Decision Support System for Material Selection Using Vikor Method

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ABSTRACT

Selection of correct and optimize way of the material is one of the immense important requirement for manufacturers. Increasing demand of manufacturing products and their variants makes this selection procedure more complicated and requires greater expertise involvement and hence takes more time. Eventually the selection is based on the previous records and performance of the available material with some suggestions from the expertise. This study tries to propose the way of selection of material for helical compression spring with reference to part requirement such as modulus of elasticity, tensile strength, modulus of torsion, Rockwell hardness and cost. The study reveals the part and process requirement for efficient and economical output through material selection. Such material selection decision support system enables conflict free decision making which routes to the minimization of rejection and rework time. It utilizes the VIKOR method of multi criteria decision making to rank the various alternatives along with Analytical Hierarchical Process (AHP) which is theory of measurement through pair wise evaluation and priority scale given by expertise to establish an accurate and correct hypocritical model which decides priority of the materials which can be implemented. Material selection will help in systematic and analytical manner to address every element of selection - complexity due to interrelation of attributes, wide range of materials alternatives available, variety of application areas, and expertise requirement.

Keywords*: Material Selection, Analytical Hierarchical Process (AHP),VIKOR.*

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1. INTRODUCTION

While selecting the most suitable material from an ever increasing array of feasible alternatives, with each having its own characteristics, applications, advantages and limitations. The designers should have a clear understanding of the functional 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 efficient 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. 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[12].

1.1 Requirements of Spring Materials [1]

In the spring material selection and the working process designing, the following points shall be taken into consideration. [1] Selected materials are such that the quality of finished springs satisfies customer's quality requirements. [2] Availability of selected material.

[3] Economical feasibility of material and spring working processes.

[4] The manufacturing processes, where the material quality should not be deteriorated.

[5] No pollution, safety, and regulations observance through spring manufacturing to disposal or recycling.

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 modelling 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. E. Bal Besikciet 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 micrometre. Deflection data on each spring were collected, plotted and successfully modelled 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. 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. 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. 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. 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 tensional stresses. Ronald E. Giachetti [10] stated that the material and manufacturing process selection problem is a multi-attribute decision making problem.

3. METHODOLOGY

The foundation for compromise solution was established by Yu and Zeleny and later advocated by Opricovic and Tzeng. It focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. The compromise solution is a feasible solution that is the closest to the ideal solution, and a compromise means an agreement established by mutual concession. The compromise solution method which is also known as the VIKOR method can be the base for negotiations, involving the decision maker's preference on criteria weights. The multiple attribute merit for compromise ranking was developed from the -metric used in the compromise programming method. The main procedure of the VIKOR method is described below,

Step 1: The first step is to determine the objective, and to identify the pertinent evaluation attributes. Also determine the best $(m_{ij})_{max}$ and the worst $(m_{ij})_{min}$ values of all attributes.

$$Ei = \sum_{j=1}^{M} (mj[ij(m)\underline{maxij)max - (m - ij(m)min}ij)] \quad \ldots\ldots\ldots\ldots\ldots\ldots 1 \; W$$

Sr. No.	Name of Material	E [MPax103]	Modulus of Torsion G [MPax103]	Rockwell hardness	Tensile Strength	Cost
1	IS 4454 P I G2	207	79.3	52	147	8500
2	IS 4454 P I G3	207	79.3	60	230	13600
3	IS 4454 Part IV	193	69	45	245	11000
4	AISI 316	193	69	45	245	10000
5	Monel 400	179	65.5	32	180	11000
6	Beryllium Co	128	48.3	43	230	12000

Table: - Decision Matrix

Step 2:- Normalization of the Matrix

Sr. No.	Name of Material	E [MPax103]	Modulus of Torsion G [MPax103]	Rockwell hardness	Tensile Strength	Cost
1	IS 4454 P I G2	1	1	0.8666	0.6	1
2	IS 4454 P I G3	1	1	1	0.9387	0.625
3	IS 4454 Part IV	0.9323	0.8701	0.75	1	0.7727
4	AISI 316	0.9323	0.8701	0.75	1	0.85
5	Monel 400	0.8647	0.8259	0.5333	0.7346	0.7727
6	Beryllium Co	0.6183	0.6090	0.7166	0.9387	0.7083

Table: - Normalization

Step 3:- Rationalization of the Matrix

Sr. No.	Name of Material	E [MPax103]	Modulus of Torsion G [MPax103]	Rockwell hardness	Tensile Strength	Cost
1	IS 4454 P I G2	0	0	0.2856	1	0
2	IS 4454 P I G3	0	0	0	0.1530	1
3	IS 4454 Part IV	0.1771	0.3321	0.5356	0	0.6060
4	AISI 316	0.1771	0.3321	0.5356	0	0.4
5	Monel 400	0.3543	0.4450	1	0.6632	0.6060
6	Beryllium Co	1	1	0.6070	0.1530	0.777

Table: - Rationalization

Step 4: Calculate the values of E_i and F_i

Sr. No.	Name of Material	E_i
1	IS 4454 P I G2	0.287140204
2	IS 4454 P I G3	0.128265306
3	IS 4454 Part IV	0.241343551
4	AISI 316	0.222798096
5	Monel 400	0.551785667
6	Beryllium Copper	0.71718824

Table: - Values of Ei

Sr. No.	Name of Material	F_i
1	IS 4454 P I G2	0.25
2	IS 4454 P I G3	0.09
3	IS 4454 Part IV	0.06963
4	AISI 316	0.06963
5	Monel 400	0.1658
6	Beryllium Copper	0.38

Table: - Values of Fi

Step 5: Calculate the value of P_i

Fi	Fi - Fi min	Fi max - Fi min	(Fi - Fi min) / (Fi max - Fi min)	(1-V)
0.25	0.180	0.3103	0.581	0.290
0.09	0.020	0.3103	0.065	0.032
0.06	0	0.3103	0	0
0.06	0	0.3103	0	0
0.16	0.096	0.310	0.309	0.154
0.38	0.310	0.3103	1	0.5

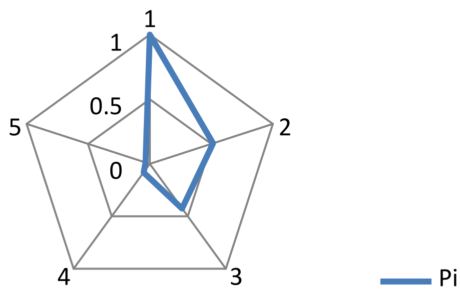
Table: - Performance Index Calculations

Step 6: Arrange the alternatives ascending order, according to the values of Pi. Similarly, arrange the alternatives according to the values of Ei and Fi separately. Thus, three ranking lists can be obtained.

Sr. No.	Pi	Ei	Fi	Order
1	1.0000	0.5939	0.2397	6
2	0.5145	0.4451	0.2382	5
3	0.4255	0.7327	0.28	1
4	0.0803	0.6303	0.235	4
5	0.0328	0.7516	0.27	2
6	0	0.4210	0.2312	3

4. RESULT AND DISCUSSION

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



5. CONCLUDING REMARKS

Material selection is the vital parameter which needs to be focused during helical compression spring application. As the design is verified and approved by the end customer the only way to the achieved the desired results is through the material selection. Though it is a single term it has many complications for selections, hence a proper decision support system using multi criteria decision system (MCDM) is need to be developed. This decision support system must be full proof to avoid failure hence an ANSYS can be used for robustness of the support system.

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