WEIGHT OPTIMIZATION OF HELICAL COMPRESSION SPRING

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ABSTRACT

This paper 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. Various techniques used for weight optimization of helical compression spring are linear programming method, non linear programming method, dynamic programming method, harmony search algorithm method and using another or composite material. 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 optimized 3D CAD spring model will be developed and validated in ANSYS for stresses developed.

KEYWORDS: *Helical Compression Spring, Weight, Weight Optimization, Stresses, Solid Circular Wire, Hollow Circular Wire.*

I. PROBLEM DEFINITION

For predefined load application spring made from solid circular wire/rod will be designed. To optimize the weight of spring, a spring made from hollow circular wire/rod of same material and satisfying all given constraints will be designed referring the design equations.

II. INTRODUCTION

A spring is an elastic machine element that deflects under the action of the load and returns to its original shape when load is removed. Or a spring is an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. Spring is used to cushion, absorb or control energy due to either shock or vibration as in car springs, railway buffers, air-craft landing gears, shock absorbers and vibration dampers, to apply forces, as in brakes, clutches and spring loaded valves, to control motion by maintaining contact between two elements as in cams and followers, to measure forces, as in spring balances and engine indicators, to store energy, as in watches, toys etc.

Today's manufacturers are mainly concentrated on weight optimization of the product. Less weight ultimately results in less material required and less cost of product. Aiming at weight optimization of product, spring being a component of product, the weight reduction of spring can reduce the weight of product. As the weight of the product is reduced material required for product and cost of product will also be reduced.

This work describes design of compression spring made from solid wire/rod for a particular load application. Next step is optimizing the compression spring for weight for same problem. The weight optimization of spring can be achieved by designing the spring as if it is made from hollow circular wire/rod.

III. LITERATURE REVIEW

2.1Andrea Spaggiari, Igor Spinella and Eugenio Dragoni [1], in their work 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).

2.2Atish B. Dighewar [2], in his work presented design optimization of spring using genetic algorithm. Attention is focused on reducing the weight and stresses keeping into considerations the various critical points. The spring is designed to operate with tension load, so the spring stretches as the load is applied to it. The aim of the present work is to design the extension spring for various material like steel, stainless steel, music wire (High carbon steel), oil Tempered (High carbon steel) for same loading condition, since each material has different compositions and properties. On applying the GA, the optimum parameter of spring have been obtained, which contribute towards achieving the minimum weight.

2.3 Aurel P. Stoicescu [3], in his work presents the optimal design method of the helical springs of the automobile suspensions according to the criterion of the minimum mass. For this purpose, at a given spring rate, the torsional stress corresponding to the maximum force applied to the spring, the fatigue stress, the buckling stability condition and the constraints relating to the spring index and to the outer coil diameter are considered. Expressing analytically the coefficients that are necessary to calculate certain helical spring stresses of an automobile suspension they have elaborated a nonlinear programming model with constraints for the optimal design of an automobile spring suspension according to the criterion of the minimum mass. The reduction of the spring mass by optimal design may be of 16%.

2.4 Avakash P Patel and V. A. Patel [4], in their work presented optimization of helical spring for minimum weight by using harmony search algorithm. An Artificial phenomenon, musical harmony can be used for developing harmony search algorithm. In music the process of searching better harmony is the base of the algorithm. In musical performance seeks a best state as the optimization algorithm seeks a best state.

2.5 Mehdi Bakhshesh and Majid Bakhshesh [5], in their research, steel helical spring related to light vehicle suspension system under the effect of a uniform loading has been studied and finite element analysis has been compared with analytical solution. Afterwards, 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 effect of applied loads have been calculated. It has been shown that spring optimization by changing material spring causes reduction of spring weight and maximum stress considerably.

2.6 Mohamed Taktak, Khalifa Omheni, Abdessattar Aloui, Fakhreddine Dammakb, Mohamed Haddar, in their work a numerical method to model the dynamic behavior of an isotropic helical spring is coupled with optimization algorithms to construct a dynamic optimization method based not only on mechanical and geometrical objective functions and constraints; but also on dynamic ones. In the proposed dynamic optimization problem, four geometric parameters are chosen as design variables (wire diameter, middle helix diameter, active coils numbers and spring pitch). In addition of mechanical and geometrical constraints, dynamic ones related to natural frequencies of the helical spring are added. Two objective functions are chosen to be optimized: the spring mass and its natural frequencies. This method is then applied to the case of circular cross section helical spring, and then optimization results are presented and discussed. The result of simulation shows that by these algorithms the helical spring mass can be greatly reduced and the design quality is improved by moving away the helical spring first natural frequency from working zone.

2.7 Xiao Qimin, Liu Liwei, Xiao Qili, in their work introduces the optimization of helical spring based on particle swarm algorithms and simulation in MATLAB. Directed by the theory of Particle Swarm Optimization algorithm, with the minimum weight of helical spring as objective function, with wire diameter, mean coil diameter and number of active coils as design variables, with shear stress, maximum axial deflection, critical frequency, buckling, fatigue strength, space and dimension as constraint conditions, the complex helical spring optimal design mathematics model with three design variables and fourteen inequality constraints conditions is established. When the model is simulated in MATLAB the minimal optimal value of variables and the minimal weight of helical spring can be obtained.

IV. SCOPE OF THE WORK

In this work, dimensions of the springs made from solid as well as hollow circular wire of same material and for same problem are determined analytically. After determination of dimensions for both springs 3D CAD models will be developed. These 3D CAD models are then tested in ANSYS for the stresses induced. After tests, various parameters like weight, stresses induced etc. will be compared.

