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ORIGINAL CONTRIBUTION

EXPERIMENTAL ANALYSIS OF EFFECTS OF PROCESS PARAMETERS ON SURFACE QUALITY IN SURFACE GRINDING OF STEEL

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ABSTRACT

In the manufacturing jobs producing smooth surface finish plays a vital role. To fulfil this smooth finish, surface grinding process is mostly used. The parameters to be considered in surface grinding are surface quality and material removal rate. Steel is a very important engineering material and surface grinding of steel is also an important practical engineering process. Various grades of steel are available in practice. In this paper EN8 steel is taken up for analysis. The parameters considered are wheel speed, table speed, depth of cut, feed rate, flow rate of coolant. The variation of surface roughness is modelled by response surface methodology (RSM) and a complete realization of the process parameters and their effects are realized,

KEYWORDS: Surface grinding, surface roughness, RSM, optimization.

1. INTRODUCTION

In order to improve surface finish, abrade hard materials and tighten the tolerance on flat and cylindrical surfaces by removing a small amount of material, surface grinding is an essential finishing process. In grinding an abrasive material rubs against the metal part and removes tiny pieces of material [1]. Grinding removes the metal faster than removal of metal by tools with single cutting edges such as chisels. Apart from being used as material removal process it is also used to sharpen the edges of a cutting tool and sharp objects such as knives etc. although the basic mechanism of material removal is the same. The quality of this material removal process is observed through two characteristics [2.3,4, 5,6,] viz. surface roughness and material removal rate. These are directly related to the performance of mechanical pieces, productivity and production costs. Grinding is employed for finishing various mechanical components such as engine crank shafts, splined shafts, lathe guideways, long pipes, worms, toothed gears, pinions, racks and surfaces. According to the shape of the table and its movements, surface grinding machines can be divided into two categories – planer type and rotary type. In planer type surface grinder the table is of rectangular shape and traverses under the wheel. In rotary type surface grinder, the table is of circular shape and it rotates under the wheel. According to the position of the spindle, surface grinder can also be classified as horizontal spindle and vertical spindle. The material chosen for this analysis is EN8 steel. Response surface methodology (RSM) [7] is used to model the surface roughness as well as analyze the effects.

2. METHODOLOGY

A set of experiment were conducted on surface grinding machine on EN8 material to determine the effect of machining parameters namely wheel speed, table speed, feed rate, etc. In this work experimental results were used by imposing upper and lower limit for the input machining parameters. Grinding wheel used for the present work is the aluminium oxide abrasive with vitrified bond and water miscible coolant was supplied in all grinding experiments, The jobs have undergone the chemical cleaning and facing process before grinding. Chemical cleaning is done for the removal of scales and rust. Material removal rate is calculated by taking the ratio of differences in initial weight and final weight to machining time. The surface roughnesses (CLA value) of the jobs are evaluated on the surface test instrument. The sequential steps on the experimental analysis are given below:--

1) Study the properties of material

2) Selection of work piece material

3) Preparation of work piece by facing and chemical cleaning.

4) Cutting and weighing of material

5) Machining of work piece

6) Recording of machining parameters

7) Analysis of results and interpretation

3. EXPERIMENTAL PROCEDURE

3.1. Scheme of the experiment:-

Five machining parameters are chosen for this work viz wheel speed, table speed, feed rate, depth of cut and flow rate of coolant. The response variable which is to be modeled through these parameters is surface roughness (R_a). For experimental planning and setting of parameters a central composite routable two level factorial (half fraction) design matrix with 5 factors, 6 centre points and no blocks (alpha=2.00) was chosen .Here no of factors is 5 and each factors have 5 no of levels. The various process parameters and their values at different levels are given in the following table 1.

3.2. Selection of workpiece material:--

The material selected for the present study is EN 8 steel. The materials are obtained in the form of rectangular parallelepiped pieces of dimension 100 mm X 8mm X 8mm. The chemical composition and hardness have been checked and analyzed using Direct Reading Spectrometer and Brinell Hardness Tester. The chemical composition was found to be –

carbon -0.40-0.45%, silicon – 0.08-0.32%, manganese 0.48-0.72%, sulphur -0.02-0.07%,

phosphorus – 0.04-0.065% and balance was iron. The Brinell hardness was found to be 198.

