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EXPERIMENTAL STUDY OF SURFACE ROUGHNESS WITH ROTATING SQUARE EVOLUTIONARY OPERATION METHOD (ROVOP) IN HARD TURNING

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ABSTRACT

This research paper deals with the Rotating Square Evolutionary Operation Method (ROVOP). This technique is used to scan the entire area to determining optional values of cutting feed and depth of cut for decide average surface roughness (Ra) of AISI 52100 bearing steel of 48-50 HRc.with keeping cutting speed constant. In factorial design, two extreme values of the parameters are considered and to know the optimum values of surface roughness with obtained regression equation.

Keywords: *Surface roughness, ROVOP , hard turning.*

I. INTRODUCTION

Hard turning is a cost-effective, highly productive and flexible machining process for ferrous metal work pieces that are often hardened above 45 HRc and up to 62 HRc. Hard machining is performed by using ceramics and polycrystalline cubic boron nitride (PCBN, commonly CBN) cutting tools due to the required tool material hardness. Hard turning is a lathe machining process where most of the cutting is done with the nose of the insert. Most hard turning applications involve turning of hardened steels [1].Surface roughness is a measure of the technological quality of a product and a factor that greatly influences functional characteristics and manufacturing cost of the component. There are various simple roughness amplitude parameters that are commonly specified to designate the surface finish. Out of those, the most common and significant parameters were considered in this experiment and measured to compute the surface quality. ROVOP technique is used for determine surface roughness of AISI 52100 bearing steel of 48-50 HRc..[2] The paper first gives background for this study,experimental setup and design are then discussed, along with the experimental observations on the surface roughness. Finally, conclusions are presented. Such surface roughness knowledge will help better understand and model the hard machining process, making hard machining a viable technology. Hard turning offers a number of potential benefits over traditional form grinding, including lower equipment costs, shorter setup time, fewer process steps, greater part geometry flexibility, and elimination of the use of cutting fluid [3,4,5].Hard turning is, therefore, of a great interest to both the manufacturing industry and research community.

II. EXPERIMENTAL WORK

2.1 Experimental design

As shown in Table 1, three cutting parameters (cutting speed v, feed rate f and depth of cut a_p) were selected as the independent factors in turning of EN31 Steel. Each cutting parameter have three levels, which were denoted by ‘1’, ‘2’, and ‘3’, respectively.

Table 1 Cutting parameters and their levels

Cutting parameters	**Levels**		
	1	**2**	**3**
Cutting speed ,v (m/min)	250	300	350
Feed rate, f (mm/rev)	0.03	0.04	0.05
Depth of cut, a_p (mm)	0.1	0.2	0.3

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Based on Taguchi's technique, a standard L_9 (3^3) orthogonal array was designed as shown in Table 2.

Table 2 Experimental design based on Taguchi's technique

Expt. No.	Cutting speed ,*v* (m/min)	Feed rate, *f* (mm/rev)	Depth of cut, a_p (mm)
1	250	0.03	0.1
2	250	0.04	0.2
3	250	0.05	0.3
4	300	0.03	0.2
5	300	0.04	0.3
6	300	0.05	0.1
7	350	0.03	0.3
8	350	0.04	0.1
9	350	0.05	0.2

2.2 Workpiece material, machine tool and cutting tool

EN 31 Steel, 80 mm in diameter and 250 mm in length were prepared for the turning experiments. The chemical compositions is given in Table.3

Table 3 Chemical composition of the work material

Sample Description	C (%)	Cr (%)	Mn (%)	Si (%)	S (%)	P (%)
Sample	0.92	1.06	0.51	0.22	0.039	0.040

Before turning experiments, the exterior surfaces of the specimen were turned to remove the original oxidation layers and other defaults. In this research, all the turning experiments were carried out on a CNC lathe machine.The cutting tool used for this experiment is supplied by Mitsubishi (Japan).The Un-coated type Cubic Boron Nitride (CBN) inserts were used for turning experiments.The geometry and grade of insert is NP-CNMA120408G. Figure 1 shows PCBN cutting tool insert. The CBN tool material is one of the hardest known after diamond [6]. It is a super abrasive material and has a cubic atomic structure, like diamond.

Fig. 1 Geometries of the tooling system

Its main characteristics are its grain size, percentage of CBN and its types of binder.Inserts are recommended for Structural steel, carburised steel and high alloy steel in the range of 35-65 HRc.No cutting fluids were used during turning process. Fig. 1 shows the geometrical information about the tool-holder and the indexable insert used in the turning experiments.

III. RESULTS AND DISCUSSION

Analysis of the experimental data obtained through Taguchi experimental design [7]was carried out using MINITAB 16. Table 4 and Table 5 shows process parameters and results of surface roughness (Ra) values with Hobson surface tester. A logarithmic transformation can be applied to convert the non linear form of equation into the additive (linear) form. This is one of the most popularly used data transformation methods in empirical model building.

