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# Process Characteristics of Abrasive Jet Machining

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***Abstract*:- Abrasive Jet Machine is the device used to remove material by means of high velocity carrier gas and Abrasive mixture. It is a non-traditional machining process where there is no physical contact between tool and work-piece. The Abrasive Jet machining can be employed for machining super alloys and refractory from materials. This process is based on surface erosion process. The process parameters that control metal removal rate are air quality and pressure, Abrasive grain size, nozzle material, nozzle diameter, stand of distance between nozzle tip and work surface.**

## INTRODUCTION:

Abrasives are costly but the abrasive jet machining requires very less investment and less maintenance cost. The carrier gas is used as coolant, the cutting action is accurate and therefore better surface finish is obtained. In the current day situation it is widely used in manufacturing of electronic devices such as LCD's, PCB, MEMS, and semiconductors. There is increase in demand for development of micromachining technologies for materials which are difficult-to-machine because of their properties such as extreme hardness, brittleness, corrosion resistance and low melting temperatures.

AJM is used to carry out operations like cutting, cleaning, polishing, de burring, etching, drilling and finishing the operation. The nozzle is the most important part in the abrasive jet apparatus/setup. The process is mainly used to cut difficult and deep shapes in hard and brittle materials which are sensitive to heat. The process can be easily controlled by varying the parameters such as Velocity, Flow rate, Pressure, Standoff distance, Grit size, and nozzle angle. Abrasive jet machining (AJM) is a nontraditional machining process which operates work-piece without producing heat and shock.

## PRINCIPLE OF AJM:

Fine micro abrasive particles are accelerated in a gas stream. The particles are directed towards the focus of machining approximately less than 3 mm from the tip. As the particles impact the work-piece surface, they fracture the surface and create holes/cavities. Once the particle hits the surface, it causes a small damage, and the gas stream carries both the abrasive particles and the fractured (wear) particles with it.

*Abrasive particles used in abrasive jet machining:*

In AJM, it is considered that hard abrasive particles take part in material removal process, whereas carrier gas helps to blow away removed particles from machining zone. Such abrasives must have few basic properties for efficient removal of material and also to get desired quality of finish. Amongst the desired characteristics proper hardness, irregular shape, presence of sharp edges and proper flow features are must. Different types of abrasives having a range of grit size can be used depending on work piece material and the operation which needs to be performed. Aluminum oxide (alumina) of average grit size 10 – 50µm is commonly used for grooving and drilling operations, moreover when work-piece is hard. Whereas for very hard work-piece silicon carbide (SiC) is preferred because it is harder than alumina. For other processes like polishing and coating removal, glass beads and crashed glass are mostly used. Size of abrasives have a great impact on quality of finish as well as material removal rate. Larger grit size produces larger cavity and thus MRR improves with the kind of surface finish. Whereas, fine abrasives reduce MRR but improve surface finish and accuracy.

