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Research Paper

OPTIMIZATION OF CUTTING PARAMETERS FOR SURFACE ROUGHNESS OF STAINLESS STEEL SS304 IN ABRASIVE ASSISTED DRILLING

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This paper is concerned with optimization of surface roughness when drilling of stainless steel SS304 with HSS drill. This study included drilling of SS304 with supply of Sic abrasive having grain size 650 and 1250 mesh size through abrasive slurry system. Abrasives not only used for cooling purpose but also increases the surface finish, MRR and reduce tool wear. Experiments were conducted on a universal milling machine. Response Surface Methodology (RSM) is applied for executing the planning of experiments. Analysis of variance is employed to find the significant control factors and percentage contributions of each control factor. The drilling parameters namely spindle speed, feed rate; slurry concentration and mesh size were optimized using multiple performance characteristics for surface roughness. The result shows that the feed rate, and spindle speed are the most significant factors which affect the surface roughness and performance in the drilling can be effectively improved by using this approach.

Keywords: Abrasives ANOVA, drilling, HSS drill bit, RSM, Stainless steel SS304, Surface roughness

INTRODUCTION

Stainless steel resists chemical and electrochemical influences of atmosphere, water, acids and bases. The main alloying elements are chromium and nickel. The first ensures the corrosion resistance while the second extends the austenitic region into the environment temperature (Groover, 2007). These materials play an extremely important role in industry in addition to their applications in automotive, aircraft, aerospace industries, building and medical apparatus where high corrosion occurs (Korkut *et al*., 2004). The machining of stainless steel generally gives short tool lives, limited metal removal rate, large cutting forces and power consumption due to their high temperature strength, rapid work hardening during machining with most

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tool material at high cutting speeds (Lin, 2012).

Many researchers have concentrated on the determination of the best drilling process of stainless steel SS304. Hence many numerical and experimental methods have been developed and used in the past decade in order to predict and determine significant parameters which affect the drilling process. Surface roughness also plays an important role how a real object will interact with its environment. Roughness usually wears more quickly and have higher friction coefficient than smoother surface do. Roughness is often a good predictor of the performance of a mechanical component. Decreasing roughness of a surface will increases manufacturing costs. Surface roughness is also a important characteristic (Kadirgama *et al.*, 2008). Sanjay and Jyothi (2006) investigated the effect of cutting speed, Drill diameter, feed and machining time on surface roughness, during drilling of mild steel bar with HSS drills using RSM model. Adachi *et al.* (1990) investigated the effect of cutting speed 27 m/min and feed of 0.1 mm/rev on cutting parameters such as cutting force and tool wear, during the drilling of austenite stainless steel with TiN-coated drills. Lin (2002) conducted experiments using TiN coated WC to drill stainless plates and found that high drilling speed and feed rate would create a large surface roughness and affect tool life simultaneously.

Karnik and Gaitonde (2008) developed an RSM model to study the effect of process parameters such as cutting speed, feed, drill diameter , point angle ,and lip clearance angle on burr height and burr thickness during drilling of AISI 316L stainless steel. Kurt *et al.* (2009) have studied the optimization of cutting parameters using tag chi method in the drilling of Al 2024 alloy using uncoated TiN and TiAlN coated drills. Karnik *et al.* (2008) described the comparison of the burr size predictive model based on RSM during drilling of AISI 316L stainless steel work material using HSS twist drill. Cicek *et al.* (2012) studied the performance of treated M35 HSS drills in drilling of AISI 304 and AISI 316 SS was evaluated in terms of thrust force, surface roughness, tool wear and tool life and chip formation. Kadirgama *et al.* (2008) investigated the optimization of surface roughness when milling mould Aluminium alloys (AA6061-T6) with carbide coated drills using RSM and RBFN.

Pirtini and Lazoglu (2005) developed a new mathematical model for estimation of cutting force and surface roughness based on mechanics and dynamics of drilling process. RSM were employed to find the optimal levels and to analyze the effect of process parameters such as slurry concentration, spindle speed, feed rate on surface roughness of stainless steel SS304.

