Analysis and Optimization of Precision Boring Process for HE 30 Aluminum Automotive Component

[1]Sunil J Raykar,[2]Najaktali M Qureshi

[1]Assistant Professor,[2]Lecturer Selection Grade
[1]Production Engineering Department, [2]Mechanical Engineering Department
[1,2]D Y Patil College of Engineering and Technology, Kolhapur,India.

***Abstract*—In this work analysis of boring process for HE 30 Aluminum automotive component is carried out experimentally. Surface roughness and circularity of bore are two most important parameters which decide the accuracy of boring operation. In this analysis surface finish and circularity are investigated in order to optimize cutting parameters (speed, feed and depth of cut), insert (uncoated carbide and PCD) and environment (wet/dry).Techniques like ANOVA and Taguchi are used for analysis.. Results predict that PCD insert generates very fine surface finish when wet machining is carried out but on other side environment and type of insert have very negligible effect on circularity of bore.**

Keywords: - Boring, Surface Roughness, Grey Relational Analysis, Circularity, Optimization, Taguchi.

1 Introduction

Boring is a process of finishing a previously drilled, cast, cored hole. It is a precision machining process for generating internal cylindrical forms by removing metal with single or multipoint cutting tool. This process is commonly performed with work piece rotating and cutting tool is fed against and into work piece. Growing demand of low cost production and improved quality has forced manufacturing industry to continuously progress in machining technologies. Quality of finished hole generally depends upon three features, namely dimension, surface roughness, and circularity. Surface roughness influences the performance of mechanical parts and their production costs because it affects factors, such as, friction, ease of holding lubricant, electrical and thermal conductivity, geometrical tolerances and more. The process is mostly used in applications where close dimensional tolerances and good surface finish are required[1].In a boring operation, boring bars are long, round and flexible. So the mechanism behind the surface roughness and circularity is very complex and is dynamic and process dependent. Cutting tool vibration affects the dimensional precision, surface roughness of bored hole. Cutting tool vibrations are influenced by cutting parameters like cutting speed, depth of cut, and tool feed rate. These Cutting parameters are required to be selected carefully to ensure quality of hole.

Large numbers of researchers have analyzed the dynamics of boring process experimentally. Atabey et al.[2] has shortened the cycle time and improved the quality of bore by controlling cutting forces. Munawar et al.[3]investigated cutting parameters effect for minimizing surface roughness in boring of AISI 1018 steel. Yang et al.[4]developed mathematical model to identify optimal setting to minimize roughness and deviation from roundness. Beauchamp et al.[5] analyzed cutting parameters effect on surface roughness by single point boring tool. Astakhov [6] analyzed the effect of feed, depth of cut and bore diameter on wear rate of boring tool.

2 Experimental Details:-

2.1 Work piece material

Aluminum alloy 6082, popularly known as HE 30, is most widely used alloy in 6000 series. It is heat treatable, medium strength, structural alloy with excellent corrosion resistance. It is used in highly stressed applications, trusses, bridges, transport applications, automobile, and machine components. Chemical composition of work piece material is shown in (Table 1). Component drawing is kept confidential as per policies of organization where this work has been carried out, however fig (1) indicates machined components.

Table 1 Chemical Composition of HE 30 Aluminium

	Al	**Cu**	**Mg**	**Si**	**Fe**	**Mn**	**Zn**	**Ti**	**Cr**
HE-30,Al Alloy,6082	Balance	0.0 to 0.1	0.6 to 1.2	0.7 to 1.3	0.0 - 0.5	0.4 to 1.0	0.0 to 0.2	0.0 to 0.1	0.0 to 0.25

Figure 1 Machined Component

2.2 Machine

Experiments were conducted on CNC machine manufactured by DOOSAN south Korean company, specifications of machine are as follows

Model – DOOSAN Puma 400 L

Spindle – Main spindle motor power -22 KW

Max spindle torque -996 N- m

Spindle speed – 3000 rpm

Control system – Fanuc 18i -TB

2.3 Cutting inserts

The investigation is carried out by using the inserts suggested by manufacturer's catalogue and according to suggestions from sponsoring organization. Three types of inserts are used in the investigation are as mentioned below.

