IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X,
PP 12-20
www.iosrjournals.org

Optimization Of Drilling Parameters For Minimum Surface Roughness Using Taguchi Method

Sumesh A S [1], Melvin Eldho Shibu[2]

[1] *PG Scholar, Department of Mechanical Engineering, Sree Narayana Gurukulam College of Engineering Kadayiruppu. E-mail:ssumesh1122@gmail.com Mob: 7025534693*
[2] *Assistant Professor, Department of Mechanical Engineering, Sree Narayana Gurukulam College of Engineering Kadayiruppu. E-mail:itzmelvin@gmail.com Mob: 9747308688*

Abstract: *The objective of the present work is to optimize process parameter such as cutting speed, feed, and drill diameter. Taguchi methodsare widely used for design of experiments and analysis of experimental data for optimization of processing conditions. The researchcontributions are classified into methodology for investigation and analysis, input processing conditions and response variables. This paperfocuses on the optimization of drilling parameters using the Taguchi technique to obtain minimum surface roughness (Ra). A number of drilling experiments were conducted using the L_9 orthogonal array on a radial drilling machine. The experimentswere performed on cast iron using HSS twist drills. Analysis of variance (ANOVA) was employed to determine the most significantcontrol factors affecting the surface roughness. The cutting speed, feed rate and drill diameter were selected as control factors. After the nine experimental trials, it was found that the drill diameter was the most significant factor for the surface roughness. The results of the confirmation experiments showed that the Taguchi method was notablysuccessful in the optimization of drilling parameters for better surface roughness. Commercial software package MINITAB17 is used for performing the analysis.*

Key words: *Drilling, Taguchi method, Analysis of Variance, surface roughness*

I. Introduction

Drilling is a process of producing round holes in a solid material or enlarging existing holes with the use of multi-point cutting tools called drills or drill bits. Drilling is a continuous machining process. Various cutting tools are available for drilling, but the most common is the twist drill. 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.There are number of research works related to various drilling parameters optimization for achieving the performance responses. Among them surface roughness, material removal rate (MRR) and thrust forces on drill bit are the major performance responses.

Material removal rate (MRR) is the primary response variable while considering productivity. The material removal rate depends on input parameters and the machine during drilling operation. So the primary objective of optimization analysis during drilling operation is to optimize the input parameters. Also material removal rate (MRR) play a major role in surface roughness.

The primary objective in all the research works relating to drilling parameter optimization is to optimize the input parameters such as spindle speed, fees rate, drill bit diameter etc. Simply the optimization means improving the material removal rate and reducing the surface roughness value. The other aspect governing the drilling parameter optimization is quality of the product. Quality relating to the product characteristics like surface roughness, wear resistance, cost etc. Design of experiment and analysis of experimental data play a significant role in parameters optimization and cost of optimization. Among all the design of experiment techniques Taguchi method is the simplest one. Analysis of variance (ANOVA) is used for analyzing the data obtained during experiment. The grey relational analysis is the most accurate and effective analysis tool for the data obtained during CNC drilling.Many of the researches in parameter optimization uses wide variety of design experiments and analysis focused on different performance parameters and different materials. So this paper concentered on drilling parameters optimization in different material using Taguchi method.

1.1. Drilling

Drilling is a most common and complex used industrial machining processes of creating and originating a hole in mechanical components and work piece. The tool used, called a drill and the machine tool used is called a drill machine. Drilling can also be define 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. The drilling operations performed on a drilling machine, which rotates and feed the drill to the work piece and creates the hole. Drilling usually performed with a rotating cylindrical tool that has two cutting edges on its working end (called a twist drill). Rotating drill fed into the stationary work piece to form a hole whose diameter is determined by the drill diameter. Drilling makes up about 25% of all the machining processes performed.A variety of drilling processes (Figure 1) are available to serve different purposes. Drilling is used to drill a round blind or through hole in a solid material. If the hole is larger than ~30 mm, a smaller pilot hole is drilled before core drilling the final one. For holes larger than ~50 mm, three-step drilling is recommended. Core drilling is used to increase the diameter of an existing hole. Step drilling is used to drill a stepped (multi-diameter) hole in a solid material. Counter boring provides a stepped hole again but with flat and perpendicular relative to hole axis face. The hole is used to seat internal hexagonal bolt heads. Countersinking is similar to counter boring, except that the step is conical for flat head screws.

