Dynamic Analysis of Leaf Spring using Different Composite Materials

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Abstract— A leaf spring is a straightforward type of spring regularly utilized for the suspension as a part of wheeled vehicles initially called a covered or carriage spring, and here and there alluded to as a semi – curved spring or truck spring or level plate. The configuration of leaf spring should be possible in two ways one the mono leaf spring or the multi leaf spring. Mono leaf spring is utilized for the lighter vehicle which comprises of a solitary plate. While in the multi leaf spring a leaf spring can produced using the quantity of leaves called cutting edges. The sharp edges are changing long. The cutting edges are generally given an underlying ebb and flow or cambered so they will have a tendency to fix under the heap. The leaf spring depends on the hypothesis of a light emission quality. The lengthiest edge has eyes on its finishes. This cutting edge is called primary or expert leaf. The remaining cutting edges are called graduated clears out. Every one of the cutting edges is bound together and is mounted on the hub of the vehicle. The whole vehicle load lay on the leaf spring. The front end of the spring is associated with the casing with a straightforward pin joint, while the backside of the spring is associated with a shackle. The shackle is the adaptable connection which interfaces the leaf spring back eye and casing. At the point when the vehicle runs over the projection out and about surface, the wheel climbs, this prompts redirecting the spring. A leaf spring takes the type of a barrel bend formed length of spring steel of rectangular cross- segment. The focal point of the circular segment gives area to the hub, while tie openings are given at either end to joining to the vehicle body. In this paper, survey and static analysis on different leaf spring materials, which are using in automobiles. Static analysis done on different standard load conditions.

Keywords: Leaf Spring Material, Epoxy, Glass fiber, Carbon Fiber, EN 45 Spring Steel

I. INTRODUCTION

Mechanical framework which comprises of springs and safeguards. The car suspension is mounted on the axles, not coordinate but rather some type of springs. This is done to separate the vehicle body from the street stuns, which might be as bob, pitch, roll or influence. These inclinations offer ascent to an uncomfortable ride furthermore cause extra stretch in the vehicles outline anyone. In suspension framework the vitality of street stun cause the spring sway. These motions are limited to a sensible level by damper which is all the more ordinarily called a safeguard.

The motivation behind the complete suspension framework is to separate the vehicle body from street stuns and vibrations which would somehow or another be exchanged to the travelers and burden. It should likewise keep the tires in contact with the paying little mind to street surface. A fundamental suspension framework comprises of spring, axles, safeguards, arms, bars and rotating appendages [2].

The spring is the adaptable part of the suspension. Fundamental sorts are leaf springs, curl springs and torsion bars. Advanced traveler vehicles ordinarily utilize light loop springs. Light business vehicles have heavier springs than traveler vehicles and can have curl springs at the front and leaf springs at the back.

Overwhelming business vehicles more often than not utilize leaf springs or air suspension.

Strong or bar axles associate the wheels on every side of vehicle. This implies the development of a wheel on one side of the vehicle is exchanged to the wheel on the other side. With free suspension, the wheels can move autonomously of each other, which diminish body development. This keeps the other wheel being influenced by development of the wheel on the inverse side and this decreases body development [17].

At the point when a wheel strikes a knock, there is a response power and vitality is exchanged to the spring which makes its way. Motions left uncontrolled can bring about loss of footing between the haggle street surfaces. Safeguards hose spring motions by compelling oil through little openings. The oil warms up, as it ingests the vitality of the movement. This warmth is then exchanged through the body of the safeguard to the air. At the point when a vehicle hits a check, the span of the response power relies on upon the amount of un- sprung mass is at every wheel gathering. The sprung mass alludes to these parts of the vehicle bolstered on the springs. This incorporates the body, the casing, and the motor and related parts [18]. Un-sprung mass incorporates the wheels, tires, brake congregations and suspension parts not upheld by the spring.

Haggle unit that are little and light, take after street forms without an extensive impact on whatever is left of the vehicle. In the meantime, a suspension framework must be sufficiently solid to withstand loads forced by vehicle mass amid cornering, quickening, braking and uneven street surface.

Front suspensions are delegated needy and autonomous suspensions. The most widely recognized ward front suspension is the pillar hub, which is utilized less and less as a part of late vehicles in light of various impediments like bigger un-sprung mass, pressing space and extensive caster change. Some rough terrain application vehicles tend to at present utilize the bar hub subordinate front suspension as they offer high ground leeway. The most widely recognized kinds of front free suspensions are the twofold wishbone suspension. The twofold wishbone suspension otherwise called the twofold an arm suspension has parallel lower and upper sidelong control arms. The fundamental point of interest of the twofold wishbone is that the camber can be balanced effortlessly by changing the length of the horizontal upper control arm such that it has a negative camber in bump [3].

