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EXPERIMENTAL ANALYSIS OF VARIOUS PARAMETERS OF AJM PROCESS ON ALUMINA CERAMIC MATERIAL

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Abstract: **Abrasive jet machining offers a solution to the expanding need for machining brittle materials and for increasing complex operations to provide intricate shapes and work piece profiles. AJM Machine capable of producing straight, normal as well as angular hole. Machine was successfully tested with control parameters such as pressure, stand of distance, particle size and abrasive type on Alumina Ceramic material to measure the response parameters such as MRR (Metal Removal Rate) for productivity purpose, ROC (Radial overcut) and Taper for quality purpose. A full factorial experiment with three levels of each for three control parameters are planned giving a total 3^3 = 27 trial for drilling with different parameter setting.**

***Index Terms* – Abrasive Jet Machining, MRR, ROC, Taper, SOD, Pressure, Alumina Ceramic**

I. INTRODUCTION

Manufacturing processes can be broadly divided into two groups and they are primary manufacturing processes and secondary manufacturing processes. The former ones provide basic shape and size to the material as per designer's requirement. Casting, forming, powder metallurgy are such processes to name a few. Secondary manufacturing processes provide the final shape and size with tighter control on dimension, surface characteristics etc. Material removal processes are mainly the secondary manufacturing processes. Material removal processes once again can be divided into mainly two groups and they are "Conventional Machining Processes" and "Non-Traditional Manufacturing Processes". Examples of conventional machining processes are turning, boring, milling, shaping, broaching, slotting, grinding etc. Similarly, Abrasive Jet Machining (AJM), Ultrasonic Machining (USM), Water Jet and Abrasive Water Jet Machining (WJM and AWJM), Electro-discharge Machining (EDM) are some of the Non Traditional Machining (NTM) Processes.

Abrasive Jet Machining (AJM) presents the working of abrasive jet machining and removing materials from the brittle and heat sensitive materials by the application of a high speed stream of abrasive particles carried by a gas medium through the nozzle. In particular drilling of holes of minimum diameter and maximum depth is also possible in AJM with greater accuracy and surface finish. Since no heat is induced while machining the surface, the workplace is not subjected to thermal shocks. The abrasive jet machining apparatus can be used for determining the material removal rate (MRR) for materials like glass, ceramics and aluminium sheet by varying the parameters like pressure, nozzle tip distance (NTD) and size of the abrasive flow rate.

In abrasive jet machining, a focused stream of abrasive particles, carried by high pressure air or gas is made to impinge on the work surface through a nozzle and work material is removed by erosion by high-velocity abrasive particles. The AJM differs from sandblasting. In AJM the abrasive is much finer and the process parameters and cutting action are carefully controlled.

PRINCIPLE OF ABRASIVE JET MACHINE

This machining process works on the basic principle of abrasive erosion. If a high velocity abrasive particles strike on a hard or brittle work piece, it removes some metal at the striking surface. This metal removal process takes place due to brittle fracture of metal and also due to micro cutting by abrasive particle. This is principle process of abrasive jet machining.

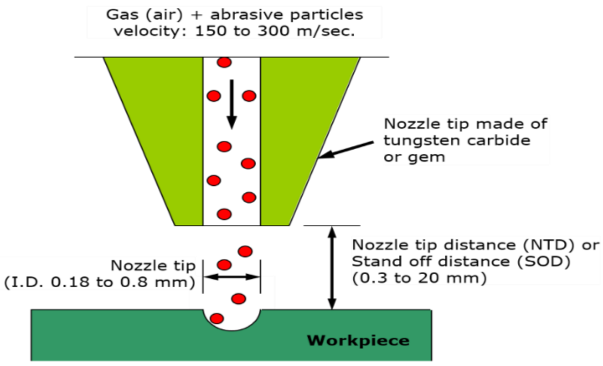


Fig-1.1: Principle of abrasive jet machine

If this is a work surface which is to be either cut or finished. Then the abrasive jet, one abrasive jet will be just forced from this nozzle. So, this is the nozzle. Nozzle and this will be directed towards this surface, this is we call that target surface and this will be at very high speed. This will be moving towards the surface and here a gas will be there which is in most of the cases it is air or it can be a argon gas or it can be other generally neutral gas plus abrasive materials.

