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An Experimental Investigations on Machining Parameters in Micro-drilling Process

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Abstract

Under various fundamental machining process Drilling is one of them. For getting holes below 1mm Micro Drilling process which is high precision process are preferred. It is used for the purpose increasing quality of special parts and items. Along with high precision it is also preferred for high spindle speed application to improve productivity and quality. It has an attractive applications like Printed circuit boards, Fuel injection nozzles, Watch parts, Camera parts, Medical needles, Aeronautics, Mobilephones, Computerset. One of the major goal in machining operation is material Removal Rate . This paper deals with how the MRR can be optimized considering the input parameters like, speed, feed and depth of hole and Investigation had done by Designing Experiment in Taguchi and Analyzing using ANNOVA and signal to noise ratio. Taguchi method not only optimize quality characteristics through the setting of design parameters, but also reduce the sensitivity of the system performance to sources of variation

Keywords: Micro-drilling, Cutting tool, Material removal rate, Taguchi, ANNOVA**.**

INTRODUCTION

In current scenario micro drillings have a great influence for manufacturing to apply special parts and items. The micro drill tools play a critical role is increasing the productivity of a cutting process. The price of a micro-drill cutting tool itself is relatively low, the costs caused by tool failures are considerably higher[1]. Micro drilling is characterized not just by small drills but also a method for precise rotation of the micro drill and a special drilling cycle[7]. In addition, the walls of a micro drilled hole are among the smoothest surfaces produced by conventional processes. Taguchi method is a well known experiment design method applied in many industries to optimize quality characteristics through the setting of design parameters with orthogonal array, followed by Analysis of variance to find influence and Significant factors on MRR.[2]

Many researchers had worked on Micro-drilling for analyzing behavior of drill tool , torques, thrust forces, stresses etc. also optimization works are carried out but the drill diameters considered were from 0.6mm to 1mm. while below that the process had carried out on Non-conventional machining processes[20]. But this research had done the investigations on two size drill i.e. 0.3mm and 0.5mm drill diameters. Here the conventional tool was used but machine used was CNC Micro-drilling with high spindle speed for a work piece material Brass.

DESIGN OF EXPERIMENT

Design of Experiment was done by Taguchi method, which is a robust design method technique, which provides a simple way to design an efficient and effective experiment. In order to efficiently reduce the conventional experimental tasks, the orthogonal array by using design parameters are proposed and adopted. The performance measure, signal-to-noise ratio(S/N) used to obtain the optimal parameter combinations.[3] In the Taguchi method, a loss function is defined to calculate the deviation between the experimental value and the desired value. Usually, there are three categories of the performance characteristics in the analysis of the signal-to-noise ratio, i.e., the lower the-better, the higher the- better, and the nominal-the better. To obtain optimal machining performance, the MRR should be more than medium and less than higher so nominal the better is desired optimum value . Therefore, nominal-the better MRR was selected. This method, the S/N ratio is used to determine the deviation of the performance characteristic from the desired value. [4] Orthogonal array is a systematic statistical way of software testing It is used when the number of inputs to the system is relatively small, but too large to allow for exhaustive testing of every possible input to the systems.. Orthogonal arrays formed for three levels for two different drill diameters i.e. 0.3mm and 0.5mm.Which is given in table no.1 Design of Experiment was done in most powerful tool i.e. MINITAB 17.[19]

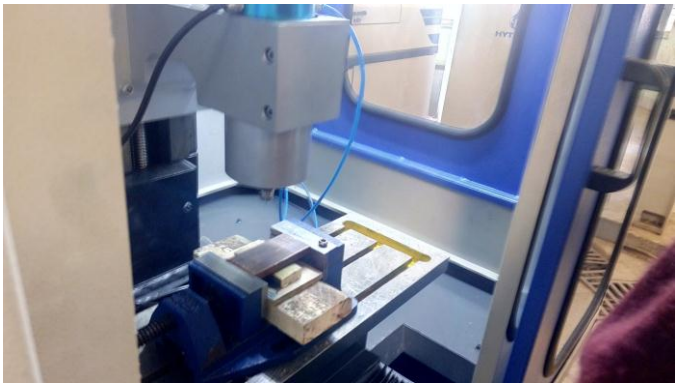

Figure 1: CNC Micro-drilling Machine

EXPERIMENTATION

After designing the experiment ,actual experiment was carried out on CNC Microdrilling machine (fig no.1) before that Machining time was calculated for each experiment and each experiment was conducted three times , that means three readings of Material removal Rate was measured. Machining time and MRR were calculated as follows,

$$MT = \frac{DOH}{Speed \times Feed} \quad \text{---------- (1).}$$

$$MRR = \frac{Initial\ weight - Final\ weight}{Density \times Machining\ time} \quad \text{----------(2).}$$

The values of both were recorded in the table given below.

