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Modeling and Fabrication of Abrasive Jet Machining

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Abstract - *Abrasive jet machining (AJM) is that the one among the fashionable machining process in various industries for difficult to machine materials. AJM is a non-conventional machining process in which removal of material takes place by impact of high speed stream of abrasive particles carried in gas or air medium from a nozzle. The AJM is competitively used to cut different shapes in hard and brittle materials like glass, ceramics, metals etc. The different components of AJM like nozzle, vibrator, pressure regulator, and mud filter, mixing chamfer are fabricated with appropriate design calculations. In AJM turning operation are often through with the assistance of motor, spindle and chuck arrangement by moving the nozzle in linear direction.*

Key Words: AJM (Abrasive Jet Machining), Material Removal Rate (MRR), Stand Off Distance (SOD), Abrasives, Filter.

1. INTRODUCTION

Abrasive Jet Machining (AJM) is that the removal of fabric from a piece by the appliance of a high speed stream of abrasive particles carried in gas medium from a nozzle. The AJM process is different from conventional sand blasting by the way that the abrasive is far finer and therefore the process parameters and cutting action are both carefully regulated. The method is employed chiefly to chop intricate shapes in hard and brittle materials which are sensitive to heat and have a bent to chip easily. The method is additionally used for drilling, de-burring and cleaning operations. AJM is fundamentally free from chatter and vibration problems thanks to absence of physical tool. The cutting action is cool because the carrier gas itself is a coolant and takes away the warmth.

Abrasive jet machining (AJM), also called as abrasive micro-blasting, pencil blasting and micro-abrasive blasting, [1] is an abrasive blasting machining process that uses abrasives propelled by a high velocity gas to erode material from the work piece. Common uses include cutting heat-sensitive, brittle, thin, or hard components and various materials. Specifically it's wont to cut intricate shapes or form specific edge shapes.

2. LITURATURE REVIEW

Harsh Pandey(2018) presented various issues observed in abrasive jet machining on composite fiber reinforced polymer (CFRP) material and the effect of abrasive jet machining are analyzed in processing these Composite material. By effective design of CFRP the efficiency can be improved and the divergence of the jet can be reduced. Abrasive jet machining can be used for drilling operation of composite fiber reinforced polymer material. Experiment work was done by considering Standoff Distance and pressure are machining parameter study material removal rate and Over Cut. For material removal rate both standoff distance and pressure are significant factor and for Overcut only pressure is significant factor. Where material removal rate increases with increases in pressure. For increase in Standoff Distance first material removal rate increase than it is remain constant after that it is decreases. [1]

Kasturi Panigrahietal (2014) presented the working of abrasive jet machining on brittle material that is glass by the application of high speed stream of abrasive particles carried by a gas medium through nozzle. The drilling of glass with different thickness and varying pressure has been carried out through abrasive jet machining in order to determine its machinability. Experimental result and graph shows that pressure has a direct impact on material removal rate. Hence when pressure increases, material removal rate also increases. [2]

Jukti Prasadn Padhyetal (2010) presented the drilling experiment on glass workpeice using Aluminium Oxide as Abrasive powder. Experiment work was done by considering Standoff Distance and Pressure as a machining Parameter to study material removal rate and overcut. The effect of observed value of material removal rate and Overcut was analyzed by Taguchi design. From analysis is it was concluded that the pressure and standoff distance. Both are significant for overcut. Individual optimal setting of parameters are carried out to minimize the overcut and maximize the material removal rate. [3]

R. Balasubramaniam 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 rises the entry side diameter and the entry side edge radius rises, Increase in stand-off distance also increases MRR. As the central line velocity of jet surges, the MRR at the central line of the jet drastically surges. But there is no increase in MRR near to the periphery of the jet the increase in entry side diameter and edge radius is not significant. As the peripheral velocity increases, edge radius and entry side diameter also increases. [4]

Dr. M. Sreenevas Rao. Et al. (2014) reviewed that Inguli C. N. (1967) was the first to explain the effect of abrasive flow rate on material removal rate in abrasive jet machining. Along with Sarkar and Pandey (1976) concluded that the standoff distance increases the material removal rate and penetration rate increases and on reaching on optimum value its start decreasing. J. Wolak (1977) and K. N. Murthy (1987) investigated that after a threshold pressure, the material removal rate and penetration rate increases with nozzle pressure. The maximum material removal rate for brittle and ductile material are obtained at different impingement angles. For ductile material impingement angle of 15-20 results in maximum material removal rate and for brittle material normal to surface results maximum material removal rate. [5]

