Process Parameters Optimization for Abrasive Assisted Drilling of SS316

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Abstract

Stainless steel 316 grade has broad applications in medical equipments. SS316 has property of corrosion resistance that provides its applications in various areas. This paper presents the optimization of process parameters (spindle speed, feed and slurry concentration) in abrasive assisted drilling. Also analysis of variance is carried out for the contribution of parameters and interaction among various factors. In present investigation we have taken Silicon Carbide as abrasive particles. Silicon carbide and water as slurry concentration by weight. SiC concentration varies from 15% to 25% are optimized using multiple performance characteristics for surface finish. This abrasive slurry concentration performs the dual function of coolant as well as cutting fluid. Feed rate and speed of spindle are most significant factors which affects the surface roughness. An overall improvement of 10% in surface finish has been obtained with abrasive assisted drilling.

Keywords - *Abrasive, Anova, Drilling, RSM, SS316, surface finish, SiC*

I. INTRODUCTION

Drilling is one of the most common and fundamental process of material removal used in the manufacturing. Drilling is preliminary step for many operations such as reaming, tapping and boring [Sanjay and Jyothi, 2006]. It is widely used in variety of manufacturing industries including aerospace and automobile sector [Gaitonde et al., 2008].Surface roughness resulting from drilling operation has traditionally received researchers attention. It has an impact on the mechanical properties like fatigue behaviour corrosion resistance, creep life etc. It also affects other functional attributes of parts like friction wear, light reflection heat transmission, lubrication, electrical conductivity etc [Shoa et al., 2008].Surface quality of drilled holes and formation of exit burr on part edges during drilling has several undesirable features on product quality and functionality [T. Rajmohan et al., 2012]. Drilling of AISI 304 SS with cryogenically treated HSS drill and hole quality were investigated. The life of cutting tool plays a major roll in increasing productivity and consequently is economical factor . Slurry concentration during drilling effect the tool life. Parameters effects during drilling were investigated [Goyal K.K. et al., 2014]. Several factors influence the quality of drilled holes. The most obvious one are cutting parameters and cutting tool configuration [Islam et al., 2009] The twist drill, the cutting geometry , the drill and work piece materials are the most important factors which influence the drill performance and quality of hole [Kurt et al., 2009]. The defect located on the wall of the hole is affected by the drill's cutting edges and the material being drilled [Bhatnagar et al., 2004]. The feed rate and the drill diameter are the important factors affecting the thrust force , while the feed and spindle speed contribute to the surface roughness [Tsoa and Hocheng, 2008]. Mandal et al. applied the Taguch method and regression analysis to asses machinability of AISI 4340 steel with newly developed Zirconia toughened alumina ceramic insert . It has been observed that depth of cut has maximum contribution on tool wear [Mendal et al., 2011]. The taguchi method was notably successful in the optimization of drilling parameters for surface roughness and thrust force [Kivak et al., 2012]. Analysis of result of the result revealed that optimal contribution of low feed and low depth of cut with high cutting speed is beneficial for reducing thrust machining force and surface roughness [suresh et al., 2012]. For surface finish heat produce during grinding is the major source of damage [Che-Haron et al., 2005].

II. EXPERIMENTAL SETUP

The entire drilling test was carried out on CNC milling machine. Abrasive slurry of silicon carbide having grain size 20µm was used as cutting fluid for present work. The slurry used with varying concentration of 15%, 20% & 25%. The work material used for the experimental work is SS316 of size (70×140×12). A standard high speed twist drill with 2 – flute with a 30^0 helix angle and 118^0 point angle has been used in the present work. Density of HSS drill used is 7.9g/cm^3 having modulus of elasticity 224GPa and hardness 65 HRC.

Table 1: **Composition for SS316 grade stainless steel.**

Grade	c	Mn	Si	P	S	Cr	Mo	Ni
316	.08	2	.75	.030	.045	16	2-3	10

Table2: Mechanical properties of SS316 grade stainless steel.

grade	Tensile Strength (Mpa)	Yield Strength .2 proof (Mpa)	Elongation (% in 50 mm)	HRB	HB
316	558	290	50	B79	201

III. RESULTS AND DISCUSSION

The surface finish as output factor obtained for three level experimental design considering process parameters as spindle speed, drill feed and slurry concentration are shown in following tables.

