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Optimization of Drilling Process Parameter on machining of EN9 Steel by RSM

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ABSTRACT: Drilling is one of the most fundamental machining process. In today’s manufacturing industry the main objective is to manufacture low cost and high quality product in less time. In this study drilling of EN9 steel is performed by HSS tool and parameter selected for optimization is feed rate, spindle speed and diameter. The aim of this study is to optimize parameter for maximum material removal rate (MRR). The experiment was conducted based on response surface methodology (RSM) and further analyzed by Analysis of variance (ANOVA).

KEYWORDS: RSM, Drilling, Box Benken, MRR, ANOVA.

I. INTRODUCTION

EN 9 steel plays an important role in various manufacturing processes. EN9 steel is a medium carbon, high tensile strength with good wear resistant properties. EN9 Steel suitable for camshaft, gears, cylinder. From study it is observed that on EN9 steel most of the work is performed on turning operation while drilling received less attention. Drilling is a process of producing round holes in a solid material or enlarging existing holes with the use of multi tooth cutting tools called drills or drill bits. The twist drill is a cutting tool with two symmetrical opposite cutting edges, each removing part of the material in the form of chip from the work piece and produce a hole in the material. The workpiece material selected for investigation is EN9 steel, the size of the workpiece material is 294.64mm*152.4mm*20mm.

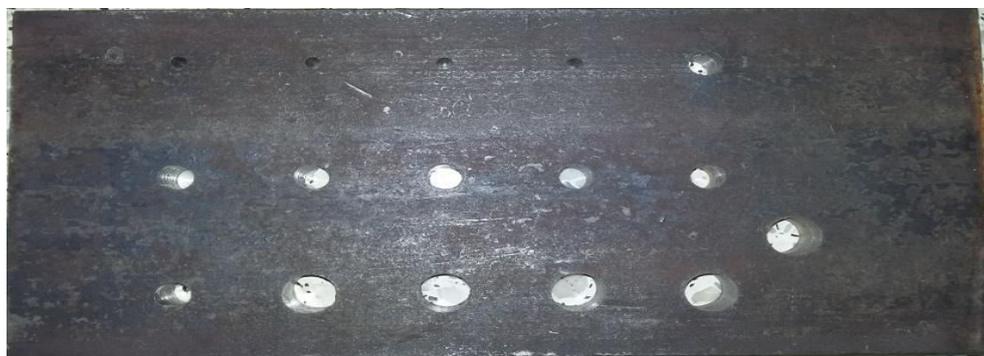


Figure 1 Workpiece material

Table 1 Chemical Composition of EN9 Steel

	C%	Si%	Mn%	Cr%	Mo%	Ni%	W%	V%	Co%
EN 9	0.50-0.60	0.05-0.30	0.5-0.80	-	-	-	-	-	-

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II. RELATED WORK

Adem Çiçek · Turgay Kıvak · Ergün Ekici, have done work on Optimization of drilling on AISI 304 steel parameter by selecting cutting speed, feed rate and Three drill categories (conventional heat treatment—CHT, cryogenic treatment—CT, cryo-tempering—CTT), results shows that cutting speed is most influential parameter. **B Vijaya** and hole diameter. **Aimin Yang , Yang Han , Yuhang Pan , Hongwei Xing , Jinze Li** by using RSM optimization is done on titanium alloy TC 11 They selected three parameters as cutting speed, feed rate, depth of cut, and the prediction accuracy was verified by the one-way ANOVA. The result shows that the feed has the most important effect on surface roughness. **Ramnath, S Sharavanan and J Jeykrishnan**, Studied optimization of process parameter in drilling of fibre hybride composite using Taguchi and Grey analysis.MRR is studied and shows that spindle speed and drill bit diameter is most effected on MRR. **A Navnath, T Kartikeya Sharma** have done work on optimization of drilling process in Dry Drilling of AL2014 Alloy at low speed. HSS is selected as a twist drill and the cutting tool, spindle speed and feed rate were selected as control factor to obtained minimum surface roughness

III. METHODOLOGY

Recently various methods are used to optimize Material removal rate such as response surface methodology, genetic algorithm, Taguchi method etc. Response surface methodology is statistical method used to plan experiment and to optimize cutting parameter. Mathematical model is developed by using Response surface Methodology. The developed model is may be first order model or second order model depends upon the number of selected parameter is further divided in to factorial design, full factorial design, central composite design and box behnken design. The above mention design is chosen as per the experiment.

