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OPTIMIZATION OF CUTTING PARAMETERS FOR IMPROVING SURFACE ROUGHNESS OF STAINLESS STEEL D3 WITH ABRASIVE ASSISTED DRILLING

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Abstract— High strength, low thermal conductivity, high chromium and high work hardening tendency of Stainless Steel D3 are the main factor that makes them machinbility very difficult. This study is concerned with optimization of cutting parameters for improving the surface roughness of Stainless Steel D3 with Silicon Oxide and Alumina Oxide abrasives. The experimentation includes drilling of D3 steel with abrasives having mesh size of 1500, 1200, 800 with 35%, 25% and 20% slurry concentrations. Parameters such as abrasive size, abrasive type, slurry concentration, and spindle speed and feed rate is considered. For design of experiments Taguchi L18 array is used with MINI Tab 16 software and also analysis of variance is used for calculating the percentage contribution of each parameters. The result indicates that abrasive size and type of abrasive are the most significant factors which affect the surface roughness D3 steel.

Keywords — Surface roughness, Abrasive assisted drilling, D3 Steel, Analysis of variance, Taguchi, MINI Tab 16

1 INTRODUCTION

Drilling is the one of the basic fundamental operation for the removal of material removal rate particularly in metal pieces. Conventional and Non-conventional methods are available for drilling of D3 steel. The problem behind using these processes is a short tool life and poor surface finish of work piece (Kurl et.al, 2009). Drilling with non-conventional methods leads to lesser material removal and poor surface finish which in turns affects the production rate. Surface roughness is the most important factor in today's manufacturing industry (Sanjay and Jyothi, 2006). After Drilling, some other non-conventional finishing processes such as magnetic lapping and abrasive flow machining processes are used to improve the surface roughness of the materials (Walia et.al., 2007; Singh et.al, 2008; Gorana et.al., 2006;). These extra processes are time consuming and also increase the cost of the process which leads to lower productivity. This problem can solve by Abrasive Assisted Drilling.

Material D3 steel is hard steel. The chromium present in gives the better corrosion properties and provides hardness (Parikar et.al, 2012). The Steel used in industrial, architectural and transportation fields. Machining of D3 Steel gives poor surface finish, short tool lives, large cutting forces and larger power consumption due to their high temperature strength. Rapid work hardening is observed with most materials when cutting at high speeds (Sanjay and Jyothi, 2006). The above problems can be solved by using non-conventional machining processes. But limitation of non conventional machining is lesser productivity and more timing consuming process. Therefore a process modification is imparted in case of hard materials to improve the surface quality of the material.

Previous authors have developed some non-conventional methods such as Ultrasonic machining (USM), Electron Beam Machining (EBM), Electro Chemical Machining and Electron Discharge Machining (EDM) for drilling of hard materials. Researchers used many numerical and experimental techniques in order to find out the significant parameters in case of drilling. Kivak et al., (2012) using taguchi technique investigated the effect of drilling of AISI 316 steel with multilayer coated HSS drills and with PVD monolayer. The results indicate the surface roughness is mainly affected due to the tool used. Kilikap et al., (2011) uses response surface methodology for optimizing drilling parameters for AISI 1045 steel. Results indicate that feed rate and cutting speed were the important parameters while drilling of AISI 1045 steel. S Jayabal (2010) et al., studied the influence of cutting parameters on thrust force and torque while drilling of E-glass composites. Results show that 90degree point angle of tool gives better results for thrust force. Deepak Pal et al., (2012) studied the optimization of grinding parameters for minimum surface roughness by taguchi method. From results it is concluded that the surface roughness is decreases when the speed is changed from 100 to 160 rpm, similarly when grinding wheel grain's change from G46 to G60 surface roughness decreases.

From previous studies it is indicates that surface roughness of drilled work piece need to pay some attention. Also some additional processes for finishing increase the cost of the product. Previous research indicates that abrasives are generally uses in non conventional processes, so drilling with abrasives in conventional drilling method has not been studied much. In this paper effect of drilling parameters on D3 is studied. The factors such as type of abrasive, abrasive grain size, feed rate, rpm and rotational speed is trying to optimize with Taguchi method.

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2 EXPERIMENTATION

In abrasive assisted drilling is a machining process in which orthogonal cutting and abrasive machining together works to give final product. It consist of high speed drill bit with abrasive slurry is flowing around the rotating drill bit. Centrifugal force of rotating drill helps to scrub the abrasive particle with the walls of drilled hole. Because of centrifugal action the abrasive particles comes in contact with work piece and provide surface finish and removes the debris. The entire drilling experiments were performed on 3-Axis high speed vertical milling machine (Model No. VF3) with D3 steel as work piece material. Material composition is shown in Table 1 and 2. A standard HSS twist drill having 3-flute, right hand cut drill with a 30 helix angle and 118 point angle is used for drilling. The chemical composition of tool material is shown in Table 3. The process parameters type of abrasive, abrasive size , rotational speed, feed rate , slurry concentration are optimized with Taguchi method on Mini Tab 16 software. A total of 18 experiments are performed which is present in Table 4.

