Design and Analysis of Helical Compression Spring for Special Purpose Application

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ABSTRACT

The die set system used in the wire straightening and cutting system is comprises of die plate, bolster plate and guides with mutually helped by helical compression spring. This spring plays an important role in smooth movement of the die set by supplying energy stored in it as well as keeps sufficient pressure on the plate provided at the bottom of the rod. It acts as suspension system to absorb the shocks and stores the mechanical energy. It is made up of elastic materials such that it can twist, pulled or stretched by the application of force and regain its original shape when the force is released due to this the stress are produced along the length of the helical compression coil spring. On account of these stresses coil springs have been undergone the failure prematurely before its service life. The present work is investigation on reduction of the premature failure and improves the service life of helical compression spring. The life of spring is improved by optimum design and analysis by variation of wire diameter. Results indicate that the stresses are decreased for increase values of wire diameter and number of turns of coil spring. Due to this, deflection of spring as required is achieved hence reduction of the premature failure of coil spring is attained.

Keyword : - *Key word1 Helical Compression Spring, Premature Failure, Die Plate*

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1. INTRODUCTION

A spring is a resilient member capable of providing large elastic deformation. A spring is basically defined as an elastic body whose function is to distort when loaded and to recover its original shape when the load is removed. Mechanical springs are used in machines and other applications mainly to exert force, to provide flexibility, to store or absorb energy. Springs are elastic bodies that can be twisted, pulled, or stretched by some force. They can return to their original shape when the force is released. In other words it is also termed as a resilient member[3].

Spring material and its quality can be normally taken into consideration or highlighted in such cases as (i) Spring installed in mechanical products failed either by fracture or by significant deformation in use. Here the quality requirements set up in the initial quality design stage were not achieved in the actual product (ii) A mechanical product newly designed or improved where a new design of spring is required of higher quality (iii) A cost reduction requested for the spring have been used without any difference of the quality. Here although the quality requirements at the design stage were satisfied in use the springs were used in the severer condition than the initially expected or some important quality requirement failed to be included in the initial quality requirements in the design stage[5].

When a spring has failed due to the above reasons an investigation is need to be carried out to find out the quality of the material used for the spring and manufacturing process used to make it. Considering the availability, quality level, price and the matching with working processes, the most suitable material can be chosen.

2. LITRATURE REVIEW

After Studying the Literature it can be concluded that a lot of work has been done in the field of design, analysis and material selection for compression spring .

Kaiser B., Pyttel B. and Berger, C. [1] reported on procedure and preliminary research results of long-term fatigue tests up to a number of 109 cycles on shot peened helical compression springs with two basic dimensions, made of three different spring materials (oil hardened and tempered SiCr- and SiCrV-alloy steel). Their result shows that the various spring types in test exhibit different fatigue properties and also different failure mechanisms in the VHCF regime.

Pollanen I. and Martikka H. [2] proposed optimum design of the spring which minimize of wire volume, space restriction, desired spring rate, avoidance of surging frequency and achieving reliably long fatigue life. Their result was verified by using full 3D solid FEM analysis with MSC Nastran by which the stresses and also strains, deformations and natural frequencies and modes are obtained.

Prawoto Y., Ikeda, M., Manville S.K. and Nishikawa, A. [3] discussed about automotive suspension coil springs, their fundamental stress distribution, materials characteristic, manufacturing and common failures. An in depth discussion on the parameters influencing the quality of coil springs is also presented. This paper discussed 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.

Berger C. and Kaiser B [4] reported that the results of very high cycle fatigue tests on helical compression springs which respond to external compressive forces with torsional stresses. The results of these investigations can add an important contribution to the experience of fatigue behaviour in the very high cycle regime. Most investigations performed on that field deal with specimens under tensile or rotating bending load.

Ronald E. Giachetti [5] stated that the material and manufacturing process selection problem is a multi-attribute decision making problem. These decisions are made during the preliminary design stages in an environment characterized by imprecise and uncertain requirements, parameters, and relationships. Material and process selection decisions must occur before design for manufacturing can begin

Krishna S., Vignesh S [6] achieved a composition of alloy has to be precisely correlated at a state of best alloy combination to make good resilience spring ranging from 2mm- 3mm wire thickness which can be achieved by a proper selection of alloys with different aspects of mechanical properties in a real time power generation device for rapid movement of the rack and pinion power generator.