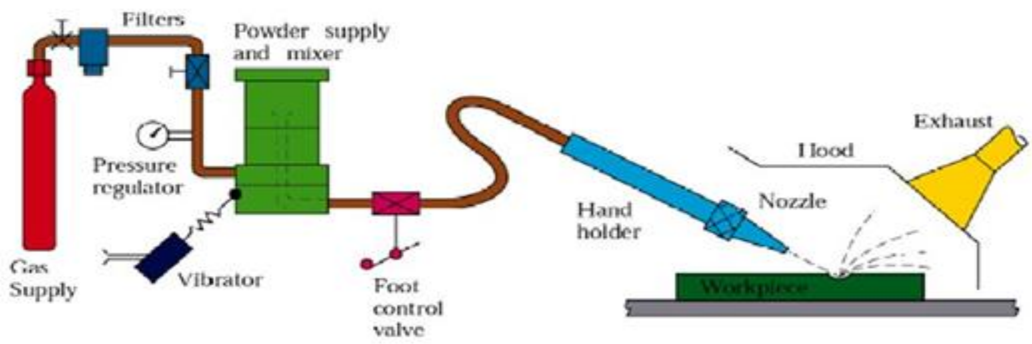


FIGURE 1: SCHEMATIC DIAGRAM OF AJM

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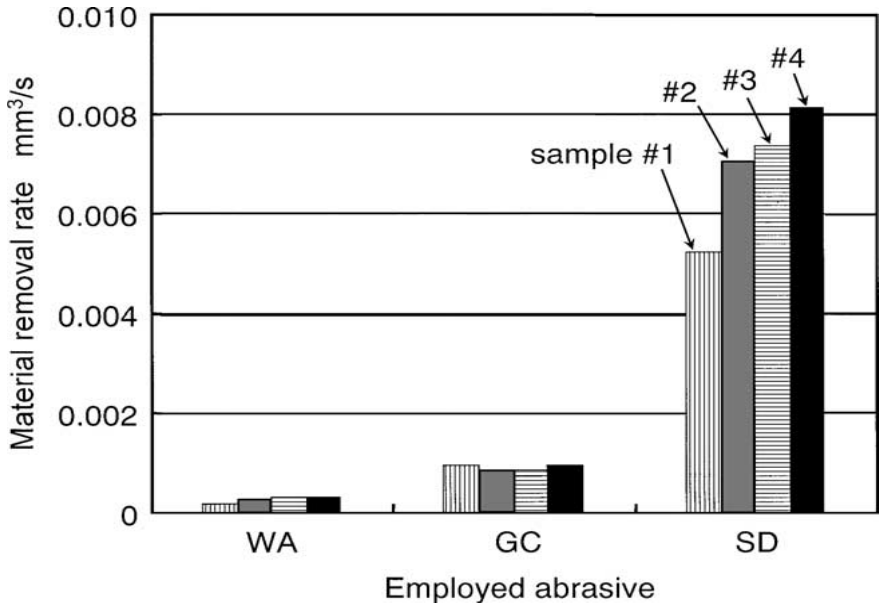
LITERATURE REVIEW:

The experiment and research is done by the various researchers with respect to abrasive jet machining. Parameters like velocity of gas, pressure, nozzle tip distance (NTD) , material removal rate (MRR), substance integrity are studied and explained along with operations such as cutting, drilling.

**Jiuan-Hung Ke 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.




**Kumar Abhishek et..al, (2016)** considered wide uses of the micro abrasive jet machining. For example machining of Micro-gaps on Soda lime Glass utilizing micro abrasive jet machine to deliver smaller scale features, for example, micro holes on brittle materials. This procedure is likewise great to machine heat sensitive materials. It has wide modern applications and in building fields too. This paper investigation gives ideal machining parameter to machining hole on soda lime glass thickness.

FIGURE (2): FABRICATED PORTABLE ABRASIVE JET MACHINE

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**P.M.Khodke et..al, (2013)** analysed on Optical microscopy has indicated that abrasive particles utilized in abrasive jet machining have sharp edges with shapes like cone or pyramid. Also, microscopic assessment of cross section of work samples dissolved by AJM shows that, for brittle materials, material removal is because of convergence and propagation of cracks created by adjacent particles on target surface. An analytical model has been created dependent on the above perceptions for foreseeing the material removal in abrasive jet machining process. The model additionally proposes the basic estimation of mass flow rate which has been substantiated tentatively. Furthermore, the impact of speed and mass flow rate of abrasive particles on material removal rate is examined and studied.

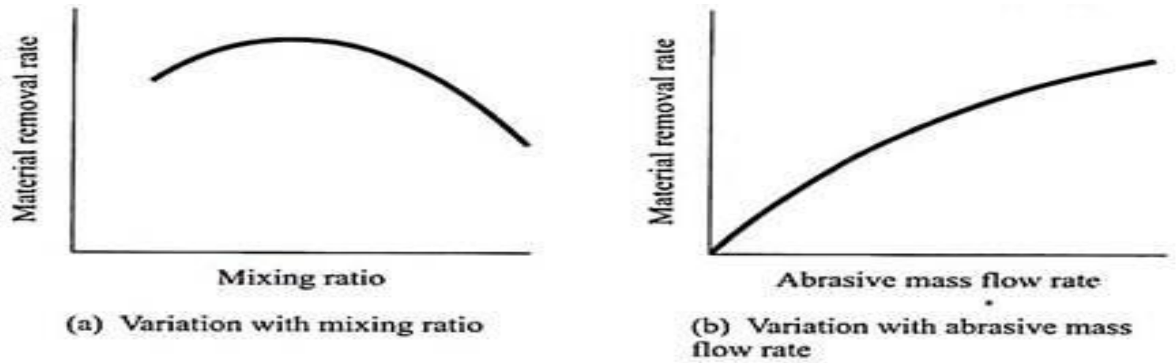


Fig. 6.3 Material removal rate characteristics in AJM.

