Research Article *ISSN: 2319-507X*
Saikrishna Kishore, IJPRET, 2013; Volume 1(8): 1-10 *IJPRET*

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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OPTIMAL DESIGN OF HELICAL COMPRESSION SPRING BY USING GENETIC ALGORITHM

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IJPRET-QR CODE *PAPER-QR CODE*

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Accepted Date:
12/03/2013
Publish Date:
01/04/2013
Keywords
Genetic Algorithm
Flexibility

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Abstract

Optimal problems are often met in engineering practice. Springs are important mechanical members which are used to store energy, to provide flexibility and to exert force. Helical springs are most popular type of springs. The method of helical spring optimization is a typical one which can be used to solve mechanical optimum design problem. An optimization is to be used for the design of a helical spring. This optimization function has to perform by a systematic analysis of helical spring requirements in the light of information on available materials and their performances. The optimization phase will utilizes a finite element model to take into account of various constraints under loading conditions. The optimization problem has to be formulating to satisfy one objective, namely minimum weight. This optimization will gives flexibility to the designer, as requirement. Thus, a mathematical model has to develop and examine with genetic algorithm by available space and number of coils. This study initiates to strengthen the appropriate relations of helical spring design parameters

1.0 INTRODUCTION

A spring is a device, in which the material is arranged in such way that it can undergo a considerable change, without getting permanently distorted. A spring is used to absorb energy due to resilience, which may be restored as and when required. The quality of a spring is judged from the energy it can absorb e.g., in which, when the spring referring its original shape. A carriage spring is used to absorb shocks. It is thus obvious that spring, which is capable of absorbing the greatest amount of energy for the given stress is known to be the best one.

The spring is the medium of transmitting the weight of the body of vehicle or wagon to the axle of the box down to journal and hence to rail. Spring observes the shocks produced during dynamic conditions by the track irregularities, helps preventing hot axles, reduces wear and tear of other components and adds to the riding quality of the shock and in addition to these it prevents off-loading of wheels to a great extent and avoids derailment. As such, it plays highly important role in efficient rolling stock performance. Their failure results in havocs of derailments, so there through and intensive care and maintenance at every stage deserves prime importance

A spring is defined as an elastic body, which is to distort when loaded and to recover its original shape when the load is removed.

The helical spring are made up of wire called in the form of helix and is primarily intended for compressive or torsion loads. The cross section of the wire from which the springs is made may be circular, square or rectangular. Helical springs are used in secondary suspension trolleys, buffing and gear and primary-suspension of ICF trolleys for absorbing vertical shock directly or in assistance of laminated bearing springs. In comparison to laminated bearing springs, helical springs are considered of better quality for the cases of failure are very rare in this type of springs. They last longer and are quite capable enough to sustain the vertical shocks easily and such they contribute very much towards riding – comforts.

In buffing and draw gear, they absorb longitudinal shock and avoid damages to the stock and add to passenger comforts. At the time of accidents their contribution is of a high order in consuming the shocks and alleviates sufferings. They are economical as their manufacturing process is very simple and easy

They are manufactured out of silco manganese spring steel to IS specification no. IS 3195-1975 of circular, square or rectangular section by hot rounding the rod of specified diameter, for specified springs to the turns and lengths. Both the ends are pre-tapered so that the top and bottom coil is so formed as to keep the spring in 90^0angle when kept on a table from any end.

Some helical springs of shorter diameter, just new to equal to the inner diameter of standard springs are also manufactured and are fitted inside the outer helical springs are called nested springs or inner springs. In some trolleys there is set of three helical springs are in each other and called the outer, middle and inner springs.

The helical springs are said to be the closely coiled when the spring wire is coiled so close that the plane containing each turn is nearly at right angles to the to the axis of the helix and the wire is subjected to rotation. In other words, in a closely coiled helical spring, the helix angle is very small; it is usually less than 10^0. The major stresses produced in helical springs are shear stresses due to twisting. The load applied is parallel to or along the axis of the spring.

