Study on Advanced Approaches in Abrasive Jet Machining (AJM)

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Abstract

Abrasive Jet Machining (AJM) can be used for achieving highly accurate, sharp edges and precisely sized components for space, missile and nuclear industries. Abrasive Jet Machining (AJM) is an advanced machining process requiring low capital cost and operational cost because the investment cost on various equipments is less as compared to other non-traditional machining process. Abrasive Jet Machining (AJM) provides a better surface finish. In this paper, the extensive review and development on the Abrasive Jet Machining (AJM) are studied.

Keywords: Abrasive Jet Machining (AJM), Material Removal Rate (MRR), Stand-off distance (SOD), Kerf, Surface finish.

1. INTRODUCTION

In Abrasive Jet Machining (AJM), abrasive particles are made to impinge on the work material at a high velocity. The jet of abrasive particles is carried by carrier gas or air. The high velocity stream of abrasive is generated by converting the pressure energy of the carrier gas or air to its kinetic energy and hence high velocity jet. The nozzle directs the abrasive jet in a controlled manner onto the work material, so that the distance between the nozzle and the work piece and the impingement angle can be set desirably. The high velocity abrasive particles remove the material by micro-cutting action as well as brittle fracture of the work material.

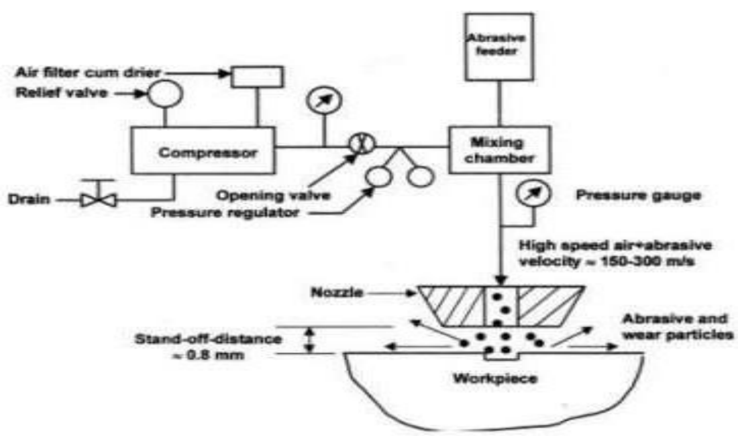

Fig. 1 Schematic representation of AJM

AJM is different from standard shot or sand blasting, as in AJM, finer abrasive grits are used and the parameters can be controlled more effectively providing better control over product quality. In AJM, generally, the abrasive particles of around 50 μm grit size would impinge on the work material at velocity of 200 m/s from a nozzle of I.D. of 0.5 mm with a stand-off distance of around 2 mm. The kinetic energy of the abrasive particles would be sufficient to provide material removal due to brittle fracture of the work piece or even micro cutting by the abrasives.

2. LITERATURE REVIEW

Dr. A. K. Paul et al.[1] carried out the effect of the carrier fluid (air) pressure on the MRR and the material removal factor(MRF) have been investigated experimentally on an indigenous AJM set-up developed in the laboratory. Experiments are conducted on Porcelain with silicon carbide as abrasive particles at various air pressures. It was observed that MRR has increased with increase in grain size and increase in nozzle diameter. The dependence of MRR on stand-off distance reveals that MRR increases with increase in SOD at a particular pressure. Dr. M. Sreenevasa Rao [2] reviewed that Ingulli C. N. (1967) was the first to explain the effect of abrasive flow rate on material removal rate in AJM. Along with Sarkar and Pandey (1976) concluded that the standoff distance increases the MRR and penetration rate increase and on reaching an optimum value it start decreasing. J. Wolak (1977) and K. N. Murthy (1987) investigated that after a threshold pressure, the MRR and penetration rate increase with nozzle pressure. The maximum MRR for brittle and ductile materials are obtained at different impingement angles. For ductile material impingement angle of 15-20 results in maximum MRR and for brittle material normal to surface results maximum MRR.X. P. Li et al. [3] stated that during cutting of work piece, reinforcement particles made impact on surface of the work which causes wear of work specimen. These particles get dislodged in material surface. It is reported that pressured air approach minimizes the tool wear and also prevent of particles from being embedded in work piece. Experimental tests for cutting of SiC-Al has been carried out with tungsten carbide tool with or without the aid of the pressured air jet are conducted. It shows that pressured air jet method significantly minimize the wear of work piece. A. Ghobeity et al. [4] have experimented on process repeatability in abrasive jet machining. They mentioned that many applications have several problems inherent with traditional abrasive jet equipment. Poor repeatability in pressure feed AJM system was traced to uncontrolled variation in abrasive particle mass flux caused by particle packing and local cavity formation in reservoir. Use of mixing chamber improved the process repeatability. For finding out process repeatability they measured depth of machined channel A. Ghobeity et al. [5] stated that particle distribution can greatly affect the shape and depth of profile. Analytical model has developed with by considering the particle size distribution. It results that if particle size distributed uniformly it helps to maintain uniform velocity of abrasive jet which causes improvement in MRR. A. El-Domiaty et al. [6] did the drilling of glass 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. The large diameter of the nozzle lead to the more abrasive flow and which lead to more material removal rate and lower size of abrasive particle lead to the low material removal rate. They have introduced an experimental and theoretical analysis to calculate the material removal rate.

