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Measurement of the Effect of Controlling Parameters on Performance of Abrasive Jet Machine

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Abstract: ***Abrasive Jet Machine (AJM) widely used for cutting brittle materials. The present study focus on experimental investigation for performance parameters like Material Removal Rate (MRR) and Surface Roughness (SR) with variation in controlling parameters. Here, air pressure, abrasive particle temperature and speed of mixing chamber considered as controlling parameters for measurement of their effects on performance parameters of AJM. Compare to conventional method of AJM, unique feature of heating jacket and rotary mechanism provided in the newly developed AJM for experimental purpose. Experimental results reveal that the MRR and SR gets increased with increase in pressure, temperature and speed of mixing chamber.***

Keywords: Abrasive material, Compressed air, compressed gas, Glass, MRR, Taguchi Method.

I. INTRODUCTION

AJM is a non-traditional machining process which is mostly used in machining of hard and brittles materials. In this machining process a high velocity stream focus of abrasive particles and produce forces to impinge on work piece. By effect of erosion or brittle fracture the abrasive particles remove metal from work piece. Common applications of AJM includes cutting of hard, thin or brittle and heat-sensitive materials. Specifically, it is used for cutting the irregular shape of metal. [1]

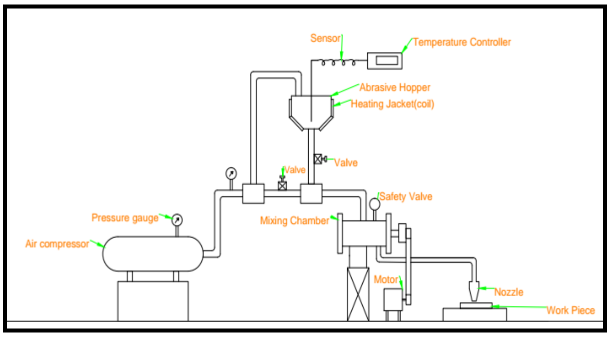

Fig. 1. Schematic Diagram of AJM

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Here Fig. 1 shows the schematic layout of AJM. A hopper is provided to store the abrasive particles with pre-defined sizes of the particles. The hopper is connected with the mixing chamber through pipe. A control valve provided between hopper and mixing chamber to control the flow of abrasives as per requirement. An air compressor is connected to hopper as well as mixing chamber as shown in Fig. 1. High velocity compressed air supplied to the mixing chamber to mix the abrasives with air and it is also supplied to the hopper for create force, and the abrasive particles to supply high velocity abrasive particles to the mixing chamber. A control valve also provided between the compressor unit and the mixing chamber to control the air flow to the mixing chamber as per requirement. Here, the AJM having two unique features in which heating jacket is provided outside the hopper to heat the abrasive particles and rotary mechanism provided for purpose of to mix the abrasive particles in the mixing chamber uniformly. The rotary motion provided through the electric motor connected with the mixing chamber. The high velocity abrasive jet impinged through nozzle on the workpiece. Due to high velocity of abrasive jet the material from workpiece gets remove through the erosion process and the desired shape of cavity or through cut can be obtained.

II. BACKGROUND

Intensive literature review carried out to identify the research gap and found that number of researcher has performed experimental work on the abrasive jet machining process. They have made efforts to identify the effect of input parameters on the performance parameters like MRR, SR and Kerf Width. This section includes discussion on input parameters taken for study by other researchers and their effect on the performance parameters.

Air Pressure: The groove depth on the workpiece increases with the air pressure, and higher kinetic energy of the impacting particles is due to higher pressure. As the abrasive jet enters into the work piece, it drops its kinetic energy; therefore, the kerf becomes thinner, and a taper is formed on the kerf. Smaller kerf taper angle observed due to higher air pressure [5]. MRR increased with increase in the air pressure [2, 3, 4, 6, 7, 11, 14, 15, 16, 17, 19, 20, 21, 22, 23]. It is detected that over cut and taper cut reduced by increasing air pressure [4]. The surface roughness decreased as jet pressure increases [3, 7,]. The mass flow rate of abrasive elements is increased as pressure increases [23].