**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.

**Venkatesh V.C.et.al, (2009)** Their paper gives the results of machining under different conditions. A commercial AJM machine was utilized, with nozzles of diameter extending from 0.45 - 0.65 mm, the nozzle materials utilized is either tungsten carbide or sapphire, which have high tool lives. Silicon carbide and aluminum oxide were the two abrasives utilized. Other parameters considered were nozzle tip separations (5–10 mm), spray angle (60° and 90°) and pressures (5& 7 bars). The materials machined were glass, pottery, and electro-release machined (EDM) die steel. Material removal rate (MRR) and the machined cavity measurements were estimated. The blind holes that were penetrated were seen as non circular and tube shaped but rather practically circular and chime mouthed. High material removal rate conditions didn't really yield little tight clean-cut machined regions, an alluring component for AJM applications. Exact assessment was done to portray quantitatively the impacts of different machining conditions. Throughout these examinations a super hot area was found to frame under specific conditions and joined by high material removal; a metallurgical investigation of this intensely hot zone and its connection to ideal AJM machining conditions are presented. Abrasive jet machining (AJM) is a process that removes material by directing a high speed stream of abrasive particles onto a work piece.

**R. 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.

**S. Kanzaki, Y. Yamauchi, (2003)** considered the impacts of work piece properties on machinability in abrasive jet machining of clay materials. The three kind of basic abrasives which are, Aluminum Oxide, Silicon Carbide, and manufactured precious stone were utilized for conducting the experiment. The objective materials utilized were four kinds of ceramic which are, ZrO2, Si3N4, Al2O3, SiC. A laser scanning magnifying lens was utilized to measure the volume that was removed by abrasive jet machining. The machinability of the AJM process was contrasted and the established models of solid particle disintegration, wherein the material expulsion is expected to begin in the perfect crack formation system. Further, it was discovered that the AJM test results didn't rely upon the erosion models, on the grounds that the overall hardness of the abrasive against the target material, which has not considered in the models, is basic in the machining procedure. It was additionally presumed that AJM procedure had high potential micromachining strategy as harm free for some materials in light of the fact that the cracks didn't broaden downwards by the effect of the molecule during the machining process.

**S. Ally, et..al, (2012)** Utilized surface developed models to foresee Abrasive jet machining of metallic substrates. The abrasive jet angle of erosion rate was estimated. The material is Aluminum 6061-T6, Ti-6Al-4V Titanium combination and 316L stainless steel. The jet inclination angle was estimated utilizing 50 micrometers Al2O3 abrasive powder propelled at a normal speed of 110m/s. The peak erosion rate was found to occur 200 to 350 comparative with the surface for every one of the three frameworks. It was discovered that Aluminum has a high volumetric disintegration rate than Titanium amalgam which is higher than the hardened steel erosion rate on a volumetric basis, which inturn is essentially lower than a brittle material, for example, glass and polymers. It was likewise discovered that where a high level of control carves is wanted; AJM of metals is most appropriate for scratching of moderately shallow highlights. It was inferred that scanning electron micrograph and EDX examination of the eroded surface of 316L pure give a lot of molecule following with a less sum in the Titanium composite.

**N. S. 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.

**Rajkamal Shukla, Dinesh Singh. (2017)** Used Taguchi method for experimental investigation of abrasive water jet machining parameters. The material used is AA6351 aluminum alloy. Parameters such as transverse speed, standoff distance and mass flow rate are considered to obtain the influence of these parameters on kerf top width and taper angle. Regression models have been developed to correlate the data generated using experimental results. The percentage contribution of standoff distance in kerf top width and taper angle is found to be 77.642% and 81.774% respectively.

**A. Ghobeity, T. Krajac. (2008)** Predicted models of abrasive jet micro machining for masked and unmasked borosilicate glass channels by using 25 micro meter aluminum oxide. A novel technique is used for the velocity distribution of the particles in the jet of an abrasive jet micro machining. It was found that the velocity decreased linearly from the center line of the jet to the periphery, Weibull distribution followed by the probability of a particle arriving at the surface a given radial distance from the center of the impacting jet. To predict the cross sectional profile of unmasked channels this Weibull distribution was used with an extension of the already existing model. Time-dependent particle mass flux and velocity distribution were used for modeling of the effect of the nozzle.