3.3. Chemical treatment of the work pieces:-

After all the work pieces were tested for hardness and chemical composition the material has been chemically washed in the diluted solution of 25% HCl for descaling and rust removal from the surface of work pieces. HCl is the strongest acid used for descaling purpose.

3.4. Marking, cutting and facing of work pieces:-

After the chemical treatment, work pieces are measured and marked for cutting. The steel is cut from long steel flats as supplied in proper size by application of a power hacksaw. It is then faced on centre lathe for their flat surfaces across the cross section after proper filing.

3.5. Grinding of workpieces by surface grinder:-

After facing is done on lathe machine all the work pieces have been weighed. Experiments are conducted on a high precision semi automatic 2-axes CNC surface grinder (figure 1). The work pieces were placed one by one on the work bed of the surface grinder according to the scheme of the experiment. All the work pieces are cooled in water, chemically washed again and descaled again after grinding is over and then they are dried for sufficient time and then weighed.

3.6. Measurement of surface roughness:-

The surface roughness was tested in a surface roughness testing machine (figure 2). The surface roughness (R_a) was measured in perpendicular to the cutting direction. Five readings were taken were taken on each face of the samples to check the surface roughness and the averages were taken for analysis.

3.7. Application of the protective coating:-

A protective coating was applied on the cross section of the work pieces so as to break the contact of the grinded surface from the environment to avoid the oxidization of the material. The protective coating can be removed by using acetone.

4. EXPERIMENTAL RESULTS AND DISCUSSIONS

The results of the experiments are tabulated in table 2. The relationship between the input parameters and the responses are used to develop the empirical models. MINITAB software is used to develop the second order models for output responses. The obtained relation for surface roughness is given by as follows:--

$$SR = 1.05545 + 0.02667A - 0.01000B + 0.01167C + 0.06417D + 0.01250E + 0.07455A^2 + 0.07580B^2 + 0.01580C^2 + 0.05205D^2 + 0.05580E^2 + 0.00500AB -0.03250AC + 0.02500AD - 0.03625AE - 0.04875BC + 0.0375BD - 0.01250BE + 0.04625 CD + 0.04500CE - 0.00500DE$$

Where SR= surface roughness in μm (R_a value),

A = wheel speed (RPM), B = table speed (m/min), C = feed rate (mm/stroke),

D = depth of cut (μm), E = flow rate of coolant (ml/min).

The level of significance can be tested by using analysis of variance (ANOVA). The result of ANOVA for the quadratic model is given in table 3.

4.1. EFFECT OF PROCESS PARAMETERS ON SURFACE ROUGHNESS:--

As per practical importance the parameters wheel speed, table speed and feed rate are chosen for interpretation.

4.1.1. Effect of wheel speed and table speed on surface roughness:-

The combined effect of wheel speed and table speed on surface roughness is presented in figure 3. Generally with the increase of wheel speed surface roughness increases and as table speed increase surface roughness decreases while other parameters are kept constant. But here both wheel speed and table speed are varied. It is observed that at low values of table speed surface roughness first decreases and then increases as wheel speed increases. This is due to more time of contact between the grinding wheel and the work piece and more ploughing action between the abrasive grains and materials. As table speed increases time of contact for a particular point of contact goes on decreasing resulting in less ploughing action. But later increase is mainly for more and more abrasive grains are involved in grinding gradually due to self sharpening action of the grinding wheel. Similarly at low values of wheel speed as table speed increases similar trend is obtained. Here the presence of other factors like feed rate, depth of cut and application of coolant and control of grinding temperature also cannot be avoided.

4.1.2. Effect of wheel speed and feed rate on surface roughness:--

The combined effect of wheel speed and feed rate on surface roughness is depicted in figure 4. Generally with the increase of wheel speed the surface roughness increases and as the feed rate increases surface roughness increases. But here the combined effect is to be considered. It is observed that at low values of feed rate as wheel speed increases surface roughness first decreases and then increases. This is due to decrease in time of contact and less removal of material and loading and glazing of grinding wheel but as wheel speed increases and more and more abrasive grains comes in contact due to self sharpening action of grinding wheel, more material is removed and surface roughness increases with material removal rate. At low value of wheel speed while feed rate increases surface roughness increases due to larger area is exposed to ploughing action within a short time but as wheel speed increases the ploughing action becomes uniform within the same time span.

