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"EVALUATION OF THE DESIGN OF COMPOSITE MATERIAL HELICAL COMPRESSION SPRING – A REVIEW "

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ABSTRACT

Researchers and Automobile industries are focussing on improving the efficiency and reliability of the vehicles by reducing the weight of the vehicles .it can be achieved by using a better material (low density and higher specific strength), optimization of previous design and better manufacturing processes. In this paper, the aim of study is to review all such work in which the weight reduction of the vehicle was achieved by considering helical compression spring. Many of the authors and researchers have suggested that weight reduction can be achieved by using composite material having suitable properties and capable of carrying heavy load of the vehicle. There are different methods are also discussed used for analysing and manufacturing of helical compression springs. It was shown that the weight reduction can be easily achieved but there are more aspects which should also be consider i.e. cost, new composite materials.

KEYWORDS : *helical compression spring, composite material E-glass/Epoxy, Carbon/Epoxy.*

I. INTRODUCTION

In current scenario automobile manufacturers and researchers are making effort in order to conserve material and economize cost and energy. The automobile industry is making efforts towards weight reduction of vehicle. For increasing fuel efficiency, weight of the vehicle must be reduced .the suspension system using helical compression spring of an automobile is one of the important part and reserves 20 percent of the total weight of the vehicle .the suspension system of vehicle provides not only comfort ability but also increases reliability of the system . It reduces the tyre wear rate.In this paper, the aim of study is to review all such work having aim to reduce the weight of the vehicle .In current scenario, steel is generally used for helical compression spring in suspension system. For lowering the weight of vehicle, replacement of steel spring with composite material is necessary. The composite materials have high specific strength and low value of density results in higher elastic strain energy capacity and low weight as compared to steel.Composite materials offers opportunity for substantial amount of weight saving. Springs are design to absorb & store energy & then release it, hence strain energy of material & shape becomes major factors in designing the spring.

.II. LITERATURE REVIEW

Mr. L. Del LIano-Vizcaya et. al. (2006) [1], in their work multiaxial fatigue criteria is applied to the helical compression springs. The aim of work is to determine which type of criteria and the methodology behind them, provides

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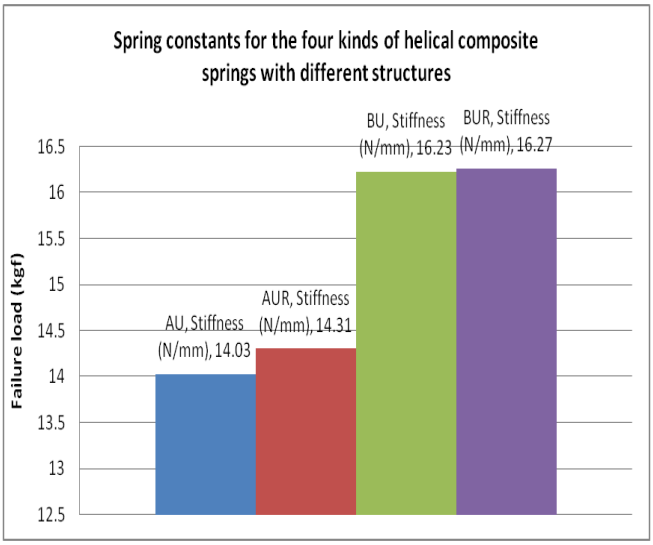
the best potential to estimate the fatigue life of mechanical springs. Fatemi-Socei, Coffin-Manson and Wang-brown methods are used in the analysis of spring. The stress analysis was carried out in the finite element code ANSYS and the multiaxial study was performed using the fatigue software nCode. A failure analysis was conducted in order to determine the fatigue crack initiation point and comparison of that location with the most damaged zone predicted by numerical analysis. Predicted lives are compared with experimental results in order to evaluate the methods defining multiaxial criteria mentioned above. Material fatigue properties were obtained from monotonic uniaxial test results through the methods M (mason) and MM (Murlidharan). The Fatemi-Socie critical plane approach gives a good prediction of fatigue life.While the Wang-brown criterion approach overestimates spring fatigue life, the Coffin-Mason criterion model provides conservative results.