Reaming operation is usually meant to slightly increase the size and to provide a better tolerance, surface finish and improved shape of an initially drilled hole. The tool is called reamer. Center drilling is used to drill a starting hole to precisely define the location for subsequent drilling operation and to provide center support in lathe or turning center. The tool is called center drill that has a thick shaft and very short flutes. Gun drilling is a specific operation to drill holes with very large length-to-diameter ratio up to 300. There are several modifications of this operation but in all cases cutting fluid is delivered directly to the cutting zone internally through the drill to cool and lubricate the cutting edges, and to remove the chips.

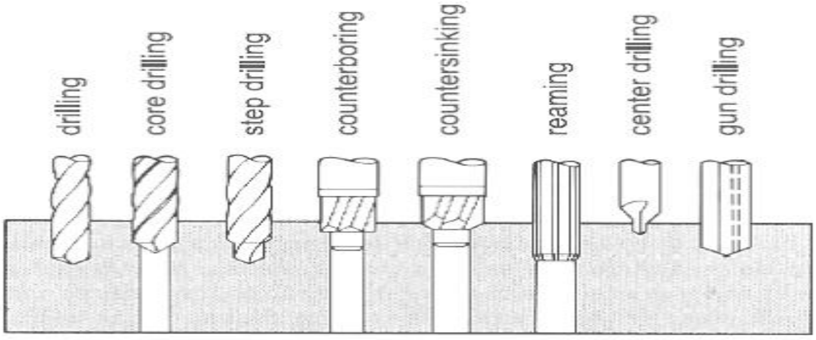

Figure 1. Different Types of Drilling Operations

1.2. Drill Geometric Attributes

Drill bits are cutting tools used to create cylindrical holes. Bits held in a tool called a drill, which rotates them and provides torque and axial force to create the hole. Different point angle drills and different diameter drills and of different length of drills can be used according to the application of work. Drills with no point angle are used in situations where a blind, flat-bottomed hole is required. These drills are very sensitive to changes in lip angle, and even a slight change can result in an inappropriately fast cutting drill bit that will suffer premature wear. Diameters range of twist drill is about 0.15 to 75 mm. Body, Point, and Shank are three basic parts of twist drill twist drill has two spiral or helical grooves called flutes separated by Lands. Angle of spiral flute is call as the helix angle around 30°. Flutes helps for extraction of from the hole. Web is the thickness of the drill between the flutes and it support the drill support over its length. Point of the twist drill has the general shape of a cone having a typical value of 118°. Point can be design in various ways. However, most common design is a chisel edge. The spiral, or rate of twist in the drill, controls the rate of chip removal in a drill. A fast spiral drill is use in high feed rate applications under low spindle speeds.

