Design Optimization of Industrial and Automobile Suspension System- A Review Study

Shiv Shankar[1] Prof. Ranjeet Kumar[2] Dr. R.S. Sikarwar[3]
[1]M.Tech Student (Machine Design) [2]Faculty [3]Director
[1,2,3]Department of Mechanical Engineering
[1,2,3]Vaishnavi Institute of Technology & Science, Bhopal (M.P.), India

Abstract— Industrial and automobile suspension systems are one of the important components of any mechanical assembly. Suspension system of any assembly reduces the effect of jerks. These are prone to get fail regularly causing it to be replaced. This replacement leads to financial losses and undue interruption in working of the components, the suspension system is fitted with. Hence in order to minimize these losses, rigorous amount of research is required in the field of industrial and automobile suspension system. A lot of research has already been done in this field. Current research paper investigates and analyses the work and research analysis which has already been performed. The results of the literature review (Current state of the art situation) have been presented as the part of conclusion.

Keywords: Design Optimization, Industrial and Automobile Suspension System

I. INTRODUCTION

Suspension is the system of tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems must support both road holding/handling and ride quality, which are at odds with each other. The tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the road or ground forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different.

A spring is an elastic object that stores mechanical energy. Springs are typically made of spring steel. There are many spring designs. In everyday use, the term often refers to coil springs.

When a conventional spring, without stiffness variability features, is compressed or stretched from its resting position, it exerts an opposing force approximately proportional to its change in length (this approximation breaks down for larger deflections). The rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring.

II. LITERATURE REVIEW

A. G. Hejib et al. The helical compression spring used in two wheelers is belonging to the medium segment of the Indian automotive market. The detailed assessment of the problem of two-wheeler suspension spring is studied. Most of time springs were failed due to raw material defects, surface imperfection, improper heat treatment, corrosion and decarburization and high weight of suspension. These problems can be solved by applied thick layer of paint as adhesive, proper heat treatment, change in shape and material of helical compression spring. In this work, the spring rate can be increased by change in structure i.e., change in number of active coils of spring. Theoretical and experimental work is done. Results obtained are compared.

Aakash Bhatt et al. Helical spring has been widely used in the suspension system of the machines. This conventionally used spring was purely manufactured with the help of steel, which as a result increased the weight of the entire working machine, which was the hindrance in increasing its efficiency. Hence our project demonstrates the feasibility of adopting composite material for design of helical coil suspension system. In this project the design analysis of combination of steel and composite material will be performed. This will result into greater stiffness with reduced weight of the spring which will be the prime advantage of this project.

Ajay Tukaram Kumbhar et al. The Helical spring is used for suspension in automobile. The Helical spring absorbed the shocks and bump. The present study explores about experimental and computational analysis of helical spring used in automobile. This study concentrated on the use of composite material for manufacturing of helical spring. Overall, this study compares the results obtained by experimental analysis of existing mild steel material helical spring by using Universal Testing machine and composite material helical spring. The validation of experimental results is given by ANSYS computational results. Finally, the Comparison is done for concluded the results.

Akshat Jain et al. The main aim of this work has to develop a helical spring for shock absorber used in suspension system which is designed to reduce shock impulse and liberate kinetic energy. In a vehicle, it increases comfort by decreasing amplitude of disturbances and it improves ride quality by absorbing and dissipating energy. When a vehicle is in motion on a road and strikes a bump, spring comes into action quickly. After compression, spring will attempt to come to its equilibrium state which is on level road. Helical springs can be made lighter with more strength by reducing number of coils and increasing the area. In this research work, a helical spring is modelled and analyzed to substitute the existing steel spring which is used in suspension. By using different materials, stress and deflection of helical spring can be varied. Comparability between existing spring and newly replaced spring is used to verify the results. For finding detailed stress distribution, finite element analysis is used to find stresses and deflection in both the helical springs. Finite element analysis is a method which is used to find proximate solutions of a physical problem defined in a finite domain. In this research work, modelling of spring is accomplished using Solid Works and analysis on Ansys.

Amol Vikas Joshi et al. A spring is an elastic object used to store mechanical energy. A shock absorber is a

All rights reserved by www.ijsrd.com

mechanical device designed to smooth out or damp shock impulse & dissipate kinetic energy. In this paper there is reviewed some papers on suspension system. The aim of this review paper is to represent a general study on the analysis of spring to fulfil the requirement of suspension system.

