Optimisation of Parameters When Polishing Aluminium Cookware Using Wool Felt Wheel

Truong Dinh Luan, Nguyen Trong Doanh, and Bui Qui Luc

Abstract Aluminium is used a used material in houseware (e.g. cookwares, kettles, sinks, etc.). Often rusted, tarnished after a period of use; especially in hot, humid environments. It will lose the beauty and clean of the product. For that reasons, polishing aluminium to a required roughness surface is necessary before using. An experimental study showed that roughness surface is correlated with factors: Velocity, friction force, time, polishing material, workpiece material. Experimental also shows that to decrease the surface roughness quickly if the velocity and friction force are increased but will happen oscillator, lots of power loss; If the friction force and time are increased, it will generate heat, burn marks in the polishing material, the surface will turn orange, not productive. So, to achieve the optimal surface roughness, it is necessary to optimize the above coefficients. This paper presents optimization of coefficient of friction force and time, (F, t) pair with fixed velocity v = 22 m/s for minimization of surface roughness.

Keywords Polishing · Aluminium · Wool felt · Optimization · Regression

1 Introduction

Metal polishing is a finishing method that uses abrasive materials to smooth a surface. When polished, the surface of metal is removed from defects and becomes more reflective and shiny. In addition to beauty value, metal polishing also serves a practical purpose. Such as, it eliminates oxidation and prevents further corrosion of the metal, greatly extending its working life.

The aluminium cookware is normally produced by shaping under the mold. Although the required shape of the finished product is obtained, its surface is still rough, dull and waviness mark so called an orange peel is appeared. Thus, the

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polishing process to diminish such marks is necessary in order to obtain better surface appearance and make it attractive.

However, there has been little discussion on the polishing of aluminium cookware. P. Tevinpibanphan et al. conducted an experiment to investigation into the polishing of stainless steel using sisal wheels [1]. Cheng and Chang experimentally investigated the electro-polishing of 304 stainless steel in order to formulate a surface roughness model [2]. Tongqing et al., optimized the chemical–mechanical polishing of a 12-inch wafer [3]. Dickman and Millman attempted to optimize polishing and buffing [4]. Gianpaolo et al., optimized a surface roughness predictive model in deterministic polishing of ground glass moulds [5].

In this paper, research the influence of some factors on surface roughness such as velocity, friction force, process time and propose a fitted model Rz. Experiments were conducted on a CNC polishing machine.

2 Experimental Procedure

2.1 Experimental Condition

Polishing experiments were conducted on a reconfigurable CNC polishing machine based on a lathe. Polishing velocity is v = 22 m/s. The workpiece used is cookwares aluminium size ø160 × 80, whose chemical composition includes Fe 0.26%, Mg 0.04%, Zn 0.216%, Cu 0.052%, Pb 0.698%, Mn 0.029% and Si 0.88% in addition to Al, medium hardness 171.5HB, original surface roughness are shown in Table 1. The polishing material used is wool felt wheel with Properties are shown in Table 2.

2.2 Surface Roughness Measurement

Surface roughness was measured by Mitutoyo SJ-301 which is portable surface roughness tester, by probe measurement method, the probe is placed in contact with the surface (Fig. 1). The arithmetic mean values (Ra, Rz) is the most popular method to describe surface roughness in engineering practice. In this paper, the Rz is selected to describe the surface roughness. Figure 2 shows measurement result when polishing using wool felt wheel (v = 22 m/s; F = 40N; t = 55 s).

2.3 Design of Experiments and Results.

In this paper, a proposed method is to determine the equation of the fitted model Rz(F, t) and then optimisation of polishing parameters for minimize (Rz). The dependent

Table 1 Original surface roughness

Surface roughness	No												Average
	1	2	3	4	5	6	7	8	9	10	11	12	
Ra	1.67	1.42	1.24	1.94	1.37	1.51	2.08	1.91	2.03	1.31	2.21	2.09	1.73
Rz	9.68	7.10	6.92	9.88	7.95	7.63	10.74	10.25	10.31	7.66	10.72	10.9	9.15

Table 2 Properties of wool felt wheel

Diameter (mm)	Thickness (mm) (Accuracy 0.1)	Hardness
150	20	Soft

Fig. 1 Surface roughness measurement method

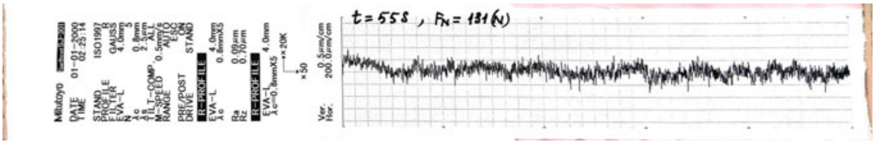

Fig. 2 Measurement result

variable is surface roughness Rz, the independent variable is Force Friction (F), process time (t) and velocity (v). In this experimental design, choose a fixed value of v = 22 m/s (corresponds to the polishing wheel speed is 2500 rpm và cookware speed 300 rpm), the selected polishing wheel speed is the maximum speed of the motor because mechanism polishing of metal without abrasives is surface flow [6], if the speed increases, the surface roughness decreases quickly. Therefore, determine the equation of the fitted model of the dependence Rz on 2 parameters is F and t. First, investigate the dependence Rz (μm) on force F(N), experimental results are shown in Table 3 and Fig. 3.

