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Application of Full Factorial Approach for Determining Impact of Parameters on Helical Compression Spring

Narendra Kumar, Love Kishore Sharma, Bhupendra Verma, Anil Kumar Sharma

***Abstract*- Helical Compression Springs finds wide application in automobiles as shock absorbers. Springs stores the energy of deformation due to applied load and retain its original position, shape or size after the load is removed. Springs can be further classified as leaf springs, torsion springs. The basic design parameters for spring manufacturing consists of spring index, pitch, free length, wire diameter, flat ends, circular ends, number of turns etc. Various research scholars have performed successful investigation on springs with different software packages.**

Our end goal in present work is to determine relationship between wire diameter and number of turns on load bearing capacity. The concept of Full Factorial Design is studied for obtaining the desired result. Pareto Chart along with OVAT analysis shows impact of factors on response. Further ANOVA analysis is carried out for determining the validity of the proposed model.

***Index Terms*—Full Factorial, ANOVA, Pareto.**

I. Introduction

Springs are basically designed to safeguard and absorb energy and mechanical work. Springs are also used for other functions such as flexibility, energy absorption, vibration absorption and mitigating shock. Springs can be classified as wire springs, flat springs or special shaped springs. Compression springs or coil springs fall under the category of wire springs and are widely utilized for opposing the axial compressive force. The classification of springs is done on the basis of their dimensional specifications or according to their shape. It can be a coil of wire helical in nature, a stamping piece or a flat wound up strip. The helical spring is manufactured using a wire or circular cross section that is bent in the form of helix. It can be further classified as on two type spherical extension springs and helical compression spring. In former the force tends to increase the length of spring or is elongated while in later the force tends to shorten the length or is compressed. In both the above mentioned types of spring the external force acts along the axis of spring and induces torsional shear stress in spring wire.

II. LITERATURE REVIEW

Navvjyoti Panda & R. S. Panwar[1] considered and examined process factors like punch angel, die opening, grain direction and pre bend condition of the strip for deep drawing of HSLA 420 & ST12 grading element. The results validate that the effect of punch angel is utmost effect on spring back, while grain direction had minimal effect. The “smaller the better” S/N ratio is taken for output spring back. The percentage contributions of all the factors are 47.45%, 38.52%, 3.57% and 1.37%. Yogendra Kumar & Hari Singh[2] investigated the effect of four turning process factors namely nose radius, cutting speed, feed rate & depth of cut on material removal rate for EN 47 spring steel. The concept of “larger the better” is applied for optimization. ANOVA results shows that the sequence of contribution of parameters is feed rate, depth of cut, cutting speed and nose radius at 95 % confidence level. Also R^2 value is found to be 96.63% which confirms the proposed model. Ronak B Choudhary & Dr. L.G. Navale [3] examined the design parameters of Helical Compression springs like spring material, pitch variable and wire diameter for concluding the best design parameter. L9 orthogonal array is applied to predict the results and optimize the output i.e. stress and fatigue life of spring. The results indicated that chrome vanadium material, 4mm wire diameter and 6mm pitch are optimum results. Arvind Gothwal [4] optimizes the spring weight using GA approach. It was observed that there is a significant decrease in weight of spring material nearly upto 49.77%. The weight of spring before GA application is 0.926 kg, while after GA implementation it gets reduced to 0.4651. Avakash P Patel &V.A.Patel [5] applied Harmony search Algorithm for optimizing the weight of helical compression spring. The material used is oil tempered carbon steel wire with 0.6% to 0.7 % carbon and 0.6 to 1% Manganese with density 7.84 10^{-6} kg/ m^3. The optimum results found were better as compared to GA approach. Sagar N. Khurd et al [6] performed FEA and RSM analysis to design helical coil spring, using combination of steel and composite material. The advantages of composite material are light weight and high temperature and corrosion resistance. The static analysis is done by finite element Method. In below fig the blue colour shows the minimum stresses i.e., 4.83433E6 acting on turns and red colour shows maximum stress of 4.7378E9. It was

Narendra Kumar, M.Tech Scholar, Department of Mechanical Engineering, Jaipur Institute Of Technology, Jaipur, India
Love Kishore Sharma, Assistant Professor, Department of Mechanical Engineering, Arya College of Engineering & Information Technology, Kukas, Jaipur, India
Bhupendra Verma, B.Voc , Automated Drivers Training Testing & Skill Institute , Ajmer , India
Anil Kumar Sharma, Assistant Professor, Department of Mechanical Engineering, Jaipur Institute Of Technology, Jaipur, India