Anil Antony Sequeira et al. In automobile sector due to the demanding need of rapid innovation and tough competition, the old products are reengineered by new product with composite materials. Regularly new innovations are carried out in suspension area of vehicles. Fibre Reinforced Material [FRP] components are the main interest of automobile industry for replacing the steel components due to "high strength to low weight" ratio. To reduce the weight and fuel consumption to some extent, automobile industries are using the Glass Fibre Reinforced Plastic [GFRP] open coil springs in suspension system of vehicle at the place of steel open coil springs. In this research, the properties of composite and steel helical spring are compared and the deciding factor is the stiffness to weight ratio. Spring geometry is modelled in CREO Software on other hand Finite Element method is used to analyse under different loading condition. Finally, steel spring has been replaced by two different composite helical spring including Carbon and Kevlar.

Anirudh Kumar Singh et al. Helical coil suspensions are used to absorb vibrations as vehicle moves on rough roads. As automobile industry demands for increased fuel efficiency, the designers emphasize on weight reduction of automobile components to the maximum extent possible without much compromise in strength. The current research analyses the Hero Honda suspension subjected to bumps on roads and causing deformation and stresses on the component. Using Taguchi Response surface optimization, response surface plots and sensitivity plots are generated for stress and strain energy. From the response surface optimization, it is evident that nearly 23% of mass reduction is possible. The CAD modelling and analysis is conducted using ANSYS 18.1 software which is based on Finite Element Analysis and response surface optimization is also conducted on the same platform.

Arko Banerjee Automobile suspension plays an important role in vehicle safety, passenger comfort and safety. During a mechanical deformation/vibration the suspension would absorb most of the energy (mechanical vibrations) and would ensure safety and comfort, most of the kinetic energy would be dissipated as Vertical motion in the vehicle. In this research paper a helical spring related to an electronic vehicle system with two different profiles under the effect of a uniform load have been studied. A model is created for an electric vehicle helical coil spring with modified profiles of the helical spring as circular and triangular fillet by using modelling software Solid works 2017. This research paper deals with the detailed analysis of the suspension system by using ANSYS workbench 18.1 simulation software. Using the Finite element approach, results are compared on the basis of Static Structure analysis. In addition, the results for the various spring profiles are compared.

Bhaskar U et al. — Helical spring is the most common element that has been used in many automobile suspension systems. In this work, hybrid spring are fabricated using the composite material and steel wire as a core material, helical spring related to light vehicle suspension system under the effect of a uniform loading has been studied and finite element model has been developed to compare with analytical solution. In the present work three different types of hybrid helical springs using cross-vowen glass fibre, cross-vowen carbon fibre and combined glass and carbon fibre along with a steel wire as a core material have been fabricated. Tests were conducted on these specimens to study their mechanical behaviour. The spring rate and deflection with respect to various loading condition have been evaluated. The results of these parameters with respect to the above three specimens have been compared with one another. The present study is an attempt to observe the feasibility of replacing composite coil spring in place of conventional steel spring. It is concluded that through a modification in the cross-section design of coil spring and with a proper material combination, it is possible to improve the properties of composite coil springs.

C. Madan Mohan Reddy et al. - The present work is carried out on modelling, analysis and testing of suspension spring is to replace the existed steel helical spring used in popular two-wheeler vehicle. The stress and deflections of the helical spring is going to be reduced by using the new material. The comparative study is carried out between existed spring and new material spring. Static analysis determines the stress and deflections of the helical compression spring in finite element analysis. The testing proto type is used to test the spring under different loading conditions. Finite element analysis methods (FEA) are the methods of finding approximate solutions to a physical problem defined in a finite region or domain. FEA is a mathematical tool for solving engineering problems. In these the finite element analysis values are compared to the experimental values. A typical two-wheeler suspension spring is chosen for study. The modelling of spring is developed on pro/E 5.0 analysis is carried out on ANSYS 14.

D.RAMYA et al. Spring is a mechanical element which is used to reduce the shocks and vibrations in any vehicle. In Railways we have two different types of suspensions which absorb the shocks and vibrations and balance the entire system under dynamic conditions. The springs both primary and secondary suspensions which have been using for the passenger railway trains are single coil helical suspension springs. Here in this paper the railway primary suspension spring is considered for the study. The concentric springs which have more than one spring with same central axis can able to bear the loads and withstand to the stresses and deformations better compared to the single helical coil springs. So, here in this present study the locomotive primary suspension is replaced with the concentric springs which have two springs with same axis one inside of the other spring. Chromium vanadium steel material is taken for the analyses of both the concentric and helical coil springs. The both concentric spring and helical coil springs are designed in Solidworks modelling software. Static, modal analyses are conducted in finite element analysis commercial tool ANSYS 15.0. The stress distributions, displacements are analyzed in Static analysis. The natural Frequencies and mode shapes are analyzed in Modal analysis. Comparison of stresses, deformations and natural frequencies for both the

All rights reserved by *www.ijsrd.com*

single helical coil primary suspension spring and replaced concentric springs are studied to determine better spring.

