International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 8, August - 2013

Application Of Taguchi Method In The Optimization Of Drilling Parameters

Kadam Shirish, M. G. Rathi
Govt. College Of Engineering, Aurangabad

Abstract

This paper focuses on the optimisation of drilling parameters using the Taguchi technique to obtain minimum surface roughness (Ra) and maximum tool life (Tl). A number of drilling experiments were conducted using the L9 orthogonal array on a CNC vertical machining centre. The experiments were performed on EN-24 steel blocks using uncoated M32 HSS twist drills under dry cutting conditions. Signal to Noise (S/N) ratio was employed to optimise control factors affecting the surface roughness and thrust force. The cutting speed, feed rate and depth of hole were selected as control factors. After the nine experimental trials, it was found that the cutting speed was the most significant factor on the surface roughness and the tool life. The results of the confirmation experiments showed that the Taguchi method was notably successful in the optimisation of drilling parameters for better surface roughness and tool life.

1. Introduction

The basic objective of drilling operations is to generate holes at minimum cost consistent with the required quality levels. The attainment of this straightforward objective can present challenges to those responsible for establishing and maintaining efficient production operation. The broad applicability of drilling results in a large variation in customer requirements, materials, tolerances, lot sizes and shop facilities that, in turn, preclude simplified solution[1].

Since the tool life equation was discovered by Taylor, several research papers have been published throughout the world for better understanding of metal-cutting phenomena. Wear and tool life are so important from the economical point of view that many efforts have been made in order to identify those quantities analytically and/or experimentally. The metal cutting process is very complex because of presence of various processes like plastic and other deformation, wear, strain hardening etc. The key factors influencing production in drilling are speed and feed rates. Therefore selection of optimum speed and feed rate is very important to get higher tool life and better quality. But selection of optimum cutting speed and feed can't be made with help of available data, because these ranges are available in tool/workpiece materials combination form rather than process and environment used in cutting process. These available ranges of cutting speed and feed are broad. A recent survey by a leading tool manufacturer indicates that in the USA the correct cutting tool is selected less than 50% of the time, the tool is used at the rated cutting speed only 58% of the time, and only 38% of the tools are used up to their full tool-life capability[2]. One of the reasons for this poor performance is the lack of the analytical models for machining. Many methods are there for modelling such as: artificial neural networks, multiple regression and finite element analysis[3,4]. The Taguchi-based optimization technique has produced a unique and powerful optimization discipline that differs from traditional practices[5,6].

Tool wear and surface roughness prediction plays an important role in machining industry for gaining higher productivity, product quality, manufacturing process planning and also in computer aided process planning. This study is an attempt to study behaviour of tool life and surface finish under varying machining parameters. The taguchi method was employed for this study.

2. Experiment

2.1 Drilling Experiments

In this study, En-24 steel round blocks were used as the workpiece material. The dimensions for workpiece were Ø150 x 45 mm. Before the experiments began, the steel blocks were ground to eliminate adverse effects of any surface defect. Blind holes of different depths were then drilled in the steel blocks. To protect the initial conditions of each test, a new drill was used for each experiment. The drilling tests were performed by using a DMG 850 model, five axes CNC vertical machine centre, equipped with a maximum spindle speed of 42000 rpm and a 7.5 kW drive motor. They were performed at four different cutting speeds (12, 14, 16 and 18 m/min) and feed rates (0.08, 0.1 and 0.12 mm/rev). All drilling experiments were conducted under dry cutting conditions.

Table 1 Cutting conditions

Speed (m/min)	12	16	20
Feed (mm/rev)	0.8	1	1.2
Depth of Hole (mm)	12	15	18

2.2 Wear Measurements

Tool life is a measure of wear takes place at cutting edge surfaces, which can be measured directly or indirectly by various means. In direct method wear is measured by seeing rake and flank surfaces under microscope. Indirect methods for determining wear are correlating with process parameters such as surface finish of workpiece, cutting forces, acoustic emission, temperature, vibration, spindle motor current, cutting conditions, torque, strain and snapshot images of the cutting tool etc are different ways[7,8]. Out of these direct wear measurement is mostly convenient and accurate. The stereo microscope is used to measure wear on flank surfaces directly. These preconfigured sets include all you need to mount an XY-measurement table directly on a Leica base. It is equipped with standard mechanical micrometer screws. The travelling range is 25 × 25mm. This microscope has maximum magnification range of 25X with an increment of ten**.** Linear travel in the direction of X, Y is possible with the help of micrometers attached to the table. A scale is provided at eye piece for measurement. Lamps are attached to get good contrast and clear focus on tool surface. At the center of table tool holding facility is provided, so that we can easily rotate the view. With the help of this we can easily measure wear with an accuracy of ±10µm. In corner wear evaluation, blind holes of 18 mm depth were drilled in En-24. The flank wear measurement was done at periodic interval. After flank wear evaluation tool was returned to CNC machine to continue the drilling process.

