Development of Test rig for Analysis of Helical Compression Spring

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Abstract: **Helical compression spring is the spring used to exert force, store and absorb energy produced in automobile. It's very important component in automobile and various industrial applications. The material of spring should have high fatigue strength, resilience, ductility and it should have high creep resistance. It largely depends upon the service for which they are used that is severe service, Average service, Light Service. Mainly two types of spring used in vehicle one is leaf spring and other one helical spring. But for small load application instead of leaf spring, helical spring are preferred due to their maintenance. Failure of compression spring is the big issue in the automobile industry which can be overcome by testing and analysis of spring with the help of fatigue testing machine. So our objectives of this dissertation work to determine fatigue life with FEA analysis and experimentation of helical compression spring. By validating these two results we get better spring for our application.**

Index Terms **: Automobile, Ansys, Compression Spring, Fatigue Life, Pro-E**

I. INTRODUCTION

A spring is an elastic component used to store energy. Spring having greater elastic properties because of that it returns to its original shape. It is also known as a resilient member. Springs are used for control of motion, storing of energy for the purpose of measuring forces.

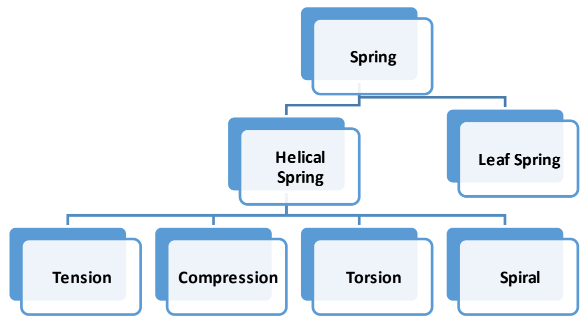

Fig. 1 Classification of spring

II. LITERATURE REVIEW

H. Skewis et al [1] discussed spring reliability as spring having capacity to take more stress because they are designed to use in vehicle suspension with the high strength to weight ration and cost of material should be low with high cyclic load carrying capacity. Reliability of a spring is related to its material strength, its characteristics, operating environment. Mostly due Corrosive effect reliability of material get changes so we will consider this during manufacturing of the spring and corrosion resistance of material must be known before using the spring. Reliability of spring also related to the surface quality and type and size of sub-surface impurities.

Stone Robert etal [2] in this paper said that intro about of fatigue and its characteristics. History will be given how fatigue test data has been evaluated. Reviews the proper methods by which spring manufacturers should determine the life of helical compression springs during the analysis of spring. From the modified Goodman Diagram we determines the fatigue life.

E Venugopal Goud etal [3] said that in this paper the advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. Leaf spring Is not used to support and control vertical loads but also to carries road induced vibrations. Vehicle subjected to millions of load cycles causes to fatigue failure.

P. M. Sonawane etal [4] in this paper the work regarding the leaf spring used in automobiles is the one of the components of suspension system. In this paper the author predict the fatigue life of semi-elliptical leaf spring with the analytical stress and deflection value. In this work describes static and fatigue analysis of advanced material leaf spring for LMV. Dimensions of a modified leaf spring of a LCV are taken by validating results and calculations. Analysis of leaf spring is done using NASTRAN solver and compared with results of analytical calculations. Meshing of model is done by using HYPERMESH. Stiffness of leaf spring calculated by using load vs deflection graph. Fatigue life of the leaf spring is also predicted using Ansys.

V. B. Bhandari [5] book of “Design of Mechanical Elements”, consist of spring chapter. In this chapter we will discuss the regarding types of springs, their applications and necessary parametric relationships, and their design.

Raymond L. Browell [6] said regarding to design of leaf products that meet their requirement of customer. In this paper for release to industry for failure of product in assembly of vehicle. While many parts may work well initially, they often fail in service due to fatigue failure caused by repeated loading significantly below static limits can cause failure if the load is repeated. Characterizing the capability of a material to survive the many cycles a component may experience during its lifetime is the aim of fatigue analysis.

Yuxin Penga, Shilong Wangb, et al. [7] A stranded wire helical spring (SWHS) is a unique helical spring and is reeled by a strand that is formed of 2~16 wires. A human machine interface is also proposed to achieve the motion control and the tension control. Results shows the tension control system is qualified a good control precision results.

