A Detailed Report on Process Parameters of Material Removal Rate in Abrasive Jet Machining

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Abstract - **This report reviews the effect of process parameters in AJM on the MRR of the process. The report also discusses various ongoing researches and developments in AJM process parameters. Report compiles several research papers presented by various researchers and their findings. It is identified from the available literature Gas pressure, Nozzle tip distance, grain size of the Abrasive.**

Keywords: Abrasive Jet Machining, Process Parameters, Material removal rate.

I. Introduction

Abrasive jet machining works on the principle that, when a stream of abrasive is carried in a medium of gas forced through a nozzle impinges on the work piece surface at a high velocity, material can be removed from the workpiece. Material removal occurs due to the erosion of the surface caused by the abrasives impacting the work surface at very high speed. The flowing gas carries away the abrasives along with the fractured bits from the work surface resulting in a smooth and a fine surface finish. Intricate and complex shapes in hard and brittle materials which are hard to machine by conventional machining, which are sensitive to heat, which are inaccessible by ordinary machining methods, which have a tendency to chip easily can be machined efficiently and easily using abrasive jet machining process. This makes the process suitable for machining under these circumstances.
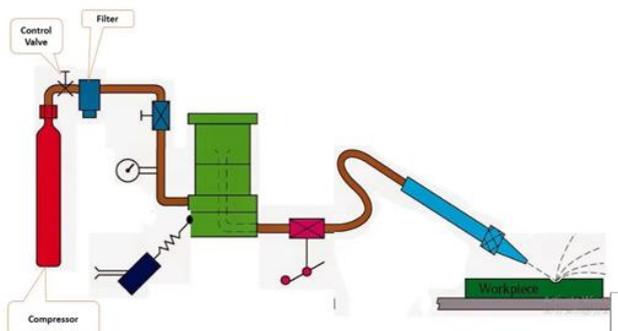

Figure 1: Abrasive Jet Machining

II. Literature Review

In this section, we discuss several research papers presented by researchers and scientists based on the experimental data obtained from various experiments performed on abrasive jet machining. Our main focus is the research papers that provide knowledge about the effects of important process parameters on material removal rate in abrasive jet machining. Several scientists and researchers have attempted to explore this area and some of their work is discussed below:

Venkatesh (1984) performed on an abrasive jet unit designed and developed in Singapore to report the effect of feed rate, pressure, spray angle, nozzle tip distance, and abrasive grit size on material removal rate. After the experiment, he concluded that for the given conditions feed rate must be 0.3 mm/s, pressure 6.5 bars, grit size 60 microns, spray angle 60, nozzle tip distance 10 mm for an optimum material removal rate of 10 mg/min.

Paul et al (1987) documented the results of a study on the effect of change input parameters on material removal rate performed on an AJM unit with vortex type mixing chamber. It was observed that in this kind of setup, suitable operating pressure is 3kgf/cm^2 and a higher standoff distance. In precision work a higher pressure and a lower standoff distance can be used for higher accuracy and penetration rate.

Ghobeity et al (2009) developed an analytical model to estimate effect on erosive efficacy in abrasive jet machining of substances. Erosive efficacy is estimated as a function of the abrasive particle size distribution and the width of the mask opening. The model demonstrated that both the average particle size and uniformity of the particles can affect the erosive efficacy of the AJM.

Yan (2014) designed and developed a set of constrained abrasive jet polishing equipment to verify the feasibility and validity of AJM. A series of polishing experiments acting on K9 optical glass and it was concluded that the three process

parameters in descending order of effectively are fluid jetting velocity, minimum machining gap and fluid jetting angle.

Massimiliano et al (2005) performed a thorough experiment on fluidized bed abrasive jet machining to investigate the influence of operating parameters on surface roughness and material removal rate. It was observed that minimum jet velocity of 12.5 m/s is required to efficiently machine the material. By using a smaller abrasive a relevant improvement in surface roughness is achieved.

Fan et al (2008) developed predictive mathematical models to assess the erosion rates in micro hole drilling using AJM by dimensional techniques. And these models were checked for their predictive abilities using an experimental investigation which observes the effect of common parameters such as air pressure, abrasive mass flow rate, and standoff distance and machining time. The experiment confirms that all the predictions are similar to the experimental real world results.

Moktadir et al (2005) presented an analytical model to represent the erosion rates in powder blasting of brittle materials with sharp materials. The model was developed by introducing surface energetic as the relaxant into a continuum equation which describes the surface evolution. Experiments were performed to verify these obtained results and it was observed that the results obtained matched very well with the model results. The model also explains the reason for the side walls of a powder blasted channel not being straight (blast lag). Experimental blast lag was also in good with the theoretical results.

III. Operation

In AJM, air is compressed to a high pressure in a compressor and compressed air at a pressure of around 5-7 bar is forced through a nozzle for material removal. The above figure shows the other important parts of the AJM equipment. Gases like Carbon dioxide, Nitrogen can be used as carrier gas which may directly be taken from a gas cylinder. Generally O_2 is not used as a carrier gas due to its oxidizing properties. The appropriate carrier gas is first forced through a regulator to attain the high pressure required for efficient material removal. Then the gas is made to pass through a series of special purpose filters to remove all contaminants and unnecessary components.

The abrasives pass through a metallic sieve before entering in to the chamber. The sieve is set to vibrate at a high frequency using an electromagnetic shaker. The abrasive mass flow rate varies with the frequency and amplitude of the vibration of the sieve. Then the abrasives are carried within the carrier gas into the machining chamber through an electro-magnetic on/off valve. The strength of the machining enclosure is very important to store or contain the abrasives and the machined bits and particles in a safe and eco friendly manner. The material is removed by the impulse force exerted on the surface of the work piece by the striking of the high velocity abrasives from the nozzle.