Mr.Chang Hsuan Chiu et. al.(2003) [2],in their work four different types of helical composite springs were made of structures including unidirectional laminates(AU),rubber core unidirectional laminates (UR),unidirectional laminates with a braided outer layer(BU), rubber core unidirectional laminates with a braided outer layer(BUR),respectively. The aim of study is to investigate the effects of rubber core and braided outer layer on the mechanical properties of the above mentioned four helical springs. In this study carbon fiber helical compression springs was made by using both carbon material as reinforced material and epoxy resin as matrix material. Besides, both rubber core and braided outer core were also added to change the structure of carbon fiber helical composite springs. In this study, a MTS (model no. LY-6040A4) is employed for the compression test of carbon fiber helical compression spring. This research is intended to determine the effect of rubber core and braided outer layer on the mechanical properties and failure behavior of the abovementioned helical compression springs. There were some results found out are as follows:

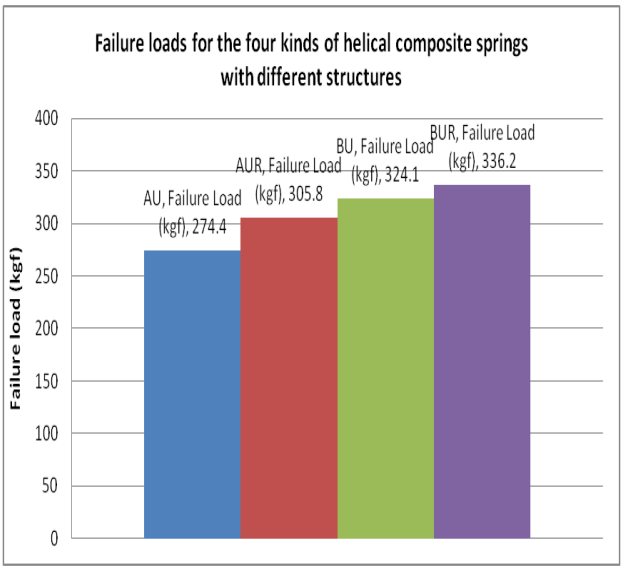
[1] [The helical composite spring used with a rubber core not only increase its static failure load in compression by approximately 12 percent, but also reduce the amount of prepregs used thus lower the cost of material and energy.

[2] The helical composite spring consist of a braided outer layer According to experimental results, the helical composite spring with a rubber core can increase its failure load in compression by about 12 percent, while the spring with braided outer layer can not only increase its failure load in compression by about18 percent, but also improves the spring constant by approximately 16percent. In addition, it can reduce the difference in fabrication of springs as well.



[3] The helical compression spring used with a BUR structure have the highest mechanical properties among those considered herein, its failure load in compression approximately bears 3362 N, and the spring constant is almost 162.7 N/mm.

[4] The fabrication of helical composite spring sounds preliminary feasible by this research. Helical composite springs have significant advantages over the conventional steel springs as discussed above in this paper. Therefore it might be expected that shock absorber with high performance and reliability to come soon.



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Mehdi Bakhshesh et. al. (2012) [3],In this research, conventional steel helical compression spring used in light vehicle suspension system has been analyzed under a effect of uniform loading and results obtained from finite element analysis is compared with analytical results. In this study steel spring has been replaced by three different composite helical springs including E-glass/Epoxy, Carbon/Epoxy and Kevlar/Epoxy. Spring weight, maximum stress and deflection have been compared with steel helical spring and factors of safety under the application of loads have been calculated. In any case, with changing fiber angle relative to spring axial, composite spring properties have been investigated. In this work solid modeling of helical compression spring was done in SOLIDWORKS software and then it is analyzed under uniform loading condition in ANSYS Software. Spring was subjected under axial loading .axial displacement and shear stress has been compared with analytical results.SOLID45 element is selected for the analysis of helical compression spring in place of SOLID92 because SOLID92 is a pyramid element that increases time of calculations and it has error occurred in nonlinear complex models. Therefore, a cubic element selected solid 45 in the stress analysis. This element is defined by 8 nodes having 3 degrees of freedom at each node. The results shows that the helical springs has been found to have lesser amount of stresses and the higher amount of stresses induced when fiber position have been considered to be in direction of loading.

Mr. Saurabh Singh (2012) [4],the objective of his work was to demonstrates the feasibility of the composite material for the design of helical compression spring. In this study the combination of steel and composite material is used in place of conventional steel only. The composite material used in analysis of helical compression spring is Eglass/Epoxy. the single composite spring has low stiffness which limits its application to light weight vehicle only therefore he was implementing the use of combination of steel and composite material for helical compression spring. The design of helical compression spring was made in CREO 1.0 software package. The analysis of the design of helical compression spring has been done on ANSYS 13.0 software package. The results obtained from the analysis of helical compression spring shows that the stiffness can be increased by in expense of manufacturing cost and material volume. The weight reduction obtained in this combination is approximately 21 percent. Mr. Pinjarla Poornamohan. et. al. (2012) [5], the objective of their work was to verify the effect of varying the material of helical compression spring used in shock absorber. In this study the shock absorber is designed and solid modelling of shock absorber was done in PRO/ENGINEER software package. Structural and model analysis of shock absorber was done on ANSYS by varying material for spring, steel and Beryllium Copper. the analysis is done by considering the loads, bike weight, single person and 2 persons approximately 1700 N on single shock absorber. Comparison was done for two material to verify the best material for helical compression in shock absorber. Structural analysis was done to validate the strength and modal analysis was done to determine the displacements for different frequencies for number of modes. There were some results found out are as follows:

