

Experimental Investigation on Laminated Composite Leaf springs Subjected to Cyclic Loading

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Abstract – An automobile industry have an interest in replacement of conventional leaf spring with composite leaf spring to get better performance with less weight. This paper deals with by replacing the conventional leaf spring with composite leaf spring. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle were taken to fabricate the special die which is further used to manufacture the composite leaf spring. A single leaf with constant cross sectional area similar to that of conventional leaf spring (CLS) in each case such as bidirectional glass fiber reinforced plastic (GFRP), bidirectional carbon fiber reinforced plastic (CFRP), bidirectional carbon-glass reinforced plastic (C-GFRP) and bidirectional glass-carbon reinforced plastic (G-CFRP) were fabricated by hand layup technique and tested by universal testing machine. By using universal testing machine, load per deflection and maximum load that a leaf spring can withstand were measured. The cyclic loading with specific duration was given to the above mentioned composite leaf springs by using a laboratory designed loading set up through milling machine. From the experimented results it was observed that if conventional leaf springs are replaced by composite leaf springs an appropriate amount of weight reduction and there by improved vehicle performance could be achieved.

Keywords – Composite leaf spring, cyclic loading, flexural strength, Composite materials, Weight reduction.

I. INTRODUCTION

Now-a-days the main focus of automobile industry is weight reduction. The automobile industry have shown increased interest for innovations, any modification, or implementation to reduce weight .This is done because of good characteristics given by the composite materials such as damping quality, corrosion resistance high strength to weight ratio etc. Weight can be reduced by introduce of better materials, better manufacturing process and optimization of design. So the composite are used as a material in place of conventional leaf spring. By using the composite materials in leaf spring it reduces the weight by 70%.This helps the vehicle with increasing fuel efficiency and riding qualities to be improved. Several researchers are devoted in the application of composite materials in automobile.

An author showed that increase in stiffness , natural frequency and reduced in stress , weight in composite leaf spring[1-5].Researchers have presented a genetic algorithms for optimal design of composite leaf spring .They found that huge weight was reduced in existing spring weight on optimization using genetic algorithms[6].An author described the design and manufactured of a functional composite spring for a solar powered light vehicle .Many testing was carried out during actual driving condition. They found that by placing of rubber pads on inside surfaces of the blades to cushion bottoming of the spring. It will reduces the impact load transferred to the chasis while suspension reaches the full deflection [7].For the freight rail application the researchers shows the paper in the design evolution process of a composite leaf spring. They described the three design of eye end attachment for a composite leaf spring [8].Author demonstrated for the application of light and heavy trucks composites elliptical spring meet the requirements with substantial weight saving. Adequate works have been carried out in the past two decades on design ,analysis and optimisation on composite leaf spring[9-11]. C.Subramanian et al fabricated the discontinuous fiber reinforced thermoplastic composite leaf spring by injection moulding and investigated the short term flexural creep performance.HRZ model was used for the creep performance evaluation. Results shows that HRZ model was found to be useful for predicting the short term creep performance[12]

Researchers was found out by fabricating, testing and comparing of natural fiber reinforced composite (NFRP)and glass fiber reinforced composite (GFRP)leaf spring by hand layup method and universal testing machine. From the result they found out NFRP leaf spring reduced in stress and deflection without compromising the stiffness in analytical and experimental[13].The U.S.Ramakanth et al was conducted the fatigue analysis with goodman's approach, soderberg's approach, Gerber's approach and mean stress approach.

The results shows that Soderberg's approach shows a maximum value of life cycles compared to the others [14]. The author concluded by comparing steel and composite leaf spring under static loading condition by modelling and analysis. From the result it was found that mono composite leaf spring was so effective than steel leaf spring [15].

In this present work, three-leaf steel springs used in Tata ace mini truck is replaced with the composite leaf spring, that is made of bidirectional glass fiber reinforced plastic (GFRP), bidirectional carbon fiber reinforced plastic (CFRP), bidirectional carbon-glass reinforced plastic (C-GRP), and bidirectional glass-carbon reinforced plastic (G-CRP). The dimensions of center leaf for both steel leaf spring and composite leaf spring are considered to be same. The primary objective is to compare the load, deflection and weight saving of the composite leaf spring. Further the composite leaf springs are tested for its left over strength, with the introduction of cyclic loading. For this analysis, a cam like arrangements has been designed and fabricated to expose cyclic loading for the leaf springs through milling machine.

