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A research paper on study the MRR of Soda lime glass at different parameters of Abrasive Jet Machine

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ABSTRACT

In this paper we use Abrasive jet machine at different parameters to study the metal removal rate of Soda lime glass. Various parameters such as pressure, angle, abrasive size, nozzle tip distance, time, initial weight and final weight are taken in consideration to achieve the desired objective. Then, by using L9 values we have find out the MMR.

1. INTRODUCTION

Modern machining methods are also named as Non Traditional machining methods. These methods form a group of processes which removes excess material by various techniques involving mechanical, thermal, electrical chemical energy or combination of these energies. There is no cutting of metal with the help of metallic tool having sharp cutting edge. The major reasons of development and popularity of modern machining methods are listed below. Need of machine newly developed metals and non-metals having some special properties like high strength, high hardness and high toughness. A material possing the above mentioned properties are difficult to be machined by the Conventional machining methods. Sometimes it is required to produce complex part geometries that cannot be produced by following conventional machining techniques. Non Traditional machining methods also provide very good quality of surface finish which may also be an encouragement to these methods. There can be a very long list of non conventional machining methods. These methods can be classified as the basis of their base principle of working. Conventional machining sufficed the requirement of the industries over the decades. But new exotic work materials as well as innovative geometric design of products and components were putting lot of pressure on capabilities of conventional machining processes to manufacture the components with desired tolerances economically. This led to the development and establishment of NTM processes in the industry as efficient and economic alternatives to conventional ones. With development in the NTM processes, currently there are often the first choice and not an alternative to conventional processes for certain technical requirements.

In Abrasive jet machining abrasive particles are made to impinge on work material at high velocity. Jet of abrasive particles is carried by carrier gas or air. The high velocity stream of abrasives is generated by converting pressure energy of carrier gas or air to its Kinetic energy and hence high velocity jet. Nozzles directs abrasive jet in a controlled manner onto work material. The high velocity abrasive particles remove the material by micro-cutting action as well as brittle fracture of the work material. In abrasive jet machining, abrasive particles are mixed with compressed air and directed on the target surface through a nozzle. The particle coming out of the nozzle with very high velocities impinges the target surface and removes the material by erosion. A large number of investigations which have been carried out on AJM explain various erosion mechanism and experiments have been carried out to determine the effect of various input parameters on material removal rate, penetration rate, and on surface finish. Different material removal mechanism has been proposed by various investigators. It has been studied that due to plastic deformation, material removal mechanism causes crack and spalling of ductile material.

2. LITRETURE REVIEW

Tsai. F. C., et al[7] (2013) Investigated polishing on SKD 61 mold steel using SIC with wax coating. This paper investigates the abrasive jet polishing of electro-discharged-machined and mold steel specimen was used 2000, 3000 or 8000 Sic particles and compound additive comprising pure water. The experiment shows that when the polishing process was performed using 2000 Sic particle with a pure water and water was additive it was found that the surface roughness is reduced from Ra=1.0 micro meter to 0.08 micro meter within 10 min of SKD 61 surface polishing the ground SKD 61 surface using 3000 Sic particles with pure water and water wax, the surface roughness is found to reduce from an initial value of Ra=0.36 micro meter to a final value of Ra=0.054 m within 60 min. A gas atomization technique is employed to fabricate wax coated 3000 Sic particle for improving the polishing performance. After the experiment the result show was that the wax-coated abrasive particle reduces the polishing time and achieves an improved surface finish.

NAGDEVE. L., et at [10] (2012) In this paper, Taguchi method is applied to find optimum process parameter for Abrasive water jet machining(AWJM).Further experimental investigation were conducted to assess the influence of abrasive water jet machining (AWJM) process parameters on MRR and surface Roughness (Ra) of aluminum. Also, optimize the AWJM process parameter for effective machining and to predict the optimal choice for each AWJM parameter such as pressure, standoff distance. This paper analysis of the Taguchi method reveals that, in general the standoff distance significantly affects the MRR while, Abrasive flow rate affects the surface Roughness. However, experiments are carried out using (L9) orthogonal array by varying pressure, standoff distance, Abrasive flow rate and Traverse rate respectively.