Ali Kaoua et al. [8] said in this paper a 3Dimensional geometric modelling of a helical spring and its FEA results are used to study the mechanical behaviour of spring under tensile axial loading. The spiraled shape of graphic design is gain through the use of CAD tools, of which a finite element model is generated. This overall equivalent stress values increases radially from 0 to 180, being maximal on the internal radial zone at the section 180. Where minimum stress level is located at the center of filament cross sectional area.

2.1 Problem Identification: From the above study of literature review we are finding problem in automobile spring like failure of spring occurs mostly due to repeated loading in the spring. So we need to determine the fatigue life of spring.

III. OBJECTIVES

1. Design and development of helical compression spring test rig.
2. Performance analysis of helical compression spring with fatigue testing machine.
3. Validate FEA results with experimental results.

IV. MATERIALS AND METHODS

4.1 Spring manufacturing processes

Springs are of very small in diameter, wire diameter is small then the springs are manufactured with a cold drawn process through a mangle. Large springs having large coil diameter and wire diameter has to manufacture by hot processes. Where we first heat the wire and then use a proper mangle to wind the coils. Springs are mainly two types that is helical springs and leaf springs.

As on selection of material we are taking four material for testing having specification as given below

Table. 1 Specification of Material

Material	Specification	Modulus of Elasticity
ASTM A 228	C 0.70-1.00% Mn 0.20-0.60%	207
ASTM A 227	C 0.45-0.85% Mn 0.60-1.30%	207
ASTM A 679	C 0.65-1.30% Mn 0.20-0.30%	207
ASTM A 229	C 0.55-0.85% Mn 0.60-1.20%	207

Table. 2 Properties of Material

Mtl.	Minimum Tensile Strength Mpa	Shear Modulus	RHN	Max Temp
ASTM A 228	230-399	79.3 Gpa	C 41-60	120^0c
ASTM A 227	1014-1951	79.3 Gpa	C 31-52	120^0c
ASTM A 679	1641-2413	79.3 Gpa	C 31-52	120^0c
ASTM A 229	1317-2234	79.3 Gpa	C 42-55	120^0c

4.2 Important considerations for synthesis of springs

1. Application of spring gives some information related to required force and spring rate or total deflection for the spring. On the basis of basic information we determines the solid and free lengths of spring.
2. Select spring index in the range of four to twelve. A spring index lower than 4 will be difficult to manufacture. Higher forces will require a smaller spring index.
3. Number of active coils should be greater than 2. In order to avoid manufacturing difficulties. The number of active coils can be estimated from a spring stiffness.
4. For initial design purposes, the solid height should be specified as a maximum dimension. Usually, applications will allow a spring to have a smaller solid height than the geometry allows, so the solid height should not be considered a strict constraint.
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6. When a spring will operate in a cage clearance of roughly 10% of the spring diameter must be specified.
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8. At the free height, the spring has no restraining force, and therefore a spring should have at least some preload.
9. To avoid compressing a spring to its solid length, and the impact and plastic deformation that often result, a clash allowance of at least 10% of the maximum working deflection should be required before the spring is compressed solid.
10. Consider the application when designing the spring and the amount of force variation that is required. For such applications, a high spring rate and low stiffness of spring is useful.

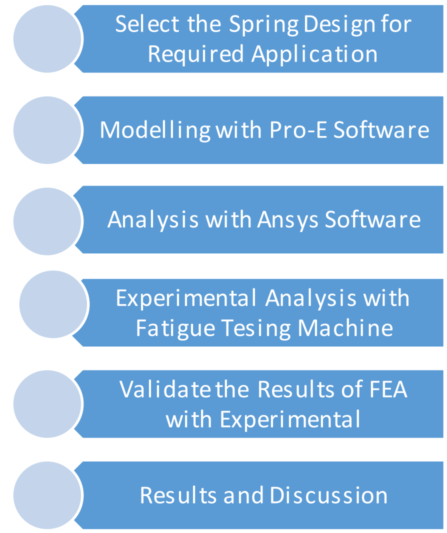

Fig. 2 Methodology for Fatigue Testing of Compression Spring

4.3 Terms used in compression springs:

1. Solid length: Solid length is a length where spring get compressed up to the coils come into contact to each other. It is product of total number of coils and diameter of wire.
2. Free length: Length of spring in free state of spring or unloading condition of spring. Free length is solid length plus maximum deflection of spring.
3. Spring index: Ratio of mean diameter of coil to wire diameter.
4. Spring rate: Load required per unit deflection.