1.1 Process Parameters and Machining Characteristics

The process parameters are listed below:

1.1.1 Material of the abrasives – Al2O3 / SiC / glass beads

> Shape – irregular / spherical
> Size – 10 ~ 50 μm
> Mass flow rate – 2 ~ 20 gm/min

1.1.2 Carrier gas

> Composition of carrier gas Air, Carbon dioxide, Nitrogen
> Density of air should be 1.3 kg/ m
> Velocity of carrier gas range 500 to 700 m/s
> Carrier gas Pressure – 2 to10 bar
> Carrier gas Flow rate – 5 to 30 lpm

1.1.3 Abrasive Jet Velocity – 100 to 300 m/s

1.1.4 Mixing ratio – Ratio of mass flow of abrasive to mass flow of gas

1.1.5 Stand-off distance from the work piece 0.5 to 5 mm

1.1.6 Impingement Angle on the work piece – 60° to 90°

1.1.7 Material of the nozzle – WC / sapphire

> Internal diameter 0.2 to 0.8 mm
> Life of nozzle – 10 to 300 hours

The essential machining properties in Abrasive Jet Machining are:

- Rate of material removal/min or gm/min
- Accuracy of machining
- Life of nozzle material

1.2 Effect of process parameters MRR

Parameters of AJM are factors that affect its Metal Removal Rate. In a machining process, the volume of material removed from a given work piece in unit time is called Metal Removal Rate.

The most essential process parameters of AJM are:

1. Mass flow rate of abrasive particles.
2. Nozzle tip distance from the work piece.

3. Pressure of gas used.
4. Velocity of abrasive particles in carrier gas.
5. Mixing ratio of carrier gas.
6. Grain size of the abrasive particles.

1.2.1 Mass flow rate of abrasive particles

Mass flow rate of the abrasives is one of the major parameters that control the MRR in AJM. In AJM, when mass flow rate in continuously increased, MRR first reaches a peak value (due to increase in the number of abrasives striking the work piece at a time) and then reduces gradually.

1.2.2 Nozzle tip distance from the work piece

NTD is the distance maintained between the nozzle tip and the surface of the work piece during AJM operation. Up to a certain max value, MRR increases along with the increase in NTD. But after that limit has been reached, MRR remains unchanged with further change in NTD up to an extent and then decreases. In addition to MRR, NTD also affects the shape and diameter of cut in AJM. For most efficient cut an NTD of 0.25mm to 0.75mm is advised.

1.2.3 Pressure of gas used

With change in pressure of the carrier gas the MRR also changes in AJM. With increasing pressure the MRR also increases. There is a direct change in MRR with change in pressure.

1.2.4 Velocity of abrasive particles in carrier gas

As the velocity increases of abrasive particles leaving the nozzle increases, the force with which the particles strike the surface of the work piece also increases. Therefore MRR is directly proportional to the velocity of abrasives.

Figure 2: Effect of process parameters on MRR in AJM process

1.2.5 Mixing ratio

Mixing ratio is a parameter for the quality of the air-abrasive mixture in AJM. It is the ratio between the abrasive mass flow rate and the air mass flow rate. As the missing ratio increases, MRR first reaches a max value and then decreases gradually.

1.2.6 Grain size of the abrasive particles

Size of the abrasives is a parameter for determining the speed at which metal can be removed from the surface. For smooth finish or surface finishing operation a smaller grain size is recommended and for rough finish or for removing material rapidly larger grain size is recommended.

IV. Conclusions

A wide range of experiments and research data from various authors have been included and compiled in this detailed review on the effects of process parameters of abrasive jet machining on MRR. It can be concluded that a tremendous amount of research, experiments and analysis has been conducted in this field to improve the MRR. It is to be observed that majority of the research have focused on the effects of nozzle diameter, abrasive particle size and stand of distance (SOD). Some research has also focused on the pressure, velocity and carrier gas selection for optimum performance.

From the amount of research and effort put into this particular section of non-traditional machining, it is to be understood that to fully understand the relationship between the process parameters and the process output, several factors have to be taken into consideration and these factors must be optimized to a higher level to obtain the highest level on accuracy, tolerance and surface finish. There is still scope of improvement in this field and further research can definitely help in increasing the MRR to the highest possible value.

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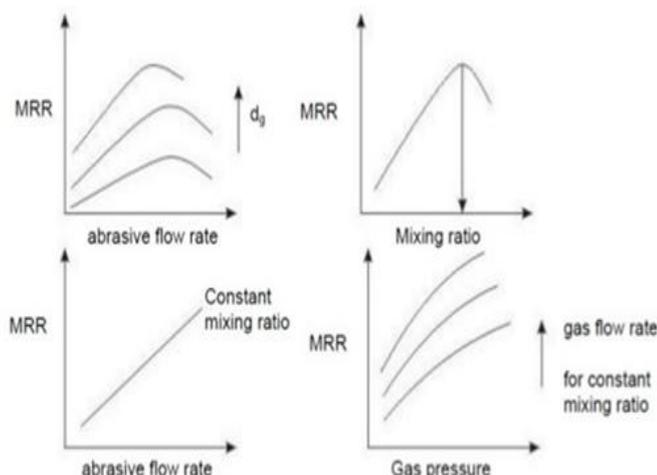[4] Yan, Zhu "Study on processing characteristics of constrained abrasive jet polishing" *IEEE*-2014.

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