The eye piece is first focused on the corner of new drill; with the help of micrometers the width of margin is measured. The measured width is used as the reference width for the tool. After machining again tool measurement is done for a worn tool; this width then subtracted from the reference margin width to get the extent of wear after particular machining period.

2.3 Surface Roughness Measurements

Surface roughness measurements were carried out using mechanical profilometer (MAHR, Perthometer) which is shown in Figure . A diamond stylus is moved vertically in contact with the sample and then moved laterally across the sample for a specified distance and specified contact force. A profilometer can measure small surface variations in vertical stylus displacement as a function of position. A typical profilometer can measure small vertical features ranging in height from 10 nano-meters to 1 milli-meter. The height position of the diamond stylus generates an analog signal which is converted into a digital signal stored, analyzed and displayed.

3. Experimental design and optimization

3.1 Taguchi Method

The Taguchi method is a quality tool that helps improve the work efficiently. It is possible to select suitable factors as shown in Table 1, which indicates factors and their levels in the cutting experiment with CNC machine, which contains 3 factors, and each factor has 3 levels. The table 2 is shown the form of orthogonal array L9 for data collection.

As mentioned earlier, Taguchi method is used for tuning the drilling process by optimizing the process parameters for best tool life and minimum roughness of hole produced. In general, the parameter optimization process of the Taguchi method is based on 8-steps of planning, conducting and evaluating results of matrix experiments to determine the best levels of control parameters [8]. Those eight steps are given as follows.

- Identify the performance characteristics (responses) to optimize and process parameters to control (test).
- Determine the number of levels for each of the tested parameters.
- Select an appropriate orthogonal array, and assign each tested parameters into the array.
- Conduct an experiment randomly based on the arrangement of the orthogonal array.
- Calculate the S/N ratio for each combination of the tested parameters.
- Analysis the experimental result using the S/N ratio and ANOVA test.
- Find the optimal level for each of the process parameters.
- Conduct the confirmation experiment to verify the optimal process parameters.

In Taguchi method to optimize cutting condition for roughness were obtained from the smaller is better S/N ratio and larger is better for tool life.

Table 2 The results of experiments and S/N ratios

Sr. No.	Speed	Feed	Depth of Hole	Tool Life	S/N TL	Ra	S/N Ra
1	12	0.8	12	528	54.45	1.51	-3.58
2	12	1	15	500	53.97	2.14	-6.61
3	12	1.2	18	378	51.54	2.55	-8.13
4	16	0.8	15	396	51.95	1.37	-2.73
5	16	1	18	384	51.68	1.97	-5.89
6	16	1.2	12	427	52.60	1.62	-4.19
7	20	0.8	18	352	50.93	1.56	-3.86
8	20	1	12	421	52.48	1.44	-3.17
9	20	1.2	15	327	50.29	1.68	-4.51

4.Analyzing and evaluating results of the experiments using the Taguchi method

The most essential criterion in the Taguchi method for analyzing experimental data is signal/noise ratio. In this study, the S/N ratio should have a maximum value to obtain optimum cutting conditions, according to the Taguchi method. Thus, the optimum cutting condition was found as 54.7279 and -2.73441 S/N ratios for tool life and Ra respectively in L9 orthogonal array in Table 2. Level values obtained from the Taguchi method for tool life and roughness are shown in Table 3 and Table 4 respectively. The different values of S/N ratio between maximum and minimum are (main effect) also have shown in Table 3 and 4. The speed and the depth of hole are two factors that have the highest difference between values, 2.18 and 1.88 respectively. Based on the Taguchi prediction that the larger different between value of S/N ratio will have a more significant effect on tool life. The depth of hole and speed is having maximum impact on surface roughness (Ra) value. Main effect plots for S/N ratios are shown in figure 1 and Figure 2.

Table 3 Response table for S/N ratios for tool life

Level	Speed	Feed	Depth of Hole
1	53.33	52.45	53.18
2	52.08	52.72	52.07
3	51.24	51.48	51.39
Delta	2.09	1.23	1.79
Rank	1	3	2

Table 4 Response table for S/N ratios for Ra

Level	Speed	Feed	Depth of Hole
1	-6.106	-3.392	-3.646
2	-4.271	-5.222	-4.616
3	-3.845	-5.609	-5.961
Delta	2.261	2.217	2.315
Rank	2	3	1

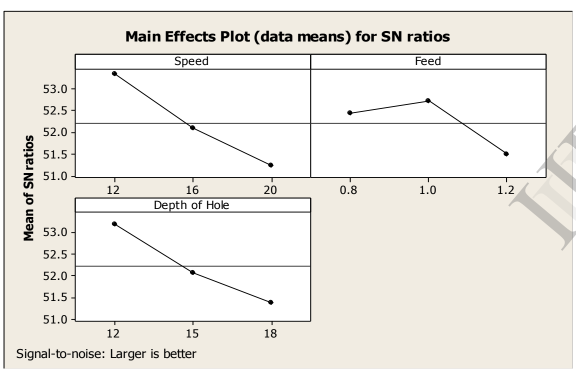

Figure 1 Main effect plots for S/N ratios (Tool Life)