Process Parameters of Abrasive Jet machining (AJM) are factors that influence its Metal Removal Rate (MRR).In a machining process, Metal Removal Rate (MRR) is the volume of metal removed from a given work piece in unit time.
The following are some of the important process parameters of abrasive jet machining:
1. Abrasive mass flow rate
2. Nozzle tip distance
3. Gas Pressure
4. Velocity of abrasive particles
5. Mixing ratio
6. Abrasive grain size

ABRASIVE MASS FLOW RATE:

Mass flow rate of the abrasive particles is a significant procedure parameter that impacts the metal removal rate in abrasive jet machining. In AJM, mass flow rate of the gas (or air) in abrasive jet is contrarily corresponding to the mass flow rate of the abrasive particles. Because of this reality, when persistently expanding the abrasive mass flow rate, Metal Removal Rate (MRR) first increments to an ideal worth (as a result of increment in number of rough particles hitting the work piece) and afterward diminishes. However, if the blending ratio is kept steady, Metal Removal Rate (MRR) consistently increments with increment in rough mass flow rate.

NOZZLE TIP DISTANCE:

Nozzle Tip Distance (NTD) is the gap provided between the nozzle tip and the work piece.
Up to a certain limit, Metal Removal Rate (MRR) increases with increase in nozzle tip distance. After that limit, MRR remains constant to some extent and then decreases. In addition to metal removal rate, nozzle tip distance influences the shape and diameter of cut. For optimal performance, a nozzle tip distance of 0.25 to 0.75 mm is provided.

*Gas pressure:*

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Air or gas pressure has a direct impact on metal removal rate. In abrasive jet machining, metal removal rate is directly proportional to air or gas pressure.

*Velocity of abrasive particles:*
Whenever the velocity of abrasive particles is increased, the speed at which the abrasive particles hit the work piece is increased. Because of this reason, in abrasive jet machining, metal removal rate increases with increase in velocity o abrasive particles.

*Mixing ratio:*
Mixing ratio is a ratio that determines the quality of the air-abrasive mixture in Abrasive Jet Machining (AJM).It is the ratio between the mass flow rate of abrasive particles and the mass flow rate of air (or gas).When mixing ratio is increased continuously, metal removal rate first increases to some extent and then decreases.

*Abrasive grain size:*
Size of the abrasive particle determines the speed at which metal is removed. If smooth and fine surface finish is to be obtained, abrasive particle with small grain size is used. If metal has to be removed rapidly, abrasive particle with large grain size is.

ABRASIVE PARTICLES USED IN ABRASIVE JET MACHINING:

In AJM, it is expected that hard abrasive particles take an interest in material removal activity, while transporter gas helps to overwhelm disintegrated particles from machining zone. Such abrasives must have barely any essential properties for productive expulsion of material just as to get wanted nature of cut. Among the ideal properties adequate hardness, unpredictable shape, presence of sharp edges and great stream attributes are fundamental. Various abrasives having a range of grit size can be used dependent on work piece material and the activity it is expected to perform. Aluminum oxide (alumina) of normal grit size 10 – 50µm is regularly utilized for cutting and penetrating activity, particularly when work material is hard. However, for difficult work material, silicon carbide (SiC) is favored as it is more harder than alumina. For cleaning and covering evacuation purposes, glass beads and crashed glass are routinely utilized. Size of abrasives impacts nature of cut just as material evacuation rate. Bigger grit size will in generally produce bigger cavity and in this way MRR improves with the sacrifice of surface finish. Then again, fine abrasives lessen MRR however improve surface quality and exactness.

CARRIER GAS FOR ABRASIVE JET MACHINING:
Basic purpose of carrier gas in abrasive jet machining is to accelerate fine abrasive particles (by momentum transfer). A compressor is used to elevate pressure of the carrier gas (as high as 20bar); abrasive grits are mixed with it in a mixing chamber (as per mixing ratio), and a nozzle is used to convert pressure energy into kinetic energy (in the form of high velocity jet). Carrier gas pressure along with nozzle diameter determines final jet velocity and thus machining performance.
Among various gases, air is commonly used in AJM as it is abundantly available at free of cost. Sometime commercially pure carbon di-oxide and nitrogen are also used to harness better performance for a particular purpose. However, pure oxygen is not used as it can quickly oxidize the work surface. Before compressing, carrier gas is dehumidified properly as presence of steam can block pipelines. When gas is compressed to high pressure, steam may condense and tiny water particles can create a larger globule after agglomerating with abrasives. Carrier gas is also made dust free before compressing to high pressure.

