Literature Review on Abrasive Jet Machining

Pratik Lande[1], Anurag Karande[2]

[1] Asst. Professor, Department of Mechanical Engineering, RGCER Nagpur, Maharashtra, India.
[2]Asst. Professor, Department of Mechanical Engineering, JIT Nagpur, Maharashtra, India.

ABSTRACT

The abrasive jet machining is an effective non-traditional machining process wherein material removal is effected by the erosive action of a high velocity jet of a gas, carrying fine-grained abrasive particles, impacting the work surface for variety of materials. With the increase of needs for machining of ceramics, semiconductors, electronic devices and L.C.D., AJM has become a useful technique for micromachining. The study shows that the AJM process the material removal rate is greatly influenced by certain parameters such as nozzle design, standoff distance, velocity and pressure of jet, shape and size of abrasive particle. This paper gives an overview of previously carried research on process parameters and development of Abrasive Jet Machining and Abrasive Water Jet Machining. Further challenges and scope of future development in abrasive jet machining are also projected.

Keyword : - *Abrasive jet machining, Abrasive Water Jet Machining, Material Removal Rate (MRR), Stand-off distance (SOD)*

1. INTRODUCTION

The abrasive jet machining process is a non -traditional machining process which operates without much shock and heat. Abrasive jet machining is used for variety of operations like cutting, cleaning, and etching operation. In the Abrasive jet machining process, the abrasive particles are made to strike on the work material at high velocity. A high velocity jet of abrasive particles is carried by a pressurized stream of compressed air. The high velocity of abrasives particles is obtained by converting the pressure energy of compressed air to its Kinetic energy . The nozzles direct abrasive jet in a controlled way onto the work material. The high velocity abrasive particles strikes the surface of the material and remove the material from the work piece by micro-cutting action as well as brittle fracture of the work material. Certain process parameters affects the performance of the AJM such as particle size, shape, pressure of air, stand -off distance, jet velocity, jet diameter, nozzle shape, nozzle distance etc. Various process parameters and are discussed in literature review.

2. BACKGROUND

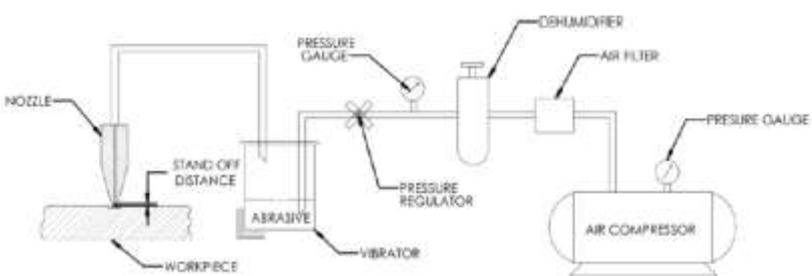


Fig -1: Schematic of AJM

This technology was first invented by Franz to cut laminated paper tubes in 1968 and was first introduced as a commercial system in 1983.In the 1980s garnet abrasive was added to the water stream and the abrasive jet was born. In the early 1990s, water jet pioneer Dr. John Olsen began to explore the concept of abrasive jet cutting as a practical alternative for traditional machine shops. His end goal was to develop a system that could eliminate the noise, dust and expertise demanded by abrasive jets at that time. In the last two decades, an extensive deal of research and development in AJM is conducted. A lot of research has been carried out by different authors and have considered various process parameters which affects the process of AJM such as MMR ,SOD , air pressure, abrasive type, size etc. This paper is based on the extensive literature review of AJM process parameters.

3. LITERATURE REVIEW

D V Srikanth ,Dr. M. Sreenevasa Rao [1] reviewed that Ingulli C. N. (1967) [2] 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 15-20results in maximum MRR and for brittle material normal to surface results maximum MRR.

