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Research Article

BALL BURNISHING PROCESS EFFECTS ON SURFACE ROUHGNESS FOR Al 6013 ALLOY

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ABSTRACT
Ball burnishing process rapidly developing and applied in many applications. The process's advantageous aspects on the material increase the quality of the product surface. In this study, a surface quality research was made on 6013 series of aluminum alloys which are used frequently in the industry. As a result of the experiments, it was seen that the ball burnishing process increased the surface qualities extremely. At the same time, the results obtained were mathematically analyzed.

Keywords: *Al 6013, Surface Roughness, Taguchi Method, Ball Burnishing*

1. INTRODUCTION

Aluminum's production availability and usage area is increasing day by day. The high strength stiffness to weight ratio and high corrosion resistance make aluminum popular in material selection (Miller *et al.,* 2000). Aluminum is easy to shape and process according to other ferrous materials (Nouari *et al.,* 2003). Even if the machined material is aluminum, the surfaces obtained after the treatment may not always be satisfactory. Because of this, surface finishing is required after machining process. Operations such as grinding, electro polishing, etc., provide only topographic correction on the surface of aluminum. During the surface finishing process, the ball burnishing process causes the surface hardness to increase due to the deformation toughness of the surface as well as the topography of the surface. Ball burnishing is easy to apply and relatively inexpensive (Buldum *et al.,* 2017; Buldum *et al.,* 2017). Once the appropriate parameters have been determined, it is a convenient method of operation in terms of processing time and consumable expenditure. This advantage is a considerable advantage for the manufacturer. There is no standard ball burnishing tool in the market. Its application is simple, and the tool is low cost product.

In this work, the 6013 series aluminum was roughly machined on a lathe and an average *Ra 6.00µ* value surface roughness was obtained. This surface was improved by ball burnishing under different process parameters. The results are also modelled and optimum conditions were defined.

2. EXPERIMENTS AND METHODS

In this study, the Al 6013 alloy was used which dimensions are 150 mm length and 25 mm diameter as shown Fig. 1. Also, the chemical properties of the Al 6013 materials used in the experiments are given in Table 1.

Fig. 1. The machined specimens for ball burnishing process

Table 1. Chemical composition of the 6013 alloy as wt.%.

Al	Mg	Si	Cu	Mn
Balance	0.91	0.67	0.86	0.7

Three samples were used for experiments and surface of the sample was divided to sections for each experiment

In the experiments, a universal lathe was used. The ball burnishing tool adopted tool post sections and a loadcell application was used to measure the applied force on specimen. The ball burnishing tool shown in Fig. 2. Medium cleanliness provided to prevent the chip or dust contact between part and tool during the operation (Ugurlu *et al.,* 2017).

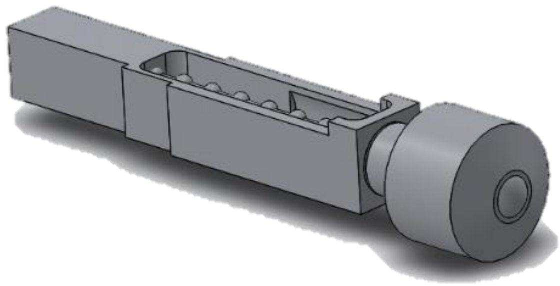

Fig. 2 The ball burnishing equipment (Buldum and Cagan, 2017)

The all specimens were coarse turned in lathe and 6.0µ Ra was obtained. The groves are machined to separate the experimental regions. In the experiments three different input variables were used and experimental scenario designed with Taguchi L9. In this study, three input parameters (levels) were selected as force, feed rate, passes. Three levels and three levels' factors were used. These factors and levels presented in Table 2. The Taguchi L9 experimental design also was given in Table 3.

