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Productivity Improvement For Peddle Driven Sewing Machine with RSM Technique

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Abstract:
The ergonomic evaluation of sewing machine operation practices are traditionally studied by several investigators in the past. The study highlights various occupational health hazards of this operation. This study published through literature describes occupational health hazard in terms of various causes of this activity .Stand alone pedal driven sewing operation, consists of a operator, stand alone pedal driven sewing machine, workstation, environmental conditions which is called as a man machine system. Data of 30 Indian workstations is collected. 40 causes / input / independent variables and effects/ output /dependant variables are used for study and are converted into five independent dimensionless terms known as pi terms as pi1,pi2, pi3, pi4,pi5. And the effects or dependant term is stated as Z3 for productivity. The mathematical co-relationships are established on the independent and dependant parameters. Response surface model concept is used for the study to a show perfect connection and nearness with the outcomes from RSM technique which can be used for future design of workstation for sewing machine.
***Keywords**: Causes, Effects, Mathematical model, Sewing machine, RSM concept.*

1.0 Introduction

The approach for study is the actual working observation of a particular type of man – machine system [13] taking place in the society at various locations in Nagpur city in India. The data is collected from thirty man machine working system. The independent variables called as causes of activity, the dependent variables as effects of activity and the extraneous variables of the activity are used for the formation of analytical relationship. The workstations of standalone pedal driven sewing machine operation are identified , observed and responses are noted by using survey based questionnaire in Indian context [5],[6]. Total 40 Independent variables and 1 dependant variable were identified and noted [7][8]. These independent variables are grouped in similar qualities using the principal of Buckingham Pi theorem [4,10]such as anthropometric data of operator, workstation data of sewing machine, environmental data of workstation and specification data of sewing machine. The mass, length and time dimensions are noted for each variable. These variables are grouped into dimensionally homogeneous groups and figured out into dimensionless quantities which are defined as Pi terms. These Pi terms are notified as Π_1, Π_2, Π_3, Π_4, Π_5. Also the dependant variable identified for study purpose is productivity and termed as Z3. The optimization of these models is logically expected to indicate magnitudes of causes / independent variables/ inputs to be set during operation of pedal driven sewing machine so as to realize the targeted performance of operation as shown in Table 1.

Table 1: Independent and dependant variables

Sr.No.	Pi terms	Details of pi terms
1	Π_1	Data of operator's anthropometry
2	Π_2	Personal data of operator
3	Π_3	Data of workplace's environmental conditions
4	Π_4	WorkStation specification data
5	Π_5	Specifications of parts of pedal driven sewing machine
6	**Z3**	**Productivity**

2.0 Method for MATHEMATICAL MODELLING

The methodology for model formulation known as Response Surface Methodology (RSM) [3, 11,16] is used, which relates the rapport amongst the output parameters and the input parameters in a second-order equation. The regression investigation was executed to evaluate the response function of a second order polynomial.

$Yk = Ao + Ai\pi ini=1 + Aii\pi ini=12 + Aij\pi inj=i+1\pi jn=1i=1+e$ (1) [15]

Where Yk = Z3 is the forecasted response, k= Productivity, A0, Ai, Aii, Aij are consistent coefficients estimated for regression and e is random error. They represent the linear, quadratic and interactive effects of πi, πi2, πi πj on output variable Z3[22]. For improving the output parameters *Yk*, it is assumed that ,the input parameters are continuous and controllable by the study with minor error. The quality of fit of the higher order equation was expressed by the coefficient of determination R^2. Usually a best fit polynomial is fitted. The parameters of the polynomials are estimated by the method of least squares. A statistical software Matlab R2018a is used for regression investigation of the data obtained and to estimate the coefficient of the regression equation.

The investigation aims at deciding the most optimum conditions at which the response parameters will have desired values for maximization of work with improvement in Productivity. In sewing machine process, the input Pi terms Π_1, Π_2, Π_3, Π_4 , Π_5 have been grouped in two groups. It is necessary to find a suitable combination of Pi terms X (Product of Π_1, Π_2, Π_3 term) and Y (Product of Π_4 , Π_5). The observed output Z3 as a function of the X and Y .

For Z3 = f (Π_1, Π_2, Π_3 , Π_4, Π_5) various combinations of input / independent Pi terms are considered by multiplication and / or division of input Pi terms can be expressed as

Yk = f (X; Y) +e

The Z3 is the nomenclature for Productivity which can be explained as in Equation 1:

Z3 = Stl / SSTDl where ⟶ Equation 1

Stl = Stitching length per day or (workdone/day)

SSTDl = standard Stitching length / day

Accordingly, the independent Pi terms Π_1, Π_2, Π_3, Π_4 , Π_5 have been grouped in two groups, i.e. for example : on OX axis log of combination of $((\Pi_1*\Pi_2) / \Pi_3)$ is plotted and on OY axis log of combination of (Π_4 / Π_5) , is plotted and the log of Z3 is plotted on OZ axis . This results into 3 dimensional mapping of activity under study. For this, the approach would be to consider various combinations of independent quantities in log form on OX and OY axis. The log of dependant quantity is plotted on OZ axis. This will yield 30 three dimensional maps of the activity under study. The simplest shape whose R^2 value is nearest to 1 is finally chosen and the corresponding algebraic representation of correlation of dependant quantity as a function of independent quantities is considered for 3 dimensional form of model. From amongst these algebraic representations the one which has nearest value of R^2 to 1 is chosen as model.