1. Mode of loading: Cyclic loading
2. Outer diameter of coil, D_o = 35 mm
3. Inner diameter of coil, D_i = 29 mm
4. Wire diameter, d_i = 3 mm
5. Pitch, P = 8 mm
6. Mean diameter of coil D = 32 mm
7. Number of active coil, N = 4.25Nos
8. Total Number of coil N_t = 5.25Nos.
9. Free Length, Lo= P* N_t = 42 mm
10. Solid Length Ls= d * N_t = 15.75 mm
11. Max. Force F_{max}=100 N
12. Min. Force F_{min} = 0N
13. Spring Index C =D/d =8 mm

15. Wahl's stress factor

$$Ks = \frac{4(11.6)-1}{4(11.6)-1} + \frac{0.615}{8} = 1.148$$

16. Shear stress :

$$\tau = \frac{8\,F\,D}{\pi\, d^3}\,Ks = \frac{8*100*32}{3.14*27} * 1.148 = 346.64\ N/mm^2$$

17. Ultimate Tensile Strength = 2810 Mpa.

18. Torsional Yield Strength, Ssy = 0.45* Sut = 1264.5 Mpa.

Modulus of Elasticity, G = 77200 Mpa

19. Spring Rate,

$$k = \frac{G*d^4}{8*D^3*N} = \frac{77200*3^4}{8*32^3*4.25}$$

k = 5.61 N/mm

Deflection, y = F/k = 17.82 mm

20. Weight $W = \frac{\pi^2 * d^2 * D * N * \gamma}{4}$

$$W = \frac{\pi^2 * 3^2 * 24 * 4.25 * 82 * 10^{-6}}{4} = 0.2473\ N.$$

V. EXPERIMENTATION

5.1 Modelling of spring: As a modelling of spring done with the help of Pro-E 4.0 with a dimension of wire diameter size 3mm, outer diameter 35mm, inner diameter 29mm and length of spring 148mm.

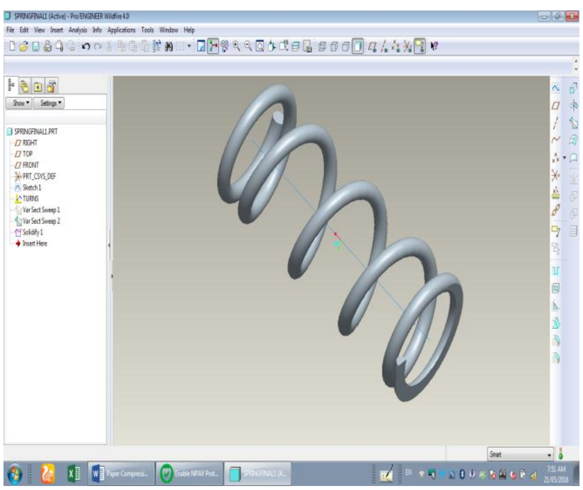

Fig. 3 Modelling of spring with Pro-E

5.2 Meshing of Spring: In meshing dividing smaller elements of finite dimensions called finite elements. Meshing carries with the help of Ansys where it was meshed by taking edge length as 5mm as a result of which a total of 7569 elements and 15425 nodes were created.

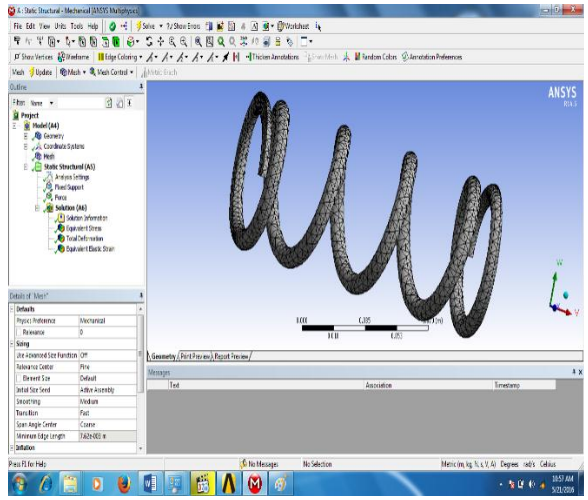

Fig. 4 Meshing of Compression Spring Model

5.3 Analysis of spring: For all boundary conditions and load is applied (100N) on top surface of spring also by applying material properties that is modulus of elasticity and density of a material.

