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MODELING AND ANALYSIS OF LEAF SPRING USING FINITE ELEMENTS METHOD

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ABSTRACT

Leaf spring has a great importance in a modern automobiles industry and it is the main component of the suspension system. It is used in vehicles to absorb vibration and shock. In this paper, the simulation and analysis of leaf spring has been achieved. Leaf springs with two types (multi-leaf spring and parabolic leaf spring) are simulated by using solidworks 2018. The analysis process is achieved by using finite elements analyzer ANSYS 15 with two materials are selected for leaf spring, the conventional steel and carbon composite under two different loads (5000, 10000) N to estimate the total deformation, stress, strain and shear stress. The results showed that the multi-leaf spring could withstand the load and deformation better than the parabolic leaf spring. The carbon composite is more suitable to manufacture the leaf spring than the conventional steel because of its high strength and light weight.

Keywords: Multi-leaf spring, parabolic leaf spring, ANSYS 15, Solidworks 18, Steel, Carbon composite.

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1. INTRODUCTION

The spring may be defined as an elastic element. When the load applied, the spring expands in size and then regains its origin size when the load diminished. Leaf spring considers the simplest shape of spring that used mostly in the suspension system of the light and heavy automobiles. Its duty to absorb the vibration of vehicles, shocks and road bumps which are occurred because of the road irregularities with the means of spring deflection in order to store the potential energy and released it slowly. The spring capacity of absorbing and storing more energy makes the vehicles more safety and comfortable. Leaf spring usually consists of flat leaves fabricate from conventional steel called blades. The multi-leaf spring has many different leaves with graduated length. The longest leaf is known as master leaf which is bent at both the ends to form spring eyes. The leaves held together by a bolt which passes through the center of each leaf. In practice, the spring is attached on the axle of vehicle. The spring in the front end is linked with the frame by the pin joint and the rear end of the leaf spring is linked to the frame through a shackle, so that the whole vehicle load rests on the spring [1]. Many researchers have done the analysis and experiments on the leaf springs to enhance its fatigue resistance, load carrying capability and to reduce the overall weight of an automobile. Most of these researches focused on the number of leaves, material, geometric parameters, type of leaf spring and load acting on the suspension system. Raghavedra et al. presented with respect to stiffness, strength and weight a comparative study between leaf spring fabricated of laminated composite and steel. The results showed that the mono leaf spring made of carbon/epoxy has more stiffness and strength and less in weight than steel which used in the research with similar design specifications [2]. Meghavath. Peerunaik et al. calculated the stress, frequency and deflection which occurred in the leaf spring. They used the maximum safe load is 4000 N for mono leaf springs fabricated of composite carbon/epoxy in contrast with steel leaf spring. It could observe that the values of excitation frequency and natural frequency and for both springs are the same when the same geometric parameters of the spring are used. The natural frequency is approximately kept constant with number of leaves, but it is increased by increasing of camber and decreased with increasing of span [3]. Mahanthi and Murali compared between the leaf springs produced from composite materials like KEVLAR, EN47, E-Glass Epoxy and S-Glass Epoxy with conventional steel spring. The results showed that the Kevlar is better than the other composites and conventional steel and. Leaf spring manufactured of Kevlar is light in weight and withstand minimum deformation comparing with other materials [4]. Madhava and Deepak modeled a new class leaf spring by using Functionally Graded Structural concept and Functionally Graded Material. Analysis is carried out on composite leaf spring and conventional material leaf spring by using the FGM & FGS. These materials have less stress, deformation and strain, high damping capacity and structural strength [5]. Harshit et al. presented a paper on static analysis and fatigue of parabolic leaf spring with three-layer of steel and composite materials. They improved that the weight of the leaf spring made of Kevlar/epoxy fiber, is less by 64% in contrast with steel spring, also, the results showed the fatigue life composite parabolic leaf spring produced from E–Glass epoxy is more than the steel spring under the same conditions [6]. Mithari et al. analyzed steel leaf spring and mono composite (E- Glass epoxy) leaf spring under dynamic load. It could be concluded that the composite leaf spring having the ability of absorbing vibration more than leaf spring manufactured of steel .in addition the results showed that the natural frequency of composite material was higher in contrast with the steel leaf spring. The mono composite leaf spring was less in weight about 84.4% than the steel leaf spring [7]. George and Sarathdas focused on the analysis and design of conventional steel in contrast with E-Glass-Flax-Epoxy based hybrid composite leaf spring. They proved that the leaf spring of hybrid composite have less deflection and stress in contrast with conventional steel leaf spring. There was reduction in weight about 84.49% if the E-Glass-Flax-Epoxy hybrid composite leaf spring is used instead of conventional steel leaf spring [8]. Dwivedi and Jain compared the leaf spring of steel with spring fabricated of E-Glass /Epoxy composite. The results demonstrated that the stress and deflection happened in composite leaf spring is less in contrast with conventional leaf spring. Furthermore, the E-Glass epoxy leaf spring is less in weight as contrast with conventional steel leaf spring [9]. Sagar B Mahajan et al. Presented a research on the analysis and modeling of leaf spring made of composite (Glass Fiber Reinforced Composite- GFRC). Static analysis is done with Ansys14.5 [10]. This paper is an attempt to simulate and analysis of leaf spring. Leaf springs with two kinds are chosen, multi-leaf spring and parabolic leaf spring with two materials conventional steel and carbon composite. The modeling process carried out with solidworks 2018 with specific dimensions while the analysis process is achieved with finite elements analyzer ANSYS 15 under two different loads (5000 and 10000) N to estimate the total deformation, stress, strain and shear stress. Based on the results, it can be observed which type of leaf spring can withstand more deformation and will be lighter in weight so that, there will reduction in weight of vehicle and consequently better fuel efficiency.

