International Journal of Engineering Research
Volume No.4, Issue No.7, pp: 363-367

ISSN: 2319-6890(online), 2347-5013(print)
01 July 2015

Production & Process Optimization of Micro Alloyed Steel Roller Shaft of an Under Carriage

Dr. S. Gajanana, **Kulkarni Rahul, Shreyas Gampa, Tharun Vempati, JV Srinath**
Mechanical Engineering Department, M.V.S.R. Engineering College, Nadergul, Hyderabad-501510,
Telangana, India
Corresponding Email: g_saparey@redffmail.com

Abstract: Manufacturing or production is one of the most important sectors of any field. It involves various steps or processes to convert raw materials into finished products. With the more precise demands of modern engineering products and competition to provide good quality, the surface finish, dimensional accuracy along with metal removal rate (MRR) plays a very important role. The selection of optimum cutting conditions (depth of cut, feed and speed) is an important element of process planning for every machining operation. In order to optimize the output parameters i.e., MRR, power consumption and surface roughness, the process variables are varied. Inspite of major advancements in metal cutting practices, the metal cutting industries continues to suffer from major drawback of not running the machine tools at their optimum operating condition. Furthermore, their prediction helps in the analysis of optimization problems in machining economics, in adaptive control applications, in the formulation of simulation models used in cutting databases. In the present work full factorial design of experiments (DOE) technique is used in order to find the effect of input parameters on MRR and surface roughness for Micro Alloyed Steel Roller Shaft work material of an under carriage at Berco Undercarriages India Pvt Ltd. Contribution of each factor on output is determined by Analysis of Variance (ANOVA) and using MAT LAB software the optimum values of process parameters for MRR and surface roughness are generated.

Keywords: DOE, ANOVA, Factors, MRR, Surface Roughness

1. INTRODUCTION

Milling is the process of cutting away material by feeding a work piece past a rotating multiple tooth cutter. The machined surface may be flat, angular, or curved. The surface may also be milled to any combination of shapes. To machine the ferrous material, harder cutting tool is needed. One of popular cutting tools that are used is High Speed Steel (HSS). This study helps to improve the performance of a milling process by using High Speed Steel cutting tool as a cutter. It is worth to understand the capability of carbide cutting tool during machining of ferrous metal for a better understanding of milling machining characteristic. The shaft on which the experimentation is to be performed is a Roller Shaft, which is used in an Undercarriage. Berco Undercarriages India Pvt Ltd is one of the leading manufacturer of Undercarriage parts in the world which facilitates extensive research work. This knowledge will help mass production machining in the industry.

2. FACTORIAL DESIGN OF EXPERIMENTS:

The full factorial design of an experiment is the procedure of selecting the number of trials and conditions for running them, essential and sufficient for solving the problems that has been set with the required precision. Factorial designs are widely used in experiments involving several factors where it is necessary to study the joint effect of the factors on a response. However there are several special cases of the general factorial design that are important because they are widely used in research work and also because they form the basis of other designs of considerable practical value.

2.1 OBJECTIVE & METHODOLOGY

The mathematical model is developed by using factorial design of experiments to predict the metal removal rate required for milling of Micro Alloyed steel with low carbon content with High speed steel (H.S.S) 4 flute mill cutter. The three factors, namely *speed, feed and depth of cut* are analyzed simultaneously by the main effects with two and three factor interactions. The developed model is tested for its adequacy and significance of each coefficient is checked by student’s t-test at 5% significance level.

The investigation study is planned with the following objectives:

a. Postulation of mathematical model for MRR & Surface Roughness.
b. Adoption of two level factorial design of experiments and selection of test regions for the variables (factors).
c. Conducting the experiments as per design.
d. Estimation of coefficients of postulated model.
e. Analysis of results
    i. Checking the adequacy of the postulated model by ‘F-test.
    ii. Testing the significance of each coefficient of the model by model‘s t-test’.
    iii. Determination of percentage contribution of each factor.

