International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 3
March 2018

Optimizing Process Parameters of Lapping by Analysis of Variance and Taguchi approach for Stainless Steel

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ABSTRACT
Lapping is a finishing process extensively used in the manufacturing industry in which the material removal takes place due to relative motion between the work material, loose abrasive grains and the lapping plate. This study discusses the effects of the various process parameters influencing the material removal rate and surface finish. This is done by conducting a series of experiments by varying the process parameters and calculating the material removal rate and surface roughness. Experiments based on design of experiments were conducted varying lapping load, lapping time, paste concentration, lapping fluid and by using different types of abrasives. Statistical method of Taguchi has been used in this work. Optimum machining parameters for surface roughness are estimated and verified with experimental results . The confirmation test exhibits good surface finish by using Al_2O_3 abrasive particles along with oil as a carrier fluid..

Keywords: Lapping, Taguchi, ANOVA, Optimization, Stainless steel

1. INTRODUCTION

Lapping, commonly used as a finishing operation, has been used for achieving ultra-high finishes and close tolerances between mating pieces. This process is characterized by its low speed, low pressure, and low material removal. The lapping process is carried out by applying loose abrasive grains between two surfaces and causing a relative motion between the two surfaces resulting in a good surface finish.

A lapping machine usually consists of a rotating lap which can hold several work pieces at one time. The work pieces are contained within control rings that prevent work pieces from moving off the lap. The quality of the part which is being lapped is mainly determined by lapping method, type of abrasive used, addition agent, lapping tool, lapping pressure, lapping motion and pre machining procedure etc.. When we consider the lapping technology as a input and procedure to study is the output, the machining condition as the input and the machining quality and efficiency as the output, then the need to study the lapping technology is to define the relationship between input and output. Although the aim of lapping is to improve surface finish, sometimes parts are rejected after lapping because of burn, friction, incomplete lapping, scratches, micro voids, and wear. Scratches may be caused by excessive load, low supply of abrasive slurry, or high friction and burn may be caused by excessive load . Uneven distribution of load occurs when the lapping table is not flat, but rather concave or convex in shape. Even components are affected by pressure because of which extra heat is created at the faces of the component, and the faces will get distorted . So it is necessary to study the lapping technology and analyze the effect of the different process parameters such as different types of abrasives, their grain size, various carrier fluid, the lapping cycle time, abrasive concentration, load forces, and plate speed to achieve the desired surface finish, by optimizing the process parameters, so that the

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manufacturing industries can produce the high quality products to satisfy the needs and requirements of the customers.

2. METHODOLOGY

Preparation Of Work piece

The workpiece made of SS 321 in the form of outer diameter of 50 mm and inner diameter of 45 mm, which is shown in Figure 1. This is used for experimentation purpose as this metal is most commonly used in manufacturing industries.

Figure 1: Stainless Steel Work piece

Figure 2: Single Plate lapping machine

Experimental Design

Design of experiments techniques (DOE) is a tool that can be used to determine simultaneously the individual and interactive effects of many factors that could affect the output results in any design. A standard Taguchi L8 (2^5) Orthogonal Array is chosen for this investigation as it can operate five parameters, each at two levels. By combining the orthogonal Latin squares in a unique manner Taguchi prepared a set of common OA's to be used for a number of experimental situations. A common OA for 2-level five factors is shown in Table1. This format is chosen from a preliminary work, that identified five parameters (a) lapping load (b) Paste concentration (c) Type of abrasive (d) Lapping time; (e) Lapping fluid as important lapping variables which affect the finishing rate

. Taguchi method stresses the importance of studying the response variation using the signal – to – noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The surface roughness is considered as the quality characteristic with the concept of "small-the-better". The S/N ratio used for this type response is given by Tahuchi.

$$S/N = -10 \log_{10} \text{(mean of sum of squares of measured data)}$$

Table 1. L8 (2^5) Orthogonal Array

Experiment			Column		
	1	2	3	4	5
1	1	1	1	1	1
2	1	1	1	2	2
3	1	2	2	1	1
4	1	2	2	2	2
5	2	1	2	1	2
6	2	1	2	2	1
7	2	2	1	1	2
8	2	2	1	2	1

The experiments were carried out with five factors at two levels each, Table 2. The fractional factorial design used is a standard L8 (2^5) orthogonal array. This orthogonal array is chosen due to its capability to check the interactions among factors. The machining has been carried out and the experimental data for the surface roughness values and the calculated signal-to-noise ratio are shown in Table 2.