In Fig. 3, when increasing the force to 24N, the surface roughness decreases quickly (Rz = 2.36 μm), then continuing to increase the force, the surface roughness also decreases but slowly (Rz = 2.12 μm), up to the value of 40N, the surface roughness tends to increase (due to the pressure of the polishing wheel on the workpiece reduces the polishing speed, about 10%). Therefore, estimate the polishing force parameter domain to 24 ÷ 40N.

Second, continue to investigate the dependence Rz (μm) on process time t(s), experimental results are shown in Table 4 and Fig. 4.

Table 3 Experimental results of relation Rz and F

t = 15 s		t = 25 s		t = 35 s	
F [N]	Rz [μm]	F [N]	Rz [μm]	F [N]	Rz [μm]
0	9.15	0	9.15	0	9.15
7.8	6.18	7.8	5.70	8.1	4.18
12.6	5.05	13.5	5.42	19.5	3.03
17.1	4.93	24	2.36	30	1.59
25.5	4.51	39	2.05	34.2	1.44
36.9	3.92	45	2.12	45	1.60

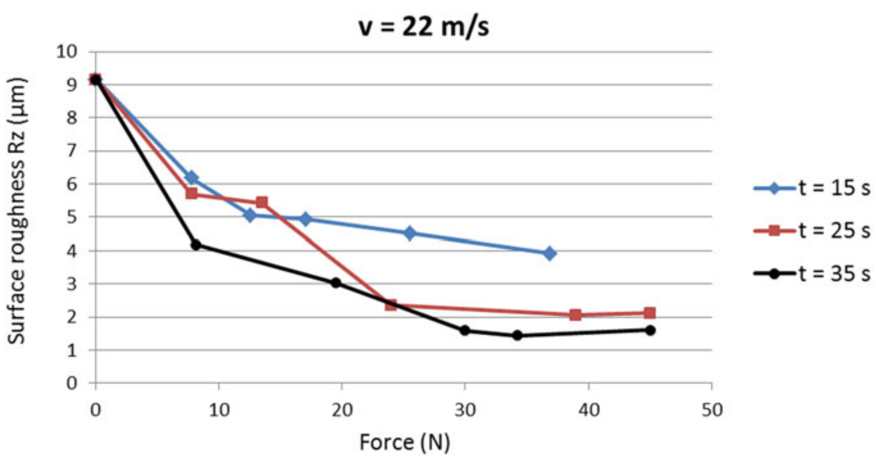

Fig. 3 Relation surface roughness Rz and force F

Table 4 Experimental results of relation Rz and time t

F = 24[N]		F = 31[N]		F = 38[N]	
t [s]	Rz [μm]	t [s]	Rz [μm]	t [s]	Rz [μm]
0	9,15	0	9,15	0	9,15
25	3,01	25	1,33	25	1,57
35	1,43	35	1,50	35	1,54
45	1,50	45	1,09	45	1,51
55	1,39	55	1,25	55	1,00

In Fig. 4, during 25 s the surface roughness decreases quickly (Rz = 1.33 μm), from 25 s ÷ 45 s the surface roughness decreases but slowly (Rz = 1.09 μm), from 45 s ÷ 55 s the surface roughness remained almost the same, sometimes increased. The Fig. 4 shows that plots Rz due to the force F = 31N and the force F = 38N is almost the same, so in order to minimize the negative effects of the large F force,

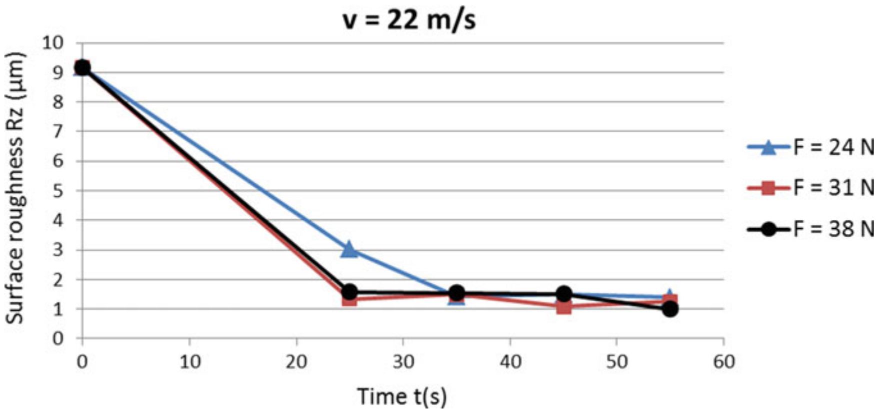

Fig. 4 Relation surface roughness Rz and time t

such as: high temperature, lots of power loss, burn marks in the polishing material, system oscillator. So choose the maximum force to be 32N.

