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Fabrication of Abrasive Jet Machine

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Abstract -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 suspended in a gas medium from a nozzle. The material removal process is mainly caused by brittle fracture by impingement and then by erosion. The Abrasive Jet Machining will chiefly be used to cut shapes, drill holes and de-burr in hard and brittle materials like glass, ceramics etc. In this project, a model of the Abrasive Jet Machine was designed using CAD packages like AutoCAD and CATIA. Care was taken to efficiently use the available material and space. The machine was fabricated in the institute workshop with convectional machine tools like arc welding machine, hand drill, grinding machine using commonly available materials like mild steel sheet and rod, aluminum sheet, glue, polythene sheet, glass fiber which are commonly available in the local market. Care has been taken to use less fabricated components, because, the lack of accuracy in fabricated components would lead to a reduced performance of the machine.The different functional components of AJM are the machining chamber, work holding device, abrasive drainage system, compressor, air filter and regulator, abrasive nozzle, and mixing chamber with cam motor arrangement. The different components are selected after appropriate design calculations.

Key words- Harmonics compensation, Power quality, Reactive power, STATCOM, Synchronous reference frame theory (SRF).

I.INTRODUCTION

1. Abrasive jet machining principle

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 is different from conventional sand blasting by the way that the abrasive is much finer and the process parameters and cutting action are both carefully regulated. The process is used chiefly to cut intricate shapes in hard and brittle materials which are sensitive to heat and have a tendency to chip easily. The process is also used for drilling, de-burring and cleaning operations. AJM is fundamentally free from chatter and vibration problems due to absence of physical tool. The cutting action is cool because the carrier gas itself serves as a coolant and takes away the heat.

2. Equipment

A schematic layout of AJM is shown in Figure. The main components being the compressor, air filter regulator, mixing chamber, nozzle and its holder, work holding devices and X-Y table. Air from the atmosphere is compressed by the compressor and is delivered to the mixing chamber vie the filter and regulator. The mixing chamber contains the abrasive powders and is made to vibrate by an electric motor and cam arrangement. Then the abrasive particles are passed into a connecting hose leading to the nozzle. This abrasive and gas mixture emerges from the orifice of nozzle at high velocity. The feed rate of abrasive air is controlled by the amplitude of vibration of the mixing chamber. A pressure regulator installed in the system controls the gas flow and pressure.

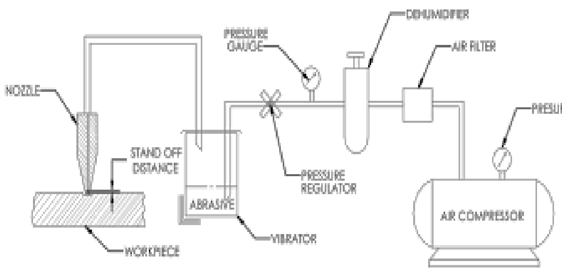

Figure 1. Layout of abrasive jet machine

The nozzle is mounted on a plate which is screwed to the frame. The work piece is moved by moving the x-y table to control the size and shape of the cut. Dust removal equipment is necessary to protect the environment.

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3. Variables effecting performance

The major variables affecting the performance parameters like material removal rate, machine accuracy etc. are as follows: - The major variables that influence the rate of metal removal and accuracy of machining in this process are as follows: -
1. Composition and density of carrier gas
2. Types of abrasive
3. Size of abrasive grain
4. Velocity of abrasive jet
5. Flow rate of abrasive jet
6. Work piece material
7. Geometry, composition and material of nozzle
8. Nozzle tip distance (stand-off distance)
9. Shape of cut and operation type
10. Mixing ratio
11.Impingementangleangle

