Optimization of Single Roller Burnishing Parameters Micro-hardness of Al Alloy Using Response Surface Methodology

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Abstract

The purpose of this research is to create an RSM model that can be used to predict the surface hardness after a single-roller burnishing procedure. To increase the surface micro-hardness, a single-roll burnishing technique is developed using the Taguchi approach. Minitab was used to create the RSM model of burnishing based on variables such as feed rate, force used in each pass, and the total number of strokes. The created RSM surface is applied to the experimental findings, and the outcomes of both are compared. The microhardness of aluminium alloy was predicted experimentally and with the aid of RSM.

Keywords: Taguchi method, Response surface methodology, Surface hardness, Predicted hardness, Burnishing process.

1. Introduction

Roughness refers to the persistent appearance, on the surface of the machined item, of machining marks of varying height and spacing. The surface features may be seen as a series of hills and valleys with varied elevations and spacing between them. The real contact area is often significantly less than the apparent contact area because these peaks and troughs touch each other. Since the initial contact between the workpiece and the tool happens at several sites and the contact between the two grows with increasing load, Adams and Nosonovsky [1] provided a thorough explanation of the phenomenon of roughness deformation. Elastic, plastic, viscoelastic, or viscoplastic deformation takes place at contact sites. At the point of contact, the voltage is much higher than the nominal value. When these forces are high enough, a plastic deformation takes place that lasts forever. According to K.O. Lowa [2], this will result in a smoother surface by reducing the height and spacing of the imperfections. Mechanical and metallurgical qualities are modified by plastic deformation.

In their mathematical model, Hongyun Luoa [3, 4], Korzynski [4, 5], and Djordje Vukelic [5] made a number of assumptions. According to the research, the depth of penetration or the power used to penetrate is the decisive component. Sample and tool mechanical properties (Young's modulus, Poisson's ratio, density, and hardness), as well as surface properties (roughness radius, surface roughness, and surface height standard deviation), must be collected and entered into a computer for the mathematical model to be developed. This restricts the model's applicability, which is why editors often resort to empirical models. There have been a number of studies and statistical models established. Hassan and Al-Jalil [6] investigated the relationship between polishing power and the optimal number of ball passes for brass components. To further understand the relationship between surface roughness and the two primary polishing factors, force and tool fit, a second-order mathematical model was built utilising response surface methods. M.H. El-Axir's [7] research focused on non-ferrous metals. M.H. El-Axir, El-Axir* [8, 9], and El-Axir* [10]. Polishing was used by Klocke and Liermann [11] for hard-turned surfaces. The use of artificial neural networks (ANNs) for fitting nonlinear data has become more common in recent years. Roll polishing of AL6061 in a parallel orientation and a cross orientation was investigated by Tang and Hakim [12]. An artificial neural network method was created for this research. A feed-forward-back propagation network optimised using the Levenberg-Marquardt learning algorithm is used for this purpose.

2. Experiment methodology

.The workpiece material used in this study was aluminum 6061 alloy. The chemical composition of the material is tested in the laboratory.

Table 1: Composition of Aluminium alloy in %

Mg	Si	Cu	Zn	Mn	Cr	Fe	Ti
0.2	0.4 - 0.8	0.15 - 0.4	0.25	0.15	0.04 - 0.35	0.7	0.1

The lathe machine spins a 100-millimetre-long, 32-millimetre-diameter aluminium rod. Speed = 450 rpm and feed = 0.25 mm/rev are the starting processing parameters. A single-roll polished carbide tool is used once the turning process is complete. The procedure for burnishing is shown in the diagram below. Experiments changed the speed, feed, burnishing force, and number of passes, all of which are individually adjustable. Table 2 lists the parameters and the ranges across which they may vary. Table 3 DOE is used to plan experiments. Using DOE, scientists may determine how many variables influence experimental outcomes independently and in combination. DOE also aids in controlling numerous design factors that have a substantial influence on production, making even a mediocre design more reliable. A sample workpiece was prepared for testing by turning it on a lathe. A Vickers microhardness tester is used to evaluate the surface microhardness (Fig. 3). Burnished parts were tested using a Vickers microhardness tester to determine their microhardness. A diamond indenter is used to impart a force of 500g to the workpiece while the components are safely secured in a V-block. Between 5 and 15 seconds, the indenter is pressed into the material. Use a microscope (400X magnification) after taking out the indenter. Take readings along the two diagonals of the notch on Fig. 4's surface.

Fig 1. Experimental Setup

Fig. 2 Burnished Speciman

Fig. 3 Vickers Hardness Tester

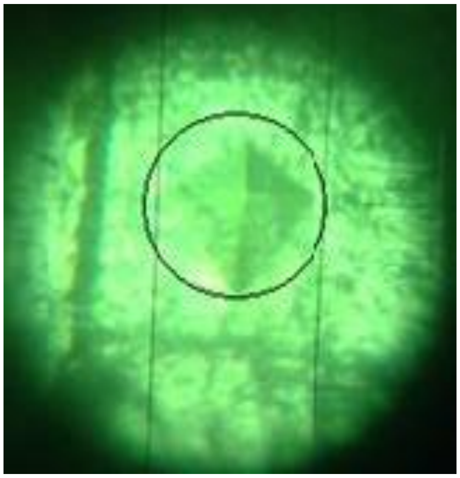

Fig 4. Diamond Indenter Impression

3. Result and discussion

The L25 orthogonal array used in the Taguchi analysis is used to arrange the experiments. Experiments are conducted using the factors and levels described below.