Like the front suspensions, back suspensions too are of needy and free suspension sorts, Some of the basic utilized ward back suspensions are the turn bar, leaf springs, live and dead axles, the primary point of preference of a turn shaft is that it is modest, minimized and is suitable for little autos where bundle space is constrained. Live axles utilize longitudinal leaf spring to connect the hub to the vehicle suspension. Live back axles are not utilized as a part of little autos because of their high sprung mass and are utilized predominantly just on pickup trucks.

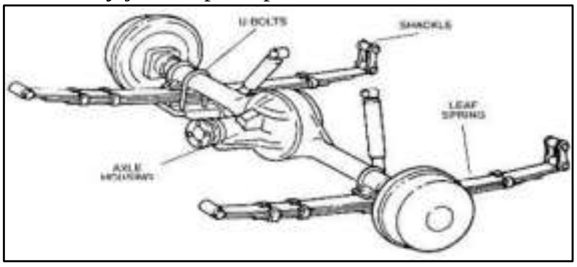

Fig. 1: Suspension System of automobile

As per A.M. Whal (1991): "A mechanical spring might be characterized as a flexible body whose essential capacity is to redirect or misshape under burden (or to ingest vitality) and which recoups its unique shape when discharged in the wake of being twisted". He goes ahead to characterize the principle elements of springs as one of four things: to assimilate stun, to apply power, to bolster a structure, or to give load control. This expansive definition incorporates things that individuals don't typically consider as springs. Under this definition flying machine wings, the suspension of an auto and even the shoes we wear will be considered springs. once the heap is discharged, these all things mutilate under burden and come back to their unique shape. A shoe will assimilate the effect of the foot fall and the twisting of the curve of the foot and come back to its ordinary state when these inputs are evacuated [20].

Clearly such springs have diverse properties and capacities, thus cannot be all dissected with the same strategies along these lines, accordingly, the motivations behind this paper, we will consider an overlaid or carriage spring, and infrequently alluded to as a semi – circular spring or truck spring or level plate. It is understood that springs, are intended to retain and store vitality and afterward discharge it gradually. Capacity to store and assimilate more measure of strain vitality guarantees the agreeable suspension framework.

Subsequently, the strain vitality of the material turns into a central point in planning the springs. The relationship of the particular strain vitality can be communicated.

Fig. 2: Types of spring

A leaf spring is a straightforward type of spring regularly utilized for the suspension as a part of wheeled vehicles initially called a covered or carriage spring, and here and there alluded to as a semi – curved spring or truck spring or level plate. The configuration of leaf spring should be possible in two ways one the mono leaf spring or the multi leaf spring.

Mono leaf spring is utilized for the lighter vehicle which comprises of a solitary plate. While in the multi leaf spring a leaf spring can produced using the quantity of leaves called cutting edges. The sharp edges are changing long [8]. The cutting edges are generally given an underlying ebb and flow or cambered so they will have a tendency to fix under the heap. The leaf spring depends on the hypothesis of a light emission quality.

The lengthiest edge has eyes on its finishes. This cutting edge is called primary or expert leaf. The remaining cutting edges are called graduated clears out. Every one of the cutting edges is bound together and is mounted on the hub of the vehicle. The whole vehicle load lay on the leaf spring. The front end of the spring is associated with the casing with a straightforward pin joint, while the backside of the spring is associated with a shackle. The shackle is the adaptable connection which interfaces the leaf spring back eye and casing. At the point when the vehicle runs over the projection out and about surface, the wheel climbs, this prompts redirecting the spring [18]. A leaf spring takes the type of a barrel bend formed length of spring steel of rectangular cross-segment. The focal point of the circular segment gives area to the hub, while tie openings are given at either end to joining to the vehicle body.

Leaf springs can serve finding and to some degree damping and in addition springing capacities. While the interleaf contact gives a damping activity, it is not very much controlled and results in stiction in the movement of the suspension. Therefore makers have explored different avenues regarding mono-leaf springs [5].

A further favorable position of a leaf spring over a helical spring is that the end of the leaf spring might be guided along an unmistakable way as it redirects to go about as an auxiliary part notwithstanding vitality retaining gadget. The primary capacity of leaf spring is to bolster vertical burden as well as to confine street incited vibrations. It subjected to a great many burden cycles stacking to weariness disappointment.

Leaf spring assimilates vertical vibrations; stuns and knock load by method for spring redirection so that the potential vitality is put away in the leaf spring as strain vitality and after that discharged gradually [11]. Leaf spring positions and backing the pivot as well.

