Drilling parameter optimization of AISI 310 austenitic stainless steel using Taguchi method

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Abstract –
Drilling is the one of important operations for all structure which is quite often used as a final operation before assembly. The objective of this investigation is to optimize drilling parameters such as cutting speed, tool geometries and depth of cut such as hole roundness and hole surface roughness in drilling SS310. In this research, experiments are carried out as per Taguchi design of experiments and an L16 orthogonal array used to study the influence of various combinations of drilling parameters and tool geometries on quality of the hole The drilling experiment has to be carried out by using twist drill and CNC machining center. This work is useful for optimum values selection of various drilling parameters and tool geometries that would not only minimize the Roughness but also reduce the hole roundness error and hole surface roughness, so it can improve the quality of the drilled hole.

Keyword: Speed, Depth of cut, End point angle, Surface roughness, orthogonal array

Introduction

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 hole.

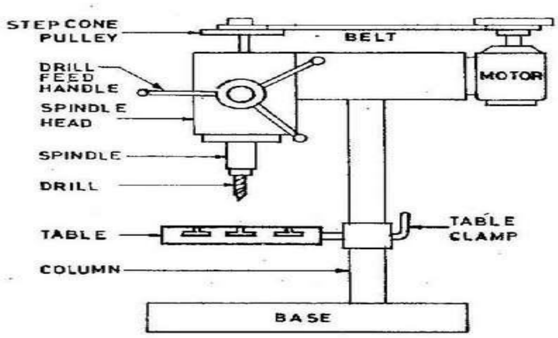

Figure.1 Drilling machine setup

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.

2.1 LITERATURE REVIEW

The behavior of a material is greatly dependent upon its surface, the environment and its operating conditions. Surface engineering can be defined as the branch of science that deals with methods for achieving desired surface requirements and behavior in service for engineering components. The surface of any component may be selected on the basis of texture and colour, but engineering components generally demand a lot more than this.

Engineering components must perform certain functions completely and effectively under various conditions, possibly in aggressive environments. Modem process environments, which contribute to wear, can be very complex, involving a combination of chemical and physical degradation. Surface properties of the component used in a particular working environment have to be designed with that environment in mind.

P.VENKATARAMAIAH [1] et al had Investigated on the controllable parameters (cutting speeds, feed rates, type of drill tool, cutting fluids) of drilling operations with influence the response of (torque, cutting force, surface roughness, material removal rate, power) in En8. Drilling is done by HSS tool only, by using taguchi method. Optimized through of two phases artificial neural network (ANN) continued to that ANN is analyzed with S/N ratio of Taughi approach **A.NAVANTH [2]** et al were studied of taguchi method based optimization of drilling parameter in dry drilling of al 2014 alloy at low speeds. Optimization of the parameters was carried out using Taguchi method. **M. MONTOYA [3]** et al were investigated to establish the wear mechanisms of coated and uncoated tungsten carbide drills when drilling carbon fiber reinforced plastics (CFRP)/aluminum alloy (Al) stacks. During the drilling experiments, thrust forces were measured. For both coated and uncoated drills, abrasion was the dominant tool wear mechanism, affecting the entire cutting edges higher wear was observed on uncoated tools which caused a significant increase in thrust force during drilling both Al and CFRP materials. **YOGENDRATYAGI [4]** et al were found the drilling of mild steel with CNC drilling machine by using a tool high speed steel by applying Taguchi methodology. A L9 array, taughuchi method and analysis of variance (ANOVA) are used to formulate the procedure tried on the change of parameter. Design offers a systematic method for optimization surface finish as well as high material removal rate (MRR). **ARSHAD NOOR SIDDIQUEEA [5]** et.al were concentrated on optimizing deep drilling parameters based on Taguchi method for minimizing surface roughness. The experiments were conducted through CNC lathe machine using solid carbide cutting tool on material AISI 321 austenitic stainless steel. Four cutting parameters such as cutting fluid, speed, feed and hole-depth, each at three levels except the cutting fluid at two levels were considered. Taguchi L18 orthogonal array was used as design of experiment. The signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) was carried out to determine which machining parameter significantly affects the surface roughness and also the percentage contribution of individual parameters. Confirmation test was conducted to ensure validity of the test result. The results revealed that the combination of factors and their levels identified the machining done in the presence of cutting fluid, at a speed of 500 r.p.m. with a feed of 0.04 mm/s and hole-depth of 25 mm yielded the optimum i.e. minimum surface roughness. **J. GANESH [6]** et.al, were analyzed in 12mm twist drill with coated carbide is used.H13 Die steel play an important role in many application such as Shaft, Axle, Gears and fasteners due to their strength to weight ratio. The present work was to optimize the cutting condition (Cutting speed, feed in dry cutting to the depth of hole) parameters for minimum surface roughness, optimum power utilization and tool life are optimized. With different process parameters like spindle speed, and feed rate to find optimal machining conditions of minimum surface roughness (Ra), Out of roundness and Material removal power are designed and conducted based on design of Experiments using L16orthogonal array and Optimized by Taguchi Design of experiments and analysis of variance are utilized to analyze a dominating parameter of surface roughness. **SUMEDH.S [7]** et.al Design Response Surface Methodology was developed by**[7].** The input parameters considered for drilling of T105Cr1 EN31 steel were spindle speed (N), feed rate (f), drill diameter (D) and point angle (Ɵ). The drill bit was used Titanium Aluminum Nitride coated twist drill having 6 mm and 8 mm in diameters.