Verma A.P. & Lal G,K. (1984) [3] concluded that the depth of erosion by abrasive He concluded that both material removal rate as well as penetration rate depend on stand-off distance, mixture ratio, pressure and grain size. The maximum values of material removal rate and penetration rate are obtained at different values of stand-off distance. The maximum value of penetration rate appears to occur where the particle velocity is maximum, while the maximum material removal rate occurs due to the combination of particle velocity and impingement area. Increase in mixture ratio causes increase in material removal rate as well as penetration rate.

Neema & Pandey (1977) [4] proposed an equation for material removal rate by equating the kinetic energy of the particles impinging on to the work of
deformation during indentation.

$$Q = k\ N\ d^3 v^{3/2} (Þa/12\sigma y)$$

Where k is a constant; N is the number of abrasive particles taking quite a time; d= the size or diameter of an abrasive particle; fa= the density of the abrasive material; v= the velocity of the abrasive particle; and 9 y, =the yield stress of the work material.

Varun R & Dr. T S Nanjundeswaraswamy [5] that Venkatesh, (1984) carried out Parametric Studies on Abrasive Jet Machining using experimental approach and studied the effects of feed rate, spray angle, pressure, abrasive grain grit size, SOD and material removal rate. Ordinary optical and toughened glass specimens were machined using aluminium oxide and silicon carbide powder. These specimens were easily machined using AJM, but in case of toughened glass, only compressive layers could be machined, i.e. drilling a hole was not possible. Severe wear was observed at the exit nozzle, whereas wear was considerable in the mixing chamber and almost negligible in the inlet nozzle.

Dr. A. K. Paul &R. K. Roy.[6] 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.

R. Balasubramaniam J. Krishan, N. Ramakrishnan. [7] stated that as the particle size increases, the MRR at the central line of the jet drastically increases; but the increase in MRR nearer to the periphery is very less. As the stand-off distance increases the entry side diameter and the entry side edge radius increases, Increase in stand-off distance also increases MRR. As the central line velocity of jet increases, the MRR at the central line of the jet drastically increases. But there is no increase in MRR nearer to the periphery of the jet. The increase in entry side diameter and edge radius is not significant. As the peripheral velocity of the jet increases, the edge radius and entry side diameter increase. It also increases the MRR.

Dr. M. Sreenivasa Rao [8] focused on exploring the effect of material thickness on drilling in drilling time using abrasive jet machining using glass, ceramics, fibre sheets due to their brittleness where these are difficult to machine by conventional methods. Over each material samples holes of different sizes were generated. He observed that drilling time is non-linearly related to material thickness and he machinability of the material significantly influences the time to drill a hole of specified size . He also concluded that the width of cut decreases on decrease in SOD and the drilling time increases with the increment of Kerf.

M. Wakuda , Y. Yamauchi , S. Kanzaki [9] carried out experiments with different abrasive size, on various ceramic material and concluded that the micro cracks produced on the ceramic surface did not propagate throughout the material this leads to the conclusion that the AJM process has great potential as a damage free machining process which leads precise control over the machining process.

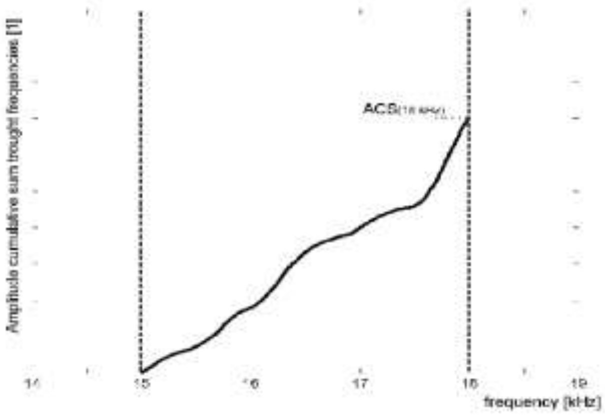
M. Wakuda , Y. Yamauchi , S. Kanzaki [10] gave the response of the material for various commercial abrasive like WA, GC and SD abrasive.
WA abrasive had insufficient hardness to dimple the alumina ceramics. The impingement by WA grits produced minute defects, each of which has a size equivalent to that of the impacting abrasive. WA abrasive grit has no potential for AJM of alumina ceramics.
AJM with GC abrasive successfully produced smooth-faced dimples, although it has relatively low material removal rates. The material response to the abrasive impacts indicated a ductile behavior, which was elevated temperature during machining. SD abrasive had high machining efficiency but has relatively rough appearance and irregular cracks.