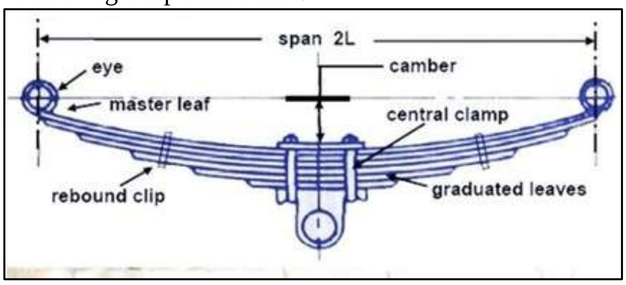

Fig. 3: Leaf Spring

II. RELATED WORK

Senthil kumar and Vijayarangan has present leaf spring ingests the vehicles vibrations, stuns and knock loads(induced because of street abnormalities) by method for spring avoidances, so that the potential vitality is put away in the leaf spring and after that remembered gradually. Endeavors were taken for limited component Analysis for multi leaf springs. static and weariness investigation of steel leaf springs and composite multi leaf spring made up of glass fiber strengthened polymer utilizing life information examination. The measurements of existing traditional steel leaf springs of a light business vehicle are taken and are checked by plan estimations. Static investigation of 2-D model of ordinary leaf spring is likewise performed utilizing ANSYS 7.1 and contrasted and trial comes about [1].

Shiva Shankar et al. Gives presentation of composite materials made it conceivable to decrease the heaviness of the leaf spring with no lessening on the heap conveying limit and solidness. Studies were directed on the use of composite structures for car suspension framework [2, 3].

Malaga. Anil Kumar et al. Portrays the three diverse composite materials have been utilized for investigation of mono composite leaf spring. They are E-glass/epoxy, Graphite/epoxy and carbon/epoxy. E-glass/epoxy composite leaf spring can be recommended for supplanting the steel leaf spring both from firmness and empasize perspective. A similar study has been made in the middle of steel and composite leaf spring as for quality and weight [4].

GSS Shankar, sambagam vijayarangan explains the vehicles business has demonstrated enthusiasm for the supplanting of steel spring with fiberglass composite leaf spring because of high quality to weight proportion [5].

H.A. Al-Qureshi Described a solitary leaf, variable thickness spring of glass fiber fortified plastic (GFRP) with comparative mechanical and geometrical properties to the multi leaf spring, was outlined, created and tried. Glass fiber fortified plastic (GFRP) presents favorable circumstances over graphite/epoxy, for example, lower affectability to splits, effect and wear harm. The leaf spring model was thought to be an allegorically decreased, consistent width shaft conveying a focused load and thought to be symmetrical with various line lengths for the two appendages of the spring. A limited component program is utilized to display the conduct of leaf spring. [6].

M. Raghavendra et al. Portrays plan and investigation of covered composite mono leaf spring. Weight decrease is currently the fundamental issue in car businesses. In the present work, the measurements of a current mono steel leaf spring of a light vehicle is taken for displaying and investigation of covered composite mono leaf spring with three diverse composite materials to be specific, E-glass/Epoxy, S-glass/Epoxy and Carbon/Epoxy subjected to the same load as that of a steel spring. The plan limitations were anxieties and diversions. The three diverse composite mono leaf springs have been displayed by considering uniform cross-segment, with unidirectional fiber introduction plot for every lamina of a cover. Static investigation of a 3-D demonstrate has been performed utilizing ANSYS 10.0. Contrasted with mono steel leaf spring the covered composite mono leaf spring is found to have 47% lesser hassles, 25%~65% higher solidness, 27%~67% higher recurrence and weight lessening of 73%~80% is accomplished [7].

Smita C. Saddu,Vikas V. Shinde has depict the examination of steel and composite material leaf spring. At that point these outcomes are contrasted and that of the exploratory results. The outcomes is inferred that anxieties created in the composite material leaf spring is less as contrasted and that of the steel material leaf spring, so it demonstrates that composite material is more powerful and temperate than the traditional leaf spring with comparative outline determination. The examination is done through CATIA V5R19 [8].

M. Venkatesan and D. Helmen Devaraj Described the plan and exploratory investigation of composite leaf spring made of glass fiber fortified polymer. The goal was to look at the heap conveying limit, firmness and weight reserve funds of composite leaf spring with that of steel leaf spring. A weight lessening of 76.4% was accomplished by utilizing enhanced composite leaf spring [9].

