Fatigue Analysis of Helical Spring using CATIA V5 and FEA Software

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Abstract

This paper focuses on using competent CAD software CATIA V5 and UNI Graphics (UG) for Fatigue Analysis of the spring when it is subjected to cyclic loading. The analysis offers an insight into the expected life of the spring while it is subjected to the predetermined loads during its operation. In settling on spring designs the designer must choose the operating stress that fits his spring configuration and material choice. The solution must meet the chosen conditions of load, travel, and available space.

Keywords- *Helical Springs, Fatigue Strength, CATIA*

1. Introduction

A spring may be defined as an elastic member whose primary function is to deflect or distort under the action of applied load; it recovers its original shape when load is released.
Coil springs are manufactured to very tight tolerances to allow the coils spring to precisely fit in a hole or around a shaft. A digital load tester, or coil spring compression tester can be used to accurately measure the specific load points the metal spring. Compression springs are able to have two entirely different spring rates or a different spring constant associated with its design. Compression springs can be made from non-magnetic spring wire like Phosphor Bronze or Beryllium Copper. In determining the proper compression spring design the designer usually has a few known details. Load, movement, and space allowed are the factors generally known at the start of the design process[1].
It is a mechanical device which is used for the efficient storage and release of energy. Depending upon the requirements, a spring can take different shapes, such as the helical coil of a wire, a piece of stamping or a flat, wound-up strip. Helical compression springs are most common spring type. Compression springs are coil springs that resist a compressive force applied axially. Compression springs or coil springs have a spring constant and may be cylindrical springs, conical springs, tapered, concave or convex in shape. The changing of compression spring ends, direction of the helix, material, and finish all allow a compression spring to meet a wide variety of special industrial needs.
They have a wide range of applications and can be found in almost all mechanical products.

1) Door locks, in compressors, in valves, in electric switches.
2) As a shock absorbers in vehicles, Railway buffer, Aircraft landing gears.
3) To measure forces as in balances.

2. Design of Helical Springs

The design of a helical compression spring involves the following considerations [2].

- Modes of loading – i.e., whether the spring is subjected to static or infrequently varying load or alternating load.
- The force deflection characteristic requirement for the given application.
- Is there any space restriction.
- Required life for springs subjected to alternating loads.
- Environmental conditions such as corrosive atmosphere and temperature.

Considering these factors the designer select the material and specify the wire size, spring diameter, number of turns spring rate, type of ends, free length and the surface condition.

3. Finite Element Analysis (Simulation)

The finite element method (FEM) is practicalapplication often known as finite element analysis (FEA)is a numerical technique for finding approximate solutionsof partial differential equations

(PDE) as well asof integral equations.Finite Element Analysis [3] is a simulationtechnique which evaluates the behaviour of components,equipment and structures for various loading conditionsincluding applied forces, pressures and temperatures.Thus, a complex engineering problem with non-standardshape and geometry can be solved using finite elementanalysis where a closed form solution is not available. Thefinite element analysis methods result in the stressdistribution, displacements and reaction loads at supportsetc. for the model.

Thus the various steps involved in the finite element analysis are

1) Select suitable field variables and the elements.
2) Discretise the continua.
3) Select interpolation functions.
4) Find the element properties.
5) Assemble element properties to get global properties.
6) Impose the boundary conditions.
7) Solve the system equations to get the nodal unknowns.
8) Make the additional calculations to get the required values.

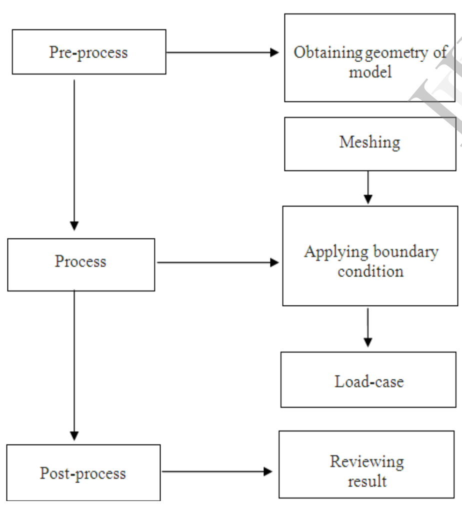

Fig. 3 Basic Step in Finite Element method

4. Dimensional Finite Element Analysis of Compression Spring [4]

Modelling is done using CATIA [5] V5R20 and Analysis is carried out by using NASTRAN 2005 software for better understanding.SOLID (HEXA 8) element is a single order 3-D, 8-node element. HEXA 8 has linear displacement behaviours and is well suited to modelling irregular meshes (such as those produced from various CAD/CAM systems). The element is defined by 8 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elasto-plastic materials, and fully incompressible hyper elastic materials.