2. METHODOLOGY

In this paper the simulation and analysis of leaf spring has been achieved. Two types of leaf spring (multi-leaf spring and parabolic leaf spring) modeled in solidworks 2018 as shown in Figure 1. and Figure 2. below

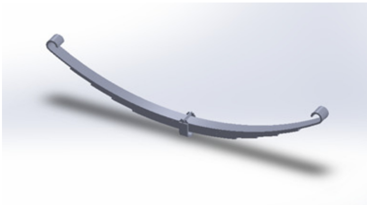

Figure 1 Multi-leaf spring.

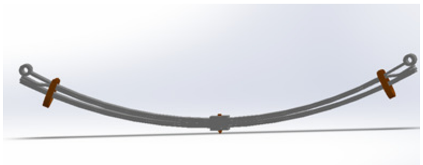

Figure 2 Parabolic leaf spring

The dimensions of multi-leaf spring and parabolic leaf spring listed in Table.1 and Table.2 respectively

Table 1 The dimensions of multi-leaf spring.

Parameters	value
Length of leaf master	1300 mm
No. of leaves	5
Eye diameter	40 mm
Width	60 mm
Thickness	8 mm

Table 2 The dimensions of parabolic leaf spring

Parameters	value
Length of leaf master	1300 mm
No. of leaves	4
Eye diameter	40 mm
Width	60 mm
Thickness	8 mm
Eye diameter	20 mm

Two materials are chosen for leaf spring, steel and carbon composite. Their properties (i.e materials) listed in Table.3

Table 3 Properties of materials.

Materials	Steel	Carbon Composite
Density	7850 kg/m3	1600 kg/m3
Young modulus	2E+11 pa	2.28 E+11 pa
Poisson ratio	0.3	0.28

The numerical analysis was carried out with finite elements analyzer ANSYS 15. The multi leaf spring was meshed with number of nodes was 707443 and number of elements was 170953 as shown in Figure3. below.

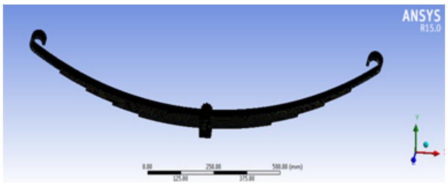

Figure 3 The mesh of multi-leaf spring.