IV. ANALYSIS BY RSM

In this study Box behnken design is selected for experimental plan, three parameter are feed rate, spindle speed and diameter. In this work, secondary mathematics regression method is adopted to establish the relationship between the Material removal rate and processing parameters.factors and levels of parameters for experiment is given in Table2.

Table 2 : Factors and levels of process parameter

Factor	Name	Units	Type	Low level	High level
				(-1)	(+1)
A	speed	RPM	Numeric	700	800
B	Feed rate	mm/min	Numeric	10	50
C	Diameter	mm	Numeric	4	12

Design expert software version11 was employed and the experimental plans and results are given in Table3

Table 3: Experimental plan for Drilling of EN9steel

Std	Run	Factor 1 A:A RPM	Factor 2 B:B mm/min	Factor 3 C:C mm	Response 1 MRR mm ³ /min
15	1	700	30	8	1.055
3	2	600	50	8	1.507

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1	3	600	10	8	0.301
5	4	600	30	4	0.223
10	5	700	50	4	0.439
9	6	700	10	4	0.0879
12	7	700	50	12	3.957
11	8	700	10	12	0.791
13	9	700	30	8	1.055
8	10	800	30	12	3.433
4	11	800	50	8	2.01
7	12	600	30	12	2.034
14	13	700	30	8	1.055
6	14	800	30	4	0.301
2	15	800	10	8	0.402

An ANOVA (analysis of variance) table is commonly used to summarize the experimental results. The table concludes information of analysis of variance and case statistics for further interpretation. Table 4 shows the ANOVA table for MRR after transformation as recommended by Box-Cox plot (State-Ease, Inc., 2011) using square root transformation (generated by the Design Expert software).

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Table 4: Modified ANOVA Table

Transform: Square Root					
Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	3.49	5	0.6990	101.34	< 0.0001 significant
A-A	0.0758	1	0.0758	10.99	0.0090
B-B	1.07	1	1.07	155.44	< 0.0001
C-C	2.18	1	2.18	316.31	< 0.0001
AC	0.0307	1	0.0307	4.45	0.0642
BC	0.1346	1	0.1346	19.51	0.0017
Residual	0.0621	9	0.0069		
Lack of Fit	0.0621	7	0.0089		
Pure Error	0.0000	2	0.0000		
Cor Total	3.56	14			

Std. Dev. 0.0830 **R²** 0.9825
Mean 1.00 **Adjusted R²** 0.9729
C.V. % 8.28 **Predicted R²** 0.9221
Adeq Precision 33.8237

The **Predicted R²** of 0.9221 is in reasonable agreement with the **Adjusted R²** of 0.9729; i.e. the difference is less than 0.2. **Adeq Precision** measures the signal to noise ratio. A ratio greater than 4 is desirable. Ratio of 33.824 indicates an adequate signal. This model can be used to navigate the design space. The **Model F-value** of 101.34 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. After Anova procedure graphical analysis is performed plot of residual vs. predicted and normal probability plot of residual.