Nagdeve. L., et al [11] (2012) In this research paper, Taguchi method is applied to find optimum process parameters for Abrasive Water Jet Machining (AWJM).The objective of experimental investigation is to conduct research of machining parameters impact on MRR and SR of work piece of Al 7075. The approach was based on Taguchi's method, analysis of variance and signal to noise ratio (SN Ratio) to optimize the Abrasive Water Jet Machining process parameters for effective machining and to predict the optimal choice for each AWJM parameter such as Traverse speed, Abrasive flow rate, Standoff distance and Abrasive grit size. This paper also presents analysis of various parameters and on the basis of experimental results, analysis of variance (ANOVA), F-test and SN Ratio.

Kumar Karna, S., et al[22] (2012) This examined to optimize the process by applying the Taguchi method with orthogonal array robust design. Therefore, Off-line quality control is considered to be an effective approach to improve product quality at a relatively low cost. Also analysis of variance (ANOVA) was used to study the effect of process parameters on the machining process. The approach was based on Taguchi method, the signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) are employed to study the performance characteristics.

Rama Rao, S., et at[21] (2012) In this research paper the influence of the various process parameters, i.e. voltage, feed rate and electrolyte concentration on the predominant machining criteria, i.e. the metal removal rate (MRR) was studied. The orthogonal arrays of Taguchi, the signal-to-noise (S/N) ratio, the analysis of variance (ANOVA), and regression analyses are employed to find the optimal process parameter levels and to analyze the effect of these parameters on metal removal rate values. The confirmation test with the optimal levels of machining parameters was carried out in order to illustrate the effectiveness of the Taguchi optimization method.

Chatterjee, A., et al[2] (2011) In this paper An effect of inherent characteristics of water jet flaring on straightness of the through cut has been studied. Also an attempt has been made to establish the effect of jet traverse speed on straightness of the cut and surface roughness through experiments for different materials like aluminum, stainless steel, sand stone and marble. This paper also deals with the quantitative taper angle analysis and qualitative roughness analysis for above materials.

Kandpal Chandra, B., et at[3] (2011) In this paper investigated the testing and analyze various process parameters of abrasive jet machining. This paper also includes various results of experiments have been conducted by changing pressure, nozzle tip distance on different thickness of glass plates and ceramic plates. It was observed that as nozzle tip distance increases, material removal rate (MRR) increases as it is in the general observation in the abrasive jet machining process. As the pressure increases material removal rate (MRR) is also increased as we found in AJM process. Similarly as abrasive particle size increases MRR increases.

Chandra. B., et at[4] (2011) This paper deals with various experiments which were conducted to assess the influence of abrasive jet machining (AJM) process parameters on material removal rate and diameter of holes of glass plates using aluminum oxide type of abrasive particles. Also the experimental results of the present work are used to discuss the validity of proposed model as well as the other models. With the increase in nozzle tip distance (NTD), the top surface diameter and bottom surface diameter of hole increases as it is in general observation of abrasive jet machining process. As the pressure increases, the material removal rate (MRR) is also increased. This paper includes various results of experiments have been conducted by changing pressure, nozzle tip distance on different thickness of glass plates.

Routara. B.C. et at[5] (2011) examined the multi-objective optimization problem to determine the optimal process parameters in machining of soda lime glass in Ultrasonic machining process. In this study, the process parameters such as Concentration of slurry (C), Power (P) and Static load (F) have been considered. The response variables like material removal rate (MRR), dimensional tolerance i.e. hole over size (HOS) and circularity of holes i.e. out of roundness (OOR) have been established. Also grey relational analysis has been coupled with Taguchi method in the investigation. Also, Taguchi orthogonal array, the signal-to-noise ratio, and the analysis of variance were used to investigate the optimal levels of process parameters. The confirmation tests

were conducted to verify the results and it was observed that this approach is efficient in determining the optimal process parameters based on multiple performance characteristics.
El-Domiaty. A., et al[1](2009) In this paper Drilling of glass sheets with different thicknesses have been carried out by Abrasive Jet Machining process (AJM) in order to determine its machinability under different controlling parameters of the AJM process. Here both experimental and theoretical analyses were introduced. Also, the effect of nozzle diameter (D) on the material removal rate (MRR),when different sizes of abrasive particles are used. The relationship between the cut-off distance and the required time to drill a glass plate with a 2 mm thickness were also discussed.

Wensink. H., et al[8] (2009) Investigated about high resolutions powder blast micro machining. It is technique in which a particle jet is directed towards mechanical material removal. It is a directional etch technique for brittle material like glass, silicon etc. It was studied that blasting with 9 pm particles results in a higher slope of the channel side wall. It was found that small channels etch slower compare to wider channels. Powder blasting is a directional etch technique for wide class of material. This technique fits between the common micro machining technique due to its lithographic masking .Here electro plated copper used as a new mask for powder blasting. After the experiment it was observed that blast lag (small channels etch slower compared to wider channels) is decreased by using 9 pm instead of 30 pm particle.

