A Study of Surface Roughness in Drilling of EN-9 Steel using Taguchi Approach

Ajinkya B. Kashmire, H. V. Shete, N. D. Jadhav

***Abstract:** Drilling is one of the most common and fundamental machining processes. In machining, Carbide twist drills with diameter of 10 mm are used. Most of automotive components are manufactured using a conventional machining process, such as turning, drilling, milling, shaping and planning, etc.. These focus on producing high quality products in time at minimum cost. The surface roughness is considered to be a measure of the quality of a product. The aim of the present work is to optimize cutting conditions (Cutting speed, feed and cutting fluid pressure) parameters for minimum Surface Roughness in drilling of EN-9 using Taguchi Approach. Experiments were conducted based on the design of experiments (DOE) and followed by optimization of the results using Analysis of Variance (ANOVA) to find the minimum surface roughness.*

***Keywords:** Surface Roughness, Analysis of Variance (ANOVA), Design of Experiments (DOE), Taguchi.*

I. INTRODUCTION

In drilling, wearing of tool occur due to temperature and frictional forces between tool and metal chips. So that coolant is used in cutting zone to dissipated heat and cutting chips from working area. Deep drilling is known for making first-pass high-finish straight holes of varying depths and diameters. Drilling without coolant can result in excessive thermal distortion and poor tool life.

During the drilling of the work piece, it has long been recognized that the drilling conditions (drill and workpiece materials, drilling parameters like feed rate and spindle speed) affect the performance of the operation to a greater piece to remove the material in the form of chips that move along the fluted shank of the drill extent. These drilling conditions should be selected to optimize the economics of drilling operations. So, it can be achieved by using design of experiments (DOE). The proposed work will be employed for optimization of drilling conditions for minimum surface roughness using response surface methodology based on Taguchi approach.

II. LITERATURE REVIEW

In past few decades, research efforts seem to have been diverted towards the study of surface finish/roughness in metal machining. It may be due to the reason that the surface finish/roughness has great importance with regard to friction, wear, fatigue resistance etc. of the machined part/surface.

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Anil Jindal [1] et. al. studied to accomplish ideal cutting conditions extraordinary procedures are required. In boring, instrument can be utilized to expel the undesirable material from the work piece by making a wanted opening, in high creation where it have high cutting speed, encourage and profundity of cut. Along these lines, this warmth will decrease dimensional precision and apparatus life and disables the surface trustworthiness of the item. For this situation, high weight coolant (HCP) is exceptionally powerful to lessen temperature. At the point when the temperature will increment in high sum then consequently device wear increments. These outcomes are in diminishing the apparatus life. In instrument wear, high temperature influences roundness of gap, chip shape and shading. HPC is connected in an indistinguishable bearing from the boring tool. Subsequently, HCP will enhance roundness and furthermore credit to powerful grease activity, which keeps the chip staying on the instrument and makes the cut doable.

C. Manikandan and B. Rajeswari [2] were found that tool cost for the machining operation will influence the generation cost. The choice of cutting apparatus and cutting parameters for relating work material is critical amid the machining operation. The primary target of the present work is to explore the impact of various cutting parameters on surface get done with, machining time and material removal rate (MRR) paradigm. The Taguchi L9 orthogonal array is used for test getting ready for drilling of EN24 with HSS drill in CNC turning focus. The outcomes are broke down to accomplish ideal surface unpleasantness, machining time and material removal rate (MRR). The cutting parameters for penetrating EN24 material with the rapid steel drill are dissected utilizing Taguchi technique.

N. G. Patil [3] et.al. Found the hard to-cut materials like Inconel 718 are utilized for aviation, steam turbine, bearing industry, atomic and car applications. In machining, grinding and warmth era at the cutting zone are the continuous issues, which influence the instrument life and surface wrap up. Warm era posture confinements amid the turning of such cutting edge materials because of their impossible to miss qualities,.