EXPERIMENTAL SET-UP

The entire drilling experiments were carried out on 3-Axis high speed Universal AMAN Milling Machine (Model No. 1140). Abrasive Slurry was used as coolant in these experiments. Silicon carbide Sic was used as abrasive having grain size 1250 mesh. Abrasive slurry was used with concentration 20%, 25%, 30% on stainless steel SS304. For the surface roughness, surface roughness tester was used. The composition and physical properties of the work piece are shown in

Tables 1 and 2. The chemical composition of HSS drill bit is shown in figure. The drill, used for hole making in the stainless steel, was a standard high speed steel twist drill. This drill is a 3-flute, right hand spiral, right-hand cut drill with a 30° helix angle and 118° point angle. The material used for the experimentation is Stainless steel 304. Experiments are planned according to BBD of Response Surface Methodology (RSM). Response Surface Methodology (RSM) is one such factorial design based statistical analyzing method. The two most common designs commonly used in RSM are Central Composite Design (CCD) and Box Behnken Design (BBD).

Work Piece Material Composition

Table 1: Composition Ranges for 304 Grade Stainless Steel

Grade	C	Mn	Si	P	S	Cr	Mo	Ni	N
304 Min.	–	–	–	–	–	18.0	–	8.0	–
Max.	0.08	2.0	0.75	0.045	0.030	20	–	10.5	0.10

Source: Ficici et al. (2012)

Table 2: Mechanical Properties of 304 Grade Stainless Steel

Grade	Tensile Strength (Mpa) min	Yield Strength 0.2% Proof (Mpa)	Elongation (% in 50 mm) min	Hardness Rockwell B (HRB)	Brinell (HB) Max.201
304	515	205	40	92	201

Source: Ficici et al. (2012)

Figure 1: Experimental Drilling Set Up

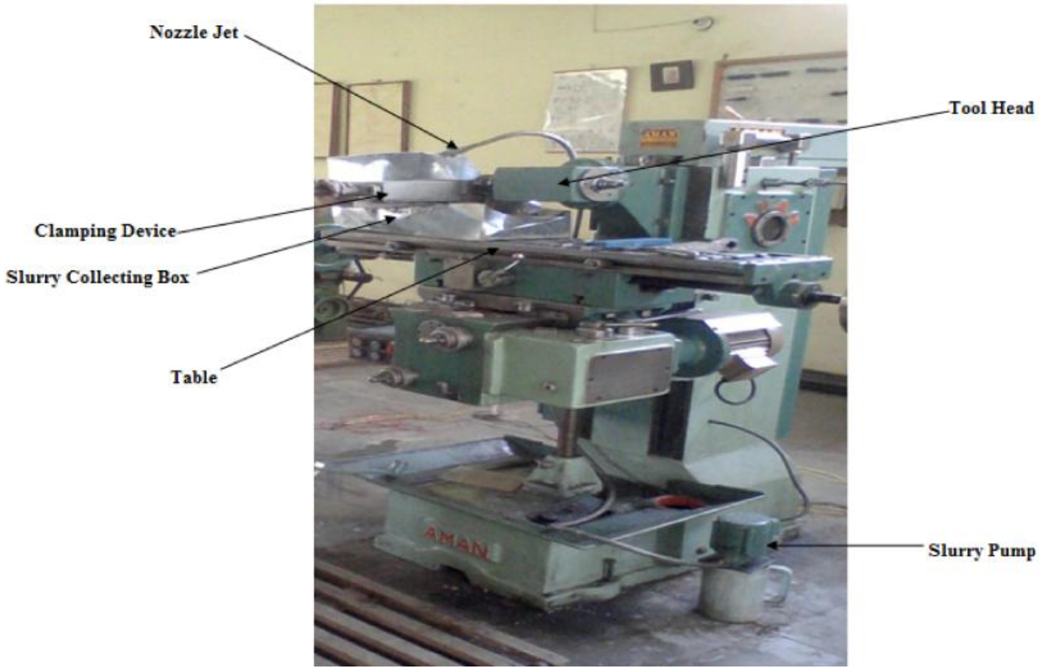


Figure 1 Shows the Experimental drilling set up used in the present work.

Tool

Table 3: Chemical Composition of HSS Drills

C	Cr	Co	Mo	V	Si	Mn
0.9	4.2	4.8	5.0	6.5	2.0	0.3

Source: Karnik and Gaitonde (2008)

Table 4: Control Factors and Their Limits

Parameters	Units	Lower Limit	Upper Limit
Speed (A)	RPM	345	740
Feed (B)	Mm/min.	32.5	78
Slurry Concentration (C)	%	20	30