Hsun Shin. Y., et al,[23] (2008) Study of micro fluidic chip fabrications by micro powder blasting. The high speed gas flow used by micro powder blasting mixed the micro particle and gas to impact the brittle substrate by the specialize nozzle. To fabricate the pattern channel in soda glass with a width down to 50 micro meter and depth down to 90 micro meter, this experiment combined various diameters. Al2O3 eroding particle with novel masking technique. There are two polymers consisted in the masking technology.

1) The brittle epoxy resin SU8 for its photo sensitivity
2) The elastic and thermal curable poly (dimethyl siloxane)(PDMS) for its erosion resistance.

Different types of processing parameter (gas pressure, Nozzle/ substrate distance ,particle size, impact angle and erosion time) is used in this experiment to find the optimal process by single parameter method. The outcome is when the gas pressure increases the micro channel become deeper. When the nozzle distance increases, the micro channel decreases the depth. The surface roughness of micro channel of micro fluidic chip is about 5 to 6 micro meters. Jianxin. D., et al[9] (2007) Studied gradient ceramic, nozzles wear mechanism by using abrasive jet machines. Nozzle is most important part in AJM. Mostly ceramics materials are used in manufactured nozzle because it has high wear resistance. In this paper, a (W,Ti) C/Sic gradient ceramic composite was developed to be used as nozzle material. The erosion wear behavior of the (W,Ti) C/Sic gradient nozzle was investigated and compared with a conventional ceramic nozzle. It was found that gradient ceramic nozzle exhibited an apparent increase in erosion wear resistance over the conventional ceramic nozzle. It was observed that mechanism responsible for that the tensile stresses at the entry region of the nozzle were less as compared with the conventional nozzle. After the experiment conclusion was that the gradient structure in ceramic nozzle was effective because it provides the improvement of erosion wear resistance of connectional ceramic nozzles in abrasive air jet machining.

Achtsnick. M., et al[13] (2005) Investigated a modeling and evaluation of the micro abrasive blasting. In this machining process material removal process is based on the erosion mask-protected brittle substrate by an abrasive laden air jet. In this paper micro abrasive blasting is analyses by means of a set of models containing different sub models for the particle jet, the erosion mechanism of a single particle sub models for the machining results. In this study a flow model was developed which one dimensional and isentropic for calculate the particle exit velocity of each individual particle in the air flow for two different type of nozzles. The size of particle and its position inside the air jet are based on probability distribution functions. A classical indentation fracture mechanism is used to model the interaction between incoming particle and the substrate surface. After this the simulation shows that Laval-type nozzle is able to increase the particle velocity with more than 30% compare to the conversing nozzle and the blasting profile is near uniform with the relatively flat bottom particle velocity is verified with the help of particle image velocimetry (PIV) and surface roughness measurement and find the blasting performance of both nozzles type.

Zhang. L., et al[12] (2004) Investigated micro abrasive intermittent jet machine. The machining of micro holes by using micro abrasive jet machining, the colliding abrasive accumulate in the bottom of the hole preventing the direct impact of abrasives particles onto the work piece. Hence the machining efficiency decreases in the paper a investigated a new method micro (AJM) known as abrasive intermittent jet machining. (MAIJM). In this machining for some period of time no abrasive is injected into the gas stream from the nozzle for little period of time so that a continuous flow of gas without abrasive blow away any abrasive particle which is accommodate inside the hole. Some further experiment conducted to conform the validity of the developed statistical model by comparing the model predictions to the experimental result.

Park. D. S., et al[6](2003) Investigated micro-grooving of glass by using micro-abrasive jet machining micro (AJM) removes hard and brittle materials, effectively just like sand blasting. This paper finds the performance of micro AJM in the micro grooving of glass. After the machining a 80 micro meter Lint type groove was formed. The results showed good performance in the micro-grooving of glass. After fine-tuning of the mashing process and the compensation for film wear, micro-AJM could be effectively applied to the micro machining of semiconductor, electronic devices and LCD.

Kantha Babu.M., et at [14] (2003) This paper studied the effect of recycling of local garnet abrasives (origin: southern India) while cutting aluminium using abrasive water jet machining. The influence of pressure, traverse rate, and abrasive flow rate on American Foundrymen's Society grain fineness number, average particle size, depth of cut, top kerf width, bottom kerf width, kerf taper, and surface finish obtained using a specially formulated optimised abrasive test sample have been studied.

