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EXPERIMENTAL INVESTIGATION OF EFFECT OF MACHINING PARAMETERS ON SURFACE ROUGHNESS IN ROLLER BURNISHING PROCESS

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Abstract: Burnishing is a chip less finishing method, which employs a rolling tool, pressed against the work piece, in order to achieve plastic deformation of the surface layer. Burnishing processes are largely considered in industrial cases in order to restructure surface characteristics. These study deals with investigating the effect of burnishing process parameter with roller burnishing tool on CNC Machine using Response Surface Methodology and develop the Mathematical Model. The Work piece material and Tool material are Aluminium Alloy 6351 T6 and Roller of Carbide used as burnishing tool. As per previous research the effect of burnishing speed, feed, ball diameter, burnishing force and no. of tool passes playing important role on the quality of the work surface produced and its wearing characteristics. The process parameters used are cutting speed, interference, tool feed, number of tool passes and response Parameters are Surface Roughness and Hardness. In design of experiment total L31 experiment has been carried out with four factors and five levels. From the experiment it was identified that the minimum Surface Roughness obtained is 0.080 µm at 450 rpm, 0.064 mm/rev, 2 mm, 4 for Cutting Speed, Feed Rate, Interference and Number of Tool Passes respectively. It was identified that the maximum Hardness obtained is 107 BHN at 450 rpm, 0.064 mm/rev, 5 mm, 3 for Cutting Speed, Feed Rate, Interference and Number of Tool Passes respectively. The analysis of variance (ANOVA) was performed to statistically analyze the results.
Keywords: Roller Burnishing Process, Surface Finish, Response Surface Methodology

I. INTRODUCTION

Machining of any materials like turning and milling have inherent irregularities and defects like tool marks and scratches that cause energy dissipation (friction) and surface damage (wear). To overcome these limitations, conventional finishing processes such as grinding, honing, and lapping have been traditionally employed. However, since these methods essentially depend on chip removal to attain the desired surface finish, these machining chips may cause further surface abrasion and geometric tolerance problem especially if conducted by unskilled operators. Accordingly, burnishing process offers an attractive post-machining alternative due to its chip less and relatively simple operations. Burnishing is a very simple and effective method for improvement in surface finish, surface roughness and surface hardness. It is widely used for increase the surface quality and imparting the physical and mechanical properties to any type of work materials. Burnishing is a cold working surface treatment process in which plastic deformation of surface irregularities occurs by exerting pressure through a very hard and smooth roller on a surface to generate a uniform and work hardened surface. Surface treatment is an important aspect of all manufacturing processes. Roller burnishing is a super-finishing process.

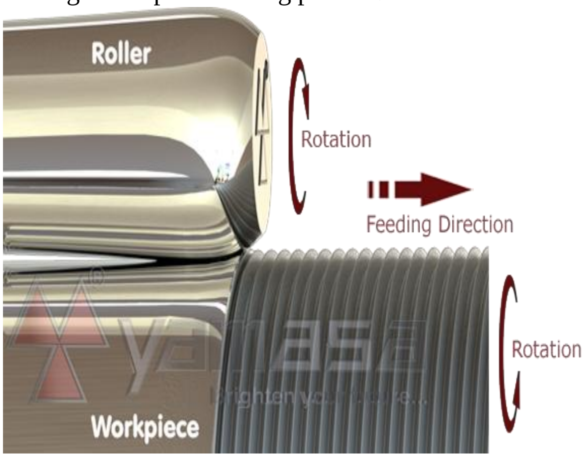

Figure 1: Roller burnishing process

II. TOOL AND WORKPIECE MATERIALS

The 6351 T6 Aluminium alloy round bar of 45 mm ø size has been used as a work piece material for the present experiments with tungsten carbide single roller burnishing tool. Al 6351 T6 is special hot-worked Aluminium alloy with good hardness and toughness properties. It is used for the making Aluminium cylinders which are used for industrial medical, and underwater applications. This material is highly susceptible to sustain load cracking in the neck and shoulder area of the cylinder. Al 6351-T6 is also used for the transportation of materials that are poisonous and hazardous. The working life and dimensional accuracy of Al 6351 T6 can be improved with suitable heat treatment.

A. Machining Parameters and Experimental Design

The three machining parameters considered for this study were Spindle speed (RPM), feed (mm/rev) Burnishing force (kgf), No of tool pass. The parameters were set at five levels each. The summary of the parameters are shown in Table 1.

Table 2.1: Different machining parameters used in the experiment and their levels

Process parameter	Level				
	(-2)	(-1)	(0)	(1)	(2)
Spindle	50	250	450	650	850

speed(X1)					
Feed(X2)	0.024	0.044	0.064	0.084	0.104
Burnishing force(X3)	2	3.5	5	6.5	8
No. of pass(X4)	1	2	3	4	5

B. Experimental Setup:
The experiments were carried out on a CNC lathe machine (ASKAR MICRONS SPIN FLAT) . The workpiece dimension is 40mm diameter. The cutting conditions were randomized. Mitutoyo surface roughness tester was used to measure the Ra.