here in this process there are several factors which are very, very important. One important factor is this distance and then the angle of this nozzle at which it is striking this work surface. Of course, the concentration of the abrasive particles with this gas is also another important factor, but the limitation, basic limitation of this process is that this material, work material should be preferably brittle like say glass, etcetera. In these brittle materials, this brittle fracture phenomenon occurs more readily and we get measuring effect more prominently. This process is also known by several other names like abrasive micro blasting, pencil blasting, micro abrasive blasting etcetera. This abrasive jet machining process is an effective measuring matter for hard and brittle materials such as glass, silicon, tungsten and ceramic. As we know tungsten and tungsten carbide these materials are very, very hard and very difficult to be machined by other machining methods. However, this process like abrasive jet machining process is useful for machining or at least finishing these materials like tungsten carbide or tungsten, tungsten or silicon etcetera apart from of course, glass.

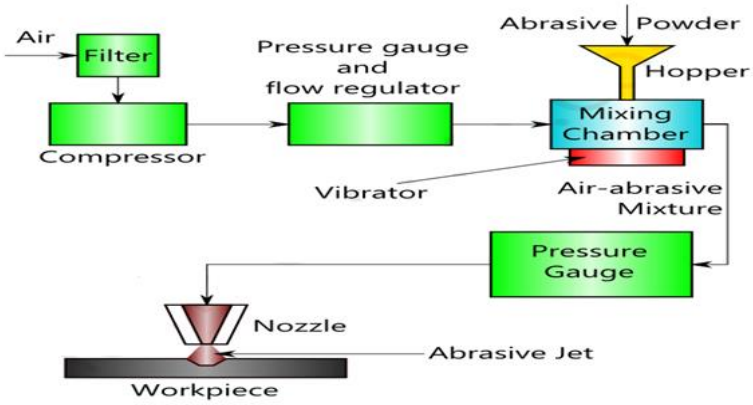


Fig 1.2: schematic diagram of Abrasive jet machine

The schematic of this process is like this. So, this is what the nozzle I was talking about through which the mixer of the abrasive and air is coming at a very high velocity. And this is the work piece on which this mixer of abrasive particles and air or other gas generally some neutral gas like argon etcetera are used, are striking on this work piece surface. As I told earlier the angle at which this is striking the work piece is very, very important. In this particular configuration it is shown the angle is something around 45 to 50 degree with this work piece surface, but not necessarily. It can be 90 degrees as well or it can be at 60 degree or something like that.

However, if we make this angle smaller and smaller the effectiveness of this cutting jet will come down and again the distance from this nozzle tip to this work piece is also very vital. We will discuss this point later on with different schematic. Here the other arrangements are shown like this is the gas intensifier or the gas supply pressurized gas device. This comes through this nozzle or some gas flow control device and here this is one of the very crucial component in this entire set up in which the gas and the abrasive gets mixed. And since we know the abrasive particles can abrade any surface therefore, during mixing itself the inner surface of this mixing chamber gets abraded by this abrasive particle. More over to get proper mixing of this gas and the abrasive particles these are kept at some frequency vibration vibrated at some frequency and therefore, the problem becomes magnified. Therefore, the life of this particular component is generally very less and this causes the increase in the cost of operating this particular setup. Generally, tungsten carbide material is used for this chamber as well as this nozzle which also experiences the abrading high velocity abrading particles while flowing through this.

This pressurized gas and abrasive mixture is then being flown through this whole system, through this flow control valve and this can be made handheld as well as it can be mechanized, at times it can be robot controlled as well and can be made to target the point where the cutting or the finishing is to be carried out. However, one big problem with this particular process is the control of the abrasive particles after working as we know all, almost all abrasive particles are injurious for our health, inhaling this particle can cause disorder in our biological system.

