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Study on surface finish of AISI 2080 steel based on the Taguchi method

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Abstract. Surface finish and dimensional accuracy play a vital role in manufacturing engineering applications. Grinding is one of the most important methods for producing a better surface quality**.** This paper describes a study of the influences of cutting parameters such as table speed, depth of cut and feed rate on surface finish of AISI 2080 steels, based on the Taguchi (L27) method. The experimental results showed that the table speed was the machining parameter, which had a greater effect on the surface finish, followed by depth of cut, whereas feed rate showed no significant effect. Analysis of variance indicated that a better surface finish was obtained at 190 m/min speed, 0.003 mm depth of cut and 0.08 mm/rev feed rate.

1. Introduction

In the manufacturing industry, surface quality is one of the most important parametres in order to evaluate the product quality. A better surface finish is desired in many engineering applications because it minimize friction and wear, improved the fatigue strength, corrosion resistance, precision fits, thereby enhancing the operating hours of machined parts. Obtaining the better surface finish in any machining processes such as lathe, milling, drilling and grinding depends on various parameters like machining parameters, tool and workpiece material properties and cutting conditions. In grinding operation, the surface roughness also depends on cutting speed, feed rate, depth of cut, lubrication, machine vibrations etc. However, an appropriate selection of the grinding parametres is more important [1, 2, 3].

Taguchi designs are used to analyze and optimize the machining parametres because a desirable product quality can be achieved with system and parametric design [4, 5]. Several researchers have conducted on development of matheamatical models of surface roughnesses for different steels such as carbon steel [6], En8 steel [7], En18 steel [8], AISI 1040 [9], AISI 4140 [10, 11] and use of oil effect [12] using a Taguchi technique. There are numbers of studies carried out on different steels by using the statistical method [5-11]. However, no study is performed on grinding of AISI 2080 steel with statistically and experimentally. Therefore, the aim of the present work was to investigate the surface finish of under different girinding conditions. The Taguchi L27 (3^{13}) method and ANOVA were adopted to identify the effect of process parameters on the surface finish of tested materials.

2. Experimental

2.1. Materials

Chemical composion of AISI 2080 steel is shown in table 1. Its size is about 40x80x120 mm. Due to 11.5%Cr and 2%C content, it has a high thermal stability of tool steel. It is known as higher wear resistance material. Thus, they are prefered to use cutting tool, burr cutting, cutting tool for plastic moulding and paper, deep pressing tool and pressing brace.

Table 1. Chemical composions of AISI 2080

C	Si	Mn	Cr	Mo	Ni	V	W
2.00	0.20	0.30	11.5	-	-	-	-

Table 2 indicates **s**tandard use of grinding wheel surface and their some properties. A series of parametres were devised to quantify the information from stylus measurement data such as R_a (an average surface roughess/center line average), R_z (an average of maximum peaks to minimum valleys) and R_q (root mean square roughness). Among these parameters, it proves too general to describe the surface's functional nature. Figure 1 shows a Mohr Pertometer types of stylus equipment used for measuring the surface roughness of the steel.

Table 2. Standard use of grinding wheel surface.

Type of abrasives material	SiC-EKR	Silicon carbide
Grain size	60	Medium size
Hardness of grinding Wheel	K	Medium hardness
Degree of wheel's structure	6	Microstructure of wheels
Combining materials	V	Ceramic
Dimension of grinding wheel	350*40*127	Diemeter of wheel/thickness of wheel/diameter of flange

Taguchi experimental plan with notation of L27 (3^{13}) was chosen. This experiment specifies three principal wear testing conditions, including the table speed (*A*), depth of cut (*B*), feed rate (*C*) of tested materials as process parameters. The codes and levels of control parameters are shown in Table 3. Each combination of experiments was repeated three times to acquire a more accurate result. Orthogonal array and analysis of variance (ANOVA) were employed to investigate the influence of process parameters on the grinding of the steel.

