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Maximizing Efficiency of Double Threaded Square Screw using Full Factorial Experimental Design

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Abstract- The objective of present work is to maximize the efficiency of double threaded square screw using full factorial experimental design. Minitab 17[a] statistical package is used for finding the optimum level of three factors namely coefficient of friction, mean diameter of the screw and lead of screw that affect the value of response variable i.e. efficiency of square threaded screw. Main effect plot, surface plots as well as contour plots have been drawn in this paper showing the effect of different levels of factors on the response variable.

Index Terms- Double threaded square screw; Full Factorial design; ANOVA; Efficiency.

1. INTRODUCTION

A screw thread is normally used for conversion of rotational motion into linear motion. It is a ridge wrapped around a cylinder or cone in the form of a helix, with the former being called a straight thread and the latter called a tapered thread. A screw thread is the essential feature of the screw as a simple machine and also as a fastener [1].

The mechanical advantage of a screw thread depends on its lead, which is the linear distance the screw travels in one revolution. In most applications, the lead of a screw thread is chosen so that friction is sufficient to prevent linear motion being converted to rotary that is so the screw does not slip even when linear force is applied so long as no external rotational force is present[1].

Optimization of efficiency of square threaded mechanical screw jack with respect to different helix angle was done [2]. Mathematical model were made to quantify the effect of varying helix angles and it was concluded that with increase in the helix angle, the efficiency increases up to certain limit and beyond that decrease in the value was observed. The optimum value of efficiency was found at the following values of different parameters, helix angle 3.6952936°, coefficient of friction 0.20 and bearing pressure between nut & screw 150 kg/cm^2.

In this paper, the factors influencing the efficiency of double square threaded screw include coefficient of friction, mean diameter of the screw and lead of screw. A series of experiments are performed on these parameters to investigate their effect on efficiency of double threaded square screw. To study the effect of these three factors on the response variables well as to evaluate the effect of interaction among these factors on efficiency of square threaded screw, a full factorial experimental approach has been applied in this paper.

Factorial design technique offer distinct benefit over OFAT approach that every possible combination of factors is considered with minimum amount of experimentation. Since all probable combination of factors is considered while maintaining randomization, outcome is comparatively much better, more reliable and free from any experimental biasness.
Minitab statistical package is used for the optimization purpose and the results are presented graphically and statistical model has also been established to predict the effect of different parameters on the objective function.

[a]*Information on Minitab 17 can be obtained from Minitab.com. A 30 day trial version of the software is available as a free download.*

2. DEFINING FACTORIAL DESIGN

Factorial design is an important technique to find out the effects of multiple variables on a response. In this study, three factors namely

(a) Coefficient of friction (A)
(b) Mean diameter of the screw (B) and
(c) Lead of screw (C)

have been considered as design parameters and efficiency of square threaded screw is taken as response variable. The design of experiments is carried out by 2^3 full factorial design using Minitab 17 software.

The low and high levels of factors used, coded as +1 and -1 respectively are shown in Table 1.

Table 1: Factors/Parameters and level of factors

Factors	Level 1	Coding for Level 1	Level 2	Coding for Level 2
Coefficient of friction (A)	0.05	-1	0.15	+1
Mean diameter of the screw (B), mm	21.5	-1	36.5	+1
Lead of screw (C), mm	10	-1	14	+1

Since there are 2 levels for each factor, the design requires eight (2^3) test runs. These tests are then performed in a random order and the value of the response variable i.e. efficiency of square double threaded screw is listed in the right side column of Table 2.

Table 2: Design Matrix and Value of Response Variable

Standard Order	Run Order	A	B	C	Response (Efficiency Screw in %)
8	1	1	1	1	43.9
4	2	1	1	-1	36.3
3	3	-1	1	-1	63.3
1	4	-1	-1	-1	74.2
2	5	1	-1	-1	48.5
6	6	1	-1	1	56.2
5	7	-1	-1	1	79.7
7	8	-1	1	1	70.4

3. ANALYZING FACTORIAL DESIGN

Various plots like Main Effects plot and Interaction plot are obtained to examine effects of parameters on response variable using Minitab.