Table 3: Control factors and their measuring units

Process parameters	Measuring Units	Lower Limit	Middle Limit	Upper Limit
Slurry Concentrate Ion(A)	%	15	20	25
Feed(B)	Mm/min	25	50	75
Speed(C)	RPM	300	500	700

Table 4: Results shown with design expert software for abrasive assisted drilling.

Sr. no.	Slurry concentration (silicon carbide) in %	Feed of drill in mm/min.	Speed of spindle in RPM	Surface Roughness µm
1	15	25	300	1.65
2	20	25	300	1.59
3	25	25	300	1.73
4	15	50	300	1.77
5	20	50	300	1.73
6	25	50	300	1.86
7	15	75	300	1.96
8	20	75	300	1.92
9	25	75	300	1.86
10	15	25	500	1.20
11	20	25	500	1.10
12	25	25	500	1.94
13	15	50	500	1.39
14	20	50	500	1.31
15	25	50	500	1.41
16	15	75	300	1.87
17	20	75	300	1.86
18	25	75	300	1.94
19	15	25	700	0.98
20	20	25	700	0.92
21	25	25	700	1.10
22	15	50	700	1.00
23	20	50	700	0.98
24	25	50	700	1.15
25	15	75	700	1.65
26	20	75	700	1.66
27	25	75	700	1.75
28	20	50	500	1.26
29	20	50	500	1.32
30	20	50	500	1.30
31	20	50	500	0.98
32	20	50	500	1.28

Table 4.3 Surface Roughness of Experiments with Abrasive Slurry:

Sr. no.	Speed RPM	Feed mm/m	Surface roughness with Slurry Concentration			Surface roughness
			15%	20%	30%	
1	300	25	1.65	1.59	1.73	1.66
2	300	50	1.77	1.73	1.86	1.78
3	300	75	1.96	1.92	1.86	1.91
4	500	25	1.20	1.10	1.94	1.41
5	500	50	1.39	1.31	1.41	1.37
6	500	75	1.87	1.86	1.94	1.89
7	700	25	0.98	0.92	1.10	1.00
8	700	50	1.00	0.98	1.15	1.04
9	700	75	1.65	1.66	1.75	1.68

Table 4.4 Comparision of Surface Roughness of Experiments with and without Abrasive Slurry:

Sr. no.	Speed RPM	Feed mm/m	Surface roughness		Percentage improvement
			with	without	
1	300	25	1.66	1.86	9.78
2	300	50	1.78	1.92	7.29
3	300	75	1.91	1.99	4.02
4	500	25	1.41	1.69	16.56
5	500	50	1.37	1.60	14.37
6	500	75	1.89	1.98	4.54
7	700	25	1.00	1.18	15.25
8	700	50	1.04	1.16	10.34
9	700	75	1.68	1.84	8.69

A. Regression equation for surface roughness

Regression equation for response function i.e. Surface roughness in terms of input parameters is given below. These model equation indicate the individual interaction and second order effect of input parameters.

B. Final Equation in Terms of Coded Factor

Surface roughness =
$+1.29+0.071*A+0.24*B0.27*C.072*AB+0.025*AC+0.11*BC+0.14*A^2 .22*B^2-.016*C^2$

C. Final Equation in Terms of Actual Factors:

surface roughness= -0.19760* slurry con-0.025038* feed-2.53808E-003* speed-5.80000E-004* slurry con * feed+2.50000E-005* slurry con * speed+2.15000E-005* feed * speed+5.70538E-003* slurry con^2+3.53548E-004* feed^2-3.92473E-007* speed^2