Table 3. Grinding parametres and their levels

Symbol	Parameters	Level 1	Level 2	Level 3
A	Table speed (m/min)	190	290	390
B	Depth of cut (mm)	0.003	0.007	0.010
C	Feed rate (mm/rev)	0.04	0.08	0.12

3. Results and Discussion

3.1. Analysis of wear results

The experimental layout and the results of surface roghness of the steels considered are shown in Table 4 and figure 2. The tests relevant to this table were carried out at a fixed material, but with the parameters indicated. It is evident from the figure that the table speed showed a higher effect than the other ones. On the other hand, the surface roughness was maximum for trial 27 due to using the third-level of speed (390 m/min), the third level of depth of cut (0.010 mm) and the third-level of feed rate (0.12 mm/rev).

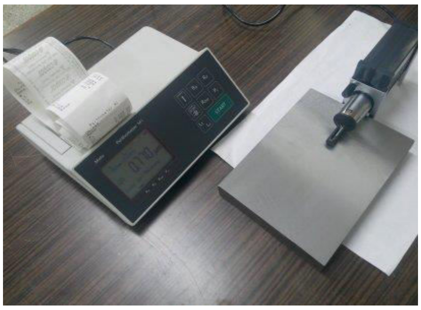

Figure 1. Mohr Pertometer types of stylus equipment used for measuring the surface roughness of the steel.

Figure 2 shows the mean surface roughness as a function of speed, depth of cut, and feed rate. The surface roughness increased more or less linearly with table speed on the tested samples, indicating an improved surface finish at lower speed. This figure also illustrates the surafce finish as a function of depth of cut, whose values were in the range of 0.80 µm to 1.22 µm). As seen, the roughness decreased with lowering the depth of cut. The decrease in the surface finish was more affected by the speed than by the depth of cut. It was observed that, feed rate had a very slight effect on the surface finish.

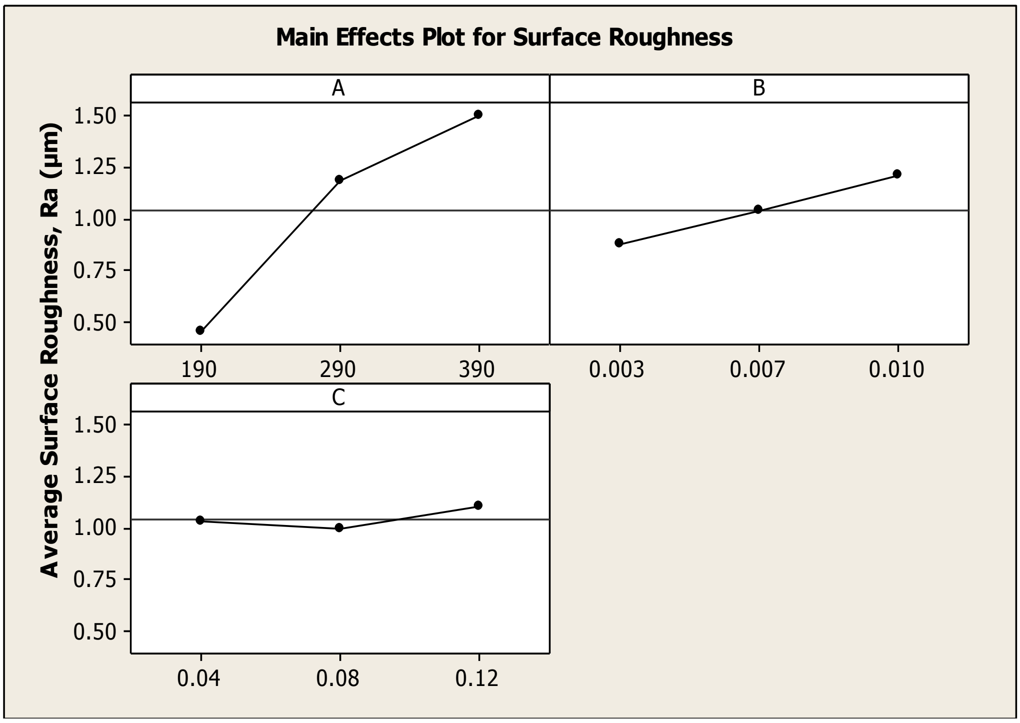

Figure 2. Mean surface roughness of steel as functions of factors of table speed (A), depth of cut (B), and feed rate (C).

