MATEC Web of Conferences **78**, 01036 (2016) DOI: 10.1051/matecconf/20167801036
IConGDM 2016

An experimental result of surface roughness machining performance in deep hole drilling

Azizah Mohamad[1,*], *Azlan* Mohd Zain[1], *Noordin* Mohd Yusof[2], and *Farhad* Najarian[2]

[1] Soft Computing Research Group, Faculty of Computing, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia
[2] Department of Materials, Manufacturing and Industrial Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

Abstract. This study presents an experimental result of a deep hole drilling process for Steel material at different machining parameters which are feed rate (*f*), spindle speed (*s*), the depth of the hole (*d*) and MQL, number of drops (*m*) on surface roughness, R_a. The experiment was designed using two level full factorial design of experiment (DoE) with centre points to collect surface roughness, R_a values. The signal to noise (S/N) ratio analysis was used to discover the optimum level for each machining parameters in the experiment.

1 Introduction

Deep hole drilling is a complex machining process in which the ratio of hole depth to hole diameter exceeds 10 [5]. Deep hole drilling is a relatively complex drilling production process due to the high hole diameter to length ratio which makes the tool shaft prone to vibration and results typically in low quality holes from geometry and surface roughness viewpoints [1]. Deep hole drilling processes are used to generate drill holes with a high length to diameter ratio. A good holes, which are holes with better straightness, better roundness and smoother surface roughness, there are many factors need to be considered such as material, spindle speed, feed rate and tool diameter [9]. According to Hayajneh (2001), the important machining parameters that effect hole quality is spindle speed and feed rate [6]. Surface roughness, R_a is an important aspect in evaluating the quality of products. R_a is widely used as an index of product quality and in most cases a technical requirement for mechanical products [3, 12]. Normally, R_a value is influenced by many factors such as machining parameters, cutting phenomena, workpiece properties and cutting tool properties [15, 16]. Based on previous literature, R_a is one of the machining performance measurements frequently considered by researchers [4, 11, 13, 14].

This study focuses on an experimental result of R_a in the deep hole drilling process. The flow of the experiment and analysis of result also discussed.

[*] Corresponding author: azizahbtmohamad@yahoo.com.my

2 Experimental procedure and equipment

The deep hole drilling experiment was carried out at Production Laboratory using CNC 3 Axis Milling Machine (MAHO MH500E2). Figure 1 shows the CNC 3 Axis Milling Machine. This machine was used to produce the holes on the steel for conducting the deep hole drilling process.

Fig. 1. CNC 3 Axis Milling Machine.

The tool used for this study is High Speed Steel, (HSS) with twist drill bits and workpiece material is Steel. The HSS diameter is 5.0 mm and the illustration of HSS is shown in Figure 2. Table 1 shows the mechanical properties of the HSS based on the book catalogue of Drilling Tools (YG-1 Drilling Tools Catalog 2009/2010).

Fig. 2. HSS with twist drill bit.

Table 1. Mechanical properties of the HSS used in the experiment.

Characteristics	Properties
Standard	DIN 1869/1
Tool materials	HSS Co5 (Cobalt 5% is used in the tool material)
Helix angle	38°
Tolerance of toll diameter	H8
Point angle	130°
Drill diameter, d1	5.0 mm
Overall length,L1	195 mm
Flute length, L2	135 mm

3 Deep hole drilling parameters and experimental design

Design of experiment (DoE) is a collection of powerful statistical analysis techniques used for modelling, developing, improving, and optimizing various manufacturing and other useful processes [1]. It also for structuring and organizing method for determining the relationship between input parameters, which affect the process and the output of the process. DoE is an important step in the selection of machining parameters and their levels within an effective and suitable experimental run [4].

The Two Level Full Factorial Design with centre points is used as DoE in this study. Twenty experimental numbers were executed, which consists of sixteen data of two levels, which 2^k full factorial analysis where k is referred to number of machining parameters involved in these experiments with four centre points.