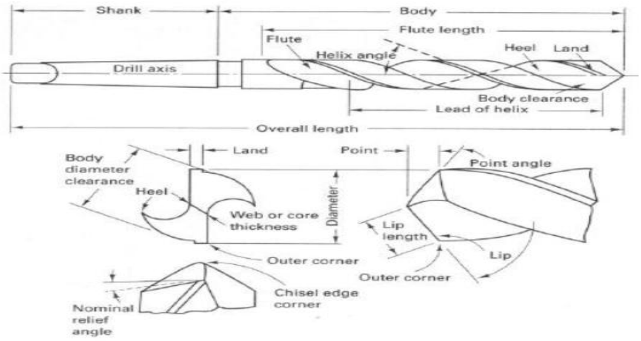

Figure 2. . Nomenclature and Geometry of Twist Drills

II. Literature Review

In the study conducted by Turgay Kıvak and Gurcan Samtas, the effect of drilling parameters on surface roughness and thrust force were investigated. A number of drilling experiments were conducted using the L16 orthogonal array on a CNC vertical machining center. The experiments were performed on AISI 316 stainless steel blocks using uncoated and coated M35 HSS twist drills under dry cutting conditions. Analysis of variance (ANOVA) was employed to determine the most significant control factors affecting the surface roughness and thrust force. The cutting tool, cutting speed and feed rate were selected as control factors. After the sixteen experimental trials, it was found that the cutting tool was the most significant factor on the surface roughness and that the feed rate was the most significant factor on the thrust force. The results of the confirmation experiments showed that the Taguchi method was notably successful in the optimization of drilling parameters for better surface roughness and thrust force. As a result of experimental trials performed using the Taguchi OA, it was found that the cutting tool was the most significant factor affecting the surface roughness with a percentage contribution of 39.14%, and that the feed rate was the most significant factor affecting the thrust force with a percentage contribution of 82.77%.

In another similar work by YogendraTyagi, and VedanshChaturvedi, described the Taguchi technique for optimization of surface roughness in drilling process. In this the drilling of mild steel with the help of CNC drilling machine operation with Tool use high speed steel by applying Taguchi methodology has been reported. The Taguchi method is applied to formulate the experimental layout to ascertain the Element of impact each optimum process parameters for CNC drilling machining with drilling operation of mild steel. A L9 array, Taguchi method and analysis of variance (ANOVA) are used to formulate the procedure tried on the change of parameter layout. The available material study in focuses optimization of CNC Drilling machine process parameters to provide good surface finish as well as high material removal rate (MRR).The surface finishing and material removal rate have been identified us quality attribute and are assumed to be directly related to productivity. The selection of optimal machining parameters i.e., spindle speed, depth of cut and feed rate) for drilling machine operations was investigated in order to minimize the surface roughness and to maximize the material removal rate.This paper has discussed the feasibility of machining Mild Steel by drilling machine with a HSS Tool. We can conclude that, the Spindle Speed of drilling machine Tool mainly affects the Surface Roughness. The Feed Rate largely affects the Material Removal Rate.

In another work by A. Navanth, T. Karthikeya Sharma, described the Taguchi technique for optimization of surface roughness in drilling process. The experiments were performed on AI 2014 alloy block using HSS twist drills under dry cutting conditions. The measured results were collected and analyzed with the help of the commercial software package MINITAB16. Analysis of variance (ANOVA) was employed to determine the most significant control factors affecting the surface roughness and holediameter. The cutting tool, spindle speed and feed rate were selected as control factors. The main and interaction effect of the input variables on the predicted responses are investigated. The predicted values and measured values are fairly close.It was identified that a spindle speed of 300 rpm, point angle & Helix angle of 1300/200 and a feed rate of 0.15 mm/rev is the optimal combination of drilling parameters that produced a high value of s/n ratios of hole roughness. And also identified that a spindle speed of 200 rpm, point angle & Helix angle of 900/150 and a feed rate of 0.36 mm/rev is the optimal combination of drilling parameters that produced a high value of s/n ratios of Hole Diameter.

III. Methodology

1.3. Design Of Experiment (Doe)

Design of Experiment is a powerful approach to improve product design or improve process performance where it can be used to reduce cycle time required to develop new product or processes. Design experiment is a test or series of test that the input variable (parameter) of a process is change so that observation and identifying corresponding changes in the output response can be verify. The result of the process is analyzed to find the optimum value or parameters that have a most significant effect to the process. The objectives of the experiment may include.

