

Design And Fabrication of Abrasive Glass Cutting Machine

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Abstract—Abrasive Jet Machining (AJM) is a non-traditional machining process that removes material through erosion using a high-velocity stream of abrasive particles carried by a pressurized gas. This project focuses on the design and fabrication of a flexible AJM system with three-axis travel to improve precision and efficiency in machining applications, especially for brittle materials such as glass. The system integrates a nozzle, compressor, FRL unit, pressure regulator, and dust filter. Key components are chosen to optimize machining efficiency while reducing custom fabrication. The system's performance is evaluated based on machining accuracy, material removal rate, and operational stability. The results demonstrate improved cutting performance and reliability, indicating that the designed AJM setup is suitable for industrial glass machining applications.

Key words— Abrasive Jet Machining, Glass Cutting, Non-Traditional Machining, Material Removal, Erosion, Precision Manufacturing.

I. INTRODUCTION

Abrasive Jet Machining (AJM) is a non-conventional machining process that removes material by directing a high-velocity stream of abrasive particles through a nozzle toward the workpiece. The process is particularly useful for machining hard and brittle materials like glass, ceramics, and silicon, which are difficult to process using traditional machining methods. Unlike conventional cutting, AJM produces minimal heat, eliminates tool wear, and allows for intricate shapes and delicate operations.

In AJM, fine abrasive particles such as aluminum oxide or silicon carbide are entrained in a high-speed gas stream, usually air, and directed at the workpiece. The erosion caused by particle impact removes the material. AJM is widely used for micro-machining, deburring, drilling small holes, and surface texturing.

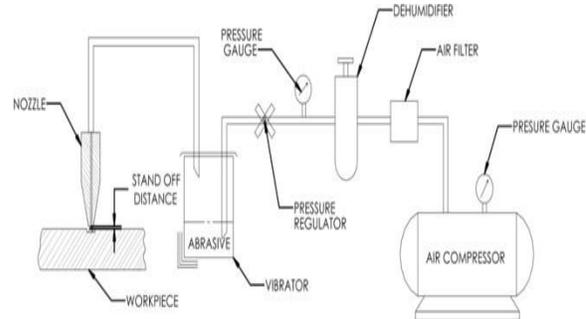


Fig: detail diagram of abrasive jet machine

II. PROCEDURE

In abrasive jet machining abrasive particles are made to impinge on the work material at high velocity. Jet of abrasive particles is carried by carrier gas or air. The high velocity stream of abrasives is generated by converting pressure energy of the carrier gas or air to its kinetic energy and hence high-velocity jet. Nozzles direct the abrasive jet in a controlled manner onto the work material. The high-velocity abrasive particles remove the material by micro cutting action as well as brittle fracture of the work material. AJM is a process of removal of material by impact erosion through the action of concentrated high-velocity stream of grit abrasives entrained in high velocity gas stream.

AJM is different from shot or sand blasting, as in AJM, finer abrasive grits are used and parameters can be controlled more effectively providing better control over product quality. Nozzle is made of either circular or rectangular cross section and head can be straight, or at a right angle. It is so designed that loss of pressure due to the bends, friction, etc., is minimum possible. With increase in wear of a nozzle, the divergence of jet stream increases resulting in more stray cutting and high inaccuracy.