Table 2. Ball burnishing parameters

	Levels		
Factors	1	2	3
Force (N)	100	200	300
Feed (mm/min)	0.05	0.1	0.2
Number of passes	1	2	3

Table 3. Experimental layout using an L9 orthogonal array

Experiment Number	Force	Feed	Number of Passes
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The Taguchi method is generally used for to define the select the optimal parameters used in experiments. The method systematic and effective usage area. It provide low cost technical information for qualified systems (Pavani *et al.* 2015; Gaitonde *et al.,* 2016). The experimental design also provide to reach shortly to results with time and cost (Pavani *et al.,* 2015). The system let the user to choose results evaluation approach like 'Nominal is better', 'Smaller is better' and 'Larger is better' (Pedersen *et al.,* 2016). In this study, surface roughness values are getting importance when they have lower roughness values. So, in the options "Smaller is better" was selected. Those options computed with following equations.

$$S/N = -10\log\left(\frac{1}{N}\left(\sum_{i=1}^{n} Y_i^2\right)\right) \quad (1)$$

Where Yi is the surface roughness value, n is the number of tests and N is the total number of data points for equation (1).

2.1. Experimental Tests and Analysis

Surface roughness is commonly use to define the characterization materials. The topographical shift on surface the parts measured and the surface roughness average "*R*a" was taken accordance for ISO 4287 norm and the Ra value can be expressed by the following equations (Arbizu *et al.* 2003):

$$R_a = \frac{1}{L}\int_0^L |y|\,dx = \frac{1}{L}\left(\sum S_{ui} + \sum S_{lj}\right) = \frac{S}{L} \quad (2)$$

Therefore,

$$R_a = R_t(S_u + S_l) \quad (3)$$

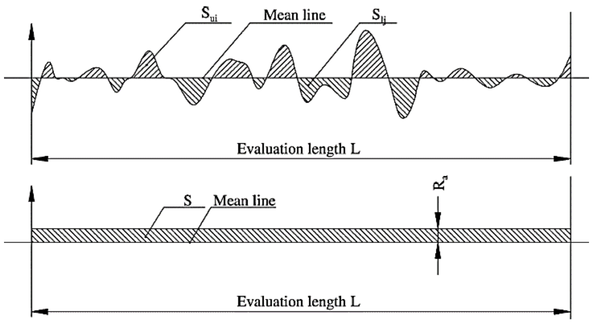

Fig. 3 Scheme of surface roughness (Aldas *et al.* 2014)

After experiments, the surface roughness values were measured performed using a Mitutoyo portable roughness meter model Surftest SJ 201and in different points and arithmetic means are noted.

3. RESULTS AND DISCUSSION

In this experiments, different process conditions such as the effect of the force, feed rate and number of passes effects on Al6013 surface roughness were investigated. The obtained surface roughness values were also mathematically modelled and S/N ratios calculated. That values are presented in Table 4.

Table 4. Parameters and results after burnishing process

Experiments	Parameters			Results	
	Force	Feed rate	Number of Passes	Ra (µm)	S/N Ra (µm)
1	100	0.05	1	0.2615	11.6506
2	100	0.1	2	0.1830	14.7510
3	100	0.2	3	0.7680	2.2928
4	200	0.05	2	0.3960	8.0461
5	200	0.1	3	0.8900	1.0122
6	200	0.2	1	1.4070	-2.9659
7	300	0.05	3	0.5330	5.4655
8	300	0.1	1	1.3450	-2.5744
9	300	0.2	2	1.1050	-0.8672