4. ProcessParameters and Machining Characteristics.
The process parameters are listed below:
• Abrasive
– Material – Al2O3 / SiC / glass beads
– Shape – irregular / spherical – Size – 10 ~ 50 μm
– Mass flow rate – 2 ~ 20 gm/min
• Carrier gas
– Composition – Air, CO2, N2
– Density – Air ~ 1.3 kg/m3
– Velocity – 500 ~ 700 m/s
– Pressure – 2 ~ 10 bar
– Flow rate – 5 ~ 30 lpm
• Abrasive Jet
– Velocity – 100 ~ 300 m/s
– Mixing ratio – mass flow ratio of abrasive to gas –
– Stand-off distance – 0.5 ~ 5 mm
– Impingement Angle – 600 ~ 900
• Nozzle
– Material – WC / sapphire
– Diameter – (Internal) 0.2 ~ 0.8 mm
– Life – 10 ~ 300 hours

The important machining characteristics in AJM are
• The material removal rate (MRR) mm3 /min or gm/min
• The machining accuracy
• The life of the nozzle

5. Operating characteristics

The main performance measuring parameters of AJM are as follows: -
1. The material removal rate in gm/mm3
2. The accuracy and surface finish of the machined surface 3 the nozzle wear rate

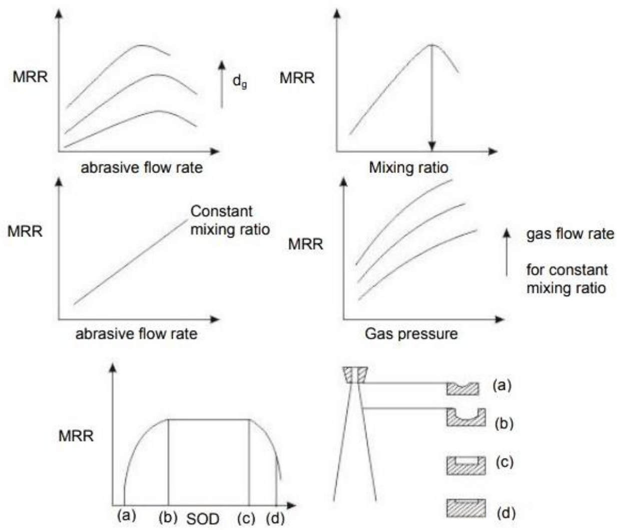

Figure 2: Operating characteristics

As seen in the graph MRR increases with increase in abrasive flow rate due to greater number of particles striking per unit time. Also, MRR increases with increase in mixing ratio which is the ratio of weight of particles to that of the weight of air. But further increase in mixing ratio decreases MRR due to the fact that the volume of carries gas which is responsible for the high velocity is reduced. MRR increases with increase in abrasive flow rate when mixing ratio is constant. The MRR increases with increase in gas pressure as the particles will strike with greater velocity with higher pressure. Another important parameter is the stand-off distance which is the distance between the nozzle tip and work piece. As seen in the graph MRR first increase with increase in SOD then remains constant for a period of time and then decrease. This is due to the fact that flaring of jet occurs at a large distance from the nozzle tip. Also the shape of the cavity becomes less accurate as the nozzle tip distance increases.

6. Advantages and disadvantages

The main advantages are listed as follows:
1. It has the ability to cut intricate holes shape in materials of having any hardness and brittleness.
2. Also it can cut fragile and heat sensitive material without damage as physical tool is absent.
3. No alteration in microstructure of materials as no heat is generated.
4. Capital cost is low.

7. The major disadvantages include

1. Material removal rate is low and hence its application is limited to small scale machining.
2. Stray strings can occur and so its application is limited.
3. Embedding of the abrasive particles in the work piece surface may occur while machining softer material.

4. The abrasive material may accumulate at nozzle and fail the process if moisture is contained in the air.
5. It cannot be used to drill blind holes.
6. Tapering occurs due to flaring of the jet
7. Risk to environment is higher

8. Uses and applications

The major area of application of AJM process is in the machining of brittle materials and heat sensitive materials like quartz glass, sapphire, mica and ceramics semiconductor materials. It is also used in countering, drilling, cutting slot, thin sections, de-burring, for producing integrate shapes in hard and brittle materials. It is often used for cleaning and polishing of plastics like nylon. Delicate cleaning, such as removal of smudges from antique documents, is also possible with this method. Micro machining is possible in brittle materials by this method.