Dhareshwar S Patil et al. This study deals with the elaborate design optimization technique for helical compression spring with analytical method. Concentration is made on reducing weight of helical compression spring keeping the induced stresses within permissible limits. The spring is acted upon by compressive force so the spring gets compressed. The entitled work comprises, design of helical compression spring made from wire of solid circular section for a problem and optimizing the weight of solid wire spring by redesigning it with hollow circular section instead of solid circular section. After analytical design procedure the solid wire spring and optimized spring (i.e., spring made from hollow circular wire) are manufactured. After manufacturing of springs, analytical results are validated experimentally and in ANSYS.

Dhiraj V. Shevale et al. A mechanical spring is an elastic body which has primary function is to deflect under load and return to its original shape when load is removed. Shocks and vibrations generated from the road surface are detached from structure to the passengers by automobile suspension system. Spring undergoes different types of forces like twist, pull, stretch, etc. Force is linear tensile or compressive or it can be radial. The torque act on the spring causes rotation. The main purpose of this paper is to enlighten some point related to the fatigue stress analysis of spring used in automobile suspension system. Its analysis is carried out Theoretically, experimentally and numerically with the help of different softwares, but FEM is best tool for the analysis.

Ganesh Bhimrao Jadhav et al. - Aim of this paper is to analyse feasibility of adopting composite material for design of helical coil spring. Combination of springs with steel and composite material i.e., Glass fibre epoxy resin is to be used in place of conventional spring steel. The cause of implementing combination of steel and composite material is the low stiffness of single composite spring, which limits its application to light vehicles. Fuel efficiency of automobiles can be maximized by lowering the weight of the vehicle. The spring of the suspension system plays an important role for a smooth and jerk free ride. So, it is required to design the springs very precisely. The use of conventional steel as spring increases the weight and manufacturing process energy required is more so manufacturers are willing to use composite materials light in weight and also have corrosion resistance, it can also withstand high temperature. Manufacturing composite material is quite costlier than the steel spring. The use of composite material is beneficial if manufacturing process is standardized it can increase the efficiency of the vehicle adherence overcome the material cost.

Godwin Raja Ebenezer N et al. In this paper, nature inspired algorithms, namely, Simulated Annealing (SA), Fire fly (FA) and Cuckoo Search (CS) are proposed to get dynamic optimal solution for a helical spring design problem. The problem has four design variables and thirteen inequality constraints. To solve this problem, a dynamic model of the cylindrical helical spring having mechanical, geometric objective functions and dynamic constraints is considered. The dynamic constraints are related to the natural frequency of the spring. The sensitivity of the spring to its first natural frequency where resonance appears with large displacements is also accounted. The objective is to minimize the mass of the spring and to maximize the natural frequency of the spring. The design variables considered are: diameter of the wire, diameter of the middle helix, active number of coils and pitch of the spring. The problem is computed in MATLAB environment. Results of simulation are analysed and compared with literature.

Goran Vukelic et al. Results of experimental and numerical analysis of a broken motor vehicle helical spring are presented in this paper. Location of the fracture is on a first active coil of the spring. Experimental part of the research employed optical microscopy that revealed fractured surface microstructure and allowed for detection of inclusions. Corroded fracture surface limited scanning electron microscopy examination (SEM). Nevertheless, corrosion pits on the edge of the spring wire which served as crack initiation points could be detected by SEM along with radiating ridges left by the fracture front that propagated to the opposite edge of the wire. Optical emission spectrometer with glow discharge source sample stimulation was used to determine material chemical composition that is adequate to spring steel 61SiCr7. Additionally, hardness test was performed and obtained value was used to derive maximum tensile strength of the steel. Experimentally collected data served as input for numerical analysis of helical spring. Finite element analysis of a helical spring model was performed. Stress distribution was determined and fatigue life of the undamaged helical spring predicted. Results were compared with those obtained analytical. Causes of failure are outlined assessing the results of the performed experimental and numerical analysis. Insufficient corrosion protection and excessive contact between the coils caused damage that developed from initial crack to final fracture of the spring. Results obtained by this research are valuable in understanding fracture behaviour of helical spring mounted in suspension system of various motor vehicles. Given the presented results, further improvements of spring design can be made in order to reduce failures.