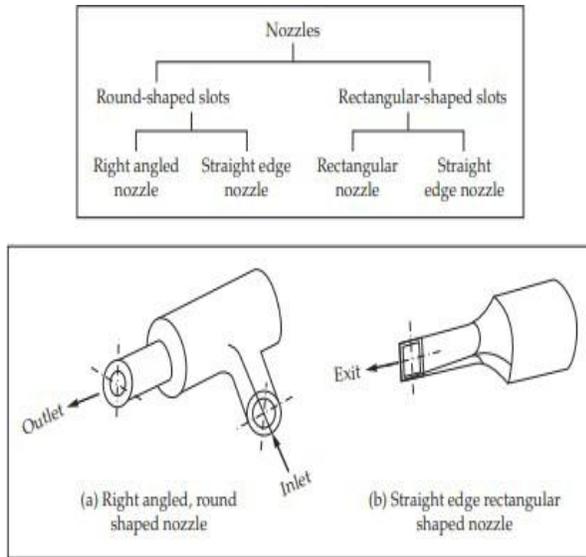


Fig: types of nozzle and shape of nozzle

Desired properties of materials used for nozzle

1. Material has to withstand the erosive action of abrasive particles.
2. It should have good wear resistance properties: Increase in wear of the nozzle leads to divergence of jet stream. Divergence of jet steam causes stray cutting and inaccurate holes.
3. It should have good resistance to corrosion.
4. It should be designed such that loss of pressure due to bend and friction is minimum.
5. Abrasives should have sharp and irregular shape.
6. It should be fine enough to remain suspended in the carrier gas.
7. Should be cheap and easily available.
8. It should have excellent flow characteristics. Silicon carbide and aluminium oxide are used for cutting operation. Sodium bicarbonate, dolomite, glass beads are used for cleaning, etching, deburring and polishing applications.

III. LITERATURE REVIEW

- Dr. Pushpendra Kumar Sharma 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 standoff distance increases the entry side diameter and the entry side edge radius increases, Increase in standoff 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.

- C.S. Kalra has presented an experimental study to understand the effect of process parameters (like nozzle diameter, air pressure, abrasive mass flow rate) on the cutting performance measures (like groove depth and width) in abrasive jet micro-grooving of quartz crystals. Groove depth increase by increasing the abrasive mass flow rate which leads to more particles impinging the target surface and gives more material removal. However, excessive abrasive flow rate increases inter-particle collision which reduces the average removal rate per particle.
- Dr. A. K. Paul & P. K. Roy (1987) Carried out the effect of the carrier fluid (air) pressure on the MRR, AFR, and the material removal factor (MRF) have been investigated experimentally on an indigenous AJM set-up developed in the laboratory. Conducted Experimentation on the cutting of Porcelain with Sic abrasive particles at various Air pressures. Observed that MRR has increased with increase in grain size and increase in nozzle diameter. The dependence of MRR on standoff distance reveals that MRR increases with increase in SOD at a particular pressure.
- Sarkar & Pandey (1980) suggested a model to calculate MRR (Q) during AJM. $Q = x Z d^{3/2} (8/12Hw)^{3/4}$, Where Z is no of particles impacting per unit time, D is the mean diameter of Abrasive grain, K is the density, V is the velocity of abrasive particles, how is hardness of work material, X is a constant.

- Ghobeity et al. have experimented on process repeatability in abrasive jet machining. They mentioned that many applications have several problems inherent with traditional abrasive jet equipment. Poor repeatability in pressure feed AJM system was traced to uncontrolled variation in abrasive particle mass flux caused by particle packing and local cavity formation in reservoir. Use of mixing chamber improved the process repeatability. For finding out process

repeatability they measured depth of machined channel.

- Dr. M. Sreenevasa Rao, D. V. Shrekanth. Stated that particle distribution can greatly affect the shape and depth of profile. Analytical model has developed with by considering the particle size distribution. It results that if particle size distributed uniformly it helps to maintain uniform velocity of abrasive jet which causes improvement in MRR.
- Kumar Abhishek and Somashekharhire math studied wide applications of the micro abrasive jet machine.i.e Machining of Micro-holes on Sodalime Glass using Developed Micro-Abrasive Jet Machine to produce micro features such as micro holes on brittle materials [2].This process is also favorable for to machine heat sensitive materials. It has wide industrial applications and in engineering fields also. This paper analysis optimal machining parameter to machining hole on soda lime glass thickness about 1.6mm for multiple parameter characteristics. Kumar Abhishek and Somashekhar hiremath stated that gray relational analysis (GRA) is used for escalation the process parameter for the material removal rate (MRR) based on gray relational grade obtained for the actual process. Development of process parameter has been carried out. Air pressure was found to be a most significant factor for multiple parameter characteristics. the importance of selected performance parameter such as air pressure, a standoff distance are confirmed using gray relational analysis .the result obtained from the experiment of machining of micro holes on soda lime glass including the size of hole, material removal rate and radial outlet are presented in this paper.
- Vishal Gupta , P.M. Pandeya ,Mohinder Pal Garg , Rajesh Khannab ,N.K.Batrab works on Minimization of kerf taper angle and kerf width with the help of Taguchi's method in abrasive water jet machining of marble [7]. Abrasive water jet cutting is a non-traditional machining method that gives a productive alternative to conventional techniques. This paper attempts to investigate kerf characteristics in abrasive water

jet machining of marble which is having wide applications in domestic, commercial and industrial construction work.

