DESIGN AND ANALYSIS OF CONICAL SPRING FOR PERFORMANCE ENHANCEMENT OF MIRROR ASEEMBLY USING HYBRID APPROACH

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Abstract - *Design in continuously varying situation becomes very difficult task for any designer. When dealing with such drastic varying situation the at most knowledge of the designer is tested to find the optimum solution. The compact assemblies like mirror assemblies requires the heavy and rigid design for accommodating in a very little space with specialized manufacturing ideas and compactness. The design and development of the conical spring for the mirror assembly is the attempt for achieving the specific goals of compact design restrictions. The efficient and effective design of the sub-assemblies considerably reduces the weight and size of the main assembly. While working condition the main assembly and sub-assemblies should not fail in accordance with proper functioning of it. Performance of the system depends upon the effectiveness of the design of the subassemblies and their efficient development for ensuring the working of the assembly. The system performance should be enhanced and causes of the failure should be reduced or eliminate. The main objective of the work is to design and develop the conical spring for the performance enhancement of the mirror assembly. The material selection for the spring is again the crucial point to be focus which is carried out by the MCDM techniques like AHP and SWM, WPM.*

Key Words: **Performance Enhancement of Assembly, SWM, WPM**

1.INTRODUCTION

While designing the components of the assembly system their efficient working must be ensured. For specific applications such criteria are not available many times. The effective design of the subassemblies must be ensured for the prevention of the failure as well as performance enhancement. For such designs the material selection is also one of the vital parameter which is need to be considered. The overall advantages and disadvantages of the different materials and their parameters need to be understood prior to the manufacturing of the product.

The inventers should have a pure compassionate of the purposeful requirements for each individual component and a detailed knowledge of the considered criteria for a specific engineering design. Improper selection of material may often lead to huge cost involvement and ultimately drive towards premature component/product failure. Selection of proper materials for different components is one of the most challenging tasks in the design and development of products for diverse engineering applications. So the designers need to identify and select proper materials with specific functionalities in order to obtain the desired output with minimum cost involvement and specific applicability.

Selecting the most appropriate material in the presence of multiple, generally conflicting criteria is a typical multi-criteria decision-making (MCDM) problem. Thus, a systematic and well-organized approach to material selection is necessary in order to select the best alternative for a given application.

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 [12].