Wakuda. M., et al[15] (2003) The study of material response to particle impact during abrasive jet machining of alumina ceramics with the help of AJM. In this paper try to identify material response of alumina ceramics to the abrasive particle impact in AJM process. Three types of abrasive partials were used to dimple the sintered alumina samples. It was observed the material response to particle impact depends on the abrasives. Aluminum oxide abrasive leads to roughening the alumina surface but did not cause any engraving due to lack of abrasive hardness against that of the work piece. Silicon carbide abrasive produced the smooth surface and it shows the type behavior under the elevated temperature caused due to abrasive impacts. Synthetic diamond abrasive caused large scale fragmentation and there for the impacted surface becomes rough.

Balasubramanian. R., et al[18] (2002) The experimental work done on a plaster of Paris specimens to study the effect of various parameters of Abrasive Jet Machine on the shape of the surface generated by abrasive jet machining. The various parameters are standoff distance, nozzle diameter, pressure, particle size, velocity of jet etc. After the experiment some conclusions are obtained.
As the stand of distance increases the entry side diameter and entry side edge radius also increase.
As the centre line velocity increases the MRR at centre line of jet increases. But there is no increase in MRR nearer to the periphery of jet. As the peripheral velocity of the jet increases the edge radius and the entry side diameter increase. It also increases the MRR. As the particle size increases MRR at the centre line more than MRR nearer to periphery.

Wakuda. M., et al[16] (2002) Study the effect of properties of work piece on machinability in AJM. Ceramic specimen was used. The establish models of solid particle erosion in which the material removal is assumed to originate in the ideal crack formation system was compared to the machinability during the AJM process. It was clarified that the erosion model are not significantly applicable to AJM results because the relative hardness of the abrasive against the target material which is not taken in to the account in the models. After the experiment some observation are obtained. There was no strength degradation occurs for AJM surfaces.Which was evidence that radial cracks do not propagate downwards due to partial impacts.

Balasubramaniam. R., et al [19] (1998) Study the generation of an edge radius an abrasive jet in external deburring. The study was done the affect of various input parameters like abrasive grit size mixing ratio standoff distance and thickness. The variation in the diameters at the entry and exit side of the specimen were also investigated. The edge radius generated was affected by the parameter stand of distance and the variation in the diameter was affected by the nozzle diameter. The results of the edge radius generation was conducted to stainless steel burr specimen.

Balasubramaniam. R., et al20] (1997) Study of AJM for deburring process .An experiment conducted to identify the effect of various parameters of AJM like jet height and angle of impingement etc. on deburring process. In this experiment stainless steel specimen is used and the excremental design based on taguchi method. A profile protector was used to measure the edge quality and also the visual inspection was conducted to analyze the surface damage of the specimen here the results are also analyze by the ANOVA method. After the experiment some conclusions are obtained. It was found that burr removal was affected by the parameters jet height and angle of impingement.

Chen. Y.H., et al[24] (1996) evaluated the use of the Taguchi method of experimental design in optimizing process parameters for micro engraving of iron oxide coated glass using a Q-switched Nd, YAG laser. The effects of five key process parameters - beam expansion ratio, focal length, average laser power, pulse repetition rate and engraving speed - have been explored. The primary response under study is the engraving line width. An L16 orthogonal array was used to accommodate the experiments. The study indicated that a minimum line width of 18 mm could be obtained with beam expansion ratio of 5 ´, focal length of 50mm, laser average power of 0.4 W, pulse repetition rate of 5 kHz, and engraving speed of 5000mm/min.

Ray. P.K., [17] (1987) This research paper discusses the study of various input parameters(pressure, mixing ratio, stand of distance etc.) of abrasive jet machining(AJM) on the material removal rate. The experiment carried out with vortex type mixing chamber. The study was restricted to abrasive jet drilling only.