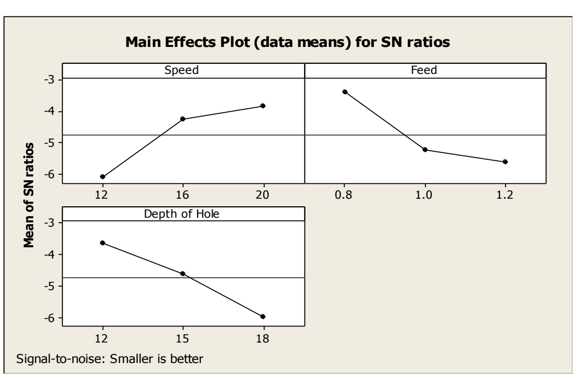

Figure 2 Main effect plots for S/N ratios (Ra)

4.1 Confirmation experiment

The final step of Taguchi method is conducting confirmation experiments to evaluate quality characteristics. The experiments were performed on obtained optimal combination of influencing factor levels. The experiment was repeated three times to get average value and to know variance. It was found that variance in recorded value is not significant.

Table 5 Result of confirmation experiment

Test	1	2	3	Predicted Value
Level	Speed (1), Feed (2), Depth of Hole (1)			
Tool Life (No. of holes)	532	524	528	536
Level	Speed (3), Feed (1), Depth of Hole (1)			1.05
Ra	1.03	1.09	1.11	

4.2 Discussion

In this study Taguchi is used effectively to study effect of machining parameters on tool life and surface roughness. The speed of tool plays an important role in deciding both responses. As speed increases the roughness of hole produced decreases may due to velocity of chip is faster at higher cutting speed than at low cutting speed. This leads to a shorter time for the chips to be in contact with the newly formed surface of workpiece and the tendency for the chips to wrap back to the new face form is little as compared to low speed[9]. As depth of hole is increasing the roughness value decreases this may due to clogging of chips. The tool life as shown, there is a specific combination of the cutting speed and feed at which tool life is at a maximum. Changing the cutting speed and/or feed on either side reduces tool life while the minimum tool wear rate under a given combination of these parameters corresponds to the optimal cutting temperature[10].

5. Conclusions

The Taguchi method was applied to know the behaviour of the tool life and roughness on machining parameters in drilling EN-24.

1. Taguchi's design method is suitable to analyze the metal cutting problem as described in this paper.
2. Generally, the use of high cutting speed, low feed rate and low depth of hole leads to better surface finish.
3. Signal to noise ratio is analyzed to know the significance of the factors.
4. In dry drilling high speed, low feed are recommended for higher surface finish of hole.
5. The result of present investigation is valid within specified range of process parameters.

References

[1]R. King, Handbook of High Speed Machining Technology, Chapman and Hall, London, 1985.

[2] V.P. Astakhov, S.V. Shvets, A System Concept in Metal Cutting, Journal of Materials Processing Technology 79 (1998), 189 – 199.

[3] D. D'Addona, T. Segreto, A. Simeone, R. Teti, ANN Tool Wear Modeling In The Machining of Nickel Superalloy Industrial Products, CIRP Journal of Manufacturing Science and Technology 4 (2011) 33–37.

[4] Wen-Tung Chien, Chung-Shay Tsai, The Investigation on The Prediction of Tool Wear And The Determination of Optimum Cutting Conditions In Machining 17-4PH Stainless Steel, Journal of Materials Processing Technology 140 (2003) 340–345.

[5] M. Kurt, E. Bagci, Y. Kaynak, Application of Taguchi Methods In The Optimization Of Cutting Parameters For Surface Finish And Hole Diameter Accuracy In Dry Drilling Processes, International Journal of Advanced Manufacturing Technology 40 (2009) 458–469.

[6] S. M. Ali, N. R. Dhar, Tool Wear and Surface Roughness Prediction using an Artificial Neural Network (ANN) in Turning Steel Under Minimum Quantity Lubrication (MQL), World Academy of Science, Engineering and Technology 38, 2010.

[7] G.F. Micheletti, In Process Tool Wear Sensors for Cutting Operations, Ann. CIRP 25 (1976) 483–495.

[8] Viktor P. Astakhov, Tribology of Metal Cutting, Elsevier ISBN–13: 978-0-444-52881-0.

[9] J.A. Ghani, I.A. Choudhury, H.H. Hassan, Application of Taguchi method in the optimization of end milling parameters, Journal of Materials Processing Technology 145 (2004) 84–92.

[10] Makarow, Optimization of Cutting Processes (in Russian), Machinostroenie, Moscow, 1976.