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Study on Effectiveness of HSS and HSS-Cobalt Twisted Drills on Surface Roughness

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ABSTRACT

This paper focuses on the optimization of drilling parameters by using Taguchi method for achieving maximum Material Removal Rate (MRR) and minimum Surface Roughness (Ra). The experiments were carried out on material EN8, medium carbon steel using HSS and HSS-Cobalt drills. Four cutting parameters such as Drill Type (HSS, HSS-Cobalt), Point Angle (90º, 118º, 135º), feed rate (90, 240, 450 mm/min), speed (900, 1200, 1500 RPM) were considered as the control factors. The signal-to-Noise (S/N) Ratios and the analysis of variance (ANOVA) have been employed to determine the effectiveness of parameters on the responses. The results revealed that feed rate was the most significant factor for material removal rate and Drill–type was for surface roughness. The models predicted for the responses were found to be best fit and accurate for the future predictions.

Keywords: *EN 8 Steel; Material Removal Rate (MRR); Surface Roughness (Ra); Taguchi Method; Analysis of Variance (ANOVA).*

1.0 Introduction

Drilling is one of the oldest and the most widely used of all machining processes, comprising about one third of all metal machining operations. It is used to create or to enlarge a hole in a work piece by the relative motion of a cutting tool, called a drill or drill bit. The choice of a drilling method depends on the size, tolerance and surface finish needed, as well as the production requirements. Several factors influence the quality of drilled holes. The most obvious ones are the cutting conditions (cutting speed and feed rate) and cutting configurations (tool material, diameter, and geometry).

Turgay Kivak, et al., discussed the effect of cutting parameters on the hole quality (circularity and hole diameter) and tool wear during the drilling of super alloy Inconel 718 with coated and uncoated carbide drills was investigated. Drilling tests were carried out with uncoated and TiN and TiAlN coated carbide drills of 5mm diameter using a CNC vertical machining center under dry cutting conditions by drilling blind holes of 8mm depth and employing four different cutting speeds (10, 12.5, 15, 17.5 m/min) and three different feed rates (0.05, 0.075, 0.1 mm/rev). It was observed that there was a decrease of tool performance and hole quality at high cutting speed and feed rate combinations. A serious increase in tool wear was observed when increasing cutting speed. The Utmost wear type was seen in the form of flank wear and chisel edge wear. B. P. Patel et. al studied experimentally the cutting parameters required to optimize the Geometric dimensions and tolerancing (GD&T) requirements such as perpendicularity. This paper reports an experimental investigation of a full factorial design performed on EN8 and EN31 materials using HSS drill with point angle 118° and helix angle 30° by varying the drilling parameters such as spindle speeds, feed and coolant ratio to determine optimum cutting conditions. The work piece Geometric dimensions and tolerancing (GD&T) requirements analyzed by perpendicularity. Analysis of variance (ANOVA) was carried out for perpendicularity on EN8 and EN31 materials and their contribution rates were determined. Design of Experiments (DOE) methodology by full factorial Design was used in the multiple objective optimizations (using Mini Tab 16, software) to find the optimum cutting conditions for least perpendicularity defect. J.Patel etc. all have studied the effect of drilling parameter such as spindle speed , feed rate and coolant ratio for

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obtaining optimum perpendicularity for materials EN8, EN24 & EN31 as a work piece materials using cobalt alloy steel drill with point angle 135° and helix angle 30°.This study shows that how significant the drilling parameter are for obtaining optimum perpendicularity . Analysis of variance (ANOVA) was carried out for perpendicularity and their contribution rates determined optimum cutting conditions for least perpendicularity defect obtained by using design of experiments (DOE) methodology for achieving optimization using Minitab 16 software.

2.0 Experimentation Details

2.1 Selection of work piece

The work piece of EN8 steel (40HRC) having dimensions of 200 mm * 175 mm * 25 mm has been considered for the experimentation. The selected material is a medium carbon steel having chemical compositions of Carbon (C): 0.36-0.44, Silicon (Si): 0.10-0.40, Manganese (Mn): 0.60-1.00, Sulphur (S): 0.05 max, Phosphorus (P): 0.05 max. It has a very wide range of industrial applications such as in automobile parts, connecting rods, shafts, gears, keys, studs & bolts, axels & spindles etc. The work piece with holes is shown in figure 1.

Figure 1: Work Piece after Machining

2.2 Experimental design as per taguchi method

Based on taguchi method for the selected drilling process parameters given in the table 1, L18 Orthogonal Array (OA) has been chosen. The design given in table 2 has been followed for making holes on the work piece by using HSS and HSS- Cobalt twisted drills.After conducting the experiments the results of Material Removal Rate (MRR) and Surface Roughness (R_a) were measured.