3. PROBLEM FORMULATION

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods and, marketing and advertising. Taguchi methods are considered controversial among some traditional Western statisticians but others accept many of his concepts as being useful additions to the body of knowledge. The goal of a Taguchi's experimental design is to identify optimal settings for all the design parameter, not to build the model fitting of process Taguchi has achieved substantial pay offs just by conducting many main-effect-only-experiments and checking the results by confirmation experiments. If it can be proved that the system could be described well by even only main effects, the optimal condition determined by only main effect analysis can be very efficient and simple method for optimization. Orthogonal array has been used to minimize the number of test runs while keeping the pair-wise balancing property in Taguchi's method for that purpose. These basic principles serve as a screening filter, which allows the examination of the effects of many process variables, identifying those factors, which have a major effect on process characteristics using a single trial with a few reactions. For example, optimization experiment would normally require each variable to be tested independently. Thus, a trial run investigating the effects and interactions of four reaction variables each at three concentration level, would require an experiment with 81 (i.e. 34) separate reactions. Using an orthogonal array, however, an estimate of the effect of each variable can be carried out using only nine experiments. Providing that three level are used for each variable tested, the number of experiments required (E) is calculated from the equation E=2k+1, where K is the number of factors to be tested. If the calculated number is not a multiple of three, then the required number of variables to be tested is the next multiple. Hence, as the number of experiments required becomes more marked; e.g. to test 9 factors would require 39 = 19683 experiments to analyze fully, whereas using Taguchi's methods this could be reduced to just 21 (2*9+1=19), 19 is not a multiple of three and then next integer divisible by three is 21.

4. EXPERIMENTAL WORK

In experimental setup there is

1) Reciprocating air compressor
2) Abrasive chamber
3) Central valves
4) Mixing chamber
5) Nozzle
6) Work piece

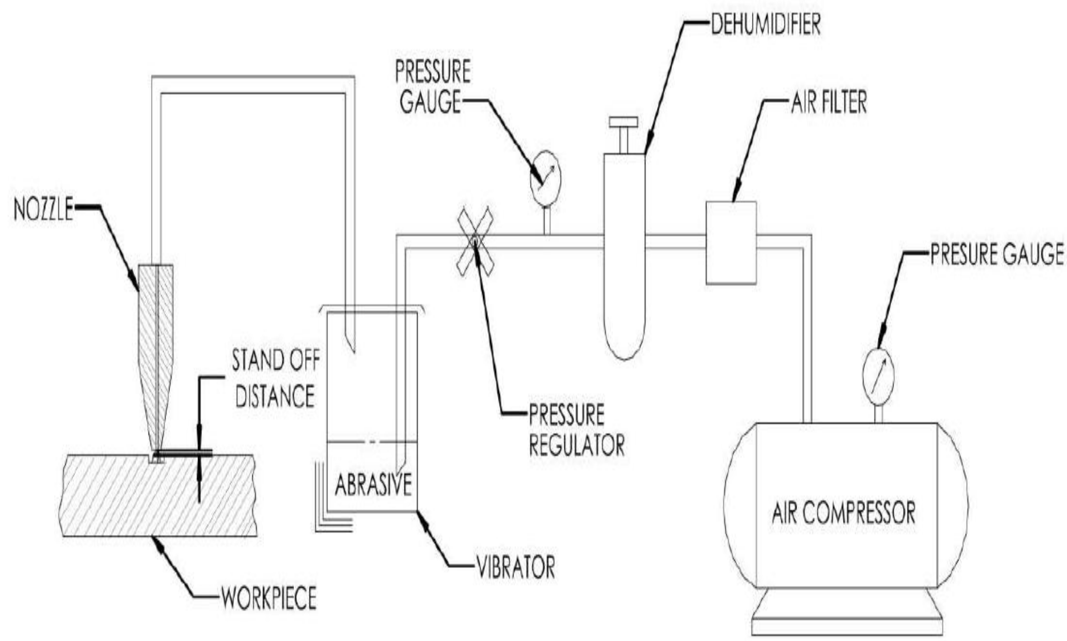

Fig 4.1: AJM setup

Table. 4.1 Abrasive jet machine characteristics

Carrier gas	Compressed Air
Nozzle tip distance	6-18 mm
Abrasives	Al2O3(aluminum oxide)
Pressure	2-10 kgf /cm2
Nozzle	stainless steel
Material used	Soda lime glass

Improvement during the experiment on AJM

- The pressure regulator and pressure gauges are replaced by the new ones for preventing the leakage in the flow process.
- Now the abrasive feeder is relocated just above the mixing chamber with a valve in between to control the flow of abrasive particles.
- After the mixing chamber a valve is provided to control the mass flow rate of the mixture coming out of the mixing chamber.

5. RESULTS AND CONCLUSION

The following results are obtained by using Pressure, angle, abrasive size as a AIM parameters .Then, by using L9 values we have find out the MMR .So, following test results are as in tabular form.