Abrasive Mass Flow Rate: The depth of groove increased by growing mass flow rate of the abrasive which mains, more particles impacting the surface of work piece and higher MRR achieved. However, extreme abrasive flow rate results into inter-particle crashes which reduce the average MRR per particle. The kerf taper angle decreased with growing the abrasive mass flow rate [5]. MRR is increased with increase in mass flow rate of the abrasive [7].

Abrasive Particle Size: The MRR improved with increases in the abrasive particle size [2, 3, 6, 22]. Also it is establishing that, the MRR increased with decreasing the abrasive mesh size decreasing, the MRR is also increases. (Abrasive mesh size decreasing means the abrasive particle size increases) [20].

Nozzle Diameter: As the nozzle diameter increases, the abrasive particles flow rate increases and ultimately the MRR increased [2, 4, 7]. It is also found that for the glass reinforced plastic, the MRR increased with increasing nozzle diameter. It is detected that over cut and taper cut decreased by increasing nozzle diameter [4]. Nozzle diameter is the most influencing factor for the MRR [20].

Nozzle Tip Distance (NTD) Or Stand of Distance (SOD): The MRR increased with increases in the NTD [3, 6, 17, 22]. It is experiential that when NTD decreasing then taper cut and over cut decreased. [4, 14,]. Bottom surface diameter and the top surface diameter of hole increases when the NTD increased [6, 17]. When increase in the SOD, the entry side diameter and entry side edge radius also increased [6]. At higher SOD, the taper cut slot was also to be a higher. The MRR is increases when the pressure increases, but if the SOD is constant then no more effect on MRR [11]. As the SOD increases, edge radius, MRR and the entry side diameter are also increased [6]. If MRR to be enhanced, SOD should be on high and if accuracy and better surface finish are the requirements, the smaller SOD with high air pressure is suggested [13]. For kerf width, SOD is the most influencing factor. [20]. For certain limit the SOD increases then the MRR increased, out there that limit the MRR gets decreased [20]. The SOD not looks to have a significant weightage on the variation of cutting on work piece [23].

Air Temperature or Hot Air Jet: The Air temperature is the most important factor on Roughness of machined surface (Ra) and MRR. It is seen that at high temperature, there is an enough proof of additional plastic deformation accompanied by brittle fracture failure so that results in reduction of roughness and increase of MRR [12]. It is practically seen that thermal strains and temperature are maximum near to the jet positions and increases laterally the cutting path as the jet advances [9]. Hot air jet provides additional MRR compared to the other machining processes [12]. The higher erosion rate of PTFE at cryogenic temperatures was because of change in the properties of the polymer associated with several thermal transitions, rather than a decrease in particle embedding [8]. It is incidental that the kerf taper angle depends on viscosity of slurry, which is a purpose of temperature. Kerf taper can be reduced by lowering the slurry temperature [10]. The low temperature machining results in quicker MRR. The reasons are not yet completely clear [18].

Angle of Abrasive Jet: - If decreasing the value of jet angle in AJM process on tempered glass, the MRR gets increased [22].

Mixing Ratio: - The MRR and penetration rate goes to high and the surfaces finish value which is measured in Ra decreases due to increase the value of the abrasive mixing ratio and grit size [7]. The mixing ratio is increasing, increasing MRR at certain level than MRR decreasing [17].

Work Feed Rate: - The feed rate increase at that time widths of cut slightly increase. At greater work feed rate, the taper cut slot was found to be a higher [11].

The following objectives can be made based on research papers found:

(1) To develop an experimental set up having unique features like, provision to provide heating to the composite abrasives within mixing chamber, provision to provide rotary or oscillating motion to the mixing chamber.