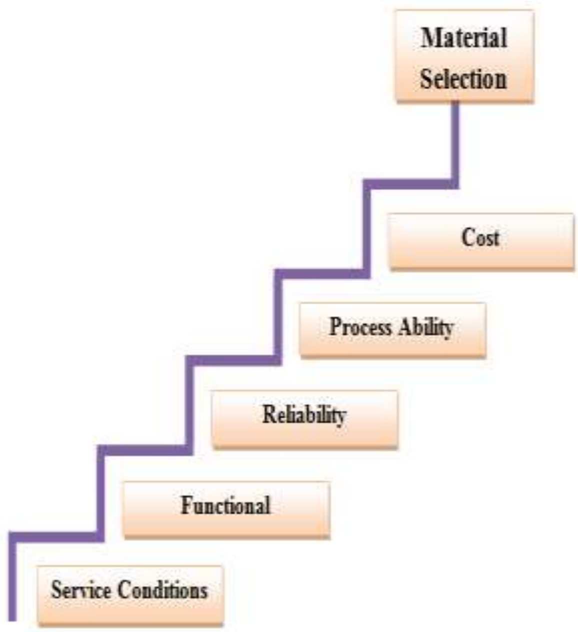


Fig-1: Factors for Material Selection

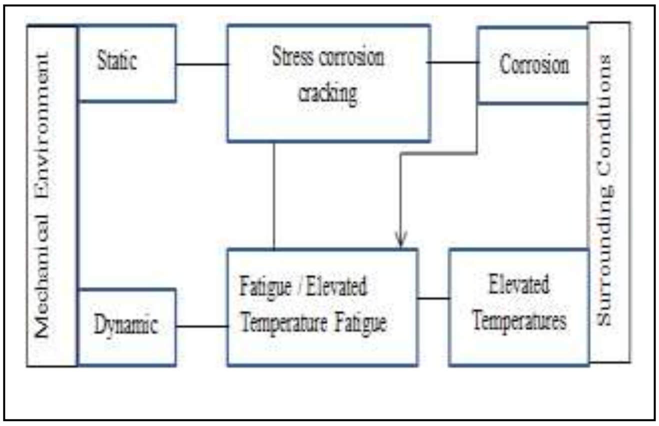
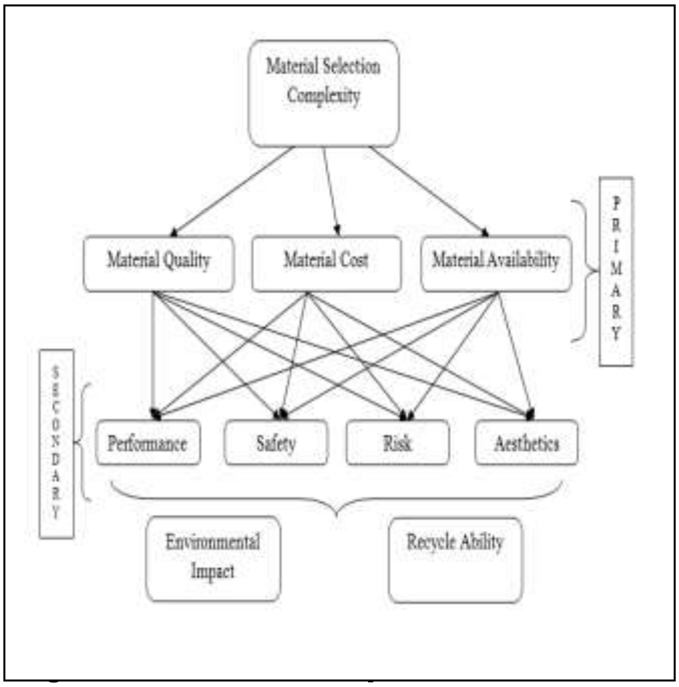
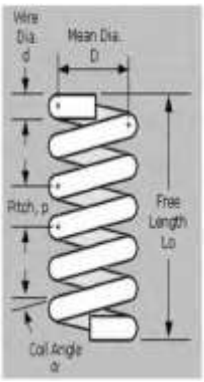


Fig -2: Factors Related to Spring Durability





D = Mean diameter

d = Wire diameter

p = pitch

L_0 = Free Length

W = Load / Force

Fig -4: Spring Nomenclature

2. Literature Review

Francisco Rodrigues Lima Junior et al. [1] studied comparative analysis of these two methods in the context of supplier selection decision making. The comparison was made based on the factors: adequacy to changes of alternatives or criteria; agility in the decision process; computational complexity; adequacy to support group decision making; the number of alternative suppliers and criteria; and modeling of uncertainty. Del Llano-Vizcaya et al. [2] applied multi axial fatigue criteria are applied to the analysis of helical compression springs.

The critical plane approaches, Experimental fatigue lives are compared with the multi axial fatigue criteria predictions. The stress analysis was carried out in the finite element code ANSYS, and the multi axial fatigue study was performed using the fatigue software Code. E. Bal Besikci et al. [3] observed that the potential for fuel economy in shipping ranging between 25% to 75% is possible by using existing technology and practices and technical improvements in the design of new ship. Despite the existence of many technology and design-based approaches, limitations of emerging these measures have led to discussions about the potential energy savings through operational changes. T. Hamilton et al. [4] an experimental apparatus that both supports and equalizes the applied loads on springs was developed. The spring deflection versus applied load was measured using an optical sight mounted on a micrometer. Deflection data on each spring were collected, plotted and successfully modeled using Hooke's Law. Pavani P. N. et al. [5] established a precise spring rate in which load is proportional to deflection. Functional requirements are necessary for both dynamic and static spring applications. Special performance characteristics are individually built into each spring to satisfy a variety of precise operating conditions. Typically, a wave spring will occupy an externally small area for the amount of work it performs. Kaiser B. et al. [6] 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 et al. [7] 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 et al. [8] 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. Berger and Kaiser [9] 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 [10] 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 S. Krishna et al. [11] 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.

3. Methodology

Company is facing a lot of problems due to lack of design expertise and variable environment of customer requirements. The system which enables fool proofing through the design and selection of proper material and which is strengthen by the analysis of existing and developed spring eliminating the problem is desirable.

