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Study on Simulation for Optimal Material Selection used for Suspension System

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ABSTRACT

Now days, automobile industry facing mainly two issues. One of them is fuel efficiency and second one is gas regulation. Reducing the weight of vehicle can increase the fuel efficiency so, the automobile sector focused to make new vehicles that's provided high fuel efficiency with very small cost. And the weight reduction is attaining by use superior material, optimization of design and using greater manufacturing process. In automobile, today use over 70% of iron and steel by weight. So industries shown increase interest for replacement of steel and iron parts by composite materials, because composites material have big strength as compared weight ratio, superior corrosion to resistance, good fatigue life etc. There are numerous parts in automobiles that can be replaced with composite materials. And one of them is leaf spring suspension system. Leaf spring is a mechanical part, which absorb load, vibration and up and down movement of tire when vehicle drive across irregular roads. So, for reduce the weight of leaf spring the analysis is carried out on model of "Mahindra canter" leaf spring with same dimension geometry. E-glass, S-glass, and carbon as4 composite material were chosen for the leaf spring because they are more cost-effective and have the same mechanical and geometrical properties as steel leaf springs..Steel, E-glass, S-glass, and carbon AS4 were all included in the analysis, which was done in ANSYS under the same loading conditions. Steel and composite leaf springs have been compared in terms of their weight and strength.. Composite leaf spring reduces weight 67.76% for E-glass, 64.22% for S-glass and 77.58% for carbon AS4 over steel leaf spring. There are many materials are used for leaf spring, but at last the result is found that, the fiber glass material has better strength characteristics and light in weight as compared to steel for leaf spring.

INTRODUCTION

In the current environment, the automotive industry is primarily concerned with cost savings and improving the performance of weight reduction in automobiles. And the first step in reducing the weight of vehicles is to use better materials, enhance the design, and use improved production techniques[1]. The leaf spring is one of the parts of an automobile that is simple to replace. Leaf springs are a mechanical component used in automotive suspension systems Leaf spring is nominated with many names likes as -Semi-elliptical leaf spring, Laminated spring Carriage spring etc. The past of spring is started with a decade's back 1750, firstly it is start using in ENGLAND and after that is used in other countries such as FRANCE and GERMANY, Shape of leaf spring is pinpoint on axle of vehicles and it is looped on both ends, which is connected to the frame of vehicle. In heavy vehicles to obtain desired stiffness effect and get better riding quality a combination of short and long leaves are be better[2]. The main purpose of leaf spring is helping of necessary damping and spring effect. Sometimes, the friction of interleaf can be cause of sticking and then mono leaf spring is discovered as another option of multi leaf spring. In vehicles mounting of leaf spring gives greatly effect in the performance of vehicles and make better riding quality and different situations of road conditions. Leaf spring can be mounted on both the ends of vehicles frame, In vehicles shackle is a short wavering arm, which is stand on the compression of spring concaved to carry swiveling members.

In automobiles, some of the vehicles provided with different spring arrangement, such as VOLVO XC90 [3], This model of car is provided with transverse spring which was made of composite material. This type of suspension system works alone with respect to a specific tire, which is provided in attachment with and not gets disturbed by movement of its close tire. when we give more attention on the past of leaf spring, A British engineer "OBADIAH ELLIOTT" invented the model of elliptical and full elliptical leaf spring in 1804[4].

- -In structure of elliptical leaf spring two circular arcs are joined at tips. Top center of upper arc joined with frame and bottom are linked with live suspension component of an axle.
- -In semi-elliptical structure of leaf spring a extra suspension is provided in form of trailing arm. it may need help from HOTCHKISS drive.
- -in the structure of quarter elliptical leaf spring, the thicker part of leaves is linked with rear end and free end is attached with differential of vehicles.
- -in the structure of non-elliptical leaf spring, there are many leaf spring are mounted on differential of vehicles in curved structure known as yoke, to avoid inter leaf friction, dampers are placed between the springs such as pieces of wood and metal.

