Synthesis And Analysis Of Abrasive Jet Machine For Brittle Material Machining

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Abstract

Abrasive Jet Machining (AJM) is the process of material removal from a workpiece 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. The different components of AJM are Compressor, dehumidifier, Pressure Regulator, nozzle, etc. The different components are selected after considering all the requirements for machining. In this paper, a working model of the Abrasive Jet Machine is made 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.

Keywords: Abrasive Jet Machining, Brittle material cutting, Synthesis, Analysis.

1. Introduction

Abrasive Jet Machining (AJM) is the removal of material from a work piece by the application of a high speed stream of abrasive particles carried in gas medium from a nozzle. The AJM process differs from conventional sand blasting in that the abrasive is much finer and the process parameters and cutting action are carefully controlled. The process is mainly used to cut complex shapes in hard and brittle materials which are sensitive to heat and have a tendency to chip easily. The process is also used for removing burrs from work piece and cleaning operations. AJM is inherently free from chatter and vibration problems. The cutting action is cool because the carrier gas serves as a coolant.

1.1. Equipment

A schematic layout of AJM is shown in Fig-1. The filtered gas, supplied under pressure to the mixing chamber containing the abrasive powder and vibrating at 50 c/s, entrains the abrasive particle and is the passed into a connecting hose. This abrasive and gas mixture emerges from a small nozzle at high velocity. A pressure regulator controls the gas flow and pressure.The nozzle is mounted on a fixture. The work piece is placed in front of nozzle in order to cut shapes in it. Hand operation is sometimes adequate to remove surface contaminations or in cutting where accuracy is not very critical. Dust removal equipment is necessary to protect the environment. Commercial bench mounted units including all controls, motion producing devices, and dust control equipment are available.

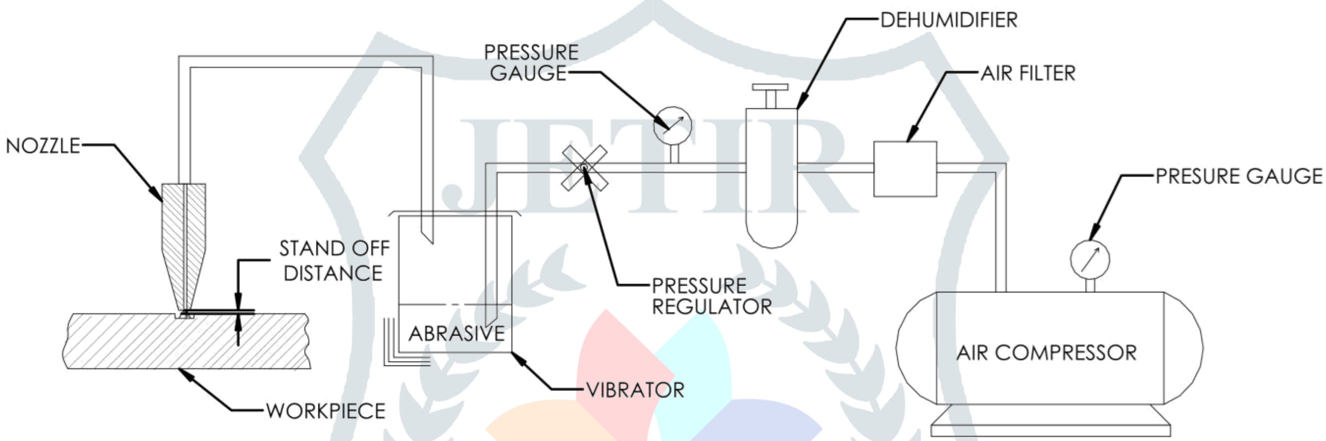

Fig-1: Schematic Layout of Abrasive Jet Machine

Table 1: Characteristics of different Variables

Medium	Air , CO_2 ,N_2
Abrasive	SiC, Al_2O_3 (of size 20μ to 50μ)
Flow rate of abrasive	3 to 20 gram/min
Velocity	150 to 300 m/min
Pressure	2 to 8 kg/cm2
Nozzle size	0.07 to 0.40 mm
Material of nozzle	WC, Sapphire
Nozzle life	12 to 300 hr
Stand-off distance	0.25 to 15 mm (8mm generally)
Work material	Non Metals like glass, ceramics, and granites. Metals and alloys of hard materials like germanium, silicon etc.