4.1.3. Effect of table speed and feed rate on surface roughness:--

The combined effect of table speed and feed rate on surface roughness is portrayed in figure 5. It is observed that at low value of feed rate as table speed increases surface roughness first decreases and then increases. This is due to the fact that when table speed is zero but at a definite feed rate contact time is more and ploughing action is not uniform over the surface. But as table speed increases ploughing action becomes uniform and time of contact of a particular point on the work piece surface with the grinding wheel becomes less thus removing less material from a particular spot. Hence surface roughness decreases with the increase of table speed. Simultaneously it is observed that at low value of table speed if feed rate increases surface roughness increases mostly and at high value of table speed as feed rate increases surface roughness decreases.

4.1.4. Optimization of desired response:-

Thus from the graphs and interpretations a contradictory effect is observed within the prescribed range of input parameters which demands for optimization of the desired response.

The response optimization is plotted in figure 6. The goal was set for minimizing the surface roughness. The lower bound was set at 1.1 μm , the upper bound was set at 1.2 μm and the target was the lower bound. Initial values for wheel speed, table speed, feed rate, depth of cut and flow rate of coolant was set at 1000 RPM, 8 m/min, 2 mm/stroke, 5 μm and 800 ml/min respectively. The predicted optimum response was found to be 1.13504 μm with the desirability value of 0.64961 μm.

5. CONCLUSION

It is concluded from the above observations that in surface grinding controlling the input parameters are of tremendous importance. All the possible controllable parameters are considered at a time and at the same time a multiple regression second order equation describing the relations between the input parameters and desired response is derived describing their level of significance. Further it is noticed that there is contradictory effects of the input parameters on the desired response as far as within the working range of parameters. Thus at last optimization of desired response is also worked out with a certain desirability function value.

References

[1] Bhateja,C.P (1982). Grinding: theory,techniques and trouble shooting, Society of Manufacturing Engineers (SME), Dearborn.

[2] Srivastava,S.K (2001). Tribology in Industries,S.Chand & Company Limited.

[3] Brinksmeimer, E, Tonshoff, H.K, Czenkusch, C and Heinzel C (1998). Modelling and optimization of grinding process, Journal of Intelligent Manufacturing, ij 303-314

[4] Hecker, L.R and Steven, Y.L (2003), Predictive modelling of surface roughness in grinding, International Journal of Machine Tools and Manufacture, 43, 755-761.

[5] Shaji, S and Radhakrishnan,V (2003), Analysis of process parameters in surface grinding with graphite as lubricant based on Taguchi Method, Journal of Material Processing Technology,141,51-59.

[6] Janardhan, M. and Krishna, A.Gopala (2011), Determination and optimization of cylindrical grinding process parameters using Taguchi Method and Regression Analysis, IJEST (ISSN: 0975-5462), 3(7), 5659-5665.

[7] K.Anish, K.Vinod and K.Jatinder (2012), Prediction of surface roughness in Wire Electric Discharge Machining (WEDM) process based on Response Surface Methodology, International Journal of Engineering and Technology, 2(4), 708-719.

Table 1: Levels of Independent Control Factors

Sl. No	Control Factor	Symbol	Level of factors					Unit
			-2	-1	0	1	2	
1	Wheel speed	A	1000	1250	1500	1750	2000	RPM
2	Table speed	B	8	10	12	13.5	15	m/min
3	Feed rate	C	2	3	4	5	6	mm/stroke
4	Depth of cut	D	5	7	10	12	15	µm
5	Flow rate of coolant	E	800	1000	1150	1300	1400	ml/min

Table 2: Experimental Observations

Sl. No.	Levels of parameters					Surface Roughness (SR) (µm)
	A	B	C	D	E	
1	-1	-1	-1	-1	1	1.25
2	1	-1	-1	-1	-1	1.30
3	-1	1	-1	-1	-1	1.34
4	1	1	-1	-1	-1	1.33
5	-1	-1	1	-1	-1	1.22
6	1	-1	1	-1	1	1.29
7	-1	1	1	-1	1	1.36
8	1	1	1	-1	-1	1.17
9	-1	-1	-1	1	-1	1.22
10	1	-1	-1	1	1	1.32
11	-1	1	-1	1	1	1.37
12	1	1	-1	1	-1	1.61
13	-1	-1	1	1	1	1.65
14	1	-1	1	1	-1	1.51
15	-1	1	1	1	-1	1.40