Image 1.Conventional model of multi- leaf spring used in automobiles [5]

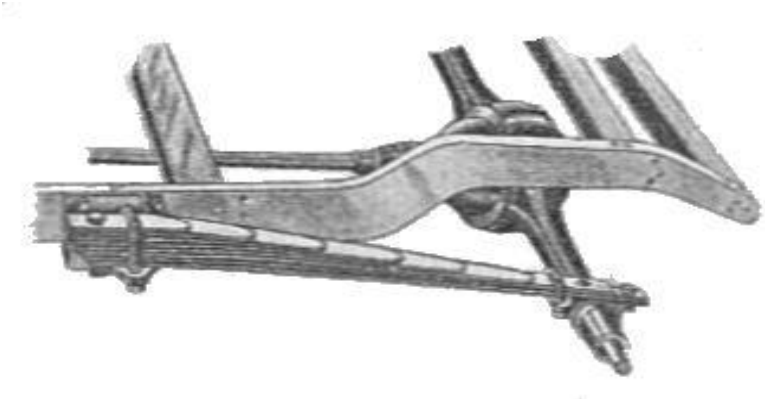

Image 2.Used and implementation of three-quarter elliptical leaf spring carriage [6]

LITERATURE REVIEW

Mr. Abdul Rahim Abutalib, Aidy Ali, G.goudah, Nur Aziada Che Lah and A.F. Golestaneh. They have worked on a composite material leaf spring for better fatigue performance then steel in automotive application. They change steel leaf spring with composite material leaf spring and analysis with same load condition by using ANSYS software and result is found that, the composite material leaf spring have superior fatigue performance and weight reduction by ANSYS software. They consider light and heavy truck with conventional steel leaf spring, and when the result is compared of composite and steel leaf spring. They found that better fatigue performance and weight reduction in composite leaf spring in compare of conventional steel leaf spring [7].

K. K. Jadhao D.R. R. S. Dalu- In this paper, They have worked on experimental and numerical investigation of composite leaf spring by using ANSYS software. They describe static analysis of steel leaf spring and composite multi leaf spring. The main purpose of this work is comparing the load carrying capacity, stiffness and weight saving of composite leaf spring than steel leaf spring. In composite material GFRP and polyester resign is used, which reduced total cost of leaf spring. When they have compare experimental result and analysis the result, the final result is found that, composite leaf spring

have much lower stress and high stiffness than that of steel leaf spring and the weight reduction in composite leaf spring is about 85% than that of conventional steel leaf spring[8].

Markarand B. Shirke and Prof. V.D Wakchauhe- In this paper, they have worked on studied on performance association of static and fatigue behavior of steel and glass epoxy composite material leaf spring. The dimension of leaf spring is used in this study is a light motor vehicle for analyzing of stress and deflection using ANSYS workbench 14.0 software. The main motive of this study is to reduced cost, weight which is capable of carrying given static external force without failure.

When they have replaced the steel leaf spring by composite material and analysis done on it, with same load carrying capacity. The result is found that, the composite leaf spring have 62.27% lesser stress and deflection as compared to conventional steel leaf spring. And for fatigue result they found that the composite material leaf have 109 cycle and steel have 106 cycle, which is low as composite material leaf and the weight reduction is achieved 65.28% in composite leaf spring over than steel leaf spring[9].

Joo- Teck Jeffery and Tarlochan Faris.- in this paper, they investigated the static and fatigue behavior of steel and composite leaf spring using ANSYS V12 software. In this work, a light commercial vehicle leaf spring dimension is used for design and analysis. The materials which are used as composite are E-glass fiber/epoxy and E-glass fiber. The same dimension is used in composite material leaf and conventional material spring with same load carrying capacity. When the analysis are done on ANSYS, the result is observed that the bending stress and deflection in composite leaf are lower than of steel leaf spring, the fatigue of e-glass epoxy and e-glass are 3 or 4 times higher than that of steel leaf spring[10].

