Static structural analysis of helical compression spring materials

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Abstract - **The shock absorber of an automotive suspension system has a helical compression spring to store the energy. The material used for spring design must be elastic with sufficient strength to overcome changes in external loads. The elastic properties are used to understand the stability of the materials. The structural analysis is used to find out mechanical strength of materials. The computerized simulated results are obtained by using finite element analysis. The spring steel is the good selection for design of spring among stainless steel, mild steel and chromium vanadium steel.**

keywords **- spring, structural, spring steel, mild steel, chromium vanadium steel**

I.INTRODUCTION

The shock absorber of an automobile suspension system is designed to handle shock impulse load and to dissipate kinetic energy. It improves ride quality by limiting excessive suspension movement and damping spring oscillations over rough road. The kinetic energy stored in the spring during compression will be released on exceeding the allowed range of suspension movement. The springs are classified as coil springs and leaf springs in automotive suspension system. The coil springs is a helical tension or compression springs of round or squared wire made to resist tensile, compressive or torsion loads. The helical compression spring is one of the elastic members in automotive suspension system. It is being an important part of suspension system which absorbs energy and shocks that are received by the wheels from road irregularities. It offers resistance to compressive forces applied axially and one of the most efficient energy storage devices available. The compression springs are either placed over a rod or fitted inside a hole. The material selection for the spring depends on cost, allowable stress and fatigue and corrosion resistance. The isotropic materials have identical elastic modulus and Poisson's ratio in all directions. Their mechanical and thermal properties are the same in all directions. They have homogeneous or non-homogeneous microscopic structures. The steel demonstrates isotropic behavior whose microscopic structure is non-homogeneous. The mild steel is very strong and can be made from readily available natural materials. It is called as mild steel because of its low carbon content. It has high resistance, tensile and impact strength. The mild steel bends or deforms under stress. The stainless steel spring is economical with high tensile strength with corrosion resistance and magnetic properties. The degree of cold working with the chemical composition of stainless steel determines the tensile strength. The spring steel is used widely in automotive and industrial suspension applications. It has certain properties such as it is resistant to water, environmental and pollution exposure along with high yielding strength and also known to be resilient. This allows spring steel to return to its original shape from its deflection or twisting. The chromium vanadium steel is made by alloying chromium, carbon, vanadium, and other metals. These springs offer benefits of specific load tolerances, hardness, corrosion resistance and stress relieving characteristics due to their typical chemical composition. Hence, the spring steel is employed for high impact load and stress applications. The common requirement for spring material is high strength so that it does not become plastically deformed in service. Hence, static structural analysis on the above four materials are conducted in this research work.

II.LITERATURE REVIEW

The main function of an automobile suspension system is to detach the chassis structure and occupants from shocks and vibrations generated by the irregular road surface. The road shocks and impulse loads are absorbed by the elastic resistance device namely suspension springs. Mohan Reddy et al. [1] compared theoretical, experimental and analytical values of hard drawn spring steel and chromium vanadium steel for helical compression spring. The maximum shear stress and deflection are the criteria considered to evaluate the suitable material for spring design. The total deformation of the oil tempered spring steel is greater than the beryllium copper which indicates that the stiffness of spring steel material is better than beryllium copper. It is concluded that the beryllium copper is safe material for the maximum loading as compared to oil tempered spring steel [2]. It is concluded on modeling and analyses that low carbon structural steel material is best suitable for production of helical spring compared to chromium vanadium steel materials which are used in motor vehicles [3]. High carbon steel and beryllium copper are considered for modeling and analysis of a suspension system. The beryllium copper is recommended as best material due its reduced stress concentration [4]. The helical compression spring of an automobile horn is modeled and static analysis carried out by using ANSYS. It is also observed that maximum stress is developed at the inner side of the coil [5]. Achyut et al. [6] compared spring steel and phosphor bronze as spring materials in terms of natural frequency. The stiffness is more for spring steel because the total deformation value of it is lesser than phosphor bronze. The main function of compression spring is the absorption of shocks and vibrations. It also absorbs energy and therefore, it is necessary to study failure of springs. The failure is explained with the help of shear stress and deformation effects under the static or variable loads. In general steel alloys are used in suspension system which offers high resistance to shock, vibration and variables loading. So, it is necessary to select the appropriate material for each purpose [7]. Aniekan et al. [8] concluded that the failure is quicker in high carbon steel than stainless steel and chrome vanadium but their cost is higher. The high carbon steel works relatively with lower cost. The resilience of spring material is the ability to absorb energy and to resist shock and impact loads. It is the amount of energy absorbed per unit volume within elastic limit [9]. The shear stress and deflection values are have been calculated using Finite Element Analysis (FEA) for chromium silicon, chromium vanadium and hard drawn spring steel. The FEA results prove that the maximum deflections for all the materials are almost have closer values. But, the maximum shear stress of chromium silicon steel spring is lesser comparative to the chromium vanadium and hard drawn steel [10]. From the review it has been observed that in design of helical compression spring, the selection of appropriate material is very important. The spring material must have high strength and elastic limit and with low modulus. Since, the springs are resilience in nature and hence their materials must have larger elastic range. It has been decided to conduct FEA analysis using ANSYS for getting static structural results on different materials. The stainless steel, spring steel, mild steel and chromium vanadium steel are considered for our study.