F. Anand Raju stated that as abrasives is increased that is the grit no. is increased the MRR decreases i.e. the finer the abrasive particles, less is the material removal rate. But if the pressure is increased keeping Standoff distance to optimum the MRR can be increased to some extent. If coarser abrasive is used for machining then MRR is high to a wide range of standoff distance. Also it is stated that as the standoff distance increases material removal decreases. At optimum value of standoff distance the material removal rate is maximum which decreases if the standoff distance is varied on either side of the optimum value as pressure is increased the amount of material removed also increases. Where material removal is of prime importance, there stand-off distance should be kept optimum, abrasive of coarser size should be used and high pressure should be employed. While in cases where surface finish is of prime importance low stand-off distance high pressure and finer abrasive should be used. [6]

Matthew W.Chastagner and Albert J.Shih. et al.studied AJM for edge generation, conoscopy laser for edge profile measurement, and B-spline and curve fitting methods for better representations of the developed edge. Based on the results of the AJM Inconel 718 samples, radii below 0.14 mm can be developed on 90º edge. For extended blasting times, the edge radius did not change much, but the collateral damage increased rapidly. The nozzle angle and standoff distance to the edge have proven to be important in reducing the collateral damage to the edge. For the distances and angles studied, the radius size did not appear to be dependent on distance and angle. However, the collateral damage depth increased and the distance of the damage decreased as l was decreased or as α was increased. Therefore, if small amounts of damage on adjacent surfaces are acceptable, it is best to place the nozzle away from the sample and at a specific angle. Also, a B-spline was demonstrated to have a better fit than the arc. However, how to accurately describe and quantify the edge profile is still a challenging research topic. This study indicates that a new technical challenge is in the generation of large edge radiuses. AJM has major limitation of generate large edge radius. Mechanical methods, such as brushing or grinding, with flexible supports are candidate processes to create edges with large radius. [7]

Pranav P Kulkarni, Prashant Pati et al. stated that Abrasive Jet Machining (AJM) or Micro Blast Machining is a 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. The process is particularly suitable to cut intricate shapes in hard and brittle materials which are sensitive to heat and have a tendency to chip easily. As Abrasive jet machining (AJM) is similar to sand blasting and effectively removes hard and brittle materials. AJM has been applied to rough working such as debarring and rough finishing. 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 experimental results of the present work are used to discuss the validity of proposed model as well as the other models. With the increase in nozzle tip distance (NTD), the top surface diameter and bottom surface diameter of whole rises as it is in general observation of abrasive jet machining process. As the pressure increases, the material removal rate (MRR) is also increased. [8]

Tarun Batra and Devilal et al. stated that According to the various research papers available till date, lot of work has done on abrasive particles and its geometry, different process parameters, volume of material removal during machining. An extensive review of the research and development in the AJM has been conducted in this paper. It was shown that AJM process is receiving more and more attention in the machining areas, particularly for the processing of difficult-to-cut materials. Its unique advantages over other conventional and un-conventional methods make it a new choice in the machining industry. Very less research has been done on study of effect of abrasive flow rate on performance characteristics. [9]

Md abdul Junaid, Mohammed Feroz Ahmed, Syed Fahad, Mohd Fahad Baig, Mohd Ul Haq et al. stated that the model of abrasive jet machine is fabricated. This process is used to cut plate of 2-5mm thickness. Also non-straight profiles can be machined by moving the guide way (x table). Glass fumes or powder is not produced during drilling operation. Also the surface finish obtained is better than the diamond tool. The process is non- contact, simple and clean. But, the material removal rate is low. In this project, a model of the Abrasive Jet Machine is designed using available hardware and software etc. taking into consideration of commercially available components. Care has been taken to use less fabricated components rather than directly procuring them, because, the lack of accuracy in fabricated components would lead to a diminished performance of the machine [10]

Vasu Ramu, V. Venkateshwaran, N Thirumavalavan et al. stated that Abrasive Jet Machining (AJM) is the process of material removal from a work piece by the application of a high speed stream of abrasive particles carried in a gas medium from a nozzle. The material removal process is mainly by erosion. The AJM will chiefly be used to cut shapes in hard and brittle materials like glass, ceramics etc. AJM is an effective machining process for processing a variety of Hard and Brittle Material. And has various distinct advantages over the other non-traditional cutting technologies, such as, high machining versatility, minimum stresses on the work piece, high flexibility no thermal distortion, and small cutting forces. It also known as micro-abrasive blasting. It is a mechanical energy based unconventional machining process used to remove unwanted material from a given work piece. The process makes use of an abrasive jet with high velocity, to remove material and provide smooth surface finish to hard metallic work pieces. Due to low capital investment and operative cost the AJM is compatible to other advanced manufacturing processes. In future with slight modifications, AJM will become an important machine tool on shop floor. [11]

3. METHODOLOGY

For manufacturing of abrasive jet machining setup it is required to calculate the diameter of a nozzle and striking velocity. After calculating the diameter and the striking velocity the components are procured according to the design of components are then mounted on the fabricated frame previously. The frame is to be fabricated according to size and shapes of the component. Once the setup is ready then the testing of the setup will be taken and then the system will be validated and upgraded according to the results. Fig. 1 shows the methodology procedure.

