Journal of Manufacturing Engineering, June 2015, Vol. 10, Issue. 2, pp 112-116

TAGUCHI METHOD BASED OPTIMIZATION OF DRILLING PARAMETERS OF EN31 STEEL WITH PVD COATED AND UN-COATED DRILLS

Ramesh V[1], Mohammed [*]Hasian Y[2], Gopinath T S[3]

[1]Associate Professor, Mechanical Department M.I.E.T. Engineering College, Trichirapalli-620007, Tamilnadu, India
[2,3]Final year student (B.E), Department Mechanical Engineering, M.I.E.T. Engineering College, Trichirapalli-620007

ABSTRACT

The methodology of Modified Taguchi optimization method for simultaneous minimization and maximization of Surface roughness (Ra), machining time and material removal rate of EN31 affect the aesthetical aspect of the final product and hence it is essential to select the best combination values of the CNC drilling process parameters to minimize as well as maximize the responses. The experiments were carried out by a CNC lathe, using physical vapour deposition coated (TiAlN, CrAlN) & un-coated HSS drilling tool insert for the machining of EN31.

The experiments were carried out as per L_{27} orthogonal array with each experiment performed under different conditions of such as speed, type of drilling tool, and feed rate. The Taugchi method and analysis of variance (ANOVA) was employed by using MINITAB-16 software to identify the level of importance of the machining parameters on Surface roughness (Ra), Machining time and Material Removal Rate (MRR).

Keywords*: CNC lathe – Coated drills - Orthogonal array - Machining parameters - Modified Taguchi method – ANOVA – MINITAB -16.*

1. Introduction

Drilling is one of the basic machining process of making holes and it is essentially for manufacturing industry like automobile industry, medical industry, and aerospace industry. Especially drilling is necessary in industries for assembly related to mechanical fasteners. It is reported that around 55,000 holes are drilled as a complete single unit production of the AIR BUS A350 aircraft. Drilling of metals is increasing requirements for producing small products and more highly functional. With increasing demand for precise component production, the important of drilling processes is increasing rapidly. Because of the requirement of deeper and smaller holes required in the above said industries, It is required for drilling process technologies to achieve higher accuracy and higher productivity.

There are several convectional and non-conventional manufacturing process by which drilling can be performed. Drilling using laser beam, electron's beam and electric discharge methods and also electrolytic polishing, electro chemical machining has been frequently used by industries and researches. However, for general application,

Conventional drilling process is preferred due to the higher economical benefits than other processes and also it has highly productivity than other non - convectional drilling processes.

Physical vapour deposition (PVD) describes a variety of vacuum deposition methods used to deposit thin films by the condensation of a vaporized form of the desired film material onto various work piece surfaces (e.g., onto semiconductor wafers). The coating method involves purely physical processes such as high-temperature vacuum evaporation with subsequent condensation, or plasma sputter bombardment rather than involving a chemical reaction at the surface to be coated as in chemical vapour deposition.

EN31 is an important material with desirable properties, including high resisting in nature against wear and can be used for components which are subjected to severe abrasion, wear, high surface loading. Hence, EN31promises fruitful development for applications in the automobile sector due to its high strength.

2. Taguchi Approach

A large number of experiments have to be carried out when the number of the process parameters increases. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the

*Corresponding Author - E- mail: hasian.437@gmail.com

 © SME

entire parameter space with a small number of experiments. The experimental results are then transformed into a signal – to – noise (S/N) ratio [1,2] to measure the quality characteristics deviating from the desired values. Usually, there are three categories of quality characteristics in the analysis of the S/N ratio, i.e., the – lower – better, the – higher – better, and the – nominal – better. The S/N ratio for each level of process parameter is compared based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio Furthermore, a statistically significant with the S/N and ANOVA [3] analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design.