V. OBJECTIVES OF STUDY

The following are the objectives of the study

- Study the application weight optimization technique for spring
- Develop 3D CAD models of springs referring analytically determined dimensions.
- Conduct analysis in ANSYS on 3D CAD models.
- Validate analytical results with results obtained from ANSYS.
- Validate applicability of the proposed weight optimization technique.

VI. VALIDATION

Results for this work shall be validated in ANSYS software.

VII. FUTURE WORK

The proposed methodology for weight optimization of helical compression spring is different from than that seen in the current practices. Thus it is seen that there is more scope to work on this method. The proposed work comprises selection of problem, theoretical analysis, developing 3D CAD model, testing and comparison. Testing will be carried out in analysis software like ANSYS.

7.1 Theoretical analysis

- Design equations referred from IS codes and books will be used for designing spring made from solid circular wire/rod.
- These design equations are again referred to formulate the design equations for spring made from hollow circular wire/rod.

7.2 Problem selection

In this stage problem will be selected for which spring made from solid circular wire/rod will be designed. To optimize the weight of spring, a spring made from hollow circular wire/rod of same material and satisfying all given constraints will be designed referring the design equations.

To compare the weight of the hollow wire helical spring with that of a solid-wire spring, it is assumed that the two springs:

- Are made from the same material
- Have the same spring index
- Have the same spring rate i.e. stiffness,
- Undergo the same maximum load
- Sustain the same maximum shear stress.

7.3 Developing 3D CAD Models

In this stage 3D CAD models of the springs made from solid as well as hollow circular section will be developed using the dimensions determined analytically. 3D CAD models of the spring made from solid as well as hollow circular wire are as shown in the figure 1, 2 & 3.

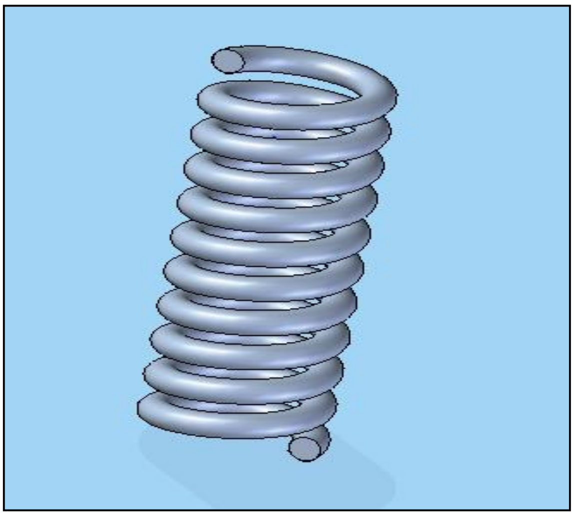

Figure1: Spring Made From Solid Circular Wire

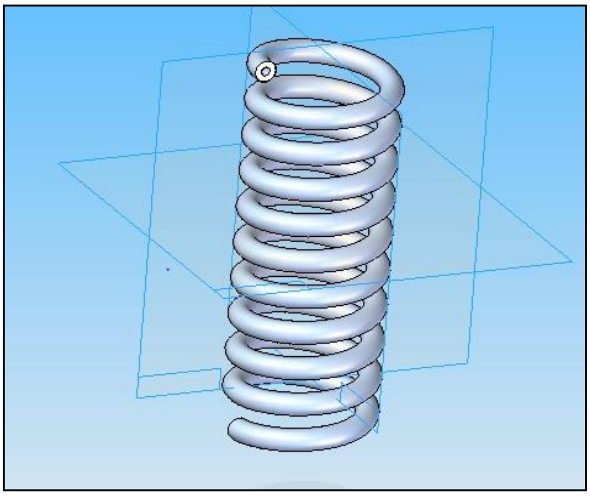

Figure2: Spring Made From Hollow Circular Wire

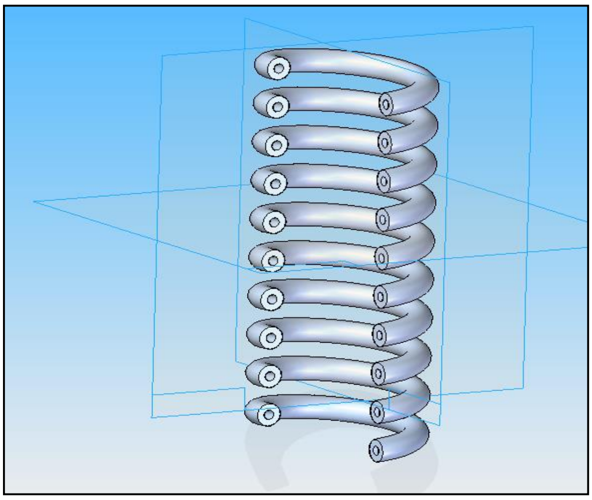

Figure 3: Sectional View of Spring Made From Hollow Circular Wire

7.4 Comparison &Validation

In this stage 3D CAD models are analysed in ANSYS software. Results obtained are then compared with results obtained from analytical method. The concurrence of the results shall offer validation for this work.

VIII. SOFTWARE TOOLS USED

- Solid Edge V20 for 3D CAD modeling.
- ANSYS 14.5 for stress analysis and distortion developed.

IX. CONCLUSION

Main objective of the work is to validate the applicability of the weight optimization technique in which spring is designed with hollow circular wire. Failure of helical compression spring occurs in torsion. In case of torsion, the section having larger moment of inertia will have greater torsional strength. Thus weight can be reduced by designing the spring with hollow circular wire instead of solid circular wire. Thus this technique of weight optimization for helical compression spring can be effectively implemented with assumption that both springs are made from the same material, have the same spring rate i.e. stiffness, undergo the same maximum load, sustain the same maximum shear stress

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