R Balsubramainam, J Krishnan, N Ramakrishnan [11] have carried out research on the shape of the surface produced by AJM. The changes were observed on the entry size and the process parameters were varied. The MRR increases at the centerline of the jet and is negligible at the periphery. Increase in standoff distance increases the MRR. MRR increases as increase in the jet line velocity but only at the center.

A.A. Khan∗, M.M. Haque [12] gave the comparative analysis of the performance of garnet, aluminum oxide and silicon oxide during abrasive water-jet machining of glass. The authors concluded that taper of cut increases with increase in SOD. Garnet abrasives produced a larger taper of cut followed by $Al_2O_3$and SiC. Taper of cut also increased with increase in work feed rate and reduces with increase in pressure. The increase in feed rate reduced the average width of cut since the surface to be cut was exposed to the jet for a shorter time. The cutting ability of SiC is greater than Al_2O_3 and Garnet.

Huaizhong Li investigated [13] the resolution of the flow field and the description of physical interactions between the carrying and abrasive media with the help of CFD analysis to understand the dynamic characteristics of high speed abrasive air jet. The predicted particle velocity was improved for increase in sharpness of the abrasive media from from φ=1toφ= 0.6 which was compared to the measured velocities along the jet centre line axis.The particle shape i.e. sphericity did not significantly influence the flow field of the air jet.

Jurisevic, B., Brissaud, D., & Junkar, M. (2004) [14] used the sound detection method for the monitoring AJM. The authors observed attributes of the emitted sound (the RMS value of the sound signal in the time domain and the ACS of the signal power spectra in the frequency domain) with standoff distance. The RMS value increases when the stand-off distance increases.as shown in fig below for the work piece having thickness 6.1 mm



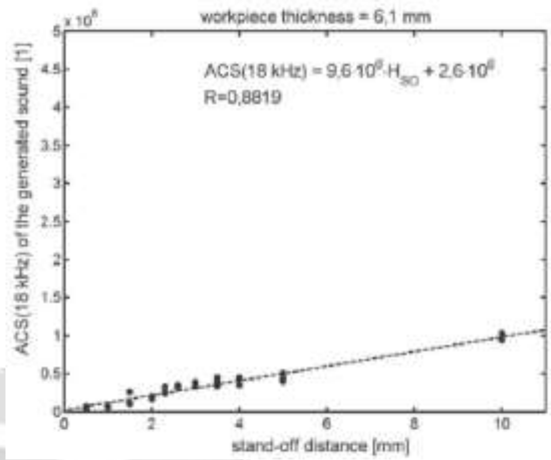


Chart-1: ACS values at the upper edge frequency area.

Chart-2: Mean and Max ACS for work of the observed piece thickness 6.1 mm

4. CONCLUSIONS

A substantial review of the research and development in AJM is presented in this paper. There is great scope on material behavior to determine optimum values of crucial governing parameters like stand-off distance, pressure and feed rate for a variety of materials. Nozzle design can be optimized for faster production. A wide range of experimental investigation can be performed to understand the relationship between various process parameters.
There is much scope of research in AJM to study the effect of abrasive particle size, shape, hardness and abrasive flow rate. The Optimized models can be developed by using various optimization techniques.

5. ACKNOWLEDGEMENT

The authors hereby thank the authors of the below mentioned references for their valuable contribution which enabled us to make this comparison.

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