road leads to wheel movement in upward and downward direction in the rear axle, thereby making deflection of spring. Due to deflection of the springthe leaf tends to straighten lengthwise. Due to the use of spring, additional fluctuating stresses on automobile frame are reduced to a reasonable level. Also the deflection of spring needs to be controlled to avoid pitting or rolling, while in motion.

A spring with constant width and thickness was earlier fabricated by hand lay-up technique which is very simple and economical. In this paper the Leaf spring is modelled and assembled in Creo software and is imported in ANSYS. Computer Aided Analysis is done using FEA concept and in which the fatigue life of both steel and composite leaf is compared using ANSYS software. Stresses, deflection and stiffness results for selected materials is plotted.

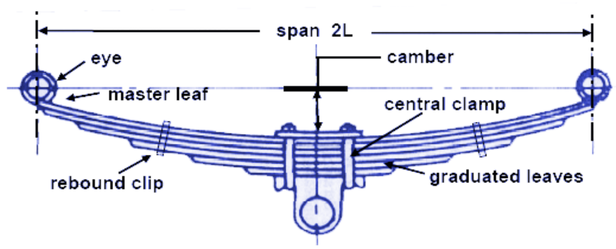

Fig: 1 Schematic representation of Leaf Spring [3]

II. OBJECTIVES

i) Change in material properties will yield high strength as compared to the conventional steel material hence material optimization will be observed.

ii) The weight of the complete stack assembly of the composite leaf spring will have reduced weight as compare to the steel leaf spring.

iii) Optimization of complete manufacturing cost.

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iv) Composite material will increase energy storage capability of leaf spring which insures better suspension.

III.LITERATURE REVIEW

Towards developing the efficient spring, **Preshit B. Waghmare** et al., [4] have studied about the replacement of steel leaf spring with *fibreglass composite leaf spring* due to high strength to weight ratio. Hence the composite leaf spring in which stresses are developed are much lower than steel spring without affecting the strength and stiffness have proved more efficient. The only disadvantage composite spring gives is a low chipping resistance, when it is subjected to poor road conditions .The natural frequencies are compared with excitation frequency at different speeds and road irregularities and found that both of them are almost same for steel and composite spring. Hence this study concludes that composite leaf spring is much more efficient, provided vehicle should not cross the natural frequency.

Ms.SurekhaSangleet al. [5] has implemented about replacement of conventional leaf spring with *carbon/epoxy* composite material which will increase strength to weight ratio. The study concluded that the composite material of carbon/epoxy is more reliable than the conventional leaf spring. It can be observed from the comparison that the deflection and bending stress induced in carbon/epoxy composite leaf is lesser than the conventional steel leaf spring.

More varieties of glass/epoxy are analysed by **B.VijayaLaxmi**et al. [2] for semi elliptical leaf spring which is almost universally used in light and heavy vehicles instead of standard leaf spring. The models of leaf spring using carbon steel, *E-glass, S-glass and C-glass* are analyzed in COSMOS and concluded that E-glass is better than carbon steel upto 8 leafs, as though the stresses are higher, it has good yield strength and less weight and hence easy to manufacture.

ShivamNandevet al. [7] concluded that under static load condition the weight reduction by 25kg when Aluminium Reinforced with Boron Carbide is used and almost 22kg when E-glass is used. Deflection of Composite leaf spring is less as compared to steel leaf spring with same load condition. Here strength validation is done using structural analysis in ANSYS

T. N. V. Ashok Kumar et al. [8] have concluded that by comparing three materials i.e. *M.S., 50% Kevlar Fibre and S2 glass*, 50% Kevlar fibre is better since its weight is less and stress value and frequencies analyzed are less than S2 glass and M.S. As per the studies, the material with maximum strength and minimum modulus of elasticity in longitudinal direction is more suitable material for leaf spring. So the spring of nine leaf of M.S. is replaced with the S2 glass and Kevlar.