B. Sutharson et al. In this the elastic properties of salt treated woven jute characteristic fiber and woven glass fiber strengthened crossover composites and untreated half breed composites were explored. Impact of stacking succession and fiber treatment on rigidity, hardness and effect quality of soluble base treated woven jute normal fiber and woven glass fiber strengthened half and half composites and Untreated Hybrid Composite has been researched tentatively. It has been watched that the pliable properties increment regarding jute fiber content. The outcomes demonstrate that the properties of jute composites can be impressively enhanced by fuse of glass fiber as great glass utilizes [10].

Pankaj Saini et al. the composite material were they utilized was glass fiber strengthened polymer (E-glass/epoxy), carbon epoxy and graphite epoxy is utilized against ordinary spring. The plan parameters were chosen and examined with the target of minimizing of the composite leaf spring when contrasted with the steel leaf spring [11].

Shishay Amare Gebremeskel In this a solitary E-glass/Epoxy leaf spring is outlined and reenacted taking after the plan standards of the composite materials considering static stacking as it were. It is demonstrated that the subsequent outline and reproduction hassles are much underneath the quality properties of the material, fulfilling the most extreme push disappointment foundation. The planned composite leaf spring has additionally accomplished its satisfactory exhaustion life. This specific plan is made particularly for light weight three wheeler vehicles [12].

M. M. Patunkar and D. R. Dolas they have done study Design, assembling, testing and investigation of mono composite leaf spring under static stacking condition. The material chose for the study was glass fiber fortified plastics. A spring with steady width and thickness was created by hand layup system .The investigations were led on load testing machine (in different load condition) and numerical examination was done by means of (FEA) utilizing ANSYS programming. Come about demonstrates that, the anxieties and avoidance of logical information will bring down when contrast and fabricating and investigated information [13].

Amrita Srivastava and Sanjay Choudhary Comparative examination between steel leaf spring and Jute/E glass fortified Epoxy leaf spring. The cross breed composite leaf spring is found to have lesser weight, lesser cost, lesser burdens and higher solidness. The CAD models of Leaf spring are arranged in Unigraphics NX6 and imported in static basic examination workbench of Ansys 14.5 where limited component investigation (FEA) is performed. The plan imperatives are anxieties and diversions [14].

Vijayarangan S, Ganesan N. The cost of materials constitutes almost 60-70% of the vehicle cost and adds to the better quality and execution of the vehicle. The presentation of fiber strengthened plastics (FRP) made it conceivable to decrease the heaviness of a machine component with no lessening of the heap conveying limit [15].

Aggrwal M.L and Chawla The weariness quality of 65Si7 spring steel has been assessed tentatively as a component of shot peening parameters for the application in car vehicles [16].

M.L. Aggrawal and V.P. Aggrawal Fatigue quality of shot peening leaf spring from research facility tests of EN45 steel spring is ascertained. A considerable measure of research has been done to enhance exhaustion quality of material by making compressive lingering push field in there surfaces through shot peening [17].

B. Vijaya Lakshmi, I. Satyanarayana is think about the heap conveying limit, solidness and weight investment funds of composite leaf spring with that of steel leaf spring. The outline limitations are burdens and diversions. The measurements of a current ordinary steel leaf spring of a Heavy business vehicle are taken Same measurements of routine leaf spring are utilized to create a composite multi leaf spring utilizing E- GLASS/EPOXY, C-GLASS/EPOXY, S-GLASS/EPOXY unidirectional covers. Expert/Engineer programming is utilized for demonstrating and COSMOS is utilized for examination. Static and Dynamic investigation of Leaf spring is performed utilizing COSMOS [18].

Ashish V. Amrute et al. Manages substitution of customary steel (65si7) leaf spring of a light business vehicle with composite leaf spring utilizing E- glass/Epoxy. Measurements of the composite leaf spring are to be taken as same measurements of the traditional leaf spring. The goal is to look at the heap conveying limit, hassles and weight reserve funds of composite leaf spring with that of steel leaf spring. The limited component demonstrating and examination of a multi leaf spring has been done. The CAE investigation of the multi leaf spring is performed for the avoidance and anxieties under characterized stacking conditions. The hypothetical and CAE results are analyzed for approval [19].

Minoru Iwata et al. Presented twisted and rotationally blocked structure into polyimide chain utilizing lopsided dianhydride and got recently created polyimide having a decent thermo pliancy. For the assessment of the recently created polyimide on radiation strength, they lighted the polyimide with proton bar, assessed its toughness by utilizing mechanical properties, and contrasted and routine business polyimide. From the trial comes about, they could affirm the high radiation resistivity of recently created thermoplastic polyimide [20].

