A STUDY OF OPTIMIZATION OF DRILLING PROCESS PARAMETERS USING TAGUCHI METHOD

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ABSTRACT

The aim of this work is utilize Taguchi method to investigate the effects of drilling parameters such as spindle speed, feed rate and drill diameter on surface roughness and material removal rate in drilling of gray cast iron using solid carbide tool. The Taguchi method, a powerful tool to design optimization for quality, is used to find optimal cutting parameters. Orthogonal arrays, the signal- to- noise ratio, the analysis of variance are used to analyze the effect of drilling parameters on the quality of drilled holes. Number of experiments based on L 9 orthogonal array is conducted using CNC vertical machining centre. Statistical software Minitab18.1 is used to analyze experiment results. ANOVA is used to determine the most significant control factors affecting the surface roughness and material removal rate. ANOVA has shown that the drill diameter has significant role to play in producing higher material removal rate and lower surface roughness. The optimum levels of various parameters obtained in present work for MRR are Spindle speed 800 rpm, feed rate 90 mm/min and Drill diameter is12.7 mm. The optimum levels of various parameters obtained in present work for SR are, Spindle speed 1000 rpm, feed rate 70 mm/min and Drill diameter is 10 mm.

KEYWORDS: Drilling optimization, surface roughness, material removal rate, signal-to-noise ratio, ANOVA.

I. INTRODUCTION

Drilling is a process of producing round holes in a solid material or enlarging existing holes with the use drills or drill bits. Drilling is a continuous machining process. Various cutting tools are available for drilling. Wide variety of drill processes are available to serve different purposes (core drilling, step drilling, counter boring, counter sinking, reaming, center drilling, gun drilling etc.).With the rapidly growing technologies quality and productivity are the major concern. Productivity is concerned with the material removal rate (MRR) during machining operation and quality refers to the product characteristics. So the quality and productivity can be improved through parameters optimization.

Drilling is a most common and complex used industrial machining processes of creating a hole in mechanical components and work piece. "Drilling can also be defined as a rotary end-cutting tool having one or more cutting edges called lips, and having one or more helical or straight flutes for the passage of chips and passing the cutting fluid to the machining zone."

II. LITERATURE REVIEW

Sumesh A S. et. al. [1] has conducted experiment using Taguchi technique to obtain minimum surface roughness (Ra).for validation ANOVA Software is used. Experiments were performed on cast iron using HSS twist drills. A number of drilling experiments were conducted using the L9 orthogonal array on a radial drilling machine , it is observed that the variation in drilling parameters are optimized with respect to multiple performances in order to achieve a good quality of holes in drilling. Finally variation in parameter it was identified that a spindle speed of 80 rpm, drill diameter of 4mm and a feed rate of 0.1 mm/rev is the optimal combination of drilling parameters that produced a high value of S/N ratios of hole roughness.

Yogendra Tyagi et.al [2] - has studied on drilling of mild steel with the help of CNC drilling machine, with tool high speed steel, to optimize various process parameters using Taguchi method and L9 array, taguchi method and analysis of variance (ANOVA) are used.Finally it is found that, the Spindle Speed of drilling machine Tool mainly affects the surface roughness and the Feed Rate largely affects the MRR.

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Nisha Tamta et.al. [3] has conducted experiment to optimize the drilling machining process for Surface roughness (Ra). The drilling parameters were chosen as Spindle speed, Feed rate and Drilling Depth. L9 orthogonal array used to conduct the experiments. Signal to noise (S/N) ratio and analysis of variance (ANOVA) is used to analyze the effect of the drilling parameters on material. Optimization of parameters is done by Taguchi method using statistical software MINITAB-15. Finally it is conclude that optimum parameter combination for the minimum Surface roughness (Ra) are, Spindle speed 3000 (rpm), Feed rate 15(mm/min.) and Drilling Depth 9 (mm) ,the ANOVA and S/N ratio showed that Drilling Depth is obtained as the most significant factor for Ra followed by Spindle speed.

Kunal Sharma et. al. [4] has conducted experiment to study the performance characteristics of AISI 304 stainless steel using CNC drilling process, with input parameters spindle speed, feed rate and point angle ,to get minimum surface roughness and minimum ovality. Experiments are Conducted based on Taguchi L16 orthogonal array by taking point angle, drill diameter, feed rate and spindle speed at two levels. The Taguchi based signal-to-noise ratio analysis is used to obtain the relation between the machining parameters and performance characteristics. The feed is the most effective parameter and that the small variation in feed will show large increase in surface roughness.