I. Sultana [4] et. al. Studied the huge measure of warmth and cutting temperature is related machining materials. Additionally, Temperature of the high cutting zone is more and additionally increments because of high generation machining. Assurance of the greatest temperature and temperature dissemination at the chip-apparatus interface zone is of specific significance on account of its impeding impact on Tool life, and additionally, the nature of the machined part. Predominantly contemplate manages a view to upgrade the weight.

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(P) and stream rate (Q) of high weight coolant to acquire enhanced machining exhibitions in turning AISI-4320 steel by uncoated carbide embed in regard of cutting temperature, chip decrease co-productive and surface harshness.

Anselmo Eduardo Diniz [5] et.al. Studied the high-pressure coolant (HPC) delivery system delivers a high-pressure fluid to the tool and work piece in machining processes for better entrance of the liquid into the cutting zone high weight liquid is to permit upgrading the cooling impact, and diminishing device wear through grease of the contact zones. The principle goal of their work is to see how device wear instruments are impacted by liquid weight under various cutting velocities in the get done with turning of AISI 1045 steel utilizing covered carbide devices.

A. Drilling

In manufacturing industries, the production of holes in workpiece is a common and most important process. There are many tools and processes for producing the holes. The selection of tools and process mainly depends on type of material, the size of the hole, quantity of holes produce in given time periods. Among the many hole making process, drilling is a major and commonly use hole making process. For some of processes, drilling is the initial process, such as reaming, tapping and boring. As the drill rotates and feed into the work piece, material is removed in the form of chips that move along the fluted shank of the drill. Drilling process involves relative motion between the drill and the work piece. Generally, the drill rotates and feed into the work piece for large workpieces, but sometimes workpiece rotate and feed into the drill. Figure 1 show the drilling process in which the drill is fed into the workpiece.

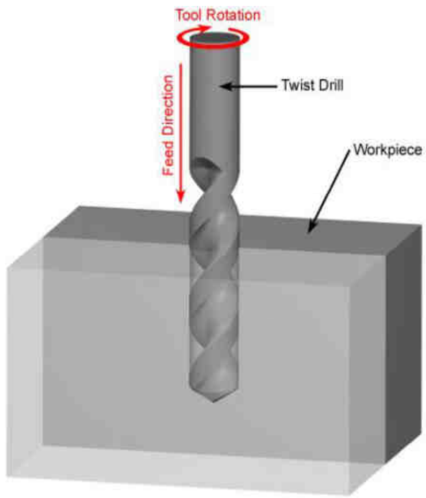

Figure 1 Drilling Process

Usually, the hole diameters produced using drill are slightly larger than the diameter of drill (oversize). The amount of oversize depends on the selection of drill, on the machine and on the skill of machine operator.[6]

B. Surface Roughness

The surface roughness is considered to be a measure of the technological quality of a product. Surface roughness is the one of the critical performance parameter that has an appreciable effect on several mechanical properties of machined parts such as fatigue behavior, corrosion resistance, creep life, etc. It also affects other functional attributes of machined parts like friction, wear, light reflection, heat transmission, lubrication, electrical conductivity, etc. Hence, achieving the desired surface quality is of great importance for the functional behavior of the mechanical parts. Out of all the surface condition criteria, *Ra* and *Rt* (expressed in μm) are often used to characterize the roughness of machined surfaces. *Rt* is total roughness (maximum depth or amplitude of the roughness), and *Ra* is arithmetic roughness (mean arithmetic deviation from the mean line of the roughness) as given in Eq. (1).

$$Ra = \frac{\Sigma A + \Sigma B}{L} \quad (1)$$

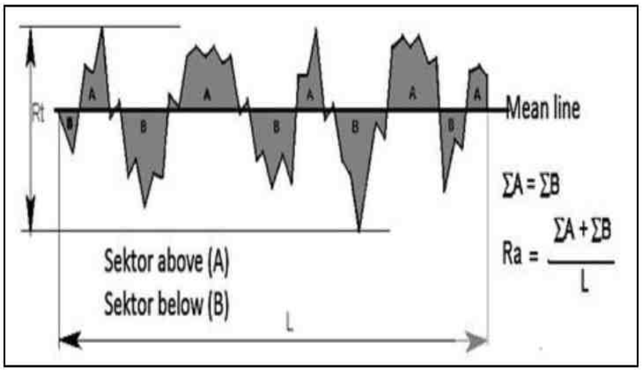

Figure 2 Schematic of parameter definition used to compute the mean arithmetic deviation(Ra) and total roughness (Rt)