Parkhe Ravindra and Sanjay Belkar Describes plan and investigation of composite mono leaf spring with Carbon/Epoxy composite materials is displayed and subjected to the same load as that of a steel spring. The outline requirements were hassles and diversions. The composite mono leaf springs have been displayed by considering Varying cross-segment, with unidirection [21].

III. Experimental Setup

A. Material Specification and Properties

For the structural analysis of master leaf spring, there are 10 types of material used and four types of load range is selected for better evolution of the spring. In the present work result of all materials confined only for maximum stress induced during the analysis and maximum deformation in leaf spring body.

Sr. No.	Parameter	Values
1.	Total Length of the spring (Centres of Eye to Eye)	1548 mm
2.	Free Camber (At no load condition)	273 mm
3.	No. of full length leave (Master Leaf)	01
4.	Thickness of leaf at centre	7.75 mm
5.	Width of leaf spring	70 mm
6.	Kerb Weight of vehicle	1820 N
7.	Max. Load given on spring (Calculated from chassis and load carrying capacity on axles)	2645 N
8.	Internal Diameter of Berlin Eye	35.75 mm
9.	Young's Modulus of the spring	204 x 10^{-3} N/mm^2
10.	Weight of the leaf spring	13.029Kg

Table 1: Specification of Existing Mono Steel Leaf Spring (EN 45 Spring Steel)

Parameters	Specification
Material	Polycarbonate with 20% Glass Fiber
Density	1340 Kg/m^3
Young modulus	5.93E+09 Pa
Poission's Ratio	.38
Bulk modulus	8.2361E+09 Pa
Shear modulus	2.1486E+09 Pa
Tensile yield strength	73.4Mpa
Compressive yield strength	79.3Mpa
Tensile ultimate strength	110Mpa

Table 2: Properties of conventional Leaf Spring (EN 45 springs steel)

Parameters	Specification
Material	EN 45
Tensile Ultimate Strength	615.4 Mpa
Tensile Yield Strength	375.8 Mpa
Density	7860 kg/m^3
Poisson's Ratio	0.290
Young's Modulus	204 x 10^3 Mpa

Table 3: Polycarbonate with 20% Glass fiber (20GF) PC

Parameters	Specification
Material	Polycarbonate with 30% Glass Fiber
Density	1430 Kg/m^3

Young modulus	8.2E+09 Pa
Poission's Ratio	.38
Bulk modulus	1.1389E+10 Pa
Shear modulus	2.971E+09 Pa
Tensile yield strength	73.4 Mpa
Compressive yield strength	79.3Mpa
Tensile ultimate strength	130Mpa

Table 4: Polycarbonate with 30% Glass fiber (30GF) PC:

Parameters	Specification
Material	Polycarbonate with 40% Glass Fiber
Density	1520 Kg/m^3
Young modulus	1.03E+10 Pa
Poission's Ratio	.38
Bulk modulus	1.4306E+10 Pa
Shear modulus	3.7319E+09 Pa
Tensile yield strength	72.4Mpa
Compressive yield strength	79.3Mpa
Tensile ultimate strength	150Mpa

Table 5: Polycarbonate with 40% Glass fiber (40GF) PC:

Parameters	Specification
Material	Epoxy carbon_UD
Density	1540 Kg/m^3
Young's modulus X direction	2.09E+05 Mpa
Young's modulus Y direction	9450 Mpa
Young's modulus Z direction	9450 Mpa
Possion's Ratio xy	0.27
Possion's Ratio yz	0.4
Possion's Ratio xz	0.27
Shear modulus xy	5500 Mpa
Shear modulus yz	3900 Mpa
Shear modulus xz	5500 Mpa

Table 6: EPOXY CARBON UD

Parameters	Specification
Material	Epoxy carbon Woven
Density	1480 Kg/m^3
Young's modulus X direction	91820 Mpa
Young's modulus Y direction	91820 Mpa
Young's modulus Z direction	9000 Mpa
Possion's Ratio xy	0.05
Possion's Ratio yz	0.3
Possion's Ratio xz	0.3
Shear modulus xy	19500 Mpa
Shear modulus yz	3000 Mpa
Shear modulus xz	3000 Mpa

Table 7: EPOXY CARBON WOVEN

Parameters	Specification
Material	Epoxy EGlass_UD
Density	2000 Kg/m^3
Young's modulus X direction	45000 Mpa
Young's modulus Y direction	10000 Mpa
Young's modulus Z direction	10000 Mpa
Possion's Ratio xy	0.3
Possion's Ratio yz	0.4
Possion's Ratio xz	0.3
Shear modulus xy	5000 Mpa
Shear modulus yz	3800.2 Mpa
Shear modulus xz	5000 Mpa