The relation between the normal probability *Pr* and the residual *R* for the steels tested is shown in figure 3. The distributions of errors was assumed to be normal because it lays down very closely around the line. In general, the residual *R* was lower than ±0.5. However, sometimes the variance of observation grew as the magnitude of observation increased, because the error or noise in the experiment is a constant percentage of the size of observation. Figure 4 indicates a residual vs. fitted value for surface finish of the steel. The residual is mostly cumulated around zero except a few points over that. This also confirms the previous figure.

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Table 4. Experimental design and results for average surface roughness of steel at grinding process

Exper. No.	Table speed (m/min)	Depth of cut (mm)	Feed rate (mm/rev)	Mean surface roughness (R_a), μm
1	190	0.003	0.04	0.379
2	190	0.003	0.08	0.426
3	190	0.003	0.12	0.525
4	190	0.007	0.04	0.283
5	190	0.007	0.08	0.314
6	190	0.007	0.12	0.409
7	190	0.010	0.04	0.436
8	190	0.010	0.08	0.624
9	190	0.010	0.12	0.709
10	290	0.003	0.04	0.966
11	290	0.003	0.08	0.881
12	290	0.003	0.12	1.175
13	290	0.007	0.04	1.398
14	290	0.007	0.08	1.158
15	290	0.007	0.12	1.252
16	290	0.010	0.04	1.454
17	290	0.010	0.08	1.192
18	290	0.010	0.12	1.184
19	390	0.003	0.04	1.155
20	390	0.003	0.08	1.184
21	390	0.003	0.12	1.233
22	390	0.007	0.04	1.621
23	390	0.007	0.08	1.409
24	390	0.007	0.12	1.513
25	390	0.010	0.04	1.634
26	390	0.010	0.08	1.787
27	390	0.010	0.12	1.921

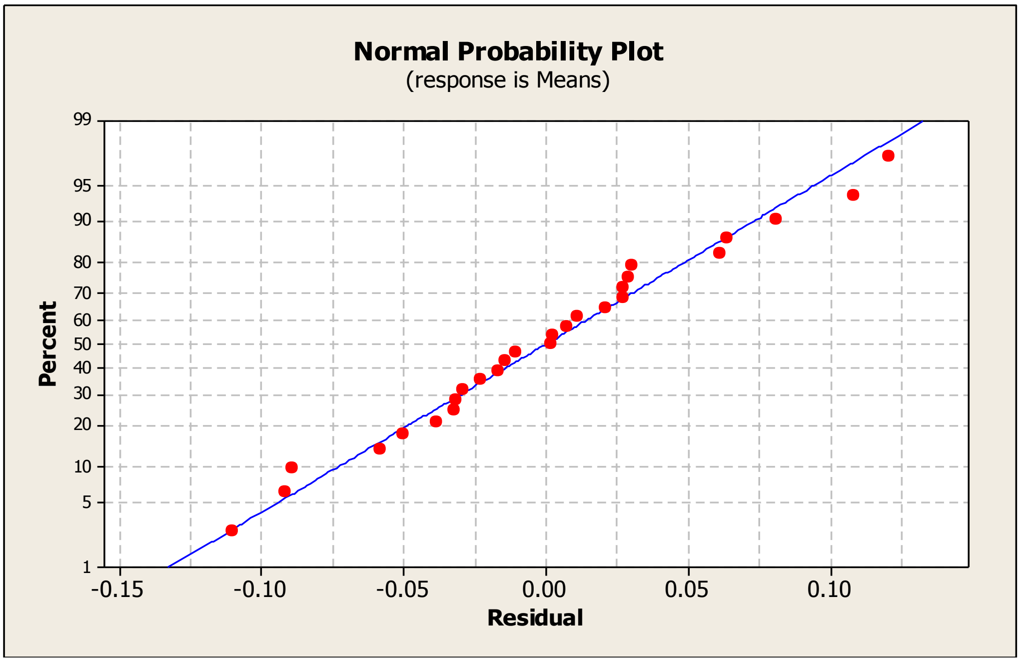

Figure 3. The normal probability *Pr* vs. residual *R* of steels.