16	1	1	1	1	1	1.52
17	-2	0	0	0	0	1.18
18	2	0	0	0	0	1.38
19	0	-2	0	0	0	1.43
20	0	2	0	0	0	1.14
21	0	0	-2	0	0	1.07
22	0	0	2	0	0	1.02
23	0	0	0	-2	0	1.14
24	0	0	0	2	0	1.24
25	0	0	0	0	-2	1.21
Sl. No.	Levels of parameters					Surface Roughness (SR) [μm]
	A	B	C	D	E	
26	0	0	0	0	2	1.20
27	0	0	0	0	0	1.08
28	0	0	0	0	0	1.08
29	0	0	0	0	0	1.08
30	0	0	0	0	0	1.08
31	0	0	0	0	0	1.08
32	0	0	0	0	0	1.08

Table 3: Anova for Response Surface Quadratic Model

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	20	0.687220	0.687220	0.034361	2.35	0.074
Linear	5	0.125300	0.125300	0.025060	1.71	0.212
Square	5	0.405820	0.405820	0.081164	5.54	0.009
Interactions	10	0.156100	0.156100	0.015610	1.07	0.456
Residual Error	11	0.161052	0.161052	0.014641		

Lack of fit	6	0.161052	0.161052	0.026842	---	---
Pure error	5	0.000000	0.000000	0.000000		
Total	31	0.848272				