The max. stresses induced in the helical compression spring used in shock absorber are less than respective yield stress value.
By comparing the results for both materials, the stress induced in steel helical compression spring than beryllium copper material helical compression spring.by comparing the results for present design and modified design of shock absorber using helical compression spring of increased diameter by 2mm,the stress and displacement values obtained from present design are less than modified design.

Tausif M. Mulla et. al. (2012) [6],in this project the aim of work is to analysed a helical compression spring employed in three wheelers Auto-rickshaw.the purpose of work is to ensure the reliability of spring for that the stress analysis of helical compression spring was done by using finite element method. The design of helical compression spring is taken from the three wheelers auto-rickshaw front suspension system. ANSYS 13.0 software package is used for the analysis of helical compression spring. The 3D modelling of design of helical compression spring was done then it is analysed by ANSYS using finite element method. At the first the helical spring was meshed with element SOLID187.this element is a higher order 3-dimensional 10-node element. SOLID 187 have a quadratic displacement nature and is best suited to modelling irregular meshes. The element is defined by 10 nodes having 3 degrees of freedom at each nodal; x, y and z directions respectively. This element was used for Tet-meshing.in the second case, the helical compression spring was modelled with element SOLID95/SOLID186.this element is for solid structures having 20 nodes. It can tolerate irregular shapes with high accuracy. It was beast suited to curved model shapes and have compatible displacement shapes. It is defined as 8 nodes having 3 degrees of freedom at each node; translations

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in the nodal x, y and directions respectively. In this study the max shear stress induced on inner side of spring subjected to a maximum load of 167 kg.

Bruno Kaiser et. al. (2012) [7], in this project The aim of this research work was to determine statistically based results for the fatigue properties of helical compression springs made of various spring steel wire materials, which were to be tested in wire diameters between 1 mm and 8 mm. Test results: Goodman-diagrams In order to enable a comparison, the Goodman diagrams representing the test results and the Goodman-diagrams of the standard DIN EN 13906 are presented correspondingly in the same diagrams. To design these diagrams more clearly, only the Goodman diagram of the results for a failure probability of 10 % are figured (without application of any safety factors). Goodman-diagrams for shot peened and pre-set helical compression springs of oil hardened and tempered SiCr-alloyed spring steel wire (VDSiCr) in 5 diameters from 1 to 8 mm. The allowable stresses (upper horizontal lines) in these diagrams are limited to 0.6 x tensile strength of the corresponding wire as explained before. The ascending lines of the diagrams represent the fatigue test results for a failure probability of 10%. This report represents results of numerous fatigue tests (till 107 cycles) on helical springs with diameters from 1 to 8 mm, made of six different spring steel wire grades. The fatigue ranges of the test springs are demonstrated as Goodman-diagrams and compared to given Goodman-diagrams in DIN EN 13906-1. This comparison shows, that the test results (for a failure probability of 10%) for shot peened springs made of VDSiCr, TDSiCr, DH and DM are significantly higher than the standards values for corresponding springs, even taking into account, that the test results do not yet include any safety aspects. For unpeened springs made of two stainless spring steel wire grades, however, the test results (again for a failure probability of 10%) were not remarkably higher than the standards values for corresponding springs. After having completed these fatigue investigations limited at 10^7 cycles, some long term fatigue tests on shot peened helical compression springs were operated, in one case up to a maximum number of 1.5 x 10^9 cycles. The fatigue range of shot peened helical compression springs made of oil hardened and tempered Cr-Si-alloyed spring steel wires shows a significant decrease in the extremely high cycle region.