In this study, there are four machining parameters that had been put into consideration which is feed rate, f (mm/min), spindle speed, s (rpm), depth of hole, d (mm) and MQL, number of drops m (ml/hour). The machining parameters and their levels are shown in Table 2. The R_a value of the machined work piece was measured using the Handysurf Profile Meter.

Table 2. Levels of machining parameters for deep hole drilling.

Machining parameters	**Units**	**Level**		
		-1 (LOWER)	**0 (CENTER POINT)**	**+1 (UPPER)**
Feed rate, f	mm/min	65	75	85
Spindle speed, s	rpm	900	1000	1100
Depth of hole, d	mm	50	55	60
MQL, number of drops, m	ml/hour	20	30	40

Full Factorial Design is used widely because they are easy to design and analyse, efficient to run and full of information [7]. Then it is simplest and most common type of factorial design [2].

4 Results and discussion

The experimental results for R_a along with their computed S/N ratio values are shown in Table 3.

From the table, the minimum value obtained is 2.8 µm. The optimal values of machining parameters that contribute to minimum R_a are 85 mm/min for feed rate which in level +1, 1100 rpm for spindle speed which in level +1, 60 mm for depth of the hole which in level +1 and 40 ml/ hour for number of drops of MQL which in level +1. The lower the better (LB) category of S/N ratio has been selected for R_a and used to identify the optimal level of machining parameters [8]. The calculation of LB category can be referred in Eq.1.

$$S/N_{LB} = -10 \log \left(\frac{1}{n}\sum_{i}^{n} {y_i}^2\right) \quad (1)$$

where,
y_i= the observed data (R_a)
n= the number of observations

Table 3. Experimental results for R_a and S/N ratio.

Exp No.	Feed rate, *f* (mm/min)	Spindle speed, *s* (rpm)	Depth of hole, *d* (mm)	MQL, number of drops, *m* (ml/hour)	Surface roughness, (µm)	S/N ratio for R_a
1	-1	-1	-1	-1	4.4	-12.8691
2	-1	+1	-1	-1	3.8	-11.5957
3	+1	-1	-1	-1	4.0	-12.0412
4	+1	+1	-1	-1	5.0	-13.9794
5	0	0	0	0	4.5	-13.0643
6	-1	-1	+1	-1	4.0	-12.0412
7	-1	+1	+1	-1	4.1	-12.2557
8	+1	-1	+1	-1	3.3	-10.3703
9	+1	+1	+1	-1	4.1	-12.2557
10	0	0	0	0	5.3	-14.4855
11	-1	-1	-1	+1	4.4	-12.8691
12	-1	+1	-1	+1	3.1	-9.8272
13	+1	-1	-1	+1	4.5	-13.0643
14	+1	+1	-1	+1	3.7	-11.3640
15	0	0	0	0	4.1	-12.2557
16	-1	-1	+1	+1	3.9	-11.8213
17	-1	+1	+1	+1	4.2	-12.4650
18	+1	-1	+1	+1	4.4	-12.8691
19	+1	+1	+1	+1	2.8	-8.9432
20	0	0	0	0	4.6	-13.2552

The highest of S/N ratio value corresponds to the better machining parameters [10]. The mean response table of S/N ratio for each level of the machining parameters is summarized in Table 4.

Table 4. The mean S/N response table for R_a.

Level	Feed rate, *f* (mm/min)	Spindle speed, *s* (rpm)	Depth of hole, *d* (mm)	MQL, number of drops, *m* (ml/hour)
-1	-11.9680	-12.2432	-12.2013	-12.1760
0	-13.2652	-13.2652	-13.2652	-13.2652
+1	-11.8609*	-11.5857*	-11.6277*	-11.6529*
*	Indicate the optimum level			

Based on the Table 4, R_a value has been identified as minimum at the Level +1 of feed rate(*f*), Level +1 of spindle speed (*s*), Level +1 of depth of hole (*d*) and Level +1 MQL (*m*) respectively. The symbol of '*' corresponded to the highest value of S/N ratio among their levels and then it is identified as the optimum level. Consequently, the level that has a higher value of S/N ratio determines the optimum level of each machining parameters. In Table 4 for feed rate level +1 (f_{+1} = -11.8609), spindle speed level +1 (s_{+1}=-11.5857), depth of hole level +1 (d_{+1} = -11.6277) and MQL level +1 ($m+_1$ = -11.6529) has the highest S/N ratio value, which indicated that the machining parameters at that level produced minimum value R_a. As a result, the optimum combination to get the minimum R_a is $f_{+1}s_{+1}d_{+1}m_{+1}$as shown in Table 5.