IV. METHODOLOGY

AJM is also named as abrasive micro blasting, is a nonconventional machining process that carried a high-pressure air stream with small abrasive particles to impinge the work surface through a nozzle for material removal of the work piece. The material removal occurs by the erosive action of the abrasive particles striking the work piece surface. The material removal capability of AJM is very low so it is used in a finishing process. It is as an effective machining method for hard and brittle materials and it's it is similar to sand blasting process but difference is finer abrasive powders and smaller nozzles are used in AJM.

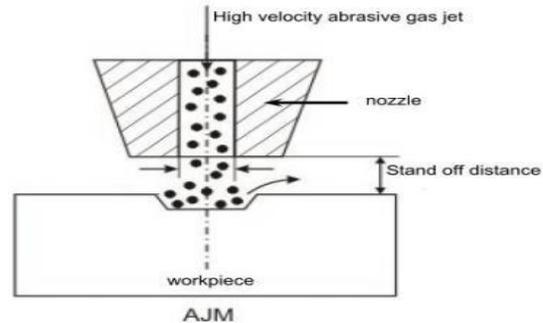


Fig: Schematic diagram of AJM

A schematic diagram of AJM is shown in Fig. in AJM; carrier gas is compressed at a high pressure in an air compressor. Gases like dry air, CO₂, N₂ are used as a carrier gas. At first the carrier gas is passed through a pressure regulator to obtain the desired working pressure. The gas is then passed through a FRL unit (filter lubricator and regulator). This unit removes dust particle and also lubricate and regulate the flow of carrier gas. After that the carrier gas enters into the mixing chamber. The abrasive particles placed in the abrasive container. Abrasive particle are enter into the mixing chamber as per our requirement by the application of vibrator. The abrasive particles are then carried by the carrier gas from the mixing chamber to work piece through nozzle. The total machining process is enclosed for safe and eco-friendly purpose. line diagram of AJM is indicated in the Fig.

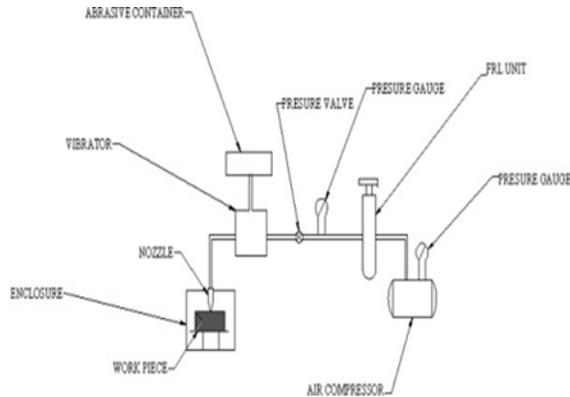


Fig. Line diagram of AJM

IV. COMPONENTS MATERIAL REMOVAL RATE

The material removal takes place from the work piece by the application high velocity abrasive jet particle. Due to the kinetic energy of particle causes erosion of work piece. The material removal is depend upon the certain parameter such as abrasive flow rate, mixing ratio, gas pressure, stand- off distance etc. The MRR depends on different process parameter. The Fig. shows that Material removal rate (MRR) increases with increase of abrasive flow rate due to the more number of particle impingement in unit time But after reaching a optimum value material removal rate decreases with further increase of abrasive flow rate because of mass flow rate of gas decreases with increase of abrasive flow rate.

Similarly Material removal rate (MRR) increases with increase of mixing ratio (M_{abr}/M_{gas}). But after reaching a optimum value material removal rate decreases with further increase of mixing ratio.

Material removal rate (MRR) continuously increases with increase in abrasive flow rate when mixing ratio is kept constant. Material removal rate (MRR) increases with increase of gas pressure. At first Material removal (MRR) rate increases with increase in stand-off distance then it is remains constant for a period of time and after that decreases with increase in stand -off distance. This phenomena occurs due to penetration rate of abrasive material is optimum at certain level. After that it will decreases.

Air compressor Air compressor is shown in the figure, which compresses air from low pressure to high pressure by taking input energy from electric motor. In AJM, high pressure (2 - 6 bars) air jet is required so that the abrasive particles can strike the work piece at

high velocity. In this experiment reciprocating air compressor (maximum pressure= 21 kgf/ cm² or 300 lb/in²) was used for compressing the air. The outlet pressure of compressor is controlled by valve mechanism which is manually control. For running the compressor a new three phase control panel was procured from outside (Schneider electric pvt.ltd).