III.METHODOLOGY

The three dimensional model of a helical compression spring with the help of measured dimensions is created using SOLIDWORKS. The static structural analysis is conducted by FEA method using ANSYS Package. The load and other boundary conditions are kept same for all the four materials for comparative purpose. The spring is an elastic component with high strength, quality, reliability and service life, which is able to store applied forces. The modulus of elasticity in tension and shear are related through Poisson's ratio which are important to spring design. The modulus varies as a function of chemical composition, cold working and degree of aging and these variations can be adjusted using spring dimensions. The stiffness of spring is the force per unit deformation and it depends on dimensions unlike elastic modulus which depends on materials. The stiffness must be positive for stable materials. The performance of materials is compared with the help of Poisson's ratio. The ranges for total deformation and shear stress for all the four materials are obtained as results of structural analysis.

IV.RESULTS AND DISCUSSIONS

The elastic properties and static structural analysis on the four materials obtained by FEA are illustrated with the help of figures and tables. The steel is an important engineering material for the manufacture of helical compression springs used in the automotive suspension system. The stainless steel has been used in recent times for spring material. The unique feature of spring steel is the ability to withstand considerable twisting or bending forces without any distortion. The chrome vanadium steel is the alloy steel for improved stress, fatigue and long endurance life conditions. This material is suitable for impact and shock loading conditions. The mild steel can be heat treated and used as spring material. The Poisson's ratio is defined the ratio of transverse contraction to longitudinal extension strains along the direction of force. The numerical limits for Poisson's ratio are set between -1 and 1/2, in which all stable isotropic materials are available with free surfaces. This range is derived from concepts of stability and elastic moduli must be positive. They are interrelated with Poisson's ratio. The Poisson's ratio is greater than -1 for a positive bulk modulus. A positive shear modulus implies that the Poisson's ratio less than 1/2. These are measures for spring stiffness. The normal materials must have a positive ratio. The table 1 shows the physically conducted test report on the materials. The analytical results show that spring steel has more stiffness of 15.29 N/mm than others. The shear stress of 170 MPa and shear modulus of 1.12 MPa of spring steel are more than other materials namely stainless steel and mild steel. The tables 2 and 3 show the simulated results obtained in ANSYS. The table 2 indicates the elastic properties of materials considered for this work. The Poisson's ratios of all the materials are positive and within the range. This indicates that the materials are stable without any constraints. The stainless steel has a ratio of 0.30 which is slightly higher than other materials.