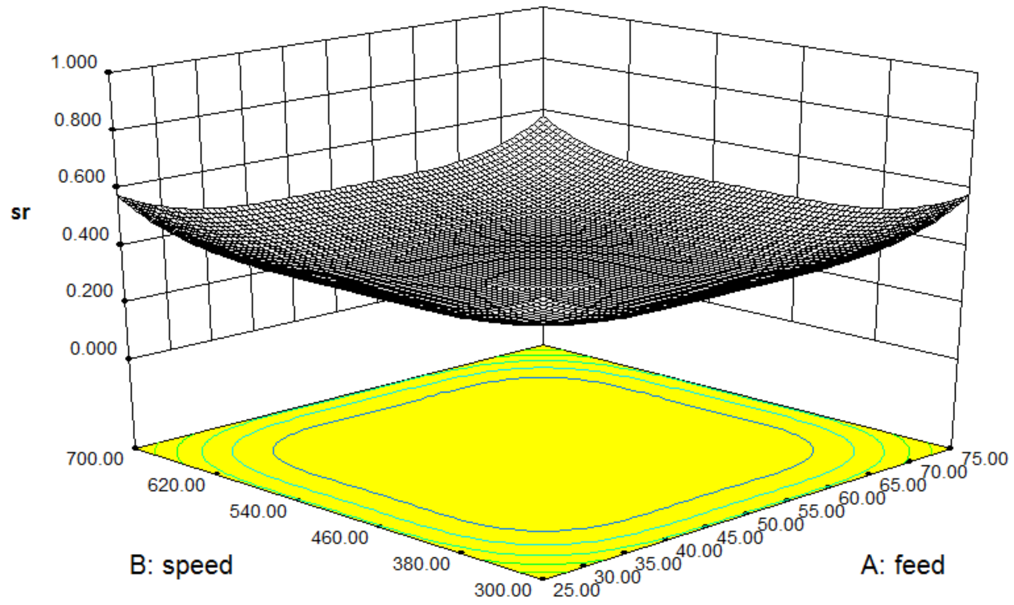

Fig 1 Surface response plot for surface roughness versus feed and speed

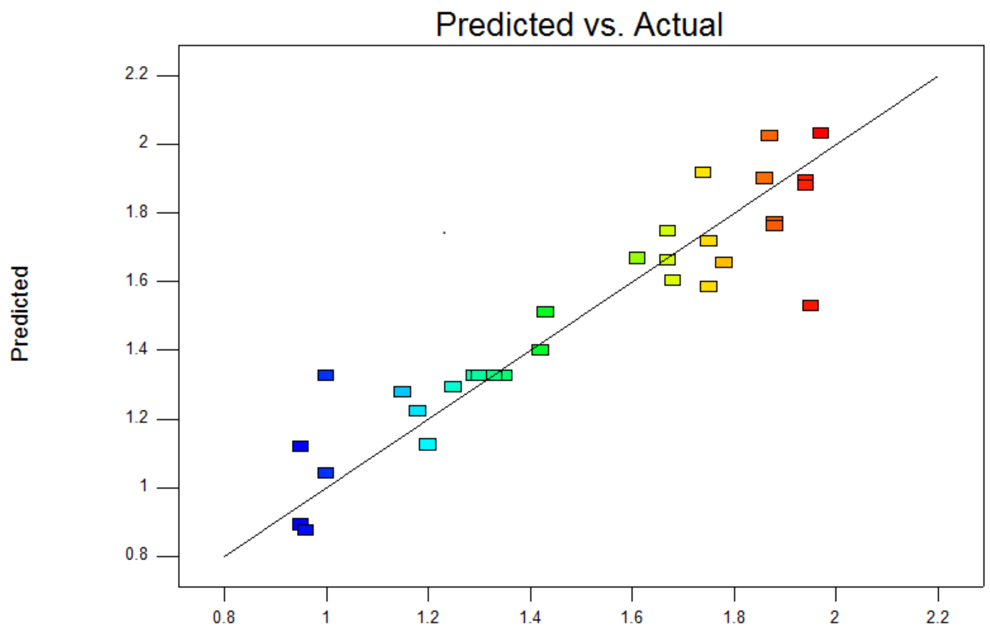

Fig 2 Predicted vs Actual surface finsh

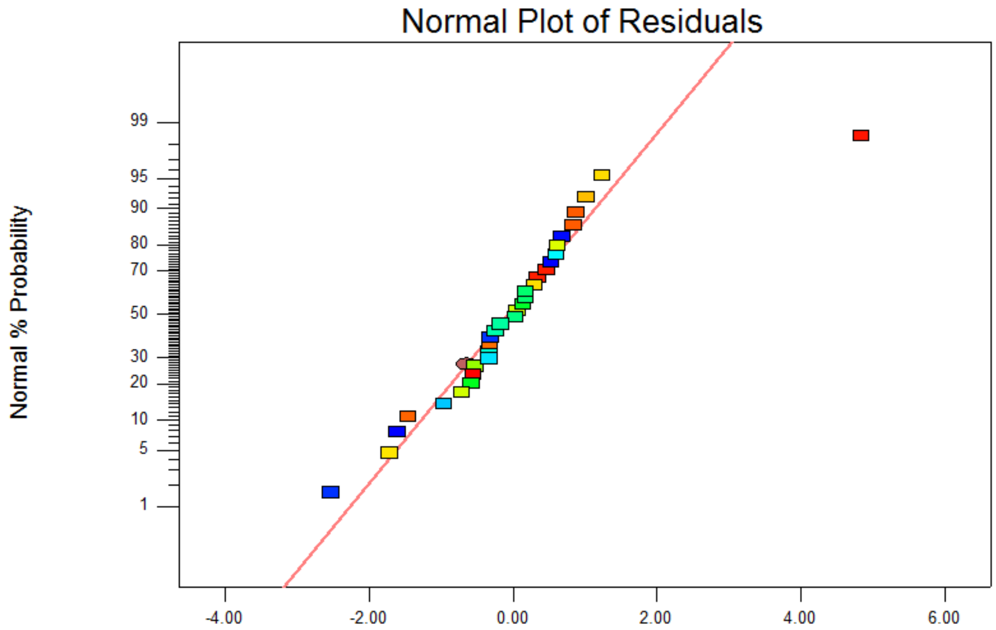

Fig 3 Normal plot of residuals

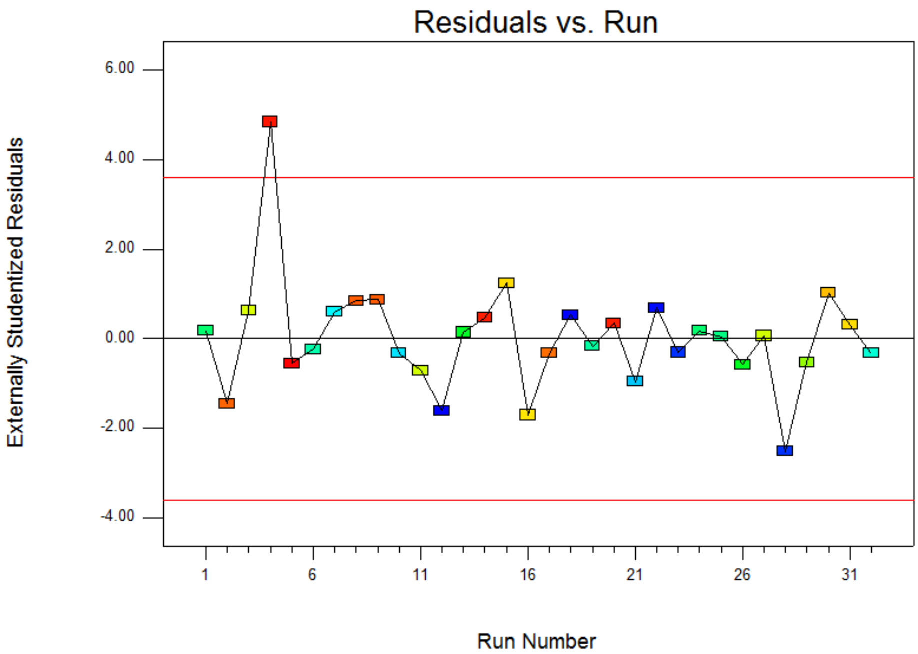

Fig 4 Residuals vs. Run

Average improvement = (14.37+7.29+4.54+16.56+9.78+8.69+4.02+10.34+15.25)/9

Average improvement =90.84/9

Average improvement = 10.09%

IV. CONCLUSION AND FUTURE SCOPE

In the present work drilling of stainless steel SS316 using abrasive slurry as dual functionality of a coolant and cutting fluid has been carried out. The concentration of silicon carbide abrasive has been varied from 15% to 25%. It has been observed that the surface roughness of drilled surface significantly improves through the use of abrasive particles. The overall improvements in the surface finish amounting to 10%. The use of abrasive in comparison to the plain coolant is very promising which will lead to huge savings in the cost and improve the quality. In the present investigation, the effect of the three input parameters i.e. speed, feed rate, and slurry concentration were studied Out of all selected parameters, speed and feed were significantly affecting the surface roughness of stainless steel SS316 in comparison to the slurry concentration. However, an overall improvement of 10% was observed in surface finish by using the abrasive slurry instead of only coolant. In future abrasive assisted drilling may be studied for other hard materials such as matrix materials composites. Study of other parameters like abrasive mesh size and different type of abrasives, depth of cut, material removal rate, burr height, tool wear etc. can also be studied.

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