The drilling operation was carried out on HSS Tool Room Mill USA made CNC milling machine under dry condition. To confirm the validity and correctness of the established mathematical model ANOVA is used for the in depth analysis of effect of finish drilling process parameters on the responses. Analysis of the parametric influence on responses were plotted through 3D surface plot and contour plots. **SUMESH A S 1, [8]** et.al analysed to optimize process parameter such as cutting speed, feed, and drill diameter. Taguchi methods are widely used for design of experiments and analysis of experimental data for optimization of processing conditions.

Optimization of drilling parameters using the Taguchi technique to obtain minimum surface roughness (Ra). A number of drilling experiments were conducted using the L9 orthogonal array on a radial drilling machine. The experiments were performed on cast iron using HSS twist drills. Analysis of variance (ANOVA) was employed to determine the most significant control factors affecting the surface roughness. The cutting speed, feed rate and drill diameter were selected as control factors. **M SUNDEEP1[9]** et.al were focused to make an experimental investigation on drilling behavior of Austenitic stainless Steel (AISI 316) and attempt made to optimize the process parameters using L9 Orthogonal array design of experiment of Taguchi methodology. The process parameters of spindle speed, feed rate and drill diameter are influenced by surface roughness and Metal removal rate during Drilling operations. **J. PRASANNA [10]** et.al were investigated, through holes were machined in a Ti–6Al–4V plate of 0.4 mm thickness using twisted carbide drill bits of 0.4 mm diameter by conventional dry drilling. The Taguchi's experimental design and Analysis of Variance (ANOVA) techniques have been implemented to understand the effects, contribution, significance and optimal machine settings of process parameters, namely, spindle speed, feed rate and air pressure.

TAGUCHI METHOD

Dr.Genichi Taguchi introduced an optimization method that helped in making calculations of experiments easier and rapid. It was originally made to make the improvement in the quality of goods that were being made in japan. This technique helped in introducing a method that only require a specific set of experiments to find the effectiveness on the responseparameters.

Orthogonal Array represents the data structure and the matrix that it shows contains the data for the experiments. In addition, the number of runs during experiment is defined by orthogonal array. In order to reach maximum quality of product three steps are very important in Taguchi method which is System Design, Parameter Design and tolerance design. Taguchi analysis was done using MINITAB17 software and the results and graphs were plotted with that. MINITAB17 is software which a brilliant tool for the calculations and researches using several algorithm. The experiments were designed using Taguchi orthogonal array and both the design of experiment follow the same methodology. The DOE is a L_{16} orthogonal array with three process parameters having fourlevels.