N.P. Dhoshi, Prof. N.K. Ingole And Prof. U.D. Gulhane.- In this paper, for analyzing of stress and deflection in composite leaf. They consider tractor-trailer with seventeen-leaf spring and analysis is done by using ANSYS 11.0 software. The purpose of this work is to compare load carrying capacity, stiffness and weight saving of composite leaf with that of steel leaf spring. They have compared finite element result of stress in leaf spring with analytical and experimental result. In this work, they replace conventional steel leaf spring by composite material E-glass epoxy leaf spring and analysis stress and deflection with same load carrying capacity. The dimension of both spring composite and steel are same and number of leaves also be same. Then the result is found that composite leaf spring have much lower stress and deflection than that of steel leaf spring and 80% of weight reduction in composite leaf spring compare than steel leaf spring[11].

Ashish V. Amrute, Edward Nikhil Karlus.- In this paper, for analyzing off conventional steel leaf spring and composite material leaf spring they use Tata ace ex vehicle. The motive of this work is to compare the load carrying capacity, stresses and weight saving of composite leaf spring with steel leaf spring. In this work place of composite material used E-glass epoxy and when it is compared with conventional steel in same dimension or loading condition. The result is found that the bending stress is decreased by 25.07% in composite leaf, means stress is less induced with same load carrying condition. And the weight of conventional steel is 10.27kg where e-glass epoxy springs have weight only 3.26kg. Then the weight reduction is achieved 67.88% by using composite material in place of steel material [12].

Kumar Krishan and Aggarwal M.L- In this paper, they have worked on computer aided FEA comparison of mono steel and mono GRP leaf spring. They used SUP9 conventional steel material and glass reinforced polymer as composite material for analysis of stress and deflection using ANSYS9 software. The main purpose of this work is to compare stiffness, weight saving with same load carrying capacity with that of steel leaf spring. The dimension and number of leaves are for both steel and composite leaf spring isbeing same. When they doing both analytic and experimental process for getting result then, the result is found that the deflection is reduced by 65% in composite leaf over than SUP9 conventional steel. And the bending stress is decreased by 83.64% over than steel leaf spring or weight reduction is achieved by71.85% in composite leaf over than the conventional steel leaf spring [13].

M.Venkatesan and D. Helman.-In his work, they worked on a passengers cars with seven-leaf steel spring are replaced with composite material leaf spring and analysis of stress and deflection by using ANSYS10. Software The main motive of this work is compare the load carrying capacity, stiffness and weight saving of composite leaf spring with that of conventional steel leaf spring. The composite material which is used is E-glass/epoxy. The no. of leaves and dimension are same for both leaf springs, when the analysis is done on both leaf spring with same load carrying capacity, then the result is found that the E-glass epoxy leaf spring have 63.35% less stress, 64.95% higher stiffness and 126.98% higher natural frequency than that of conventional steel leaf spring. And the weight reduction is achieved by 76.4% by using composite material leaf spring [14].

M. M Patunkars and D.R. Dolas.- In this paper, they used a commercial vehicle suspension system with leaf spring for modeling and analysis of deflection, stress and weight reduction by using ANSYS10 software. Under the static load condition by using FEA. The composite material which is used in leaf spring are glass fiber rain forced plastic. When they replace steel leaf spring by composite material spring and doing analysis with same load condition. Then there is a bigger difference between deflection and stresses of composite material and steel leaf spring. Deflection of composite leaf spring is much lower than as compared to steel leaf spring with same dimension and same loading condition. They conclude that conventional steel spring have weight 23kg and composite material spring have 3.59 kg weight only. Then the weight reduction is achieved by 84.40% in composite leaf over than conventional leaf at same level of performance [15].