2. Related Work:

The literature study of Abrasive Jet Machine acknowledges that Machining process was started a few decades ago. Till now there has been a thorough and detailed experiment and theoretical study on the process. Most of the studies argue over the hydrodynamic characteristics of abrasive jets, hence determining the influence of all operational variables on the process effectiveness including abrasive type, size and concentration, impact speed and angle of impingement. Other papers found new problems concerning carrier gas typologies, nozzle shape, size and wear, jet velocity and pressure, stand-off-distance (SOD), or nozzle-tip-distance (NTD). These papers express the overall process performance in terms of material removal rate, geometrical tolerances and surface finishing of work pieces, as well as in terms of nozzle wear rate. Finally, there are several significant and important papers which focus on either leading process mechanisms in machining of both ductile and brittle materials, or on the development of systematic experimental-statistical approaches and artificial neural networks to predict the relationship between the settings of operational variables and the machining rate and accuracy in surface finishing.

Computational fluid dynamics (CFD) simulation of the formation and discharge process of an air-water flow in an abrasive waterjet (AWJ) head is presented by Umberto Prisco& Maria Carmina D'Onofrio. Numerical simulations have been conducted using the commercial code Fluent® 6.3 by Ansys. Dynamic characteristics of the flow inside the AWJ head and downstream from the nozzle has been simulated under steady state, turbulent, two-phase flow conditions. The final aim is to gain fundamental knowledge of the ultrahigh velocity flow dynamic features that could affect the quality of the jet, such as the velocity and pressure distributions in different parts of the AWJ head and at the outlet. Experiments have been performed on effect of jet pressure, abrasive flow rate and work feed rate on smoothness of the surface produced by abrasive water jet machining of carbide of grade P25. Carbide of grade P25 is very hard and cannot be machined by conventional techniques. The abrasive used in investigations was garnet of mesh size 80. It was tried to cut carbide with low and medium level of abrasive flow rate, but the jet failed to cut carbide since it is too hard and very high level of energy is required. Minimum rate of abrasive flow that made it possible to cut carbide efficiently was 135 g min^{-1}. With increase in jet pressure the surface becomes smoother due to higher kinetic energy of the abrasives. But the surface near the jet entrance is smoother and the surface gradually becomes rougher downwards and is the roughest near the jet exit. Increase in abrasive flow rate also makes the surface smoother which is due to the availability of higher number of cutting edges per unit area per unit time. Feed rate didn't show significant influence on the machined surface, but it was found that the surface roughness increases drastically near the jet entrance. The study of the results of machining under various conditions approves that a commercial AJM machine was used, with nozzles of diameter ranging from 0.45 to 0.65 mm, the nozzle materials being either tungsten carbide or sapphire, both of which have high tool lives. Silicon carbide and aluminum oxide were the two abrasives used. Other parameters studied were nozzle tip distances (5–10 mm), spray angles (60° and 90°) and pressures (5 and 7 bars) for materials like glass, ceramics, and electro-discharge machined (EDM) die steel. The holes drilled by AJM may not be circular and cylindrical but almost elliptical and bell mouthed. High material removal rate conditions do not necessarily yield small narrow clean-cut machined areas.

3. Design And Fabrication Of Components

3.1. Nozzle

The abrasive particles are directed into the work surface at high velocity through nozzles. Therefore, the material of the nozzle is subjected to great degree of abrasion wear and hence these are made of hard materials such as tungsten carbide or synthetic sapphire. Tungsten carbide nozzles are used for circular cross-sections in the range of 0.12-0.8 mm diameter, for rectangular sections of size 0.08 x 0.05 to 0.18 x 3.8 mm and for square sections of size upto 0.7 mm. Sapphire nozzles are made only for circular cross-sections. The size varies from 0.2 to 0.7 mm diameter. Nozzles are made with an external taper to minimize secondary effects due to ricocheting of abrasive particles. Nozzles made of tungsten carbide have an average life of 12 to 30 hours while nozzles of sapphire last for about 300 hour of operation when used with 27 μm abrasive powder.