3. EXPERIMENTAL PROCEDURE

The toughened glass was used to calculate the Material Removal Rate (MRR) at different pressure, angle and abrasive mesh size. The glass work-piece is rectangular in shape. The Machining Time is 6 sec. The MRR is calculated by using the formula:

$$MRR = \frac{\text{(intial weight- final weight)}}{\text{machining time}}$$

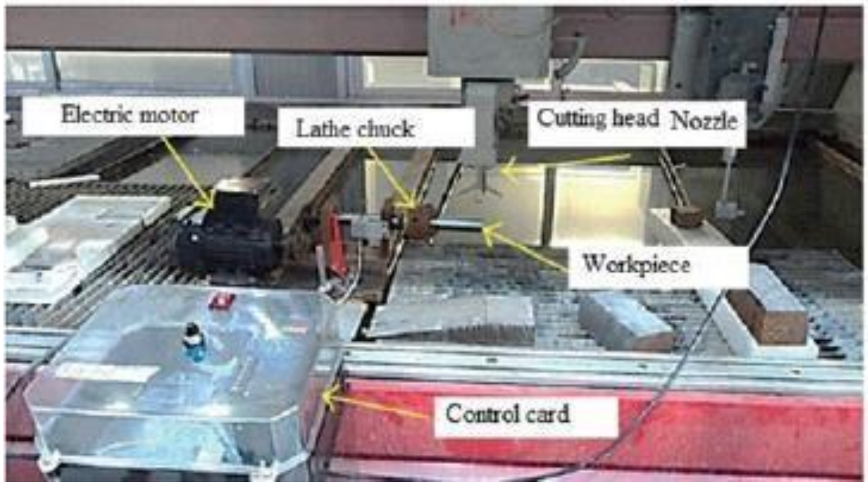

Fig. 2 Experimental Setup

Total nine experiments were conducted using different parameters. Taguchi L9 Orthogonal array was used for obtaining the optimal solution to the problem.

Table: 1 Various Process Parameters in AJM

Parameter	**Coding**	**Levels**		
		1	**2**	**3**
Pressure (kg/cm^2)	A	6	8	10
Angle b/w nozzle jet and work-piece	B	50^0	30^0	0^0
Abrasive mesh size	C	1100	600	420

The mass flow rate of abrasive (15 gm/min) entering the chamber depends on the amplitude of vibration of the sieve and its frequency. The abrasive particles are then carried by the carrier gas to the machining chamber via an electro-magnetic on-off valve. The machining enclosure is essential to contain the abrasive and machined particles in a safe and eco-friendly manner. The machining is carried out as high velocity (200 m/s) abrasive particles are issued from the nozzle onto a work piece traversing under the jet.

Table: 2 Material Removal Rate (MRR) of Taguchi L9 Orthogonal Array

Exp. No.	A	B	C	MRR (gm/sec.)
1	1	1	1	0.0033
2	1	2	2	0.0048
3	1	3	3	0.0083
4	2	1	2	0.0085
5	2	2	3	0.0102
6	2	3	1	0.0095
7	3	1	3	0.0125
8	3	2	1	0.0112
9	3	3	2	0.0147

In AJM, air is compressed in an air compressor and compressed air is used as the carrier gas. Gases like CO_2, N_2 can also be used as carrier gas which may directly be issued from a gas cylinder.