II. MATERIAL PREPARATION

The dimensions of an existing conventional middle steel leaf spring of a Tata ace mini truck were taken and accordingly die is fabricated as shown in the Figure 1. By using the hand layup method, the GFRP laminates, CFRP laminates were made as per the following procedures. The glass fiber of 600gsm of bidirectional are taken and cut into 18 layers of size 900mm x 60mm. Then the resin combination of LY556 epoxy resin and HY951 hardener is mixed in the ratio of 10: 1 by weight. Wax coating was applied on the surface of the die to get good surface finish and also its helps during removal of the leaf from the die. Layers of the fabric mat are stacked by one over the other until the required thickness has been reached. In between the layers, resin mixture was poured and rolled out by using rollers to remove the entrapped air bubbles. Care was taken to ensure complete wetting of fibers and removal of entrapped air and excess resin. 18 layers of glass fiber mats were placed over another with the resin mixture on the special die. A wax coated steel plate of similar dimension of leaf spring was placed on the top of the laminate with same counter weight, so as to ensure the uniform distribution of resin mixture and to get good surface finish of the composite leaf spring.



Fig 1. Die used for composite leaf spring fabrication

The set up was allowed to cure for 24hrs with atmospheric room temperature. Then after 24 hours, the leaf was removed from the die. Finally laminate was trimmed by using grinding machine, to get the required dimensions. Same procedure is followed for fabrication of carbon fiber laminate. For fabrication of carbon-glass laminates, 10 layers of carbon fiber fabric and 8 layers of glass fiber fabric were used. The four types of composite leaf spring fabricated are shown in the Figure 2. Two laminates, one with starting and ending layer of carbon fiber mat and other with starting and ending layer of glass fiber mat were fabricated by stacking one over another with appropriate resin mixture.



Fig 2. Fabricated composite leaf spring.

III. EXPERIMENTAL TECHNIQUES

In this present study, the composite leaf spring deflection test is done by using 40 tons capacity of universal testing machine. Deflection for various loads, maximum load, and maximum deflection for mono glass fiber leaf spring, mono carbon fiber leaf spring, mono carbon- glass fiber leaf spring, and mono glass-carbon fiber leaf spring were measured by using universal testing machine. The spring is loaded from zero to the prescribed maximum deflection and back to zero. The load is applied at the Center of the spring. The vertical deflection of the spring Center is recorded in the load interval of 100N, for mono leaf spring as shown in the Figure 3. The deflection against loading of the various types of springs and weight of the springs are shown in the Table 1.



Fig. 3. Testing of composite leaf spring using Universal Testing Machine

TABLE I
Weight of the mono leaf springs

Leaf	Weight in kg
GFRP	0.690
CFRP	0.720
G-	0.782
C-	0.740
CLS	2.38

Further, the composite leaf springs are tested for its left over strength, with the introduction of cyclic loading. For this analysis, a cam like arrangements has been designed and fabricated to expose cyclic loading for the leaf springs through milling machine. The maximum deflection among the composite leaf spring is fabricated and approximately taken as 60mm with reference to the Table 2.

TABLE 2
Deflection test for various leaf spring

Load in N	Deflection in mm				
	Conventional Leaf	Glass fiber Leaf	Carbon fiber leaf	Carbon - glass leaf	Glass - carbon leaf
100	6	9	7	8	7
200	9	18	15	20	14
300	14	31	29	32	23
400	18	42	40	41	30
500	24	55	53	50	41

Hence initial cyclic loading of 1/3rd total deflection for specific duration was given to the composite leaf springs through the laboratory designed cam setup that is shown in the figure 4.



Fig. 4. Cam arrangement set up for cyclic loading in milling machine

The cyclic loading frequency was fixed as 63 cycles per minute. By increasing the exposure time, the number of cycles of loading was increased. As initial trial, each category of specimens are given 3780 cycles of loading and is eventually tested for its load bearing capacity against deflection using universal testing machine as shown in Table 3.