In open-coiled helical springs, the wire is coiled in such a way that there is a gap between the two consecutive turns, as a result of which the helix angle is large. Since the application of open coiled helical springs are limited, therefore our discussion shall confine to closely-coiled helical springs only.

2.0 Materials for Helical Springs:

The material of spring should have high fatigue strength, high ductility, high resilience and it should be creep resistant. It largely depends upon the service for which they are used i.e., severe service, average service or light service

The springs are mostly made from oil-tempered carbon steel wires containing 0.60 to 0.70 percent carbons and 0.60 to 1.0 percent manganese. Music wire is used for small springs. Non-ferrous materials like phosphor bronze, beryllium copper, monels-metal, brass etc., may be used in special cases to increase fatigue resistance, temperature resistance and corrosion resistance.The following table shows the valves of allowable shear stress, modules of rigidity and modules of elasticity for various materials used for springs.

The helical springs are either cold formed or hot formed depending upon the size of the wire. Wires of small sizes less than 10mm diameter are usually would cold whereas large size wires are would hot. The strength of the wires varies with size; smaller size wires have greater strength and less ductility, due to the greater degree of cold working.

Table 1 Material property of spring materials

Material	Minimum Tensile Strength MPa	Modulus of Elasticity E(MPa X 10^3)	Modulus in Torsion G(MPa X 10^3)
Oil tempered wire	CLI- 1138-2020 CLII--1317-2234	207	79.3
Carbon epoxy wire	1100-1900	140	68

2.1 Oil tempered wire

This specification covers two classes of oil-tempered steel spring wire intended especially for the manufacture of mechanical springs and wire forms. The steel may be made by any commercially accepted steel-making process and shall either be ingot cast or strand cast. The finished wire shall be free of detrimental pipe and undue segregation. The wire shall be oil quenched and tempered to produce the desired mechanical properties such as tensile strength. Cast, heat, and product analysis shall conform to the chemical composition requirements prescribed for carbon, manganese, phosphorus, sulfur, and silicon. Tension, wrap, and surface tests shall be performed .General. The alloy spring steels have a definite place in the field of spring materials, particularly for conditions involving high stress and for applications where shock or impact loading occurs. Alloy spring steels also can withstand higher and lower temperatures than the high-carbon steels and are obtainable in either the annealed or pre tempered conditions.

I. 2.2 Carbon epoxy composite wire

A carbon fiber reinforced composite coil spring is provided which is made from a braid formed of carbon fibers oriented at a preferred angle to the braid axis of approximately plus or minus 45° and impregnated with a resin which serves as a substantially continuous matrix phase. Longitudinal reinforcing fiber may be incorporated into the braid to prevent it from straightening under longitudinal tension. The carbon fiber reinforced composite coil spring is formed by wrapping the braid, impregnated with a non-solidified resin, within a groove which extends helically along the surface of a helical mandrel and solidifying the resinous matrix material, and then removing the solid composite coil spring from the helical mandrel.

3.0 DESIGN PROCEDURE

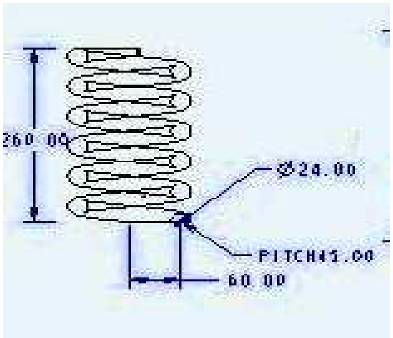

Figure.1: Dimensions of spring

Data assumption

Axle load of Wheel — 20.3 T

Maximum load of 4— Wheel car share is = 20.3 X 4 = 81.20 T

Tare Weight of a wagon 25.00 to 26.00 T say = 26.00 T

Wheel weight is unspring of mass= 6.00 T

Spring mass under empty condition = 26.00 — 6.00 = 20.00 T

Maximum load spring can have 4— wheel car including tare weight of wagon

= 81.20 T (say) = 82.00 T

4.0 RESULTS

4.1 STAINLESS STEEL WIRE WITHOUT LOAD

ISSN: 2319-507X
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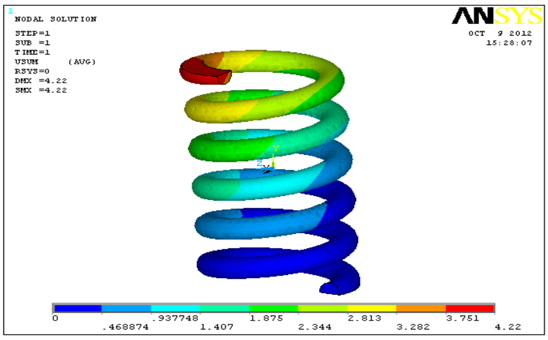