Harshal Rajurakar et al. The present work is carried out on modelling, analysis of suspension spring is to replace the existed steel helical spring used in popular two-wheeler vehicle. The stress and deflections of the helical spring is going to be reduced by using the new material. The comparative study is carried out between existed spring and new material spring. Static analysis determines the stress and deflections of the helical compression spring in analytical as well as finite element analysis. The structural reliability of the spring must therefore be ensured. So, for this purpose the static stress analysis using finite element method has been done in order to find out the detailed stress distribution of the spring. The analytical & finite element analysis carried out by changing cross sectional area of helical spring from circular to rectangular to check its feasibility. Finite element analysis methods (FEA) are the methods of finding approximate solutions to a physical problem defined in a finite region or domain. FEA is a mathematical tool for solving engineering problems. In these the finite element analysis values are compared to the analytical values. A typical two-wheeler suspension spring is chosen for study. The modelling of

All rights reserved by *www.ijsrd.com*

spring is developed on pro/E 5.0 analysis is carried out on Ansys 14.

Jian Zhang et al. This paper presents a modelling study of the dynamics of a helical spring element with variable pitch and radius considering both the static stiffness and dynamic response by using the geometrically exact beam theory. e geometrically exact beam theory based on the Euler–Bernoulli beam hypothesis is described, of which the shear deformations are ignored. Unlike the traditional spliced curved beam element method, the helical spring element is described with curvature vector and axial strain by establishing and spline-interpolating a function of the radius, the height, the polar angle, and the torsion angle of the whole spring. In addition, a model smoothing method is developed and applied in the numerical analysis to filter the high-frequency oscillation component of the flexible multibody systems, so as to correct the system dynamic equations and improve the calculation efficiency when solving the static equilibrium of the spring.) is study also carries out five numerical trials to validate the above dynamic procedure of the helical spring element.) e example of the spring static stiffness design shows that the proposed helical spring procedure enables one to deal with practical engineering applications.

Jun Ke et al. Composite helical spring has gained considerable attention due to its high strength to weight ratio and corrosion resistant. It can also be utilized for different applications such as automobile suspension and railway bogie. Therefore, its design method and performance investigation are the research hotspots in the application field of composite structures. This work attempts to review most of the studies carried out on the design method of composite helical springs, including material selection, structure design, performance matching design and optimization design. Moreover, important research results on the performance investigation and manufacturing process of composite helical springs are also highlighted. Finally, the emerging trends in the research of composite helical springs are discussed.

K Pavan Kumar et al. A spring is an elastic object used to store mechanical energy. They can twist, pulled or stretched by some force and can return to their original shape when the force is released. Static analysis determines the safe stress and corresponding pay load of the helical compression spring. The present work attempts to analyse the safe load of the locomotive suspension spring with different materials. A typical locomotive suspension spring configuration is chosen for study. In this present work is carried out on modelling and analysis of primary suspension spring (60Si2MnA) is to replace the earlier conventional steel helical spring (Chrome Vanadium). The work is to reduce the overall stress and deflections of the helical spring by using the new material. This work describes static analysis of the locomotive suspension spring is performed using Ansys 14.0 and compared with analytical results. The spring model is done by using Pro/E Wildfire 4.0 software.

K. Satyanarayana et al. The present work is carried out on modelling and analysis of a helical spring used in two-wheeler rear suspension system and the purpose of this project is to increase the stiffness as well as reduce the stress and deflection produced in the coil and also a comparative study is carried out between existed spring with various materials. So as to the reduce vehicle problem happens while driving on bumping road condition. The modelling of spring is carried out by SOLIDWORKS 2019 and analysis it with finite element analyzer ANSYS 18.1 and further is to check the feasibility of helical spring by changing cross-sectional area from circular to square.

Karthikeyan. S. S et al. In this paper, the implementation of composite materials in helical coil suspension system is demonstrated. Previously we were using the conventional steel for helical coil. For required stiffness, the design of such springs is very bulky and costly. Then another implementation is done on the combination of conventional steel and copper and magnesium composite material. It was successful in decreasing the weight, increasing the stiffness of the system. But there are some limitations like cost, manufacturing of copper, very low stiffness of single composite spring which was not much helpful to increase the overall stiffness of the suspension system. So, metal matrix composite material is used instead of fibres with combination of conventional steels. The intension behind the use of MMC is to improve overall stiffness and life of the system

Kishori Balasaheb Salunkhe et al. Automobile suspension plays an elevated role in passenger comfort and stability of the vehicle. Normally Suspension system is made up of the coil spring and shock absorber. Objective of this work is to study and take review of the work carried out by various researchers in the area of "analysis of helical springs used in rear suspension for motor bikes involving various geometrical parameters as well as materials. By comparing expected performance of helical springs, the comparative chart is prepared, which is useful to formulate a problem to be under taken as a topic of PG dissertation.