TABLE 3
Deflection at 3780 cycles of loading

Load in N	Deflection in mm			
	Glass fiber leaf	Carbon fiber leaf	Carbon - glass leaf	Glass - carbon leaf
100	9	7	8	7
200	17	15	18	14
300	26	23	20	21
400	34	31	27	26
500	41	39	36	33

TABLE 4
Deflection at 7560 cycles of loading

Load in N	Deflection in mm			
	Glass fiber leaf	Carbon fiber leaf	Carbon - glass leaf	Glass - carbon leaf
100	8	6	7	7
200	16	15	18	14
300	25	20	20	19
400	32	28	26	25
500	39	37	34	31

TABLE 5
Deflection at 11340 cycles of loading

Load in N	Deflection in mm			
	Glass fiber leaf	Carbon fiber leaf	Carbon - glass leaf	Glass - carbon leaf
100	8	6	6	5
200	15	14	16	14
300	24	19	20	18
400	30	25	25	23
500	37	35	32	30

Similarly, by increasing the exposure time, the cyclic loading was increased to 7560 cycles as shown in the Table 4, and 11340 cycles and tested accordingly as above shown in the Table 5.

IV. RESULTS AND DISCUSSION

Various types of composite leaf springs were tested for its maximum load bearing capacity and maximum deflection, with and without subjected to cyclic loading, with a help of a universal testing machine. Mono steel leaf spring weighs 2.38kg whereas GFRP composite leaf spring weighs only 690 grams. The static load is gradually applied to the conventional steel leaf spring and it was observed that it takes the maximum load of 800N. Whereas, the composite leaf springs takes the maximum load of 500N. Hence 500N is fixed as the

maximum load to obtain the load-deflection curve. The load-deflection curves for various mono leaf springs are shown in the Figure 5.

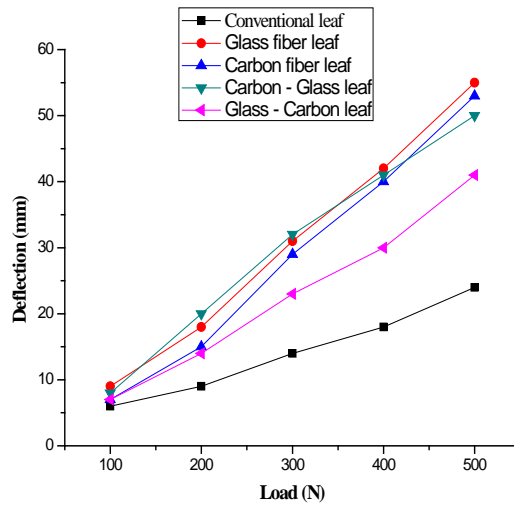


Fig. 5. Load Vs Deflection curve

From the above graph, by comparing the steel leaf spring and composite leaf spring, it was observed that 62.5% of loads are beared by composite leaf spring. But at the same time, 71% of weight is reduced by the composite leaf spring. Hence the composite leaf springs are further tested for its load bearing strength against cyclic loading. For this analysis, a cam like arrangement has been designed and fabricated to expose the cyclic loading for the various composite leaf springs through milling machine. As the initial trial, each category of specimen i.e. various composite leaf spring are given 3780 cycles of loading with a constant deflection of 20mm, using milling machine and eventually tested for the load bearing capacity. Similarly by increasing the exposure time, the cyclic loading was increased to 7560 cycles and 11340 cycles and load carrying capacity test was repeated as above. The load deflection curve for the four types of composite leaf springs namely GFRP, CFRP, C-GFRP and G-CFRP are shown in the Figure 6, Figure 7, Figure 8 and Figure 9 respectively.

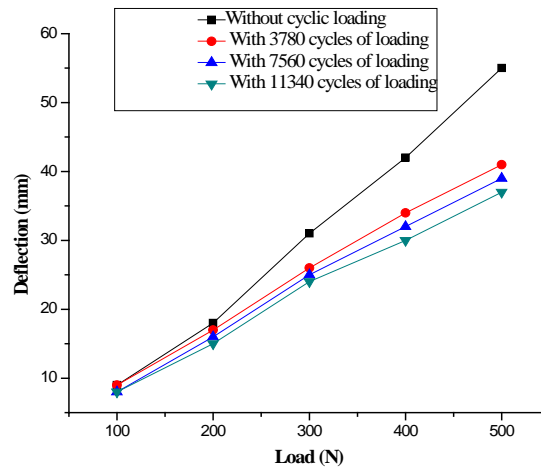


Fig. 6. The deflection test for mono glass leaf spring.

