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OPTIMIZATION OF LAPPING PROCESS PARAMETERS ON CERAMIC MATERIAL FOR IMPROVING SURFACE ROUGHNESS

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ABSTRACT

Super finishing is a micro-finishing process that produces a controlled and smooth surface condition on work pieces. It is not primarily a sizing operation; its major purpose is to produce a surface on a work piece capable of sustaining uneven distribution of a load by improving the geometrical accuracy. The wear life of the parts micro finished to maximum smoothness is extended considerably. According to the design of experimentation, mathematical model for Lapping operation on advance ceramic material is proposed and carried out. To improve the surface roughness, experimentation has been designed by using design of experiments and the results has been analyzed by using analysis of variance (ANOVA). Further confirmation experimentation has been carried out and the result obtained are verified.

It is found that the good combination of input parameters helps in obtaining a good surface finish in the lapping process.The test results can be probably applied to other materials, however, should be proved for each separate case.

Keywords: Ceramics, Lapping, Optimization, Taguchi, Roughness, Surface Finish.

I. INTRODUCTION

Ceramics encompass such a vast array of materials that a concise definition is almost impossible. However, one workable definition of ceramics is a refractory, inorganic, and nonmetallic material. Ceramics can be divided into two classes: traditional and advanced. Traditional ceramics include clay products, silicate glass and cement; while advanced ceramics consist of carbides (SiC), pure oxides (Al2O3), nitrides (Si3N4), non-silicate glasses and many others. Ceramics offer many advantages compared to other materials. They are harder and stiffer than steel; more heat and corrosion resistant than metals and polymers; less dense than most metals and their alloys; and raw materials are both plentiful and inexpensive. Ceramic materials display a wide range of properties which facilitate their use in many different product areas.

II. REVIEW OF LITERATURE

R. Sedlacek . J. Jorgenisen [1] conducted experiments on processing of ceramics – surface finish studies. Expanded ring test was used to determine the tensile strength of high purity, dense alumina. The test materials were prepared in five different nominal grain sizes ranging from 10 to 50μm. The blanks were diamond ground to final dimensions. It was found that in grinding this material extensive damage took place which had not been observed in any other alumina body ground under identical conditions. The author concluded that the strength of material depends upon the surface finish of the material. M. Komaraiah et al [2] conducted experiments on different work materials –glass, porcelain, ferrite, alumina using various tools- titanium, stainless steel. The surface roughness of the different work pieces was analyzed with respect to hardness of the tool material and abrasive used. The results showed that surface roughness decreases with decrease in the grain size and harder tool material gives low surface roughness. C. Y. Wang, X. Wei, and H. Yuan [3] conducted experiments on polishing of ceramics, Tests were carried out in a special manual grinding machine for ceramic tiles. Two grinding wheels were fixed in the grinding disc that was equipped to the grinding machine. The diameter of grinding disc was 255 mm. The rotating speed of the grinding disc was 580 rpm. The grinding and polishing wheels are isosceles trapezoid with surface area 31.5 cm^2 (the upper edge: 2 cm, base edge: 5 cm, height: 9 cm). The pressure was adjusted by means of the load on the handle for different grinding procedures. To maintain flatness and edge of the ceramic tiles, at least one third of the tile must be under the grinding disc. During the grinding process, sufficient water was poured to both cool and wash the grinding wheels and the tiles. Surface reflection glossiness and surface roughness of the ceramic tiles and the wear of grinding wheels were measured. V. Kumar [4] used design of experiment and regression approach for the statistical analysis of the ultrasonic machining of Glass. The response of the material removal rate of the glass was identified with the range of different parameters such as power rating, abrasive type, abrasive size, and slurry concentration. It was found that the grit size was most vital parameter and slurry concentration was the least significant parameter and having minimum contribution to the MRR It was conjointly ascertained that the carbide have additional impact on MRR as compared to the mixture of aluminum oxide + silicon carbide. Sunil Jha and V. K. Jain [5] used nanotechnology to measure surface roughness of ceramics by various operations and he concluded that non-conventional method for super finishing is better than conventional method but non-conventional method is costlier than conventional method. R. Cebalo, D. Bajić and B. Bilić [6] conducted experiment on optimization of the super finishing process. In this paper impact factors on surface roughness are determined. B Tholt WG and R Prioli [7] conducted experiment on Surface Roughness in Ceramics with Different Finishing Techniques Using Atomic Force Microscope and Profilometer and concluded that when the ceramic surface was ground and polished, the 3 types of ceramic restorations reacted differently to each tested polishing kit. Some of the polished surfaces obtained were at least equivalent to glaze-fired ceramic surfaces.