Table 1

Parameters	Level 1	Level2	Level3
Speed(RPM)	12000	18000	24000
Feed(mm/rev)	0.0003	0.0004	0.0005
Depth of hole(mm)	**2**	**2.5**	**3**

Table 2

Drill dia	Speed	Feed	DOH	MT	MRR1	MRR2	MRR3	Mean MRR
0.3	12000	0.0003	2	0.555556	0.252	0.2534	0.2541	0.253167
	12000	0.0004	2.5	0.520833	0.342	0.3385	0.33912	0.339873
	12000	0.0005	3	0.5	0.4239	0.4235	0.4229	0.423433
	18000	0.0003	2.5	0.462963	0.3791	0.38151	0.3813	0.380637
	18000	0.0004	3	0.416667	0.51	0.509	0.50868	0.509227
	18000	0.0005	2	0.222222	0.63585	0.64	0.63499	0.636947
	24000	0.0003	3	0.416667	0.507	0.50868	0.50755	0.507743
	24000	0.0004	2	0.208333	0.669	0.67529	0.67824	0.674177
	24000	0.0005	2.5	0.208333	0.8478	0.84541	0.8468	0.84667
0.5	12000	0.0003	2	0.555556	0.7065	0.712	0.7012	0.706567
	12000	0.0004	2.5	0.520833	0.942	0.94	0.9441	0.942033
	12000	0.0005	3	0.5	1.1775	1.198	1.1677	1.181067
	18000	0.0003	2.5	0.462963	1.05975	1.0614	1.05789	1.05968
	18000	0.0004	3	0.416667	1.413	1.49	1.402	1.435
	18000	0.0005	2	0.222222	1.76625	1.77	1.759	1.765083
	24000	0.0003	3	0.416667	1.413	1.421	1.431	1.421667
	24000	0.0004	2	0.208333	1.884	1.91	1.912	1.902
	24000	0.0005	2.5	0.208333	2.355	2.365	2.3579	2.3593

ANALYSIS

After performing experimentation task , analysis of Signal to Noise Ratios was done for both drill diameter where optimization was done for nominal-the-better given in table no4 and table no,6 for diameter 0.3mm and 0.5mm respectively. After that Analysis of variance(ANNOVA) technique was carried out from which maximum influencing factor and significant factors were sort out[15]. It is quite clear from table no 4 and 6 that influence of Speed from F value is more on MRR and also more significant as P value is low and below 0.5. Accordingly the surface plot shown from fig no.3 to 5 and fig 7 to 9.

Analysis for Signal to noise ratio for Drill diameter 0.3mm

Response Table for Signal to Noise Ratios

Nominal is best (-10×Log10(s^2))

Table 3

Level	Speed	Feed	DOH
1	59.99	59.42	52.46
2	**57.39**	54.78	**56.83**
3	55.43	**58.61**	63.52
Delta	4.56	4.64	11.06
Rank	3	2	1