2.2 POSTULATION OF MODEL FOR METAL REMOVAL RATE (MRR)

Objectives:-

- To study the effect of cutting parameters on metal removal rate and surface roughness in various machining process such as turning, grooving, milling, and drilling.

- To find optimal values of metal removal rate and surface roughness and their corresponding process parameters using MAT LAB program.

Scope:-

- Using ISCAR Carbide Steel cutting tool.
- Using Micro Alloyed Steel with low carbon as a work piece.
- Applied a turning, grooving, end milling, drilling cutting process on the work piece.

The machining variables (Factors) are identified to develop the mathematical model to predict the maximum metal removal rate and the best surface finish. These include speed (s), feed (f) and depth of cut (d). The first order model with two and three factor interactions which can be expressed as:

$$y = b_0x_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}\,x_1\,x_2 + b_{13}\,x_1\,x_3 + b_{23}x_2x_3 + b_{123}x_1x_2x_3$$

A two level full factorial design of experiments is adopted for calculating the main and the interaction effects of the four factors at two levels; $2^k = N$ experiments are conducted to fit an equation, where 'k' is no. of factors and 'N' is no. of trials. The design plan with high and low limits as indicated Table -1

Table-1: Average and variation of different parameters for turning

Factors	Units	Designation		Test Levels		Average (AVG)	Variation Interval (VI)
		Natural	Coded	Low	High		
Spindle Speed	rpm	s	X_1	180	144	162	18
Feed	mm/rev	f	X_2	0.5	0.4	0.45	0.05

Table-2: Average and variation of different parameters for Milling

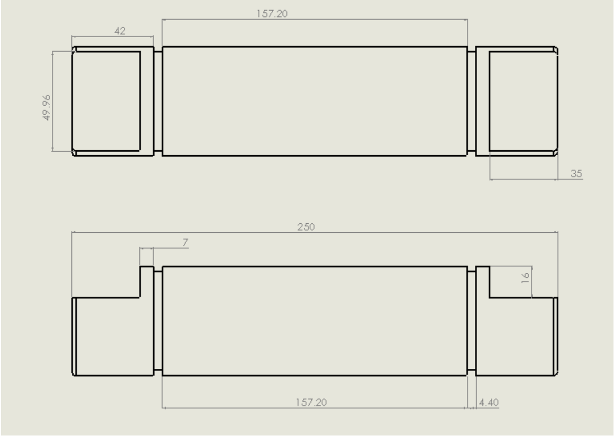
Factors	Units	Designation		Test Levels		Average (AVG)	Variation Interval (VI)
		Natural	Coded	Low	High		
Spindle Speed	rpm	s	X_1	800	1000	900	100
Feed rate	mm/rev	f	X_2	0.8	1.2	1.0	0.9
Depth of Cut	mm	d	X_3	1	4	2.5	1.5

3. MATERIAL OF THE SHAFT

Micro Alloyed Steel

- Micro-alloyed steel is a type of alloy steel that contains alloying elements like vanadium, titanium, molybdenum, zirconium, boron and rare earth metals
- They are used to refine the grain microstructure or facilitate precipitation hardening.
- These steels lie, in terms of performance and cost, between carbon steel and low alloy steel.
- Yield strength is between 500 and 750 MPa (73,000 and 109,000 psi) without heat treatment.

3.1 Shaft Drawing:



4. MODEL DEVELOPMENT

In the present work, sequence of steps followed in the development of model are:

4.1 CALCULATION OF REGRESSION COEFFICIENTS

The values of regression coefficients b_0, b_1, $b_2 \ldots b_{1234}$ are calculated by regression analysis and are given in the following table. Here the number of replications for the response i.e; y_1 and y_2 and average of these is 'y'.