3.0. Procedure for Model Formation:

As explained in methodology of Model Formation the combination of all Pi terms in OX , OY are formed out. Total 30 combinations were formed [3,16]. Data was inputted in all 30 combinations and **3** dimensional and 2dimensional graphs are plotted for Log Z3 vs 30 combinations of Π_1, Π_2 ,Π_3 ,Π_4, Π_5. The combinations of independent pi terms is plotted on abscissa and corresponding variation of Z3 on ordinate . As per the theoretical logic of Response surface modeling by various studies R^2 value nearing to 1can be suggested as very perfect fit data[16],[11] . R^2 will give information about the goodness of fit of a model. The coefficient of determination R^2 is a statistical measure showing the correctness of regression line. If R^2 is nearing 1then it indicates that, the regression line perfectly fits the data. In general, we can model the expected value of *y* as an *n*th degree polynomial, yielding the general polynomial regression model [11,16]

$y = A0 + A1 x + A 2 x 2 + A 3 x 3 + \cdots + A n x n + \varepsilon$.

3.1 Actual work

After inputting the values in combinations of independent and dependant Pi terms all the graphs are drawn and the graphical analysis is done[12,19]. This approach of graphical analysis leads towards the RSM model and goodness of fit. It is graphical representation of graph number 12 out of all 30 combinations which shows R^2 value nearing to

1.Table 2 depicts the combination of values which is selected for RSM model amongst of all 30 combinations formed. The appropriate Regression model is one, with higher the values of R^2 and the smaller the value of RMSE.

(Π4*Π5) /Π3	Z3	Π1/ Π2
X	Z3	Y
0.203974	1.69897	-0.13686
0.20544	1.69897	-0.13283
0.220386	1.69897	-0.09422
0.22596	1.69897	-0.07281
0.238443	1.69897	-0.036
0.242025	1.69897	-0.02093
0.245067	1.69897	-0.01251
0.253647	1.69897	0.01267
0.256124	1.69897	0.029844
0.259529	1.69897	0.044761
0.264749	1.69897	0.050141
0.317651	1.69897	0.153888
0.352759	1.69897	0.270114
0.362611	1.69897	0.332821
0.376822	1.69897	0.404662
0.41656	1.69897	1.124406
0.133169	1.875061	-0.58965
0.164372	1.875061	-0.23705
0.184116	1.875061	-0.20419
0.200928	1.875061	-0.15528
0.208696	1.875061	-0.10144
0.227192	1.875061	-0.06251
0.273791	1.875061	0.055046
0.288839	1.875061	0.088986
0.295172	1.875061	0.0998
0.309313	1.875061	0.110403
0.358479	1.875061	0.329484
0.365405	1.875061	0.388778
0.379775	1.875061	0.701492
0.388194	1.875061	0.902531
0.203974	1.69897	-0.13686

Table 2: Values of combination of Pi terms:

This combination of 2D and 3D graphical analysis nearing the R^2 value nearest to 1 is shown in figure 1, figure 2 and figure 3 respectively.