Figure 1: Photograph of surface grinder

Figure 2: Photograph of surface roughness tester

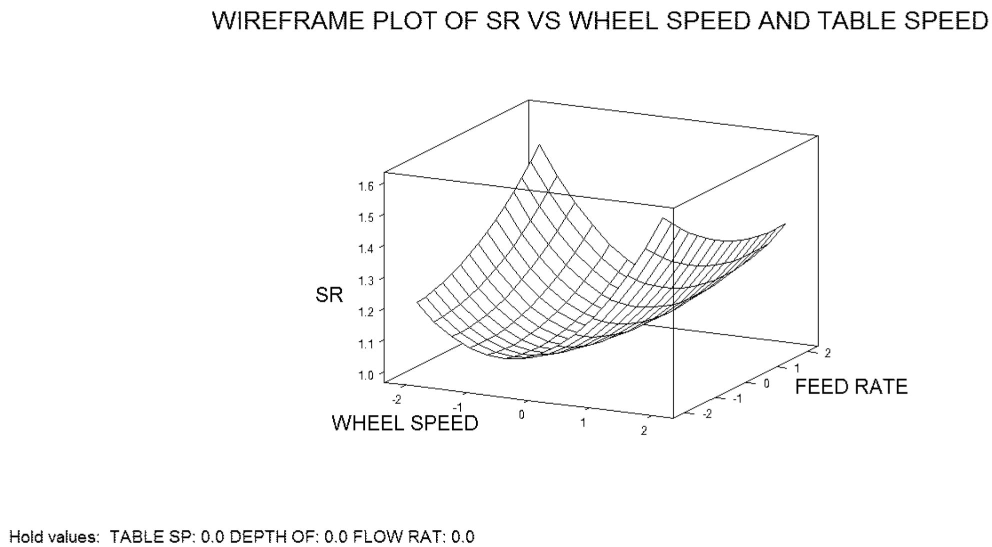

Figure 3: Effect of wheel speed and table speed on surface roughness

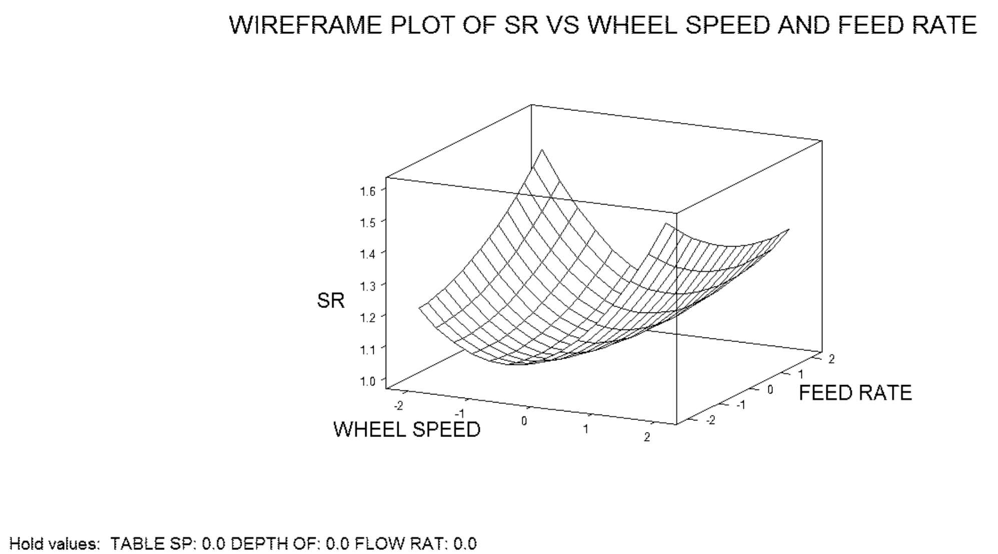

Figure 4: Effect of wheel speed and feed rate on surface roughness

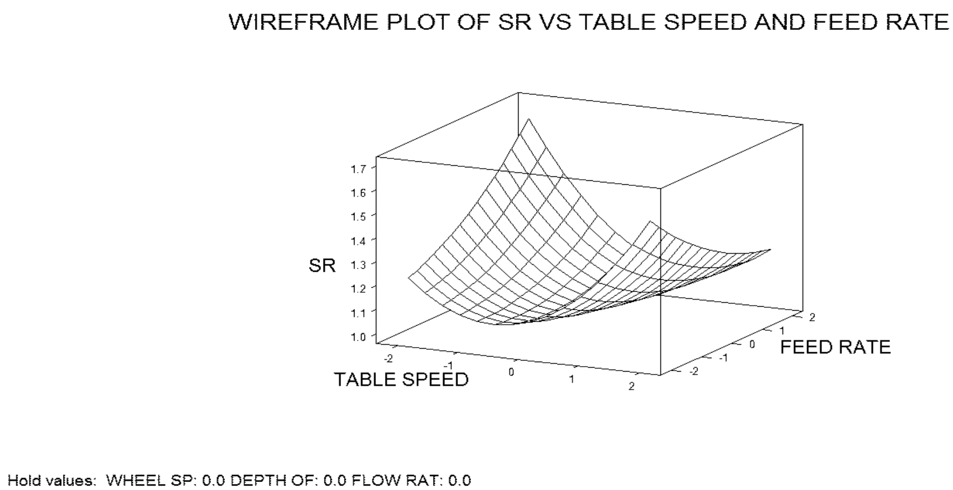

Figure 5: Effect of table speed and feed rate on surface roughness

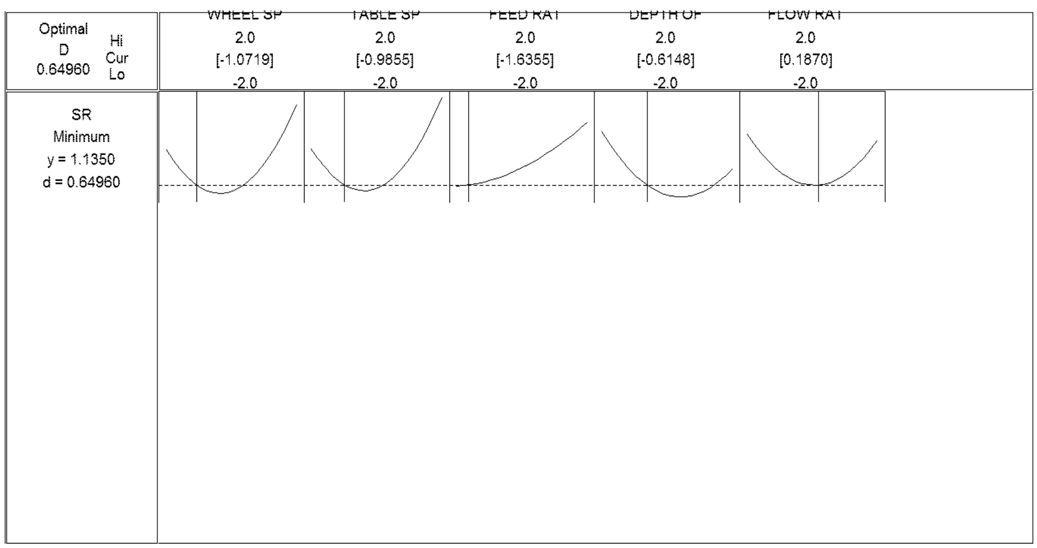

Figure 6: Response optimization for surface roughness