The important machining characteristics in AJM are:

a. MRR
b. The Machining accuracy
c. The life of nozzle

Generally oxygen is not used as a carrier gas. The carrier gas is first passed through a pressure regulator to obtain the desired working pressure. The gas is then passed through an air dryer to remove any residual water vapour. To remove any oil vapour or particulate contaminant the same is passed through a series of filters. Then the carrier gas enters a closed chamber known as the mixing chamber. The abrasive particles enter the chamber from a hopper through a metallic sieve. The sieve is constantly vibrated by an electromagnetic shaker.

A double-acting single cylinder, air compressor of 1 hp and electric motor with working pressure of 10 kg/cm^2 is connected for supplying continuous high-pressure air to act as working fluid medium for AJM. The compressed air then passed through the air filter-regulator-lubricator (FRL) or dehumidifier unit to prevent any agglomeration and clogging of abrasives at the exit of the nozzle. The nozzle is properly designed and manufactured by the high carbon and high chromiumcontainedD2 steel possessing with high wear and abrasion resistance.

Assumptions

(i) uniform mixing of abrasiveswith the compressed air inside the fluidized bed,
(ii) availabilityof homogeneous mixture at the nozzle exit,
(iii) normalposition of the nozzle with respect to work-piece to reducenozzle wear,
(iv) each abrasive particle is a multipoint cuttingtool with sharp edges having excellent flow characteristics,
(v) restriction of reuse of the abrasives and
(vi) negligible effect ofmachine vibration, are considered in this experimental work.