(2) To investigate the effect of input parameters (i.e. air jet pressure, abrasive flow rate, cut-off distance, SOD, impact angle, machining time, abrasive size, traverse speed etc.) on output parameters (i.e. MRR, SR, depth of cut, cut off width, taper angle, kerf width etc.).

III. DESIGN OF EXPERIMENT

In industry, design of experiments is used to scrutinize the variables of process or the product which may affect the quality of product. In any business important goal are to increasing productivity and improving quality. So in this paper we can recognize the process condition and product components that enhance the product quality, one can have direct development efforts to enhance the product's manufacturability, reliability, quality, and arena performance.

3.1. Process Parameters: - Process parameters are also considered as input parameters which are used for AJM are Pressure, Abrasive particle, RPM, Nozzle Diameter, Temperature and output parameters are MRR and SR.

1) Air Pressure (kg/cm^2) - The pressure is one of the most imperative parameter for drilling, cutting operations by AJM. Generally, when pressure is increased the MRR is increased. Maximum working pressure is 15.2 bar.

2) RPM (Revolution/Minute) - Revolution per minute (RPM) is a measure of Shaft rotation. The speed of DC Motor is 50 to 200 RPM for experimental purpose. Speed measuring instrument used is Tachometer for all mechanical components.

3) Temperature - For find out output parameter like MRR temperature is one of the most effective parameter for Abrasive particles for drilling, cutting operations by AJM. Generally, when temperature is increased MRR is also increased but SR is decreased.

3.2. Constant Parameters

1) Abrasive Particles - Abrasive particle is basic requirement to perform operation like cutting, drilling process. There are so many types of abrasive particle are use in AJM process such as Aluminum oxide (Al_2O_3), Sea sand, Silicon carbide, Alumina, Garnet, Sand (SiO_2), Emery. Al_2O_3 as abrasive materials with grain size 80 mesh. Higher grain size abrasive material gives higher MRR and slightly reduced surface finish of product.

2) Stand of Distance (SOD) – SOD and Pressure are important parameter for measuring output parameter MRR. In these experiments SOD is considered as constant parameter. For experiment work SOD is considered as 8 mm according to the material and plate thickness.

3) Nozzle Diameter - The nozzle is used to made pressurized impact on working plate through abrasive particle to impact on the work piece material and by these the work piece is going to cut.

The diameter of the nozzle is 1.20 mm selected according to the material and plate thickness. Here single point nozzle with constant diameter is used.

3.3. Output Parameters

1) MRR - The amount of the material removed per minute can be defined as MRR. The erosion rate of material depends on grain size of erodent abrasive. As the pressure increases, the MRR also increases.

Based on Volume method MRR = (Initial Weight (W1) - Final Weight (W2)) / (Time (t))

2) SR – The SR is denoted by µm. Certain functional qualities of work piece, like light reflection, heat transmission, lubricant holding capacity, coating friction, wear and tear etc. affected by SR. Roughness is a measure of a surface. It is measured by the vertical deviations of an actual surface from its ultimate form. If the deviation is large, the surface is uneven; and if small, the surface is flat/fine. And for these, the preferred surface finish is usually definite and suitable processes are required to maintain the quality.

Table- I: Factors with levels

Sr. No.	Factors	Level 1	Level 2	Level 3
1	Pressure (kg/cm^2)	6	8	10
2	Temperature (°C)	60	80	100
3	RPM	100	150	200

Here, different parameters were taken with different levels and the levels defined base on pilot experiments. Below the pressure 6 kg/cm^2, cutting effectiveness gets reduced whereas above 10 kg/cm^2 the glass may crack or break during operation.

IV. EXPERIMENTAL SETUP AND PROCEDURE

Fig. 2. Experimental Set-up AJM

The range of pressure generated by the compressor is 2 to 12 kg/cm^2. The air is allowed to flow into mixing chamber as the valve of compressor open and the other inlet of air provided to hopper to avoid back flow of abrasive. Heating provided to the abrasive within the hopper and heated abrasive reaches to the mixing chamber with high pressure air.