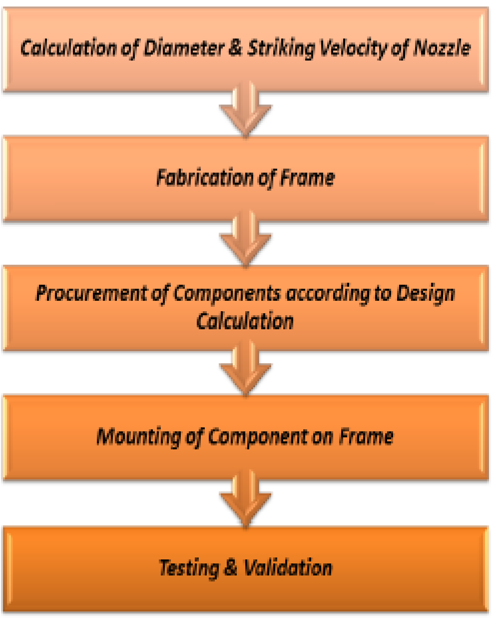

Fig -1: Methodology

4. DESIGN AND VALIDATION WORK

Design of Nozzle

For maximum transmission of power, the diameter of nozzle is given by,

$d = [D^3/8FL]^{1/4}$

Where,

Length of Pipe (L) =5m

Diameter of Pipe (D) =0.005m

Coefficient of Friction (F) =0.01

d=0.001762m=1.762mm

Dimensions of nozzle is shown in Fig. 2

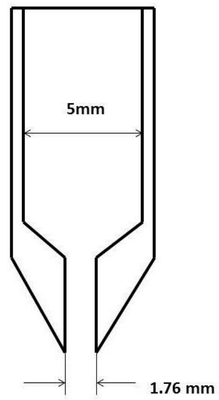

Fig -2: Dimensions of Nozzle

The velocity at outlet of nozzle is given by,

$V=\sqrt{(2gh/(1+4FLa^2/DA^2))}$

v=161.8m/s {Approx. 150-300m/s}

Nozzle Material: - Tungsten Carbide

Available Abrasives: - Silicon Carbide, Aluminum Oxide, Boron carbide, Sand

Stand of Distance: - 0.25 to 15 mm

Design of Mixing Chamber

The required amounts of abrasives are supplied during a mixing chamber. Filleted Propellant is fed into the blending chamber where in abrasive particles are fed through a sieve. Sieve is formed to vibrate at 50-60Hz and mixing ratio is controlled by the amplitude of vibration of sieve. Configuration of mixing chamber is shown in Fig.3

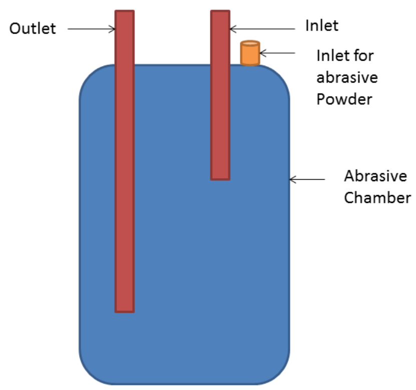

Fig -3: Mixing Chamber

The high air from the compressor is skilled a FRL unit to get rid of any impurities. Then it's fed to the abrasive chamber which has one inlet for the incoming compressed gas and outlet for mixture of abrasive particles and air. The abrasive particles are introduced from the side so to make a cyclone to facilitate better mixing. The chamber is of cylindrical shape made from mild steel.

Density of Abrasive: 1.3gm/cc

Assume, 100gm abrasive particle stored in hopper.

Volume of Cylinder= Mass of abrasive particles/Density of Abrasive particles

=100/1.3
V =76.92cc

5. CONCLUSIONS

- During this project, an entire model of abrasive jet machine is fabricated. Before fabrication an entire CAD model was prepared for optimum use of fabric and space. Most of the components are made locally and complicated parts which affect the accuracy greatly are procured from outside. After fabrication the testing of the setup is administered and setup is validated.
- The effect of Process Parameters (i.e. Abrasive flow, Standoff Distance) on the Operating Characteristics like Material Removal Rate, Mixing Ratio is validated on the fabricated Abrasive Jet Machining setup.
- The Abrasive Jet Machining setup is tested for cutting of brittle material (glass) and located applicable for cutting with good accuracy.
- The Abrasive Jet Machining setup is additionally tested for cutting in intricate shaped corners of work piece and located useful for purpose of cutting on intricate shaped work piece.

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