FRL UNIT

FRL unit stands for filter regulator and lubricator. It is necessary for filtering the air and regulating the air pressure and lubrication of component. The dust particle and moisture particle are suspended in the air. It is necessary for removing the particle otherwise pipeline may result in coagulation and jam the nozzle opening. The pressure is controlled by the pressure regulator, which is consists of a loading element, a measuring element and a restricting element.

It is a single stage pressure regulator. By rotating the top screw of FRL unit, pressure is controlled with in the safe limit. For fixing the upper limit of pressure top screw is necessary. A particulate air filter is a device composed of fibrous or porous materials which removes solid particulates such as dust, pollen, mold, and bacteria from the air. Filters containing an adsorbent or catalyst such as charcoal (carbon) may also remove odors and gaseous pollutants such as volatile organic compounds or ozone. Air filters are used in applications where air quality is important, notably in building ventilation systems and in engines.



Fig: FRL unit

PIPING CIRCUIT

Total piping circuit system was used for smooth flow of compressed air and mixture of compressed air and abrasive powder. Nylon Braided hose pipe (fig.) having 12mm diameter are used, which is bought from market.

The piping systems are required for carrying the compressed air from the compressor to the mixing chamber and from the mixing chamber to the nozzle orifice via the FRL unit. It is used for its long life, durable, easy available and also having very small head loss when it is bend.



Fig: Nylon braided hose pipe

SANDBLASTING GUN

sandblasting, is the operation of forcibly propelling a stream of abrasive material against a surface under high pressure to smooth a rough surface, roughen a smooth surface, shape a surface or remove surface contaminants. A pressurised fluid, typically compressed air, or a centrifugal wheel is used to propel the blasting material.

Sand blasting is also known as abrasive blasting, which is a generic term for the process of smoothing, shaping and cleaning a hard surface by forcing solid particles across that surface at high speeds; the effect is similar to that of using sandpaper, but provides a more even finish with no problems at corners or crannies. Sandblasting can occur naturally, usually as a result of particles blown by wind causing aeolian erosion, or artificially, using compressed air, An artificial sandblasting process was patented by Benjamin Chew Tilghman on 18 October 1870.

Sandblasting equipment typically consists of a chamber in which sand and air are mixed. The mixture travels through a hand-held nozzle to direct the particles toward the surface or work piece. Nozzles come in a variety of shapes, sizes, and materials. Boron carbide is a popular material for nozzles because it resists abrasive wear well.



Fig: sandblasting gun

GLASS MATERIAL

Glass is a solid-like and transparent material that is used in numerous applications in our daily lives. Glass is made from natural and abundant raw materials (sand, soda ash and limestone) that are melted at very high temperature to form a new material: glass. At high temperature glass is structurally similar to liquids, however at ambient temperature it behaves like solids. As a result, glass can be poured, blown, press and moulded into plenty of shapes.

Glass manufacturing has an age-old tradition which dates back to around 3500 BC when glass is believed to have been first artificially produced in Egypt and Mesopotamia to be used as jewellery and later as vessels. Since then processes have constantly evolved from craftsmanship to today's high-tech industrial processes and the number of glass types and applications have multiplied.

Glass has shaped Europe's cultural heritage, regions, industries, living conditions, technological deployments, etc. like no other substance. Simply think of glass masterpieces such as Bohemian crystal, the Murano Island of Italy, the Mirrors Gallery of Versailles' palace or stained glass in Cathedrals.

Glass is all around us nowadays and continues to offer cutting edge solutions, either in itself or used in combination with other materials for high-tech applications; a trend which is very likely to continue in the future.

Glass industries are characterized by a multitude of production processes depending on the final product manufactured and its end-applications. However, all

these manufacturing processes have a common origin: glass first needs to be melted!

Glass melting requires raw materials which are of two kinds: different types of sand and recycled glass. These raw materials are mixed together, charged in a furnace where there are melted at around 1500°C to form molten glass. The molten glass is then taken out of the furnace to be shaped and cooled down afterwards. For many applications the glass obtained may be further processed to have specific properties such as increased mechanic strength and higher resistance to breakage.