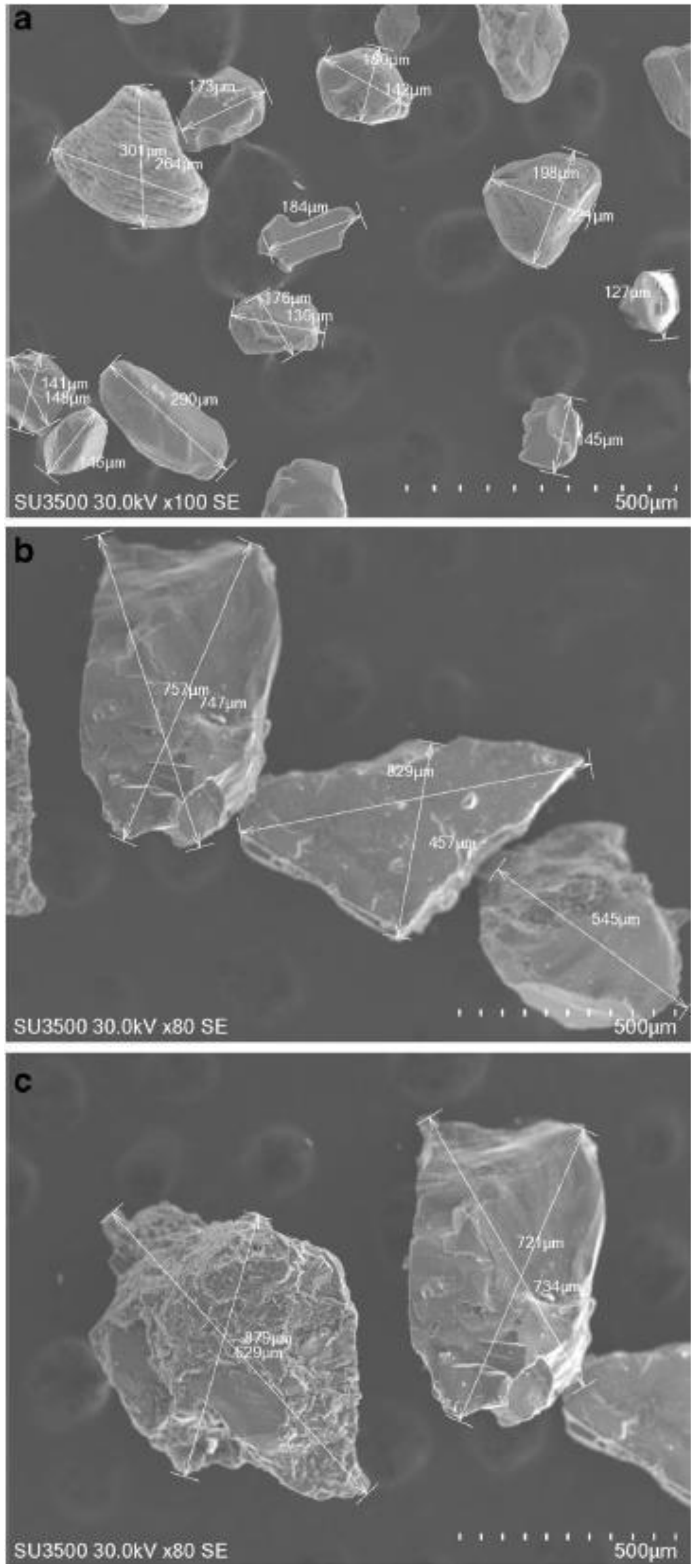

Fig. 3 SEM images of abrasive grains of different size

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4. RESULTS AND DISCUSSION

The MRR increases with increasing the pressure and with decrease in angle and abrasive grain size. The MRR is directly proportional to the pressure. Using the Signal to Noise ratio (S/N ratio), the response variation is studied. The MRR was taken as a quality characteristic using the concept of "larger-the-better".

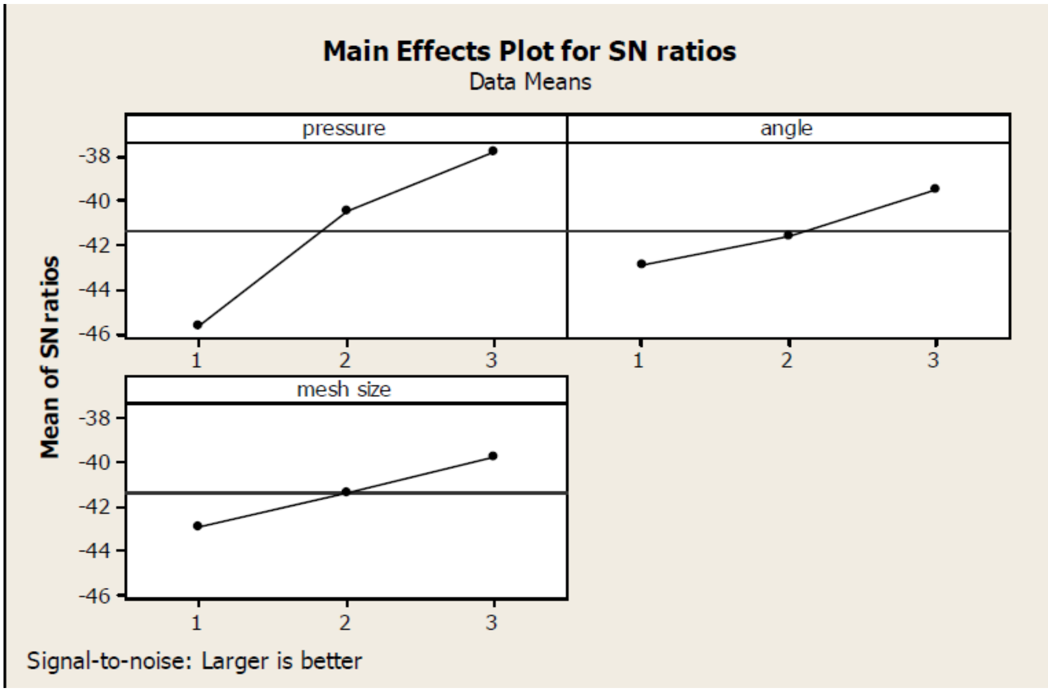

Fig. 4 Graph showing S/N Ratio, Larger is better

5. CONCLUSION

In the study, it has shown that increasing the nozzle feed rate and stand-off distance results in improved surface roughness. The increase in pressure and abrasive flow rate results in improved MRR. It is quite possible to reduce noise and vibration problem in AJM. The spindle speed and abrasive flow rate have an impact on material removal volume affecting the machining depth during AJM. With the decrease in abrasive grain size, the surface roughness decreases. However, with the increase in machining time, the surface roughness decreases significantly. The improper mixing chamber construction causes various problems such as humidification, noise and vibrations resulting in decrease in machining efficiency.

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