Table 8: EPOXY GLASS UD

Parameters	Specification
Material	Kevlar Epoxy
Density	1400 Kg/m^3
Young's modulus X direction	80000 Mpa
Young's modulus Y direction	55000 Mpa
Young's modulus Z direction	80000 Mpa
Possion's Ratio xy	0.34
Possion's Ratio yz	0.34
Possion's Ratio xz	0.4
Shear modulus xy	2200 Mpa
Shear modulus yz	1800 Mpa
Shear modulus xz	2200 Mpa

Table 9: Kevlar Epoxy

Young modulus	1.9E+10 Pa
Poission's Ratio	0.3
Bulk modulus	1.5833E+10 Pa
Shear modulus	7.3077E+09 Pa
Tensile yield strength	215 Mpa
Tensile ultimate strength	330Mpa

Table 10: Thermoplastic polyimide with 30% carbon fiber

Parameters	Specification
Material	Thermoplastic polyimide 30% Glass fiber
Density	1540 Kg/m^3
Young modulus	1E+10 Pa
Poission's Ratio	0.3
Bulk modulus	8.3333E+09Pa
Shear modulus	3.8462E+09 Pa
Tensile yield strength	175 Mpa
Tensile ultimate strength	270Mpa

Table 11: Thermoplastic polyimide with 30% Glass fiber

IV. RESULTS AND DISCUSSIONS

Table 12, 13, 14 & 15 shows the deflection (mm) and maximum stress (MPa) on different material at 500 N, 1200N, 2000N and 2645 N respectively. These analysis are done in ANSYS 16.0 and standard working conditions.

S.No.	Materials	Deflection in (mm)	Maximum stress in Mpa
1.	Spring steel EN 45	10.588	113.28
2.	Polycarbonate with 20% Glass Fiber	357.05	114.7
3.	Polycarbonate with 30% Glass Fiber	258.21	114.7
4.	Polycarbonate with 40% Glass Fiber	205.56	114.7
5.	Thermoplastic polyimide 30%	111.45	113.28
	carbon fiber		
6.	Thermoplastic polyimide 30% Glass fiber	211.75	113.28

7.	Kevlar Epoxy	47.95	196.89
8.	Epoxy carbon_UD	19.278	210.13
9.	Epoxy Carbon Woven	24.81	178.76
10	Epoxy EGlass_UD	54.9	153.59

Table 12: Deflection (mm) and maximum stress (MPa) at 500 N

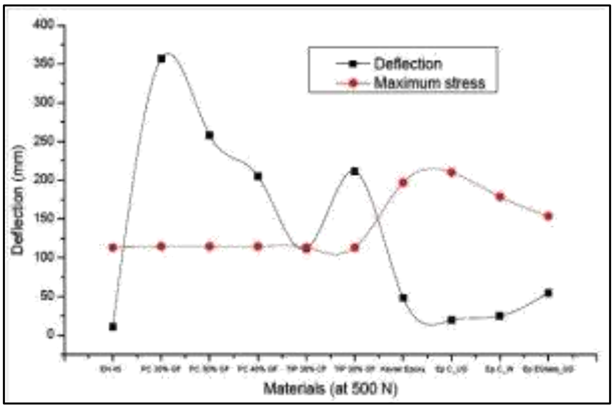

Fig. 4: Deflection (mm) and maximum stress (MPa) at 500N

S.No.	Materials	Deflection in (mm)	Maximum stress in Mpa
1.	Spring steel EN 45	25.41	271.87
2.	Polycarbonate with 20% Glass Fiber	856.92	275.28
3.	Polycarbonate with 30% Glass Fiber	619.7	275.28
4.	Polycarbonate with 40% Glass Fiber	493.35	275.28
5.	Thermoplastic polyimide 30% carbon fiber	267.48	217.87
6.	Thermoplastic polyimide 30% Glass fiber	508.2	217.87
7.	Kevlar Epoxy	118.09	472.53
8.	Epoxy carbon_UD	46.267	504.3
9.	Epoxy carbon_Woven	59.544	429.03
1	Epoxy EGlass_UD	131.76	368.61