Figure 2 Vertical milling machine

EXPERIMENTALWORK

Table 1 Level of machining parameters

Levels	Process parameters		
	Spindle Speed (rpm)	DOC mm	EPA°
1	250	0.10	118
2	350	0.15	123
3	450	0.2	128
4	550	0.25	133

MACHINE USED

The experiments were conducted on the VMC-400. It is a vertical milling/drilling machine, which is manufactured by HMT. This vertical machining center is equipped with the Fanuc India series O-M controller for the execution of programs. The machine is capable of running at 4000rpm of spindle speed. The maximum feed that can be attained in this specific machine is 2000mm/min.

Fig: 3 VMC400 machine

CUTTING TOOL

Fig: 4 Drill bit

Stainless steel is a material that cannot be machined easily because of its properties. Therefore, the cutting tool need to be the right one in order to get optimum results. The cutting tool used here for drilling is HSS (High Speed Steel) drill bits. HSS drills are easily available and are cost effective as compared to the other.

WORKPIECE MATERIAL

Fig: 5 SS310 Material

Stainless steel is better than other type of steel as it doesn't corrode or rust. Stainless steel is found in many grades but the one that was selected for this dissertation was AISI 310

Table 2 L16 Orthogonal array

No	Designation	SPEED (N) (rpm)	DOC (mm)	EPA°
1	A1B1C1	250	0.10	118
2	A1B2C2	250	0.15	123
3	A1B3C3	250	0.20	128
4	A2B1C2	250	0.25	133
5	A2B2C3	350	0.10	123
6	A2B3C1	350	0.15	118
7	A3B1C3	350	0.20	133
8	A3B2C1	350	0.25	128
9	A3B3C2	450	0.10	128
10	A3b2c4	450	0.15	133
11	A3B2C1	450	0.20	118
12	A3B4C2	450	0.25	123
13	A4B1C4	550	0.10	133
14	A4B2C1	550	0.15	128
15	A4B3C2	550	0.20	123
16	A4B4C3	550	0.25	118

Chemical composition of material

Table 3 Chemical composition

Chemical Composition	310
Carbon	0.25 max
Manganese	2.00 max
Silicon	1.50 max
Phosphorus	0.045 max
Sulphur	0.030 max
Chromium	24.00 - 26.00
Nickel	19.00 - 22.00

DESIGN OF EXPERIMENTS

SURFACE ROUGHNESS MEASUREMENT

Surface roughness is defined as the finer irregularities of the surface texture that usually result from the inherent action of the machining process or material condition.A portable surface roughness tester (ModelNo TR 210 manufactured by Beijing TIME High Technology Ltd. Beijing City, China) has been used to measure surface roughness(Fig:6)indicators of finished work pieces.

Fig: 6 SS310 Material

RESULTS FOR SURFACE ROUGHNESS

In this experiment, the surface roughness for each hole was measured and noted as response. The result of the surface roughness (SR) is represented along with parameters in the given table. S/N (SR) represents the signal-to-noise ratio for surface roughness.

Table: 4 Output response for surface finish

S NO	SPEED	DOC	EPA	RA	SNRA
1	250	0.10	118	1.338	-2.529
2	250	0.15	123	1.942	-5.765
3	250	0.20	128	1.856	-5.372
4	250	0.25	133	1.603	-4.099
5	350	0.10	123	1.373	-2.753
6	350	0.15	118	1.788	-5.047
7	350	0.20	133	2.212	-6.896
8	350	0.25	128	1.124	-1.015
9	450	0.10	128	2.649	-8.462
10	450	0.15	133	1.555	-3.835
11	450	0.20	118	1.422	-3.058
12	450	0.25	123	1.702	-4.619
13	550	0.10	133	1.890	-5.529
14	550	0.15	128	1.019	-0.163
15	550	0.20	123	2.061	-6.282
16	550	0.25	118	1.931	-5.716