Table 1: Composition ranges for D3 Steel (Parikar et.al., 2012)

Elements	C	Mn	Si	Cr	Ni	W	V	P	S	Cu
Percentage	2.00-2.35	0.60	0.60	11.00-13.50	0.30	1.0	1.0	0.03	0.03	0.25

Table 2: Chemical Composition of HSS dills (Karnik et.al. 2008)

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

Table 3: Effects of process parameters on Ra data and S/N ratio

Experiment No.	Abrasive Type	Abrasive (Mesh Size)	RPM	SLUURY CONC. (%age)	FEED RATE (mm/min)
1	SILICON	800	1500	20	100
2	SILICON	800	2500	25	150
3	SILICON	800	3500	35	200
4	SILICON	1200	1500	20	150
5	SILICON	1200	2500	25	200
6	SILICON	1200	3500	35	100
7	SILICON	1500	1500	25	100
8	SILICON	1500	2500	35	150
9	SILICON	1500	3500	20	200
10	ALUMINA	800	1500	35	200
11	ALUMINA	800	2500	20	100
12	ALUMINA	800	3500	25	150
13	ALUMINA	1200	1500	25	200
14	ALUMINA	1200	2500	35	100
15	ALUMINA	1200	3500	20	150
16	ALUMINA	1500	1500	35	150
17	ALUMINA	1500	2500	20	200
18	ALUMINA	1500	3500	25	100

3 Results and Analysis

Surface roughness is measured using surface roughness tester. The average value of surface roughness and signal to noise ratio is shown in Table 5. The S/N ratio is obtained using Taguchi methodology. Here the term 'signal' represnts the desirable value (mean) and noise represents the undesirable value (standard deviation). Thus, the S/N ratio represents the amount of variation present in the performance characteristic For Ra, as the objective is to minimize the response, lower-the-better type S/N ratio was selected to transform the raw data. The values S/N for Ra as response is shown in Table 5.

Table 4: Factors Effect on S/N for Ra

S.No.	Ra 1	Ra 2	Ra 3	S/N1	MEAN1
1.	0.987	0.942	0.973	0.8097	0.9673
2.	0.804	0.8017	0.8119	1.8554	0.8058
3	0.980	1.040	1.115	0.0853	1.045
4.	1.390	1.343	1.356	-	1.363
5.	1.341	1.371	1.376	-	1.3626
6.	1.442	1.560	1.410	-	1.4706
7.	1.985	2.010	1.891	-	1.9620
8.	2.101	2.122	2.109	-	2.1106
9.	2.210	2.231	2.329	-	2.2566
10.	1.210	1.205	1.188	-	1.2010
11.	1.132	1.134	1.155	-	1.1403
12.	1.120	1.114	1.141	-	1.1125
13.	1.714	1.764	1.671	-	1.7163
14.	1.652	1.631	1.554	-	1.6123
15.	2.005	1.997	1.994	-	1.998
16.	2.150	2.205	2.127	-	2.160

17.	2.110	2.110	2.121	-	2.113
18.	2.187	2.183	2.152	-	2.174

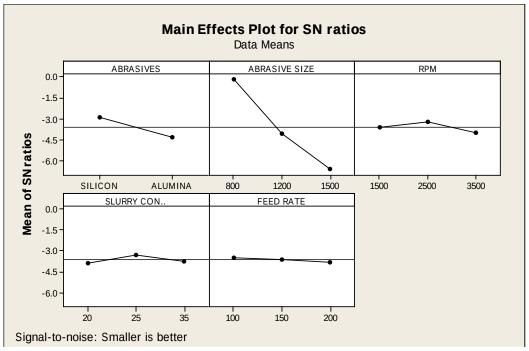

Table 5: Anova Result for Ra

Source	D.O.F	SS	MS	F	P	Percentage Contribution
Abrasive Size	2	3.74191	1.87086	165.64	0.000	87.5045
Type of abrasive	1	0.21214	0.21210	18.70	0.001	7.08382
Rpm	2	0.06003	0.03001	0.72	0.491	1.33865
Slurry Conc.…	2	0.03237	0.016162	0.01	0.914	0.8787
Feed Rate	2	0.01261	0.006301	0.12	0.852	0.40162
Error	8	--------	----------	------	------	2.80171
TOTAL	17	4.0597				100

Table 6: Factors Effect on S/N for Ra

Level	Abrasive	Abrasive Size	Rpm	Slurry Concentration	Feed Rate
1.	-2.7043	-0.1609	-3.5102	-3.8530	-3.4567
2.	-4.2244	-4.0601	-3.2247	-3.2640	-3.5760
3.	………	-6.6213	-4.0086	-3.7264	-3.8058
Delta	1.4198	6.4610	0.7839	0.5891	0.3475
Rank	2	1	3	4	5

From graphs of SN ratios the value of silicon abrasives shows better results of surface finish as compared to alumina. With an increase in abrasive size and increase in RPM value the value of SN ratios start decreasing. Rpm and Slurry concentration is also affecting the surface finish of the material. From graphs it is found that at 2500 rpm at 25% slurry concentration the best surface finish is obtained. Feed Rate is showing very mild effect on material as seen from Table 6. From Analysis of variance the percentage of each factor is calculated. The percentage of abrasive size is 87.50%, type of abrasive is 7.08382%, and rpm is 1.33%.

4 Conclusion

The preliminary experiments are carried out to find the optimum minimum value of surface roughness in case of slurry silicon and alumina, slurry of silicon and water and slurry of alumina and water. The best results are comes out to be with a abrasive size of 800, slurry is of silicon, feed rate of 150mm/min with 1500 rpm with a slurry concentration of 25%..

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