Y.N.V. Santhosh Kumar, M. Vimal Teja.- In this paper, they discuss about advantage of composite materials such as higher specific stiffness and strength, higher strength to weight ratio. they design and analysis of composite material leaf spring and the composite material which are used is E-glass/epoxy. The main objective of this work is replacing conventional steel leaf spring by composite material leaf spring and analysis on it, for find better stress, deformation and weight saving with same loading capacity. The dimension and leaves are be same for both springs and the model of leaf spring was designed in PROE and analysis on done using ANSYS software. And the result is found that composite materials leaf spring have only 39.4% weight of steel leaf spring and weight reduction on composite leaf was 60.48% over than conventional steel, and have well stresses within allowable limits and with good factor of safety[16].

Mr. Anand Kumar A. Satpute and Prof. S.S. Chavan.- For their work, they consider and used "maruti omni" rear suspension system design and testing for analysis of strength and weight reduction with steel leaf spring using ANSYS software. The objective of this work is compare strength and weight saving of composite leaf spring than conventional steel leaf spring. When they doing analytical and experimental with composite material of glass fiber7781 and epoxy resin with steel. Then the result is found that, the analytical and experimental analysis are almost same. After that if they use composite material for leaf spring, they have to change thickness of leaves is 5mm to 12mm. Then the weight reduction is achieved 88% but the composite material have chipping resistance and it may avoid by using carbon fibers[17].

Dev Dutt Dwivedi and V.K. Jain.- In this work, they used a three layer leaf spring with full length leaves. The design and analysis of composite leaf spring is done on ANSYS14.5. In composite material E-glass epoxy material are used and when it is compared with conventional steel leaf spring. Then the result is found that, E-glass epoxy material have better strength and light in weight as compared to conventional steel leaf spring. A wide study have been done in this paper, about fatigue life of conventional and composite leaf spring and the result is found that composite leaf have less deflection for a particular load as compared to steel leaf spring. And the stress generated in composite leaf is less as compared to steel spring; directional deformation is low in composite leaf as compared to steel leaf spring. E-glass epoxy leaf spring is lighter in weight as compared to conventional steel leaf spring [18].

Malaga, Anil Kumar, T.N. Charyulu And Ch. Ramesh- in this paper, they have worked on replacement of multi-leaf steel spring by three other type composite(E-glass epoxy, graphite epoxy, carbon epoxy) leaf spring for same load carrying capacity and stiffness. The composite material have more elastic strain energy, storage capacity and high-strength to weight ratio as compared to those of steel. The reduction of weight is possible without reduction on load carrying capacity and stiffness. The dimension parameter of steel leaf spring and composite spring are same for both and analysis was done on using ANSYS9.0 software. Then the result is found that, the conventional steel leaf spring have 596.047 and E-glass epoxy, graphite epoxy, carbon epoxy have 475.606mpa,155mpa,1061mpa von-mises stress respectively. And the displacements in conventional steel leaf springis 92.591mm, E-glass epoxy have 89.858mm, graphite epoxy have 80.369mm and carbon epoxy have 82.662 mm respectively. Composite leaf spring reduced weight by 85% for e-glass epoxy, 94.18% for graphite epoxy and 92.94% for carbon epoxy over than conventional steel leaf spring[19].

Pankaj Saini, Ashish Goel and Dushyant Kumar.- In this paper, light vehicle leaf spring dimension is used for design and analysis by made of composite material. For analyzing they used ANSYS9 software for analysis of stress and deflection with ten steel leaf spring. The main purpose of this work is to compare stress and weight saving of composite leaf spring with conventional steel leaf spring. The material which is used as composite material are E-glass epoxy, carbon epoxy and graphite epoxy as compared to conventional steel. The dimension which is used for conventional steel leaf spring and composite material leaf spring are be same. At last when the static analysis is done, then the result is found that the maximum displacement of 10.16mm in conventional steel leaf spring and E-glass epoxy 15mm, graphite epoxy 15.75mm and carbon epoxy have 16.21mm displacement respectively. And the stress in steel leaf spring is 453.92mpa for e-glass epoxy is 163.22mpa, for graphite epoxy 653.68mpa and for carbon epoxy 300.30mpa respectively. And the weight

reduction is 81.22% for e-glass epoxy, 91.95% for graphite epoxy and 90.51% for carbon epoxy over than conventional steel leaf spring[20].