1.4. Analysis Of Variance (Anova)

The Analysis Of Variance (ANOVA) is a powerful and common statistical procedure in the social sciences. It is the application to identify the effect of individual factors.In statistics, ANOVA is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different explanatory variables. In its simplest form ANOVAgives a statistical test of whether the means of several groups are all equal, and therefore generalizes.

1.5. TAGUCHI METHOD

The Taguchi technique is a methodology for finding the optimum setting of the control factors to make the product or process insensitive to the noise factors. Taguchi's techniques have been used widely in engineering design, and can be applied to many aspects such as optimization, experimental design, sensitivity analysis, parameter estimation, model prediction, etc. The distinct idea of Taguchi's robust design that differs from the conventional experimental design is that of designing for the simultaneous modelling of both mean and variability. Taguchi based optimization technique has produced a unique and powerful optimization discipline that differs from traditional practices. While, traditional experimental design methods are sometimes too complex and time consuming, Taguchi methodology is a relatively simple method.

Taguchi method uses a special highly fractionated factorial designs and other types of fractional designs obtained from orthogonal arrays (OA) to study the entire experimental region of interest for experimenter with a small number of experiments. This reduces the time and costs of experiments, and additionally allows for an optimization of the process to be performed. The columns of an OA represent the experimental parameters to be optimized and the rows represent the individual trials (combinations of levels).

Traditionally, data from experiments is used to analyze the mean response. However, in Taguchi method the mean and the variance of the response (experimental result) at each setting of parameters in OA are combined into a single performance measure known as the signal-to-noise (*S/N*) ratio. Depending on the criterion for the quality characteristic to be optimized, different *S/N* ratios can be chosen:

- Smaller-The-Better
- Larger-The-Better
- Nominal-The-Best

Smaller – The –Better

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

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

Larger – The – Better

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

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

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

Nominal – The – Better
The S/N equation for the Nominal-The-Best is:
S/N = 10 * log (the square of the mean divided by the variance)

$$S/N = 10\log_{10}\left(\frac{y^2}{s^2}\right)$$

IV. Experimental Set Up

In the present work, radial drilling machine is used to drill holes on cast iron; the machine setup is shown in figure 3.

Figure 3. Radial Drilling Machine

1.6. High Speed Steel (Hss)

Advent of HSS in around 1905 made a break through at that time in the history of cutting tool materials though got later superseded by many other novel tool materials like cemented carbides and ceramics which could machine much faster than the HSS tools. The basic composition of HSS is 18% W, 4% Cr, 1% V, 0.7% C and rest Fe.

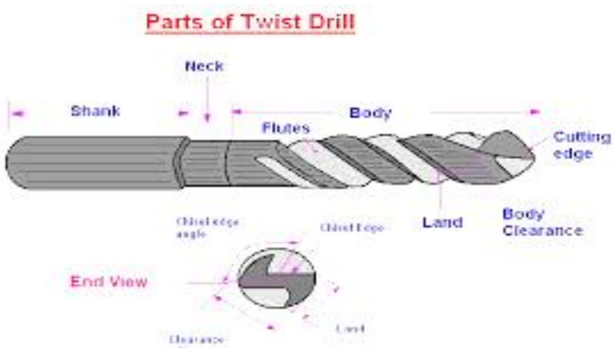

Figure 4. High Speed Twist Drill

1.7. Work Material Details

Work material - CAST IRON
Work material thickness – 12 mm

Table 1. Chemical composition of Cast Iron

	C	Si	Mn	Cr	Ni	Mo	Mg
FG	3.0 – 4.0	0.5 – 2.0	<1	<1	<1	<0,5	–
HS	2.5 – 3.5	1.5 – 2.5	0.5 – 1.5	<1	<1	0.5 – 1.5	–
SG	2.5 – 3.5	1.5 – 2.5	0.5 – 1.5	<1	0.5 – 1.5	<1	0.05 – 0.15

1.8. Surface Finish Measurement

Surftest SJ-201P: Surftest SJ-201P (Portable surface roughness tester) instrument is widely used to measure the shape or form of components. A profile measurement device is usually based on a tactile measurement principle. The surface is measured by moving a stylus across the surface. As the stylus moves up and down along the surface, a transducer converts these movements into a signal which is then transformed into a roughness number and usually a visually displayed profile. Multiple profiles can often be combined to form a surface representation. Surftest SJ-201P is shown in figure 5.