The exact composition of glass may vary to meet specific applications requirements but the most commonly use type of glass, soda-lime glass, is made of silica sand, soda ash, limestone, dolomite and glass cullets (recycled glass). Additional materials such as iron oxide or cobalt can be added to the mix to give a green or blue colour to the glass.

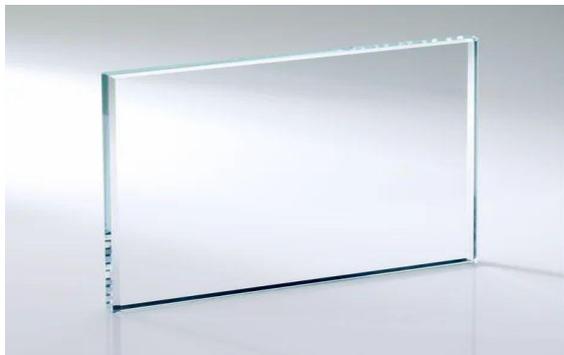


Fig: glass material

SAND

Using fine sand as an abrasive in Abrasive Jet Machining (AJM) to cut glass is a cost-effective and efficient method for precision machining. The fine sand particles, when propelled at high velocity using compressed air, impact the glass surface and gradually remove material through micro-abrasion. This process enables intricate cutting, shaping, and engraving of glass without excessive heat generation, which is a common issue in traditional machining methods. One of the key advantages of using fine sand as an abrasive is its availability and affordability. Unlike synthetic abrasives, fine sand is naturally occurring and can be sourced at a lower cost. It also provides a consistent cutting performance, especially when the particle size is controlled within a specific range. The sharp edges

of fine sand grains enhance the material removal rate, making it effective for cutting delicate and brittle materials like glass without causing cracks or breakage. The efficiency of glass cutting using fine sand depends on several process parameters, including abrasive flow rate, nozzle pressure, and stand-off distance. A higher velocity of sand particles improves the cutting speed but may also lead to excessive surface roughness if not controlled properly. Maintaining an optimal stand-off distance ensures precise cutting with minimal chipping at the edges. Additionally, regulating the abrasive flow rate prevents clogging in the nozzle and maintains a steady machining process. Proper dust collection and filtration systems must be implemented to ensure a safe working environment. Moreover, the selection of high-quality, well-graded sand minimizes nozzle wear and enhances overall machining performance.

In conclusion, fine sand is an effective abrasive for cutting glass in Abrasive Jet Machining, offering precision, cost-effectiveness, and minimal thermal damage. By optimizing process parameters and implementing safety measures, this method can be utilized for various glass machining applications, such as engraving, shaping, and cutting intricate patterns. With proper handling and control, fine sand can be a viable alternative to other abrasives used in AJM for glass processing.



Fig: sand particles

FABRICATION OF STEEL FRAME

Welding is a materials joining process in which two or more parts are coalesced at their contacting surfaces by a suitable application of heat and/or pressure. Many welding processes are accomplished by heat alone, with no pressure applied; others by a combination of heat and pressure; and still others by pressure alone, with no external heat supplied. In some welding

processes a filler material is added to facilitate coalescence. The assemblage of parts that are joined by welding is called a weldment.

Welding is most commonly associated with metal parts, but the process is also used for joining plastics. Our discussion of welding will focus on metals. Welding is a relatively new process. Its commercial and technological importance derives from the following:

- Welding provides a permanent joint. The welded parts become a single entity.
- The welded joint can be stronger than the parent materials if a filler metal is used that has strength properties superior to those of the parents, and if proper welding techniques are used.
- Welding is usually the most economical way to join components in terms of material usage and fabrication costs. Alternative mechanical methods of assembly require more complex shape alterations (e.g., drilling of holes) and addition of fasteners (e.g., rivets or bolts). The resulting mechanical assembly is usually heavier than a corresponding weldment.
- 4- Welding is not restricted to the factory environment. It can be accomplished “in the field.”

PROCESS PARAMETERS

There are various parameters which affects on strength of the weld. In that welding current, welding voltage, electrode size, welding speed. Basically by varying welding current, deposition of welding material may vary. High welding current cause's microstructure become finer and increase in tensile strength and low current caused root of the metal plate not weld completely which weakened the joint. Also the welding voltage is important parameter in welding process. The voltage is necessary for proper arc maintenance. Bead forming is too small due to too high voltage. The size of electrode to be chosen is based on the thickness of the plate. While too big electrode may stick and be hard to start, too small electrode will spatter and even can catch fire. The Speed at which electrode moves or deposition takes place.