This process is considered highly flexible where the abrasive media is carried by a flexible hose which we have already seen in the previous schematic. And this can reach out to some difficult areas and internal regions. Thus abrasive jet machining process creates localized forces and generates lesser heat than the conventional machining processes. Basically, it is a mechanical process where no heat is generated and it is eroding in nature. There is no damage to the work piece surface and also the process does not have tool work piece contact. Hence, lesser amount of heat is generated. The power consumption in abrasive jet machining process is considerably low.

PROJECT IDENTIFICATION AND METHODOLOGY:

Brittle and hard solids can be classified in four groups: minerals, polycrystalline ceramic aggregates (traditional and advanced), single crystals and amorphous glasses. Minerals are frequently used as raw materials in the production of a large range of products such as abrasives, gemstones, metals and alloys, single crystals synthetically produced on a commercial scale, etc. Traditional ceramics and glasses are extensively used to manufacture many products currently used in daily life. Advanced ceramics have been widely adopted as functional as well as structural engineering materials (Chiang et al. 1997). Functional ceramics and glasses are extensively used in the production of electric, electronic, magnetic and optical components for high performance systems such as transducers, resonators, actuators and sensors. The past decades have seen a tremendous resurgence in the use of advanced ceramics in structural applications such as roller and sliding bearings, adiabatic diesel engines, cutting tools, etc. Conventional forming and sintering processes of ceramic powders do not necessarily give the high dimensional accuracy and the good surface quality required for functional and structural components. Thus, precision machining technologies have been developed for the manufacture of cost-effective and quality-assured precision parts produced by brittle and hard solids.

Abrasive jet machining offers a solution to the expanding need for machining brittle materials such as single crystals, glasses and polycrystalline ceramics, and for increasing complex operations to provide intricate shapes and work piece profiles.

This machining process is non-thermal, non-chemical, creates no change in the microstructure, chemical or physical properties of the work piece and offers virtually stress-free machined surfaces. It is therefore used extensively in machining hard and brittle materials that are difficult to cut by other conventional methods. The abrasive jet machining parameters affecting the machining response are studied and some of the key parameters are selected for an experimental evaluation of their effect on machining performance parameters material removal rate, taper and overcut while machining alumina ceramic.

THE MAIN OBJECTIVES OF THIS WORK ARE AS FOLLOWS:

1. To investigate experimentally the effect of process parameters like pressure, abrasive mesh size, standoff distance and work piece material thickness on the material removal rate, taper and overcut in drilling of alumina ceramic.
2. To analyze the effect of these parameters on the material removal rate and dimensional accuracy in terms of radial overcut and taper.

ABRASIVE JET MACHINING METHODOLOGY

The process flow chart for abrasive jet machining process:

Table 3.1: Abrasive Machine Parameters

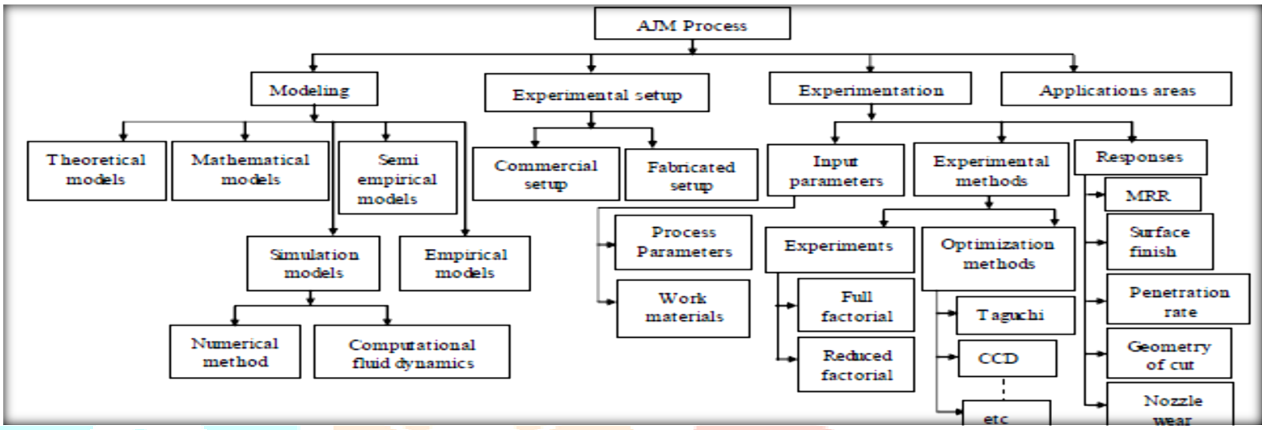


Fig 3.1: Flow chart of AJM research work

METHODOLOGY

As per project definition and work contain in a project following are major area of work in step wise found