B. Srikanth Goud and G. Bheemanna.- In his work, a conventional steel leaf spring is designed and modeled in 3D modeling software pro/Engineer. The main objective of this work is replacing conventional steel leaf spring by composite material leaf spring with same dimension. The composite material which is used is E-glass epoxy and aluminum reinforced with boron carbide. When the analysis was done, then the result is found that the weight reduction is almost 267kg in aluminum reinforced with boron carbide and 246kg in e-glass epoxy over than conventional steel leaf spring [21].

METHODOLOGY

A wide study about the structure & performance of conventional leaf spring- for going towards the research, study about the performance of conventional steel is primary step. Until, we cannot knowing the performance and behavior of conventional steel leaf spring then we cannot going towards the invention of composite leaf spring

Image 3 Leaf Spring

As, we discuss above leaf spring is ,made of conventional steel and the main purpose of leaf spring is absorb the shocks and vibrations, which comes due to irregularity of road roads and bumbs. The leaf spring is generally made of some long leaves called master leaf and some shorts leaves, which support the rear axle of a vehicle [22]. These longs and shorts leaves are attached from one above another by pins or clipping which hold the leaves together. The leaves are bent for certain radius of curvature, when any vehicle passes through irregular road condition the tires of vehicle moves up and down. These movements of tire cause movement in leaf spring, the deflection in leaf spring absorb and dissolve the load in nearby then the load will not distrub the vehicle component or passenger seated inside the vehicles. As compared to short leaves master leaves will be more deflected. Both ends of the leaf spring is designed to a circular shape, , the spring's front end is fastened to shackle. [23]. Shackle is a flexible component, which helps the vehicles spring to travel through long way. When you drive through different road surface lakes rocks, bump etc. shackle make sure the length of the leaf spring change proper during the movement of suspension [24]. One another purpose of shackle is to keep maintain the balance of vehicles.

Shackle are located at the rear end of each leaf spring in suspension system of any vehicles. Shackle link the spring and vehicle frame with the eye spring bolt. Leaf spring cannot take all the loads, which comes due to irregularity of roads and bumbs, they depand on the flexibility of shackles. A leaf spring shackle make sure that, the vehicle stay more year of operating in various weather and during various conditions[25]. But now, when we talk about the convention and composite leaf spring, the weight of conventional steel is more than as compared to composite material and its increased the overall weight of leaf spring. The size of conventional leaf spring is also big as compared to composite material leaf spring which is a cost consuming.

Composite Material-A composite material is created by combining two or more materials that have various physical and chemical properties. This new material is then fastened to a particular work[26]. Composite materials have improved stiffness and strength while also becoming stronger, lighter, or electricity-resistant. In today situation, composite materials are mostly used material due to their adaptability to varied situations. And composite materials is easy to mixed with other material and give more desirable property for serve a particular function. The composite material has high strength and hardness, with decrease density than bulk materials [27].

Materials for Leaf Spring-
Plain carbon steel with a carbon content of 0.90 to 1% is typically the material used to make leaf springs. Following the process of formation, the leaves are heated. Greater strength or a higher load capacity, more deflection, and improved fatigue properties are all results of heat treatment in steel products. Nevertheless, in this study we replaced steel with E-glass/epoxy, S-glass/epoxy, and Carbon AS4 and measured stress, strain, and displacement in these composite materials.

Glass fiber- Glass fiber composite have lower in cost over than steel, and it's have high strength, high chemical resistance and better insulating property. But there are some demerits of glass fiber, it's have low elastic modulus, low fatigue strength and high density. Which are responsible of increasing weight and size in leaf spring [42].
Carbon Fiber- Specific strength, high modulus, minimal thermal expansion, and high fatigue strength are all characteristics of carbon fiber**.** [43].