- **Table 5.1 Test NO.1 conducting on AJM parameters**

Pressure (kg/cm2)	4
Angle (degree)	450
Abrasive(mesh size)	800
Nozzle tip distance (mm)	6
Initial weight(gram)	27.6382
Final weight(gram)	27.6245
Time(sec.)	6
MRR (g/sec.)	0.0023

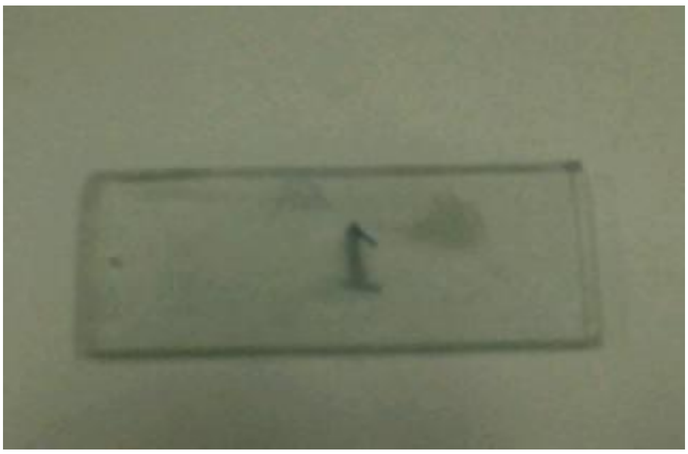

Fig. 5.1 Work piece after Test NO.1 conducting on AJM parameters

- **Table 5.2 Test NO.2 conducting on AJM parameters**

Pressure (kg/cm2)	4
Angle (degree)	25o
Nozzle tip distance (mm)	10
Abrasive(mesh size)	600
Initial weight(gram)	27.1774
Final weight (gram)	27.1578
Time(sec.)	6
MRR (g/sec.)	0.0033

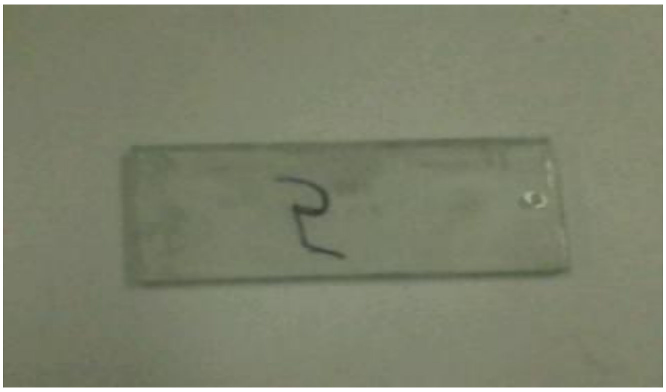

Fig. 5.2 Work piece after test NO.2 conducting on AJM parameters

Table 5.3 Test NO.3 conducting on AJM parameters

Pressure (kg/cm2)	4
Nozzle tip distance (mm)	12
Angle (degree)	0o
Abrasive(mesh size)	250
Initial weight(gram)	27.5980
Final weight(gram)	27.5644
Time(sec.)	6
MRR (g/sec.)	0.0056

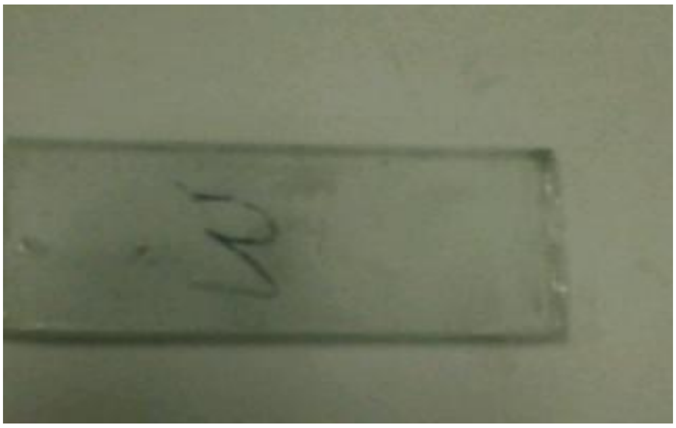

Fig. 5.3 Work piece after test NO.3 conducting on AJM parameters

Table 5.4 Test NO.4 conducting on AJM parameters

Pressure (kg/cm2)	6
Nozzle tip distance (mm)	12

Angle (degree)	45o
Abrasive(mesh size)	600
Initial weight(gram)	27.7710
Final weight(gram)	27.7366
Time(sec.)	6
MRR (g/sec.)	0.0057