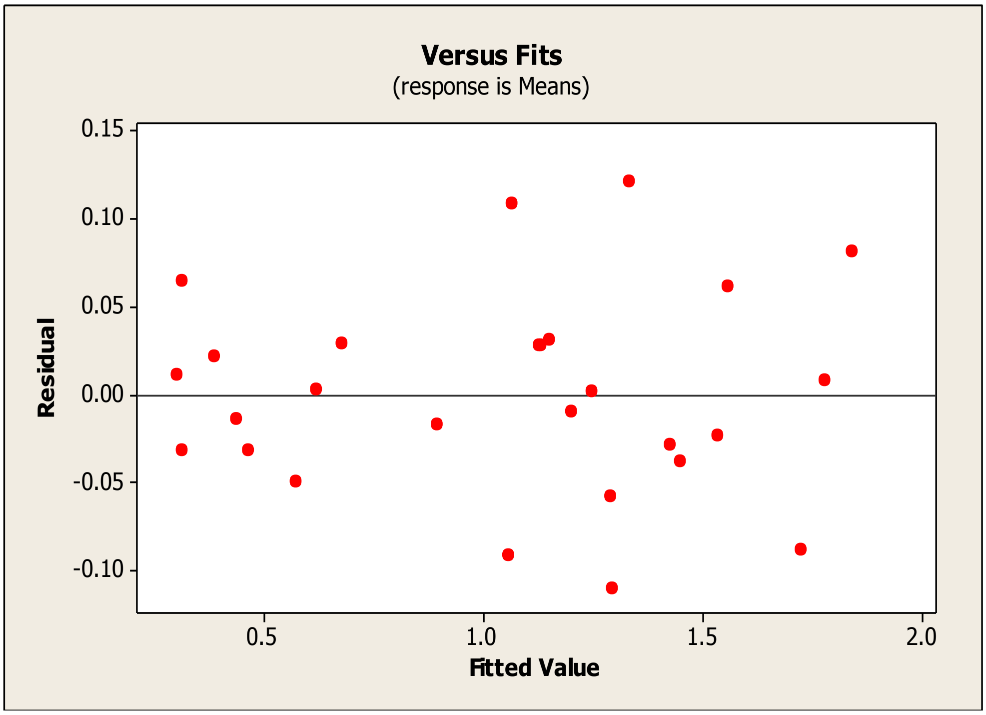

Figure 4. Residual vs.fitted value.

Table 5 shows the response for the means of surface roughness of tested steel specimens. The response table can enable one to decide the significance of the parameters of performance characteristics. In the response table, surface roughness are shown for different levels of parameters. According to the calculated values of delta, the parameters were ranked. The control factors were sorted in relation to the values of differences. The strongest influence was found to exerted by the factor *A* (1.039 μm), followed by the factor *B* (0.335 μm). The factor C showed the least effect, since the difference was about 0.105 μm. The minimum surface roughness gave the combination of level 3 of the factor *A*, level 3 of the factor *B*, and level 2 of the factor *C*. The optimum mean values of response for the surface finish were found to be A1, B1, and C2.

Table 5. Response table for mean surface roughness of steels.