Response Table for Signal to Noise MT-Smaller is better

Table : 5 Response Table for Signal to Noise

LEVEL	SPEED	FEED	DOC
1	-6.598	-6.510	-7.190
2	-6.883	-6.385	-5.725
3	-6.487	-6.809	-6.655
4	-7.024	-7.288	-7.422
DELTA	0.537	0.903	1.697
RANK	3	2	1

Analysis of Variance for RA

Table: 6 Anova for RA

SOURCE	DF	SEQ SS	ADJ MS	F	P	% of contribution
SPEED	3	0.05974	0.01991	0.45	0.727	7
FEED	3	0.13134	0.04378	0.99	0.459	15
DOC	3	0.42836	0.14279	3.22	0.104	48
ERROR	6	0.26592	0.04432			30
TOTAL	15	0.88536				100

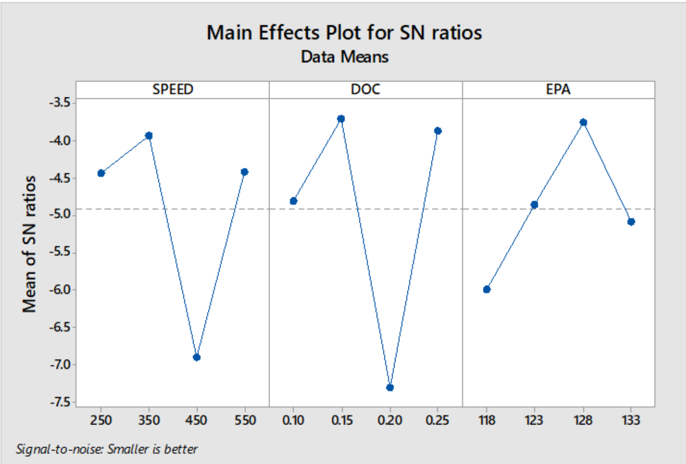

Fig : 7 SN ratio graph for RA

RESULTS FOR DIAMETER ERRORS

Table : 7 Output response diameter error

Trial	PEED	FEED	E P A	DIAERR	SNRATIO
1	250	0.10	118	10.123	-20.1062
2	250	0.15	123	10.249	-20.2136
3	250	0.20	128	10.421	-20.3582

4	250	0.25	133	10.268	-20.2297
5	350	0.10	123	10.316	-20.2702
6	350	0.15	118	10.209	-20.1797
7	350	0.20	133	10.310	-20.2652
8	350	0.25	128	10.081	-20.0701
9	450	0.10	128	10.291	-20.2492
10	450	0.15	133	10.172	-20.1481
11	450	0.20	118	10.249	-20.2136
12	450	0.25	123	10.301	-20.2576
13	550	0.10	133	10.230	-20.1975
14	550	0.15	128	10.236	-20.2026
15	550	0.20	123	10.208	-20.1788
16	550	0.25	118	10.214	-20.1839

Response Table for Signal to Noise Rations- Circle Smaller Is Better

Table : 8 Response Table for Signal to Noise

LEVEL	SPEED	FEED	DOC
1	-20.23	-20.21	-20.17
2	-20.2	-20.19	-20.23
3	-20.22	-20.25	-20.22
4	-20.19	-20.19	-20.21
Delta	0.04	0.07	0.06
RANK	3	1	2

Analysis of Variance of Circle

Table : 9 Anova for diameter error

SOURCE	DF	SEQ SS	ADJ MS	F	P	% of contribution
SPEED	3	0.004942	0.001647	0.16	0.922	5
FEED	3	0.017419	0.005806	0.55	0.667	18
DOC	3	0.011255	0.003752	0.36	0.788	12
ERROR	6	0.063370	0.010562			65
TOTAL	15	0.096986				100