III. METHODOLOGY

As seen from the above literature review, the important problem that is faced in today's industries are to determine the material removal rate and surface finish. The MRR and surface finish are dependent on number of parameters like rotary speed, time taken, abrasive concentration, load applied, and type of work material. Hence these parameters are to be optimized in such a way to obtain the maximum result. So, a systematic approach must be developed to obtain the required results.

The various input process parameters which influence the output process parameters are to be identified. The required orthogonal arrays are designed. The experiments are to be carried onCeramic component, according to the design of experiments. The surface roughness value and the material removal rate are measured. Taguchi method is used for design of the experiments. The correlations between the independent and dependent variables are established using “Statistica” software. The optimization of parameters is done using “Minitab” software. The various process parameters to be optimized are abrasive concentration, time taken and load applied.

IV. EXPERIMENTAL DETAILS

The experiments are conducted on Ceramic (Al_2O_3), which is identified as most commonly used materials in the manufacturing of seals used at elevated temperature and thus selected for the experiments. Prior to lapping, the surface grinding operation is carried out on the work piece. The thickness of the specimen is 15mm with diameter of 30mm. The available loads are 5kg, 6kg and 7 kg. The three levels of time for lapping is taken as 5, 10, 15 minutes. The abrasives are mixed in the ratio of 1:4, 1:5, and 1:6. (Ex: The ratio1:4 denote, one part of abrasive mixed with four parts of oil by weight).

The most commonly used abrasive material for lapping ceramic is diamond slurry. The rough lapping is carried out using diamond slurry of type ‘O’ (25) and the finish lapping is done using diamond slurry of type ‘O’ (3). It is the objective of this paper to obtain sufficient data by lapping with a range of abrasive concentration, load applied and lapping time to determine the surface finish. The slurry was prepared by mixing the abrasive with machine oil in the appropriate ratio.

The operation was carried on a lapping machine, details are given in table 4.1 Lapping machine specification. The parts of the machine include a heavy-duty steel fabricated housing, abrasive distribution system with pump, tank with infinitely variable flow control, cast alloy lap plate which is radially serrated, three adjustable conditioning rings with yoke and bearing assemblies.There is an automatic lapping cycle timer, drive unit with 0.37kw motor and gear box, three pressure plates with lifting eye bolts and three felt pads.

Fig 4.1 Lapping Machine

Table 4.1 Lapping machine specification

Sr. No	Description	Value	Sr. No	Description	Value
1	Lap Plate OD	300mm	8	Pump motor	0.11kw/0.15HP
2	Conditioning ring	107mm	9	Timer range	0-30 mins
3	Maximum length	800mm	10	No. of conditioning rings	03
4	Maximum width	675mm	11	Standard power supply	440V/3Phase/50HZ
5	Height	610mm	12	Manufacturer	Guindy Machine ltd

6	Lap plate speed	48rpm	13	Model	08/02
7	Main motor	0.37kw/.5 HP	14	Year	2010

The surface roughness of the specimen is measured by Mitutoyo surface roughness tester. The device is powered by electrical supply. The device has a sensitive probe in it, which contacts the surface to be examined and reveals the “Ra” value.

The “Ra” value is displayed in the digital meter of the device. First the device is tested in the

Standard specimen to check for the errors before measuring the specimen. Then the surface roughness of the components is measured.