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Design-Expert® Software

Sqrt(MRR)

Color points by value of
Sqrt(MRR):
0.296 1.989

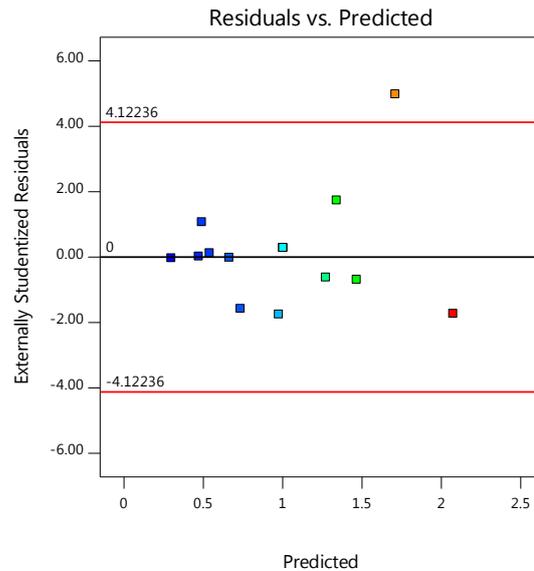


Figure 2: Residuals vs predicted plots for MRR

Figure 3 revealed that residuals spread on a straight line imply that errors are distributed normally.

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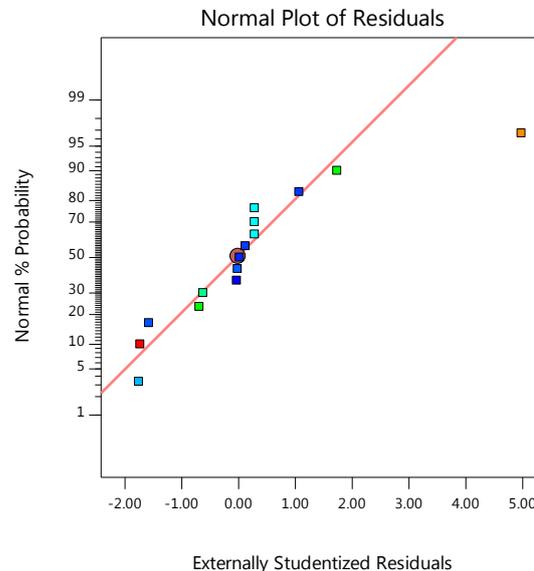


Figure 3: Normal probability plots of residuals for MRR

V. RESULT AND DISCUSSION

The following equations are the final empirical models in term of coded factors and actual factors for MRR respectively. These equations were generated by the Design Expert software after the transformation had been carried out.

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Final Equation in Terms of Coded Factors

$$\text{Sqrt(MRR)} = +1.00 + 0.0973 A + 0.3661 B + 0.5222 C + 0.0876 AC + 0.1834 BC \quad (1)$$

Final Equation in Terms of Actual Factors

$$\text{Sqrt(MRR)} = +0.504483 - 0.000778 A - 0.000040 B - 0.091468 C + 0.000219 A * C + 0.002293 B * C \quad (2)$$

Optimization of Drilling Parameters for Maximum MRR:

Optimization is performed numerically and graphically. In the numerical optimization test, the desired goals for the factors and response were set by using the design expert software. Table 5 shows the setting of the factors for achieving the desired goals of the responses.

Table 5 : Constraints

Name	Goal	Lower Limit	Upper Limit
A:A	is in range	600	800
B:B	is in range	10	50
C:C	is in range	4	12
MRR	maximize	0.296479	1.98922

Higher material removal rate is preferable for every machining process, the optimal solution suggested by the software is given in table 6.

Table 6: Optimization Results for MRR

s. no	spindle speed(RPM)	Feed rate (mm/min)	Diameter(mm)	MRR(^{mm} ³ /min)
1	795.705	48.631	11.305	4.323

VI. CONCLUSION

Mathematical models developed to predict the various machining characteristics are statistically valid and sound within the range of the factors investigated. Verification and confirmation run experiments were carried out and therefore could be used for prediction within the limits of the factors investigated. The optimized machining parameters were established to achieve the desired response. Of all the machining parameters investigated, feed rate and Diameter was found to be the most significant factor.

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