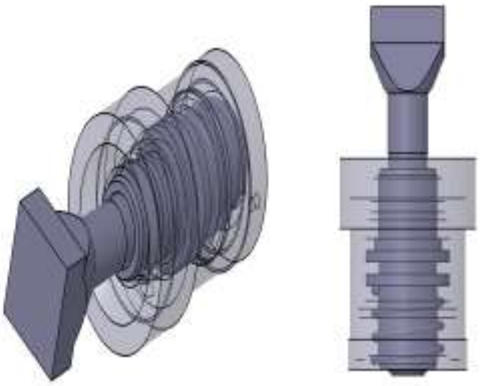
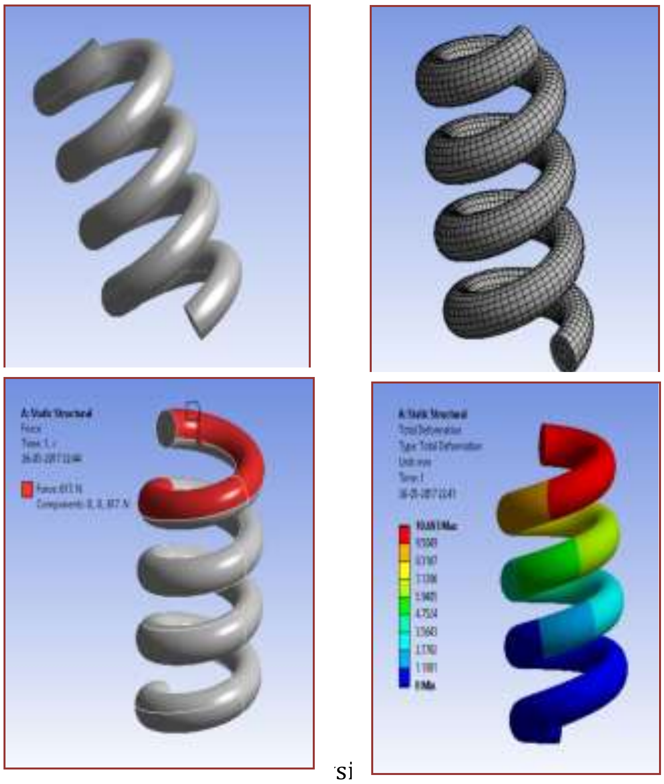


Fig -5: Mirror Assembly Details

3.1 Finite Element Analysis

Basic concept in FEA is that the body or structure may be divided into smaller elements of finite dimensions called “Finite Elements”. The original body or the structure is then considered as an assemblage of these elements connected at a finite number of joints called “Nodes” or “Nodal Points”.