Table 2. Burnishing Parameters

Level	Speed	Feed	Force	No. Of Pass
1	77	0.25	4	1
2	100	0.3	5	2
3	250	0.35	6	3
4	450	0.4	7	4
5	700	0.5	8	5

Table 3. Experiment Matrix

Sr. No.	Speed	Feed	Force	No. Of Pass	Micro Hardness	RSM Predicted Micro Hardness
1	77	0.25	4	1	124	122
2	77	0.3	5	2	126	125
3	77	0.35	6	3	128	124
4	77	0.4	7	4	127	124
5	77	0.5	8	5	131	129
6	100	0.25	5	3	126	123
7	100	0.3	6	4	126	124
8	100	0.35	7	5	127	123
9	100	0.4	8	1	132	131
10	100	0.5	4	2	123	121
11	250	0.25	6	5	125	124
12	250	0.3	7	1	128	126
13	250	0.35	8	2	132	130
14	250	0.4	4	3	123	121
15	250	0.5	5	4	125	124
16	450	0.25	7	2	128	127
17	450	0.3	8	3	131	130
18	450	0.35	4	4	122	121
19	450	0.4	5	5	126	123
20	450	0.5	6	1	128	124
21	700	0.25	8	4	131	128
22	700	0.3	4	5	122	120
23	700	0.35	5	1	126	124
24	700	0.4	6	2	128	125
25	700	0.5	7	3	139	129

The relationship between feed rate, force, and surface microhardness is shown in a three-dimensional figure in Fig. 5. The smoothness of a surface is greatly improved by increasing the feed rate. Feed rates that increase the contact area between the tools and the working surface cause plastic deformation and imperfections. However, the feed value is amplified, the microscopic profile is bent by force, and the surface profile deteriorates when the surface area is tiny. Figure 4 displays a 3D plot of a fitted force vs. microhardness. The microhardness was shown to improve with both increased force and tool passes. When both are increased, the tool's maximum asperity height is exceeded, leading to surface hardening.

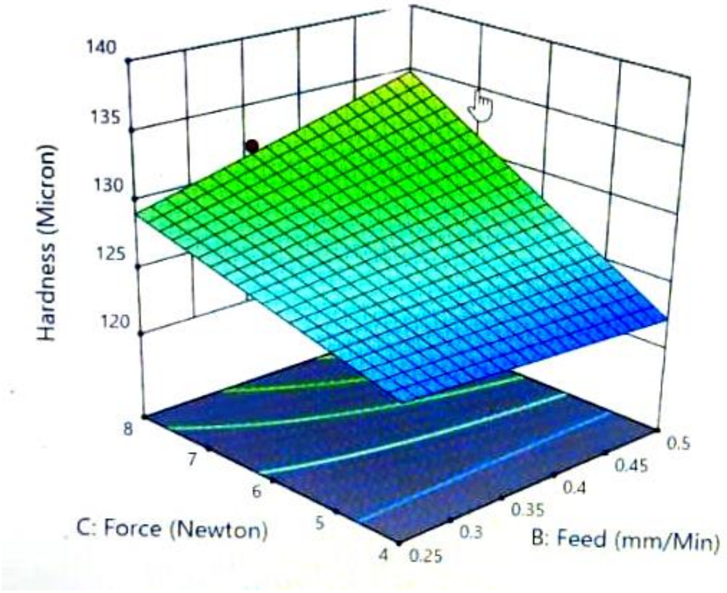

Fig 5. Three Dimensional Surface Plot of Surface Microhardness

4. Conclusions

Aluminium 6061 alloy is burnished using a single roller burnishing tool. The method of DOE experimentation is used. Experiments manipulated machining parameters including feed rate, cutting force, and tool pass count. Surface microhardness is the response variable. Applying analysis of variance, we identify the variables most responsible for the observed changes in surface microhardness. The statistical validity of the model is examined using ANOVA. The microhardness of the response surface was modelled mathematically as a function of the process parameters. The RSM Surface predictions and the experimental data were compared. The optimal level of microhardness is reached by using a desirability function strategy. According to the study's primary findings, the two most important criteria for microhardness are force and the number of tool passes. Response surface microhardness exhibits substantial interaction between a wide variety of tunable factors. The interplay between force and tool passes has a significant impact on microhardness. In the first phase of burnishing, the plastic deformation of the asperities acts as a surface smoothing mechanism. Work hardening occurs in the last phase, elevating microhardness. In addition to the burnishing parameters, the starting surface roughness also affects the reactions. With RSM, we may adjust the quadratic model to match a wide range of answers. Using ANOVA, we may test the robustness of the model. Speed 450 RPM, feed 0.3 mm/rev, force 8 N, and three passes provide the best burnished state. The obtained surface microhardness is 131 HV.

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