MATERIAL MACHINING CAPABILITY TESTING:

AJM Machine capable of producing straight, normal as well as angular hole. Machine was successfully tested for drilling a hole and capability for various materials such as, Glass, Ceramic, Granite, Aluminum and Mild Steel. And we decide to fixed parameter it is shown in table 3.1.

Sr no	Parameter	Level
1	Air Pressure	4 Kg/cm2
2	Stand of distance	4 mm
3	Particle Size	400 Mesh
4	Abrasive type	Sic

MATERIAL MACHINING CAPACITY

After the decide the fixed parameter of the experiments then we had to select the material like Glass, Ceramics, Granite, Aluminum and mild steel which is shown in fig. 4.1. After the selection of different material experiments are conducted. As shown in the following table there are measure the response parameter are MRR, Taper, ROC.

Table. 3.2 Material Machining Capacity

Material	Thickness(mm)	MRR(mg/sec)	Taper (radian)	ROC (mm)
Glass	2.00	0.0543	0.3845	0.765
Ceramic	2.00	0.07023	0.0625	2.0314
GFRP	2.00	0.043	0.345	1.8156
Acrylic	2.00	0.0034	0.25	1.3455

Among the response parameter MRR is for productivity purpose and Taper and ROC is for Quality purpose as shows the MRR is higher in Ceramic material so productivity of ceramic material is high.

DESIGN OF EXPERIMENT:

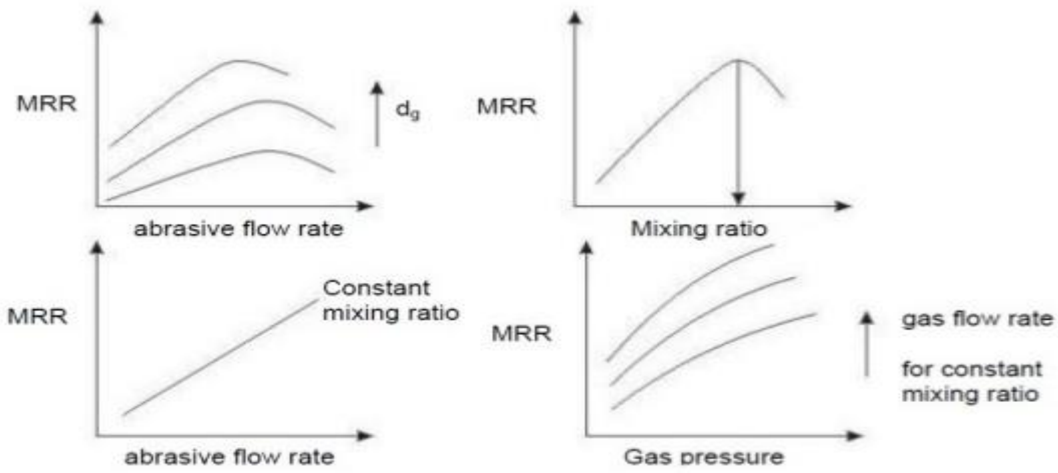
SELECTION OF CONTROL VARIABLES

Major AJM variables that control material removal rate, taper cut and radial over cut are air pressure, mixing ration of air-abrasive particle, stand of distance, nozzle diameter, work piece thickness and abrasive size.

1) **Air Pressure:**

As shown in graph as the air pressure increases the material removal rate increases.

