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Taguchi Method Based Optimization for Surface Roughness in Drilling Operation of EN-31 Steel Material and DOE Approach

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Abstract—Drilling is on the basic machining process of making holes and it is essentially for manufacturing Industry like Aerospace Industry, Automobile Industry and Medical Industry.In the present work by using Taguchi approach the End Milling of EN 31 Steel Alloy is carried out in order to Optimize the Milling process parameter and the Surface Roughness.A run order was devlop by using Three Milling Process parameter i.e. Speed,Feed Rate and Depth of cut.Each having Three levels using L_9 Orthogonal Array.The Nine Experiment are perfomed and surface roughness is calculated the Signal to Noise Ratio (S/N Ratio) of predicated value and verification Test value are vaild when compare with the Optimum values.

Index Terms—DOE Approach, EN-31 Material, Milling Process, Signal to Noise Ratio (S/N), Taguchi Method.

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1 Introduction

Drilling is one of the manufacturing operation to make the Holes by Rotating a wedge shaped cutting tool called drll bit.The production of holes is component is major material removal process is metal cutting Industry. Especially Drilling is necessary in Industry for assembly relates to mechanical fastners.It is reported that around 55000 holesare drilling as a complete single unit production of the Airbus A350 aircraft.The objective of the project work is to find out the set of optimum value of for the selected control factor in order to reduce surface roughness using Taguchi Robust Design methodology and to devolve the prediction model for roughness. In the present work,Taguchi Method is used to determine the optimum cutting milling parameter more efficiently three controle factor viz. Cutting Speed,Feed rate Depth of cut are investigated at three different levels.the workpiece material used in EN31 steel Alloy. Taguchi method is used to optimize the process parameter i.e. Surface Roughness using Signal to Noise ratio for Milling processes of Workpiece material.Experiments are carried out using L_9 Orthogaonal Array. In the existing work, the tests were conduct by the Taguchi and DOE analysis and also generate the regression models by using MINITAB 17 statistical analysis software.

1.1 Literature survey

On the strength of the exhaustive review of work done by previous researchers [1- 12], it is found that a very little work has been found on this advance material (EN-31).
The study demonstrates detailed methodology of the proposed optimization technique which is based on Taguchi method; and ranks the parameters namely cutting speed, feed, and depth of cut through S/N ratio. Surface finish of work piece have been optimized. Surface Roughness using Signal to Noise ratio for Milling processes of Workpiece material.Experiments are carried out usin L_9 Orthogaonal Array.
Avinash A. Thakre understanding the effects of various milling parameters such as spindle speed, feed rate, depth of cut and coolant flow on the surface roughness (Ra) of finished products. The experimental plan was based on Taguchi's technique
Incluing L9 orthogonal array with four factors and three levels for each variable and studying the contribution of each factor on surface roughness. Theanalysis of mean and variance technique is employed to study the significance of each machining parameter on the surface roughness. (7)Abhang L B and Hameedullah M in the present study, experiments is conducted for three different work piece materials to see the effect of work piece material Variations in this respect. Five roughness parameters, viz., centre line average roughness, root mean square roughness; skewness, kurtosis and mean line peak spacing have been considered. The second-order mathematical models, in terms of the machining parameters, have been developed for each of these five roughness parameters prediction using response surface method on the basis of experimental results. The roughness models as well as the significance of the machining parameters have been validated with analysis of variance.
A through study of literature suggests that the machining of EN-31 alloy is very difficult compared to other alloy materials. EN-31 plate has been used as a work piece material for the present experiments because EN-31 is a high quality alloy steel giving good ductility and shock resisting properties combined with resistance to wear. The steel is a basically known as bearing steel and used for bearing production in industrial sector. Very few works have been carried out in the optimization of process parameters in milling process of EN-31 alloy with different controlled parameters such as cutting speed,feed rate and depth of cut etc,.

1.2 Milling Process

Milling is the machining process of using rotary cutters to remove material from a workpiece advancing (or *feeding*) in a direction at an angle with the axis of the tool.It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes. Milling machines are basically classified as verticalor horizontal. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machines have selfcontained Electric drive motors, coolant systems, variable spindle speeds, and power-operated and table feeds. The three primary factors in any basic milling operation are speed, feed and depth of cut. Other factors such as kind of material and type of tool materials have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine.