Levels	Main machining factors		
	A (Table speed)	B (Depth of cut)	C (Feed rate)
Level 1	0.4565	0.8809	1.0367
Level 2	1.1849	1.0401	0.9976
Level 3	1.4957	1.2162	1.1029
Delta	1.0391	0.3353	0.1053
Rank	1	2	3

3.2. ANOVA analysis

The ANOVA results for the surface roughness of steels are listed in table 6. This analysis was performed for the 5% significance level, that is, for the 95% confidence level. It is clear from the Table 5 that the factors *A* and *B* had a statistical and physical significance for the grinding process, because the value of test-F was higher than the *F*5% value and the value of error was lower than the percentage of contribution (*P*%) of each factor. In the ANOVA table, *P* shows the degree of influence of each factor on surface finish results. As seen, the factors *A* (P = 83.4%), *B* (P = 8.24%), and *C* (P = 0.83%) showed an acceptable level on the rate of surface roughness of steels. It follows from the table that the interaction factor *A***C*, and *B***C* affected the surface roughness of tested specimens negligibly because they are lower than residual values.

Table 6. Analysis of variance for the mean surface roughness of the steel.

Source	DF	Adj SS	Adj MS	Test-F	Table-F (95%)	P	P(%)
A	2	5.1200	2.5600	241.93	5.310	0.000	83.40
B	2	0.5060	0.2530	23.92	5.310	0.000	8.24
C	2	0.0510	0.0255	2.41	5.310	0.152	0.83
A*B	4	0.2560	0.0642	6.07	7.708	0.015	4.17
A*C	4	0.0744	0.0186	1.76	7.708	0.230	1.20
B*C	4	0.0379	0.0094	0.90	7.708	0.509	0.62
Residual	8	0.0846	0.0105				1.54
Total	26	6.1390					100

In the present study, the surface finish of steel when applied the grinding process was investigated using the Taguchi approach with L27 orthogonal array. It was revealed that the average surface roughness of the materials tested depended not only on the materials type, hardness, speed and lubrication, but also on the machining parameteres and the type of steel specimens. The optimum surface finish was obtained for the AISI 2080 steels under 190 m/min speed, 0.03 mm depth of cut and 0.08 mm/rev feed rate conditions applied.

4. Conclusions

The surface roughness of AISI 2080 steels were studied using a surface grinding machine. The Taguchi robust design method was employed to investigate the different grinding parametres on steel. The following conclusions can be drawn:

1. The average surface roughness decreased with decreasing speed and depth of cut, but no significant changes occurred with feed rate when machined with EKR grinding disc.
2. Among the tested parametres, the best surface finish was obtained when the test was carried out at a speed of 190 m/min, depth of cut of 0.03 mm and feed rate of 0.08 mm/rev conditions for plane grinding the steels.
3. ANOVA analysis results indicated that the table speed was the most significant factor (P = 83.4%) affecting the surface finish of steels, which was followed by depth of cut (P = 8.24%), whereas feed rate (P = 0.83%) had the least effect.

References

[1] Rudrapati R *et al* 2013 *Advanced Materials Manufacturing & Characterization* **3** 335
[2] Kahraman F 2009 *Materials and Technology* **43** 267
[3] Boothroyd G and Knight WA 2005 *Fundamentals of Machining and Machine Tools* (Boca Raton: CRC Press, Taylor and Francis group)
[4] Roy R K 1990 *A Primer on the Taguchi method* (Dearborn: Society of Manufacturing Engineers)
[5] Rao P V and Agarwal S A 2005 *Int. J. Mach. Tool. Manu.* **45** 609
[6] Malkin S 1976 *Journal of Engineering for Industry* **98** 56
[7] Thakor P S and Patel D M 2014 *International journal of Engineering Development and Research* **2** 2486
[8] Pal K and Shivhare V 2014 *International Journal of Basic and Applied Sciences* **1** 11
[9] Singh K *et al* 2014 *American Journal of Mechanical Engineering* **2** 58
[10] Singh B and Singh B 2014 *IOSR Journal of Mechanical and Civil Engineering.***10** 61
[11] Bianchi E C *et al* 2004 *Materials Research-Ibero-american Journal of Materials* **7** 385
[12] Şahin Y and Yalcinkaya S 2016 *Key Engineering Materials* **689** 7