S.V. Alagarsamy et. al. [5]- used Taguchi method to study the effects of drilling parameters such as cutting speed, feed and depth of cut on surface roughness and material removal rate in drilling of Aluminum alloy 7075 using HSS spiral drill. Orthogonal arrays, the signal- to- noise ratio, the analysis of variance are used to analyze the effect of drilling parameters on the quality of drilled holes and experiment results are collected and analyzed using statistical software Minitab16. ANOVA software is used to study the most significant control factors affecting the surface roughness and material removal rate and it is concluded that the depth of cut has significant role to play in producing higher material removal rate and cutting speed has significant role to play for producing lower surface roughness.

III. EXPERIMENTAL SETUP

The experiments be there performed by operating on a TAL V-400 VERTIMACH CNC vertical machining Centre has its spindle on a vertical axis relative to the work table. A vertical machining Centre (VMC) is typically used for flat work that requires tool access from top. The tool selected for experiment is carbide tool. The tool diameters for drilling operation are 7.5 mm, 10 mm and 12.7 mm in the vertical milling machine and point angle is 118º. This property allows carbide tool to drill holes faster than high speed steel tool.

Table: Chemical composition of Grey Cast Iron in %

Grade	C	Si	Mn	S	P
FG 200	3.32	1.99	0.61	0.11	0.095

In this experiment Grey cast iron material is used as work piece material. Finishing operation is performed on Grey cast iron work piece. A rectangular grey cast iron plate of size 90mm x 70mm x 20mm is used for drilling process.

Based on the literature review carried out, it is observed that, the research on grey cast iron material using vertical machine center (VMC) is not yet explored. This is a research gap. Hence grey cast iron is selected as work piece material.

MRR is calculated as the proportion of the change of weight of the work piece before and after machining to the product of machining period.

Surface Roughness is the size of the surface texture. It is expressed in μm and denoted by Ra. If the value comes higher that means the surface is rough and if lower comes that means that the surface is smooth. The surface roughness values are measured by Mitutoyo make surface roughness tester.

IV. EXPEIMENTATION

Taguchi Method

Dr. Genichi Taguchi's approach or DOE is highly effective wherever and whenever it is suspected that the performance of a part or process is controlled by more than one factor. The main purpose is to give a clear understanding to make the DOE technique more effective in applications, and how relate the outcome of the technique to improve the quality of products and processes. When used for product design optimization, analytical simulation is the common approach, because hardware is not often available.

The Full Factorial Design requires a large number of experiments to be carried out as stated above. It becomes laborious and complex, if the number of factors increase. To overcome this problem Taguchi suggested a specially designed method called the use of orthogonal array to study the entire parameter space with lesser number of experiments to be conducted. Taguchi thus, recommends the use of the loss function to measure the performance characteristics that are deviating from the desired target value. The value of this loss function is further transformed into signal-to-noise (S/N) ratio. Usually, there are three categories of the performance characteristics to analyze the S/N ratio. They are: nominal-the-best, larger-the-better, and smaller-the-better.

S/N Ratio

In Taguchi's design method the design parameters (factors that can be controlled by designers) and noise factors (factors that cannot be controlled by designers, such as environmental factors) are considered influential on the product quality. The Signal to Noise (S/N) ratio is used in this analysis which takes both the mean and the variability of the experimental result into account. The S/N ratio depends on the quality characteristics of the product/process to be optimized. Usually, there are three categories of the performance characteristics in the analysis of the S/N ratio, i.e.

1. Higher the better:
2. Lower the better
3. Nominal the better

The S/N ratio for each response is computed differently based on the category of the performance characteristics and hence regardless of the category the larger S/N ratio corresponds to a better performance characteristic.

Three factors were selected for this experiment. There are spindle speed, feed rate and drill diameter with three levels as shown in Table. The experiments were conducted with different cutting speeds and feed rates using different diameters of drill bits. The cutting speeds considered are 800rpm, 1000 rpm, and 1200 rpm. Feed rates considered are 50 mm/rev.,70mm/rev and 90mm/rev. and the drill diameters considered are 7.5mm, 10mm, and12.7mm.In all cutting conditions for each hole Material removal rate (MRR) and surface Roughness (SR) is measured.