There are 3 Signal-to-Noise ratios [4,5,6] of common interest for optimization of Static Problems. The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. Therefore a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic. They are

1. Smaller-The-Better,
2. Larger-The-Better,
3. Nominal is Best.

Smaller is better

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the smaller-is-better S/N ratio using base 10 log is:

$S/N = -10*\log(S\ (Y^2)/n)$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination

Larger is better

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the larger-is-better S/N ratio using base 10 log is:

$S/N = -10*\log(S\ (1/Y^2)/n)$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

Nominal is best

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the nominal-is-best I S/N ratio using base 10 log is:

$S/N = -10*\log\ (s^2)$

Where s = standard deviation of the responses for all noise factors for the given factor level combination

3. Experimental Setup

In the present work, CNC lathe is used to drill holes on EN 31; the machining setup is shown in Figure (1). The High speed steel (HSS) has been used as drill bit. The process parameters considered for this research has been shown in Table 3 along with its levels. The experimental data has been presented in Table 4.

Fig. 1 CNC lathe machine

Figure (2) coated drill bit

In this study, experiments were performed using 15.87- mm diameter HSS twist uncoated drills, HSS TiAlN-coated drills, and HSS CrAlN-coated drills. It shows the dimensional properties of the drilling tools. To guarantee the initial conditions of each test, a new tool was used in each experiment.

Details of work material

Work material - EN31
Thickness of the work material - 15mm

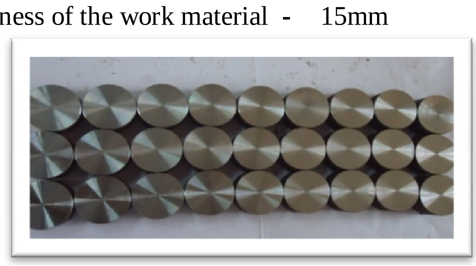

Fig. 3 Work material before drilled

 © SME

Work material preparations

The work piece material was EN 31, which is extensively used in the Automobile industry and aerospace industry. The chemical and mechanical properties of EN 31 are shown in Table 1 and 2 respectively.

Fig. 4 After the drilling of work piece

Table 1: Chemical Properties of EN 31

Composition	Wt. percentage
c	0.90-1.20
Mn	0.30-0.75
Si	0.10-0.35
S	0.40
P	0.40
Cr	1.00-1.60

Table 2: Physical Properties of EN 31

UTS(MPa)	224.07
Yield stress(MPa)	2033.95
Elongation (%)	5
Modulus of Elasticity	203395.39
Density (kg/m^3)	7833.413
Hardness (HRC)	62

Surface finish measurements

Surftest SJ-201P: Surftest SJ-201P (Portable surface roughness tester) instrument is 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).

Fig. 5 Surf tester Machine

Table 3: Process Parameters and their Levels

Levels	Process parameters		
	Speed (N) (rpm)	Feed (f) (mm/rev)	Type of drill tool
1	300	0.03	HSS
2	400	0.08	HSS+TiAlN
3	500	0.1	HSS+CrAlN

Table 4. Experimental data for EN31 of 15 mm thicknesses

Trial No.	Designation	machining time (sec)	MRR (mm^3/sec)	Ra (μm)
1	$A_1B_1C_1$	202	0.19441	1.73
2	$A_1B_1C_2$	202	0.19302	0.20
3	$A_1B_1C_3$	189	0.20571	0.63
4	$A_1B_2C_1$	98	0.39786	2.77
5	$A_1B_2C_2$	98	0.40163	0.14
6	$A_1B_2C_3$	98	0.39816	0.41
7	$A_1B_3C_1$	85	0.46200	1.21
8	$A_1B_3C_2$	85	0.46188	0.40
9	$A_1B_3C_3$	85	0.47859	0.61
10	$A_1B_1C_1$	160	0.25119	4.67
11	$A_2B_1C_2$	160	0.24388	0.20
12	$A_2B_1C_3$	161	0.24075	0.61
13	$A_2B_2C_1$	82	0.47720	2.03
14	$A_2B_2C_2$	82	0.47963	0.20
15	$A_2B_2C_3$	82	0.47341	1.52
16	$A_2B_3C_1$	73	0.53466	0.81
17	$A_2B_3C_2$	73	0.53603	0.64
18	$A_2B_3C_3$	73	0.55342	0.47
19	$A_3B_1C_1$	135	0.29067	2.88
20	$A_3B_1C_2$	135	0.28963	0.77

 © SME

21	$A_3B_1C_3$	135	0.28919	0.52
22	$A_3B_2C_1$	73	0.53644	3.63
23	$A_3B_2C_2$	73	0.53890	1.52
24	$A_3B_2C_3$	73	0.53575	1.06
25	$A_3B_3C_1$	65	0.60046	2.71
26	$A_3B_3C_2$	65	0.60138	0.33
27	$A_3B_3C_3$	65	0.61877	1.75

4. Analysis of Experimental Data

After conducting the experiments, S/N ratio for the Ra, Machining time and MRR has been calculated using Minitab-16 Software. The calculated S/N ratios were presented in Table 5. ANOVA has been performed to find the influencing factor as shown in Table 6.