concluded that force and material property are significant parameters that effect compressive stress. M. Naga Phani Sastry et al. [7] implemented probabilistic RSM for optimizing design of helical compression spring. The design parameters considered for the work are Reliability (R), Coefficient of variation of shear strength (C_s), Coefficient of variation of compressive load (C_f) and coefficient of variation of wire diameter (C_d) while spring wire diameter (d) is the response taken. The design matrix is generated using CCD. The optimum design values are shown in below table. Chaitali Chaudhari et al [8] studied the Taguchi technique for maximizing the stiffness in the leaf spring. L8 OA was considered for designing sets of experiment. Four design parameters were investigated viz, material, width, thickness and number of leaves. The principal of larger the better for S/N ratio is considered. ANOVA reveals that all four parameters have significant effect on stiffness of leaf spring. The optimum parameters are found to be material of Kevlar, width of 70mm, thickness of 8mm and number of leaves 5. Using these optimum parameters the response obtained were 1.6619e3 MPa to 8.44922e2 MPa and stiffness is increased from 48.488 N/mm^2 to 53.09 N/mm^2. Mahendra Sharma et al [9] investigated the characteristics of composite leaf spring made from fiber glass reinforced particles. ANSYS tool was utilized for proper examination of interleaf contact, stress distribution and deformation. An assessment between GFRP and steel spring is done and results revealed that composite spring has lower stresses and much lower weight.

III. Experimental Setup

The material of the spring used in current research work is 50 CrV4 i.e. Chrome vanadium are used in tractors as hydraulic plunger compression springs and Grade 2D wire used in two wheelers. The levels of the various factors are defined in below table.

Table 1 Levels of Various Factors

Factors/Levels	Low (-1)	High (+1)
Wire Diameter (mm)	16	16.5
No. of Turns	6	6.75

The above parameter settings are used for designing and manufacturing springs and the response are calculated accordingly.

IV. Research Methodology

This method of robust design enables the experimenter to investigate the effect of two or more factors on response of a predefined process. All probable combinations of the levels for every factor defined by end user are investigated, to obtain the meet the end target. This methodology predominates when interactions are present to omit the mistake, according to which the noise variables are thoroughly examined for better functioning of the system. He proposed developing design in the existence of noise variables rather than their elimination.

A full factorial design contains all possible combinations of a set of factors. This is the most fool proof design approach, but it is also the most costly in experimental resources. The full factorial designer supports both continuous factors and categorical factors with up to nine levels. In full factorial designs, you perform an experimental run at every combination of the factor levels. The sample size is the product of the numbers of levels of the factors. For example, a factorial experiment with a two-level factor, a three-level factor, and a four-level factor has 2 x 3 x 4 = 24 runs. Factorial designs with only two-level factors have a sample size that is a power of two (specifically 2f where *f* is the number of factors). When there are three factors, the factorial design points are at the vertices of a cube as shown in the diagram below. For more factors, the design points are the vertices of a hypercube. Full factorial designs are the most conservative of all design types. There is little scope for ambiguity, when we are willing to try all combinations of the factor settings.

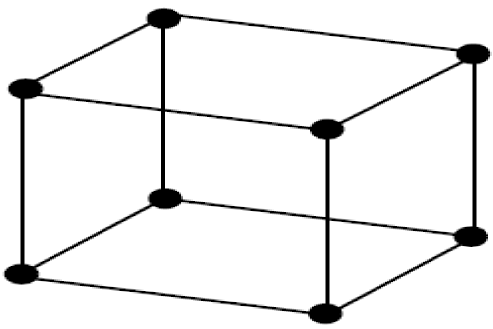

Fig 1 Full Factorial Design

V. Results & Discussion

Three variables namely, Number of turns and Wire Diameter are analyzed for optimizing the output response i.e. Load bearing capacity at 5mm compression. The graphs are generated using "Microsoft Excel 2016" package.

OVAT Analysis of Load

One variable at time method is opted for producing various graphs. In this method one input factor is varied, while the other input factors are made constant.

Effect of No. Of Turns on Load

Plot between No. of Turns and load is shown in below figure.On increasing the No. Of Turns the load bearing capacity of spring increases in a linear manner.

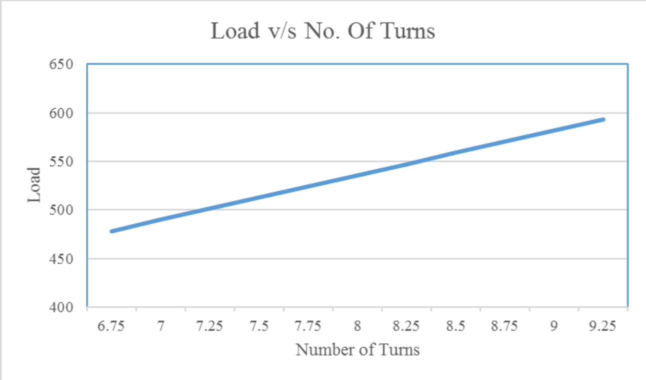

Figure 2 Load v/s No. of Turns

Effect of Wire Diameter on Load

Plot between Wire Diameter and Load is shown in below figure, on increasing the Wire Diameter theload bearing capacity increases in a linear manner.

