DESIGN AND FABRICATION OF WORKING MODEL OF ABRASIVE JET MACHINE

Mr. E.BRAVIN DANIEL bravindaniel@stellamaryscoe.edu.in

Mr. J.STALIN DEVA PRINCE starlindevaprince@stellamaryscoe.edu.in

Mr. S.S.RAJKUMAR rajkumar@stellamaryscoe.edu.in

Mr. I. P. RAKHESH rakhesh@stellamaryscoe.edu.in

Department Of Mechanical Engineering

Stella Mary's College Of Engineering, Tamilnadu, India

Abstract - With the development of technology, more and more challenging problems are faced by scientists and technologists in the field of manufacturing. The many new materials and alloys that have been developed for specific uses possess very low machinability. Producing complicated geometries in such materials becomes extremely difficult with the usual methods. To tackle such difficult jobs, two approaches are possible, viz., (i) a modification of the traditional processes and (ii) the development of new processes. This paper presents the modeling of an abrasive jet machine. The individual parts are fabricated and assembled in the workshop.
Key words: AJM, modeling, fabrication, catia, assembly, small-scale industry.

1. INTRODUCTION

Abrasive Jet machining is a nontraditional manufacturing process that can make complex shapes on the surface of hard and brittle materials. It is a process of material removal through the action of a focused stream of fluid with abrasive particles. It is especially used for machining superalloys, ceramics, glass, and refractory materials. Here, the material removals are mainly due to the impingement of the fine abrasive particles on the work surface. The metal cutting occurs due to erosion caused by the abrasive particles impacting the work surface at a high speed. As a result of repeated impact, small bits of material get loosened and separated from the workpiece surface, exposing a fresh surface to the jet. The AJM is different from conventional sand blasting, as the latter is a surface cleaning process and the AJM is a metal cutting process. The process is used mainly to cut complex shapes in hard and brittle materials, which are heat-sensitive and have a tendency to chip easily. AJM is also used for removing burrs and cleaning operations. AJM is free from vibration and chatter problems. As the carrier gas itself serves as a coolant, the cutting action is cool [1].

1.1 Concepts of AJM

A schematic layout of AJM is shown in Figure 1.1. In AJM, air is compressed in an air compressor at a pressure of 5 bar, which is used as carrier gas. Gases, like CO2, N2, etc., that may be directly issued from a cylinder can also be used as carrier gases. The carrier gas first passes through a pressure regulator to obtain the required working pressure. The gas is then passed through an air filter regulator to remove any residual water vapor. To remove any oil vapor or particulate contamination, the same is passed through a series of filters. After that, carrier gas enters a closed chamber known as the mixing chamber. The abrasive particles enter the chamber from a hopper through a metallic sieve. The sieve is constantly vibrated by an electromagnetic shaker. The mass flow rate of abrasive (16 g/min) entering the chamber depends on the frequency and amplitude of the vibration of the sieve. The abrasive particles are then carried by the carrier gas to the machining chamber via an electromagnetic on-off valve. The machining chamber is essential to contain the machined particles and abrasives in a safe and eco-friendly manner. The machining is carried out at high velocity (200–300 m/s), and abrasive particles are issued from the nozzle onto a work surface traversing under the jet.

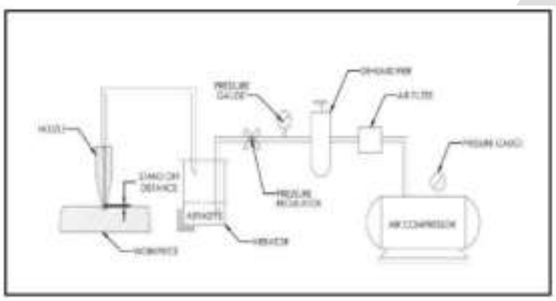

Fig -1: Schematic Layout of AJM

The components are:

1. air compressor
2. Air filter
3. Dehumidifier
4. Pressure gauge
5. Mixing chamber
6. Pressure regulator
7. Nozzle
8. Machining chamber
9. Vibrator
10. Work-holding device

- It is able to cut brittle, fragile, glass, and heat-sensitive materials without damage.
- It is able to cut intricate shapes or complex profiles in hard or brittle materials.
- As the machining action is cool, in this process, no heat is generated.
- No tool change is required.
- High-quality surface finish.
- The surface of the workpiece is cleaned automatically.