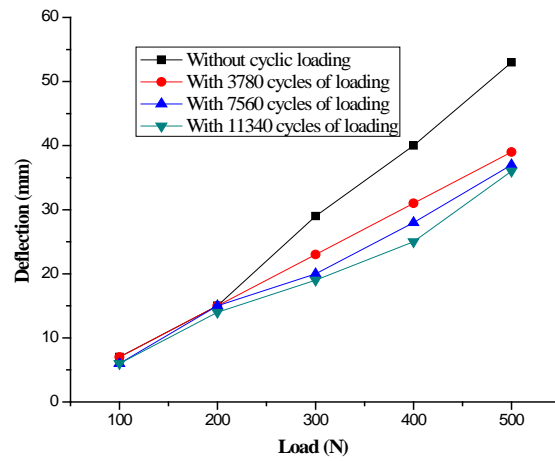


Fig.7. The deflection test for mono carbon leaf spring

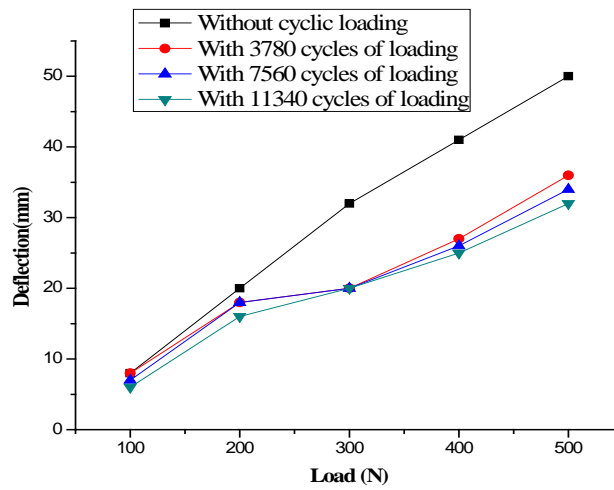


Fig. 8. The deflection test for mono Carbon-Glass leaf spring

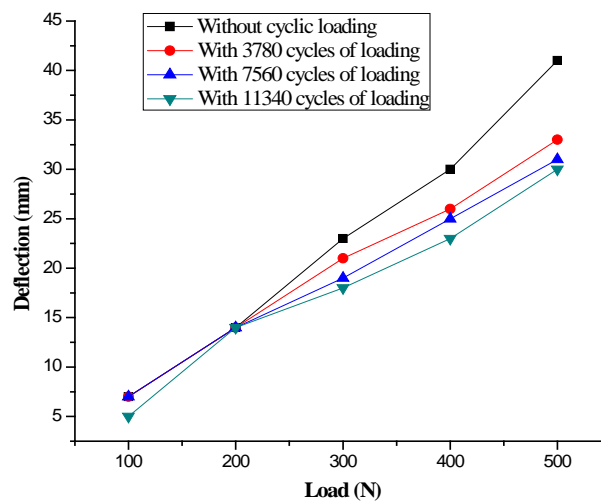


Fig. 9. The deflection test for mono Glass-Carbon leaf spring

From these graphs it was observed that the all four types of laminated composite leaf springs have the load bearing capacity of 500N.

It is well understood that for specific amount of load bearing capacity, the composite leaf springs produces low order of deflection. This can be revealed that the composite leaf springs can take more amount of load than the conventional steel leaf spring for the constant specified deflection. The reason for this increasing load bearing capacity of the composite springs may be due to toughening of reinforcement fibers that are taking place in the laminates with the application of cyclic loading, up to certain limit. Also among the composite leaf springs, the glass – carbon hybrid composite leaf spring can take more amount of load than others as shown in the fig. 6 to fig. 9. Hence it can be concluded that, the composite leaf spring would be better replacement material for the conventional steel leaf springs towards lesser deflection and higher load bearing capacity.

V. CONCLUSION

The fabrication of mono composite leaf spring was done by using hand layup method. The deflection test was carried out for mono composite leaf spring of all categories by using the universal testing machine. A cam like arrangement has been designed and fabricated to expose the cyclic loading for the leaf spring, through milling machine. After applying the cyclic loading such as 3780 cycles, 7560 cycles and 11340 cycles using milling machine, the deflection test was conducted. From the results, it is found that load bearing capacity is increased after applying the cyclic load in all types of composite leaf springs. The composite leaf springs can take more amount of load than the conventional leaf spring for constant specified deflection. Also among the composite leaf springs, the glass – carbon hybrid composite leaf spring can take up more amount of load than others. The composite mono leaf spring reduces the weight by 71% for glass/epoxy, 70% by carbon/epoxy, 67% for carbon-glass/epoxy and 68% for glass-carbon/ epoxy over the conventional leaf spring. If these kind of composite leaf springs are replaced in the automobiles, an improved vehicle performance will be obtained with appropriate load bearing properties due to the lower weight.

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