Manish C. Bahalkar et al. Currently, the automobile industries have challenges of improvements in their product quality and its performance together with the weight reduction and cost reduction. Automobile industries directed their efforts towards the use of alternative materials which results in increase of strength to weight ratio. The use of composite materials is new trend in the design of automobile components due to their light weight and costs. The present work attempts to check the feasibility of select composite materials in the design of helical coil spring used in automobile suspension systems. The design of helical coil spring is first analysed for SAE 9254 material and then compared with that of for the composite – Carbon Fibre Reinforced Plastics material. The modelling of the helical spring has been done using Solidworks 2013 and simulations were performed using ANSYS R16.1 to find the stresses, deflections at the stated loads. It was observed that the stresses developed in CFRP material helical coil spring is lower as compared to the stresses developed in SAE 9254 material helical coil spring. The results indicate that composite materials are feasible option at normal loading conditions.

N. Karthik Mahadevan et al. Helical spring is a mechanical device which is typically used to store energy and subsequently release it, to absorb shock, or to maintain a force between contracting surface. The present work is carried out on modelling, analysis of suspension spring is to replace the existing steel helical spring used in popular two-wheeler

All rights reserved by *www.ijsrd.com*

vehicle. Aim of this paper is to analyse feasibility of adopting composite material for design of helical coil spring. Combination of springs with steel and composite material i.e., mixing of carbon steel with graphite and graphite is to be used in place of conventional spring steel. The stress and deflections of the helical spring is to be reduced by using the new material. The comparative study is carried out between existing spring and new material spring. Metal matrix composite (MMC) material is used instead of fibres with combination of conventional steels. The intension behind the use of MMC is to improve overall stiffness and life of the system. The cause of implementing combination of steel and composite material is the low stiffness of single composite spring, which limits its application to light vehicles. Fuel efficiency of automobiles can be maximized by lowering the weight of the vehicle. The spring of the suspension system plays an important role for a smooth and jerk free ride. So, it is required to design the springs very precisely. The use of conventional steel as spring increases the weight and manufacturing process energy required is more so manufacturers are willing to use composite materials light in weight and also have corrosion resistance, it can also withstand high temperature. Manufacturing composite material is quite costlier than the steel spring. The use of composite material is beneficial if manufacturing process is standardized it can increase the efficiency of the vehicle adherence overcome the material cost.

N. Lavanya et al. The suspension system is used to observe the vibrations from shock loads due to irregularities of the road surface. It is performing its function without impairing the stability, steering (or) general handling of the vehicle. Generally, for light vehicles, coil springs are used as suspension system. A spring is an elastic object used to store mechanical energy and it can be twist, pulled (or) stretched by some force and can return to their original shape when the force is released. The present work attempts to analyse the safe load of the light vehicle suspension spring with different materials. This investigation includes comparison of modelling and analyses of primary suspension spring made of low carbon-structural steel and chrome vanadium steel and suggested the suitability for optimum design. The results show the reduction in overall stress and deflection of spring for chosen materials.

Niranjan Singh the main functions of automobile suspension systems are to isolate the structure and the occupants from shocks and vibrations generated by the road surface. The suspension systems basically consist of all the elements that provide the connection between the tyres and the vehicle body. A spring is an elastic object used to store mechanical energy. It is an elastic body that can be twisted, pulled, or stretched by some force. It can return to their original shape when the force is released. It is a flexible element used to exert a force or a torque and, at the same time, to store energy. The force can be a linear push or pull, or it can be radial, acting similarly to a rubber band around a roll of drawings. The torque can be used to cause a rotation. The main objective of this research paper is to through some light on the fatigue stress analysis of springs used in automobiles. Theoretical, Numerical and Experimental methods are used for the analysis of springs but Finite Element Method is the best for its analysis and calculating the fatigue stress, life cycle and shear stress springs.

Nitin Chauhan et al. A spring is a machine component that deflects under external load and regains its original shape on removal of the force. A helical compression spring is commonly used type of spring where length of spring reduces on application of force. This paper discusses the modelling of helical compression spring and then finite element analysis using the popular software Ansys Workbench. Comparison of results with analytical solution is done to verify the procedure.