Table: Machining parameters and their level

Machining Parameter	Level 1	Level 2	Level 3
Cutting speeds (rpm)	800	1000	1200
Feed Rate (mm/rev)	50	70	90
Drill diameters (mm)	7.5	10	12.7

The design of experiment by taguchi L9 orthogonal array is formed using MINITAB 18.1 and experiments are performed accordingly .The following table shows the observations of MRR and Surface roughness.

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Table: Taguchi design and experiment and observations.

Trial. No	**Process Parameters**			**Output Parameters**	
	Spindle Speed (rpm)	**Feed Rate (mm/ min)**	**Drill Diameter (mm)**	**Avg. MRR (gm/sec)**	**Avg. SR (µm)**
1	800	50	7.5	0.28	0.436
2	800	70	10	0.65	0.552
3	800	90	12.7	1.34	0.471
4	1000	50	10	0.46	0.637
5	1000	70	12.7	1.00	0.535
6	1000	90	7.5	0.47	0.419
7	1200	50	12.7	0.73	0.351
8	1200	70	7.5	0.36	0.427
9	1200	90	10	0.82	0.474

V. RESULTS AND DISCUSSION

The objective of this research is to study the effect of various input parameters i.e spindle speed , feed rate and drill diameter on Material Removal Rate (MRR) and Surface Roughness (SR). In this chapter, we are discussing about influence of machining parameters i.e spindle speed , feed rate and drill diameter on material removal rate (MRR) and surface roughness(SR) of gray cast iron machined work piece with carbide tool & find out which parameter is most important during an experiment

The graphs shown below are the main effect plot of S/N ratios for process parameters viz. Spindle Speed, feed rate and Drill Diameter.

A.Taguchi Analysis for MRR

The S/N ratios for MRR are calculated as given in below Equation. Taguchi method is used to analysis the result of response of machining parameter for “Higher is best” criteria.

The Signal-To-Noise ratio for the Higher-the-better is:

S/N = -10*log (mean square of the inverse of the response)

Where: n= number of measurements in trial/row, in this case n=1, 2…, 9 and Yi is the i^{th} measured value in a run/row. i =1, 2…, 27.

$$S/N = -10\log_{10}\left(\frac{1}{n}\sum\frac{1}{y_i^{\ 2}}\right)$$

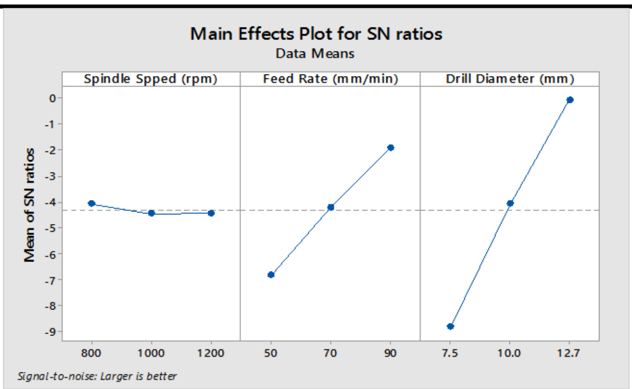

Fig: Main Effects Plot of SN Ratios for Material Removal Rate (gm/sec)

Table: Response table for Signal to Noise Ratios: Higher is best

Level	Spndle Speed (rpm)	Feed Rate (Mm/Min)	Drill Diameter (mm)
1	-4.08506	-6.83677	-8.83636
2	-4.45846	-4.21178	-4.08243
3	-4.43515	-1.93012	-0.05988
Delta	0.3734	4.90666	8.77648
Rank	3	2	1

Drill Diameter:

From the observation of main effects plot the Maximum MRR is produced when 12.7 mm drill diameter is used. It shows that increase in drill diameter gives increase in MRR.

Feed Rate:

Another observation of the present work is that the increase in feed rate improves the MRR. Maximum MRR is produced at 90 mm/min feed rate.

Spindle Speed:

The Spindle Speed is another factor that shows the variation in MRR. Maximum MRR is produced at 800 rpm.

B. Analysis of Variance for S/N Ratio of MRR

Analysis of variance for MRR is given in below table. These values are obtained from MINITAB 18.1 software. It shows that Feed rate and Drill diameter are the significant parameters for MRR. Increase in Feed rate and drill diameter results in larger material removal from the work piece.