1.3 Surface Roughness

Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. Surface roughness of turned components has greater influence on the quality of the product.Whenever two machined surfaces come in contact with one another the quality of the mating parts plays an important role in the performance and wear of themating parts. The height, shape, arrangement and direction of these surface irregularities on the workpiece depend upon a number of factors such as:

- The machining variables which include
  - Cutting speed,
  - Feed and
  - Depth of cut.
- The tool geometry
  Some geometric factors which affect achieved surface roughness include:
  - Nose radius,
  - Rake angle,
  - Side cutting edge angle and
  - Cutting edge.
- Work piece and tool material combination and their mechanical properties
- Quality and type of the machine tool used,
- Auxiliary tooling and lubricant used and
- Vibrations between the work piece, machine tool and cutting tool.

1.4 Experiment Setup and Design

The aim of the present work is to find out the set of optimum values for the selected control factors in order to reduce surface roughness using Taguchi's Robust Design Methodology. The work material selected is EN -31 steel alloy. The experiments are conducted using $L_9\,(3^3)$ orthogonal array.

Figer N0.1 Specification of CNC Vertical Milling Machine

Drill Tap Machining Centers				DTC Series
			SPARK	DTC-300
Stroke X, Y & Z axes		mm	300 x 250 x 250	400 x 350 x 310
Table size		mm x mm	500 x 330	600 x 350
Max. load on Table	-Std / Opt	kgf	150	200 / 400
Max. spindle speed	-Std.	rpm	6000	6000
	-Opt		8000	8000
Spindle power		kW	5.5 / 3.7	5.5 / 3.7
Spindle taper			BT-30	BT-30
ATC capacity	-Std / Opt	Nos	6	12
Rapid traverse – X / Y / Z axes	-Std	m / min	20 / 20 / 15	32 / 32 / 32
	-Opt			40 / 40 / 40

Figer 2 CNC Vertical Milling Machine


Figer 3 Experimental Setup of CNC Vertical Milling Machine

1.5 WORKPIECE MATERIAL

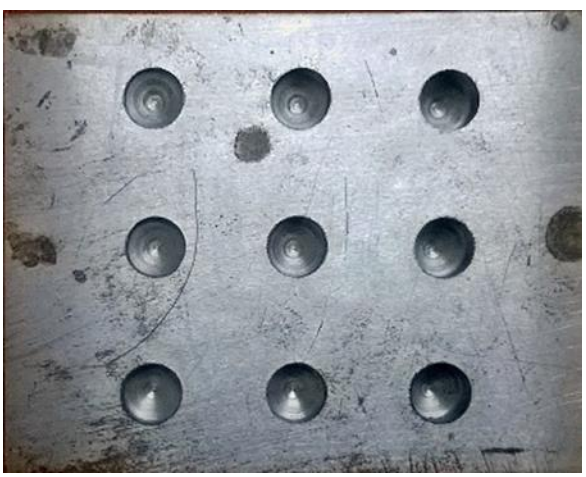
The work piece material used is EN-31 Steel belongs to steel alloy of 100mm long, 75mm breadth and 10mm thickness in the form of plates. The EN-31defined a number of Emergency Number Steel alloy standards with a numbering scheme for easy reference and are mentioned them in the form of grades.

Chemical Composition of EN-31

Element	Chemical Composition (wt%)
C	1.08 %
Si	0.25 %
Mn	0.53 %
S	0.015 %
P	0.022 %
Ni	0.33 %
Cr	1.46 %
Mo	0.06 %

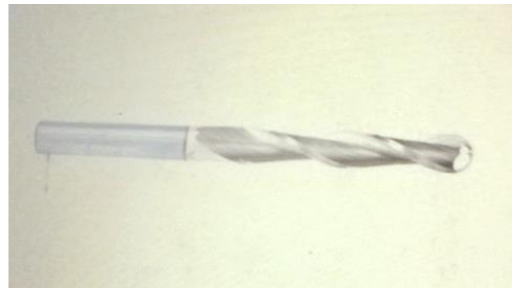
Mechanical Property of EN-31

Element	Objective
Tensile strength	750 N/mm²
Yield Strength	450 N/mm²
Reduction of Area	45%
Elongation	30%
Modulus of Elasticity	215 000 N/mm²
Density	7.8 Kg/m3



Figer NO.4 work piece used for machining Process

1.6 Cutting Tool



Figer NO.5 Brass Coated Carbide Cutting Tool

The cutting tool used is brass coated carbide inserts with a tool diameter of 10mm.It consists of very high hardness and good Toughness and it is principally intended for roughing of super alloys and steel alloys.