The domain is defined as follows:

Friction force varies in the range:

$$F = 24 \div 32\text{N}$$

Time process varies in the range:

$$t = 25 \div 45\text{s}$$

Using Stat graphics Centurion XV software, designing with 2 factors (F and t), 3^2 experiments with 3 experiments at the center, so total of 12 experiments were conducted randomly (to reduce noise factors may be affect the experiments). The experimental results are shown in Table 5.

After analyzing the variance, shows a result, Table 6.

Variables A; B; A.B; BB corresponds to the parameters F; t; F.t; t^2 have P values < 0.05, there is a significant on surface roughness Rz. But with the variable AA, corresponding parameter F^2 has a value of P = 0.4455 (>0.05, 95% confidence), there is not much influence on surface roughness Rz, so removing in the regression equation. After removing, re-estimate the regression coefficients are shown in Table 7.

With $R^2 = 87.8\%$, statistic indicates that the model as fitted explains 87.8% of the variability in Rz. The equation of the fitted model in polishing process of aluminium cookware is:

$$\mathbf{Rz = 19.1108 - 0.384167.F - 0.577833.t + 0.00825.F.t + 0.00426667.t^2}$$

Table 5 Experimental results randomly

No	F [N]	t [s]	Rz [μm]
1	28	25	2,55
2	24	35	1,55
3	32	35	1,42
4	28	45	1,62
5	28	35	1,46
6	24	45	1,48
7	32	25	1,38
8	28	35	1,39
9	24	25	3,12
10	28	35	1,42
11	32	45	1,06
12	28	35	1,41

Table 6 ANOVA analysis

Source	Sum of squares	Df	Mean square	F-ratio	P-value
A:F	0,874,017	1	0,874,017	12,93	0,0114
B:t	1,39,202	1	1,39,202	20,59	0,0039
AA	0,0,450,667	1	0,0,450,667	0,67	0,4455
AB	0,4356	1	0,4356	6,44	0,0442
BB	0,589,067	1	0,589,067	8,71	0,0256

Table 7 Regression coefficients

Coefficient	Estimate
Constant	19.1108
A:F	−0.384167
B:t	−0.577833
AB	0.00825
BB	0.00426667

In Fig. 5, the optimal condition was found using Statgraphics Centurion XV software, the values are shown in Table 8.

The optimal value (with the slowest surface roughness) is: Rz = 1.05 with F = 32N and t = 37 s.

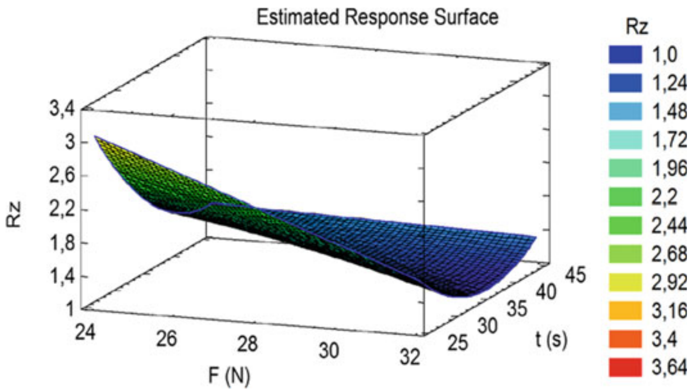

Fig. 5 Influence of force F và time t to surface roughness Rz

Table 8 Surface roughness optimization

Factor	Low	High	Optimum
F	24.0	32.0	32.0
t	25.0	45.0	36.777

3 Conclusion

This paper determined the optimisation of parameters of polishing aluminium cookware using wool felt wheel. There are three factors have significant to the surface roughness of aluminum, but in this study only two factors, friction force (F) and process time (t). The optimal conditions were found to be 32 N and 37 s.

The optimal surface roughness value is Rz = 1.05 µm.

The surface roughness can be predicted by using the fitted model was reported. In this study, surface roughness is inverse to force and time, but proportional to force and time interaction. This means that determining the optimal (F, t) pair is necessary when polishing aluminium.

In addition, It is the basis for calculating the optimal algorithms in the polishing control process aluminium cookwares.

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