Noshirwaan Aibada et al. Springs are key components in various machines. Composition plays a major role in improving spring's performance. With the advent of advanced computational systems, Numerical analysis have fostered the development in the design of springs. This work presents a review on helical compression springs with a focus on material, methods of analysis and failure criteria. A concept of "hollow helical spring" has also been presented. It features several advantages over conventional springs. It has to overcome the issue of crack generation during its manufacturing. Successful research in this area would pave way for replacement of existing solid helical springs with hollow helical springs.

Ragupathi. P et al. In a Vehicle; problems were happening while driving on bumping road condition. The prime moto of this paper is to model and analyse the performance of shock absorber by changing the wire diameter and material of the coil spring. The shock absorbers duty is to absorb or dissipate energy. It reduces the effect of travelling over rough ground, leading to improved ride quality and increase in comfort due to substantially reduced amplitude of disturbance. When a vehicle is riding on a level road and the wheels strikes a bump, then the spring compressed quickly. The compressed spring will regain its original length and causing the body to be lifted. Then the weight of vehicle will then push the spring down below its normal loaded height. This in turns causes the spring to rebound again. This process occurs over and over by each time, until the up and down movement stops. Hence, the spring design in a suspension system is utmost crucial. The analysis is performed by considering the mass of Hybrid vehicle car and with person seated on it. This Hybrid vehicle car is made by our team for a challenge organized by Imperial Society of Innovative Engineers (ISIE). The comparison is done by changing the wire diameter of the coil spring to check the best dimension for the spring in shock absorber.

Rahul, M.S et al. In this study, a compression helical spring used in commercial transport three-wheeler made of IS 4454 material is modelled as design optimization problem considering bi-objectives namely minimizing the volume of the spring and maximizing the strain energy of the spring. Volume minimization leads to reduction in the cost of the spring. Increase in strain energy in the spring leads to better utility and functionality of the spring. Helical coil spring has been modelled as a bi-objective mathematical optimization problem considering design parameters namely spring wire-diameter, mean-coil-diameter and number of active coils. The objective functions are constrained with realistic side and behaviour constraints. Non-dominated Pareto front is generated using the Non-Dominated Sorting GA-II heuristic

All rights reserved by *www.ijsrd.com*

approach. The non-dominated solutions obtained from heuristic approach are validated by numerical solution.

S Kaewunruen et al. MR fluid has been used in automobile industry for vibration suppression device. However, its dynamic interaction between structural spring and electro-magnetized MR fluid has not been thoroughly investigated. As a result, this paper highlights static and dynamic behaviours of helical spring interacting with MR fluid magnetized at various levels. Static hysteresis behaviours have been evaluated altogether with the dynamic modal properties of the system. Modal impact hammer testing technique was used to investigate the modal parameters. It is found that MR fluid improves the hysteresis capacity and dynamic properties of the systems when it is electro-magnetized. The outcome of this study will lead to a new development of new spring-dashpot system using MR fluid for better control in adaptive tuneable vibration damping and stiffness suppressing real-time dynamic motions such as the train body, passenger seats, train door, etc.

S. N. Gundre et al. This paper deals with the finite element analysis of a helical compression spring, which is employed in electric three wheelers as per considering various road conditions in India. In the design of this kind of spring both the elastic characteristics and the fatigue strength have to be considered as significant aspects. In addition to this particular elastic property, as a consequence of the research effort in reducing the mass of components typical of the automotive industry, these springs have to face very high working stresses. The structural reliability of the spring must therefore be ensured. So, for this purpose the static stress analysis using finite element analysis gives Von-Mises stresses and total deflection of helical compression spring at various loads.

III. Conclusions

Review of the above literature clearly shows that suspension systems are an important component of any automobile. In order to reduce the losses incurred, associated with the failure of suspension systems, a lot of research work has been done and most of the research indicates that there is a lot of scope for the betterment of suspension systems.

References

[1] Aakash Bhatt, Anil Devani, Parth Zalavadiya. Design analysis of helical spring of suspension system. *International Journal of Engineering Development and Research*, Volume 4, Issue 3, ISSN: 2321-9939.

[2] Akshat Jain, Sheelam Misra, Arun Jindal, Prateek Lakhian. Structural analysis of compression helical spring used in suspension system. *AIP Conference Proceedings* 1859, 020080 (2017); doi: 10.1063/1.4990233

[3] Anil Antony Sequeira, Ram Kishan Singh, Ganesh K. Shetti. Comparative Analysis of Helical Steel Springs with Composite Springs Using Finite Element Method. *Journal of Mechanical Engineering and Automation* 2016, 6(5A): 63-70 DOI: 10.5923/c.jmea.201601.12

[4] Anirudh Kumar Singh, Vaibhav Mittal. Design Optimization of Helical Coil Suspension for Mass Minimization. *International Journal of Recent Technology and Engineering (IJRTE)*, ISSN: 2277-3878, Volume-8 Issue-4, November 2019.