The increase in welding speed usually decreases the penetration. Due to speed of welding, sufficient is getting for welding because of decreases penetration. At too slow welding speed, results in piling of head. If too fast, bead will be sparse and have poor fusion. The increase in welding speed usually decreases the penetration.

JOINT GEOMETRY

According to researchers study, it is found that the fatigue life is improved by varying gap size. Gap size affects on strength of the weld. Experimentally it is found that Overlap length plays major role in strength of the weld. Stress variation of lap zone changed by the overlap length. The maximum stress decreased when overlap length is increased. Researcher studied that, the gap size is more affective factor to fatigue life. According to study strength of the weld depended on the lap length and gap size and eliminates the stress concentration in overlapping area.

Arc welding processes uses an electrical power supply to create and maintain an electric arc between an electrode and the base material to melt metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The welding region is protected by some type of inert or semi-inert gas, known as a shielding gas.

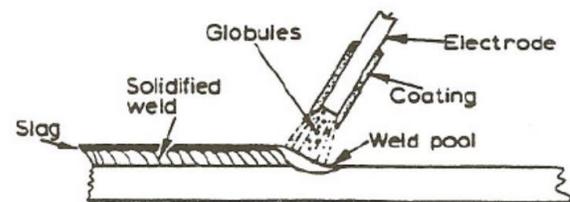


Fig: process of arc welding

To create the arc for welding, a voltage between 60 and 100 Volts is required to create the arc, but once it has been established, 20–40 Volts is required to maintain it. The following stages occur when creating an arc:

1. With the welding plant switched on, and before welding commences, no current passes through the leads and the ammeter reads zero. A voltage has been applied to the circuit, however, and the

voltmeter will read the open-circuit or no-load voltage (i.e. between 60 and 100V).

2. When the electrode is brought into contact with the job a large current, called The Short-circuit Current, passes through the leads, and the ammeter will deflect a large amount. While this is happening, however, the voltage drops almost to nothing. The tip of the electrode becomes hot because of the resistance created between it and the job.
3. If the electrode is slightly withdrawn an arc is formed between the electrode and the job. The air between the two conducts the welding current. As the arc is formed the voltage rises to between 20 and 40 V and the current falls to the value to which it has been set (i.e. the welding current). The arc is then in the normal welding condition. The heat generated by the arc melts both the work piece and the electrode, and metal is deposited in the weld pool. During the depositing of the weld metal, variations in both the voltage and current of the arc can occur and the welding plant must be capable of coping with these changes.

Equipment Used in Manual metal arc Welding

The principal equipment used in manual metal-arc welding includes:

1. Welding power source
2. Cables
3. Electrode holder
4. Earth clamp



Fig:Set-Up for Manual Metal Arc Welding

TYPES OF JOINTS

There are five basic types of joints for bringing two parts together for joining. The five joint types are not limited to welding; they apply to other joining and

fastening techniques as well. With reference to Figure 2, the five joint types can be defined as follows:

- (a) *Butt joint.* In this joint type, the parts lie in the same plane and are joined at their edges.
- (b) *Corner joint.* The parts in a corner joint form a right angle and are joined at the corner of the angle.
- (c) *Lap joint.* This joint consists of two overlapping parts.
- (d) *Tee joint.* In a tee joint, one part is perpendicular to the other in the approximate shape of the letter “T.”
- (e) *Edge joint.* The parts in an edge joint are parallel with at least one of their edges in common, and the joint is made at the common edge(s).

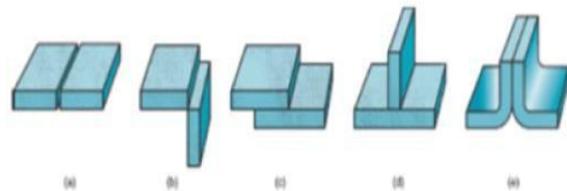


Fig: a) butt joint b) corner joint c) lap joint d) T-joint e) edge joint

TYPES OF WELDS

Each of the preceding joints can be made by welding. It is appropriate to distinguish between the joint type and the way in which it is welded—the weld type. Differences among weld types are in geometry (joint type) and welding process.