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Design of Conical spring

r_1 = 10 mm, r_0 = 4 mm, F = 617 N, n = 8, G = 79300

d = 4.2 mm

Deflection can be calculated as

$$\delta = \frac{16\, n\, (r_1 + r_0)(r_0^2 + r_1^2)\, F}{d^4\, G}$$

$$\delta = \frac{16\ 8\ (10 + 4)(10^2 + 4^2)\ 617}{4.2^4 * 79300}$$

$$\delta = 5.3 \text{ mm}$$

FEA of Conical Spring

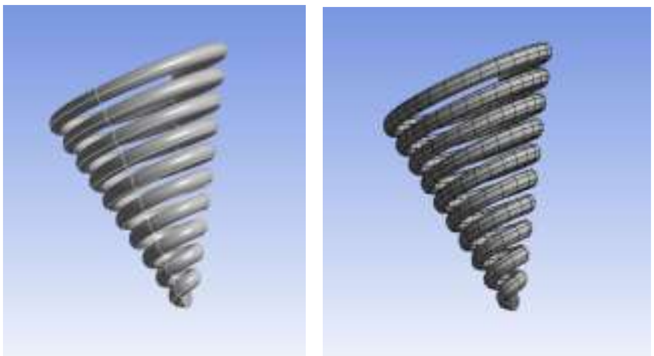


Fig -7: Geometry and Meshing of Conical Spring

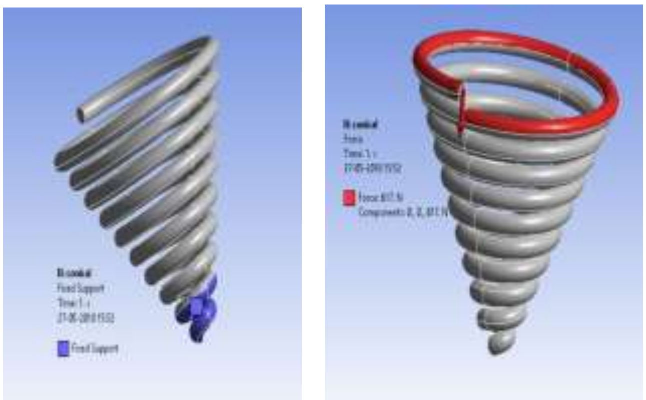


Fig - 8: Loading Condition

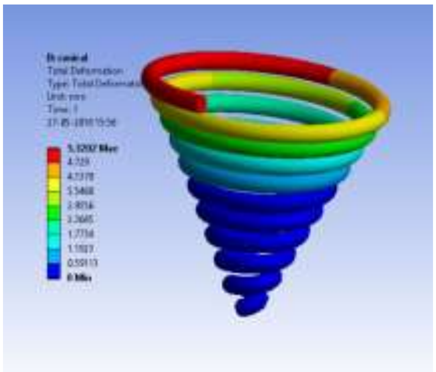


Fig -9: Deformation of Spring

3.2 Analytical Hierarchical Process (AHP)

AHP is one of the techniques which rely on the pair wise comparison of the different attributes of the system which is under study. It provides the percentage weight of the different attribute consider for the study.

TABLE I: Pair-wise Comparison Matrix

	Modulus of Elasticity	**Modulus of torsion**	**Rockwell Hardness**	**Cost**
Modulus of Elasticity	1	2	4	1 1/2
Modulus of torsion	0.5	1	0.5	4
Rockwell Hardness	0.25	2	1	1.5
Cost	0.6666	0.25	0.6666	1

(i) Calculating the geometric mean of i^{th} row and

(ii)Normalizing the geometric means of rows in the comparison matrix. This can be represented as:

$$GM_j = \left[\prod_{j=1}^{M} b_{ij}\right]^{1/M}$$

$$w_j = GM_j \Big/ \sum_{j=1}^{M} GM_j$$

TABLE II: Weight of Parameter

Sr. No.	**Criteria**	Weight
1	Modulus of Elasticity	42
2	Modulus of torsion	23
3	Rockwell Hardness	22
4	Cost	13

3.3 Simple Additive Method (SAM)

In this method a score is gained via the normalization process, each incommensurable attribute turns a pseudo-value function, that permits direct addition among attributes.

The following formulation gives the value of alternative Ai:

Step 1: Formulation of Measurement Matrix

Name of Material	E	Modulus of Torsion G	Rockwell hardness	Cost
IS 4454 Part I, Grade-2	207	79.3	52	1800
IS 4454 Part I Grade 3	207	79.3	60	1900
IS 4454 Part IV Grade 1 & 2 Stainless Steel	193	69	45	2250
AISI 316 Stainless steel	193	69	45	2100
Monel 400 AMS 7233	179	65.5	32	2000
Beryllium Copper	128	48.3	43	1950
A 286 alloy	200	71.7	42	1850

Step 2: After the formulation of measurement matrix it is normalized.

Sample Calculations for $X_{1,1}$:

$$X\ i,j = \frac{x_{i,j\,min}}{Xi,j}$$

Table III :- Calculation Matrix

Name of Material	E	Modulus of Torsion G	Rockwell hardness	Cost
IS 4454 Part I, Grade-2	1	1	0.6153	0.888
IS 4454 Part I Grade 3	1	1	0.5333	0.842
IS 4454 Part IV Grade 1 & 2 Stainless Steel	0.932	0.870	0.711	0.711
AISI 316 Stainless steel	0.932	0.870	0.711	0.761
Monel 400 AMS 7233	0.864	0.8259	1	0.8
Beryllium Copper	0.618	0.6090	0.7441	0.820
A 286 alloy	0.966	0.904	0.7619	0.864