1. CCGT09T308-AR uncoated cemented carbide manufactured by KORLOY, South Korea
2. CNMG120408-ML uncoated cemented carbide manufactured by TAEGUTEC, South Korea
3. CCGT09T308CB PCD manufactured by TAEGUTEC, South Korea(Shown in Fig. 2)

Figure2 CNMG120408-ML insert with Tool Holder

2.4 Experimental Design

Boring process is influence by many process parameters which affects its performance as well as affects the various responses of the process. In this investigation apart from speed, feed, depth of cut parameters such as insert type and environment (Wet and Dry) are also considered. Based on some trial experiment, suggestions from sponsoring industry and from the insert manufacturer catalogue the levels of process parameters are selected. The levels of parameters and their actual values are shown in Table 2.Taguchi orthogonal array was used to design the experiment. The chosen array is L_{36} with four factors at three levels and one factor at two levels hence mixed level design of L36(2^^1*3^^4) is selected, the actual values of all process parameters are as shown in Table 2.

Table 2 Process Parameters and their Levels

Parameter	Unit	Level 1	Level 2	Level 3
Cutting speed	rpm	1500	1700	1900
Feed	mm/rev	0.1	0.15	0.2
Depth of cut	mm	0.25	0.5	0.75
Insert type		1	2	3
Environment (ENV)	Wet (W) and Dry(D)	W	D	

Table 3 Details of L36 Orthogonal Array

Parameter level						Parameter level					
Run no.	ENV	Cutting Speed	Feed	DoC	Insert Type	Run no.	ENV	Cutting Speed	Feed	DoC	Insert Type
1	W	1	1	1	1	19	D	1	2	1	3
2	W	2	2	2	2	20	D	2	3	2	1
3	W	3	3	3	3	21	D	3	1	3	2
4	W	1	1	1	1	22	D	1	2	2	3
5	W	2	2	2	2	23	D	2	3	3	1
6	W	3	3	3	3	24	D	3	1	1	2
7	W	1	1	2	3	25	D	1	3	2	1
8	W	2	2	3	1	26	D	2	1	3	2
9	W	3	3	1	2	27	D	3	2	1	3
10	W	1	1	3	2	28	D	1	3	2	2
11	W	2	2	1	3	29	D	2	1	3	3
12	W	3	3	2	1	30	D	3	2	1	1
13	W	1	2	3	1	31	D	1	3	3	3
14	W	2	3	1	2	32	D	2	1	1	1
15	W	3	1	2	3	33	D	3	2	2	2
16	W	1	2	3	2	34	D	1	3	1	2
17	W	2	3	1	3	35	D	2	1	2	3
18	W	3	1	2	1	36	D	3	2	3	1

2.5 Response variables and their measurement

Thirty six experimental runs were carried out, 18 each for WET and DRY environment as per the orthogonal array as shown in (Table 3).Surface roughness (Ra) and circularity (Ψ) were measured for each components. Surface roughness (Ra) is measured by Mitutoyo make portable surface roughness tester SURFTEST SJ210.Circularity (Ψ) is measured by manually operated co-ordinate measuring machine – CRYSTA PLUS M574.The sample outputs for surface roughness for run number 27 and mean deviation from circularity for run number 14 are shown in Fig 3.

Fig 3 Surface finish and Circularity Measurement

3 Results and Discussion

Table 4 shows 36 experimental runs, according to L36 (2^^1*3^^4) orthogonal array and experimental results for two responses surface roughness (Ra), Circularity (Ψ).

Table 4 Experimental results for surface roughness (Ra), Circularity (Ψ)