Table 13: Deflection (mm Maximum Stress (MPa) at 1200 N

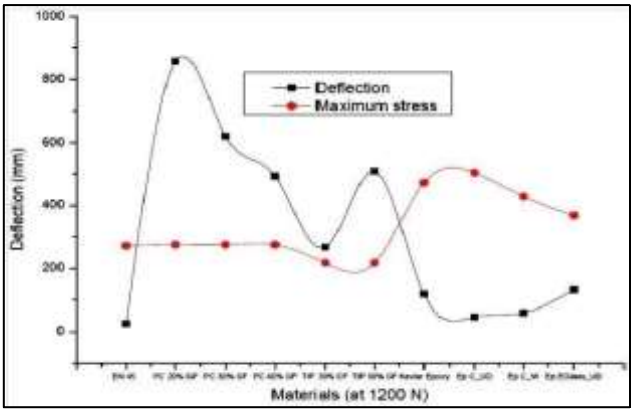

Fig. 5: Deflection (mm) and maximum stress (MPa) at 1200 N

S.No.	materials	Deflection in (mm)	Maximum stress in Mpa
1.	Spring steel EN 45	42.35	453.11
2.	Polycarbonate with 20% Glass Fiber	1428.2	458.81
3.	Polycarbonate with 30% Glass Fiber	1032.8	458.81
4.	Polycarbonate with 40% Glass Fiber	822.25	485.81
5.	Thermoplastic polyimide 30% carbon fiber	445.79	453.11
6.	Thermoplastic polyimide 30% Glass fiber	847.01	453.11
7.	Kevlar Epoxy	191.81	787.55
8.	Epoxy carbon_UD	77.111	840.5
9.	Epoxy carbon_Woven	99.24	715.06
10.	Epoxy EGlass_UD	219.6	614.35

Table 14: Deflection (mm) and Maximum Stress (MPa) at 2000 N

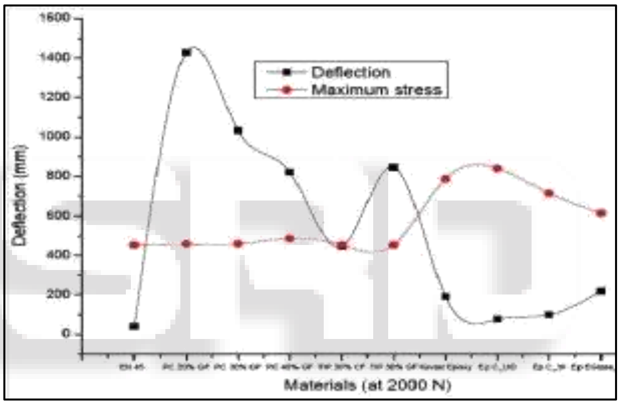

Fig. 6: Deflection (mm) & maximum stress (MPa) at 2000 N

S.No.	Materials	Deflection in (mm)	Maximum stress in Mpa
1.	Spring steel EN 45	56.008	599.24
2.	Polycarbonate with 20% Glass Fiber	1888.8	606.77
3.	Polycarbonate With 30% Glass Fiber	1365.9	606.77
4.	Polycarbonate with 40% Glass Fiber	1087.4	606.77
5.	Thermoplastic polyimide 30% carbon fiber	589.56	599.24
6.	Thermoplastic polyimide 30% Glass fiber	1120.2	599.24
7.	Kevlar Epoxy	253.67	1041.5
8.	Epoxy carbon_UD	101.98	1111.6
9.	Epoxy carbon_Woven	131.25	945.66
10	Epoxy EGlass_UD	290.42	812.48