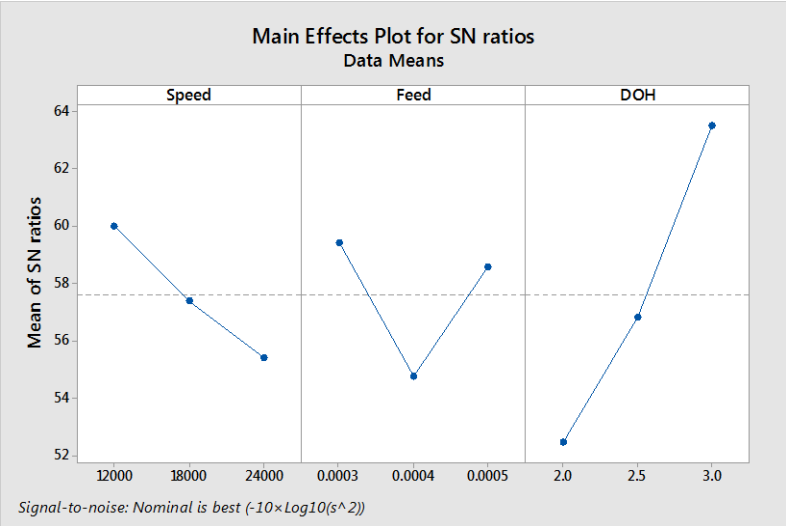

Figure 2

From above level 2 for speed ,level 3 for feed and level 2 for DOH are the optimized values of respective parameters ,which are 18000 ,0.0005 and 2.5.

Predicted values

S/N Ratio

-3.91407

Factor levels for predictions

Speed Feed DOH

18000 0.0005 2.5

ANNOVA

General Linear Model: Mean MRR versus Speed, Feed, DOH Analysis of Variance

Table 4

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed	2	0.170734	0.085367	47.06	0.021
Feed	2	0.097666	0.048833	26.92	0.036
DOH	2	0.003492	0.001746	0.96	0.510
Error	2	0.003628	0.001814		
Total	8	0.275520			

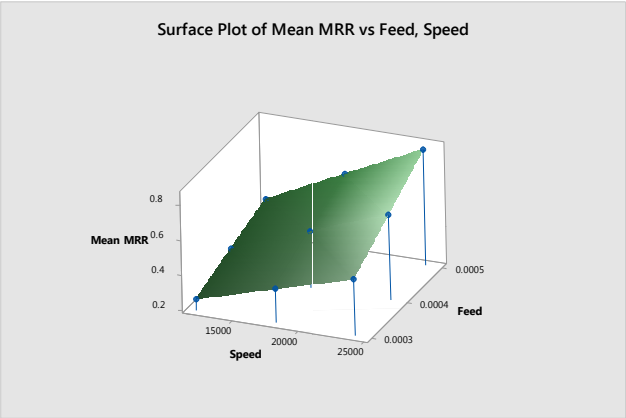

Figure 3

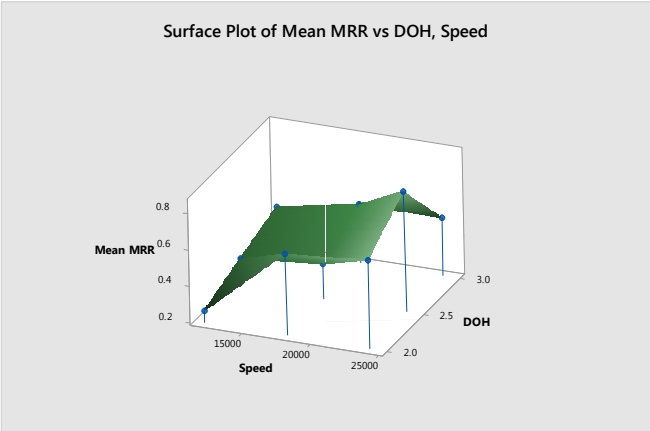

Figure 4

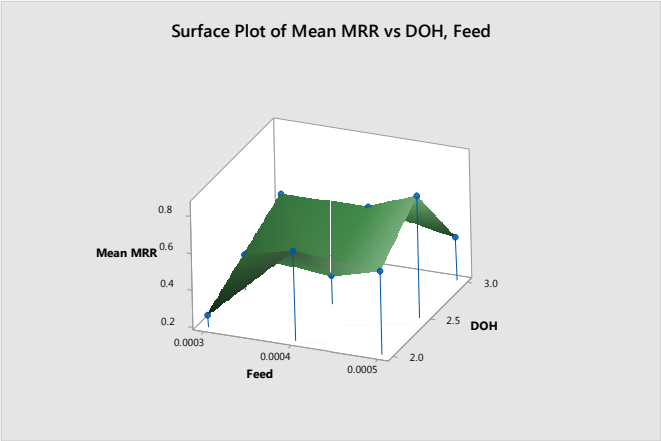

Figure 5

Analysis for Signal to noise ratio for Drill dia -0.5mm

Response Table for Signal to Noise Ratios

Nominal is best (-10×Log10(s^2))