Fig. 5.4 Work piece after test NO.4 conducting on AJM parameters

- **Table 5.5 Test NO.5 conducting on AJM parameters**

Pressure (kg/cm2)	6
Nozzle tip distance (mm)	6
Angle (degree)	25o
Abrasive(mesh size)	250
Initial weight(gram)	25.5457
Final weight(gram)	25.5049
Time(sec.)	6
MRR (g/sec.)	0.0102

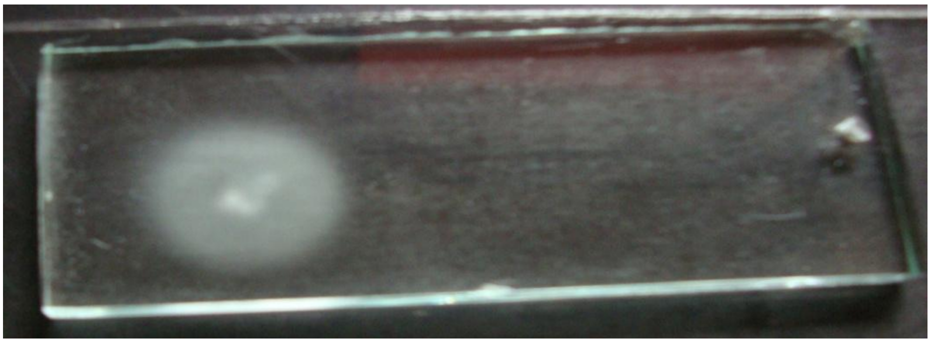

Fig. 5.5 Work piece after test NO.5 conducting on AJM parameters

Table 5.6 Test NO.6 conducting on AJM parameters

Pressure (kg/cm2)	6
Nozzle tip distance (mm)	8
Angle (degree)	5o
Abrasive(mesh size)	800

Initial weight(gram)	27.4685
Final weight(gram)	27.4301
Time(sec.)	6
MRR (g/sec.)	0.0064

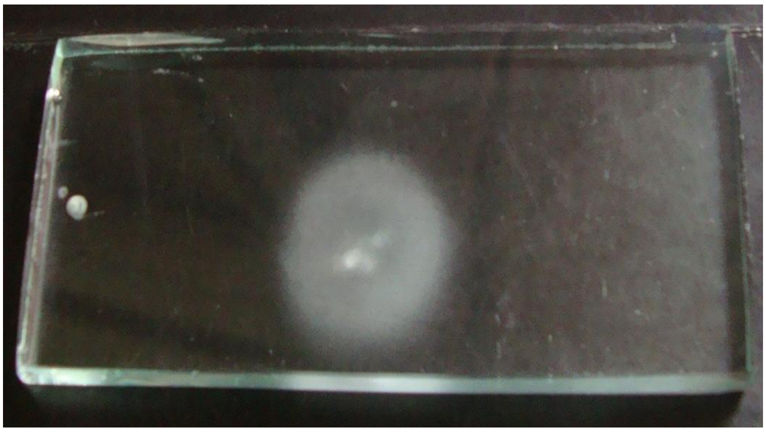

Fig. 5.6 Work piece after test NO.6 conducting on AJM parameters

- **Table 5.7 Test NO.7 conducting on AJM parameters**

Pressure (kg/cm2)	10
Nozzle tip distance (mm)	8
Angle (degree)	45o
Abrasive(mesh size)	250
Initial weight(gram)	27.2459
Final weight(gram)	27.1955
Time(sec.)	6
MRR (g/sec.)	0.0084