Table 5. S/N ratio for the responses

Trial No.	Designation	S/N for (Ra)	S/N for machining time	S/N for (MRR)
1	$A_1B_1C_1$	-4.76092	-46.107	-14.2256
2	$A_1B_1C_2$	13.9794	-46.107	-14.288
3	$A_1B_1C_3$	4.013189	-45.5292	-13.7349
4	$A_1B_2C_1$	-8.8496	-39.8245	-8.00539
5	$A_1B_2C_2$	17.07744	-39.8245	-7.92348
6	$A_1B_2C_3$	7.744323	-39.8245	-7.99885
7	$A_1B_3C_1$	-1.65571	-38.5884	-6.70716
8	$A_1B_3C_2$	7.9588	-38.5884	-6.70942
9	$A_1B_3C_3$	4.293403	-38.5884	-6.40073
10	$A_1B_1C_1$	-13.3863	-44.0824	-12
11	$A_2B_1C_2$	13.9794	-44.0824	-12.2565
12	$A_2B_1C_3$	4.293403	-44.1365	-12.3687
13	$A_2B_2C_1$	-6.14992	-38.2763	-6.42599
14	$A_2B_2C_2$	13.9794	-38.2763	-6.38187
15	$A_2B_2C_3$	-3.63687	-38.2763	-6.49525
16	$A_2B_3C_1$	1.8303	-37.2665	-5.43845
17	$A_2B_3C_2$	3.876401	-37.2665	-5.41622
18	$A_2B_3C_3$	6.558043	-37.2665	-5.1389
19	$A_3B_1C_1$	-9.18785	-42.6067	-10.732
20	$A_3B_1C_2$	2.270185	-42.6067	-10.7631
21	$A_3B_1C_3$	5.679933	-42.6067	-10.7763
22	$A_3B_2C_1$	-11.1981	-37.2665	-5.40958
23	$A_3B_2C_2$	-3.63687	-37.2665	-5.36984
24	$A_3B_2C_3$	-0.50612	-37.2665	-5.42076
25	$A_3B_3C_1$	-8.65939	-36.2583	-4.43032
26	$A_3B_3C_2$	9.629721	-36.2583	-4.41702
27	$A_3B_3C_3$	-4.86076	-36.2583	-4.16942

From Table 6, it is observed that the type of tool has been the most influencing factor in determining the Ra value. The feed rate has been the influencing factor for the machining time and metal removal rate.

From the main effects plots it is learnt that the optimal parameter combination for surface finish, Machining time and Metal removal Rate has been $A_2B_3C_1$, $A_2B_1C_3$ and $A_2B_1C_3$ respectively.

Table 6. ANOVA results for the Ra, Machining time & MRR for drilling of EN31

Analysis of variance (ANOVA) results for the roughness						
Source of variation	**DOF**	**Sum of squares (S)**	**Variance (v)**	**F ratio (F)**	**P value (p)**	**% of contribution**
Speed	2	2.7944	1.3972	2.51	0.106	7.834
Feed	2	1.1417	0.5708	1.03	0.377	3.201
Type of tool	2	20.606	10.303	18.52	0.00	57.77
Error	20	11.1280	0.5564			31.20
Total	26	35.6705				100
ANOVA results for the machining time						
Source of variation	**DOF**	**Sum of squares(S)**	**Variance (v)**	**F ratio (F)**	**P value (p)**	**% of contribution**
Speed	2	5884.2	2942.1	33.60	0.000	11.4
Feed	2	43800.0	21900.0	250.13	0.000	85.1
Type of tool	2	10.7	5.3	0.06	0.488	0.00
Error	20	1751.1	87.6			3.404
Total	26	51446.0				100
ANOVA results for the metal removal rate						
Source of variation	**DOF**	**Sum of squares (S)**	**Variance (v)**	**F ratio (F)**	**P value (p)**	**% of contribution**
Speed	2	0.068332	0.034166	240.03	0.000	13.7
Feed	2	0.427759	0.213880	1502.62	0.000	85.7
Type of tool	2	0.000173	0.000086	0.61	0.554	0.00
Error	20	0.002847	0.000142			0.6
Total	26	0.499111				100

