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Studying the Effect of Process Parameters on Micro-Hardness by Using DOE Technique

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Abstract: This paper studies the influence of process parameters, namely, the load, the load time, and the type of materials, on micro-hardness of the machined surface. The significance of the process parameters and their interactions on the hardness with the help of analysis of variance. Full Factorial Design with two centre point (2 replication) was used for designing the experiments. According to our analyses, the load time and type of material were significant factors. Load, has an insignificant effect.

Keywords: load. Load time , micro-hardness, ANOVA

1. INTRODUCTION

The Vickers hardness test was established in 1921 as an alternative to the Brinell method for measuring the hardness of a material [1]. Hardness has conventionally been defined as the resistance of a material to permanent penetration by another harder material with measurement being made after the test load has been removed, such that elastic deformation is ignored [2,3]. The basic principle of the micro hardness measurement involves measuring the length of the diagonal in a material that is deformed by a pyramid-shaped indenter during penetration under a specific load. The micro hardness of the material can be determined since different materials possess. Generally, more observations will give more accurate micro hardness results. A few observations will suffice to obtain a reasonable result without a waste of effort. During the measurement, there may be a large variation in the micro hardness depending on the type of cutting process and the cutting parameters. The hardness commonly fluctuates by 50% [4]. The hardness is highest close to the machined surface due to work hardening and is gradually reduced by the subsurface depth. During their study on the WEDM cutting process, Kasim et al. reported that the difference between the maximum and minimum hardness was 40-130 HV at different cutting parameters [5]. Another factor to be considered during the testing is the dwell time of the loading. A study by Chuenarrom et al., however, found that the variation in the indentation time did not have a significant effect on the results [6]. In this study, the effect of load, load time and type of materials were investigated.

2. EXPERIMENTALWORK

In this study we used two types of material which are steel, ASSAB DF-3 and AZ91D alloy. Micro Vickers hardness tester was used to measure micro-hardness. Figure 1 shows the Micro Vickers Tester. Table 1 illustrates the values of process parameters. Full Factorial Design with two center point (2 replication) was used for designing the experiments. Table 2 shows the experimental plan and results.

Table1. Process parameters

Input Variables	Selected Values	
Load	1kg	2kg
Load time	10Sec	20Sec
Mmaterial	A(ASSAB DF-3)	B(AZ91D)

Table 2. The experimental plan and results

Std	Run	Factor A (kg)	Factor B (sec)	Factor c	(micro-hardness)
1	8	1	10	A	390
2	6	1	10	A	400
3	12	2	10	A	383
4	5	2	10	A	394
5	1	1	20	A	373
6	9	1	20	A	361
7	3	2	20	A	364
8	16	2	20	A	373
9	15	1	10	B	66.3
10	14	1	10	B	76
11	2	2	10	B	76
12	17	2	10	B	76.5
13	4	1	20	B	58.5
14	18	1	20	B	78.4
15	7	2	20	B	59.9
16	11	2	20	B	60.9
17	19	1.5	15	A	383
18	10	1.5	15	B	77
19	13	1.5	15	A	365
20	20	1.5	15	B	76

Figure 1. Micro Vickers hardness tester

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Figure 2. Examples of measurements for micro hardness

3. RESULTS AND DISCUSSIONS

As observed from the table 3, the factors B and C significantly influence the Micro-hardness. The results indicate that the interaction between the process parameters was insignificant. The effect plot of the process parameters on response factor shown in Figures 3. As can be seen from table 3, R-squared value (0.9976), which is ~ 1, is desirable. Hence, there was only a marginal difference (< 0.2) between the Adj. R^2 and Pred. R^2. This indicates a suitable correlation exists between the input and output parameters of the model. Accordingly, the final regression models based on actual prediction factors is presented in Eq. 1.

$$\text{Hardness} = 224.41 - 8.32*B - 154.02*C \quad (2)$$

In order to verify the adequacy of the model developed, two confirmation run experiments were performed at the optimal condition, the factors were at load 1.66 (kg), load time 12.15 (sec), and material type A. Table 4 illustrates the confirmation run.