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Table 4

v	*f*	a_p	Ra
250	0.03	0.1	1.25
250	0.04	0.2	1.76
250	0.05	0.3	2.19
300	0.03	0.2	3.2
300	0.04	0.3	1.99
300	0.05	0.1	2.56
350	0.03	0.3	0.95
350	0.04	0.1	1.26
350	0.05	0.2	0.84

Table 5

log v	log *f*	log a_p	log Ra
2.39794	-1.52288	-1	0.09691
2.39794	-1.39794	-0.69897	0.245513
2.39794	-1.30103	-0.52288	0.340444
2.477121	-1.52288	-0.69897	0.50515
2.477121	-1.39794	-0.52288	0.298853
2.477121	-1.30103	-1	0.40824
2.544068	-1.52288	-0.52288	-0.02228
2.544068	-1.39794	-1	0.100371

Table 6 : Coefficients and t statistics

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Constant	3.97	3.274	1.214	0.278	-4.439	12.396
Cutting speed	-1.43	1.235	-1.164	0.296	-4.613	1.737
feed	0.141	0.812	0.174	0.868	-1.947	2.230
Depth of cut	0.0154	0.374	0.041	0.968	-0.947	0.978

The functional relationship between the surface roughness (Ra) and investigated independent variables cutting speed (v),m/min;feed (f);and depth of cut (a_p) can be represented by the following equation,
$Ra = f(V, f, a_p)$ ---- (1)

Equation may be written in logarithmic form as
$\text{Log } Ra = \log k + m \log V + n \log f + q \log a_p$ ---- (2)
Assuming exponential relationship,
$Ra = k V^m f^n a_p^q)$ ---- (3)

Where k is constant of proportionality and m, n and q are constants.
The experimental observations have been as obtained from the coefficients and t statistics Table no.6, the results could be formulated in the form as shown in the given below.
$Ra = 9932 \times V^{-1.43} f^{0.141} a_p^{0.0154}$ ---- (4)

3.1 Optimization of parameters
In case of fine hard turning the cutting speed ,V 350 m/min is considered to transform Ra equation (4) to equation (5) in terms of feed f mm/rev and a_p mm,
$Ra = 9932 \times (350)^{-1.43} f^{0.141} a_p^{0.0154}$ ---- (5)
$Ra = 2.28 \; f^{0.141} a_p^{0.0154}$ ---- (5)

The experimental data processed through "Rotating Square Evolutionary Operation" (ROVOP) technique[8,9] is shown in figure. The Table 7 shows the values at each corner points of the rotating square and corresponding surface roughness calculated from equation (5). Fig.2 shows treatment combinations through ROVOP For Ra at feed range of 0.03.to 0.05mm/rev and depth of cut for 0.1 to 0.3 mm.

Table 7 Surface Roughness (Ra) Values by Rotating Square Evolutionary Operation

Sr.No.	Feed (mm/rev)	Depth of cut (mm)	Ra (µm)
1	**0.03**	**0.1**	**1.320**
2	0.05	0.1	1.430
3	0.05	0.3	1.45
4	0.03	0.3	1.34
5	0.04	0.1	1.386
6	0.05	0.2	1.437
7	0.04	0.3	1.421
8	0.03	0.2	1.326
9	0.045	0.15	1.429
10	0.045	0.25	1.438
11	0.035	0.25	1.389
12	0.035	0.15	1.379
13	0.04	0.15	1.406
14	0.045	0.2	1.436
15	0.04	0.25	1.417
16	0.035	0.2	1.386
17	0.0425	0.175	1.421
18	0.0425	0.225	1.427
19	0.0375	0.225	1.402
20	0.0375	0.175	1.397

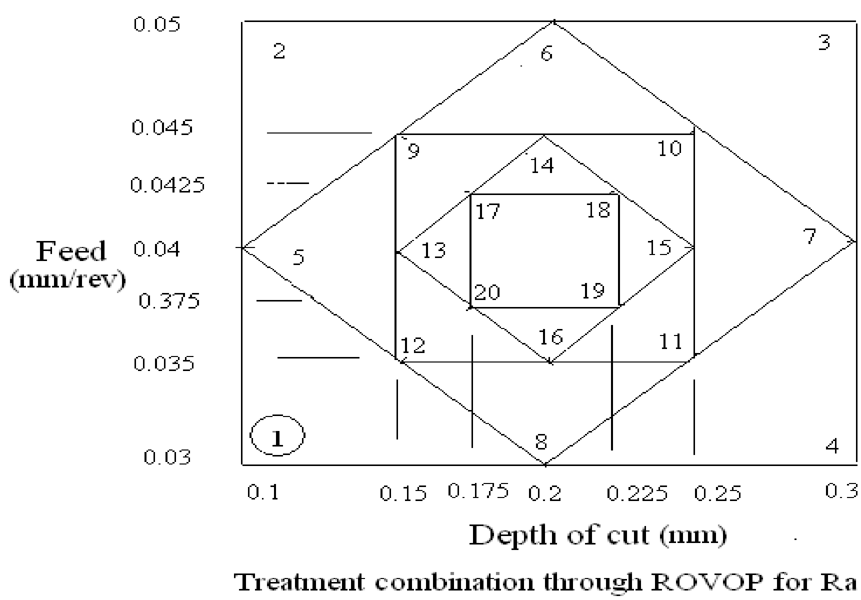

Fig.2 treatment combinations through ROVOP For Ra

IV. CONCLUSION

The following conclusions drawn from the present investigation.The surface roughness equation transformed to the equation with two variables , feed and depth of cut of turning process keeping other one variable i.e. cutting speed constant ,thus resulting in hard turning and giving satisfactory forecasts for surface roughness.The minimum surface roughness is at feed 0.03 mm/rev, depth of cut 0.1 and at maximum speed of the selected range, agreeable surface roughness equation.

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