Mr.TharigondaNiranjanBabuet al. [9] presented a general study on the performance comparison of *composite (E-glass/epoxy and Jute E-glass)* leaf spring and conventional leaf spring. Out of them, Jute E-glass/epoxy proved better on Weight, deflection and stress scales. Further ANSYS analysis shows that the introduction to composite materials has made it possible to reduce the weight, cost and deflection without any reduction in load carrying capacity and stiffness.

IV. DESIGN METHODOLOGY FORMAHINDRA BOLERO LEAF SPRING

Modelling of the Leaf Spring:

Fig. 2 Leaf Spring Designed in CREO 2.0Environment

The rear leaf spring of "Mahindra Bolero" is considered for design and analysis purpose. The model is created as per the actual measured dimension and assembled in Creo 2.0. The final component is converted into an *.igs* file to export into Ansys for analysis.

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Table: 1 Dimension of Leaf Spring of Mahindra Bolero

Parameters	**Value**
Span of leaf spring	1200 mm
Width of leaf spring	70 mm
Thickness of leaf spring	8 mm
Radius of curvature	1140 mm
Inner diameter of eye	50 mm
No. of graduated leaves	5

Material for the leaf spring:

The traditional material used for the leaf spring is usually a plain carbon steel having 0.9 to 1.0% carbon. The leaves are heat treated after the forming process. The heat treated of steel of spring products are having greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties [10].

E-glass epoxy is used in industries because of their strong adhesive properties, high stiffness, toughness and low cost [11]. Aluminium reinforced with boron carbide and E glass epoxy has high elastic strain energy storage capacity and high strength to weight ratio compared with mild steel [7]. Hence less weight and less deformation can be achieve without reducing load carrying capacity. 50% Kevlar Fibre has low density, low stress value and high strength at low weight. It also has good impact and abrasion resistance with high modulus [12].

Table: 2 Mechanical Properties of standard Material [7], [12]

Material	**Ultimate tensile (MPa)**	**Yield tensile (MPa)**	**Young's modulus (MPa)**	**Poisson's ratio**	**Density (kg/m^3)**
Steel	800	572.3	200000	0.285	1000
E-glass/ epoxy	900	205	24000	0.300	1520
Boron/ Al	-	120	144400	0.315	1020
Kevlar	1800	1380	76000	0.360	1440

Calculation of load acting on a leaf spring [13]:
Weight of a Vehicle= 2700 kg [14]
Maximum load carrying capacity = 1500 kg
Total weight = 2750+1500 = 4200 kg
Taking FOS = 2, acceleration due to gravity = 9.81 m/s^2
Therefore, Total weight = 4200*9.81 = **41202 N**

Analysis of the Leaf Spring:

The static analysis of the Leaf Spring is carried out using ANSYS workbench 14.5 to find out maximum deflection and von Mises stress when maximum static load acts at the centre of the leaf spring. The spring behaves like a simply supported beam. Here the load of 41202 N is applied in Y-direction to study the deformation of spring. The obtained displacement contour and von Mises stress distribution for Steel, E-glass/Epoxy, Boron/Aluminium, Kevlar are shown in Figure (3) to (10) respectively.

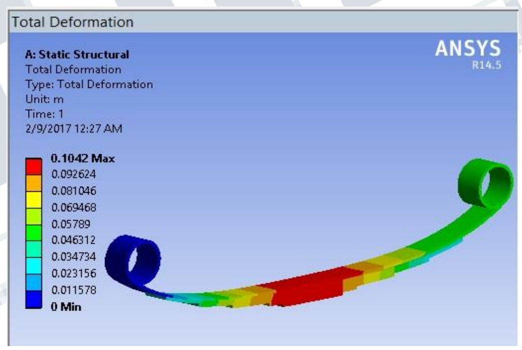

Fig. 3 Displacement Contour for Steel Leaf Spring

Fig. 4 Displacement Contour for E-glass/ epoxyLeaf Spring

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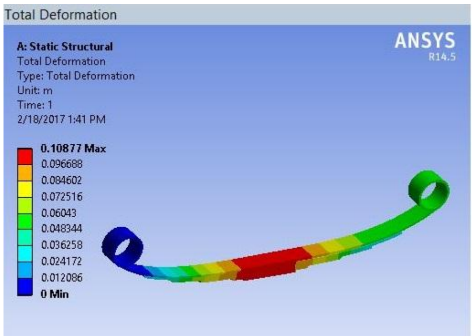