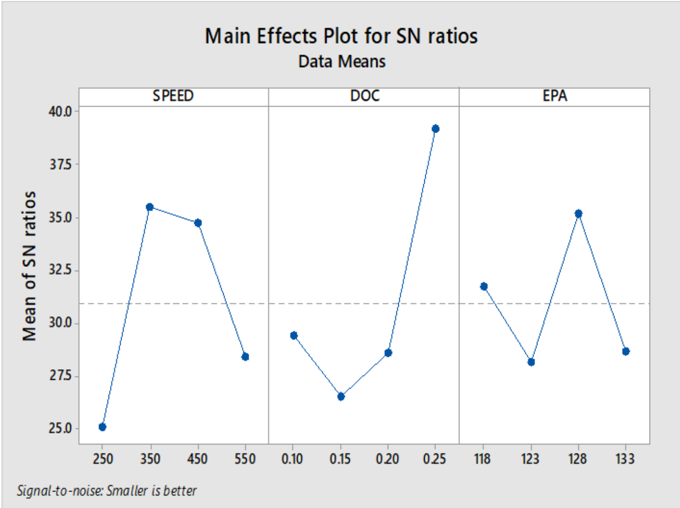

Fig: 8 SN ratio graph for diameter error

RESULTS AND DISCUSSION

The surface roughness and ovality was recorded and analysed using MINITAB software which helped us in creating graphs and plots for the results which makes it easier to understand the effect of the parameters on the responses.

- The ANOVA helps to find the response output of surface roughness shown in Table 6.
- The Surface Roughness is minimum 1.019mm at 14^{th} run.
- Optimized Surface Roughness is obtained by using L_{16}, When the speed is 550 rpm, doc 0.15mm and end point angle is 128^{0}.
- End point angle is major role in machining.
- When increasing the speed level, they affecting the Surface Roughness value.

References

P.Venkataramaiah, *G.Vijaya Kumar and P. Sivaiah Prediction and analysis of multi responses in drilling of EN8 steel under MQL using ANN-Taguchi approach*

A. Navanth, *T. Karthikeya Sharma Assistant Professor, Department of Mechanical Engineering, "A study of taguchi method based optimization of drilling parameter in dry drilling of alloy at low speeds 2014"*

M.Montoya *M.Calamaz - D.Gehin - F.Girot Evaluation of the performance of coated and uncoated carbide tools in drilling thick CFRP/ aluminum alloy stacks; Received 19 September 2012/Accepted:28january 2013/ Published online:16 February 2013.*

Yogendra Tyagi, *Vedansh Chaturvedi, Jyoti Vimal;Parametric Optimization of Drilling Machining Process usingTaguchi Design and ANOVA Approach International Journal of Emerging Technology and Advanced Engineering.Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 7, July 2012)*

Arshad Noor Siddiqueea, *Zahid A. Khana, PankulGoelb,MukeshKumarb,GauravAgarwal, Noor ZamanKhana, Optimization of Deep Drilling Process Parameters of AISI 321 Steel using Taguchi Method, Procedia Materials Science 6 (2014) 1217 – 1225*

J. Ganesh, *P. Renukadevi, P. Vijayakumar, Experimental optimization of drilling process parameters on die steel (h13) using carbide coated drill by taguchi design method, (ijmet) Volume 8, Issue 3, March 2017,*

Sumedh. *S Pathak, Dr. M. S. Kadam, development of rsm based model for machining of t105cr en31 steel by tialn coated twist drill, Volume 3, Issue 1, January- April (2012),*

Sumesh A S, *Melvin Eldho Shibu**,** Optimization Of Drilling Parameters For Minimum Surface Roughness Using Taguchi Method,(IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X*

M Sundeep *M.Sudhahar, T.T.M.Kannan, P.Vijaya Kumar and N Parthipan, optimization of drilling parameters on austenitic stainless steel (aisi 316) using taguchi's methodology, Vol. 3, No. 4, October, 2014*

J. Prasanna, *L. Karunamoorthy, M. Venkat Raman, Sai Prashanth, D. Raj Chordia, Optimization of process parameters of small hole dry drilling in Ti–6Al–4V using Taguchi and grey relational analysis, Measurement 48 (2014) 346–354*