For the parabolic leaf spring the number nodes was 1515645 and the number of elements was 750453 as shown in Figure 4. below.

Figure 4 The mesh of parabolic leaf spring.

The multi-leaf spring and parabolic leaf spring fixed in the eyes while the load (5000, 10000)N applied in the center of upper surface of the spring to calculate the total deformation, stress, strain and shear stress.

3. RESULTS

The total deformation, stress according to von – mises theory, strain and shear stress were obtained numerically for the two types of leaf spring with two materials under various values of load in order to compare between them and choose the best material that can be used in the production process of leaf spring in modern automobiles. For (5000) N the minimum total deformation occurred in multi-leaf spring fabricated of carbon composite and its value was (0.0522) mm as shown in Figure 5.below.

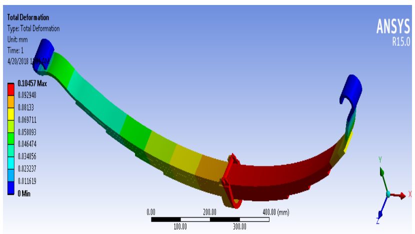

Figure 5 The total deformation of multi-leaf spring under (5000) N.

While the maximum total deformation for (5000) N occurred in parabolic leaf spring made of conventional steel and its value was (0.194) mm as shown in Figure 6. below

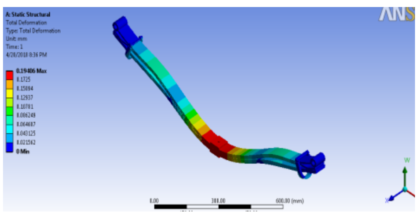

Figure 6 The total deformation of parabolic leaf spring under (5000) N.

For (10000) N the minimum total deformation occurred in multi-leaf spring fabricated of carbon composite and its value was (0.1045) mm as shown in Figure 7. below.

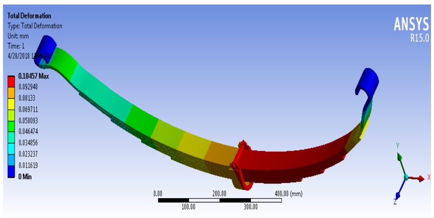

Figure 7 The total deformation of multi-leaf spring under (10000) N.

While the maximum total deformation for (10000) N occurred in parabolic leaf spring made of conventional steel and its value was (0.388) mm as shown in Figure 8. below.

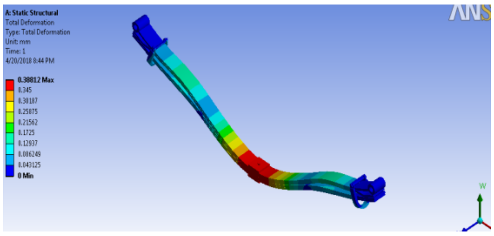

Figure 8 The total deformation of parabolic leaf spring under (10000) N

For the load (5000)N the maximum stress according to von-mises occurred in in multi-leaf spring made of carbon composite and it was (71.05) Mpa as shown in Figure 9. below

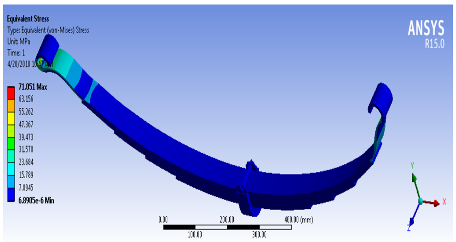

Figure 9 stress in multi-leaf spring of carbon composite under (5000)N.

For the load (10000)N the maximum stress according to von-mises occurred in in multi-leaf spring made of carbon composite and it was (142.1)Mpa as shown in Figure 10. below

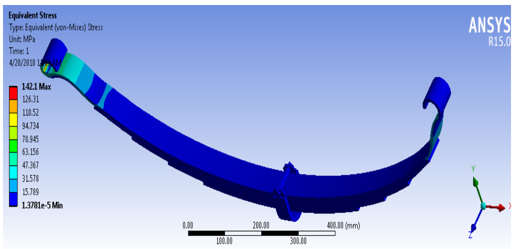

Figure 10 stress in multi-leaf spring of carbon composite under (10000) N.