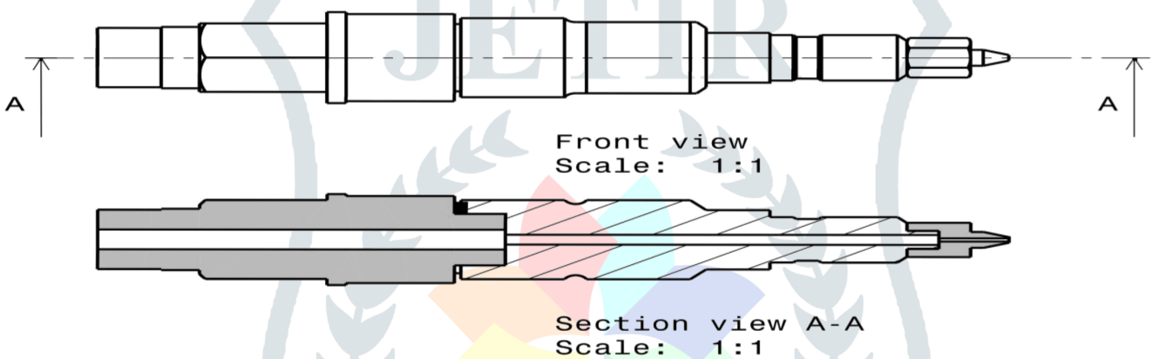

Fig 2: Nozzle

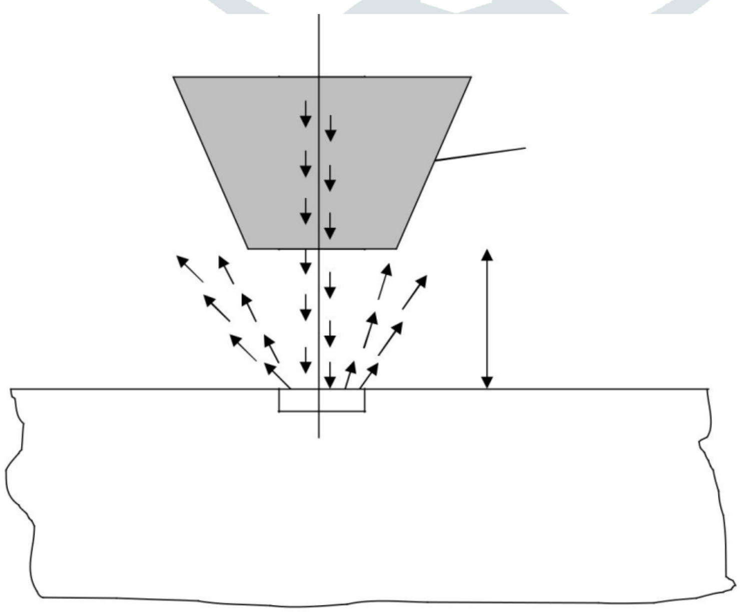

Fig 3: Abrasive action of particles

3.2. FRL Unit (Dehumidifier)

The FRL Unit (Air Filter Regulator Lubricator unit) which is otherwise called the moisture separator or dehumidifier is required for separating the moisture from air. Atmospheric air always contains some water vapour in it. As the air with high velocity is blown from the nozzle there is an abrupt rise in pressure which converts water vapour into moisture. The moisture makes the abrasive particles to agglomerate and this clogs the outlet of the Nozzle. To avoid this clogging moisture separator should be used before abrasive particles are mixed with compressed air. Different FRL Units are available commercially.