W.K. Chan, Thomas K. L [7] observed an improper selection can negatively affect productivity, profitability and undermine the reputation of an enterprise because of the growing demands for extended producer responsibility. This paper presents an integrated methodology of performing an order pair of materials and end-of-life product strategy for the purpose of material selection. The requirements of the methodology do not only include both the technical and economic factors, but also the environmental factors. Using Grey relational analysis, the multi-criteria weighted average is proposed in decision-making process to rank the materials with respect to several criteria. It will guide the selection process and help a decision maker solve the selection problem. Also discussed the impact of selecting right materials can be critical because it contributes the safety and health of the end-users. It also affects the durability, functions and quality of the product. This selection process is multi-objectives, which may contradict with one another. The selection of the final material should be a consideration of all those factors but not the particular. This paper provides a method combining multi-dimension alternatives into single dimension order pairs to determine the material and its EOL strategies simultaneously.

Prasenjit Chatterjee, Chakraborty Shankar [8] the large number of available materials together with the complex relationships between various selection criteria, often make the material selection process a difficult and time consuming task. A systematic and efficient approach towards material selection is necessary in order to select the best alternative for a given engineering application. author also used application of four preference ranking-based multi-criteria decision-making (MCDM) methods for solving a gear material selection problem. These are extended PROMETHEE II (EXPROM2), complex proportional assessment of alternatives with gray relations (COPRAS-G), ORESTE (Organization, Rangement EtSynthese De Donnes Relationnelles) and operational competitiveness rating analysis (OCRA) methods. also concluded that the best and the worst selected materials re- main the same for all these four methods. Hence, these preference ranking methods can be efficiently applied to any type of material selection decision-making problem having any type of criteria and any number of alternatives.

Edwards K. L.[9] demonstrate the range of materials information, over and above the standard range of materials test data that needs to be manipulated by a designer. The necessity for materials knowledge and experiential information, including non-use and failure, is vital to a well-informed decision making process. Recording materials information for easy retrieval is critical to achieving optimal design solutions with minimal risk.

Sharma Avinash, Bergaley Ajeet [10] Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. In this paper main focus is to review all such work in which the weight reduction of the vehicle was achieved by considering leaf spring. Many of authors suggested that weight reduction can be achieved by using composite material having suitable properties and capable of carrying such heavy load of the vehicle. As a lot of work has been done in designing of leaf springs which is discussed briefly in this text, on the basis of this study, problems in overall weight reduction by using composite materials are identified. also concluded that weight reduction can be easily achieved by using composite materials instead of conventional steel, but there occurs a problem during the operation while using the composite leaf spring.

Yong-Huang Lin, Lee Pinch Chan [11] proposed a dynamic decision making model which takes the TOPSIS technique as main structure, integrating the concepts of grey number and Minkowski distance function into it to deal with the uncertain information and aggregate the multi-period evaluations. A subcontractor selection example is adopted to demonstrate the feasibility and practicability of the proposed model. author adopted Minkowski distance function to overcome the over effects of weighting in the original TOPSIS technique. and also integrated with Minkowski distance function to propose the weighted grey number Minkowski distance function to effectively handle the uncertain information. TOPSIS technique and aggregation approach to establish an effective dynamic decision making model.

GadakhV.S. [12]application of multi objective optimization on the basis of ratio analysis (MOORA) method is applied for solving multiple criteria (objective) optimization problem in milling process. Six decision making problems which include selection of suitable milling process parameters in different milling processes are considered in this paper. In all these cases, the results obtained using the MOORA method almost match with those derived by the previous researchers which prove the applicability, potentiality, and flexibility of this method while solving various complex decision making problems in present day manufacturing environment.