Table: ANOVA for MRR (mm3/min)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed (rpm)	2	0.263	0.263	0.1313	16.02	0.059
Feed Rate (mm/min)	2	36.172	36.172	18.0859	2206.75	0
Drill Diameter (mm)	2	115.807	115.807	57.9037	7065.1	0
Residual Error	2	0.016	0.016	0.0082		
Total	8	152.258				
S = 0.09053		R-Sq = 99.99%		R-Sq(adj) = 99.96%		

C. Taguchi Analysis for Surface Roughness

The S/N ratios for SR are calculated as given in below Equation. Taguchi method is used to analysis the result of response of machining parameter for "lower is best" criteria.

The Signal-To-Noise ratio for the Smaller-The-Better is:
S/N = -10 *log (mean square of the response)

$$S / N = -10 \log_{10}\left(\frac{\sum y_i^2}{n} \right)$$

Where S/N ratios calculated from observed values, yi represents the experimentally observed value of the i^{th} experiment and n=1 is the repeated number of each experiment in L-9 Orthogonal Array is conducted.
From fig it can be observed that the parameters Concentration of Spindle speed, feed rate and drill diameter affect the SR.

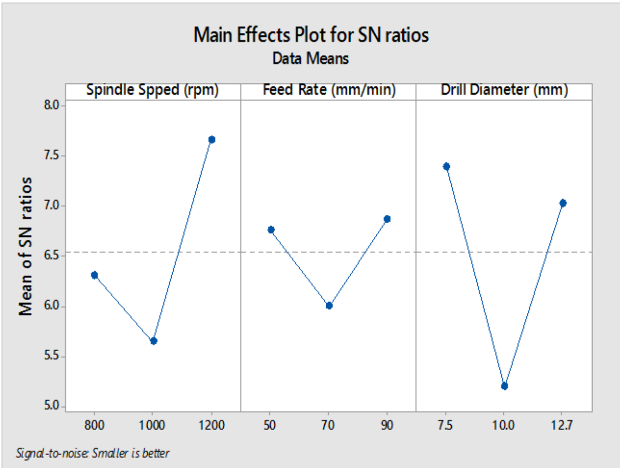

Fig: Main Effects Plot of SN Ratios for SR (in Ra µm)

Table: Response table for Signal to Noise Ratios: Lower is best

Level	Spndle Speed (rpm)	Feed Rate (Mm/Min)	Drill Diameter (mm)
1	6.307	6.75	7.393
2	5.641	5.995	5.193
3	7.664	6.866	7.026
Delta	2.023	0.871	2.200
Rank	2	3	1

Drill Diameter:
From the observation of main effects plot the high surface finish is achieved when 10 mm drill diameter is used. It shows that increase in drill diameter gives decrease in surface roughness.

Feed Rate:
Another observation of the present work is that the high surface roughness is produced when 70 mm/min feed rate is maintained. And increase in feed rate gives the decrease in surface roughness.

Spindle Speed:
The Spindle Speed is another factor that shows the variation in surface roughness. High surface finish is produced at 1000 rpm.

D. Analysis of Variance for S/N Ratio of SR

Analysis of variance for SR is given in below table. These values are obtained from MINITAB 18.1 software. It shows that drill diameter is the significant parameter for SR. Parameters spindle speed and feed rate has less impact on surface quality of work piece

Table: ANOVA for SR (in Ra μm)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed (rpm)	2	6.376	6.376	3.1879	2.32	0.301
Feed Rate (mm/min)	2	1.343	1.343	0.6713	0.49	0.672
Drill Diameter (mm)	2	8.334	8.334	4.1668	3.03	0.248
Residual Error	2	2.746	2.746	1.3731		
Total	8	18.798				
S = 1.172 R-Sq = 85.4 % R-Sq(adj) = 41.6 %						

VI. CONCLUSION

This paper presents the optimization of process parameters such as spindle speed, drill diameter and feed rate. From the experiments performed following conclusions are drawn from the present work. Taguchi method has been successfully implemented for determining optimum conditions for surface roughness and material removal rate of drilled hole.

The following conclusions have been found out from the experimentation and analysis:

1. It has been observed that the MRR is increases with increase in feed rate and drill diameter, while it decreases with increase in spindle speed.
2. MRR also showed a proportional increase with increase in feed rate and drill diameter.
3. The optimum levels of various parameters obtained in present work for MRR are, Spindle speed 800 rpm, feed rate 90 mm/min and Drill diameter is12.7 mm
4. The optimum levels of various parameters obtained in present work for SR are, Spindle speed 1000 rpm, feed rate 70 mm/min and Drill diameter is 10 mm

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