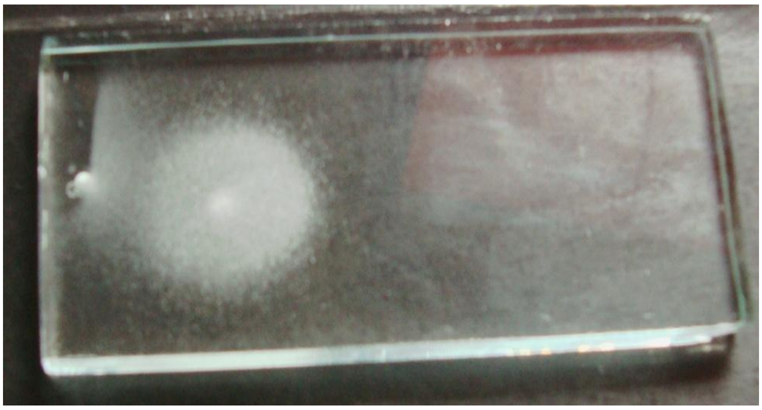

Fig. 5.7 Work piece after test NO.7 conducting on AJM parameters

Table 5.8 Test NO.8 conducting on AJM parameters

Pressure (kg/cm2)	10
Nozzle tip distance (mm)	18
Angle (degree)	25o
Abrasive(mesh size)	800
Initial weight(gram)	27.6185
Final weight(gram)	27.5733

Time(sec.)	6
MRR (g/sec.)	0.0075

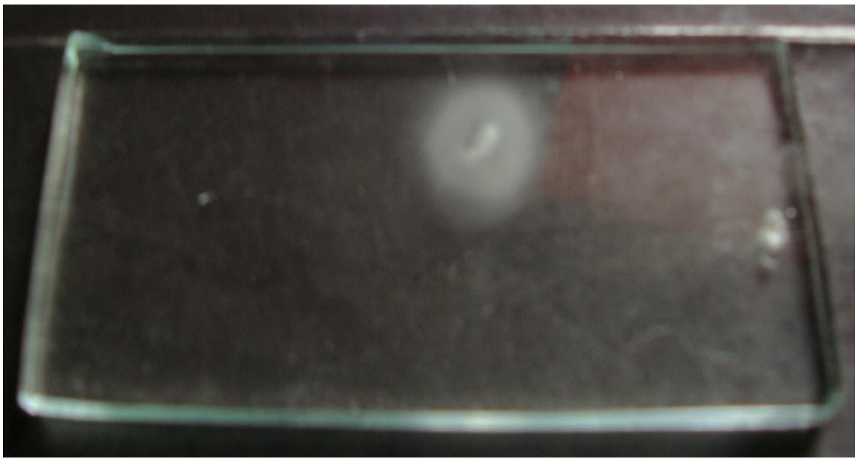

Fig. 5.8 Work piece after test NO.8 conducting on AJM parameters

Table 5.9 Test NO.9 conducting on AJM parameters

Pressure (kg/cm2)	10
Nozzle tip distance (mm)	6
Angle (degree)	5o
Abrasive(mesh size)	600
Initial weight(gram)	27.1965
Final weight(gram)	27.1373
Time(sec.)	6
MRR(g/sec.)	0.0099

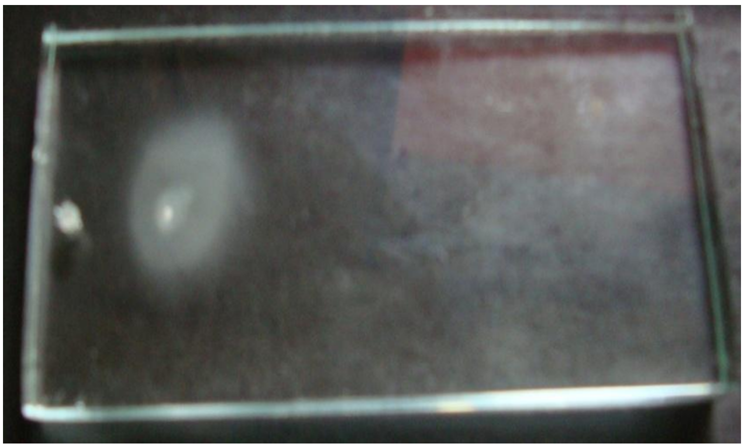

Fig. 5.9 Work piece after test NO.9 conducting on AJM parameters

6. FUTURE WORK

Although the MMR on Soda lime glass is calculated by using aluminum oxides on AJM with the application of Taguchi's method, still there is a scope for further investigation. The following suggestions may be adopted for future work:

1) The same parameters such as pressure, abrasive size, angle of work pieces, standoff distance, etc. may also be investigated on tempered glass.
2) Different abrasives (for examples Silicon carbides) can be used and compared for better results.
3) The study can also be checked on various composites materials, which include different types of their working parameters .So, as to optimize their parameters to maximum possible extent.

4) More tests may also be performed on the Soda lime glass, to see erosion the given work piece. For example - Micro structural test may be used for observe the various micro level structure of our given work piece.
5) The analysis may also be done by other methods, such as the Regression Analysis instead of that used in this particular investigation.

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