1. *Spindle Speed*

The spindle speed is measure in revolutions per minute (RPM). It is the rotational frequency of the spindle. Too much spindle speed will cause early tool wear and breakage. The spindle speed significantly affects the tool life and the quality of the surface roughness.
From the equation of spindle speed (*n*) to achieve a specific cutting speed can be expressed as Eq. (2).

$$N = Kv/\pi\, d \quad (2)$$

If N is spindle speed in revolutions/minute (rpm), k is a constant to correct the cutting speed (V) and V is the desired cutting speed, and D is diameter of the tool. [6]

2. *Feed Rate*

The feed rate is a velocity at which the cutter is feed into the workpiece. It is given in units of distance per revolution for turning, milling and other machining process that required cutting of a work piece.

$$f = N * fr \quad (3)$$

III. EXPERIMENTAL DETAILS

In this experimental work which includes selection of drilling parameters, selection of range of drilling parameters, formation of design matrix using Taguchi methods,

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Selection of work-piece material, experimental set-up and measurement of surface roughness.

A. Selection of Drilling Parameters and the Range of Drilling Parameters

The process parameters that were chosen for experimentation are given as under:

1. Spindle speed (RPM)
2. Feed (mm/rev.)
3. Cutting fluid pressure (bar)

These are the main drilling parameters that affect the surface roughness. Also, machine operator can change these parameters at the time of machining. The levels of each input parameter were decided by studying the literature in detailed and according to machine limitations. Table 1 shows the levels of drilling parameters according to Taguchi Approach.

Table 1 Drilling parameters and their levels according to Taguchi Approach

Drilling Parameters	Units	Type	Minimum (+1)	0	Maximum(-1)
Spindle Speed	(rpm)	Numeric	1100	1200	1300
Feed	(mm/rev)	Numeric	0.1	0.125	0.15
Cutting fluid Pressure	(bar)	Numeric	8	10	12

B. Machining Trial

Experiments were conducted using the design of experiments (DOE) using Taguchi Approach and then followed by optimization of the results using Analysis of Variance (ANOVA) to find minimum surface roughness. The ranges of machining conditions were based on the real industry practice for EN - 9. Total 9 numbers of experiments has been finalized according to Taguchi Approach. The table 2 shows the design layout for experimentation

Table 2 Shows the Design Layout for Experimentation

Exp. No.	Speed in rpm	Feed in mm/rev	Cutting fluid Pressure in bar
1	1100	0.100	8
2	1100	0.125	10
3	1100	0.150	12
4	1200	0.100	10
5	1200	0.125	12
6	1200	0.150	8
7	1300	0.100	12
8	1300	0.125	8
9	1300	0.150	10

C. Experimental Set Up

1. VMC Vertical Machining Centre

The drilling operations have been carried out on a VMC Machining Center, Make- Advance Cooling Systems Pvt. Ltd., India. The VMC (Vertical Machining Center) is equipped with continuously variable spindle speed up to 6500 rpm, and 2HP motor drive was used for experimentation.

2. Cutting Tool

Coated carbide tool performs better than uncoated carbide tools. On this basis, commercially accessible tungsten carbide high speed core drills with ALCRONA PRO AlCrN- Based monolayer coating having 10 mm diameter with two flute has been used for experimentation.