Fig: 4.1 various parameter effect on machining process



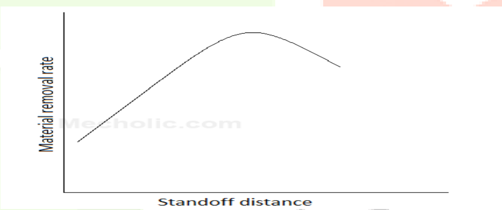
2) **Mixing Ratio:**

The mixing ratio of air and abrasive particle also effect the material removal rate as the mixing ration increases the material removal rate increases and up to maximum point than after the increase in mixing ratio will decrease the material removal rate as shown in figure 4.1.

3) **Stand of Distance:**

In starting phase, the stand of distance decreases the material removal rate than aster increase in stand of distance increase the material removal rate after reaching at the highest point the increase in the stand of distance will decreases the material removal rate.

Fig: 4.2 Effect of stand of distance on material removal rate



4) **Abrasive Size:**

Abrasive size is the affecting factor on material removal rate as the size of Abrasive increases it gives rough surface drill and if the size of abrasive decreases it gives high accurate hole dimension. Various types of Abrasive are.

Fig: 4.3 Various types of Abrasive powder

VARIABLE RELATED TO MACHINING PROCESS

Air pressure, Stand of Distance and Abrasive particle size are the major process variables affecting the performance of Abrasive jet machine. The Abrasive jet machine has a fixed air and abrasive mixing chamber which vibrates with the predefined frequency. So air pressure, stand of distance and particle size are selected as the control parameters and frequency will be our confounding parameter. Suitable level of pressure, stand of distance and particle size will be selected.

VARIABLE RELATED TO MACHINED PART

The type of material, its thickness, shape and size of cut are the major work related variable affecting Abrasive jet machine. The work material selected is alumina ceramic.

VARIABLE RELATED TO ABRASIVE PARTICLE SIZE

There is number of abrasive particle available in market. Here we are using Silicon Carbide Abrasive particle with three different mesh size number 150,220 and 400 mesh number.

Table: 4.1 Mesh size of Abrasive powder

Mesh	Micron	Inches
4	4760	0.185
6	3360	0.131
8	2380	0.093
12	1680	0.065
16	1190	0.046
20	840	0.0328
30	590	0.0232
40	420	0.0164
50	297	0.0116
60	250	0.0097
70	210	0.0082
80	177	0.0069
100	149	0.0058
140	105	0.0041
200	74	0.0029
230	62	0.0023
270	53	0.0021
325	44	0.0017
400	37	0.0015
625	20	0.0008
1250	10	0.0004
2500	5	0.0002

SELECTION OF RESPONSE VARIABLES:

The most important measure of any material removal process are material removal rate (MRR) and Accuracy. Non-convention processes like abrasive jet machining involve an overcut and taper associated with machining due to the character of the process. Hence the parameter selected to be measure as representative of the process response are,

1. Material removal rate(MRR)
2. Over cut
3. Taper

A full factorial experiment with three levels of each for three control parameters are planned giving a total 33 = 27 trial for drilling with different parameter setting.

Taguchi orthogonal arrays are highly fractional designs, used to estimate main effects using only a few experimental runs. These designs are not only applicable to two level factorial experiments, but also can investigate main effects when factors have more than two levels. Designs are also available to investigate main effects for certain mixed level experiments where the factors included do not have the same number of levels.

SELECTION OF CONTROL VARIABLES LEVEL

The main control parameter of abrasive jet machine which affect the material removal rate (MRR), radial over cut and taper are listed below with their level after studying the literature review on machining by abrasive jet machine.

1) Air Pressure:

Table: 4.2 Level of pressure

Control parameter	Level-1	Level-2	Level-3
Air Pressure	3 Kg/cm2	4 Kg/cm2	5 Kg/cm2

2) Abrasive Type and mesh size:

Silicon carbide is used as abrasive particle in this study with different mesh size.