1.7 LUBRICANT/CUTTING FLUID

The cutting fluid used in the machining is synthetic oil + water. The coolant used at mixture of 1:20 ratio i.e. is one liter of synthetic oil is mixed with 2litres of water.Holy oil is used as a lubricant for better performance.

1.8 SURFACE ROUGHNESS TESTER

Figer NO. 6 Stylus-type Profilometer

Model: Mitutoyo SJ-201P

1. Wide 350µm (-200µm to +150µm) measurement range
2. GO/NG judgment on a desired parameter.
3. RS-232C interface enables data transfer to computer or other devices using an external device.
4. Traversing length (Lt): 1.75mm, 5.6mm, 17.5mm
5. Short cut-off : Selectable
6. Evaluation length (In): 1.25mm, 4.0mm,12.50mm

2.Methodology

Taguchi method

Taguchi developed a particular design of orthogonal arrays to study the whole parameter space with a little amount of experiments. Then transformed the experimental results to taken with a signal-tonoise(S/N) ratio. It utilizes the signal to noise percentage to estimate of quality characteristics dissimilarfrom or nearing to the preferred values. S/N ratios are three types of excellence characteristics, i.e. the smaller is the better, the higher is the better, and the nominal is the finest. The formula utilized to designed for analyze S/N percentage, it is shown below.

***Smaller -is-better*:**
It is utilized where the smaller value is desired. For drilling process cutting force, torque, surface roughness
and power should be low for better quality; hence smaller S/N ratios are measured for these parameters.

$$\frac{S}{N} ratio(\eta) = -10\log_{10}\frac{1}{n}\sum_{i=1}^{n} y_i^2$$

Where yi = observed response value and
n = number of imitations.

Nominal-is- finest: It is utilized wherever the nominal or object value and difference about that value is
smallest.

$$\frac{S}{N} ratio(\eta) = -10\log_{10}\frac{\mu^2}{\sigma^2}$$

and σ = variance μ = mean

Higher-is-better: It is utilized where the bigger value is preferred.

$$\frac{S}{N} ratio(\eta) = -10\log_{10}\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}$$

Where y_i = observed react value and n = quantity of imitations.
Taguchi recommended a standard methodology for optimizing any process parameters, the steps involved in
Taguchi are

- Determination of the excellence quality to be optimized.
- Identification of the smash factors and test conditions.
- Identification of control variables and their option levels.
- Designing the matrix testing in addition to significant the information analysis procedure.
- Conducting the matrix test.
- Analyzing the information furthermore determining the best possible levels of control variables.
- Predicting the recital by these levels

3. Graphs and Tables

Table No.1.Control Factors and Levels

Factor Level	Speed (mm/min)	Feed (mm/rev)	Depth of Cut (mm)
1	500	0.12	3
2	1000	0.15	5
3	1500	0.18	7

3.1. SELECTION OF ORTHOGONAL ARRAY

Selection of particular orthogonal arrayfrom the standard O.A depends on the number of factors, levels of each factor and the total degrees of freedom.
i) Number of control factors = 3
ii) Number of levels for each control factors = 3
iii) Number of experiments to be conducted =9
Based on these values and the required minimum number of experiments to be conducted 9, the nearest Orthogonal Array fulfilling this condition is $L_9\,(3^3)$.

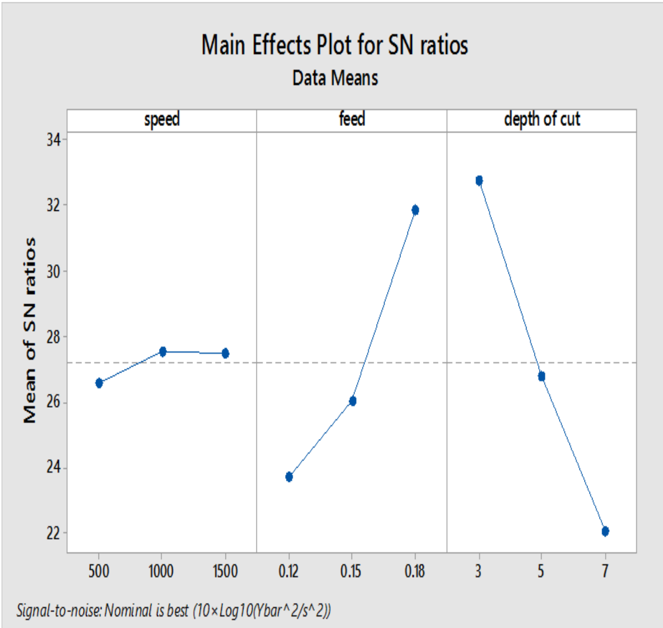
Table No.2.Control Factors and Levels

Experiment Number	Speed (mm/min)	Feed (mm/rev)	Depth of Cut (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