[5] Bahalkar, Manish C., Mr, and Niranjan L. Shegokar. "Suspension, helical coil spring, FEM, Stress analysis, strength to weight ratio." *International Journal of Engineering Sciences & Research Technology* 6.7 (2017): 444-51. Web. 15 July 2017.

[6] Banerjee, Arko. (2020). Design and analysis of helical spring profiles in an electric vehicle suspension system using finite element method. *International Journal of Advance Research, Ideas and Innovations in Technology*, (Volume 6, Issue 3), 2020, 462-467

[7] Bhaskar U, Guruchethan A M, Devendra Reddy M. Performance analysis of fiber reinforced composite spring Embedded with steel wire. *International Journal of Engineering Research and General Science*, Volume 4, Issue 2, March- April, 2016 ISSN 2091-2730.

[8] C.Madan Mohan Reddy, D. Ravindra Naik, Dr M. Lakshmi Kantha Reddy. Analysis and Testing of Two-Wheeler Suspension Helical Compression Spring. *IOSR Journal of Engineering (IOSRJEN)*, Vol. 04, Issue 06 (June. 2014), V1, PP 55-60.

[9] D. Ramya, B. Bhargavi. Comparison Between Concentric Springs & Helical Coil Springs: Application in Locomotive Primary Suspension. 2018, *International Journal of Creative Research Thoughts (IJCRT)*, Volume 6, Issue 1 March 2018, ISSN: 2320-2882

[10] Dhareshwar S Patil, Kaustubh S Mangrulkar, Shrikant T Jagtap. Weight Optimization of Helical Compression Spring. *International Journal for Innovative Research in Multidisciplinary Field*, ISSN – 2455-0620 Volume - 2, Issue - 11, Nov – 2016.

[11] Dhiraj V. Shevale, Niranjan. D. Khaire. Review on Failure Analysis of Helical Compression Spring. *International Journal of Science, Engineering and Technology Research (IJSETR)*, Volume 5, Issue 4, April 2016

[12] Ganesh Bhimrao Jadhav, Prof. Vipin Gawande. Review on Development and Analysis of Helical Spring with Combination of Conventional and Composite Materials. *International Journal of Engineering Research and General Science*, Volume 3, Issue 2, March-April, 2015 ISSN 2091-2730.

[13] Godwin Raja Ebenezer N, Saravanan R, Ramabalan S, Navaneethasanthakumar S. Helical Spring Design Optimization in Dynamic Environment Based on Nature Inspired Algorithms. *International Journal of Theoretical and Applied Mechanics*, ISSN 0973-6085, Volume 12, Number 4 (2017), pp. 709-739

[14] Goran Vukelic, Marino Brcic, Darko Pastorcic. Experimental and Numerical Analysis of a Helical Spring Failure. XIV International Conference on Computational Plasticity. Fundamentals and Applications COMPLAS 2017

[15] Harshal Rajurakar, M. C. Swami. Analysis of Helical Compression Spring for Two-Wheeler Automotive Rear Suspension. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 13, Issue 2 Ver. II (Mar. - Apr. 2016), PP 29-33.

All rights reserved by *www.ijsrd.com*

[16] Jian Zhang, Zhaohui Qi, Gang Wang, Shudong Guo. High-Efficiency Dynamic Modeling of a Helical Spring Element Based on the Geometrically Exact Beam Theory. *Hindawi Shock and Vibration*, Volume 2020, Article ID 8254606, 14 pages https://doi.org/10.1155/2020/8254606

[17] Jun Ke, Zhen-yu Wu, Yi-sheng Liu, Zhong Xiang, Xu-dong Hu. Design method, performance investigation and manufacturing process of composite helical springs: A review. *Composite Structures* 252 (2020) 112747, https://doi.org/10.1016/j.compstruct.2020.112747

[18] K Pavan Kumar, S Praveen Kumar, G Guru Mahesh. Static Analysis of a Primary Suspension Spring Used in Locomotive. *International Journal of Mechanical Engineering and Robotics Research*, Vol. 2, No. 4, October 2013.

[19] Karthikeyan. S.S, Karthikeyan. V, Leoni Praveen. C, Manigandan. G, Rathish. R. Design and Analysis of Helical Coil Spring Suspension System by Using Composite Material. *International Research Journal of Engineering and Technology (IRJET)*, E-ISSN: 2395 - 0056, VOLUME: 03, ISSUE: 04, APR-2016.