RESULTS AND DISCUSSION

Table 5: Result Matrix

Std	A:A	B:B	C:C	SR (μm)
1	345	32.5	0.25	1.65
2	740	32.5	0.25	0.7
3	345	78	0.25	1.9
4	740	78	0.25	1.66
5	345	55.25	0.20	1.77
6	740	55.25	0.20	1.05
7	345	55.25	0.30	1.86
8	345	55.25	0.30	1.15
9	542	55.25	0.20	1.2
10	542	78	0.20	1.87
11	542	32.50	0.30	1.21
12	542	78	0.25	1.94
13	542	55.25	0.25	1.32
14	542	55.25	0.25	1.35
15	542	55.25	0.25	1.34
16	542	55.25	0.25	1.37
17	542	55.25	0.25	1.31

Figure 2a: Variation of Surface Roughness with Feed Rate

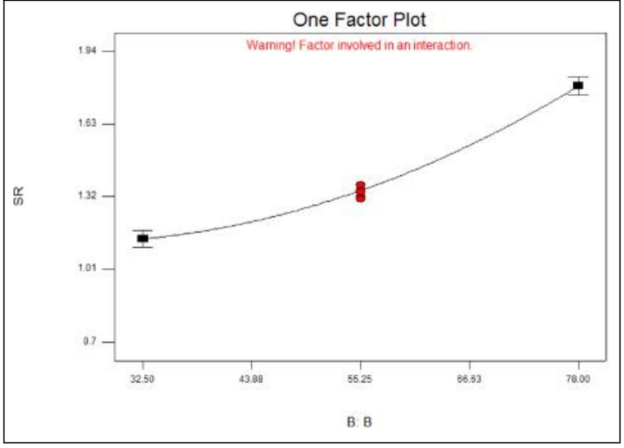


Figure 2b: Variation of Surface Roughness with Speed

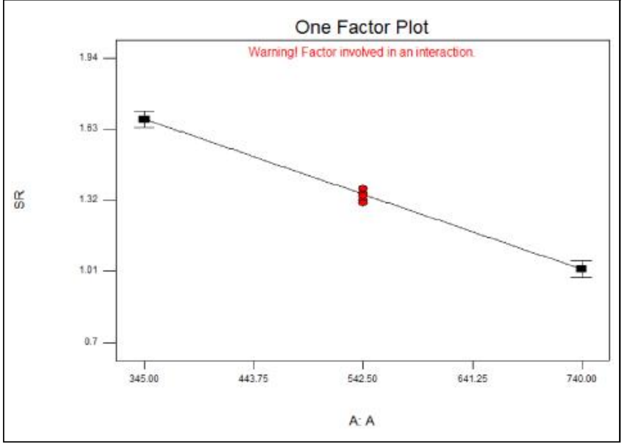


Figure 2c: Variation of Surface Roughness with Slurry Concentration

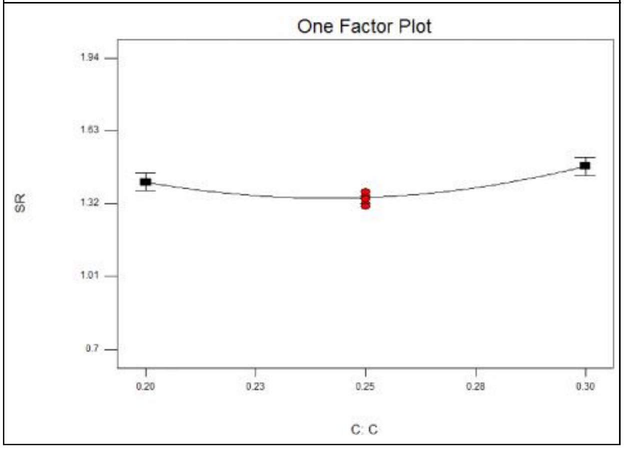


Figure 3: Variation of Surface Roughness with Speed and Feed

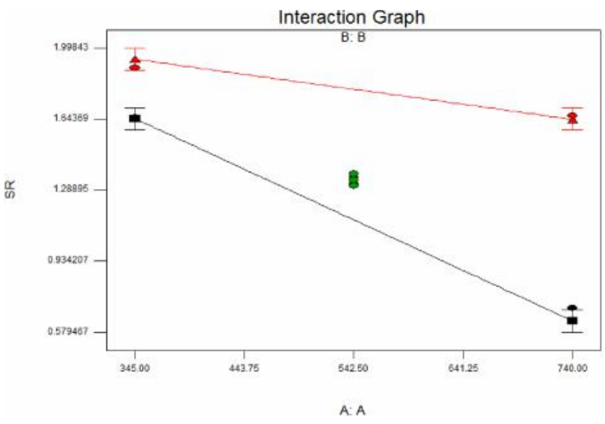


Figure 4: Surface Plot

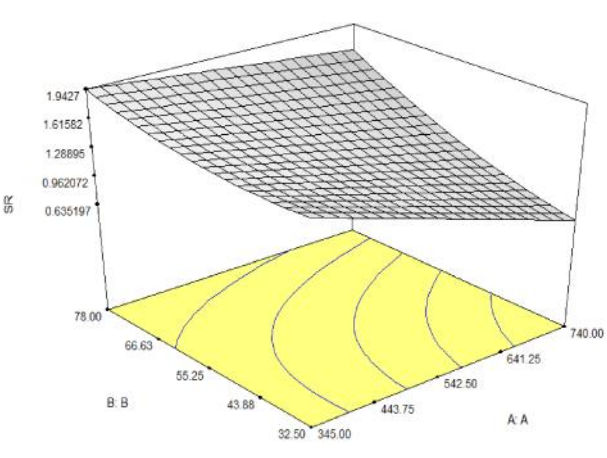
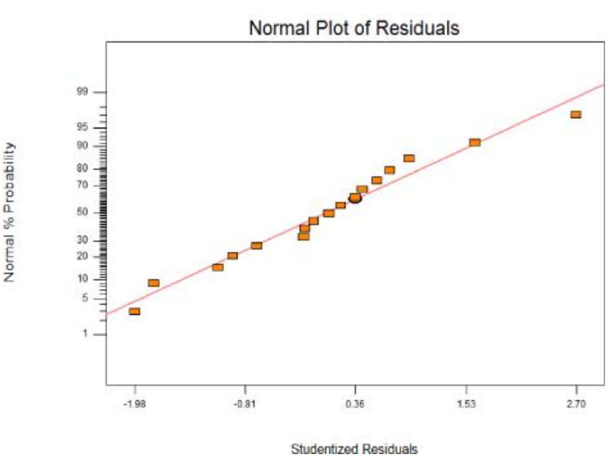


Figure 5: Normal Residual Plot



Mathematical Model

Response Surface Methodology was used for the development of mathematical model and ANOVA.

Final Equation in Terms of Coded Factors:

$$SR = + 1.35 - 0.33*A + 0.33*B + 0.034*C + 0.12*B^2 + 0.100*C^2 + 0.18*A*B \quad ...(1)$$

Final Equation in Terms of Actual Factors:

$$SR = + 5.66500 - 3.84087E - 003*A - 0.0032627*B - 19.24605*C + 2.31093E\ 004*B^2 + 39.84211*C^2 + 3.95048E - 005*A*B \quad ...(2)$$

The Model F-value of 177.99 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less thaN 0.0500 indicate model terms are significant. In this case A, B, C, B^2, C^2, AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The "Lack of Fit F-value" of 4.68 implies there is a 7.85% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good. The "Pred R-Squared" of 0.9511 is in reasonable agreement with the "Adj R-Squared" of 0.9852."Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Our ratio of 47.648 indicates an adequate signal. This model can be used to navigate the design space.The value of surface roughness from RSM model was 0.7 to 1.94 in abrasive assisted drilling of stainless steel SS304. The feed rate and speed has the most dominant effect on surface roughness. A better surface finish is obtained with low feed rate and high cutting speed.

Table 6: Analysis of Variance Table

Source	SS	DF	MS	F-Value	Prob> F	
A	1.95	6	0.33	177.99	<0.0001	Significant
B	0.86	1	0.86	469.22	<0.0001	
C	0.85	1	0.85	465.64	<0.0001	
A^2	9.113E-003	1		4.98	0.0496	
B^2	0.060	1	0.060	33.02	0.0002	
C^2	0.042	1	0.042	22.91	0.0007	
AB	0.13	1	0.13	68.92	<0.0001	
Residual	0.018	10	1.829E-003			
Lack of Fit	0.016	6	2.668E-003	4.68	0.0786	Not Significant
Pure Error	2.280E-003	4	5.700E-004			
Cor Total	1.97	16				
Std. Dev.	0.043	R-Squared	0.9907			
Mean	1.45	Adj. R Squared	0.9852			
C.V	2.95	Pred. R-Squared	0.9511			
Press	0.096	Adeq. Precision	47.648			

CONCLUSION

RSM has been found to be the most successful technique to perform trend analysis of surface roughness with respect to various combination of three process parameter (feed, speed slurry concentration).The model have been found to accurately represent surface roughness values with respect to experimental value. With the aid of abrasive better surface finish were obtained. 25% slurry concentrations have better surface finish than 20 and 30%. In future we can also optimize the value of MRR with the aid of abrasive slurry.

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