Review on Structural Analysis of Helical Coil Suspension

Vikas Sahu[1] Ashwini Bhoi[2]
[1]Research Scholar [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Raipur Institute of Technology, Raipur, India

Abstract— The design and material of helical coil suspension is crucial in improving shock absorption characteristics of an automobile. The current study throws light on researches conducted by various scholars in improving design, manufacturing techniques and optimizing material of helical coil suspension. The application of composite materials in helical coil is also envisaged with respect to structural and vibration characteristics along with improvement in strength to weight ratio. Most of the researches were conducted using FEA or experimentation techniques.

Keywords: Helical Coil Suspension, Structural analysis, Design optimization

I. Introduction

The suspension system is used to observe the vibrations from shock loads due to irregularities of the road surface. [1] The vehicles must have a good suspension system that can deliver a good ride and good human comfort. Suspension system separate the axle from the vehicle chassis, so that any road irregularities are not transmitted directly to the driver and the load on the vehicle. [2] Therefore, the suspension system performance of the vehicles should be maximized to reduce the damage and vibration. The main functions of suspension systems in vehicles are to isolate the structure and the occupants from shocks and vibrations generated by the road surface. The suspension system requires elastic resistance to absorb the road shocks and this job is fulfilled by the suspension coil springs.

The primary functions for suspension systems are; [3]

- Provide vertical compliance so the wheels can follow the uneven road, isolating the chassis from roughness in the road.
- Maintain the wheels in the proper steer and camber attitudes to the road surface.
- React to the control forces produced by the tires longitudinal (acceleration and braking) forces.

Helical coil spring It is made up of the wire coil in the form of spring. A helical spring is a spiral wound wire with a constant coil diameter and uniform pitch. The most common form of helical spring is the compression spring but tension springs are also widely used. Helical springs are generally made from round wire. It is comparatively rare for springs to be made from square or rectangular sections. The strength of the steel used is one of the most important criteria to consider in designing spring. The two most basic requirements of a coil spring design are an acceptable stress level and the desired spring rate. To minimize weight, size, and cost, we usually design springs to the highest stress level that will not result in significant long term “set.” Stress is usually considered before spring rate, in designing a spring, because stress involves mean diameter (D) and wire diameter (d), but not number of coils (N). [4]

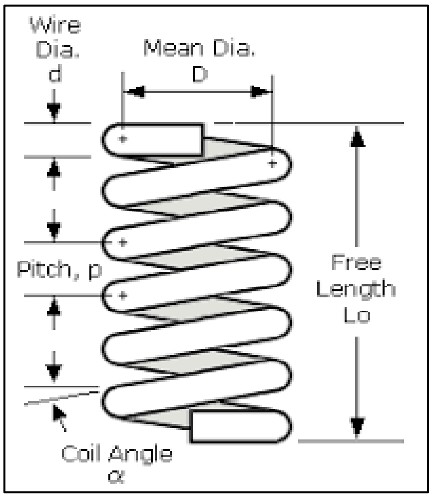

Fig. 1: Helical Coil Springs

II. Literature review

P.R. Jadhav, N.P. Doshi, and U.D. Gulhane et al [5] in this research steel coil spring is replaced by composite material. Numerical results have been compared with theoretical results and found to be in good agreementin three different composite helical springs. Compared to steel coil spring, the composite helical/coil spring has been found to have lesser stress. Weight of spring has reduced and has been shown that changing percentage of fiber, especially at Carbon/Epoxy composite, does not affect spring weight.

Chang Hsuan Chiu et al, [6] explained about four types of helical compression springs made of unidirectional laminates, rubber core unidirectional laminates, unidirectional laminates with a braided outer layer, and rubber core unidirectional laminates with a braided outer layer respectively. The results indicate that the helical composite coil springs with a rubber core has 12% more load carrying capacity while for the spring with BUR has 18% more load carrying capacity along with the improvement of 16% in spring constant. Comparison of software and theoretical analyses of coil spring made of SP ST GRD II material suggested the suitability for optimum design. The stress (shear stress) and deformation produced in the spring at the loading condition is in limit so it is safe. Relative error of maximum shear stress ranging from 6 to 10 % with reference to the applied load compared with the values calculated by using simple analytical formulae which were found in reference books and handbooks. Shear stress is having maximum value at the inner side of every coil which shows stress distribution clearly. From above analysis it is observed that the stiffness of the suspension spring is increased which increases load carrying capacity of the system. Because of the reducing number of turns the weight of the spring is reduced. It has been observed that the weight of the system is reduced up to 9% for same loading conditions. Therefore, the light weight system is achieved which will help to increase the fuel efficiency of the TWV. The load carrying capacity also increased by 11%. Based on the modeling and analyses conclude that the new design is suitable for used so it can be implement. In general, Weight of the spring is reduced by reducing number of coil spring turns and replacing the conventional steel material by SP ST GRD II (special steel grade II). [7] [8] Fundamental stress distribution, materials characteristic, manufacturing and common failures of automotive coil spring is analyzed. An in depth discussion on the parameters influencing the quality of coil springs is also presented. To assure that a coil spring serves its design, failure analysis of broken coil springs is valuable both for the short and long term agenda of car manufacturer and parts suppliers. This paper discusses several case studies of suspension spring failures. The failures presented range from the very basic including insufficient load carrying capacity, raw material defects such as excessive inclusion levels, and manufacturing defects such as delayed quench cracking, to failures due to complex stress usage and chemically induced failure. FEA of stress distributions around typical failure initiation sites are also presented. The fatigue stress, life cycle and shear stress of helical compression spring is analyzed by various research methods such as Theoretical, Numerical, Experimental and FEM methods. [9], [10]