5. Literature Review

F. N. Ahmad Refngah et al [6] in this paper presents about fatigue life prediction based on finite element analysis and variable amplitude loading (VAL). Parabolic spring in the vital component is a vehicle suspension system, commonly used in trucks. It needs to have excellent fatigue life and recently, manufacturers rely on constant loading fatigue data. The objective of this study is to simulate the variable amplitude loading for the fatigue life analysis.

Robert Stone [7] describes a working definition of fatigue and a brief discussion of fatigue characteristics. A short history is presented as to how fatigue test data has been evaluated historically. (e.g., S-N curves, Weibull distribution, modified Goodman diagrams, etc.). He also reviews the proper methods by which spring manufacturers should estimate the fatigue life of helical compression springs during the design phase.

Koutaro Watanabe et al [8] in his paper present different formulae are commonly used in different countries, such as Wahl's formula in Japan and Bergsträsser's formula in Europe. Therefore, the difference of values obtained by various formulae was compared with after clarifying the assumptions introduced in each formula.

Bruno Kaiser et al [9] in this paper firstly presents results of fatigue tests on a variety of helical springs up to a number of 107 cycles. These results were obtained in a research project which extensively investigated the fatigue properties of helical springs with five different wire diameters (1, 2, 3, 5 and 8 mm) up to 107 cycles.

Fatiguelifepredictionis basedonknowledgeofboththenumberof cyclesthepartwillexperienceat anygivenstressleveldoringthatlifecycleandanotherinfluentialenvironmentaland usefactors. The local strain-life method can be used pro-actively for a component during early design stage

From this literature review for compression spring, fatigue can be avoided by properly balancing parameters such as available space, material, rate of load application, and operating environment and to estimate fatigue life springs fatigue tests must be performed.

6. Spring Fatigue Life Prediction

Original spring fatigue is simulated as per the steps as given [10].

6.1 Life Predication:

The minimum life shown in the simulation is 3.56e6 which is more than 3 lac cycle requirement.

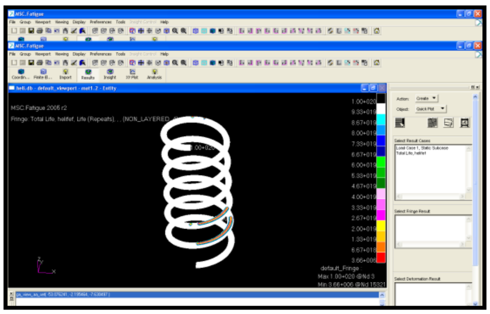

Figure 6.1 Total life plot of compression spring

6.2 Damage Detection:

Damage sum must be less than zero for the cyclic loading of a helical compression spring. The damage plot is shown in the figure below.

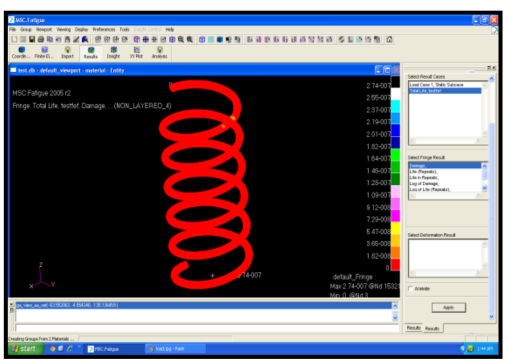

Figure 6.2 Damage plot of compression spring

7. Results and Discussion

1. Original compression spring shows the maximum deflection of 4.70 mm which is well within the permissible limit.
2. Maximum Von Mises Stress is observed to be 1080.54 MPa near the rigid element and spring element connection.
3. Maximum shear stress is observed to be 588.99 MPa near the rigid connection.
4. The minimum life predicated by simulation is about 3.56e6 cycle for the original spring design.
5. The damage sum of the original spring design is less than 1. Hence the design is safe for fatigue life

8. Future Scope

- Modified spring design can further be categorized for standardization of spring design.
- Complexity of fitting and maintained of spring need to be considered.
- Other spring materials can be suggested for enhancement of fatigue life predication.
- Modified design needs to be manufactured and tested for deformation and stress results.

9. References

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