Figure 5. Surftest SJ-201P

Table 2. Cutting parameters and their levels

Factors	Level 1	Level 2	Level 3
Cutting speeds (RPM)	80	160	250
Feeds (mm/rev)	0.1	0.125	0.15
Drill diameters (mm)	4	8	12

Table 3. Experimental data for Cast Iron

Trial No.	Speed (RPM)	Feed (mm/rev)	Drill diameter (mm)	Surface Roughness		Mean Surface Roughness
				1	2	
1	80	0.1	4	0.65	0.68	0.665
2	80	0.125	8	0.77	0.78	0.775
3	80	0.15	12	0.99	1.10	1.045
4	160	0.1	8	0.89	0.83	0.86
5	160	0.125	12	0.93	0.95	0.94
6	160	0.15	4	0.75	0.77	0.76
7	250	0.1	12	0.84	0.86	0.85
8	250	0.125	4	0.99	1.05	1.02
9	250	0.15	8	0.86	0.88	0.87

V. Analysis Of Results

The effect of various parameters such as cutting speed, feed, drill diameter and interaction between drill material and cutting speed were evaluated using ANOVA. A confidence interval of 95% has been used for the analysis. 9 trials were conducted in the experiment using L_9 experimental design. One repetition for each of 9 trials was completed to measure Signal to Noise ratio (S/N ratio).

1.9. Surface Roughness (Ra)

In this study surface roughness of 9 experimental trials with repetition has measured for each sample. The results for surface roughness for each of the 9 experimental trials with repetition are given in Table 4.

Table 4. Roughness values and S/N ratio's values for the experiments

Trial No.	Speed (RPM)	Feed (mm/rev)	Drill diameter (mm)	Surface Roughness		Mean Surface Roughness	S/N Ratio
				1	2		
1	80	0.1	4	0.65	0.68	0.665	3.54136
2	80	0.125	8	0.77	0.78	0.775	2.21379
3	80	0.15	12	0.99	1.10	1.045	-0.394339
4	160	0.1	8	0.89	0.83	0.86	1.30475
5	160	0.125	12	0.93	0.95	0.94	0.536951
6	160	0.15	4	0.75	0.77	0.76	2.38298
7	250	0.1	12	0.84	0.86	0.85	1.41102
8	250	0.125	4	0.99	1.05	1.02	-0.175759
9	250	0.15	8	0.86	0.88	0.87	1.20904

Table 5. Roughness response for each level of the process parameters

Levels	Cutting speed (RPM)	Feed (mm/rev)	Drill diameter (mm)
1	1.7869	2.0857	1.9162
2	1.4082	0.8583	1.5759
3	0.8148	1.0659	0.5179
Delta	0.9722	1.2274	1.3983
Rank	**3**	**2**	**1**

1.10. Analysis Of Variance

The results were analyzed using ANOVA for identifying the significant factors affecting the performance measures. The Analysis of Variance (ANOVA) for the mean surface roughness at 95% confidence interval is given in Table 6. The variation data for each factor were F-tested to find significance of each. The principle of the F-test is that the larger the F value for a particular parameter, the greater the effect on the performance characteristic due to the change in that process parameter. ANOVA table shows that drill diameter with F value of 0.59 cutting speed with F value of 0.26 and feed with F value of 0.48, are the factors that significantly affect the surface roughness. All others factors, namely, feed and cutting speed were found to be insignificant. Table 5 shows the ranks of various factors in the terms of their relative significance. Drill diameter has the highest rank, signifying highest contribution to surface roughness and drill cutting speed has the lowest rank and observed to be insignificant in affecting surface roughness. Main effect plot for the mean surface roughness is shown in the Figure 6, which shows the variation of surface roughness with the input parameters. As it can be, seen surface roughness decrease with increase in drill diameter from 4 mm to 12 mm. Surface roughness increased with increase in feed from 0.1 to 0.15.