Table 5

Level	Speed	Feed	DOH
1	45.11	47.12	**42.18**
2	**42.18**	38.76	51.55
3	40.93	**42.35**	34.50
Delta	4.18	8.36	17.05
Rank	3	2	1

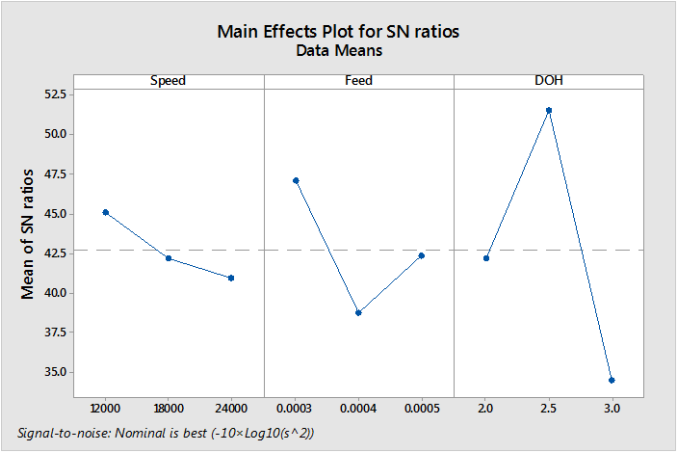

Figure 6

From above level 2 for speed ,level 3 for feed and level1 for DOH are the optimized values of respective parameters ,which are 18000 ,0.0005 and 2.Experiment no 15 contains these values.

So the MRR value is 1.76 mm^3/min

ANNOVA

General Linear Model: Mean 1MRR versus Speed, Feed, DOH Analysis of Variance

Table 6

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed	2	1.35689	0.67844	45.76	0.021
Feed	2	0.74756	0.37378	25.21	0.038
DOH	2	0.02417	0.01208	0.81	0.551
Error	2	0.02965	0.01483		
Total	8	2.15827			