Design Data of Leaf Spring-
Here we have measurement of Mahindra pickup light vehicle leaf spring measurement.

1. Total length of leaf spring eye to eye=1450
2. No. of full length of leaves= 2
3. Thickness of leaf(t)= 11mm
4. Depth of leaf (b)= 70mm
5. overall applied load= 12000N

S.NO.	Part Name	Dimension
1.	Leaf no 1.	70*11*1450
2.	Leaf no 2.	70*11*1450
3.	Leaf no 3.	70*13*1320
4.	Leaf no 4.	70*13*1140
5.	Leaf no 5.	70*12*940
6.	Leaf no 6.	70*12*800
7.	Leaf no 7.	70*12*644
8.	Leaf no 8.	70*12*464
9.	Leaf no 9.	70*11*244
10.	Packing-1	70*12*150
11.	Packing-2	70*11*150
12.	Center bolt	M12*1.75*135
13.	Center bolt nut	M12*1.75
14.	Clip 1/2	25*6
15.	Rivet	D 10
16.	Clip bolt	M8*1.25*100
17.	Clip bolt nut	M8*1.25
18.	Bush	D 30

CONCLUSION

Leaf springs and composite leaf springs have undergone structural study and design. Steel leaf spring and composite leaf spring has been analysis, Having same design and load capacity.

The stress, strain and displacement have been performed by using ANSYS for both steel and composite leaf spring.

And the result is found that the stress in steel is 191.4mpa at load 12000N. and 172.79pma, 179.47mpa, 181.33mpa for E-glass/epoxy, S-glass/epoxy and carbon AS4 respectively.

The strain is found in steel is 0.001045mm at load 12000N. and 0.00259mm, 0.00219mm, and 0.01105 for E-glass/epoxy, S-glass/epoxy and carbon AS4 respectively.

The deflection found in steel is 1.0035mm at load 12000N. and 2.633mm, 2.185mm, 8.211mm for E-glass/epoxy, S-glass/epoxy and carbon AS4 respectively. All the three composites have lower stress than that of existing steel leaf spring.

A comparatively study has been made between steel and composite leaf spring with respect to strength and weight.

Then the result is found that Composite material leaf spring reduce weight by 67.76% for E-glass/epoxy, 64.86% for S-glass/epoxy and 77.58% for carbonAS4 over conventional leaf spring.