A fillet weld is used to fill in the edges of plates created by corner, lap, and tee joints, as in Figure

Filler metal is used to provide a cross section approximately the shape of a right triangle. It is the most common weld type in arc and oxyfuel welding because it requires minimum edge preparation—the basic square edges of the parts are used. Fillet welds can be single or double (i.e., welded on one side or both) and can be continuous or intermittent (i.e., welded along the entire length of the joint or with unwelded spaces along the length). Groove welds usually require that the edges of the parts be shaped into a groove to facilitate weld penetration. The grooved shapes include square, bevel, V, U, and J, in Figure. Five basic types of joints:

- (a) butt,
- (b) corner,
- (c) lap,
- (d) tee,
- (e) edge.

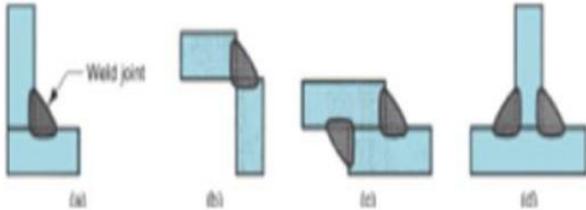


Fig: various forms of fillet welds: (a) inside single fillet corner joint; (b) outside single fillet corner joint; (c) double fillet lap joint; and (d) double fillet tee joint.

V. RESULTS

Abrasives Used:

Aluminium oxide (Al₂O₃) silicon carbide (SiC) glass beads, crushed glass and sodium bicarbonate are some of abrasives used in AJM. Selection of abrasives depends on MRR, type of work material, and machining accuracy.

| Abrasives | Grain Sizes | Application |
|---|--------------------|--|
| Aluminium oxide (Al ₂ O ₃) | 12, 20, 50 microns | Good for cleaning, cutting and deburring |
| Silicon carbide (SiC) | 25, 40 microns | Used for similar applications but for hard materials |
| Glass beads | 0.635 to 1.27 mm | Gives matte finish |
| Dolomite | 200 mesh | Etching and polishing |
| Sodium bicarbonate | 27 microns | Cleaning, deburring and cutting of soft material. Light finishing below 500°C. |

Table: gives classification of abrasives and its applications.



Fig: assembly



Fig: model view

VI. CONCLUSION

Abrasive Jet Machining (AJM) is a precise and effective non-conventional machining process that utilizes a high-velocity jet of abrasive particles carried by compressed air or gas to remove material from a workpiece through erosion. It is particularly suitable for machining hard and brittle materials like glass, ceramics, and composites, providing superior surface finish and intricate detailing compared to traditional methods. The process involves key components such as an air compressor, FRL unit, mixing chamber, nozzle, and piping system, each contributing to the controlled and efficient delivery of abrasive particles. Factors like abrasive flow rate, mixing ratio, gas pressure, and stand-off distance significantly influence the material removal rate (MRR), optimizing process efficiency and accuracy. While AJM shares similarities with sandblasting, it employs finer abrasives and smaller nozzles for precision applications. The use of fine sand as an abrasive is cost-effective and ensures consistent machining performance, although challenges like nozzle clogging and uneven erosion must be managed. The integration of a well-designed piping circuit and high-quality components enhances process stability and reliability. The FRL unit plays a crucial role in maintaining air quality, preventing contamination, and ensuring consistent pressure regulation. Glass machining using AJM benefits from minimal heat generation, reducing the risk of thermal damage and micro cracks. The choice of nozzle material, such as boron carbide, enhances durability and precision. Despite its low material removal rate, AJM is highly effective in micro-machining, engraving, and surface finishing applications.

VII. FUTURE SCOPE

The future scope of Abrasive Jet Machining (AJM) lies in advancing nozzle design, optimizing abrasive materials, and integrating automation for enhanced precision and efficiency. The development of smart nozzles with wear-resistant materials like diamond or advanced ceramics can significantly improve nozzle lifespan and machining accuracy. The use of nano-abrasives and environmentally friendly alternatives will help achieve finer surface finishes while reducing environmental impact. AI and machine learning can be integrated to optimize process parameters dynamically, leading to better control over material removal rates and reduced wastage. Hybrid machining techniques, combining AJM with laser or ultrasonic machining, can expand its applicability to complex geometries and multi-material machining. Improvements in robotics and CNC-controlled AJM systems will enable high-precision micro-machining in aerospace, biomedical, and electronics industries. Research into optimizing gas flow dynamics and pressure control can further enhance efficiency and reduce operational costs. With continuous innovations, AJM has the potential to become a key technology in high-precision, sustainable manufacturing applications.