Table: 4.3 Level of Abrasive size

Control parameter	Level-1	Level-2	Level-3
SiC Abrasive	150	220	400

Fig: 4.5 Abrasive powder of Sic

- **Properties of Silicon Carbide(Sic) Abrasive:**

Fig: 4.6 Properties of Abrasive

Silicon Carbide Properties		
Mechanical	**SI/Metric (Imperial)**	**SI/Metric**
Density	gm/cc (lb/ft^3)	3.1
Porosity	% (%)	0
Color	—	black
Flexural Strength	MPa (lb/in^{2}x10^3)	550
Elastic Modulus	GPa (lb/in^{2}x10^6)	410
Shear Modulus	GPa (lb/in^{2}x10^6)	—
Bulk Modulus	GPa (lb/in^{2}x10^6)	—
Poisson's Ratio	—	0.14
Compressive Strength	MPa (lb/in^{2}x10^3)	3900
Hardness	Kg/mm^2	2800
Fracture Toughness K_{IC}	MPa•m$^{1/2}$	4.6
Maximum Use Temperature (no load)	°C (°F)	1650

3) **Stand of distance:**

Table :4.4 Level of Stand of Distance

Control parameter	**Level-1**	**Level-2**	**Level-3**
SOD	2	4	6

SELECTION OF WORK-PIECE MATERIAL

Alumina ceramic material will be selected as work-piece material in Abrasive jet machine. Alumina ceramic nowadays widely used in very industrial application and domestic application. Alumina is one of the most cost effective and widely used material in the family of engineering ceramics. The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricated alumina shapes. With an excellent combination of properties and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications.

PROPERTIES OF ALUMINA CERAMIC MATERIAL:

1. Hard and wear resistant
2. High strength and stiffness
3. Excellent Dielectric properties
4. Resists strong acid and alkaline at elevated temperature

Fig: Properties of Alumina ceramic material

Mechanical	Units of Measure	SI/Metric
Density	gm/cc (lb/ft^3)	3.69
Porosity	% (%)	0
Color	—	white
Flexural Strength	MPa ($lb/in^2 x10^3$)	330
Elastic Modulus	GPa ($lb/in^2 x10^6$)	300
Shear Modulus	GPa ($lb/in^2 x10^6$)	124
Bulk Modulus	GPa ($lb/in^2 x10^6$)	165
Poisson's Ratio	—	0.21
Compressive Strength	MPa ($lb/in^2 x10^3$)	2100
Hardness	Kg/mm^2	1175
Fracture Toughness K_{IC}	$MPa\bullet m^{1/2}$	3.5
Maximum Use Temperature (no load)	°C (°F)	1700

EXPERIMENTAL PROCEDURE

The detailed procedure followed for abrasive jet drilling is described as under

1. Measure the weight of alumina ceramic sheet.
2. Add the abrasive powder in the mixing chamber of the abrasive jet machine
3. Adjust the desired pressure level in the abrasive jet machine by pressure regulating valve by 3 Kg/cm2, 4Kg/cm2 and 5 Kg/cm2.
4. Adjust the Desire SOD like 2 mm, 4 mm and 6 mm according to its level
5. Adjust the fixture and make suitable arrangement to fix the work piece in the work piece holder.
6. Turn on air compressor to maintain desire pressure level the abrasive jet machine.
7. Turn on machine, stop watch and wait until the drilling of alumina ceramic plate is done.
8. After machining clean, the plate and weight the plate in weight scale and record the result for calculating material removal rate.
9. Repeat the above all steps for next run for experimentation.

Fig 4.12 Alumina Ceramic Machine Work-piece

RESULT AND DISCUSSION:

OBSERVATION TABLES: -

The observations recorded during the ultrasonic drilling and blanking of glass are Recorded as shown in Table 5.1