S.N. Gundre et. al. (2013) [8],in this project the aim of work is to analysed a helical compression spring employed in Electric tricycle vehicle automotive front suspension. The purpose of work is to ensure the reliability of spring for that the stress analysis of helical compression spring was done by using finite element method. The design of helical compression spring is taken from the Electric tricycle vehicle automotive front suspension. The spring selected for the electric three wheeler vehicle having squared and grounded ends. ANSYS 13.0 software package is used for the analysis of helical compression spring. The 3D modelling of design of helical compression spring was done in CATIA V5 R20 software then it is analysed by ANSYS using finite element method. At the first the helical spring was meshed with element SOLID187.this element is a higher order 3-dimensional 10-node element. SOLID 187 have a quadratic displacement nature and is best suited to modelling irregular meshes. The element is defined by 10 nodes having 3 degrees of freedom at each nodal; x, y and z directions respectively. This element was used for Tet-meshing.in the second case, the helical compression spring was modelled with element SOLID95/SOLID186.this element is for solid structures having 20 nodes. It can tolerate irregular shapes with high accuracy. It was best suited to curved model shapes and have compatible displacement shapes. It is defined as 8 nodes having 3 degrees of freedom at each node; translations in the nodal x, y and directions respectively. In this study the max shear stress induced on inner side of spring subjected to a maximum load of 250 kg.

Ghodake A. P. et. al. (2013) [9],in their work they searched a new material against steel. For this work glass fibre reinforced plastic (GFRP) and polyester resin (NETPOL 1011) selected against conventional steel i.e. 65Si7. Here leaf spring of constant width and thickness was fabricated by hand lay-up technique. The entire dimensions were taken for design and analysis from existing conventional steel leaf spring used in the light commercial vehicle. The composite leaf spring was fabricated using hand lay-up technique and the leaf spring was also designed and numerical analysed using ANSYS by finite element method. Stresses, deflection and strain energy results for both steel and composite leaf spring material were obtained and compared. It has been observed that the composite leaf spring was lighter and more economical than the conventional steel spring with similar design specifications. It was also observed that the weight reduction of mono leaf spring was achieved up 84.94% in case of composite than steel.

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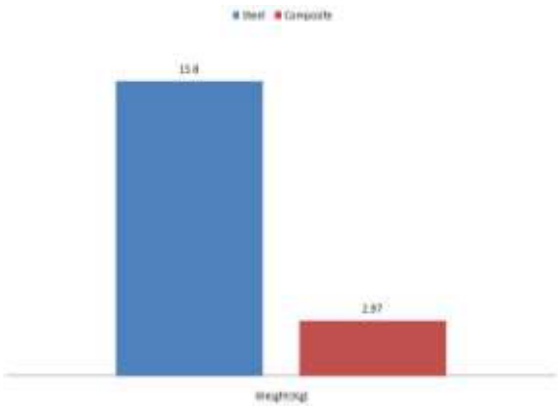

Fig. 5 Comparison of weights in steel and composite

Ramakanth U. S. et. al. (2013) [10], this work was carried out on multi leaf springs having nine leaves used by a commercial vehicle. The material of the existing leaf spring was 65Si7 (SUP9) and for getting suitable material there were two material selected as composite material as E-glass/Epoxy and hybrid (just alternate layers of steel 65Si7 and Epoxy GFRP). The leaf spring by taking dimensions from existing one designed on solid works, analysed using ANSYS and for analysing finite element method was approached. Fatigue analysis of leaf springs is carried out for steel leaf springs, and Static analysis for steel leaf springs, composite leaf springs and hybrid leaf springs. There were some results found out are as follows

- Stresses in composite leaf springs was found out to be less as compared to the conventional steel leaf springs, also a new combination of steel and composite leaf springs (hybrid leaf springs) are given the same static loading and was found to have values of stresses in between that of steel and composite leaf springs.

- Conventional 65Si7 (SUP9) leaf springs were found to weight about 58.757kgs, while the composite leaf springs weighed only 19.461kgs, and the hybrid leaf springs weighed 41.14kgs for the same specifications.

- The cost of the GFRP composite was found very high when compared to conventional steel leaf springs, while the cost of hybrid leaf springs may be lesser when compared to GFRP composite leaf springs.

- The fatigue analysis of the steel leaf springs were carried with four approaches, Soderberg's approach is found out to give better results for the analysis of life data for leaf springs.

III. CONCLUSION

As we observed in the literature review of research papers that a lot of work has been done in designing of leaf springs which is discussed briefly in this paper, on the basis of this study, problems in overall weight reduction will be overcome by using composite materials are identified. Many of the authors suggested various methods of designing, manufacturing and analyses of composite leaf springs. After studying all the available literature it is found that weight reduction can be easily achieved by using composite materials instead of conventional steel, but there occurs many problem during the operation while using the composite helical compression spring i.e.. Therefore there is an immense scope for the future work regarding use of composite materials in leaf springs to reduce the overall weight of the vehicle as well as the cost of the vehicle.

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