V. EXPERIMENTAL PROCEDURE

The experiments are conducted according to the appropriate procedure. The time of lapping is first set in the machine according to the requirements. The lapping abrasive of the required concentration is taken. The specimens are placed in the fixture which is kept on the lapping plate. The machine is turned on and the abrasive flow is maintained properly. Initially all the samples were rough lapped using diamond slurry of type ‘O’ (25) abrasive for a period of 10 minutes. This process ensured that the uneven surface generated by the machining of the components was removed and a new smooth and flat surface is generated. The other advantage is that any burrs left on the edges were also removed. After rough lapping is done, finish lapping was carried out. TheExperiment is conducted for different parameters. Then the surface roughness of the components is measured using the surface roughness tester. To conduct the experiments, design of experiment is prepared as given in table 5.1 Design of experiments for finish lapping

Table 5.1 Design of experiments for finish lapping

Test run	Abrasive concentration	Time (min)	Load (kg)	Test run	Abrasive concentration	Time (min)	Load (kg)
1	1:4	5	5	6	1:5	15	5
2	1:4	10	6	7	1:6	5	7
3	1:4	15	7	8	1:6	10	5
4	1:5	5	6	9	1:6	15	6
5	1:5	10	7				

VI. EXPERIMENTAL ANALYSIS

After conducting the experiment results are tabulated in table 6.1 Experiment Result

Table 6.1 Experiment Results

Test run	Abrasive concentration	Time (min)	Load (kg)	Surface roughness µm	Test run	Abrasive concentration	Time (min)	Load (kg)	Surface roughness µm
1	1.4	5	5	0.065	6	1.5	15	5	0.07
2	1.4	10	6	0.06	7	1.6	5	7	0.0575
3	1.4	15	7	0.07	8	1.6	10	5	0.0725
4	1.5	5	6	0.0425	9	1.6	15	6	0.0825
5	1.5	10	7	0.0575					

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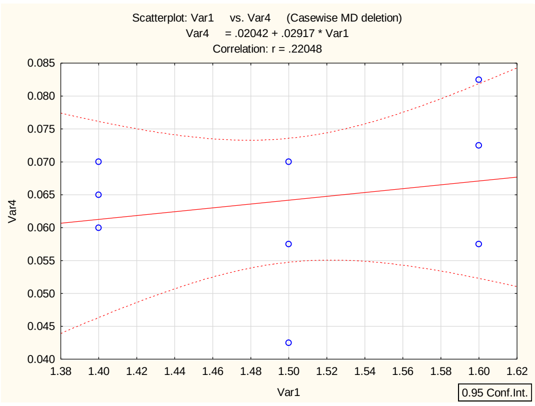
The canonical correlation is a way of establishing the relationship between the dependent and independent variables. In thispaper, the independent variables are abrasive concentration, lapping time and load applied. The dependent variable is surface finish. Using the "Statistica software", the canonical correlation is established between the dependent and independent process parameters, which are given in table 6.2 Canonical Correlation.

Table 6.2 Canonical correlations

	Abrasive concentration	Time(min)	Load (kg)	Surface roughness (Microns)
Abrasive concentration	1.000	0.000	-0.000	0.220
Time(min)	0.000	1.000	-0.000	0.724
Load (kg)	-0.000	-0.000	1.000	-0.283
Surface roughness µm	0.220	0.724	-0.283	1.000

By processing the above data by using "Statistica" software, the canonical R is found.Canonical R = 0.8086. The value of "R=0.8086", denotes that there is a good dependency between the input and output variables.

The figure 1 shows the scatter plot for the dependent and independent variables.



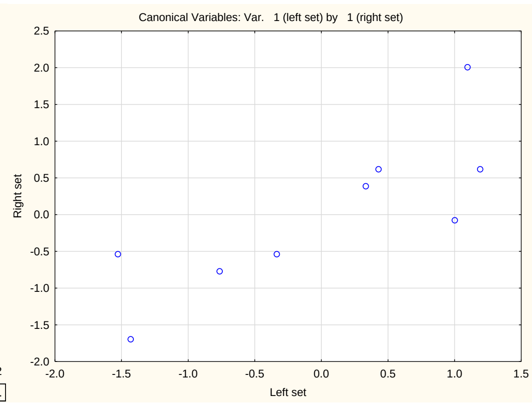


Fig 6.1 Scatter plot for Abrasive Concentration vs Surface roughness

Fig 6.2 Scatter plot for variables left set vs right set

From fig 6.1 Scatter plot for Abrasive Concentration vs Surface roughness it is clear that surface roughness depends upon abrasive concentration.In Figure 6.2 Scatter plot for variables left set vs right set the points in the plot cluster around the regression line and does not indicate any non-linear trend (e.g., by forming a U or S around the regression line). Therefore, it is evident that there are no major deviations between the input and output process parameters.