Pareto plot is also obtained to check the significance of each factor.

The analysis is made at 95% level of confidence (or 5% level of significance).

The Pareto charts in Fig. 1 shows that A is the most significant factor followed by Factor B and Factor C. Two- way and Three-way interactions in this study have not shown any significant effect on the response.

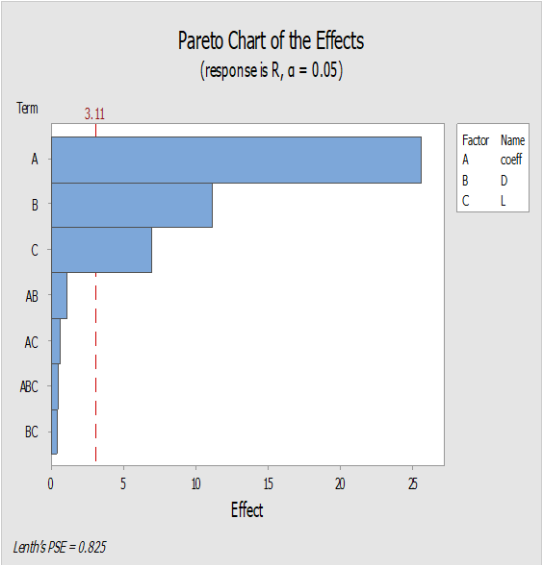

Fig. 1 Pareto Chart

Since the interactions AB, AC, BC and ABC have negligible significant effect, so the analysis is done again after omitting the above mentioned interactions.

The Pareto Chart obtained after omitting Two- way and Three-way interactions has been shown in Fig. 2.

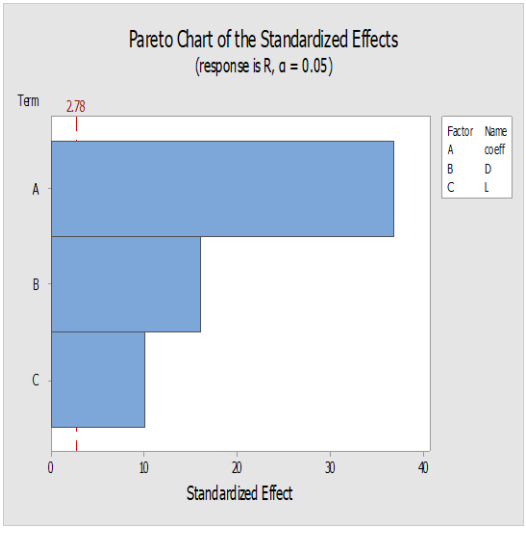

Fig. 2. Modified Pareto Chart

The main effects plots of three variables have also been shown in Fig. 3.

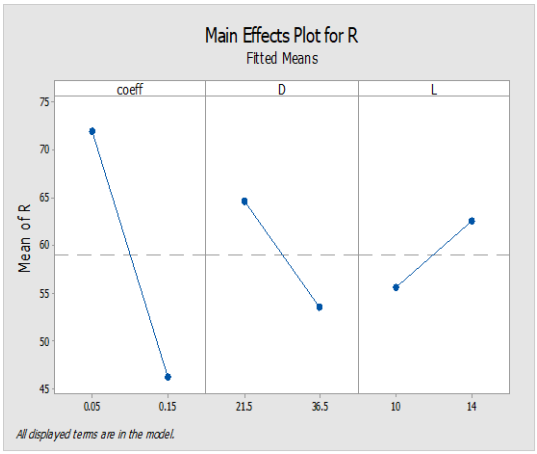

Fig. 3. Main effects plot for response

From the main effect graphs depicted in Fig. 3, conclusion can be made that all the three parameters namely coefficient of friction(A), mean diameter of screw(B) have negative correlation with the response variable while lead of screw(C) have positive effects on the response variable, efficiency of the screw. It can also be asserted from the graph that coefficient of friction has profound effect on the outcome followed by mean diameter of screw and lead of screw.

ANOVA results for the problem under consideration are presented in Table 3. The analysis is done for the level of confidence 95%.