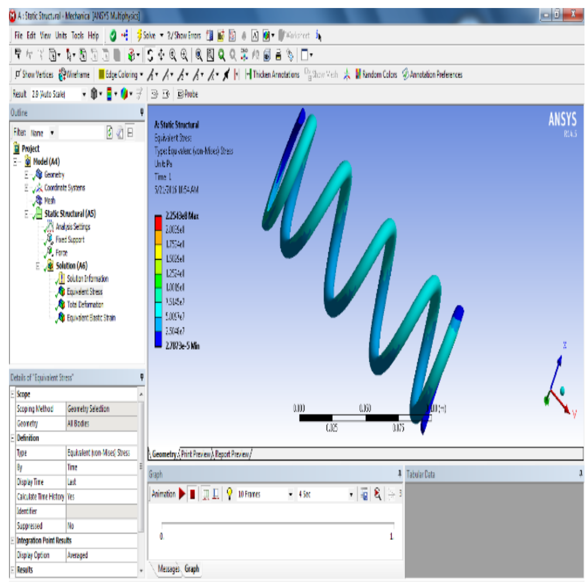

Fig. 5. Analysis with Ansys 14.0

5.4 Fatigue testing machine: Machine used to manufacture for predicting life of spring for industrial spring application. In this machine we are using counter for measuring cycles.

Fig. 7 Fatigue Testing Machine

Fig. 8 Cycle Counter for life of spring

VI. RESULTS AND DISCUSSION

As per analysis of following FEA and experimental reading are to be taken with the help of ansys software and Fatigue testing machine.

Table 3. Results of spring material

Material	**Cycles**	
	FEA	EXPT.
ASTM A 228	87232	86468
ASTM A 227	66824	65084
ASTM A 679	74350	72002
ASTM A 229	71382	69381

From this results we get better material for our application of spring for the industrial purpose.

VII. CONCLUSION

From the industry point of view we are design the fatigue testing machine and from this we get life of spring in cycles. It is also conclude that in static analysis, for the load 100 N, Life of ASTM A228 found to be more than other spring wire using software analysis as well as experimentally. Which is high quality spring and wire forms for our cyclic operation.

REFERENCES

1. G. Harinath Goud and E. Venugopal Goud, "Static analysis of leaf spring", International Journal of Engineering Science and Technology, Vol. 4, pp. 3794-3803, 20122.
2.William H. Skewis, "Failure modes of mechanical springs", Support Systems Technology Corporation
3. Robert Stone, "Fatigue life estimates using Goodman diagrams", SMI Encyclopedia of Spring Design.
4. Mr. V. K. Aher and Mr. P. M. Sonawane, "Static and fatigue analysis of multi leaf spring used in the suspension system of LCV", International Journal of Engineering Research and Applications, Vol. 2, pp. 786-1791, 2012.
5. Shigley, " Mechanical Engineering Design", Eighth Edition, Budynas–Nisbett, McGraw–Hill Primis , 2006, Ch. 10.
6. Vijay Gautam , Parveen Kumar and Aadityeshwar Singh Deo, "Effect of Punch Profile Radius and Localised Compression on Springback in V-Bending of High Strength Steel and its Fea Simulation" International Journal of Mechanical Engineering & Technology (IJMET), Volume 3, Issue 3, 2012, pp. 517 - 530. ISSN Print: 0976 – 6340, ISSN Online: 0976 – 6359.
7. Rakesh Hota, Kshitij Kumar, Ganni Gowtham and Avinash Kumar Kotni, "Experimental Investigation of Fiberglass Reinforced Mono-Composite Leaf Spring", International Journal of Design and Manufacturing Technology (IJDMT), Volume 4, Issue 1, 2013, pp. 30 - 42, Published by IAEME, ISSN Print: 0976 – 6995, ISSN Online: 0976 – 7002.
8. Browell, P. E. Product Manager New Technologies ANSYS, Inc., Predicting Fatigue Life with ANSYS Workbench, International Ansys Conference, 2006.
9. Yuxin Penga,b, Shilong Wangb, Jie Zhoub, Song Leib," Structural design, numerical simulation and control system of a machine tool for stranded wire helical springs, Journal of Manufacturing Systems, 2012".
10. Sid Ali Kaoua, Kamel Taibia, Nacera Benghanem, Krimo Azouaoui, Mohammed Azzaza,"Numerical modelling of twin helical spring under tensile loading, Applied Mathematical Modelling ,2011".