II. LITERATURE REVIEW

The literature study of Abrasive Jet Machine reveals that the machining process was started a few decades ago. Till date there has been a complete and detailed experiment and theoretical study on this process. Most of the studies argue over the hydrodynamic characteristics of abrasive jets, hence determining the influence of all operational variables on the process usefulness including abrasive size, kinds and concentration, impact speed and angle of strike. Other papers found new problems concerning carrier gas typologies, nozzle shape, size and wear rate, jet velocity and pressure, stands off distance (SOD).

These papers state the overall process performance in terms of material removal rate (MRR), geometrical tolerances and surface finish of work pieces, as well as in terms of nozzle wear rate or nozzle life. 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. Some researchers have also done the CFD simulation of machining process.

Abrasive Water Jet (AWJ) turning is a technology that still tries to find its position field of application where it can be economically viable. But a particular application of AWJ turning has proved its superior technological and economical competency, i.e. profiling and dressing of grinding wheels. Starting from the theoretical considerations, the main operating parameters of AWJ turning are identified and included in a method to generate various profiles of grinding wheels by means of tangential movement of the jet column. Roughing in single pass to concave or convex geometries (experimented depth of cuts < 30 mm), generation of thin walls/slots (thickness < 2 mm, depth > 430 mm) and intricate profile (e.g. succession of tight radii) on a variety of grinding wheels show the capability of AWJ turning to fulfill the requirements of this niche application . The machining process produces no heat and hence changes in microstructure or strength of the surface is less likely to occur. The air itself acts as a coolant and hence AJM process is regarded as damage free micromachining method. The fracture toughness and hardness of the target materials are critical parameters affecting the material removal rate in AJM. However, their effect on the machinability varied greatly with the employed abrasives particles. In recent years abrasive jet machining has been gaining increasing acceptability 9 for debarring applications. The influence of abrasive jet de-burring process parameters is not known clearly. AJM de-burring has the advantage over manual de-burring method that generates edge radius automatically. This increases the quality of the de-burred components. The burr removal process and the generation of a convex edge vary as a function of the parameters like jet height and impingement angle, when SOD is fixed. The effect of other parameters, such as nozzle pressure, mixing ratio and abrasive size are less significant. The SOD was found to be the critical factor on the size of the radius generated at the edges. The size of the generated edge radius was found to be restricted to the burr root thickness.

Jiuan-Hung et.al (2012) examined on qualities of adaptable attractive rough in abrasive jet machining which recommends that independent attractive grating with versatility are used to get machining attributes in Abrasive jet machining. Abrasive jet machine has many different points of interest as high etch rate, great machining adaptability low capital and activity cost. These days the nature of abrasive jet machined surface could be improved by parameter streamlining on the grounds that flew particles was influenced via air opposition in the wake of playing out the examination they made an outcome, Taguchi trial. According to Jiuan-Hung Kea et.al, attractive field is a primary factor for surface roughness contrast and material evacuation. In abrasive jet machining, they utilize the adaptable attractive rough not exclusively to limit the abrasive jet bearing and upgrade increasingly uniform genuine operational region and material removal rate yet in addition have a changeless impact to acquire great surface harshness than typical machining process.

S. Madhu et.al, (2018) Researched that Abrasive jet machining is applied to rough finishing, for example, de-burring and machining of earthenware production and electronic gadgets. AJM has become a important method for small scale machining. It has different kinds of advantages over the other non-traditional cutting methods, which are high machining flexibility, least weights on the substrate. This paper manages a few trials that have been directed by many scientists to survey the impact of abrasive jet machining process parameters, for example, abrasive particle, Abrasive Particle size, Jet weight Nozzle tip separation. Different tests were conducted to survey the impact of abrasive jet machine. Abrasive jet machining otherwise called abrasive micro blasting or Pencil blasting is an abrasive blasting machining process that utilizes abrasives moved by high speed gas to erode material from the work piece.