Regression coefficients b_0, b_1, b_2, b_{12}, b_{23} etc are calculated by using the formula $b_j = \dfrac{\sum_{i=1}^{N} X_{ij} Y_i}{N}$

Where N=number of trails

For milling, N=8

For turning, N=4

For drilling, N=4

Variance of reproducibility: $S_y^2 = \dfrac{2\sum(\Delta Y)^2}{N}$

Variance of adequacy: $S_{ad}^2 = \dfrac{2\sum\left(Y - Y_p\right)^2}{DOF}$

Y_p= predicted response

$Y_p = b_0 X_0[i] + b_1 X_1[i] + b_2 X_2[i] + \ldots\ldots\ldots\ldots\ldots$

Degree of freedom: DOF = N-(k+1)

Where, N = No. of trials = 8(milling), 4(turning);
k = No. of factors = 3(milling), 2(turning).

F-model = S_d^2 / S_y^2

For given values f_1 and f_2, F-table value is found from fisher table.
Here, $f_1 = N-(k+1)$, $f_2 = N$

If F-model ≤ F-table, model is adequate in linear form otherwise it is not adequate.

4.2 STUDENT'S T-TEST AT 5% SIGNIFICANCE LEVEL:

When the model is adequate in linear form, then t-test is to be conducted to test the significance of each Regression coefficient.

Standard deviation of coefficient: $S_{bj} = \sqrt{\dfrac{(S_y)^2}{N}} = 0.030$

$$\text{t-ratio} = \frac{|b_j|}{S_{b_j}}$$

For f = N, t value is should be taken from t-table and compared with t-ratio of each regression coefficient. If t-ratio ≥ t-table, the corresponding regression coefficient is significant. Non-significant coefficients are to be eliminated from the model to arrive the final form of mathematical model in linear form as

$y = b_0x_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}\, x_1\, x_2 + b_{13}\, x_1\, x_3 + b_{23}x_2x_3 + b_{123}x_1x_2x_3$

Trial No	Design Matrix		MRR			Surface Roughness(Ra)		
	X_1	X_2	Y_1	Y_2	$\hat{Y}$	Z_1	Z_2	Z
1	-1	-1	10.75	10.8	10.8	0.79	0.82	0.805
2	1	-1	12.82	12.89	12.89	0.747	0.756	0.7515
3	-1	1	12.82	12.88	12.88	0.684	0.699	0.6915
4	1	1	15.15	15.18	15.18	0.588	0.593	0.5905

Table-3: Design Matrix for Turning

5. EXPERIMENTATION

The experiments were carried out on DOOSAN FANUC Single Axis Lathe for turning and grooving operations and HAAS VF3 milling machine for milling and drilling operations. The cutter used was ISCAR carbide steel cutting tool. The work piece is a Micro alloyed steel roller shaft which is used in the undercarriages after complete machining. Each trial was replicated twice, which provide an internal estimate of the experimental error. The design matrix and summary of the experimental results are shown in below table:

Table 3: Design Matrix for Turning
Table 4: Design Matrix for Milling

	Design Matrix			MRR		
	X_1	X_2	X_3	Y_1	Y_2	$\hat{Y}$
1	-1	-1	-1	2.6333	2.742	2.688
2	1	-1	-1	0.9937	1.102	1.048
3	-1	1	-1	4.0513	4.123	4.087
4	1	1	-1	1.423	1.556	1.490
5	-1	-1	1	3.5111	3.682	3.597
6	1	-1	1	3.098	3.125	3.112
7	-1	1	1	1.1704	1.265	1.218
8	1	1	1	0.8103	0.975	0.893

Table-4: Design Matrix for Milling

In the above matrix, columns indicated the factors while the rows indicated the experiment with different treatment combinations expressed in codes +1 and -1 corresponding to high and low levels. The trail 1 in both milling and turning has a combinations of all variables set at low level.

The column of each variable X_1, X_2, and X_3 are arranged in standard order. The values of regression coefficients b_0, b_1, b_2,….,b_{123}… are calculated for metal removal rate and surface roughness.