Ganesh Bhimrao Jadhav et al [11] Glass fiber epoxy resin is 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.

Andrea Shaggier, and Igor Spinella et al [12], they contributes to enhancing the performances of SMA actuators by proposing a new SMA helical spring with a hollow section. The hollow spring is modeled, then it is constructed, and finally it is tested in compression to compare its performances with those of a spring with a solid cross section of equal stiffness and strength. Emptied of the inefficient material from its center the hollow spring features a lower mass 37% less.

Manish Dakhore et al [13], has studied value of stress found to be more at the critical section of the spring as indicated by red color. Hence possibility of failure is more at that section compared to other section of spring. This paper discusses about locomotive suspension coil springs, their fundamental stress distribution and materials characteristic. The analysis of locomotive spring is carried out by considering cases, when the locomotive at the straight path, curved path and on uphill. This paper also discusses the Experimental analysis of a helical suspension spring by using strain gauge. The stress analysis for the forces obtained and for modal and harmonic response has been carried out by FEA using ANSYS.

P.S.Valsange et al [14], have been presented the review of fundamental stress distribution, characteristic of helical coil springs. An in-depth discussion on the parameters influencing the quality of coil springs is also presented. Factors affecting strength of coil spring, FEA. Approaches by the researchers for coil spring analysis are also studied. Reduction in weight is a need of automobile industry. Thus, the springs are to be designed for higher stresses with small dimensions. This requires critical design of coil springs. This leads to critical material and manufacturing processes. Decarburization that was not a major issue in the past now becomes essential, to have better spring design.

Tausif M. Mulla et al [15], studied elastic behavior and the stress analysis of springs employed in the Three Wheeler Vehicle's (TWV) front automotive suspension is studied. The results obtained by a fully 3D Finite Element Analysis (FEA) also highlighted the poor accuracy that can be provided by the classical spring model when dealing with these spring geometries. Relatively small errors on maximum shear stress ranging from 1.5 to 4 per cent, with reference to the applied loads, are obtained when compared with the values calculated by using simple analytical model or formula. The stress distribution clearly shows that the shear stress is maximum at the inner side of every coil. The distribution of the stress is also similar in every coil. So, the probability of failure of spring is the same in every coil except end turns. In such case residual stress in every coil may be important factor which influence the failure.

Erol Sancakkar, and Mathieu Gratton et al [16], in their research they observe composite leaf springs are successfully used in the suspension of the light vehicles. The fibers used in these are unidirectional E-glass due to their high extensibility, toughness and low cost. The composite leaf spring is designed and analyzed using ANSYS. The results showed that an optimum spring width decreases hyperbolically and the thickness increases linearly from the spring eye towards the axle seat. Compare to steel springs the optimized composite spring has strength that are much lower, the natural frequency is high and the spring weight is nearly 80% lower. The use of composite materials can be extended to conventional automotive parts like, propeller shaft, drive shafts, bumper beam, side door impact beam, universal joints, bearings, brakes.

According to [17] Composites springs are manufactured by the filament winding method. All the three types of springs were manufactured by the same method. A mandrel having the profile of the spring is prepared first. This mandrel is fixed in the lathe chuck. A mold release agent like silicone gel is applied on the mandrel. Glass fiber roving/carbon fiber roving is dipped in the measured quantity of resin and wound on the mandrel by rotating it on a lathe. After the complete winding of the roving in the profile of the mandrel a shrink tape is wound on the mandrel. This shrink tape applies the required pressure on the material. The mandrel along with the material and the shrink tape is cured in atmospheric temperature for 24hours.

After curing shrink tape is removed. The excess resin on the surface of the spring is removed by filing. The cured spring is removed from the mandrel by rotating in the reverse direction.

III. Conclusion

The above literature review presents that the helical compression springs becomes quite necessary to do the complete stress analysis of the spring. These springs undergo the fluctuating loading over the service life. In addition, FEM software has been use for performing meshing simulation. Almost in all of the above cases, fatigue stress, shear stress calculation play more significant role in the design of helical compression springs. Different study shows that shear stress and deflection equation is used for calculating the number of active turns and mean diameter in helical compression springs. Composite materials are used instead of steel coil spring, it reduces the weight of the spring. Hollow compression spring are compared with solid steel coil springs.

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