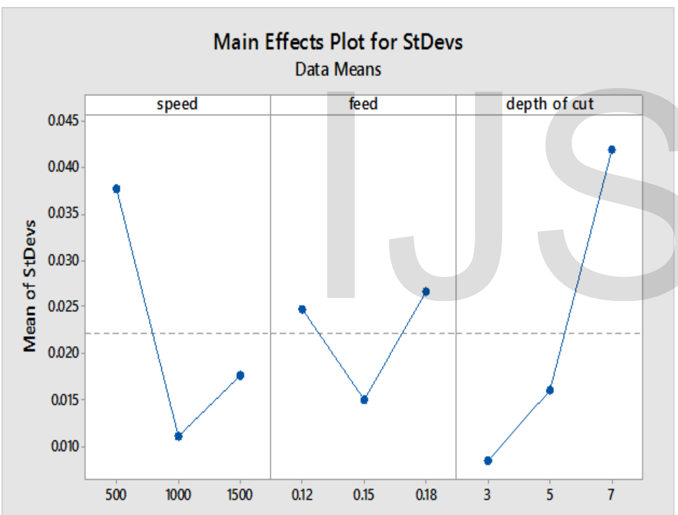
3.2 RESULTS & DISCUSSION

Table No.3 for Surface Roughness and S/N Ratio

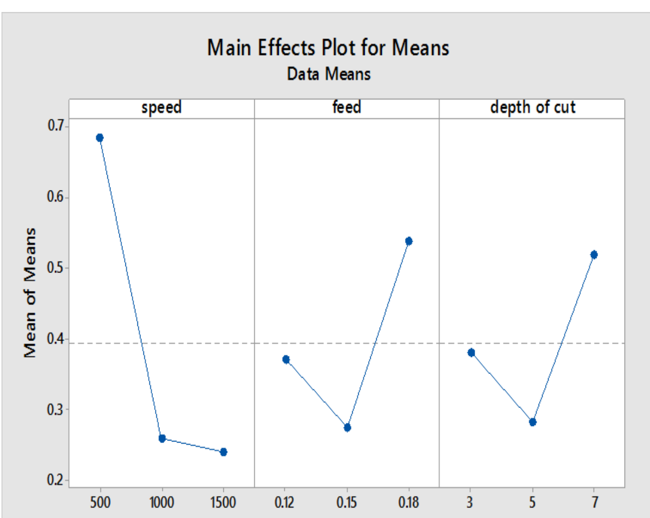
Experiment No.	Surface Roughness(Ra)			S/N Ratio
	Trail1	**Trail2**	**Mean**	
1	0.570	0.590	0.580	32.2583
2	0.490	0.450	0.470	24.4111
3	0.950	1.050	1.000	23.0103
4	0.162	0.185	0.174	20.5617
5	0.206	0.190	0.198	24.8612
6	0.402	0.410	0.406	37.1190
7	0.390	0.328	0.359	18.2644
8	0.158	0.160	0.156	28.8110
9	0.210	0.205	0.208	35.3713



Graph No.1 for Signal to Noise Ratio



Graph No.2 for Standard deviation



Graph No.3 for Surface Roughness

EN-31 Steel alloy pieces of 100mmX75mmX10mm are prepared for conducting the experiment. Using different levels of the process parameters the specimens have been machined accordingly, depending upon speed, feed, depth of cut. Then surface roughness is measured precisely with the help of a portable stylus-type Profilometer. The results of the experiments have been shown Table No 3. Optimization of surface roughness is carried out using Taguchi method. Confirmatory tests have also been conducted to validate optimal results.

From Graph NO.3, it is observed that, the surface roughness is high at low speed and certainly decreasing from moderate cutting speed to low speed conditions, it is also observed that, the surface roughness is high at low feed rate and certainly decreasing from low feed rate to moderate feed rate conditions, but again from moderate to high feed rate, the surface roughness increases.

From Graph NO.3, it is observed that, the surface roughness is high at small depth of cut and certainly decreasing from small depth of cut to moderate depth of cut conditions, but again from moderate to high depth of cut, the surface roughness increases.