Table-5: Regression Coefficients for turning

b_0	12.93
b_1	1.097
b_2	1.0925
b_{12}	0.8525

Table-6: Regression Coefficients for milling

b_0	2.228
b_1	-0.63
b_2	-0.341
b_3	-0.0691
b_{12}	-0.115
b_{13}	0.4353
b_{23}	-0.808
b_{123}	0.1306

Table-7: Regression Coefficients for surface roughness:

b_0	0.709
b_1	-0.038
b_2	-0.0686
b_{12}	-0.0118

The final model in coded form of MRR for turning is:

Y = 12.93 + 1.097*x (1) +1.0925*x (2)

The final model in coded form of Surface Roughness for turning is:

$y_{p\,=}$ 1.6684 - (0.038*x(1)) - (0.0686*x(2))

The final model in coded form of metal removal rate for milling is:

y_p = -5.3564 + (3.1024*10^{-3})(s) + (19.996*f) + (3.9541*d) - (0.0166*s*f) - (1.453*10^{-3}*s*d) - (6.6107*f*d) + (0.004353*s*f*d)

Where, speed = x (1)
Feed = x (2)
Depth = x (3)

6. ANALYSIS OF VARIANCE:

Analysis of variance is done to find out the percentage contribution of each factor and relative significance of each factor for metal removal rate and surface roughness.

Table-8: Percentage Contribution of factors and their interaction for MRR (Milling)

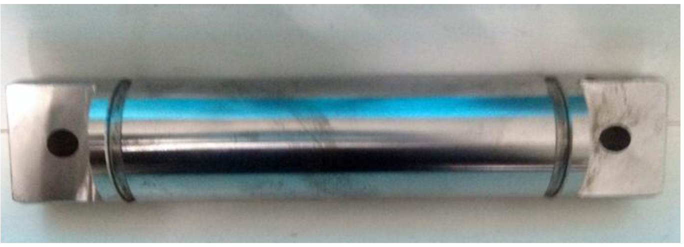
FACTOR	% CONTRIBUTION
X_1	28.7441
X_2	8.5727
X_3	0.275
X_1X_2	0.7182
X_1X_3	13.2527
X_2X_3	46.7739
$X_1X_2X_3$	1.4098
Total	99.7

Table-9: Percentage Contribution of factors and their interaction for MRR (Turning)

FACTOR	% CONTRIBUTION
X_1	0.038
X_2	50.07
X_{12}	49.6
Total	99.708
Error	0.292

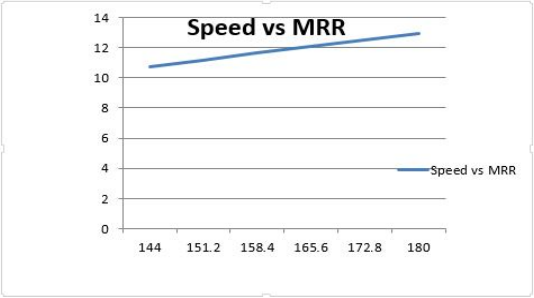
Table-10: Percentage Contribution of factors and their interaction for Surface Roughness

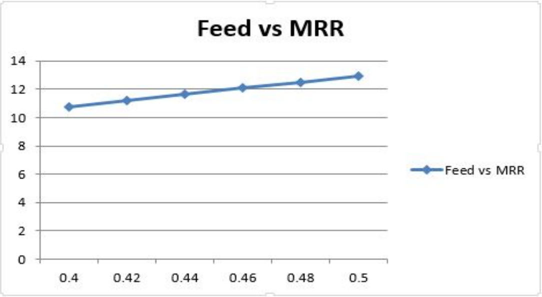
FACTOR	% CONTRIBUTION
X_1	23.24094
X_2	73.36374
X_1X_2	2.196767
Total	98.801
Error	1.198