Table 2.2: Design matrix and the Response

Run	X1	X2	X3	X4	Ra,µm
1	0	0	0	0	0.191
2	-1	-1	-1	-1	0.277
3	-2	0	0	0	0.402
4	0	0	0	0	0.150
5	1	1	1	1	0.104
6	0	0	0	0	0.774
7	0	0	2	0	0.126
8	0	0	0	0	0.100
9	1	1	-1	1	0.639
10	2	0	0	0	0.136
11	0	0	0	-2	0.134
12	0	0	0	2	0.096
13	-1	1	-1	1	1.504
14	0	0	0	0	0.099
15	1	1	1	-1	0.125
16	0	0	0	0	0.170
17	0	0	0	0	0.317
18	-1	-1	1	-1	0.115
19	1	-1	-1	-1	0.580
20	-1	1	-1	-1	0.350
21	-1	1	1	1	0.175
22	0	0	-2	0	0.214
23	1	-1	1	1	0.080
24	-1	-1	-1	1	0.540
25	1	-1	1	-1	0.095
26	-1	1	1	-1	0.120
27	1	1	-1	-1	0.115
28	0	-2	0	0	0.111
29	0	2	0	0	0.204
30	-1	-1	1	1	0.107
31	1	-1	-1	1	0.128

III. RESULTS AND DISCUSSION

Employing the parameters in Table 2.1, the levels of the parameters for each of the experimental runs in the design matrix and the observed response are given in Table2. 2[6]. The general equation for the proposed second order regression model to predict the response y can be written as:
Y = b0X0 + b1X1 + b2X2 + b3X3 + b4X4 + b11X12 + b22X22 + b33X32 + b44X42 + b12X1X2 + b23X2X3 + b34X3X4 + b14X1X4 + b13X1X3 + b24X2X4

All the coefficients are to be estimated using experimental data. Based on the result presented in Table 2, the derived model equation is shown in Eq. below,

Surface roughness Ra = = 0.865 + 0.001($X1$) - 0.007($X2$) - 30.899($X3$) + 0.108($X4$) - 0.001($X2^2$) + 309.521($X3^2$) - 0.014($X4^2$) + 0.010($X1X3$) - 1.544($X2X3$) + 0.029($X2X4$) - 1.743($X3X4$)

From Equation, the most significant parameter is X1, X2, X3, X4 and X1 X3, X2X3, X2X4, X3X4 followed by X22, X32, X42 on Ra. The missing terms are not significant for predicting Ra hence they were removed in other to improve the model.

A. Adequacy Check for The Developed Model:
The adequacy of the model was checked by analysis of variance (ANOVA)[6]. The ANOVA, table 3 for Ra shows that the p-value for model is less than 0.05, which indicates that the model is significant. In linear term all the term are significant terms. In quadratic term feed, force and no. of pass have significant effect. The model has significant interactions of feed and spindle speed, burnishing force and feed, feed and no. of pass, force and no. of pass Table 3 shows that the p-value for interaction term is less than 0.05 for Ra, this means that the effect of burnishing force on Ra depends on the spindle speed. The "Lack of Fit F-value" implies its insignificant relative to the pure error. Non-significant lack-of-fit is required for any model to be fitted.

Table 3.1: Pooled ANOVA table- Surface roughness

Source	DF	SS	MS	F	P
Regression	14	2.39388	0.170991	24.40	0.000
Linear	4	1.08404	0.017614	2.51	0.046
Square	4	0.43413	0.136788	19.52	0.000
Interaction	6	0.87571	0.145952	20.82	0.000
Residual error	15	0.10514	0.007009		
Lack of fit	8	0.09712	0.012140	10.60	0.003
Pure error	7	0.00802	0.001145		
Total	30	2.49901			
R-sq= 95.79% , R-sq(Adj)= 91.87%					

DF – Degree of freedom; SS – Sum of squares; MS – Mean square.

Checking the model adequacy, the experimental and predicted data (Fig. 1) for Ra were plotted. Fig. 1 and ANOVA analyses Table 3 for Ra indicate that the model is significant and adequate to represent the relationship between the variables and response, with very small P values (<0.05) and high value of coefficient of determination (R2 = 0.9187). Additionally, the developed response surface model for Ra has been checked by using residual analysis. The residual plots for Ra are shown in Figs 3.1. In normal probability plot, the data are spread approximately in a straight line, which show a good correlation between experimental and predicted values for the response. The plot of residual versus predicted values show minimal variation between the observed and fitted values. Residuals calculated against the order of experimentation also given. It is asserted that a tendency to have runs of positive and negative residuals indicate the existence of correlation. From the above analysis of residual plots for Ra, the model does not reveal inadequacy.