Taguchi's robust design methodology has been successfully implemented to identify the optimum settings for control parameters in order to reduce the surface roughness of the selected work piece material for their improved performance, after analysis of data from the robust design experiments the optimum setting are found is tabulated in Table No.4. These optimum settings combination is validated by conducting confirmation test, which concluded that the results (Table No.5 and 6) were within the acceptable limits of the predicted value and can be implemented in the real time application.

Table No.4 Optimum Parameters for Surface Roughness

Cutting Speed(rpm)	1500
Feed Rate(mm/min)	0.15
Depth of Cut(mm)	5

Table No.5 Conformation Test Results

Surface Roughness(Ra) Values			**S/N Ratio**
1	2	Mean	
0.090	0.095	0.092	20.67

Table No.6 Comparison of S/N Ratios

η predicted	21.70
ηconformation	20.67

4 Conclusion

The objective of the present work is to find out the set of optimum values in order to reduce surface roughness, using Taguchi's robust design. Methodology considering the control factors for the EN-31 alloy steel work piece material. Based on the results of the present experimental investigations the following conclusions can be drawn:

- In the present experimentation the optimum speed obtained using tauguchi technique is 1500rpm. Similarly the results obtained for feed and depth of cut are 0.15m/min and 5mm respectively. Hence it can be concluded that the parameters obtained are valid and within the range of EN31 machining standards.
- The S/N ratio of predicted value and verification test values are valid when compared with the optimum values. It is found that S/N ratio value of verification test is within the limits of the predicted value and the objective of the work is full filled.

References

[1] Kamal, Anish and M.P.Garg (2012), "Experimental investigation of Material removal rate in CNC millingusing Taguchi method"International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 2, Mar-Apr 2012, pp.1581-1590.

[2] H. K. Dave, L. S. Patel and H. K. Raval Effect of machining conditions on MRR and surface roughness during CNC milling of different Materials Using TiN Coated Cutting Tools – A Taguchi approach.,International Journal of Industrial Engineering.

[3] Kamal Hassan, Anish Kumar, M.P.Garg, Experimental investigation of Material removal rate in CNC milling using Taguchi method, International Journal of Engineering Research and Applications (IJERA) 2,2012, 1581-1590.

[4] Ballal, Inamdar and Patil P.V. (2012), "Application Of Taguchi Method For Design Of Experiments In TurningGray Cast Iron " International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 3, May-Jun 2012, pp.1391-1397 36

[5] Ashish Yadav, Ajay Bangar, Rajan Sharma, Deepak Pal," Optimization of milling Process Parameters for Their Effect on En 8 Material Work piece Hardness by Using Taguchi Parametric Optimization Method," International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Volume-1, Issue-3, 2012.

[6] Puneet mangla, Nishant kr. Singh, Yashvir singh (2011)"Study of effect of milling parameters on work piece hadness using Taguchi method". ICAM, pp- 695-700.

[7] Abhang L B and Hameedullah M, (2011), "Modeling and Analysis for Surface roughness in Machining Aluminium Alloy using Response Surface Methodology", International Journal of Applied Research in Mechanical Engineering,Volume-1, Issue-1

[8] Kilickap E. Optimization of cutting parameters on delamination based on Taguchi method during drilling of GFRP composite. J Expert Syst Appl 2010; 37:6116–22.

[9] Mustafa Kurt, Eyup Baggie, Yusuf Kaynak (2009), Application of taguchi methods in the optimization of cutting parameters for surface finish and hole diameter accuracy in dry drilling process., Int J Adv Manuf Technol, 40, 458-469.

[10] Zhang, P.F., Churi, N.J., Pei, Z.J., and Treadwell C., 2008, "Mechanical drilling processes for titanium alloys: a literature review," Machining Science and Technology, Vol. 12, No. 4, pp. 417-444.

[11] Julie Z. Zhang, Joseph C. CHENB, E. Daniel Kirby, " Surface roughness optimization in an end-milling operation using the Taguchi design method." Department of Industrial Technology, University of Northern Iowa, Iowa, USA (2008). Journal of Materials Processing Technology 184 (2007) 233–239 [1]. M. NALBANT, H. GOKKAYA, G. Sur,

[12] Yang, J.L., Chen, J.C. (2001). A systematic approach for identifying optimum surface roughness performance in end-milling operations. Journal of Industrial Technology, vol. 17, no. 2, p. 1-8.