5. Confirmation Tests

The experimental confirmation test is the final step in verifying the results drawn based on Taguchi's design approach. The optimal conditions are set for the significant factors (the insignificant factors are set at economic levels) and a selected number of experiments are run under specified cutting conditions. The average of the results from the con-firmation experiment is compared with the predicted average based on the parameters and levels tested. The confirmation experiment is a crucial step and is highly recommended by Taguchi to verify the experimental results [7]. In this study, a confirmation experiment was conducted by utilizing the levels of the optimal process parameters ($A_2B_3C_1$) for surface finish, ($A_2B_1C_3$) for the Machining time value and ($A_2B_1C_3$) for the Metal removal Rate in the dry drilling of EN31.

The confirmation test results shown in Table 7, validates the optimal parameter setting for surface finish, machining time and metal removal rate.

 © SME

Table 7. Results of confirmation test

Surface finish		
	Taguchi Prediction value	Confirmation Experiment value
Optimal Level	($A_2B_3C_1$)	($A_2B_3C_1$)
Ra (µm)	0.81	0.80
S/N ratio for Ra	1.8303	1.820
Machining time		
Optimal Level	($A_2B_1C_3$)	($A_2B_1C_3$)
Machining time (µm)	161	161
S/N ratio for machining time	-44.1365	-44.1365
Metal removal rate		
Optimal Level	($A_2B_1C_3$)	($A_2B_1C_3$)
MRR (mm^3/sec)	0.24075	0.24064
S/N ratio for MRR	-44.1365	-44.1363

6. Conclusions

In this study, the Taugchi technique and ANOVA were used o obtain optimal drilling parameters in the drilling of EN31 under dry conditions. The experimental results were evaluated using ANOVA. The following conclusion can be drawn.

As a result of the Taugchi experimental trials, it was found that the feed rate was the most significant factor for improving the Metal Removal rate with contribution percentage of 85.1% and 85.7% respectively. The optimum control factor for both Machining time and Metal removal rate were A_2 (spindle speed, 400rpm), B_1 (feed rate, 0.03 mm/rev) and C_3 coated tool (HSS+CrAlN). The optimum control factor for surface roughness has been A_2 (spindle speed, 400rpm), B_3 (feed rate 0.08 mm/rev) and C_1 HSS tool.

References

1. *Venkataramaiah P Vijaya Kumar G and Sivaiah P "Prediction and analysis of multi responses in drilling of EN8 steel under MQL using ANN-Taguchi approach", Department of Mechanical Engineering, S V University College of Engineering, Tirupati, Andhra Pradesh, India.*

2. *Yogendra Tyagi Vedansh Chaturvedi Jyoti Vimal (July 2012), "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, and Issue 7).*

3. *Mustafa Kurt Eyup Bagci Yusuf 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, Vol. 40 Issue 5/6, 458-62.*

4. *Rivero G Aramendi S Herranz L N Lo´ pez de Lacalle (2005),"An experimental investigation of the effect of coatings and cutting parameters on the dry drilling performance of aluminium alloys", Received: 26 May 2004 / Accepted: 22 July 2004 / Published online: 13 April 2005 © Springer-Verlag London Limited.*

5. *Montoya M Calamaz M Gehin D Girot F "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.*

6. *Turgay Kivak Gurcan samtas adem Cicek "Taguchi method based optimization of drilling parameters in drilling of ALSI 316 steel with PVD monolayer and multilayer coated HSS drills", published at 2012.*

7. *Navanth A karthikeya Sharma T "A study of taguchi method based optimization of drilling parameter in dry drilling of al 2014 alloy at low speeds", International Journal of Engineering Sciences & Emerging Technologies, August 2013.International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-1, October 2012.*

 © SME