Table 1: Process Parameters and Their Levels

Parameter	Level-1	Level-2	Level-3
Drill Type	HSS	HSS-Cobalt	-
Point angle	90	118	135
Feed, mm/min	90	240	450
Speed, RPM	900	1200	1500

Table 2: L18 OA of Process Parameters

S. No.	Drill Type	Point Angle	Feed	Speed
1	HSS	90	90	900
2	HSS	90	240	1200
3	HSS	90	450	1500
4	HSS	118	90	900
5	HSS	118	240	1200
6	HSS	118	450	1500
7	HSS	135	90	1200
8	HSS	135	240	1500
9	HSS	135	450	900
10	HSS-Cobalt	90	90	1500
11	HSS-Cobalt	90	240	900
12	HSS-Cobalt	90	450	1200
13	HSS-Cobalt	118	90	1200
14	HSS-Cobalt	118	240	1500
15	HSS-Cobalt	118	450	900
16	HSS-Cobalt	135	90	1500
17	HSS-Cobalt	135	240	900
18	HSS-Cobalt	135	450	1200

3.0 Results and Discussions

Table 3: Experimental Results & S/N Ratios

S.No.	Responses		S/N Ratios of Responses	
	MRR	R_a	MRR	R_a
1	7.0629	2.44	16.9797	-7.74780
2	18.8797	1.89	25.5199	-5.52924
3	35.0623	2.57	30.8968	-8.19866
4	7.0629	1.67	16.9797	-4.45433
5	18.8797	1.57	25.5199	-3.91799
6	35.0623	2.99	30.8968	-9.51342
7	9.4399	2.90	19.4993	-9.24796
8	23.6565	1.55	27.4790	-3.80663
9	21.1128	2.13	26.4909	-6.56759
10	11.7574	1.79	21.4062	-5.05706
11	14.1258	2.60	23.0003	-8.29947
12	28.4564	0.85	29.0836	-1.41162
13	9.4399	2.91	19.4993	-9.27786
14	23.6565	1.96	27.4790	-5.84512
15	21.1128	1.15	26.4909	-1.21396
16	11.7574	1.33	21.4062	-2.47703
17	14.1258	1.78	23.0003	-5.00840
18	28.4564	2.12	29.0836	-6.52672

The experimental results of Material Removal Rate and Surface Roughness are given in the table 3. Taguchi's Signal-to-Noise (S/N) Ratios concept and Analysis of Variance (ANOVA) were employed to analyse the affect the process parameters on the responses.

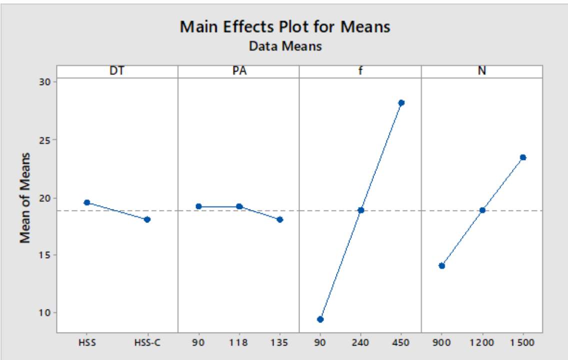
3.1 Taguchi and main effect plots analysis

The taguchi method has been employed for the analysis using MINITAB-17 Software. The Response table for means of material removal rate and surface roughness are given in the tables 4 and 5.The main effect plots were drawn for the mean values of responses and shown in figures 2 and 4. The variation of the output characteristics with respect to change in process parameters has been observed and the optimal combination of process parameters which provides desired output is found. The interaction effect among the process parameters has been observed with the interaction effect plots shown in figures 3 and 5 for the two responses respectively.

Table 4: Response Table for Means of MRR

Level	DT	PA	f	N
1	19.580	19.224	9.420	14.100
2	18.099	19.202	18.887	18.925
3		18.091	28.211	23.492
Delta	1.481	1.133	18.790	9.392
Rank	3	4	1	2

Figure 2: Main Effect Plot for Means of MRR



The optimal condition for achieving maximum material removal rate is:

- Drill-Type at level 1(HSS)
- Point angle at level 2(118°)
- Feed at level 3(450 mm/min)
- Speed at level 3(1500 RPM)

Figure 3: Interaction Plots for MRR

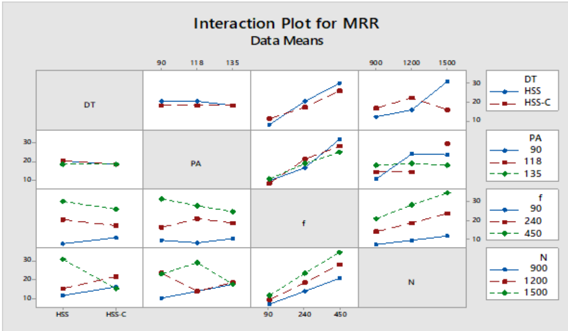


Table 5: Response Table for Means of Ra

Level	DT	PA	f	N
1	2.190	2.023	2.173	1.962
2	1.832	2.042	1.892	2.040
3		1.968	1.968	2.032
Delta	0.358	0.073	0.282	0.078
Rank	1	4	2	3