Fig. 5 Displacement Contour for Aluminium /Boron Leaf Spring

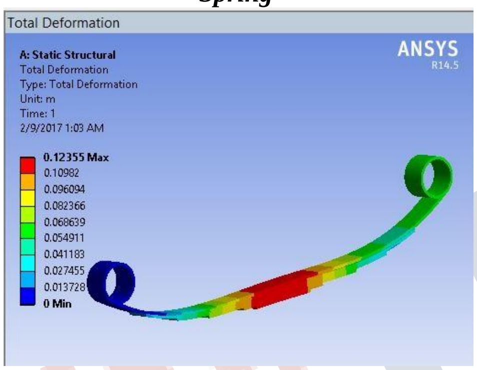

Fig. 6 Displacement Contour for Kevlar Leaf Spring

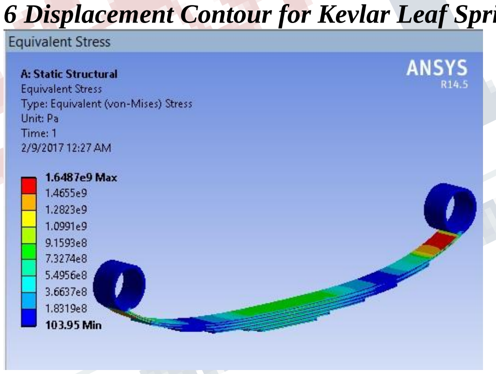

Fig.7 Von Mises Stress Distribution for Steel Leaf Spring

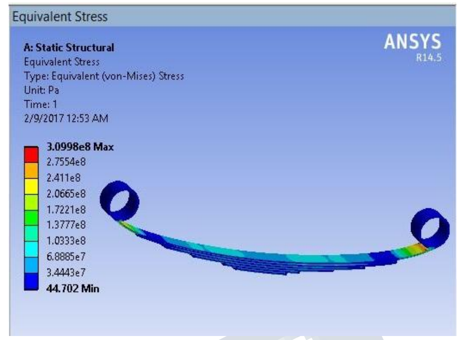

Fig.8 Von Mises Stress Distribution for E-glass/Epoxy Leaf Spring

Fig.9 Von Mises Stress Distribution for Aluminium/Boron Leaf Spring

Fig.10 Von Mises Stress Distribution for Kevlar Leaf Spring

V. RESULTS

Material	Static Load (N)	Maximum Deflection (mm)	Maximum von Mises stress (MPa)	Stiffness (N/mm)

Steel	41202	104.20	16.4870e2	395.41
E-glass/Epoxy	41202	92.50	3.0998e2	445.42
Boron/Al	41202	108.77	11.5640e2	378.80
Kevlar	41202	103.55	8.0135e2	397.89

VI. CONCLUSION

In this research work, the leaf spring is designed in Creo and the static analysis is carried out using ANSYS 14.5. From the obtained results, it can be concluded that:

i) The comparative study has been made between steel and different composite materials like E-glass/Epoxy, Boron/Aluminium and Kevlar in respect of deflection, stress and stiffness.
ii) Stress induced in composites leaf spring is much less than that of one made up of steel.
iii) E-glass Epoxy has minimum deflection and stress and posses high stiffness as compared to other composites.
iv) Material saving in case of composite leaf spring will lead to weight reduction and hence less specific fuel consumption.
v) Composite leaf spring has less cost as compare to steel leaf spring

Hence, desired composite leaf spring has good performance characteristics as compared to conventional steel leaf spring with similar design specifications.

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