Table 3: ANOVA results

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	1665.47	555.16	574.55	0.001
Linear	3	1665.47	555.16	574.55	0.001
A	1	1318.41	1318.41	1364.46	0.001
B	1	249.76	249.76	258.49	0.001
C	1	97.30	97.30	100.70	0.001

After the above analysis, following regression equation was developed between the response variable and the working parameters using Minitab 17 software and is given below:

Regression Equation in Uncoded Units

Response = 85.42 - 256.75 coeff - 0.7450 D + 1.744 L

The effect of different factors on the response variable is also depicted in the form of surface plots and contour plot in Fig. 4 and Fig. 5. It can be concluded from these plots that value of response variable increases as coefficient of friction and mean diameter is decreased and lead of the thread is increased.

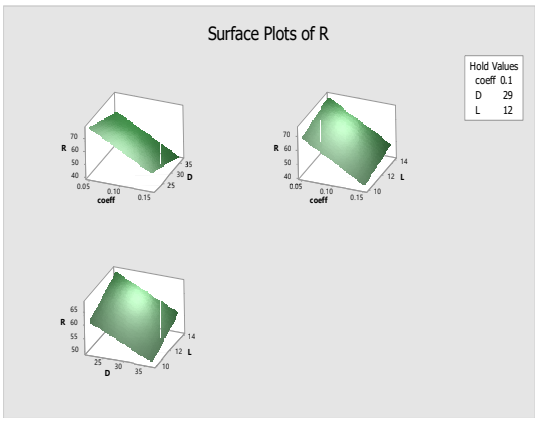

Fig. 4. Surface plots of Response

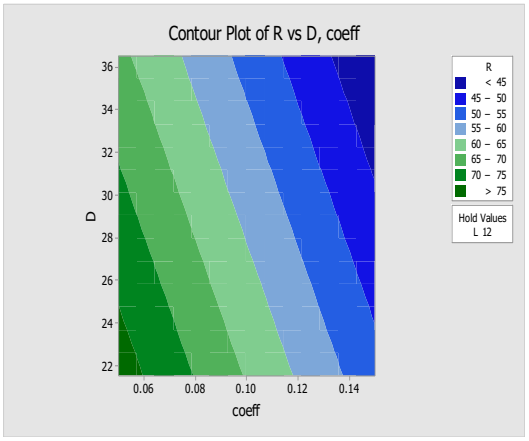

Fig. 5. Contour plot of Response

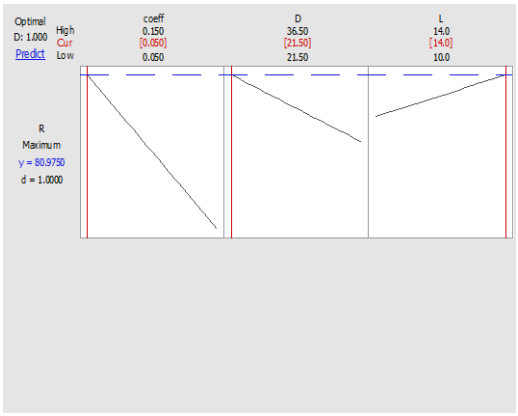

Fig. 6. Optimization plot

The optimum values for operating parameters are also found and presented in Table 4.

Table 4: Optimization table

Parameters	Optimum Values
Coefficient of friction (A)	0.05
Mean diameter of the screw (B)	21.5
Lead of screw (C)	14

With these values, the maximum value of the objection function (efficiency of square double threaded screw) was found as 79.7%.

4. CONCLUSION

In this study, the effect of factors such as coefficient of friction, mean diameter of the screw and lead of screw on efficiency of square double threaded screw have been evaluated by applying full factorial experimental approach using Minitab software.
From the analysis, it is found that value of efficiency of square double threaded screw increases as coefficient of friction and mean diameter values are lowered and lead of the thread is enlarged. Coefficient of friction is the major factor affecting the efficiency of square double threaded screw followed by mean diameter of the screw and lead of screw. A statistical model has also been developed to predict the value of efficiency of square double threaded screw.

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