NOZZLE USED IN ABRASIVE JET MACHINING:
Primary function of nozzle in abrasive jet machining is to convert pressure energy of the pressurized gas-abrasive mixture into kinetic energy in the form of high velocity jet. Nozzle also directs high velocity jet towards work surface from a specific distance (called SOD) and at a particular predefined angle, called impingement angle. Inner diameter of the nozzle is paramount parameter as it determines final velocity and cross-sectional area of the jet for certain gas pressure. As flow rate and compressor delivery pressure are constant, jet velocity will be inversely proportional to the jet cross-sectional area.
Choosing nozzle material is another decisive factor from economic point of view. Usually tungsten carbide (WC) or sapphire nozzles are used in industrial applications. WC nozzles are cheaper but have limited life (20–30hr); while sapphire nozzles have extended life (150–200hr) but are costlier. Frequent changing of nozzle is associated with idle time during machining.

*Advantages:*
- Drilling holes, cutting slots, cleaning hard surfaces, deburring, polishing, and radioing.
- Deburring of cross holes, slots, and threads in small precision parts that require a burr refinish, such as hydraulic valves, aircraft fuel systems, and medical appliances.
- Machining intricate shapes or holes in sensitive, brittle, thin, or difficult-to-machine materials.
- Insulation stripping and wire cleaning without affecting the conductor.
- Micro-deburring of hypodermic needles.
- Frosting glass and trimming of circuit boards, hybrid circuit resistors, capacitors, silicon, and gallium.
- Removal of films and delicate cleaning of irregular surfaces because the abrasive stream is able to follow contours.

*Limitations:*
- The removal rate is slow.
- Stray cutting can’t be avoided (low accuracy of □ 0.3 mm)
- The tapering effect may occur especially when drilling in metals.

- The abrasive may get impeded in the work surface.
- Suitable dust-collecting systems should be provided.
- Soft materials can't be machined by the process.
- Silica dust may be a health hazard.

## APPLICATIONS OF AJM

Abrasive jet machining can be advantageously utilized for multifarious purposes including surface cleaning, deburring, abrading and even making holes. Common applications of abrasive jet machining process are provided below. It is to be noted that, irrespective of the purpose, abrasive jet machining (AJM) is beneficial only for hard and brittle materials. AJM should be avoided if work material is soft and ductile; otherwise quality of machined surface will be poor. Read also: Applications of AJM process.

- **Work surface cleaning**—AJM can be advantageously used for cleaning metallic or ceramic surfaces (substrate must be hard). Such cleaning processes include removal of oxide, paint, coating, stain, glue, loose sand particles, etc.
- **Deflating and trimming**—Controlled abrasive jet machining can be utilized for removing flash to get desired clean product with higher dimensional accuracy and tolerance as well as sumptuous appearance.
- **Engraving**—As an alternative to laser beam machining, abrasive jet machining can also be applied for incising purposes irrespective of chemical and electrical properties of work material.
- **Ceramic abrading and glass frosting**—Very hard materials including glass, refractory, stone, etc. can be easily abraded by AJM in order to get finished surface having tight tolerance.
- **Deburring**—Abrasive jet machining is one of the efficient methods for deburring (process for removal of burr) of milled features and drilled holes, especially when work material is hard.
- **Cutting and drilling hole**—AJM can also be utilized for cutting various shapes as well as for drilling holes. However, holes, slots or pockets may lack accuracy as sharp corners cannot be obtained by this process.

## CONCLUSION:

As per the different research papers accessible till date, a ton of work has done on abrasive particles and its geometry, distinctive process parameters, the volume of material during machining. A broad survey of the innovative work in the AJM has been directed in this paper. It was indicated that AJM procedure is getting increasingly more consideration in the machining territories, especially for the processing of hard to-cut materials. Its remarkable points of interest over other conventional and unconventional methods make it a new choice in the machining business. Very less research has-been done on the investigation of the impact of abrasive flow rate on performance qualities. Subsequently there is degree for development for the investigation of the impact of abrasive flow rate on execution attributes like material removal rate and taper angle. Inappropriate blending chamber development causes different issues, for example, abrasive powder stratification, powder compaction, powder humidification and so on. This influences the machining results unfortunately.

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