Figure 4: Main Effect Plot for Means of Ra

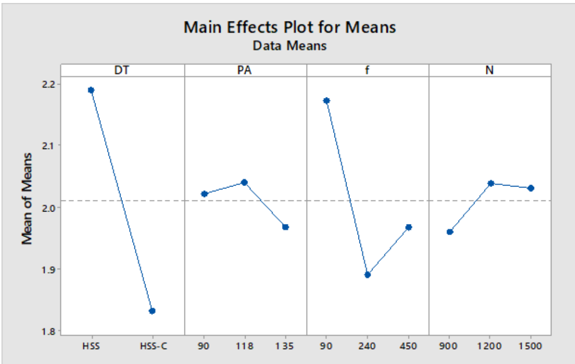
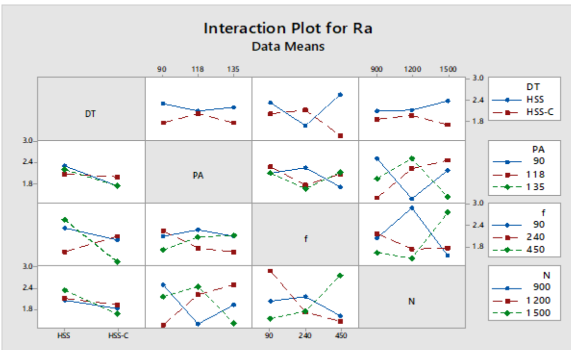


Figure 5: Interaction Plots for Ra



The optimal condition for achieving minimum Surface Roughness is:

- Drill-Type at level 2(HSS-C)
- Point angle at level 3(135º)
- Feed at level 2(240 mm/min)
- Speed at level 1(900 RPM)

3.2 Analysis of variance (ANOVA)

Analysis of variance is carried out to find the relative importance of process variables on the responses. From the table6 for MRR, it is observed that feed is the most significant parameter and followed by speed. Similarly from table 7 for R_a, it is found that Drill-type has the highest significance and feed has the lowest significance over the responses. The models developed are best fit and accurate as they following the normality and constant variance as shown in figures 6 and 7.

Table 6: ANOVA Results of MRR

Source	DF	Adj SS	Adj MS	F	P
DT	1	9.87	9.872	3.52	0.090
PA	2	5.03	2.517	0.90	0.438
f	2	1059.26	529.631	188.71	0.000
N	2	264.67	132.336	47.15	0.000
Error	10	28.07	2.807		
Total	17	1366.91			

Table 7: ANOVA Results of Ra

Source	DF	Adj SS	Adj MS	F	P
DT	1	0.57602	0.576022	1.00	0.341
PA	2	0.01748	0.008739	0.02	0.985
f	2	0.25448	0.127239	0.22	0.805
N	2	0.02221	0.011106	0.02	0.981
Error	10	5.75199	0.575199		
Total	17	6.62218			

Figure 6: Residual Plots for MRR

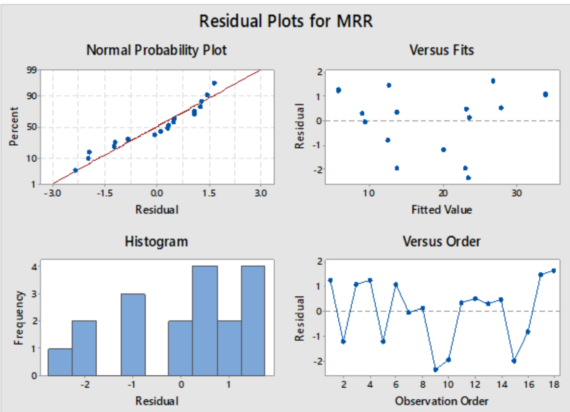
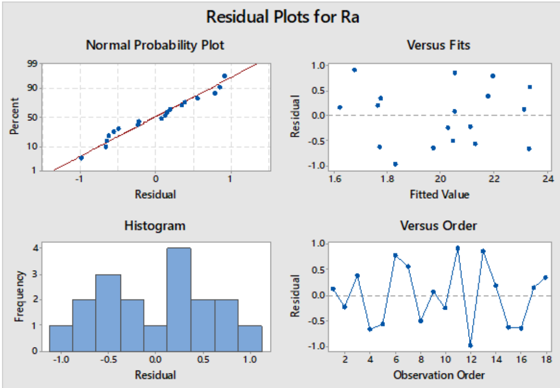


Figure 7: Residual Plots for Ra



4.0 Conclusions

From the experimental and empirical results the following conclusions can be drawn:

- The optimal combination for MRR is: Drill-Type at level 1(HSS), Point angle at level 2(118º), Feed at level 3(450 mm/min), Speed at level 3(1500 RPM).
- The optimal combination for R_a is: Drill-Type at level 2(HSS-C), Point angle at level 3(135º), Feed at level 2(240 mm/min), Speed at level 1(900 RPM).
- ANOVA results revealed that Speed and Drill-Type has the most dominant factors for Material Removal Rate and surface Roughness respectively.
- The residual plots predicted that the residuals are following the normality and constant variance hence they are fit and accurate for the future predictions of responses.

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