REFERENCES

[1]. V. Pawan Chilbule, and R. Ganesh Chauhan. (2018) "design and analysis of leaf spring using composite materials, "Internal journal of engineering research and technology; volume 7.
[2]. Online available on, "Leaf spring - Wikipedia.
[3]. online available on "Leaf Springs - an overview | Science Direct Topics"
[4]. Prashik sunil gaikwad, (2018) "compression of steel and composite leaf spring using FEA, "the University of Texas at arlington in partial fulfillment".
[5]. Parikh, H. (2021), "Diatom Biosilica as a source of Nanomaterials", International Journal of All Research Education and Scientific Methods (IJARESM), Volume 9, Issue 11
[6]. Online available on "Leaf Springs for Trucks - Bing images".
[7]. Online available on "three quater elliptical leaf spring carriage - Bing images".
[8]. Abdul Rahim Abu Talib, Aidy Ali, G. Goudah, Nur Azida Che Lah, A.F. Golestaneh, "Developing a composite based elliptic spring for automotive applications", Materials and Design, 31, 2010, 475–484.
[9]. Parikh, H. (2021), "Algae is an Efficient Source of Biofuel", International Research Journal of Engineering and Technology (IRJET), Volume: 08 Issue: 11.
[10]. K. K. Jadhao, DR. R. S. Dalu, "Experimental investigation & numerical analysis of composite leaf spring", International Journal of Engineering Science and Technology, Vol. 3, No. 6, 2011.
[11]. Makarand B. Shirke, Prof. V. D. Wakchaure, "Performance Association of Static and Fatigue Behavior of Steel and Glass Epoxy Composite Leaf Spring of Light Motor Vehicle", International Journal of Advanced Research in Science, Engineering and Technology, Vol.01, Issue 04, pp. 08-11.
[12]. Joo-teck Jeffrey, Tarlochan Faris, "Finite element analysis on the static and fatigue characteristics of composite multi-leaf spring", Journal of Zhejiang University- Science, Vol. 13, 2012, pp 195-164
[13]. N. P. Dhoshi, Prof. N. K. Ingole, Prof. U. D. Gulhane, "Analysis and modification of leaf spring of tractor trailer using analytical and finite element method", International Journal of Modern Engineering Research, Vol.1, Issue.2, pp 719-722
[14]. Patel, M., Parikh, H., & Dave, G. (2023), "Chitosan flakes-mediated diatom harvesting from natural water sources", Water Science and Technology, 87(7), 1732-1746.
[15]. Ashish V .Amrute, et al., and (2013) Design and Assessment of Multi leaf spring International Journal of Research in Aeronautical and Mechanical Engineering Issn (Online): 2321-3051 Vol.1 Issue.7.
[16]. Kumar Krishan, Aggarwal M.L, "Computer aided FEA comparison of mono steel and mono GRP leaf spring", International Journal of Advanced Engineering Research and Studies, Vol. I, Issue II, 2012, pp 155-158
[17]. M.Venkatesan, D.Helmen, "Design and analysis of composite leaf spring in light vehicle", International Journal of Modern Engineering Research, Vol.2, Issue.1, 2012, pp 213-218.
[18]. Parikh, H., Prajapati, B., Patel, M., & Dave, G. (2023), "A quick FT-IR method for estimation of α-amylase resistant starch from banana flour and the breadmaking process", Journal of Food Measurement and Characterization, 1-11.
[19]. M. M. Patunkar, D. R. Dolas, "Modelling and Analysis of Composite Leaf Spring under the Static Load Condition by using FEA", International Journal of Mechanical & Industrial Engineering, Volume 1, Issue 1, 2011
[20]. Y. N. V. Santhosh Kumar, M. Vimal Teja "Design and Analysis of Composite Leaf Spring" Dept. of Mechanical Engineering, Nimra College of Engineering & Technology, Ibrahimpatnam, Vijayawada. (2012)
[21]. Mr. Anandkumar A. Satpute, Prof. S. S. Chavan, "Mono Composite Leaf Spring –Design and Testing", Indian Journal of Applied Research, Volume 3, Issue 7, 2013.
[22]. Dev dutt Dwivedi, V.K. Jain, (2016) "Design and Analysis of Automobile leaf spring" ISSN (PRINT): 2393-8374, (ONLINE): 2394-0697, VOLUME-3, ISSUE-1.
[23]. Malaga. Anilkumar, T. N. Charyulu, Ch. Ramesh, "Design Optimization Of Leaf Spring", International Journal of Engineering Research and Applications, Vol. 2, Issue 6, 2012, pp.759-765

[24]. Pankaj Saini, Ashish Goel, Dushyant Kumar, "Design and analysis of composite leaf spring for light vehicles", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 5, May 2013.
[25]. B. Srikanth goud and G.Bheemanna,(2015)"Design optimization of a heavy vehicle leaf spring the material E Glass Epoxy and Aluminum reinforced with boron carbide", SSRG International Journal of Mechanical Engineering (SSRG-IJME) – volume 2 Issue 10.
[26]. Tilwani K., Patel A., Parikh H., Thakker D. J., & Dave G. (2022), "Investigation on anti-Corona viral potential of Yarrow tea", Journal of Biomolecular Structure and Dynamics, 1-13.
[27]. Online available on "Leaf spring - construction, working, advantages & types with PDF (mechanical post. Site)".