- The capital cost is low.

1.2 Disadvantages of AJM

Very low material removal rate. Hence, the application of AJM is limited.
The process always produces a tapered cut.
In certain substances, abrasive particles might settle over the workpiece.
Nozzle life is less.
It can’t be used for machining soft materials.
It can’t be used to drill blind holes.

1.3 Applications of AJM

Used in cutting slots, thin sections, contouring, and drilling.
It can also be used for the etching and deburring processes.
It is sometimes used for the cleaning and polishing of Teflon and plastic components.
It is used for paint removal.
It is used mainly in the textile and leather industries.
It is used in nuclear plant dismantling.

2. LITERATURE REVIEW

Balasubramaniam et al. [2] investigated the abrasive jet deburring process parameters and the edge quality of abrasive jet deburred components. An experimental design based on a Taguchi orthogonal array was used to systematically measure the influence of the major cutting parameters on abrasive jet-deburred specimens. The experimental specimens used were 1.5-mm-thick, 25-mm-square grade AISI304 stainless-steel sheets. Burrs were generated by the face milling operations. The ANOVA method was used for the visual inspection of edge quality. It was found that the deburring process is significantly affected by ‘height of the jet’ and ‘impingement angle’. It was concluded that the abrasive jet deburring process is more advantageous than the manual deburring process. The quality of deburred components mainly increases with the generation of edge radii.

Yamauchi et al. [3] investigated the effect of workpiece properties on machinability in abrasive jet machining of ceramic materials. Three kinds of common abrasives, viz., aluminum oxide, silicon carbide, and synthetic diamond, were employed for conducting the experiment. The target materials used were four kinds of ceramics, viz., ZrO_2, Si_3N_4, Al_2O_3, and SiC. A laser scanning microscope was used to measure the volume that was removed by abrasive jet machining. The machinability of the AJM process was compared with the established models of solid particle erosion, in which the material removal is assumed to originate in the ideal crack formation system. Further, it was found that the AJM test results did not depend on the erosion models because the relative hardness of the abrasive against the target material, which has not been taken into account in the models, is critical in the machining process. It was also concluded that the AJM process had a high potential as a micromachining method because it was damage-free for many materials because the radial cracks did not extend downwards from the impact of the particle during the machining process.

Ally et al. [4] used surface-evolved models to predict abrasive jet machining of metallic substrates. The abrasive jet inclination angle of the erosion rate was measured. The material is aluminum 6061-T6, Ti-6Al-4V titanium alloy, and 316L stainless steel. The jet inclination angle was measured using 50-micrometer-thick Al2O3 abrasive powder launched at an average velocity of 110 m/s.The peak erosion rate was found to occur from 200 to 350 relative to the surface for all three systems. It was found that aluminum has a higher volumetric erosion rate than titanium alloy, which is higher than the stainless steel erosion rate on a volumetric basis, which in turn is significantly lower than brittle materials such as glass and polymers. It was also found that where a high degree of control is desired, the AJM of metals is best suited for the etching of relatively shallow features. It was concluded that scanning electron micrographs and EDX analysis of the eroded surface of 316L stainless steel give a significant amount of particle adhering with a smaller amount in the titanium alloy.