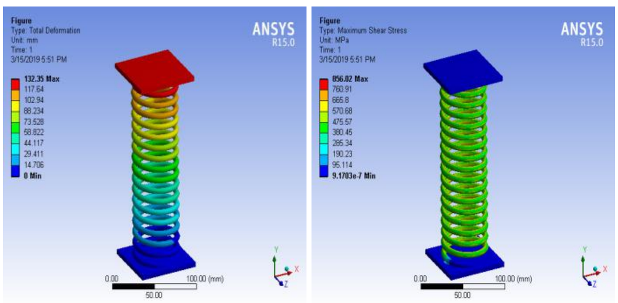

Fig. 1 Stainless steel

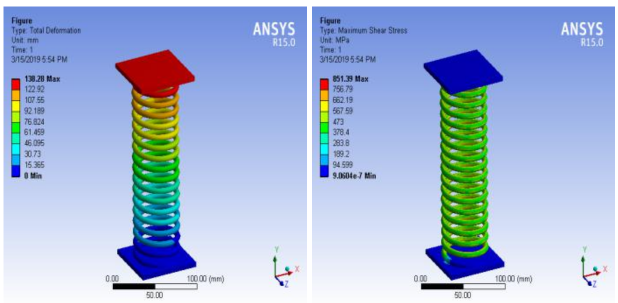

Fig. 2 Spring steel

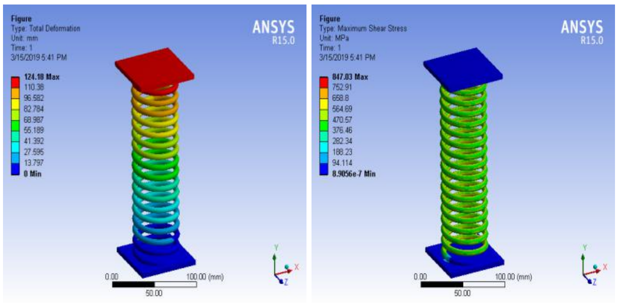

Fig. 3 Mild steel

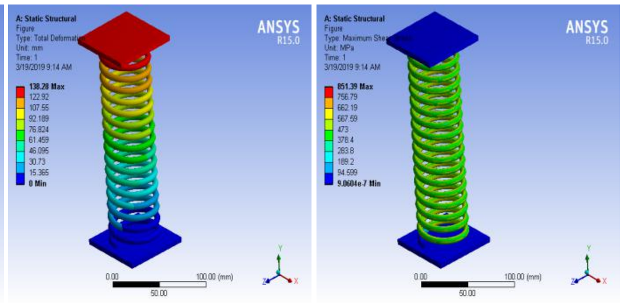

Fig. 4 Chromium vanadium steel

Table 1 Testing report

S.No	Materials	Shear stress Mpa	Shear modulus MPa	Stiffness N/mm
1	Stainless steel	106.7	0.723	14.02
2	Spring steel	170.0	1.120	15.29
3	Mild steel	106.7	0.842	13.01

Table 2 Elastic properties

S.No.	Materials	Young's modulus MPa	Poisson's Ratio	Bulk modulus MPa	Shear modulus MPa
1	Stainless steel	2.0e+005	0.30	1.6667e+005	76923
2	Spring steel	1.9e+005	0.29	1.5079e+005	73643
3	Mild steel	2.1e+005	0.28	1.5909e+005	82031
4	Chromium vanadium steel	1.9e+005	0.29	1.5079e+005	73643

Table 3 Static structural analysis

S.No.	Materials	Total deformation mm		Maximum shear stress MPa	
		Minimum	Maximum	Minimum	Maximum
1	Stainless steel	0	132.35	9.1703e-007	856.02
2	Spring steel	0	138.28	9.0604e-007	851.39
3	Mild steel	0	124.18	8.9056e-007	847.03
4	Chromium vanadium steel	0	138.28	9.0604e-007	851.39

The spring steel and chromium vanadium steel are having Young's Modulus values of 1.9e+005 MPa because of alloying elements. The mild steel has a relatively lesser Poisson's ratio of 0.28 with shear modulus of 82031 MPa due its low carbon content. The stainless steel has higher bulk modulus of 1.6667e+005 MPa. The static structural analysis is essential to find out the impact of mechanical loads on materials [11]. The figures 1 to 4 and table 3 show the results of structural analysis for all the four materials considered for study. The spring steel and chromium vanadium steel are having same ranges of total deformation and maximum shear stress. The mild steel and stainless steel are having total deformation of 124.18 mm and 132.35 mm respectively. The stainless steel has the maximum shear stress between 9.1703e-007 MPa and 856.02 MPa. For the mild steel the range varies from 8.9056e-007 MPa to 847.03 MPa. The spring steel has total deformation of 138.28mm and maximum shear stress range of 9.0604e-007 MPa to 851.39 MPa.

V.CONCLUSION

The design of helical compression spring starts with the selection of appropriate material. This research work was carried out to find out the suitable material among four considered for spring of automotive suspension system. The physical testing was conducted on three materials namely stainless steel, spring steel and mild steel. It was found that spring steel has higher shear stress, shear modulus and stiffness. The chromium vanadium steel was added with the existing list of materials in static structural analysis. The simulated results on elastic properties and structural parameters were obtained for the above four materials. The spring steel shows good result and it may be selected for spring design. This work may be extended by considering composite materials for comparison in spring design of shock absorber in suspension system.

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