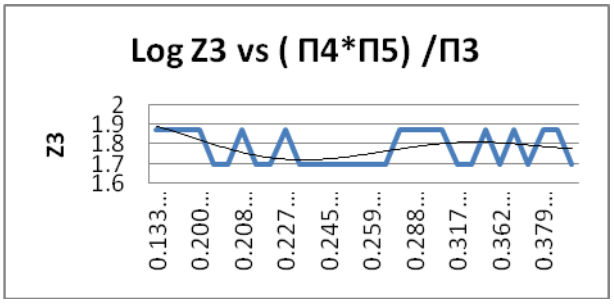

Figure 1: Log Z3 Vs (Π_4*Π_5) /Π_3

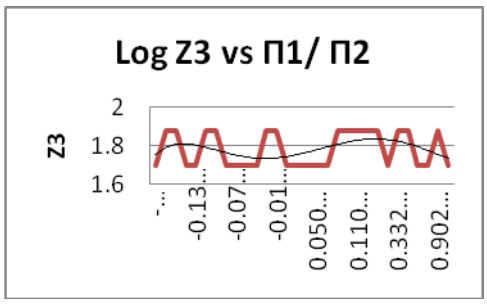

Figure 2: Log Z3 Vs Π_1/ Π_2

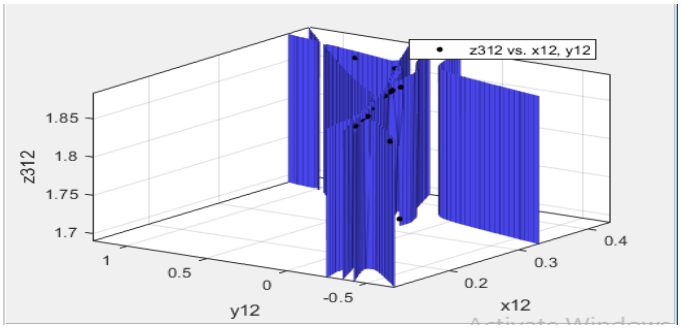

Figure 3 : 3D graph for combination as X12, Y12 and Z12

3.2 Discussion on Analysis of RSM Model and Goodness of fit

From all the values of 30 combinations of graphs drawn , and the statistics ,which is conformable with the prototypical value is the graph whose R^2 value is nearest to 1 is used for the Model of productivity (Z3). All the values of Standard error (SSE) for R square, Adjusted R square Values and RMSE values shows the goodness of fit as shown in Table 3.

Table 3 Interpretation of RSM Model and Goodness of fit

Sr.No.	Values of SSE	R-square Values	Adjusted R square Values	RMSE Values
1	0.07071	0.6946	0.0159	0.08864
2	0.0568	0.7591	0.2237	0.07872
3	0.0831	0.6403	-0.159	0.09619
4	0.07268	0.6861	-0.01144	0.08986
5	0.09124	0.6059	-0.2698	0.1007
6	0.08491	0.6333	-0.1817	0.09713
7	0.04967	0.7855	0.3088	0.07429
8	0.08104	0.65	-0.1288	0.09489
9	0.09053	0.609	-0.2599	0.1003
10	0.07665	0.6689	-0.06678	0.09229
11	0.07996	0.6549	-0.1129	0.09426
12	**0.03691**	**0.8406**	**0.4864**	**0.06404**
13	0.1032	0.5541	-0.4369	0.1071
14	0.07892	0.6591	-0.09838	0.09364
15	0.07937	0.6572	-0.1046	0.09391
16	0.03783	0.8366	0.4735	0.06483
17	0.07111	0.6929	0.01033	0.08889
18	0.086	0.6286	-0.1969	0.09775
19	0.05966	0.7423	0.1697	0.08142
20	0.1141	0.5071	0.1797	0.0822
21	0.07272	0.6881	-0.0051	0.08958
22	0.07243	0.6872	-0.0079	0.08971
23	0.08889	0.6161	-0.2371	0.09938
24	0.102	0.5593	-0.4201	0.1065
25	0.04385	0.8106	0.3897	0.0698
26	0.06295	0.7281	0.1239	0.08363
27	0.05374	0.7679	0.2521	0.7727
28	0.1171	0.4941	-0.6301	0.1141
29	0.08239	0.6442	-0.1466	0.09568
30	0.102	0.5595	-0.4194	0.1065

The R^2 value for Productivity (Z3) is 0.8406, RMSE value is 0.064, the other values of SSE is 0.03691, Adjusted R^2 is 0.4864. All these values shows that the standard error is very less 0.036which is within control. Also the R^2 estimation for output variable (productivity) is 0.8406 i.e. around 84%. Littler should be the estimations of RMSE (Root Mean Square Error) RMSE which is only 0.064.

5.0 Results of three dimensional form of Model:

The current work is giving an outline on help of Response Surface Model (RSM) [3,11,16] to enhance the Productivity of the operators to advance the profitability . The dimensional examination technique can be drawn nearer to lessen the quantity of free factors to improve the profitability as reaction variable. The model condition is arrived by utilizing Response Surface Methodology in MATLAB R2018a programming. To test whether the information are well fitted in the model or not, the estimations of SSE, R, R^2 values, Adjusted R^2 and RMSE values are also seen as in Table 3.

6.0 Conclusion

The RSM method helps in determining of mathematical model with best fits and finding the optimum set of experimental factors that produces maximum or minimum value of response.

The Regression model is progressively exact when higher is the estimated values of R^2 i.e . R^2 = 0.8406 and the littler is the estimations of RMSE (Root Mean Square Error) RMSE = 0.064.

The R^2 estimation for output variable (productivity) is around 84%. The closer the estimation of R^2 (relationship coefficient) to 1, the better is the connection between's the trial and anticipated qualities. Here the estimation of R^2 being near 1 shown a perfect connection between the outcomes and the hypothetical qualities anticipated by the model condition as seen in graphical analysis.

This study suggests the criterion for formulation of design for future workstation, to get maximum productivity from the operator the coordinates should fall within the range of RSM model which is perfectly nearing to 1. The forecast of field study information is acceptable for helping the improvement in productivity of sewing machine operators' work. Productivity to be maximum of the future workstation designed is concerned the criterion of design which would be the value of 2 quantities on OX, OY respectively and the corresponding productivity would be 1.875061.

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