D. 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. There are many parameters used related to surface roughness in literatures. In this research, a portable surface roughness tester has been used to measure surface roughness indicators of finished work pieces. The constants for surface roughness tester for all the measurements of work pieces were standard

IV. ANOVA FOR SURFACE ROUGHNESS PREDICTION MODEL

Through coolant Experiment for Surface Roughness is given below

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Table 33 through coolant Experiment for Surface Roughness

Speed	Feed	Cutting fluid Pressure	Surface Roughness	SNRA1
1100	0.100	8	1.680	-4.50619
1100	0.125	10	1.715	-4.68528
1100	0.150	12	1.918	-5.65697
1200	0.100	10	0.899	0.9281
1200	0.125	12	1.250	-1.93820
1200	0.150	8	1.640	-4.29688
1300	0.100	12	0.544	5.28802
1300	0.125	8	0.890	1.01220
1300	0.150	10	0.887	1.04153

Taguchi Analysis: RA versus Speed, Feed, Cutting fluid Pressure Linear Model Analysis: SN ratios versus Speed, Feed, Cutting fluid Pressure

Table 4 Estimated Model Coefficients for SN ratios

Term	Coef	SE Coef	T	P
Constant	-1.4241	0.1884	-7.557	0.017
Speed 1100	-3.5254	0.2665	-13.229	0.006
Speed 1200	-0.0346	0.2665	-1.298	0.324
Feed 0.100	1.993	0.2665	7.478	0.017
Feed 0.125	-0.4463	0.2665	-1.675	0.236
Cutting fluid Pressure 8	-1.1728	0.2665	-4.401	0.048
Cutting fluid Pressure 10	0.5178	0.2665	1.943	0.191

S = 0.5663 R-Sq = 99.4% R-Sq (adj) = 97.7%

Analysis of Variance for SN ratios

Table 5 Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	82.606	82.6061	41.3030	129.24	0.008
Feed	2	19.690	19.690	9.8451	47.2630.81	0.031
Cutting fluid Pressure	2	6..218	6.218	3.1092	9.73	0.093
Residual Error	2	0.639	0.6392	0.3196		
Total	8	109.154				

Response Table for Signal to Noise Ratios Smaller is better

Table 5 Response Table for Signal to Noise Ratios Smaller is better

Level	Speed	Feed	Cutting fluid Pressure
1	-4.9495	0.5689	-2.5970
2	-1.7701	-1.8704	-0.9063
3	2.4472	-2.9708	-0.7691
Delta	7.3967	3.5397	1.8279
Rank	1	2	3

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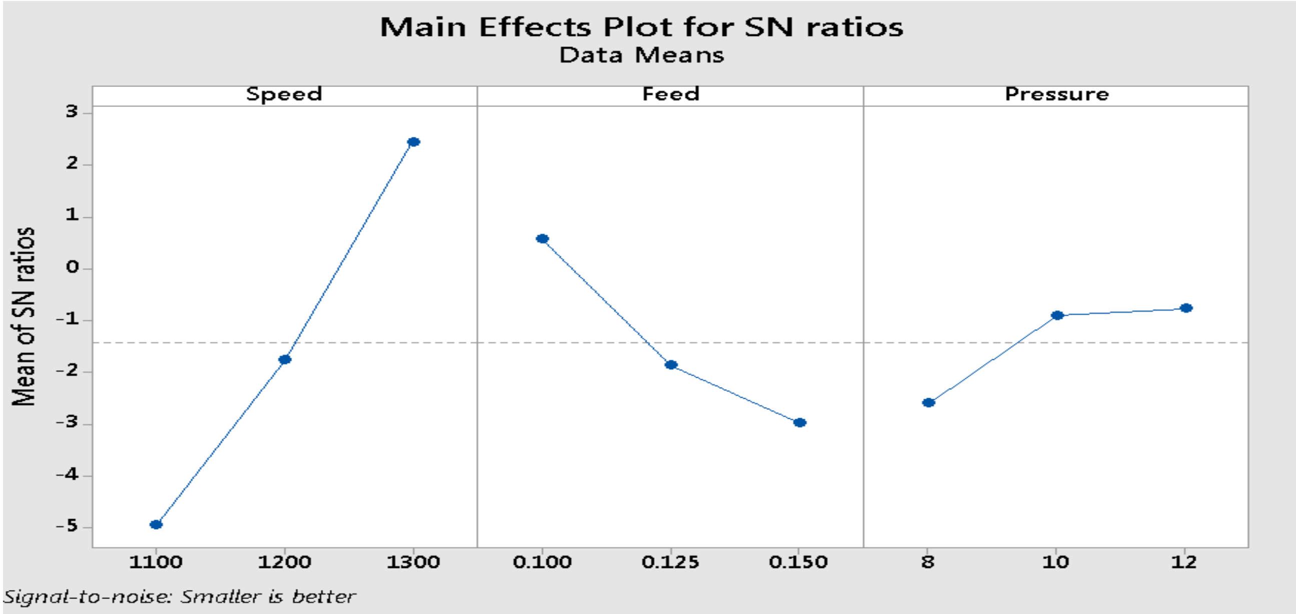