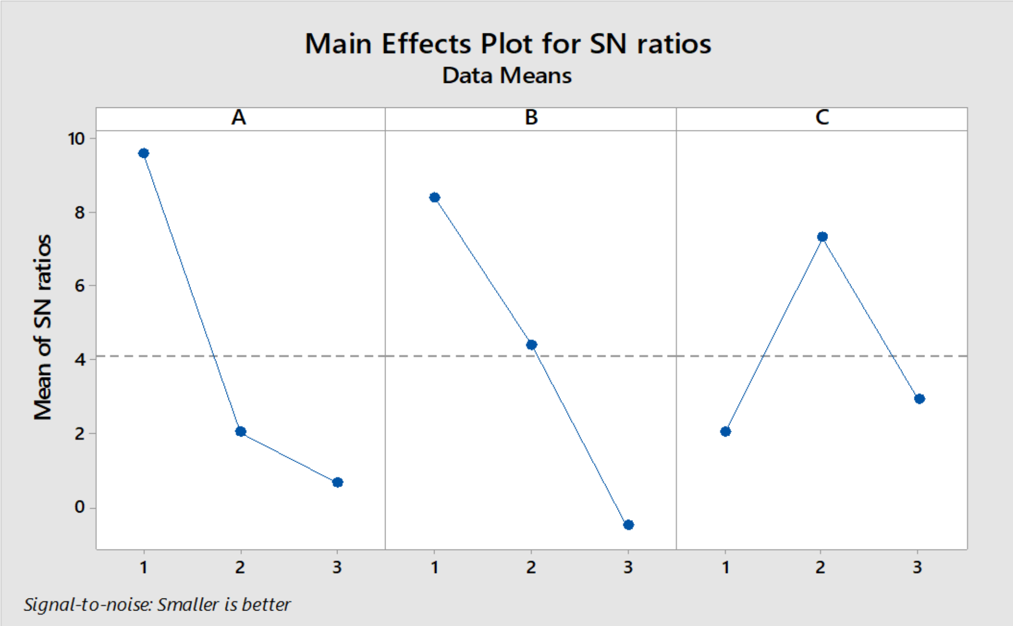

Fig. 4 S/N ratios effects on surface roughness value

In S/N ratios shows the effects of the input parameters. In Fig. 5, a section shows the force inputs and that trend of the plots show lowering tendency similarly with B section which is feed rate. On the other hand, C section Number of Passes exhibit irregular behaviors. The high points in S/N graphs show the optimum values considering the others. In this regards, A1, B1 and C2 parameters can be chosen optimum values.

The relative of the importance parameters can be defined by ANOVA technique. In this study ANOVA modelling was conducted and the results are presented as pie graphs in Fig. 5. As seen in the graphs Force input values is the most effective parameters between others with 43%. However, feed rate has also significant values with the 37% ratio. Number of passes values show the lower impact values considering feed rate and force input values. Error rate is 5% and that proves the reliability of the study.

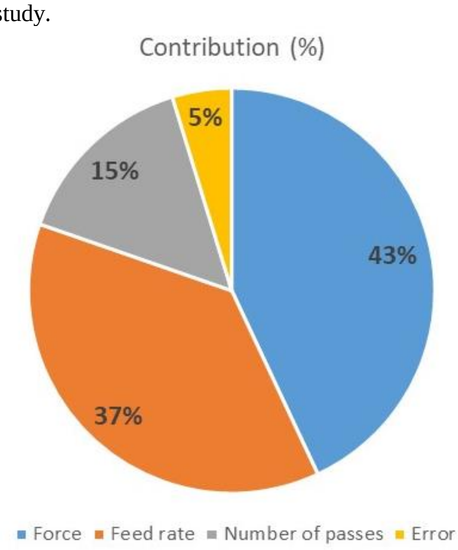

Fig. 5 Contribution of the input parameters on surface roughness

Table 5. The analysis of analysis of variance for surface roughness

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	2	137.64	68.818	9.11	0.099
B	2	119.26	59.629	7.89	0.112
C	2	47.83	23.917	3.17	0.240
Error	2	15.11	7.555		
Total	8	319.84			

In ANOVA modelling the R^2 is found as 95.28%. The high score of the high R^2 make reliable the equation for this modelling. The mathematical regression equation presented in Table 6 with coefficients.

Table 6. Coefficients of the regression equation

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	4.090	0.916	4.46	0.047	
A					
1	5.47	1.30	4.23	0.052	1.33
2	-2.06	1.30	-1.59	0.253	1.33
B					
1	4.30	1.30	3.32	0.080	1.33
2	0.31	1.30	0.24	0.835	1.33
C					
1	-2.05	1.30	-1.58	0.254	1.33
2	3.22	1.30	2.48	0.131	1.33

5. CONCLUSION

In this study, the effect of the force, feed and number of passes were investigated on surface roughness. The results are given below:

- The optimum parameter combination for the lowest surface roughness was calculated using an analysis of the signal-to-noise ratio. The parameters for optimum surface roughness are obtained as A1B1C2.

- According to the results of ANOVA, force and feed the most effective parameters on the surface roughness with a contribution ratio of 43% and 37%, respectively. Also, it is observed that number of passes 15% play roles in minimizing the surface roughness.
- While as force and feed ratio increasing the surface roughness decreasing. However, that is not validated for number of passes.

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