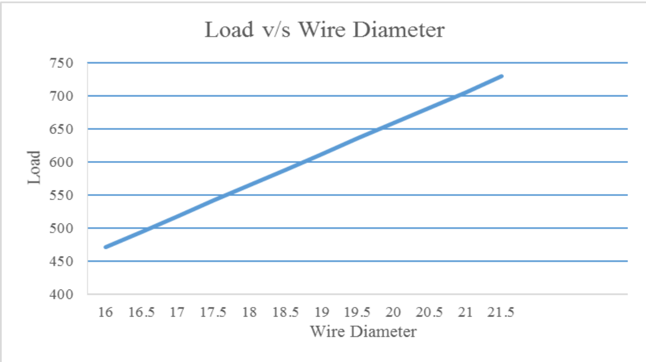

Figure 3 Load V/s Wire Diameter

Percentage Contribution of Input Parameters on Spring Weight

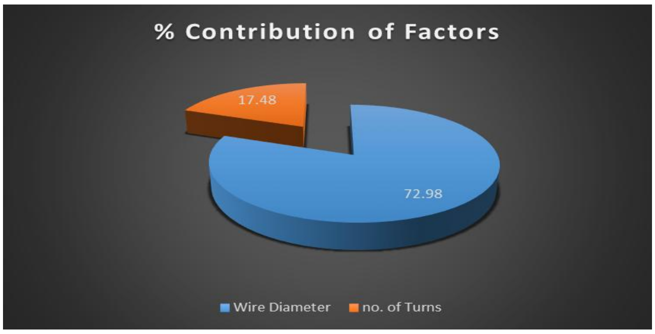

Figure 4 Percentage Contribution of Factors

The contribution of various input factors on Load bearing capacity at 5mm compression is shown in above Fig. According to this fig, we can say that contribution of No. of turns (17.48%) and Wire Diameter (72.98%).

The effect of all the individual factors is evaluated using Pareto Chart as mentioned in below figure. It is clearly seen that the Wire Diameter is the most dominating factor followed by Number of Turns.

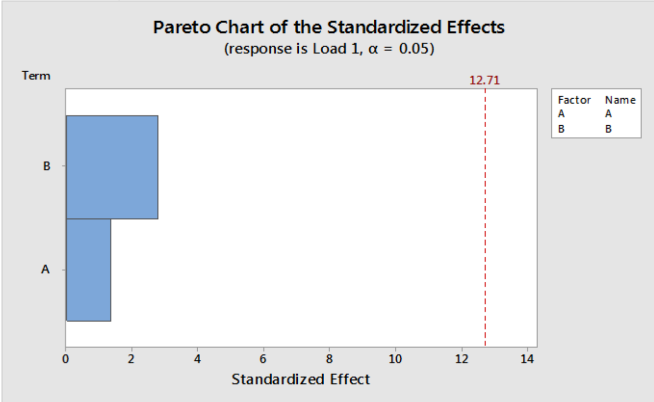

Figure 5 Pareto Chart

ANOVA

Analysis of variance is a statistical and mathematical tool which helps in explaining the significance of generated mode[10]. The contribution of each factor is also explained separately. In present study, the most significant term is wire diameter having F value=7.64, also the contribution of the same is 72.98%. The remaining terms No. of turns are having F value much lower, also these terms are contributing very less in the existing model. Therefore, we can neglect these terms easily.

Table 2 Analysis Of Variance

Source	**DF**	**Seq SS**	**Contribution**	**Adj SS**	**Adj MS**	**F-Value**
Model	2	684.5	90.45%	684.5	342.25	4.74
Linear	2	684.5	90.45%	684.5	342.25	4.74
A	1	132.25	17.48%	132.25	132.25	1.83
B	1	552.25	72.98%	552.25	552.25	7.64
Error	1	72.25	9.55%	72.25	72.25	
Total	3	756.75	100.00%			

The value of R^2 obtained is 90.45 % and R^2 (adj) 71.36% This shows that the model is statistically significant.[11]

Regression Analysis

The below equation describes the effect of individual factors namely number of turns and wire diameter on the output response i.e. load bearing capacity.

Y= - 596 + 46.0*A + 47.0*B

Y= Load at 5mm compression
A= No. of Turns
B=Wire Diameter

VI. CONCLUSION

Two Parameters Wire Diameter and Number of Turns are considered for manufacturing helical compression spring. The value of $R^2$is 90.45 % and adj $R^2$71.36, this confirms that the proposed model is statistically significant. Pareto Chart is obtained which graphically represents the most dominant factor i.e. wire diameter followed by number of turns. Percentage Contribution of wire diameter in the proposed model is 72.98 % and that of number of turns is 17.48%.

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