Figure 3 Main Effects plot for SN ratios.

Linear Regression Equation for through coolant is given below. .

Surface Roughness = 6.567 - 0.004987 Speed + 8.81 Feed - 0.0415 Cutting fluid Pressure (7)

From the regression equation it is observed that speed and Cutting fluid pressure having negative effect on Surface roughness, whereas feed having positive effect on Surface roughness and from ANOVA table it is seen that the p value of speed is 0.008, which is less than 0.05. Whereas p value of feed and cutting fluid pressure are 0.02, and 0.06 resp. as we perform the experiments with 95% confidence level. So, all speed, feed and cutting fluid pressure ut are significant parameter for surface roughness. & from S/N Ratio table Speed Level 1, Feed Level 3, Pressure level 1 are selected.

The optimal settings of process parameters for optimal Inner Diameter Through coolant are: Speed (1100rpm), Feed (0.150 mm/rev), and Coolant Pressure (8 bar).

V. CONCLUSION

Following are the conclusions drawn based on the test conducted on EN-9 during Drilling operation with Carbide Tool.

I. From the ranking shows in ANOVA table and response table for signal to noise ratios, it can be concluded that speed has a greater influence on the surface roughness followed by feed.

II. By considering optimality losses for Surface roughness through coolant Drilling are: Speed (1300rpm), Feed (0.1 mm/rev) and cutting fluid Pressure (12 bar).

III. The minimum surface roughness 0.544 µm. has been obtained with Speed (1300rpm), Feed (0.1 mm/rev), and cutting fluid Pressure (12 bar),

REFERENCES

1. Anil Jindal. "Analysis of Tool Wear Rate in Drilling Operation using Scanning Electron Microscope (SEM)," Journal of Minerals & Materials Characterization & Engineering, Vol. 11, No.1(2012), pp.43-54.
2. C. Manikandan, B. Rajeswari, "Study of Cutting Parameters on Drilling EN24 Using Taguchi Method," International Journal of Engineering Research & Technology (IJERT) IJERTV2IS70094, Vol. 2 Issue 7, July – 2013 ISSN: 2278-0181.
3. N. G. Patil, Ameer Asem, R. S. Pawade, D.G. Thakur, P.K. Brahmankar, "Comparative study of high speed machining of Inconel 718 in dry condition and by using compressed cold carbon dioxide gas as coolant," New Production Technologies in Aerospace Industry - 5th Machining Innovations Conference (MIC 2014), Procedia CIRP 24 (2014) 86 – 91.
4. I. Sultana, M. M. H. Chowdhury and N. R. Dhar, "Optimization of flow rate and pressure of high pressure coolant in turning AISI-4320 steel: temperature, chip reduction coefficient and surface roughness," proceedings of the 4th BSME-ASME international conference on thermal engineering 27-29 December, 2008, Dhaka, Bangladesh.
5. Anselmo Eduardo Diniz, Ricardo Micaroni,,"Influence of the direction and flow rate of the cutting fluid on tool life in turning process of AISI 1045 steel," International Journal of Machine Tools & Manufacture 47 (2007) 247–254.
6. Sudesh Garg, Ravi Kumar Goyal, "A Study of Surface Roughness in Drilling of AII H11 Die Steel using Face Centered Design," IJIRST Volume 1, Issue 12, (May 2015), ISSN: 2349-6010.

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