For the load (5000)N the maximum shear stress occurred in in parabolic leaf spring made of carbon composite and it was (21.916)Mpa as shown in Figure 11. below

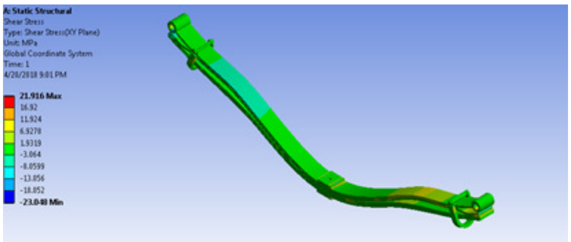

Figure 11 shear stress in parabolic leaf spring of carbon composite under (5000)N.

For the load (10000)N the maximum shear stress occurred in in parabolic leaf spring made of carbon composite and it was (118.58)Mpa as shown in Figure 12 below

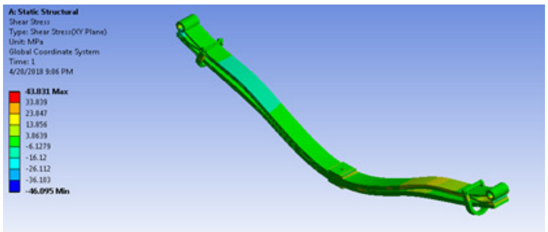

Figure 12 shear stress in parabolic leaf spring of carbon composite under (10000)N.

The results (total deformation, stress, strain and shear stress) for the load (5000)N of two types of leaf spring for the both two materials could be summarized in Table.4 below

Table 4 Results of the load (5000)N

Materials	Multi – leaf spring				Parabolic spring			
	Total deformation (mm)	**Strain (mm/mm)**	**Stress Von-mises Mpa**	**Shear stress Mpa**	**Total deformation (mm)**	**Strain (mm/mm)**	**Stress Von-mises Mpa**	**Shear stress Mpa**
Steel	0.059	0.00043	69.306	21.512	0.194	0.000278	57.426	21.76
Carbon composite	0.0522	0.00035	71.05	21.51	0.170	0.00026	59.288	21.916

The results (total deformation, stress, strain and shear stress) for the load (10000)N of two types of leaf spring for the both two materials could be summarized in Table.5 below.

Table 5 Results of the load (10000)N

Materials	Multi – leaf spring				Parabolic spring			
	Total deformation (mm)	**Strain (mm/mm)**	**Stress Von-mises Mpa**	**Shear stress Mpa**	**Total deformation (mm)**	**Strain (mm/mm)**	**Stress Von-mises Mpa**	**Shear stress Mpa**
Steel	0.1187	0.00086	138.07	43.023	0.388	0.00057	114.85	43.521
Carbon composite	0.1045	0.00078	142.1	43.02	0.341	0.00052	118.58	43.831

The comparison of total deformation for the two kinds of leaf spring with two different materials under various load shown in Figure13. below.

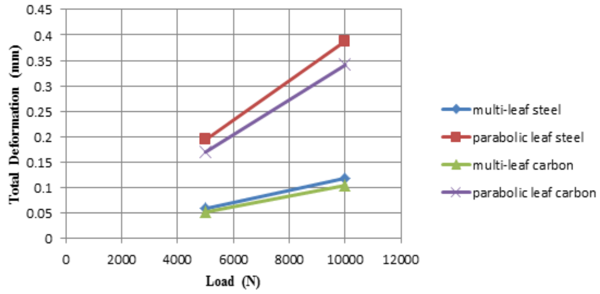

Figure 13 Total deformation (mm) vs. Load (N)

The comparison of Stress von-mises for the two kinds of leaf spring with two different materials under various load shown in Figure14. below.