Run no.	Process Parameters					Response	
	Env	RPM	Feed	DoC	Insert	Circularity(Ψ) mm	Ra(μm)
1	W	1500	0.10	0.25	1	0.016670	0.810
2	W	1700	0.15	0.50	2	0.022667	1.404
3	W	1900	0.20	0.75	3	0.052330	0.517
4	W	1500	0.10	0.25	1	0.01658	0.821
5	W	1700	0.15	0.50	2	0.023007	1.412
6	W	1900	0.20	0.75	3	0.05239	0.521
7	W	1500	0.10	0.50	3	0.018000	1.521
8	W	1700	0.15	0.75	1	0.031000	1.369
9	W	1900	0.20	0.25	2	0.078300	1.499
10	W	1500	0.10	0.75	2	0.02033	0.669
11	W	1700	0.15	0.25	3	0.078000	1.541
12	W	1900	0.20	0.50	1	0.088667	2.294
13	W	1500	0.15	0.75	1	0.026670	1.464
14	W	1700	0.20	0.25	2	0.043330	1.972
15	W	1900	0.10	0.50	3	0.101000	1.722
16	W	1500	0.15	0.75	2	0.015333	1.064
17	W	1700	0.20	0.25	3	0.071333	1.496
18	W	1900	0.10	0.50	1	0.085333	1.178
19	D	1500	0.15	0.25	3	0.035333	1.608
20	D	1700	0.20	0.50	1	0.066330	2.184
21	D	1900	0.10	0.75	2	0.045667	0.707
22	D	1500	0.15	0.50	3	0.021333	2.141
23	D	1700	0.20	0.75	1	0.040000	2.192
24	D	1900	0.10	0.25	2	0.118333	2.713
25	D	1500	0.20	0.50	1	0.044000	1.579
26	D	1700	0.10	0.75	2	0.024667	0.826
27	D	1900	0.15	0.25	3	0.056333	2.002
28	D	1500	0.20	0.50	2	0.062333	2.408
29	D	1700	0.10	0.75	3	0.051000	1.308
30	D	1900	0.15	0.25	1	0.088000	3.601
31	D	1500	0.20	0.75	3	0.049330	0.952
32	D	1700	0.10	0.25	1	0.029667	1.686
33	D	1900	0.15	0.50	2	0.083000	2.298
34	D	1500	0.20	0.25	2	0.044000	2.030
35	D	1700	0.10	0.50	3	0.054667	1.802
36	D	1900	0.15	0.75	1	0.044667	1.491

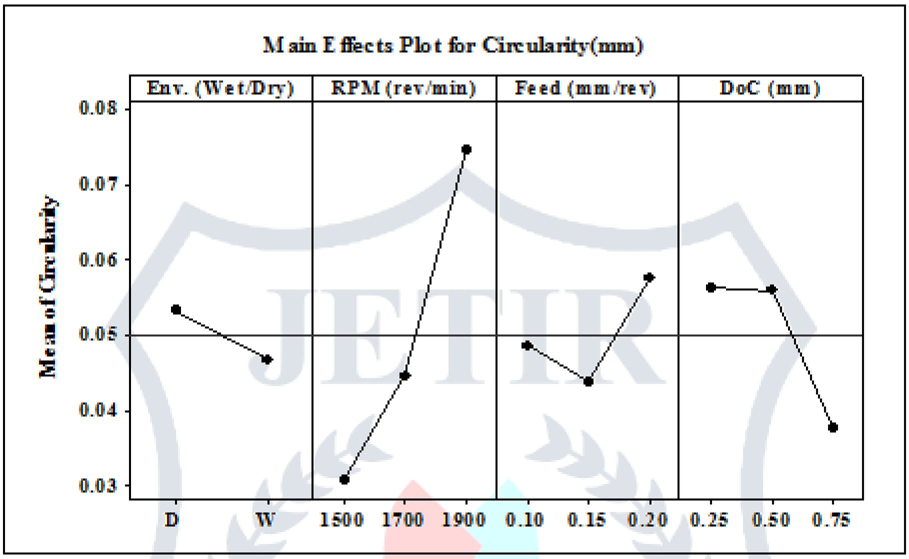
Table 5 shows ANOVA results for surface roughness and circularity. ANOVA is carried out at 95% of confidence level corresponding P and F values which are used to measure significance of process parameters on response variable are shown in Table 5.

Table 5 ANOVA results for surface roughness and circularity (Bold value indicate significance at 95% confidence level)

Process Parameters	Response Variables			
	Surface Roughness Ra		circularity (Ψ)	
	F-value	P-value	F-value	P-value
ENV	1.15	0.294	**13.22**	**0.001**
RPM	**17.86**	**0.000**	1.16	0.330
FEED	1.80	0.186	3.13	0.060
DOC	**4.01**	**0.030**	**9.69**	**0.001**
INSERT	0.32	0.731	1.18	0.323