REFERENCE

- [1] Shripad Chopade, Sagar Kauthalkar, and Pushpendra Kumar Sharma, Abrasive Jet Machining, International Journal of Modern Engineering Research (IJMER), Vol. 3, May-June 2013, pp- 1504-1511 Rajeev Kumar, C.S.Kalra Vijay Kr Sharma, Analysis on performance of Different parameters during Abrasive Jet Machining by Taguchi method.
- [2] Dr. A. k. Paul &R. K. Roy some studies on Abrasive jet machining the Journal of the Institution of Engineers (India) Vol 68 part PE 2 November 1987.
- [3] Finnie, Erosion of surface by solid particulates wear Vol.3 '.
- [4] Sarkar, P.K., Pandey, P.C., Some investigations on abrasive jet machining, Journal of Inst. Eng.(56),1976.
- [5] Ghobeity, H. Getu, T. Krajac, J. K. Spelt, M. Papini. "Process repeatability in abrasive jet micro-machining". Journal of materials processing technology 190(2007), pp.51-60, 2007.
- [6] El-Domiaty, H. M. Abed El-Hafez, and M. A. Shaker Drilling of Glass Sheets by Abrasive Jet Machining World Academy of Science, Engineering and Technology 32 2009.
- [7] Dr. M. Sreenevasa Rao, D. V. Shrekanth, Abrasive jet machining-Research Review, International journal of Advanced engineering Technology, Vol.5, pp.18-24, April-June. ' 2014.
- [8] R. Balasubramaniam, J. Krishan, N. Ramakrishnan. An empirical study on the generation of edge radius in abrasive jet external deburring (AJED), J.Mater Process Technol. 99(2000) 49.
- [9] R.H.M. Jafar, M. Papini, J. K. Spelt, Surface roughness and erosion rate of abrasive jet micromachined channels: Experiments and analytical model,-2013~Elsevier.
- [10] Alireza Moridi, Jun Wang, Yasser M. Ali, Philip Mathew and Xiaoping Li. Drilling of Glass Sheets by Abrasive Jet Machining Key Engineering Materials, vol. 443, pp. 645-651, June 2010.
- [11] Juan-Hung Ke, Feng-Che Tsai, Jung-Chou Hung, Bing-Hwa Yan, "Characteristics study of flexible magnetic abrasive in abrasive jet machining" Pro. CIRP 1 (2012), pp. 679 – 680.
- [12] Kumar Abhishek, Somashekhar S Hiremath. "Machining of Micro-holes on Soda lime Glass using Developed Micro-Abrasive Jet Machine (μ -AJM)." Pro. Techn. 25 (2016), pp. 1234 – 1241.
- [13] Kumar Abhishek and Somashekhar S Hiremath. "Improvement of Geometrical Accuracy of Micro Holes Machined Through Micro Abrasive Jet Machining", Pro. CIRP 46 (2016). Pp.47 – 50.
- [14] D.V. Srikanth, Dr. M. Sreenivasa Rao, "Metal Removal and Kerf Analysis in Abrasive jet drilling of Glass Sheets", Pro. Mater. Scie. 6 (2014), pp. 1303 – 1311.
- [15] Vasanth S, Muthuramalingam, T, Vinoth kumar P, Geethapriyan T, Murali G, "Performance Analysis of Process Parameters on Machining Titanium (Ti-6Al-4V) Alloy Using Abrasive Water Jet Machining Process", Pro. CIRP 46 (2016), pp. 139 – 142.
- [16] Dirk Biermann, Robert Aßmutha, Sebastian Schumann, Michael Rieger, Bernd Kuhlenkötter, "Wet abrasive jet machining to prepare and

design the cutting edge micro shape”. Pro. CIRP 45 (2016), pp. 195 – 198.

- [17] Vishal Guptaa , P.M. Pandeya ,Mohinder Pal Garg, Rajesh Khannab, N.K.Batrab, “Minimization of kerf taper angle and kerf width using Taguchi’smethod in abrasive water jet machining of marble”, Pro. Mate. Sci. 6 (2014), pp.140 – 149.