Table 5. Optimum value of machining parameters for deep hole drilling.

Machining parameters	Level	Value
Feed rate, *f* (mm/min)	+1	85
Spindle speed, *s* (rpm)	+1	1100
Depth of hole, *d* (mm)	+1	60
MQL, *m,* number of drops (ml/hour)	+1	40

From the result, it was found that the combination value of R_a is acceptable which is the level obtained in real machining is the same level in the S/N ratio analysis which is $f_{+1}s_{+1}d_{+1}m_{+1}$.

5 Conclusion

This study presents an experimental result of R_a in deep hole drilling process. The results were analysed using S/N ratio. From the S/N ratio analysis, the optimal machining parameters for R_a is determined as $f_{+1}s_{+1}d_{+1}m_{+1}$, which are 85 mm/min for feed rate (level +1), 1100 rpm for spindle speed (level +1), 60 mm for depth of the hole (level +1) and 40 ml/ hour for number of drops of MQL (level +1). The results show that the combination level obtained from the S/N ratio analysis is the same level with the machining parameters that produced minimum value R_a. It was found to be statistically significant each other.

Special appreciation to reviewer(s) for useful advices and comments. The authors greatly acknowledge the Soft Computing Research Group (SCRG), Research Management Centre (RMC), UTM and Ministry of Higher Education Malaysia (MOHE) for financial support through the Fundamental Research Grant Scheme (FRGS) vot No R.J130000.7828.4F721.

References

1. T. Aized, M. Amjad, Int. J. Adv. Manuf. Technol., **69**, 9 (2013)
2. M. Buragohain, C. Mahanta, Applied Soft Computing, **8(1)**, (2008)
3. P.G Benardos, G.C Vosniakos, Int, J, Mach, Tool, Manu., **43(8)**, (2003)
4. U. Caydas, S. Ekici, J. Intell. Manuf., **23(3)**, 639 (2012)
5. C.S Deng, J.H. Chin, Int. J. Adv. Manuf. Technol., **25(5-6)**, 420 (2005)
6. M.T. Hayajneh, Mater. Manuf. Process., **16(2)**, 147 (2001)
7. R. Mee, *A comprehensive guide to factorial two-level experimentation* (Springer Science & Business Media, New York, 2009)
8. M. Nalbant, H. Gokkaya, G. Sur, Mater. Des., **28(4)**, 1379 (2007)
9. A.A. Rahman, A. Mamat, A. Wagiman, Modern Applied Science, **3(5)**, 221 (2009)
10. M. Sarıkaya, A. Gullu, J. Clean. Prod., **65**, 604 (2014)
11. D.R. Salgado, F.J. Alonso, I. Cambero, A. Marcelo, Int. J. Adv. Manuf. Technol., **43(1)**, 40 (2009)
12. N. Yusup, A.M Zain, S.Z.M Hashim, Expert Syst. Appl., **39**, 9909 (2012)
13. A.M. Zain, H. Haron, S. Sharif, Expert Syst. Appl., **37(2)**, 1755 (2010)
14. A.M. Zain, H. Haron, S. Sharif, Expert Syst. Appl., **37(6)**, 4650 (2010)
15. A.M. Zain, H. Haron, S. Sharif, Int. J. Prod. Res., **50(1)**, 191 (2012)
16. A.M. Zain., H. Haron, S.N. Qasem, S. Sharif, Appl. Math. Model., **36(4)**, 1477 (2012)