Table IV :- Performance Index

Name of Material	PI
IS 4454 Part I, Grade-2	90.09402
IS 4454 Part I Grade 3	87.6807
IS 4454 Part IV Grade 1 & 2 Stainless Steel	84.06092
AISI 316 Stainless steel	84.72124
Monel 400 AMS 7233	87.71632
Beryllium Copper	67.0186
A 286 alloy	89.38057

3.4 Experimentation

Fig -10: Wire Coiling Machine

Fig -11: Testing of Spring

RESULTS AND DISCUSSION

Study provides important information regarding maximum deflection and stress introducing in the spring as well as spring index and spring rate of the existing spring which will be beneficial for the further study. While selecting the new material for spring it will be the important criteria to be considered.

Following results of ranking for the methods used are obtained by using AHP in which the material having highest modulus of elasticity is considered as best suitable material for the application. Hence IS 4454 Part I, Grade-2 material is best for compression spring.

Table 4:- Observation Table

Sr. No.	Load	Analysis Value	Experimentation Value
1	500	3.95	3.99
2	525	4.22	4.31
3	550	4.45	4.86
4	575	4.66	5.52
5	600	4.91	5.13
6	617	5.32	5.61

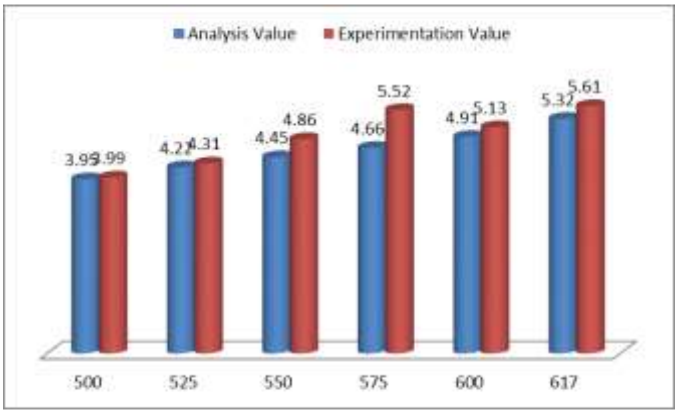
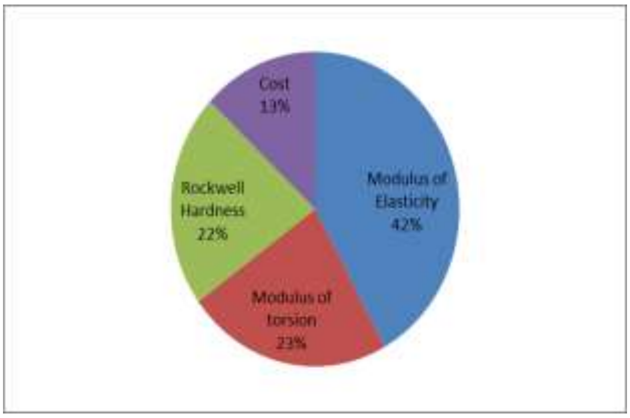


Fig -12: Graph of Analysis value Vs Experimentation Value



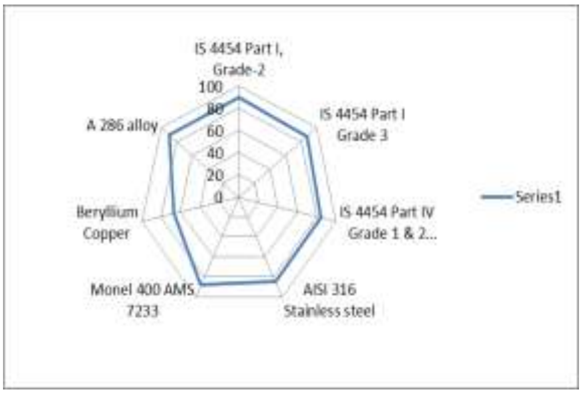


Fig -14: Best Alternative Material by SWM

Concluding Remarks

These calculations provide important information regarding maximum deflection and stress introducing in the spring as well as spring index and spring rate of the existing spring which will be beneficial for the further study. While selecting the new material for spring it will be the important criteria to be considered.

Selecting the material is the crucial parameter which needs to be focused during compression spring application.

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