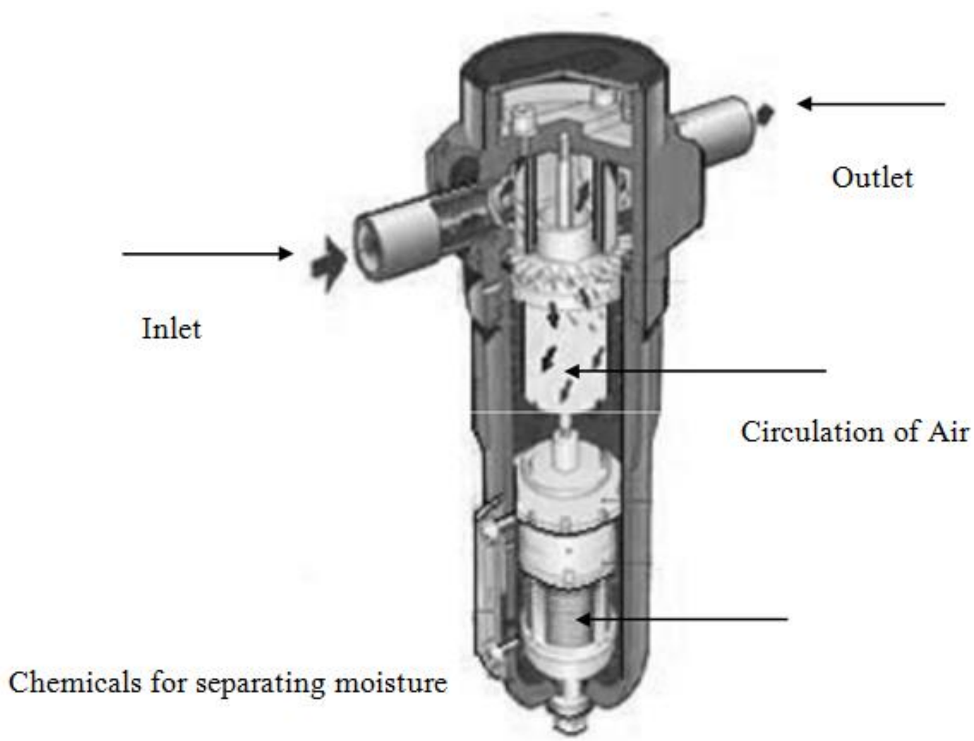

Fig 4: FRL Unit

3.3. Abrasive Container

The abrasive container was made out of a hollow cylinder. Two iron plates were welded on both ends of the container. On the top plate two holes were drilled and iron pipes were fitted with these holes. The inlet iron pipe is longer so as to make more agitation of the abrasive particles. The outlet pipe is shorter. Both the pipes are clamped with nylon pipes which carries air through them.

Fig 5: Abrasive Container

3.4. Compressor

An air compressor is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure.

Fig: 6 Air Compressor

3.5.Set-up Holder

It is designed to support all the equipments like compressor, dehumidifier, nozzle and workpiece etc. for the convenient operation during machining.

Fig 7 : Setup Holder

3.7 Total Assembly

The assembly of the abrasive jet machine can be represented as follows. It can be noted that the components like air compressor, dehumidifier and piping have been shown in the drawing.

Fig 8: View of Whole Assembly

3.8. Approximate Cost Estimation

Sl No.	Name of The Item	Cost Per Single Piece	No. of Items Required	Total Cost for Item
1.	Compressor	Rs. 8,500.00	1	Rs. 8,500.00
2	Nozzle	Rs. 1,250.00	1	Rs. 1,250.00
3	Abrasive Container	Rs. 2,50	1	Rs. 2,50
4	FRL Unit	Rs. 1,500.00	1	Rs. 1,500.00

5	Pipe	Rs. 1,000.00	1	Rs. 1,000.00
6	Angles	Rs. 1000.00	1	Rs. 1000.00
7	Other accessories			Rs. 1,500.00
Grand Total				Rs. 15,000.00

4. Conclusion

In this paper complete working model of the Abrasive Jet Machine is given. The designing and assembling of very large number of components was a tremendous task and was completed on time. However because of some parts couldn't be purchased the whole assembly was limited to drilling operation. The project can go beyond its current position and capabilities by employing automation into it. This can be done by using stepper motors or DC servo motors interfaced with standard PCI controllers or standalone controllers. 2D profiles can be converted into

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