Balasubramaniam, J. Krishnan, (1998) Examined the abrasive jet de-burring process parameters and the edge nature of abrasive jet de-burred parts. Experimental configuration dependent on Taguchi Orthogonal exhibit was utilized to methodically measure the impact of the significant cutting parameters on abrasive jet de-burred examples. The experimental examples utilized were 1.5mm thick, 25mm square evaluation AISI304 tempered steel sheets. Burrs were created by the face processing tasks. ANOVA technique was utilized for the visual review of edge quality. It was discovered that the de-burring procedure is altogether influenced by 'tallness of the stream' and 'impingement angle'. It was reasoned that Abrasive Jet de-burring process beneficial than manual de-burring process. The nature of de-burred segment principally increments by the age of edge radius.

N. Pawar, et.al, (2013) investigated abrasive material sea sand in vibrating chamber. The tungsten carbide nozzle was used in the abrasive jet micro machining process. The sand of 100-150 micron was used for the experiment. The work piece used was a glass of thickness 4 mm. The evaluated performances were material removal rate and flow rate. It was found that the impact through nozzle caused severe erosion on the material work piece. It was demonstrated that the erosion of material surface depended on velocity, direction and brittleness of the material. The experiment was performed by using the combination of two different parameters viz. Standoff distance and pressure. From the result, it was concluded that material removal rate and flow rate were similar to actually abrasive used like aluminum oxide, silicon carbide, etc. It was noticed that by increasing feed rate width of the cut was also increased. It was also found that at greater stand–off distance and feed rate, taper cut was found to be a higher slot.

Experiments have been conducted on effect of jet pressure, abrasive flow rate and work feed rate on smoothness of the surface produced by AWJM of carbide of grade P25. Carbide of grade P25 is extremely hard and thus cannot be machined by conventional techniques. The abrasive used in experiments 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 as it is too hard and very high energy is required. Minimum abrasive flow rate that made it possible to cut carbide efficiently was 135 g mins1. With increase in jet pressure the surface becomes smoother due to higher kinetic energy of the abrasive’s particles. But the surface near the jet entrance is smoother and the surface gradually becomes rougher downstream and is the roughest near the exit of jet. Increase in abrasive flow rate also makes the surface smoother which is due to the fact that availability of 13 higher number of cutting edges per unit area per unit time. Feed rate didn’t show substantial influence on the machined surface, but it was found that the surface roughness increases hugely near the jet entrance.

The study of the results of machining under various operating conditions approves that a commercial AJM machine was used, with nozzles hiving diameter ranging from 0.45 to 0.65 mm, the nozzle materials being either tungsten carbide or sapphire, which have high tool lives. SIC and aluminum oxides were the two abrasives used. Other parameters studied were standoff distance (5–10 mm), spray angles (60°and 90°) and pressures (5 and 7 bars) for materials like ceramics, glass, and electro discharge machined (EDM) die steel. The holes drilled by AJM may not be circular and cylindrical but almost elliptical and bell mouthed in shape. High material removal rate conditions may not necessarily r small narrow clean-cut machined areas.

III. FABRICATION METHODOLOGY

1. Material Selection Properties of Mild Stee

Mild steel and cast iron is selected for the fabrication. This alloy is the most commonly available of the cold-rolled steels. It is generally available in round rod square bar and rectangle bar. It has a good combination of all of typical of steel traits of steel strength some ductility and comparative ease of machining. Chemically, it is very similar to A36 hot rolled steel, but the cold rolling process creates a better surface finish and better properties for mild steel.

Table 1. Chemical Composition of Mild Steel

Carbon %	**Siliconv %**	**Manganese %**	**Sulphur %**	Phosphorous %
0.16-0.19	0.40	0.70-0.90	0.040	0.040

Table 2. Mechanical Composition of Mild Steel

Sl.no	**Mechanical composition of mild steel (ms)**	
1.	Max stress	400-560 n/mm
2.	Yield stress	300-440 n/mm
3.	0.2%proof stress	280-420 n/mm
4.	17 Elongation	10-14 % min

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2. Welding Properties of Cast Iron

Mechanical property reference data for various grey cast iron includes tensile strength, shear modulus of elasticity. Torsional modulus of elasticity endurance limit and brinell hardness data. The American society for testing material numbering system for grey cast-iron is established such that the numbers correspond to minimum tensile strength in KPSL.