Thus, the mixture of abrasive and air comes out through the nozzle at a very high speed. Pressure energy is converted into the kinetic energy of the particles of abrasive in the nozzle and mixing chamber. The abrasive comes out in the form of a line jet. This jet strikes on the work piece placed in front of nozzle at a particular SOD, perpendicular to the surface of work piece. Cutting action take place due to the impact of high velocity abrasive on the work piece.

V. RESULT AND DISCUSSION

Table- II: Abrasive Particle Al_2O_3 with Process Parameters, Air Pressure, Temperature and RPM

Sr. No.	Pressure (Kg/cm^2)	Temperature (^{0}C)	RPM	MRR (gm/sec)	SR (µm)
1	6	60	100	0.007	3.08
2	6	80	150	0.0081	3.02
3	6	100	200	0.0099	2.85
4	8	60	150	0.0103	3.11
5	8	80	200	0.0131	3.4
6	8	100	100	0.0117	3.42
7	10	60	200	0.0158	4.11
8	10	80	100	0.0137	3.93
9	10	100	150	0.0183	4.63

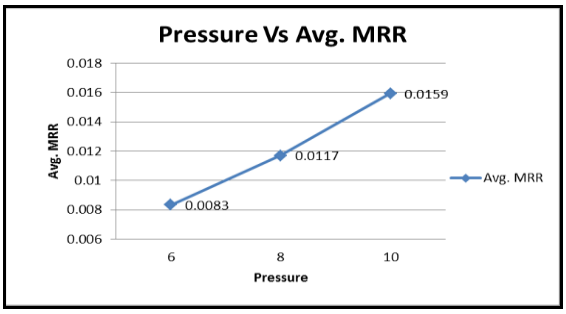

Fig. 3. Graph of Pressure vs Avg. MRR

Fig. 3 shows that the MRR is approximately linear in relation with pressure. As the pressure increases the MRR gets increase due to at high pressure, high velocity jet imparted on the work piece material and material removes from work piece.

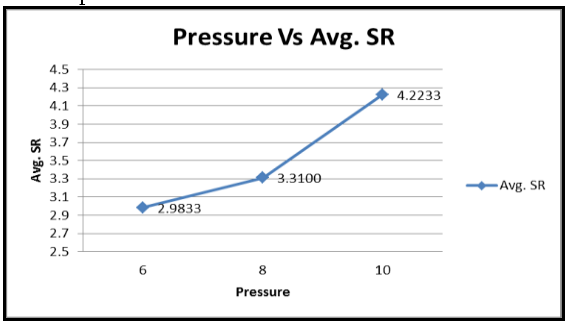

Fig. 4. Graph of Pressure vs Avg. SR

It can be depicting that from Fig. 4, the average surface finish gets increased with increased in the pressure, because as the pressure increases the velocity of abrasive particles gets increase and the abrasives at high velocity imparted on work piece and increases the SR of work piece.

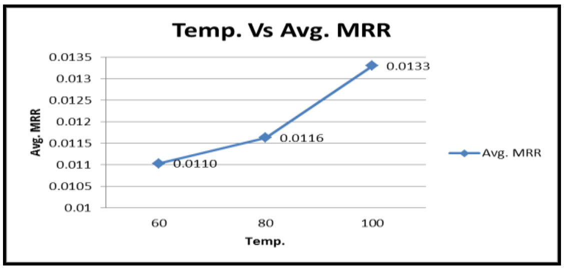

Fig. 5. Graph of Temp. vs Avg. MRR

Fig. 5 shows the result of the temperature vs MRR. This indicates that, at high temperature the MRR gets increases. At high temperature, bonding between two particles of the work piece gets reduced and material eroded due to high velocity abrasive jet.