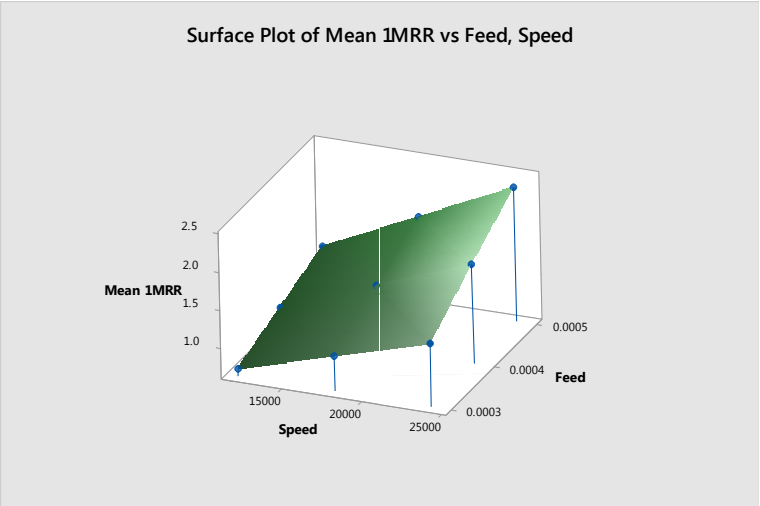

Figure 7

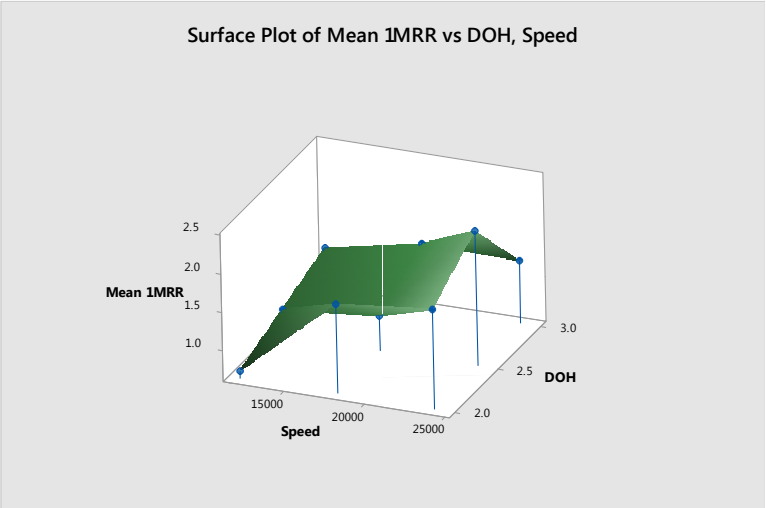

Figure 8

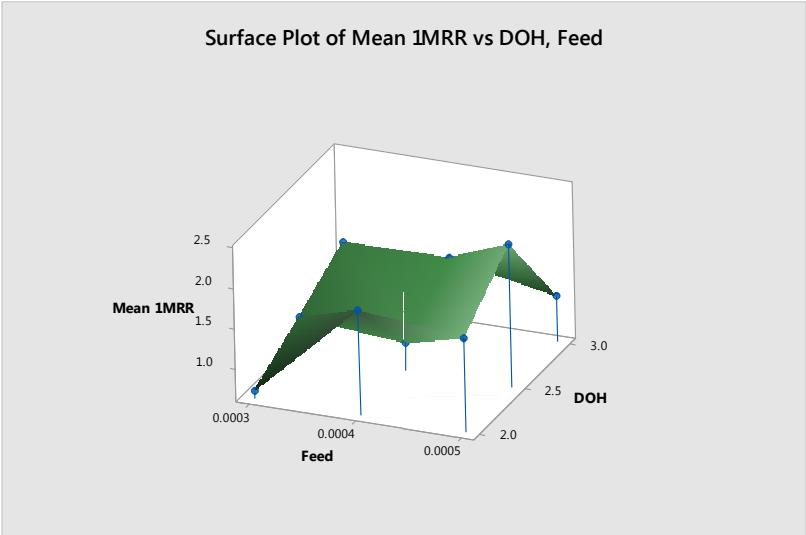

Figure 9

CONFIRMATION TEST

For Drill diameter 0.3 mm the confirmation test was carried out, taking Speed as 18000 RPM , Feed as 0.0005 mm/rev and DOH as 2.5mm.After conducting experiment for concern values ,we get the MRR as 0.636 mm^3/min. For drill diameter 0.5mm ,already the combination of Speed as 18000 , Feed as 0.0005 mm/rev and DOH 2 mm was available in Design of Experiment, which was already conducted and MRR was 1.76 mm^3/min.

RESULTS AND DISCUSSIONS

Confirmation test for drill diameter 0.3mm was successfully run on machine, we got the results for both diameters which are given in table no.7. It is quite clear that MRR as compared to the bench mark parameters, which is medium and intermediate node between two extremities of high and low. MRR obtained by Experimental method through Taguchi are greater or improved than obtained from benchmark parameter and also it was not at highest point. So we get the Optimum value of Material Removal Rate.

Result table

Table 7

Drill Dia	Bench mark	level	Experimental	level
0.3 mm	18000	A2	18000	A2
	0.0004	B2	0.0005	B3
	2.5	C2	2.5	C2
MRR	0.50 mm^3/min		0.63 mm^3/min	
0.5mm	18000	A2	18000	A2
	0.0004	B2	0.0005	B3
	2.5	C2	2	C1
MRR	1.41 mm^3/min		1.76 mm^3/min	

CONCLUSION

This type of optimization is a difficult method .As this work not only optimization using orthogonal array, but will also be used for improving material removal rate in Micro drilling, where drilling is very risky because of chances of breaking tool. Therefore instead of considering to optimize for maximum MRR , form tool life point of view the method in Taguchi was selected Nominal–the-better. Also minimum or medium MRR is not considered which may decrease production rate. Many Researchers had gone optimization to maximize the output which was not feasible for Micro-drilling. Going for Non-conventional machining would feasible from production point of view but not from investment cost which more botheration for small scale industries. The competition of small scale manufacturing industry will then be economically excited through this paper.

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