3. Fabrication Methods

Arc welding is the fusion of two pieces of metal by an electric arc between the pieces being joined – the work pieces – and an electrode that is guided along the joint between the pieces. The electrode is either a rod that simply carries current between the tip and the work, or a rod or wire that melts and supplies filler metal to the joint. Almost all the joints that are used in this fabrication are bye welding process. Welding plays a key role in this project’s fabrication. The type of welding used is electric arc welding process with the optimum voltage as 160V. It is used for making the frame of abrasive jet machine

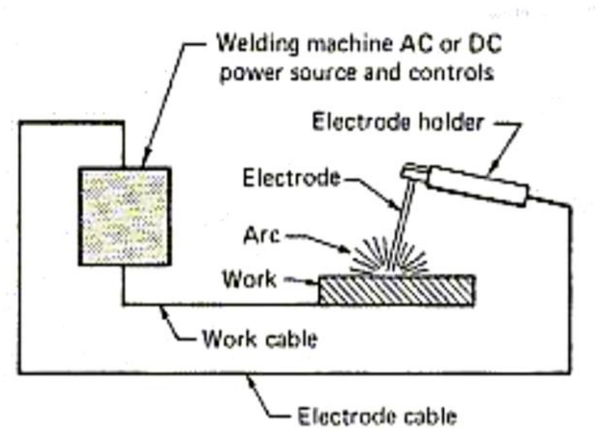

Figure . 3. Fabrication

3.1. Turning

Turning is done to reduce the diameter of hollow attachment to the bottom of the mixing chamber to attach the hose. Hollow attachment is the only part undergone this type of machining in this project. This turning operation are done in a conventional lathe machine.

3.2 Boring

Boring operation is performed to make work holding device. Plates are bored in order to place the pipe fittings for mixing chamber.

3.3. Cutting

Cutting is the process to cut the mild steel plate according to our requirements. According to the size of frame required here we cut the plates using the cut of machine and conventional band saw cutter.

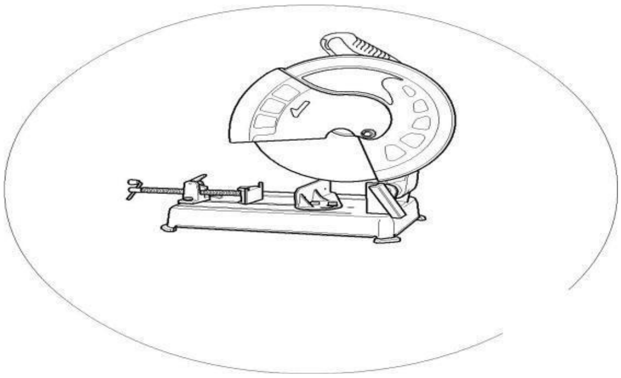

Figure. 4. Cutting

4. Working principle of abrasive jet machine:

Dry air or gas is filtered and compressed by passing it through the filter and compressor. A pressure gauge and a flow regulator are used to control the pressure and regulate the flow rate of the compressed air.

The valve is open when the speed of compressed air is at 8bar pressure Compressed air is then passed into the mixing chamber. In the mixing chamber, abrasive powder is fed. A vibrator is used to control the feed of the abrasive powder. The abrasive powder and the compressed air are thoroughly mixed in the chamber. The pressure of this mixture is regulated and sent to nozzle. The nozzle increases the velocity of the mixture at the expense of its pressure. A fine abrasive jet is rendered by the nozzle. This jet is used to remove unwanted material from the work piece. A compressor of Lt.24 is used for the follow of the compressed air into the valve of mixing chamber.