Table 15: Deflection (mm) and Maximum Stress (MPa) at 2645 N

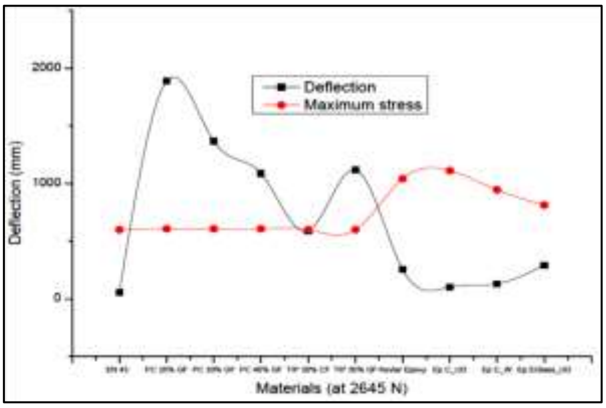

Fig. 7: Deflection (mm) & maximum stress (MPa) at 2645 N

V. Conclusion

The following conclusion can be drawn from above work:-

1) For EN 45 spring steel – the mean deflection developed in the master leaf spring at load of 2645 is 56.008 mm and maximum stress is 599.24 Mpa, the deflection and stress is safe in all respect but the weight of the master leaf for present work is 13.029, hence design is safe expect weight.
2) Polycarbonate with 20% glass fiber the max. Deflection developing is 1888.8 mm which are too high and the max. stress is 606.72 which is also too high and this material cannot sustain the load as the conventional spring material butare thing is positive regarding weight which is 2.2241 Kg that is very less as compare to EN 45 steel since material does not sustain the same load that is why it become failed
3) Polycarbonate with 30 % glass fiber – The max deflection developed in the master leaf spring at maximum load 2645 N is 1365.9mm which is too high as compared to conventional leaf spring but less than polycarbonate with 20% GF and max stress is also too high 606.77 Mpa as compared to conventional leaf the weight of master leaf is 2.3734 kg which less than EN 45 spring steel. This spring is not suitable for same spring as conventional material
4) Polycarbonate with 40% glass fiber – the maximum deflection developed in the master leaf spring at max load 2645 N is 1087.4 mm which is also too high and not desirable for leaf spring, the max stress generated is same as previous material polycarbonate with 20% and 30% GF and the weight is 2.522 Kg which is also less than EN 45 spring steel, but it is also suitable for replacing in place of conventional spring material.
5) Thermoplastic polyimide with 30% carbon fiber - the maximum deflection developed in the master leaf spring at max load 2645N is 589.56 mm which are also high and maximum stress produced is 599.24 Mpa which is also higher than material strength but deflection and stress at low load than 500N is 111.45 mm and 113.45 mm which are same as conventional if we compare with EN 45 steel but deflection is higher but generated stress are same so it may be the alternate solution in place of conventional spring its weight is also 2.3402 Kg less than conventional spring, so that it may be the solution as alternate material but for low load.
6) Thermoplastic polyimide with 30% glass fiber the maximum deflection developed in the master leaf spring at maximum load 2645N is 1120.2 mm whichis too high and maximum stress produced is same as thermoplastic polyimide with 30% carbon fiber and EN45 steel 599.24Mpa and weight of the master leaf 2.556 Kg since the deflection is very high that is why it may not suitable as alternate material
7) Kevlar epoxy - – the maximum deflection developed in the master leaf spring at maximum load 2645N is 253.67mm which is less than previous few material and maximum stress is 1041.5MPa which is too high as compared to its material strength, so that this material is fail at its high load but at high load but at low load taken as 500N the deflection and max stress are 47.95 mm and 196.29 MPa respectively it may be the alternate solution in the place of conventional spring at low and moderate load the spring weight is 2.456 Kg
8) Epoxy carbon UD - – the maximum deflection developed in the master leaf spring at maximum load 2645N is 101.98 which is also less than few material explain above eposy carbon UD is only which is too high as compare too its strength it shows that the material shows work properly at low load such that at the load of 500N the maximum deflection and the maximum strss are 19.278mm and 210MPa which is safe and the weight of the master leaf is 2.556Kg that is also very less as compared to the conventional spring material so that this can be a alternate solution for leaf spring at low load.
9) Epoxy carbon woven – the maximum deflection in the master leaf spring at maximum load of 2645 is 131.25mm which is less than other compared material and maximum stress 945.66 MPa which is also higher than its material strength but this material can work properly at low load say at 500N at which the minimum deflection and stress is 24.81mm and 178.76 MPa which are stress is 24.81 mm and 178.76MPa which are safe ,the weight of master leaf is 2.4564 Kg which is also less than as compare to conventional.
10) E Poxy E Glass –UD – The maximum deflection in the master leaf spring at the maximum load of 2645N is 290.42mm deflection and minimum stress is not so higher than other few material explain previously it may be used as another alternatives at low load the weight of the master leaf with E Poxy E glass UD is 3.3195 Kg which is second highest weight in above studies material.

To summaries that there are some material like thermoplastic polyimide with 30% carbon fiber Epoxy carbon UD E poxy carbon woven may be used as alternate material for eaf spring at low load only it is seen from perivious study that the thermoplastic polyimide with 30% carbon fiber is the most faberable material as alternate in place of conventional springs because the maximum stress generated as same as conventional leaf material EN45 spring steel Secondly E Poxy E glass UD is another alternative can be used in place of EN 45 spring steel because in this material the maximum deflection is 290.42mm at maximum load and stress is 8.81248MPa which are little bit higher than EN45 spring steel.

Other new composites can be tested in a similar way to have more alternatives for the manufacturing of leaf spring.

This work can be extended by analyzing leaf spring under dynamic conditions, since only static loading case is considered here.

The design of leaf spring can also be optimized by using either “Constant width and varying thickness design” or “Constant thickness and varying width design” as well as in Multiple leaf spring.

In future this kind of spring can be used in the vehicles, which are more efficient and responsive.

More analysis can be done in future to get the perfection in results so that the current idea can be applied in vehicles.

It can be used in hybrid vehicles as its weight is comparatively less and has more strength.

In future analysis of effect of sudden and impact load can be done.

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