Table3. Analysis of variance (ANOVA) for micr-hardness

source	Sum of square	DF	Mean square	F value	Prob>F
B	1107.23	1	117.23	15.78	0.0011
C	4.745E+005	1	4.745E+005	6763.46	<0.0001
curvature	2.28	1	2.28	0.032	0.859 not significant
Residual	1122.44	16	70.15		
Lack of fit	491.27	6	81.88	1.30	0.3408not significant
R^2	0.9976	Adj R^2	0.9874	Pred R^2	0.9346

Table4. Results of confirmation runs

No	Load time	Load	Material	Hardness		
				Actual	Predicted	Resi dual
1	1.66	12.15	A	389	383.173	5.827
2	1.5	10	A	385	386.75	1.75

4. CONCLUSIONS

Current investigation is carried out to identify and determineb the main factors that affect the micro-hardness. The specific observations of the present work are as follows:

- Load, Material type were the most significant factors that affect the micro- hardness.
- The curvauter is not significant for that we not need to second order model.
- The material type A and low values of load and time resulted in high hardness.

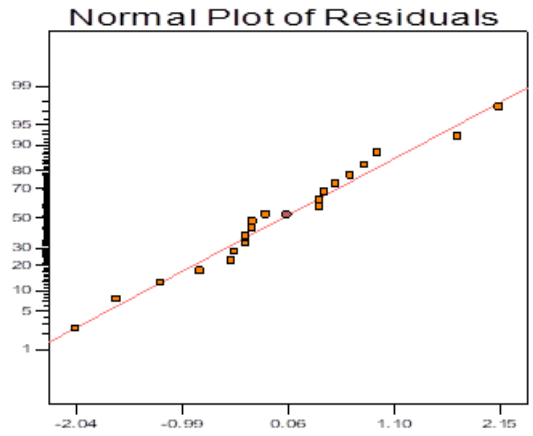

Figure 3. Normal plot of residuals

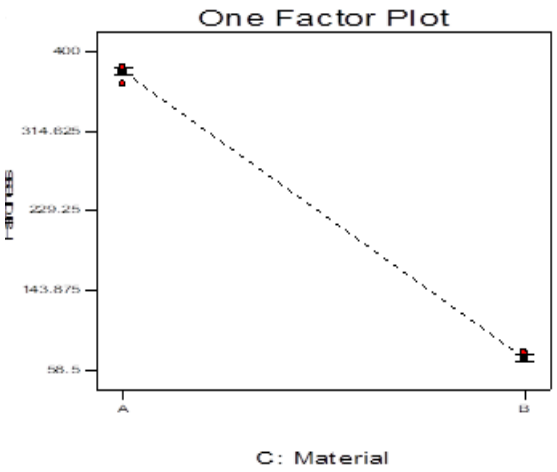

Figure 4. One factor Plot (C)

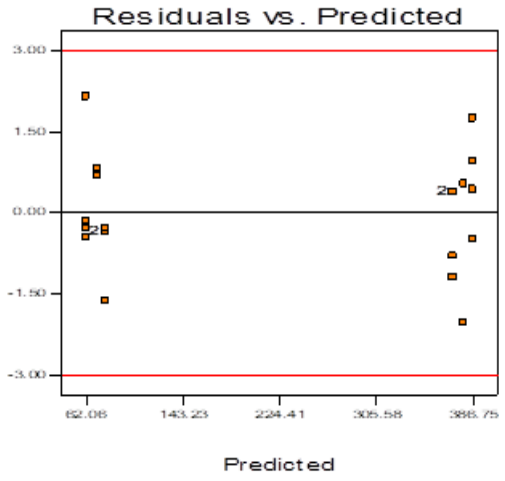

Figure 5. Residual VS. Predicted

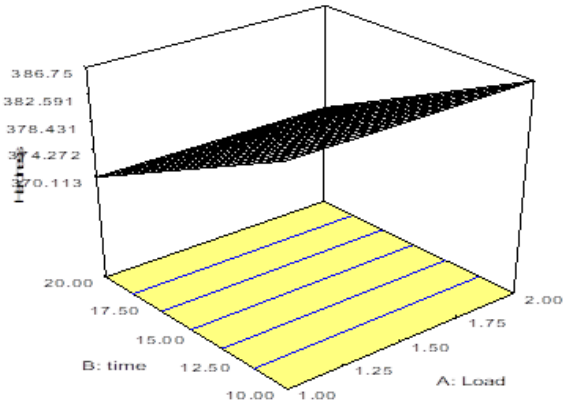

Figure 6. Contour plot

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