Figure 5. Air compressor

4.1. Mixing Chamber

The high-pressure air from the compressor is passed through a FRL unit to remove any impurities. Then it is fed to the abrasive chamber which has one inlet for the incoming compressed air and outlet for mixture of abrasive particles and air. The abrasive particles are introduced from the side so to form a cyclone to facilitate better mixing. The chamber is of cylindrical shape made up of mild steel.

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Figure 6. mixing chamber

4.2. Vibrating assembly

The vibration of abrasive container is required for the through mixing of the abrasive particle and air. The vibration is made capable by rotating cam action .The cam is connected to the electric motor and touches the end of the abrasive container. The container is hinged to an extension made out of the base. The abrasive flow rate can be varied by varying the speed of the motor. The whole system is made up of mild steel material in the institute workshop.

4.3. FR unit

FR stands for filter regulator which is necessary for filtering the air and regulating the pressure. The common impurities suspended in the compressed air are dust particles of various sizes, moisture, and oil particles. Excess moisture present in the pipeline may result in coagulation of particles and jam the nozzle opening. Air filters have a porous membrane having various pores sizes like 5, 10, or15 mms. They block the particles larger than the pores.

The line pressure is regulated by pressure regulator. A pressure regulator has are striking element, a loading element, and a measuring element. The restricting element is a type of valve. It can be a butterfly, valve globe valve, poppet valve, or any other type of valve that is capable of operating as a variable restriction to the flow.

The loading element applies force to the restricting element. It can be a simple weight, a spring, a piston actuator, a diaphragm actuator in combination with a spring. Here a single-stage pressure regulator, a force balance is used on the diaphragm to control a spool in order to regulate pressure. With no inlet pressure, the spring above the diaphragm pushes it down on the spool, holding it open. When inlet pressure is introduced, the open spool allows flow to the diaphragm and pressure in the upper chamber increases until the diaphragm is pushed upward against the spring force, causing the valve to reduce flow, thus stopping further increase of pressure. By adjusting the top screw by rotation, the downward pressure on the diaphragm can be enhanced, requiring more pressure in the upper chamber to maintain equilibrium. In this way, the output pressure of the regulator is controlled within a safe limit.

4.4. Nozzle and holder

Nozzles are the mechanical devices which increase the velocity of fluid in exchange of pressure drop. They are commonly used in internal combustion engines, space rockets, missiles, fire extinguishers etc. In abrasive jet machining the high velocity jet is created by the nozzle action. As the abrasive particles strike the nozzle they may erode the nozzle surface. So very high wear resistant materials such as tungsten carbide and sapphires are used. 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 up to 0.7 mm. Sapphire nozzles.

The size varies from 0.2 to 0.7 mm in diameter. Nozzles are made with an external taper to minimize secondary effects due to ricocheting of abrasive particles coming out. Nozzles made of tungsten carbide have an average life of 12 to 30 hours whereas nozzles of sapphire last for about 300 hour of operation. The rate of material removal and the size of machined area are influenced by the distance of the tip nozzle from the work piece. The abrasive particles from the nozzle follow a parallel path only for a short distance and then the jet of particles flares resulting in the oversizing of the hole.

It is observed that the jet stream is initially in the form of a cylindrical shape for about 1.6 mm and then it flares into a cone of 7° included angle. The material removal rate initially increases with increase in the distance of the nozzle from the work piece because of the acceleration of particles leaving nozzle. This increase is maximum up to a distance about 8 mm and then it steadily drops off because of increase in machining area for the same amount of abrasive and decrease in velocity of abrasive stream due to drag. Despite their simple design, abrasive jet nozzles can be troublesome at times. The main drawbacks are short life of expensive parts, clogging of orifice due to dirt or moisture, wear, misalignment and damage to the jewel.

Figure 7. Nozzle

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Three nozzles having orifice diameters 0.6, 0.8 and 1 mm are used to facilitate the variation of parameters. The nozzle material is tungsten carbide. They are procured from outside to increase the efficiency and accuracy. The nozzle holder is made up of mild steel plate having a 10 mm dia. hole to accommodate the nozzle. It is secured to the frame by two Allen bolts on both sides.