Table Master observation table for abrasive jet drilling

SR NO.	PRESSURE (Kg/cm2)	ABRASIVE MESH SIZE	STAND OF DISTANCE	MATERIAL REMOVAL RATE (gm/min)	RADIAL OVER CUT	TAPER (radian)
				MRR 1	ROC 1	TA 1
1	3	150	2	0.005936	0.5112	0.301016
2	3	150	4	0.006286	0.5059	0.316627
3	3	150	6	0.006115	0.5006	0.332079
4	3	220	2	0.009825	0.3558	0.247913
5	3	220	4	0.010176	0.4436	0.301189
6	3	220	6	0.009393	0.5314	0.352761
7	3	400	2	0.00564	0.443	0.132
8	3	400	4	0.009513	0.2834	0.26082
9	3	400	6	0.013433	0.6106	0.404493
10	4	150	2	0.007126	0.3606	0.292695
11	4	150	4	0.007843	0.4562	0.313734
12	4	150	6	0.010614	0.5518	0.334491
13	4	220	2	0.0128	0.2892	0.272879
14	4	220	4	0.01292	0.466	0.328294
15	4	220	6	0.014114	0.6428	0.381695
16	4	400	2	0.0125	0.1056	0.220934
17	4	400	4	0.020737	0.0453	0.365068
18	4	400	6	0.030379	0.8768	0.494978
19	5	150	2	0.011589	0.21	0.284332
20	5	150	4	0.022463	0.4065	0.310836
21	5	150	6	0.029166	0.603	0.336898
22	5	220	2	0.01913	0.2226	0.297501
23	5	220	4	0.024378	0.4884	0.354908
24	5	220	6	0.03354	0.7542	0.409974
25	5	400	2	0.005365	0.048	0.330872
26	5	400	4	0.040579	0.699	0.461646
27	5	400	6	0.041538	1.143	0.577429

ABRASIVE JET DRILLING

The observations made during Abrasive jet drilling are reported in Table 5.1. The Measurements during the replications are presented in columns with suffix 1 for first set and suffix 2 for second set. The mass of alumina ceramic material removed during machining is calculated as the difference between the mass of alumina ceramic plate before machining and after machining process. Radial overcut is calculated considering the Nozzle diameter of 2 mm and evaluating half of the difference between the largest diameter of the hole which in case of drilling is the diameter at the bottom surface and the Nozzle diameter. Taper is calculated as a ratio of the difference between the top and bottom diameters of the hole produced to the thickness of the plate.

CONCLUSION AND SCOPE FOR FUTURE WORK

The work carried out in this dissertation included a study of effect of major ultrasonic machining parameters like amplitude, pressure and work thickness on MRR, ROC and taper for ultrasonic drilling and ultrasonic blanking operations for glass material. Following major conclusions can be drawn based on the experiments and subsequent analysis.

1. The MRR is found to increase with increase in pressure.
2. There is a two factor interaction effect found on MRR and TAPER
3. From the DATA Main Plot of MRR it was noted that as the as the pressure increase SOD increases until 4 kg/cm2 then after decreasing slowly
4. The radial over cut is found to increase with increase in SOD
5. The Taper is found to increase with all control variable.

SCOPE FOR FUTURE WORK

Based on the work carried out and study of the literature following further investigations can be suggested

1 The parameters affecting AJM machining which were not selected as control variables for this work such as abrasive types, concentration and different Nozzle Diameter can be used to carry out further investigations to determine the effect of these parameters on the MRR, ROC and taper.

2. Process responses like surface roughness, temperature variations in nozzle and work, etc. can be studied to improve the basic understanding of the energy transactions in the process.

3. Different shapes can be machined to understand the effect of machining parameters on linear and non-linear edges being cut.

4. Different varieties of work materials including different glasses like borosilicate glass can be machined for comparing the machinability through ultrasonic process.

5. Study about MRR by AJM by using oval Shape nozzle may be carried out.

REFERENCES

[1] Gagandeep Singh, 2Raminder Singh "Investigation on Glass Machined by Abrasive Jet Machining" IJRMET Vol. 4, Issue 2, Spl - 2 May - October 2014

[2] Pradeep Kumar Sharma*, Gurdeep Singh Deol "A Comparative Analysis of Process Parameters during Machining of Glass Fibre Reinforced Plastic by Abrasive Jet Machining" International Journal of Advance Foundation and Research in Science & Engineering (IJAFRSE) Volume 1, Issue 3, August 2014. Impact Factor: 1.036, Science Central Value: 10.33

[3] Dr.A. k. Paul &R. K. Roy "some studies on Abrasive jet machining the Journal of the Institution of Engineers (India) Vol 68 part PE 2 November 1987

[4] Dr. M. Sreenevasa Rao, D. V. Shrekanth," Abrasive jet Machining-Research Review"", International journal of Advanced Engineering Technology, Vol. 5, pp.18-24, April-June. 2014.