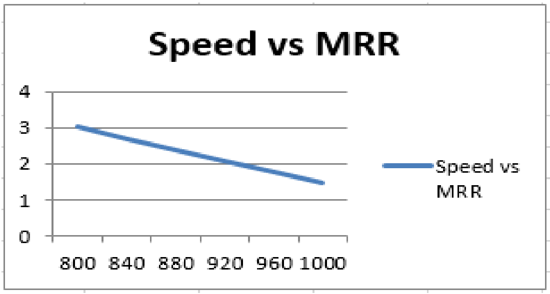
7. GRAPHICAL RELATION:

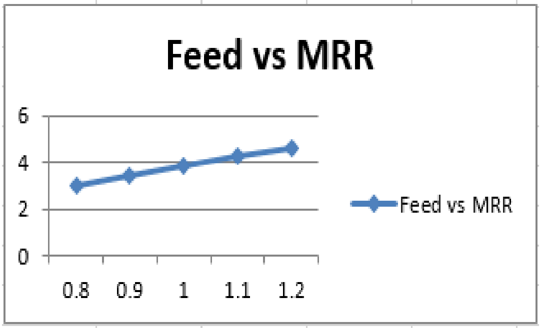
i) For Turning:

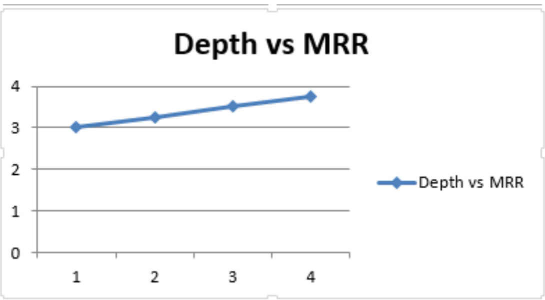




ii) For Milling:







8. RESULTS &CONCLUSIONS:

1. From ANOVA table-7, it is clear that, for milling process, the percentage contribution of interaction effect of feed and depth of cut is 46% on MRR, next followed by speed X_1 is 28% and remaining percentage is contributed by other interactions.
2. From ANOVA table-8, it is clear that, for turning process, the percentage contribution of feed X_2 is 50% on MRR, next followed by interaction effect of feed and depth of cut is 49%.
3. From ANOVA table-9, it is observed that influence of feed is more on surface roughness and next is speed.

Determination of contribution of factors helps the operator to set the parameters at required values in order to get desired quality of products.

9. REFERENCES:

i. *Alder, YP.; et al.: The Design of Experiments to find Optimal Conditions, MIR Publications, Moscow, 1975.*

ii. *Montgomery DC: Design and Analysis of Experiments", John Willey and Sons, New York, 1991.*

iii. *H.M.T.: Production Technology, TMH, New Delhi, 1988*

iv. *Panday, PC; Shan, HS: Modern Machining Process.*

v. *Dr.S.Gajanana: Development of Mathematical Model for Maximum Punch Force, 'Proceeding of National Conference on Advanced Trends in ME Research and Development', JNTU College of Engineering, Ananthapur, 21st Dec, 2002.*

vi. *Dr.S.Gajanana: Optimization of Process Parameters for Hero Honda Exhaust Valve using Design of Experiments, 'Proceeding of National Conference on Recent Advances in Computer Aided Engineering', Osmania University, Hyderabad, March 3rd & 4th, 2006.*

vii. *Dr. Gajanana.S: Development of Mathematical Model For EDM Using Two Factorial Design of Experiments, XXIII National Convention Of Mechanical Engineers And National Seminar On Emerging Trends In Manufacturing Systems And Technologies, Hyderabad, September 2007.*

viii. *Dr. S. Gajanana: "Optimization of Process Parameters of end milling process using Factorial Design of Experiment." MTT, June 2013.*

ix. *Wen-Hsiang Lai, Modelling of Cutting forces in End Milling Operations, Tamkang Journal of Science and Engineering, 2000, Vol. 3, No. 1, pp. 15-22.*

x. *Dr PC Sharma, a text book of production engineering, S.Chand, 2009*