Regression Equation

The regression equation is found using Minitab software.

Surface Roughness = 0.0238 + 0.0292 X + 0.001917 Y - 0.00375 Z

Where,

X = Abrasive concentration

Y = Time

Z = Load

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To obtain the optimal set of parameters, using the Minitab software the graphs were plotted which represents the effects of various parameters (abrasive concentration, time taken and load) on Surface finish of the work piece. From figure Fig 6.3 Main effect plot for surface roughness values, we can conclude that combination of abrasive concentration 1:5, lapping time 5 minutes and load 6 kg results into better surface finish.

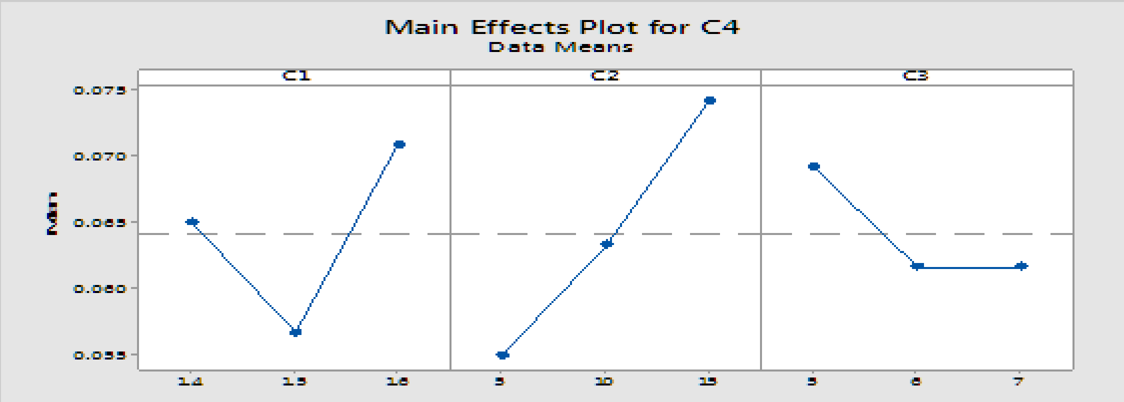

Fig 6.3 Main effect plot for surface roughness values

VII. RESULTS AND DISCUSSIONS

From the experiment, it is seen that the surface roughness decreases when the abrasive concentration decreases, resulting in a good surface finish. But, further decrease in the abrasive concentration results in increase in surface roughness. This may be due to insufficient amount of abrasive grains in the slurry that should have caused the increase in surface roughness. Also, it can be understood that the surface roughness decreases with increase in lapping time. It is also shown that the surface roughness increases with increase in load applied. This is because when the load is increased, there would be less space available for the loose abrasive grains to move. This causes more abrasive grains to come in contact between the work pieces and hence the surface roughness increases. To obtain the maximum surface finish, smaller the value better quality characteristic is used. In some applications where the job should have a very high surface finish, the optimal combination of process parameters suiting the condition is given in table 7.1 Optimum set of process parameters for better surface finish.

Table 7.1 Optimum set of process parameters for better surface finish

Process parameter	**Value**
Abrasive concentration	1:5
Time(min)	05
Load (kg)	6

VIII. CONCLUSION

The surface finish produced on the component depends on the number of factors like abrasive concentration, time of lapping, etc. So, these factors must be controlled efficiently for a good surface finish. Maintaining all these parameters within a limit is not going to be so easy. The flow of abrasive slurry should be continuous to have the desired surface finish. Surface finish is an important factor when dealing with issues such as friction, lubrication and wear. It also has a major impact on applications involving thermal or electrical resistance, noise and vibration control, dimensional tolerance, etc. Considering all these factors and the experimental results obtained, it is found that the good combination of input parameters helps in obtaining a good surface finish in the lapping process.

In this paper, the concepts of parameters that influence the surface roughness are presented. The surface finish obtained depends upon the grain size of the abrasives being used, lapping time and load applied. As the grain size increases surface roughness increase. Coarse grains are suitable for higher amount of material removal rate. Considering all these factors and the experimental results obtained, it is found that the good combination of input parameters helps in obtaining a good surface finish in the lapping process.

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