Figure.2: Displacement results of stainless steel wire material

The above image is showing distributed shape or variation of geometry shape after applying loads. The maximum displacement is 4.22 mm.

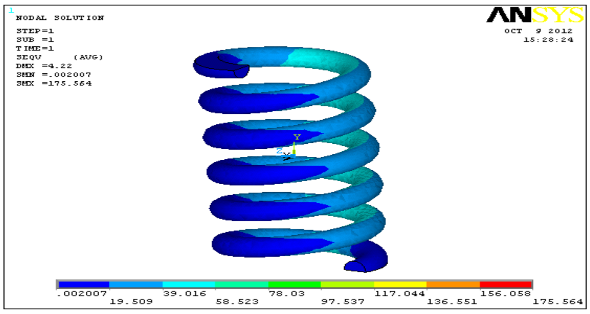

Figure.3: Vonmises stress

The above image is showing vonmises stress value. Vonmises stress depends on vonmises theory of failure.

4.2 STAINLESS STEEL WIRE WITH LOAD

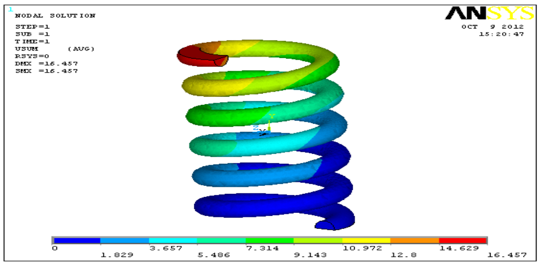

Figure.4: Displacement results of stainless steel wire material

The above image is showing distributed shape or variation of geometry shape after applying loads. The maximum displacement is 16.457 mm.

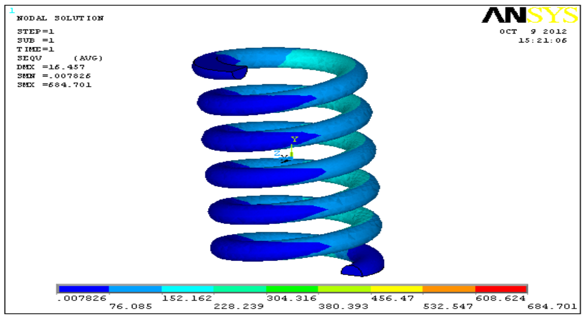

Figure.5: Vonmises stress

4.3 CARBON EPOXY WITHOUT LOAD

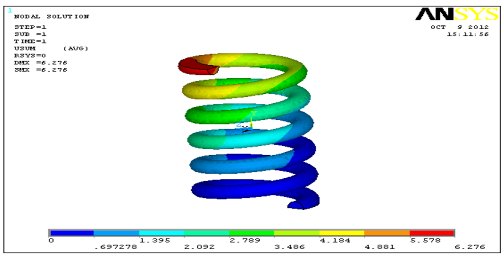

Figure.6: Vonmises stress Displacement results of Carbon Epoxy

The above image is showing distributed shape or variation of geometry shape after applying loads. The maximum displacement is 6.276 mm.