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3. PROBLEM STATEMENT

A Company is facing a lot problems due to premature failure of the die set spring under the loading of 1000 N and maximum allowable deflection of 25 mm. when the operations are carried out the spring undergo setting and does not attains original length as well as failure occurs with crack generation and distortion of the spring. Failure of die set spring may result in sudden depreciation in the resisting power of the die plate against the press force applied to form the product and consequently may lead to threat of injury or damage to the component. Hence the spring must be designed for reliability and to withstand the compression loading during operation over its life time

3.1 Objective

To study and analyze existing helical compression spring.
To study the deflection and stress on spring.
To design a spring to withstand against compression load.
To develop new model of spring with moderate specification.
To do comparative study between existing and new developed spring.

4. METHODOLOGY

Mathematical analysis has been done on existing and new spring. They both have different specification and material composition. Multi objective optimization on the basis of ratio analysis (MOORA) method is adopted for material selection criteria for new spring. Further stress and deformation modulation done by ANSYS software, it shows comparative study of stress and deformation Development and testing of the new spring done using load testing machine.

Design Considerations:
As per the industries constraints the following design parameters are considered while analysing existing spring and designing new spring. The maximum load acting on the spring is 1000 N. The maximum allowable deflection in the spring is 25 mm. The outer diameter of the shaft is 40 mm and hence clearance between spring and shaft is of 2 mm is considered

Specification of existing spring

Material: A286 Alloy
Rockwell hardness: C35-42
E = 200000Mpa
G = 71.7 X 10^3Mpa
Number of turns: 5.5
Wire Diameter: 6 mm
Mean diameter: 45
Free Length:- 90 mm

Calculation for Maximum Deflection and stress using mathematical formulation

1) *Maximum Deflection*

$$\delta = \frac{8\,WD^3 n}{\mathrm{G\ d}^4}$$

$$\delta = 43.14\ \mathrm{mm}$$

2) *Maximum shear stress*

$$\sigma = \frac{8\,WD}{\pi \mathrm{d}^3} XK$$

$$\sigma = 635.55\ \mathrm{Mpa}$$

While designing the new spring material selection will be the important criteria to be considered. Hence the multi objective optimization on the basis of ratio analysis is adopted for material selection.

Multi-objective optimization on the basis of ratio analysis (MOORA)[13]. is the process of simultaneously optimizing two or more conflicting criteria subject to certain constraints.

From MOORA method Chrome Vanadium selected. It will be the best suitable material for new spring.

Specification of new spring

Material: Chrome Vanadium
Rockwell hardness: C41-45
E = 207000Mpa
G = 79 X 10^3
Number of turns: 8
Wire Diameter: 8 mm
Mean diameter: 45
Free Length:- 90 mm

Calculation for Maximum Deflection and stress using mathematical formulation

1) *Maximum Deflection*

$$\delta = \frac{8\,WD^3 n}{G\,d^4}$$

$$\delta = 24.62 \text{ mm}$$

2) *Maximum shear stress*

$$\sigma = \frac{8\,WD}{\pi d^3} XK$$

$$\sigma = 308.832\ Mpa$$

4.1 Structural Analysis

In this section ANSYS Structural is use for experimentation. It is finite element analysis software, which makes use of complex algorithms and mathematical formulae to carry out the simulations, based on user inputs.

The CAD model as shown in fig of helical compression spring are developed by using CREO 2.0 and simulations were out using ANSYS 14.0 software