[5] A. Ghobeity, H. Getu, T. Krajac, J. K. Spelt, M. Papini. "Process repeatability in abrasive jet micro-machining". Journal of materials processing technology 190(2007), pp.51-60, 2007.

[6] F. Anand Raju, V. Gnana Prakash, Dr. M.L.S Deva Kumar "Fibre Glass Cutting by Using Abrasive Jet Machining and Analysis of Process Parameters" International Journal of Computer Trends and Technology (IJCTT) – volume 4 Issue 7–July 2013.

[7] Alireza Moridi et al., "Abrasive jet machining-Research Review"", International journal of Advanced engineering Technology, Vol. 3, April-June. 2013.

[8] Bhaskar Chandra "A Study of effect of Process Parameters of Abrasive jet machining", International Journal of Engineering Science and Technology (IJEST)

[9] Kumar Abhishek and Somashekhar S Hiremath "Improvement of Geometrical Accuracy of Micro Holes Machined Through Micro Abrasive Jet Machining" from ScienceDirect.

[10] Rajeev Kumar, Gurdeep Singh Deol, C. S. Kalrac, Vijay Kr Sharmad "Analysis on Performance of Different Parameters during Abrasive Jet Machining by Taguchi Method" International Journal of Emerging Research in Management &Technology ISSN: 2278-9359 (Volume-3, Issue-8)

[11] Goutam Shriyan, Rohit Shinde, Harshavardan Ronge "STUDY OF EFFECT OF PROCESS PARAMETERS ON THE PERFORMANCE OF ABRASIVE JET MACHINING" International Journal of Engineering Research and General Science Volume 3, Issue 3, May-June, 2015

[12] Gaurav Mahajan "A Study of Effect of Various Process Parameters on Abrasive Jet Machining Using Silicon Carbide as Abrasive Material" © 2014 IJEDR | Volume 3, Issue 1 | ISSN: 2321-9939.

[13] Punit Grover, Sanjay Kumar, Qasim Murtaza "Study of Aluminum Oxide Abrasive on Tempered Glass in Abrasive Jet Machining Using Taguchi Method" International Journal of Advance Research and Innovation, Volume 2, Issue 1 (2014) 237-241

[14] M. WAKUDA Synergy Ceramics Laboratory, FCRA, Shidami, Moriyama-ku, Nagoya 463-8687, JAPAN Y. YAMAUCHI and S. KANZAKI Synergy Materials Research Center, AIST, Shidami, Moriyama-ku, Nagoya 463-8687, JAPAN "MICRO ABRASIVE JET MACHINING OF CERAMICS"

[15] Parteek Vijay Kumar,n " Study the MRR of Tempered Glass by Using Silicon Carbide Abrasive at Different Parameters of Abrasive Jet Machine" , Department of Mechanical engineering ,Sat Priya Institute of Engineering and Technology

[16] D. V. Srikanth, Dr. M. Sreenivasa Rao, "Response Surface Methodology for Optimization of Process Parameters in Abrasive Jet Drilling of Composites", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 11, Issue 3 Ver. VIII (May- Jun. 2014), PP 20-26 www.iosrjournals.org

[17] Madhu.S , "NOZZLE DESIGN AND MATERIAL IN ABRASIVE JET MACHINING PROCESS-A REVIEW", International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.33 (2015) © Research India Publications; httpwww.ripublication.comijaer.htm

[18] Mr. Rohtash Kumar, Mr. Neeraj, "Minimization of Material Removal Rate in Abrasive Jet Machining of Tempered Glass Using Tagauchi Method", International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME) Vol. 2, Issue 1, pp: (253-260), Month: April 2015 – September 2015, Available at: www.paperpublications.org