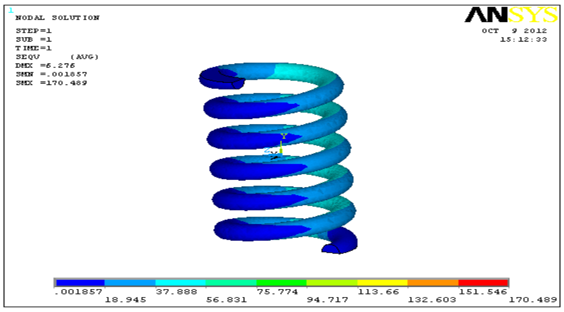

Figure.7: Vonmises stress

4.4 CARBON EPOXY WITH LOAD

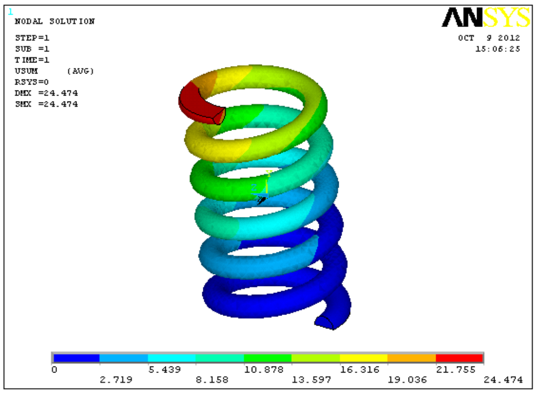

Figure.8: Displacement results of Carbon Epoxy

The above image is showing distributed shape or variation of geometry shape after applying loads. The maximum displacement is 24.474 mm.

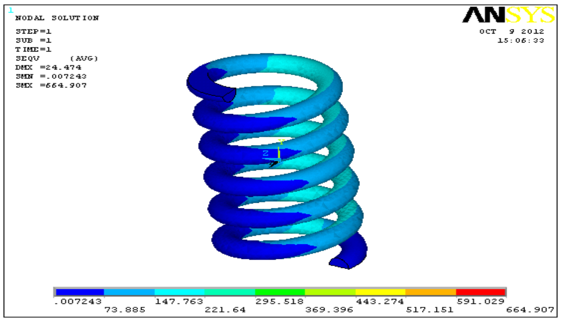

Figure.9: Vonmises stress

The following is result of calculation and standard helical spring‘s specification.

Table 2: Results of oil tempered wire

Sl.No	Name of the Parameter	Numerical Example	result
1	Coil's weight (W Kg)	12.1	7.3805
2	Coil's wire diameter (d mm)	24	19.54
3	Mean radius(R mm)	60	48.85
4	Number of active coils; n	7	11

By applying the method proposed in this formulation, it was possible to obtain results as shoen in table .2.The minimum weight obtained F (d, R, n) = 4.6905, then each the coil's wire diameter, mean radius and number of coils were (d= 19.54, R= 48.85, n= 11), respectively. After comparing the helical spring calculation results, the coil's weight (W) optimized by 38.17 % and mean radius is 18.58 %.

Table .3 Results of carbon epoxy wire

Sl.No	Name of the Parameter	Numerical Example	result
1	Coil's weight (W Kg)	1.80	1.107
2	Coil's wire diameter (d mm)	24	12.34
3	Mean radius(R mm)	60	38.5
4	Number of active coils; n	7	9

By applying the method proposed in this formulation, it was possible to obtain results as shoen in table.3.The minimum weight obtained F (d, R, n) = 1.107, then each the coil's wire diameter, mean radius and number of coils were (d= 12.34, R= 38.5, n= 9), respectively. After comparing the helical spring calculation results, the coil's weight (W) optimized by 38.5 % and mean radius is 35.83 %.

5.0 CONCLUSION

In this paper it was concluded that to formulate an optimization of helical spring weight for a constrained allowable shearing stress, number of active coils and coil's average radius as a NIP problem and solve it directly by keeping the non linear constraint by using genetic algorithm. As a result , the number of decision(design) variables did not increase, and easily got the best compromised solution.

As a result , it is obtained that a minimum weight of oil tempered steel spring wire

F (d,R,n) = 7.3805, and for composite material steel wire F(d, R. n) = 1.107,Then the coil weight of oil tempered steel wire optimized by 38.17% and composite material steel wire is optimized by 38.5%,and confirmed the efficiency of the proposed method. This study initiates to strengthen the appropriate relations of helical spring design parameters.

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