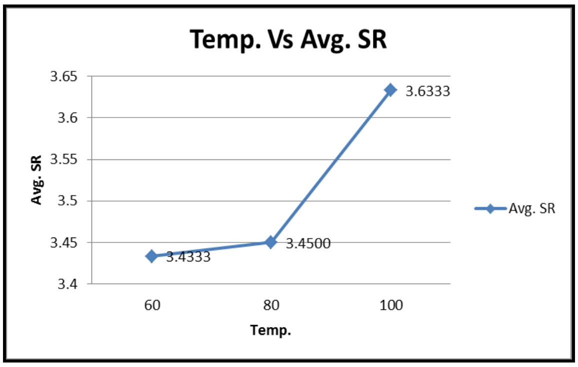

Fig. 6. Graph of Temp. vs Avg. SR

Fig. 6 indicates that the average value of SR gets increase with increase in temperature of the abrasive. The above results show that the SR not too much affected between the temperature range of 60˚C to 80˚C, but it drastically increases from 80˚C to 100˚C. It means that at high temperature, higher surface roughness observed due to weakening of material particle bond the high velocity abrasive particles imparted on the work piece material and penetrates in the work piece material. Ultimately, the SRof the work piece gets increases.

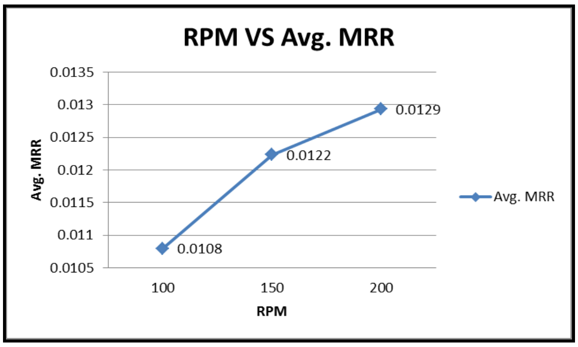

Fig 7. Graph of RPM vs Avg. MRR

As the speed of the mixing chamber increases, the whirling effect developed inside the mixing chamber and it increases the velocity of the jet along with air pressure. This high velocity jet of abrasive and air imparted on the work piece and higher work piece material gets removed. The variation of average value of MRR is not too much with reference to variation in the speed of the mixing chamber. The effect of speed of mixing chamber with respect to average MRR, presented in the Fig. 7.

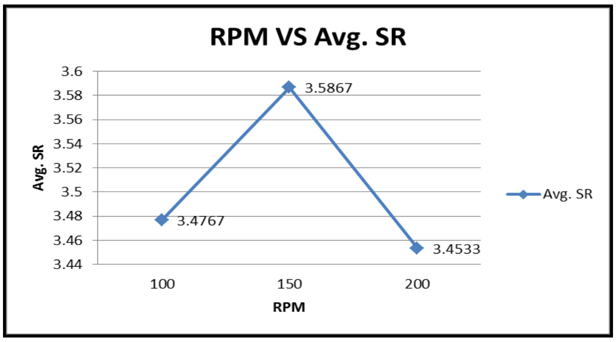

Fig 8. Graph of RPM vs Avg. SR

Fig. 8 shows that the variation in average value of SR is minimal with reference to variation in speed of mixing chamber. The unexpected results observed may be due to uncertain conditions during experiments.

VI. CONCLUSION

The following conclusions were made based on the results obtained from experimentations.

- The average MRR increases with increase in the pressure, temperature and speed of mixing chamber (RPM). This is due to high pressure jet of abrasives, at high temperature weaker the particle bond of work piece material and turbulent flow of abrasive may improve the cutting action.
- Maximum MRR observed at 10 bar pressure, 100° C temperature of abrasive, and speed of mixing chamber at 200 RPM. Whereas the SR is found maximum at 10 bar pressure, 100° C temperature of abrasive, and 150 RPM of mixing chamber.

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