Table 6. Analysis of variance (ANOVA) results for the Surface Roughness

Source of variation	DOF	Sum of squares (SS)	Variance (V)	F-ratio (F)	P-value (P)	Percentage (%)
Speed	2	1.441	0.005725	0.26	0.791	11.38
Feed	2	2.590	0.0124	0.48	0.678	20.44
Drill diameter	2	3.190	0.0147	0.59	0.631	25.18
Residual Error	2	5.450	0.027875			43
Total	8	12.671				

VI. Results And Discussion

Taguchi method is done with smaller – the – better criteria, which means that minimum surface roughness is the response. Figure 6 shows the main effect plot for S/N rations corresponding to the input parameters. From the figure it is clear that 4mm drill diameter have higher S/N ration. Similarly the speed & feed rate is 80rpm & 0.100 mm/rev. So the optimum sequence of parametersare $A_1 – B_1 – C_1$. Where A, B and C corresponding to cutting speed in rpm, feed rate in mm/rev & drill diameter in mm. Figure 7 shows the main effect plot for means, which is used for finding the optimum cutting parameters.

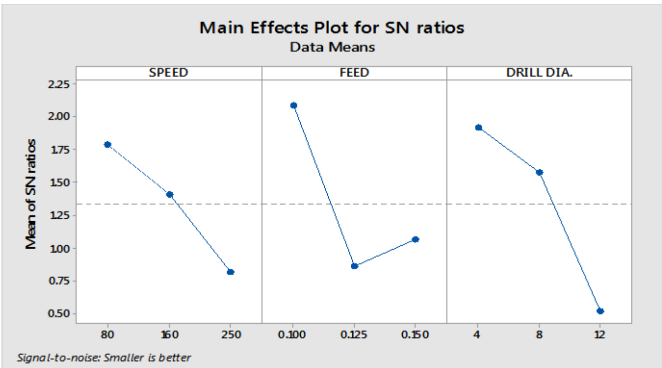

Figure 6. Main Effects Plot for SN Ratios

Figure 7. Main Effect Plot for means

VII. Conclusions

In this study, drilling of cast iron is carried out with the input drilling parameters considered as spindle speed, feed rate and drill diameter, and the response obtained is hole surface roughness. The drilling parameters are optimized with respect to multiple performances in order to achieve a good quality of holes in drilling of cast iron. Optimization of the parameters was carried out using Taguchi method.

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.

References

[1]. PHADKE, M.S. (1989) Quality Engineering using Robust Design, AT&T Bells Laboratory/Prentice-Hall, New Jersey, USA
[2]. Mustafa Kurt, EyupBagci and Yusuf Kaynak , " Application of Taguchi methods in the optimization of cutting parameters for surface finish and hole diameter accuracy in dry drilling processes," International J. Advance Manufacturing Technology., 40: 458-469,2009 .
[3]. Ichien Hsu and Tsao C.C., "Optimization of process parameter in drilling composite materials by Grey-Taguchi method," TahuaInsitute of Technology, Taiwan, 2008.
[4]. Vinod Kumar Vankanti, VenkateswaraluGanta, Optimization of process parameters in drilling of GFRP Composite using Taguchi method, J MATER R E S T E C HNOL . 2 0 1 4;**3(1)**: 35–41
[5]. Chua MS, Rahman M, Wong YS, HT, Determination of optimal cutting conditions using design of experiments and optimization techniques", In T J Mach Tools Manuf 1993; 33(2): 297–305.
[6]. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
[7]. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
[8]. R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev, in press.
[9]. M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.