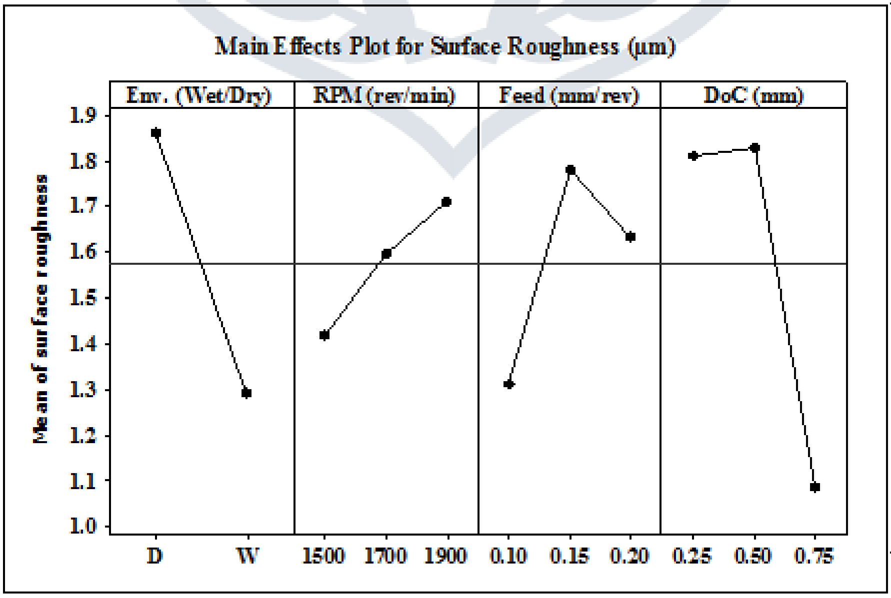
3.1 Analysis of Surface Roughness: - From ANOVA Table 5 and AOM plot shown in Fig.4 it can be clearly seen that cutting rotational speed (RPM) is the most influencing parameter with 95% confidence level. It is clearly seen from AOM plot that surface roughness increases with increase in rotational speed from 1500 to 1700 rpm but thereafter it shows tapering effect when speed increases from 1700 to 1900 rpm. After speed ,depth of cut shows a significant effect on surface roughness ,change in depth of cut from 0.25 to 0.5mm do not change roughness value much but after that from 0.5 to 0.75mm surface roughness drastically decreases. Apart from speed and depth of cut other parameters do not affect surface roughness at confidence level 95 %.Surprisingly in this investigation feed do not show significant effect on surface roughness value, here it follows a conventional trend of increasing with increase in feed from 0.1 to 0.15 mm/rev but thereafter surface roughness decreases with increase in feed from 0.15 to 0.2 mm/rev.Surface finish shows a good improvement when coolant is used as compared to Dry machining. This may be due to a fact that use of coolant reduces the friction by moving the chips away from the cutting zone. With the use of PCD inserts surface roughness shows good improvement as compared to uncoated cemented carbide inserts.

Fig 4 AOM plot of Surface Roughness



3.2 Analysis of Circularity: -From ANOVA Table 5 and AOM plot shown in Fig.5 it clear that Environment and depth of cut are most influencing parameter at 95 % confident level for circularity. Wet machining gives lower values of circularity. Increase in depth of cut from 0.25 to 0.5 mm do not have much effect on circularity however deviation in circularity decreases rapidly as depth of cut increases from 0.5 to 0.75 mm which is a favorable result for circularity. Remaining parameters do not significantly affect the circularity it can seen that deviation in circularity increases rapidly when speed changes from 1500 to 1700 rpm and upto 1900 rpm.Feed and Insert type also do not have considerable effect on circularity.

Fig 5 AOM plot of Circularity



5 Conclusions

In this work analysis and optimization of different parameters is carried out to improve surface finish, dimensional accuracy and circularity and to reduce cutting time/pass in boring operation of HE 30 Aluminium.

1) Surface roughness is minimum at lower cutting speed, higher depth of cut and fine feed, wet environment and PCD inserts. Increase in cutting speed, feed and no use of coolant adversely affects the surface roughness as it increases friction, cutting temperature and vibration.
2) Lower cutting speed, moderate feed, higher depth of cut values improves circularity. Type of inserts and environment has less influence on circularity. Higher values of machining parameters greatly affect circularity.
3) Lower cutting speed, fine feed, higher depth of cut, and wet environment and PCD insert gives excellent quality of bore hole in machining operation of HE 30 ALUMINUM.

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