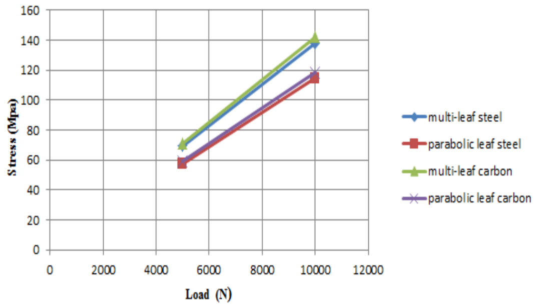

Figure 14 Stress (Mpa) vs. Load (N)

The comparison of strain for the two kinds of leaf spring with two different materials under various load shown in Figure 15.

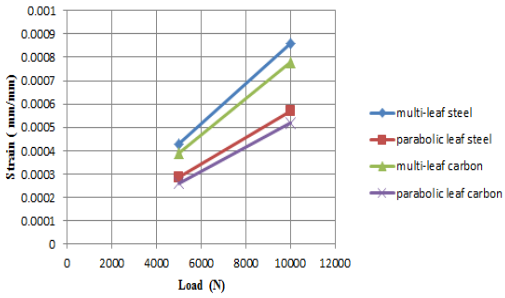

Figure 15 Strain (mm/mm) vs. Load (N)

The comparison of shear stress for the two kinds of leaf spring with two different materials under various load shown in Figure 16. below.

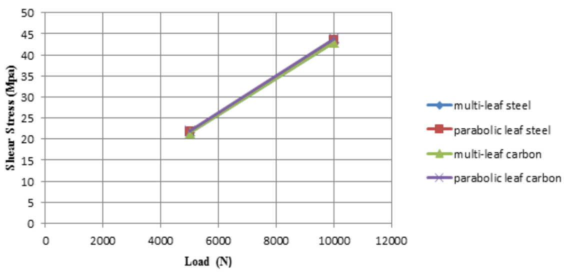

Figure 16 shear Stress (Mpa) vs. Load (N)

The comparison in weight between multi-leaf spring and parabolic manufactured of steel and carbon composite shown in Figure 17 below

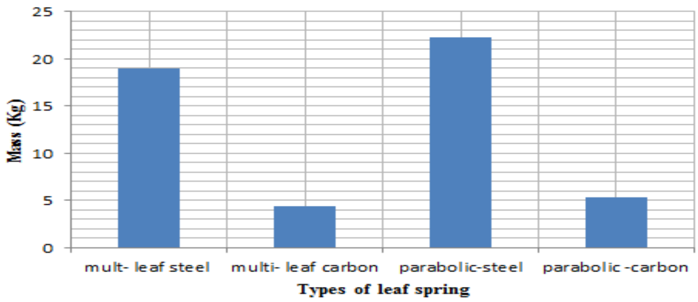

Figure17 The weight of leaf spring.

4. CONCLUSIONS AND RECOMMEDATIONS

In this study the simulation and analysis of leaf spring which is the major part of suspension system was carried out. The simulation was achieved with solidworks 2018 while the analysis was done with ANSYS 15. Two types of leaf spring (multi-leaf spring and parabolic leaf spring) were chosen with two different materials conventional steel and carbon composite under the loads (5000, 10000)N . It can be concluded that the minimum total deformation existed in multi-leaf carbon composite while the maximum total deformation occurred parabolic leaf spring fabricated of steel. By using the carbon composite instead of steel will strength the both leaf spring and reduce the total deformation about 12%. The deformation, strain stress and shear stress increased by increasing the load. It can be notice from the results that the multi- leaf spring could withstand the load and deformation better than the parabolic leaf spring that why it used in vehicles more than parabolic leaf spring. The composite materials have many advantages for the leaf spring, it strength the leaf spring and reduce the weight, for the parabolic leaf spring the reduction in weight about 76 % and for multi-leaf spring the reduction in weight about 77% that mean reduce the total weight of the vehicle and better fuel efficiency. For the future works, it is recommended to change the type of leaf spring, using different materials under various load and change the specifications of leaf spring such as the dimensions, numbers of leaves.

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