Fig-1 Geometery of Existing Compression Spring

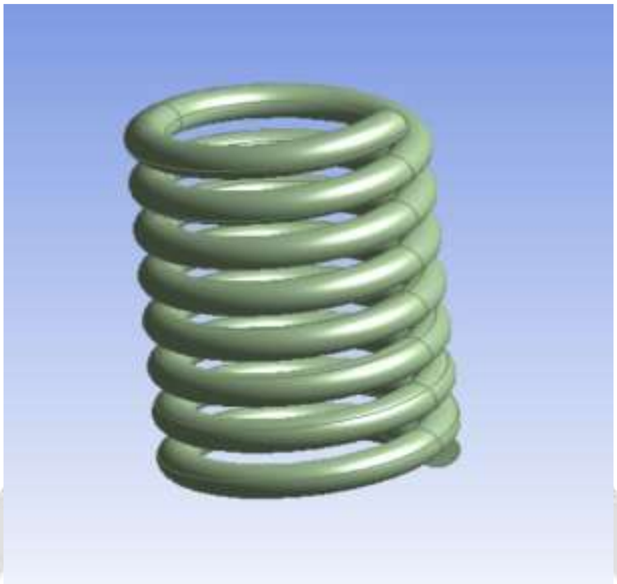

Fig-2 Geometry of new spring

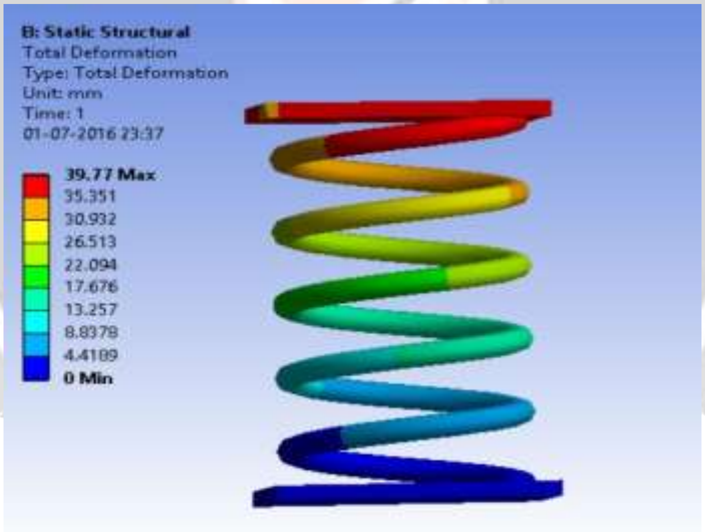

Fig-3 Total Deformation of Compression Spring for 1000 N Load

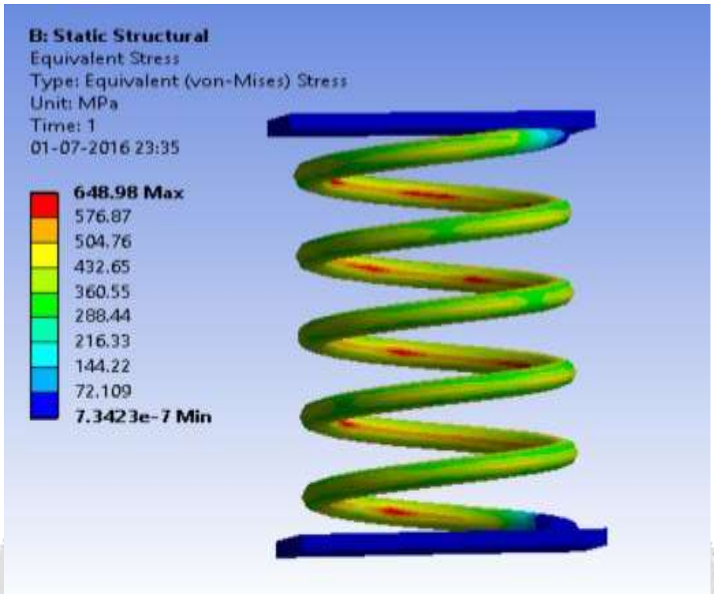

Fig-4 Von Mises Stress on Compression Spring for 1000 N Load

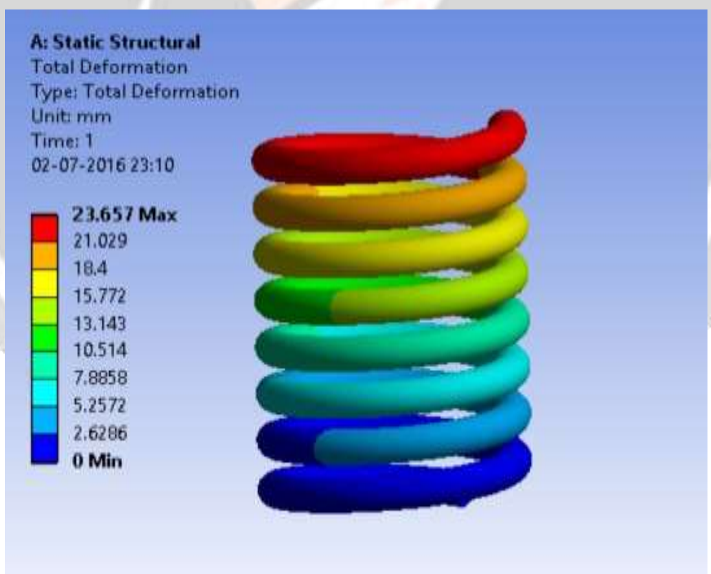

Fig-5 Total Deformation of New Compression Spring for1000 N Load

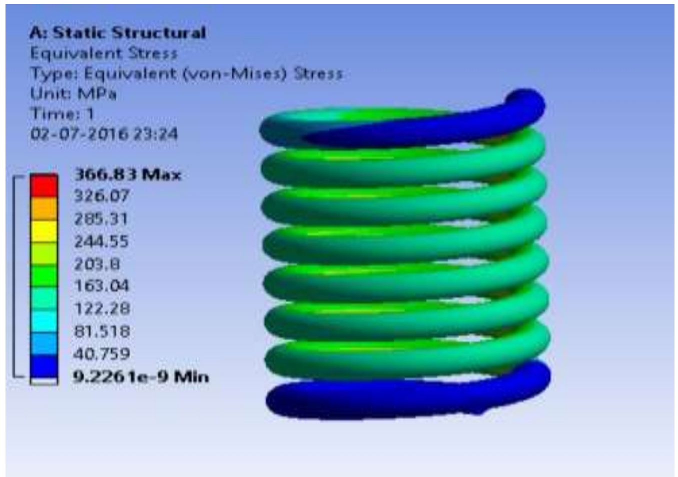

Fig-6 Von Mises Stress on New Compression Spring for 1000 N Load

For analysis on existing and new spring boundary conditions are applied to check results for 1000, 900, 800, 700, 600 and 500 N respectively.

5. EXPERIMENTAL VADILATION

The experimental procedure for the testing of the manufactured spring according to our requirement. This includes actual manufacturing and testing of the spring using load testing machine.

Fig-7 Load Testing Machine

6 RESULTS AND DISCUSSION

Following table shows the comparative result of deflection and stress for existing and new spring for different load condition using ANSYS.

Table 1 Comparison of Existing and New Spring on ANSYS

Sr. No.		Existing Spring		New Spring	
	Load (N)	Deflection (mm)	Stress (N/mm^2)	Deflection (mm)	Stress (N/mm^2)
1	500	23.86	324.49	14.56	155.9
2	600	26.51	386.3	16.62	183.42
3	700	31.81	463.56	18.70	220.1
4	800	42.42	525.37	20.78	265.95
5	900	38.46	579.45	27.01	288.88
6	1000	39.77	648.96	23.65	366.83

From table 1 it can be observed that as the load increases the deflection and stress also increases for both the springs which are quite obvious phenomenon. Therefore we know that form table 1 deflection and stresses are directly proportional to each other.

Table 2 Experimental result of new spring on load testing machine

Sr. No.	Load(N)	Deflection(mm)
1	500	10.31
2	600	11.69
3	700	13.8
4	800	15.89
5	900	19.56

6	1000	21.89

From table 2 experimental results shows that actual deflection of the new designed spring is much lower than the existing spring which is desirable to resist the die plate to move down for a shorter distance and settled back for its further operation. Hence life will be more of new spring than existing spring.

7. CONCLUSION

The deflection in the spring decreases with reduction in the stresses when change in certain parameters. The number of turns affects the deflection and stress adversely. As the number of turns increases the deflection decreases and stresses also decreases. This effect is impossible without change in wire diameter as wire diameter has the influence on the deflection and the stresses. Therefore as the wire diameter increases the deflection and stresses also decreases. This happens due to the better spring index achievement.

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