Table 2. Test Run Design

Experiment	**1**	**2**	**3**	**4**	**5**
1	3.3	1.65:5	Al_2O_3	10	Oil
2	3.3	1.65:5	Al_2O_3	15	Kerosene
3	3.3	1.65:10	SiC	10	Oil
4	3.3	1.65:10	SiC	15	Kerosene
5	6.6	1.65:5	Al_2O_3	10	Kerosene
6	6.6	1.65:5	Al_2O_3	15	Oil
7	6.6	1.65:10	SiC	10	Kerosene
8	6.6	1.65:10	SiC	15	Oil

3. LEVEL AVERAGE RESPONSE ANALYSIS FOR SURFACE ROUGHNESS

The level average response analysis is based on averaging the experiment results achieved at each level for each parameter. When performing level average response analysis for one level of one parameter, all the influences from different levels of other parameters will be counterbalanced because every other parameter will appear at different level once. So the effect of one parameter at one level on the experiment results can be separated from other parameters. In this way, the effect of each level of every parameter can be viewed independently. Table 3, shows that, as the lapping load increases, surface roughness decreases, whereas it increases with increase in paste concentration. Further, a good surface finish is achieved after using Al_2O_3 abrasives and oil as a lapping fluid. Surface roughness increase drastically by using SiC abrasive particles and considerably by using kerosene as a lapping fluid.

Table 3. Level Average Response for Surface Roughness (μm)

Parameters	**Levels**		**Test Run**	**Surface Roughness (μm)**	**Level Average Response (μ m)**
Parameter A Lapping Load	Level 1	3.3 Kg	1	0.257	0.330
			2	0.213	
			3	0.414	
			4	0.434	
	Level 2	6.6Kg	5	0.403	0.311
			6	0.247	
			7	0.274	
			8	0.319	
Parameter B Type of Abrasives	Level 1	Al_2O_3	1	0.257	0.266
			2	0.213	
			7	0.274	
			8	0.319	
	Level 2	SiC	3	0.414	0.375
			4	0.434	
			5	0.403	
			6	0.247	
Parameter C Lapping Time	Level 1	10 min	1	0.257	0.337
			3	0.414	
			5	0.403	
			7	0.274	
	Level 2	15 min	2	0.213	0.303
			4	0.434	
			6	0.247	
			8	0.319	

Parameter D Paste Concentration	Level 1	1.65:5	1	0.257	0.280
			2	0.213	
			5	0.403	
			6	0.247	
	Level 2	1.65:10	3	0.414	0.360
			4	0.434	
			7	0.274	
			8	0.319	
Parameter E Lapping Fluid	Level 1	Oil	1	0.257	0.309
			3	0.414	
			6	0.247	
			8	0.319	
	Level 2	Kerosene	2	0.213	0.331
			4	0.434	
			5	0.403	
			7	0.274	

4. ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance is a computational method used to estimate the relative contribution, in which each controlled parameter makes to the overall measured response and expressing it as a percentage. Thus the information about how significant the effect of each controlled parameter is on the experimental results can be obtained. ANOVA uses S/N ratio responses to calculate surface roughness values. The overall mean from which all the variation (standard deviation) calculated is given by = 1/n $_{i.}$ Table 4, shows the results of ANOVA analysis.

Table 4. ANOVA Results

Symbol	Parameter	Sum of Squares	Contribution
A	Lapping Load	0.150	0.39 %
B	Type of Abrasive	13.382	42.30 %
C	Lapping Time	2.154	5.56 %
D	Paste Concentration	10.562	27.27 %
E	Lapping Fluid	0.366	0.95 %
	Error		23.53 %
	Total		100 %

Grand Total Sum of Square (GTSS) = 865.697

Sum of the square due to overall mean SS_{mean}= 827.268

Sum of the squares due to variations around overall mean $SS_{variation}$ = 38.429

5. ANALYSIS OF CONFIRMATION EXPERIMENT

In order to validate the results obtained, the confirmation experiments were conducted by utilizing the levels of the optimal process parameters, for surface roughness value on single plate table top lapping machine, the optimum machining parameters as shown in Table 5 and results obtained and compared with predicted values are shown in Table 6. The optimal conditions are set for the significant factors and a selected number of experiments are run under specified cutting conditions. The average of the results from the confirmation experiment is compared with the predicted average based on the parameters and levels tested.

Table 5. Confirmation Experiments

Experiment	1	2	3	4	5
1	3.3	Al_2O_3	05 min	1.65:5	Oil
2	3.3	Al_2O_3	07 min	1.65:5	Oil

Table 6. Experimental Results

Experiment No.	1	2
Surface Roughness (µm)	0.257	0.245

6. CONCLUSION

The effect of individual lapping parameters on the surface roughness have been observed clearly. Therefore it is observed that, increase in lapping load, and by using kerosene as a carrier fluid, hampers the surface finish. The surface finish can be achieved by using Al_2O_3 abrasive particles along with oil as a carrier fluid, under low pressure. Also by increasing the paste concentration and changing the abrasive from Al_2O_3 to SiC, cause to decrease the surface finish of the component. Hence, from this we can conclude that type of abrasive particles and paste concentration plays an important role. Finally we can conclude the following :

1. Taguchi's approach is best suitable to optimize the surface roughness.
2. The significant factors for surface roughness are type of Abrasive with contribution of 42.3 %, Paste Concentration with 27.27 % and Lapping time with contribution of 5.56 %.

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