5. Machine Frame And Size

3.4 In the fabrication of AJM machine care has been taken to use available materials and old but functional equipment to reduce cost. Here the frame is made by taking pieces of old mild steel by doing various process like cutting, milling, turning, boring and welding etc. it is made in a square shape

The size of AJM frame is 3x3x3 fee

- Length of the frame = 3 ft
- Breadth of the frame = 3ft
- Height of the frame = 3ft

Figure.8. Machine Frame And Size

3.5.2. Assembly for X-Y Movement of Nozzle

The nozzle was connected to a nut and bolt assembly. The assembly consisted of two nuts one of which was fixed while the other was moving. While rotating the moving nut by 360° the nozzle moved a distance of 1 pitch which equals to 1.5mm in the X direction. In Y direction, the end of the nut was attached to a working table which also consisted of a nut for the movement of the nozzle. The purpose for moving the nozzle in Y direction was to make a slot in the work piece.

Figure 9.Model of Assembly.

6. Machining Chamber

It was cubical in shape. It was basically made up of glass structure. The entire structure was closed so as to prevent the abrasives from spreading around. It housed the nozzle assembly and the bench vice. The bench vice was used for holding the work piece. The used abrasives were removed by opening the bottom glass of the working chamber. One of the side glasses was closed in such a way that it can be removed by removing the threaded bolt. It was done so to load and unload the work- piece

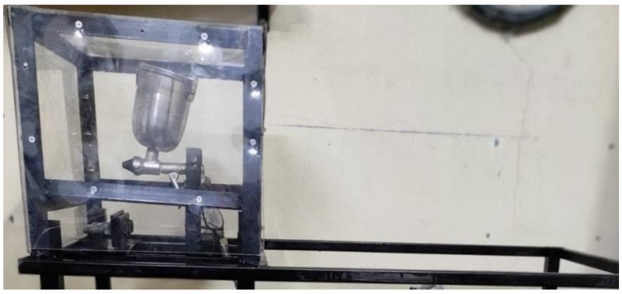

Figure 10. actual view of machining chamber

7. Complete Assembly

After fabricating different components of abrasive jet machining, a frame like structure was designed and fabricated which supports all the major components of abrasive jet machining. The figure shows the assembly design of abrasive jet machining. All the above components, including dehumidifier, carrier gas supply line and pressure gauge were mounted on the frame, which gives the overall experimental setup. The material used for manufacturing the above frame is mild steel. The carrier gas supply pipe is made up of pneumatic material which has high strength. The purpose of using pneumatic material instead of general pipe was to prevent the pipe from being eroded due to the flow of abrasive grit under high pressure.

Figure 11. Complete view of abrasive jet machine

IV. RESULT AND DISCUSSION

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. It is concluded that wide experimental investigations are required to fully understand the relationship between important AJM parameters, namely Air pressure, nozzle size and shape, abrasive mass flow rates and process output in greater detail for aluminum, brass, cast iron, ceramics, copper, composites, granite, mild steel, stainless steel and titanium as the right choice of process parameters is very important for good cutting performance. There is much scope of research in the AJM which can be performed by changing the nozzle design, pressure, angle, SOD, etc. and Comparing the effect of various parameters on MRR on different metals like super alloys, composites, glass, and ceramics, by improving the cylindricity of the hole. And also Integration of AJM with CNC, model comparison, etc. is to be held in further stages. The mathematical model can be developed by replacing the conical shape hole with cylindrical hole.

V. CONCLUSION

In AJM, a focused jet or stream of abrasive particles carried by high-pressure gas (carrier) is made to impinge on the work surface through a nozzle. The metal cutting occurs due to erosion caused by the abrasive particles impacting the work surface at high speed. As a result of the impact, small bits of materials get loosened and separated from the work piece surface, exposing a fresh surface to the jet. This process is capable of cutting intricate holes and shapes in materials of any hardness and brittleness.

FUTURE SCOPE

- Manual nut assembly has been used to vary the nozzle tip distance. This process can be done automatically.
- For shaking of the mixing chamber, we have used handle manually. This can be done automatically by using a motor.

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