[20] Kishori Balasaheb Salunkhe, Prof. A. A. Kumbhojkar, Prof. A. P. Shrotri. Review on Analysis of Helical Spring used in Rear Suspension of Various Motorbikes. *International Journal of Modern Studies in Mechanical Engineering (IJMSME)*, Volume 5, Issue 2, 2019, PP 1-5, ISSN 2454-9711 (Online) DOI: http://dx.doi.org/10.20431/2454-9711.0502001

[21] Mr Ajay Tukaram Kumbhar, Prof. E.N. Aitavade, Mr. Satyajit Ankush Patil, Mr Vijay Vishnu Kumbhar. Analysis and Experimental Validation for Behavior (Compression, Tensile, Fatigue Etc.) Of Composite Material Helical Compressive Spring Used for Four-Wheeler Suspension System. Novateur Publications, *International Journal of Innovations in Engineering Research and Technology [IJIERT]*, ISSN: 2394-3696 Volume 3, Issue5, May-2016.

[22] Mr Amol Vikas Joshi, Mr Kundan K. Chaudhari. A Review on Helical Compression Spring to Design a Shock Absorber of Bike. *Journal for Research*, Volume 01, Issue 11, January 2016, ISSN: 2395-7549.

[23] Mr. A. G. Hejib, Prof. R. L. Mankar. Experimental analysis of helical compression spring used in two-wheeler suspension system. Vol-3, Issue-4, 2017, IJARIIE.

[24] Mr. Siddhant R. Patil, Prof. Poonam S. Talmale, KCT's Late G.N. Sapkal C.O.E. Nashik. A Comparative Study of Wave and Coil Spring Using FEM Approach. *International Engineering Research Journal*, Page No 762-767

[25] N. Karthik Mahadevan, S. Ganesh, Mr. D. Vinodh. Stress Analysis of Composite Helical Spring (Cr-Va + Low carbon steel & Cr-Va + Stainless Steel). *International Journal of Pure and Applied Mathematics*, Volume 119, No. 12 2018, 15855-15867

[26] N. Lavanya, P. Sampath Rao, M. Pramod Reddy. Design and Analysis of a Suspension Coil Spring for Automotive Vehicle. *Int. Journal of Engineering Research and Applications*, www.ijera.com, ISSN: 2248-9622, Vol. 4, Issue 9 (Version 5), September 2014, pp.151-157

[27] Niranjan Singh. General Review of Mechanical Springs Used in Automobiles Suspension System. *International Journal of Advanced Engineering Research and Studies*, Int. J. Adv. Engg. Res. Studies/III/I/Oct.-Dec.,2013/115-122

[28] Nitin Chauhan, Anil B Ghubade, Rajeev Kumar. Finite Element Analysis of Helical Compression Spring Using ANSYS. *Journal of Emerging Technologies and Innovative Research (JETIR)*, December 2018, Volume 5, Issue 12.

[29] Noshirwaan Aibada, Siddhant Sundaram, Dinesh Kalani, Praveen Kumar Loharkar. Review of Studies on Helical Compression Springs with A Perspective of Material, Methods and Failure. *International Journal of Mechanical Engineering and Technology (IJMET)*, Volume 9, Issue 3, March 2018, pp. 936–945, Article ID: IJMET_09_03_095

[30] Ragupathi. P, Dhayanidhi. E, Arunachalam. S, Jegadeshwaran. A, Kamal Hassan. P. Design of Helical Spring Suspension. *Imperial Journal of Interdisciplinary Research (IJIR)*, Vol-3, Issue-4, 2017 ISSN: 2454-1362, http://www.onlinejournal.in

[31] Rahul, M.S, Anurag Tripathi, Rameshkumar, K. Design Optimization of a Helical Coil Spring Considering Multiple Objectives using Heuristic and Numerical Approach. *International Journal of Advanced Science and Technology*, Vol. 29, No. 7, (2020), pp. 257-267

[32] S Kaewunruen, O Akintoye, M Papaelias. Static and dynamic behaviours of helical spring in MR fluid. IOP Publishing, *Journal of Physics: Conference Series* 744 (2016) 012112, doi:10.1088/1742-6596/744/1/012112

[33] S. N. Gundre, P. A. Wankhade. A Finite Element Analysis of Helical Compression Spring for Electric Tricycle Vehicle Automotive Front Suspension. *International Journal of Engineering Research & Technology (IJERT)*, ISSN: 2278-0181, www.ijert.org, Vol. 2, Issue 6, June – 2013 https://doi.org/10.1155/2020/8853707

All rights reserved by *www.ijsrd.com*