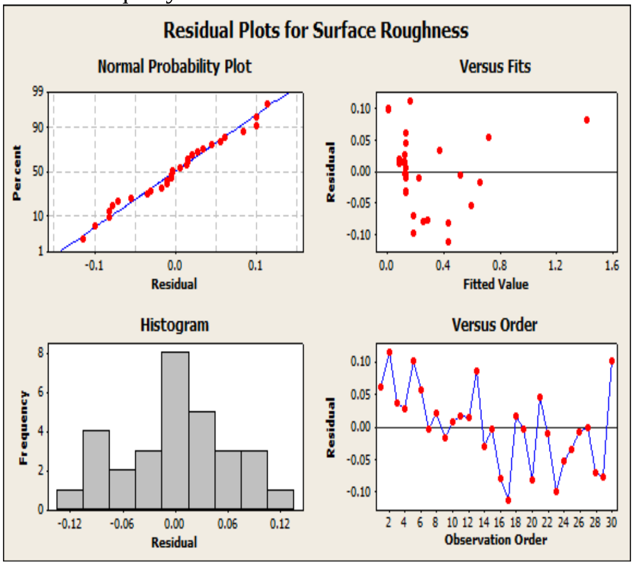

Figure 2: Residual plots for Ra

B. Effect of Machining Parameters On Ra:

1) Influences of Speed

We can clearly see from the figure 4, that surface finish improve straight way with decrease in speed [5]. However, in ordinary burnishing process that surface finish improves at certain level even speed is increased and there after increased in speed decrease surface finish. In other words, at lower spindle speed, the surface layer is plastically deformed to a greater depth because of comparatively more friction between roller element and work piece.

2) Influences of feed

It is cleared from the figure 3.2 that surface roughness increase with increase in feed. This means that effectiveness of roller burnishing decreasing with increasing feed rate [5]. There is an interaction between the ball force and the feed. With the combination of larger force and lower feed surface roughness increase due to over hardening and consequent flaking of the surface layers, similarly with the combination of lower force and larger feed surface finish reduced due to insufficient amount of burnishing force could not deform plastically surface layer of work piece. For better surface finish, it is preferable to use force 15 to 20 kgf with the feed of 0.06 mm/rev.

3) Influence of burnishing force

From the result of graph it is clearly indicate an interaction in roller force, feed and no. of pass. Figure 3.2 shows that increase with force initially surface finish improves and then deteriorates by further increase in force [5]. The surface finish improve with increase in burnishing force at certain level, i.e. up to 20 kgf force and then reduce with increasing in force. This type of behavior of material is due to following reasons.

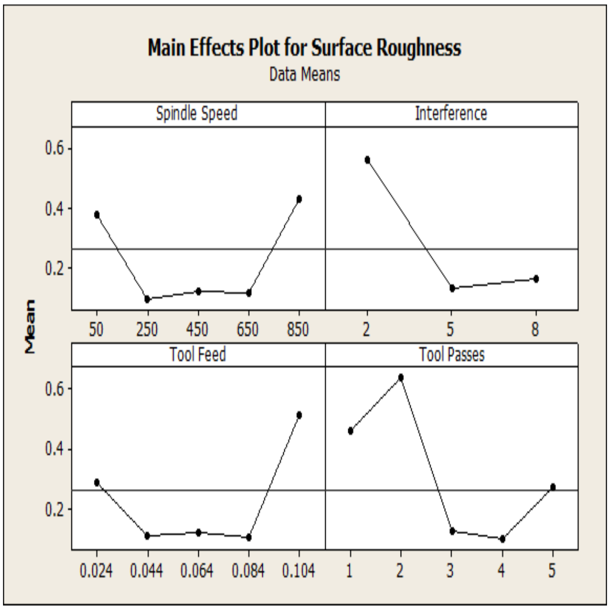

Figure 3: Main effect plots for Ra

At lower burnishing force, the deforming action of the ball may insufficient to cause the requisite metal flow from the asperity peaks to valley. On the other hand, higher force may over stressing and over hardening of surface layer leading to particle break down, i.e. flaking of surface layers.

4) Influence of No. of pass

Figure 3.2 shows an effect of No. of pass on the surface finish of work piece. It indicates that with the increasing the no. of tool pass surface finish improves [5]. A combination of higher tool pass and lower burnishing force surface finish is good but with increasing force combination with higher tool pass gives the better result. It is clearly observed that in roller burnishing process, with higher no. of tool pass good surface finish is obtain due to roller passes over same spot again and again leading to the deforming action on work piece.

IV. CONCLUSION

Surface roughness is increased with increase in No. of pass, best result is obtained with lower feed 0.06 mm/rev The effectiveness of roller burnishing decreasing with increasing feed rate. There is interaction between the roller force and the speed. A combination of higher tool pass and lower burnishing force surface finish is good but with increasing force combination with higher tool pass gives the better result. For better surface finish, it is preferable to use force 15 to 20 kgf with the No. of pass of 4.

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