S. Pawar et al. [5] investigated abrasive material sea sand in a vibrating chamber. The tungsten carbide nozzle was used in the abrasive jet micromachining process. The sand of 100–150 microns was used for the experiment. The workpiece used was a glass of 4 mm thickness. The evaluated performances were material removal rate and flow rate. It was found that the impact through the nozzle caused severe erosion on the material work piece. It was demonstrated that the erosion of the material surface depended on the velocity, direction, and brittleness of the material. The experiment was performed by using a combination of two different parameters, viz., standoff distance and pressure. From the result, it was concluded that the material removal rate and flow rate were similar to the actual abrasives used, like aluminum oxide, silicon carbide, etc. It was noticed that by increasing the feed rate, the 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 and Dinesh Singh [6] used the Taguchi method for an experimental investigation of abrasive water jet machining parameters. The material used is an AA6351 aluminum alloy. Parameters such as transverse speed, standoff distance, and mass flow rate are considered to determine 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.

Ghobeity et al. [7] predicted models of abrasive jet micromachining for masked and unmasked borosilicate glass channels by using 25 micrometers of aluminum oxide. A novel technique is used for the velocity distribution of the particles in the jet of abrasive jet micromachining. It was found that the velocity decreased linearly from the center line of the jet to the periphery, with the 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 as an extension of the already existing model. Timedependent particle mass flux and velocity distribution were used for modeling the effect of the nozzle. Further, it was demonstrated that the distribution of net erosive power over the cross section passing through the round nozzle had the same form as the distribution along the diameter of the stationary nozzle. By measuring the particle velocity across the cross-section of the jet, it was found that the velocity decreased linearly from the center to the periphery. It was concluded that by reducing the incident particle energy flux caused by mask edge scattering, the prediction of masked channel profiles is affected.

Manabu Wakuda et al. [8] investigated the material response of alumina ceramics to the abrasive particle impact in the AJM process. Three types of abrasive grains, viz., aluminum oxide, silicon carbide, and synthetic diamond, were used for the impact on alumina ceramics. AJM equipment with a microblaster (MB2-ML-001, Sintobrator, Japan) was used, which is capable of shooting fine abrasives along with a pressurized nitrogen gas stream through a small jet nozzle. It was found that the softest abrasive aluminum oxide leads to roughening of the alumina surface but causes no mark due to the lack of hardness of the abrasive against that of the work piece. It was also found that by employing silicon carbide, a relatively smooth face could be produced as a result of ductile behavior under the elevated temperature caused by the abrasive impacts. With the impingement of synthetic diamond abrasive, a large-scale fragmentation was observed, and therefore the surface became rough.

Dong-Sam Park et al. [9] improved micromachining using machining ceramics, semiconductors, electronic devices, and LCDs. For microgrooving of glass, he checked the performance of micro-AJM. Process parameters for micro-AJM were pressure, velocity, time, stand-off distance, material properties, and the number of nozzle scanning times. Microgrooving consisted of a masking process, an abrasive jet machining process, and a mask removal and cleaning process. White aluminum was used for machining, whose main ingredients were Al2O3. The results showed that when the heat amount was 160 mJ at 1050°C, the masking results were considerable and otherwise poor. In the same way, grooving results showed that when the heat amount was 150 mJ, the hole type was not well generated, but when the amount was 160 mJ, the machined grooves were generally in good condition.

3.MODELLING OF AJM

The whole 3D modelling was done in CATIA. Following articles cover the modelling of different components of AJM.

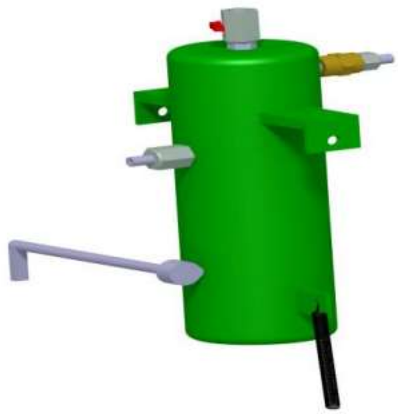

Fig -2: 3D Model of Mixing Chamber

Nozzle

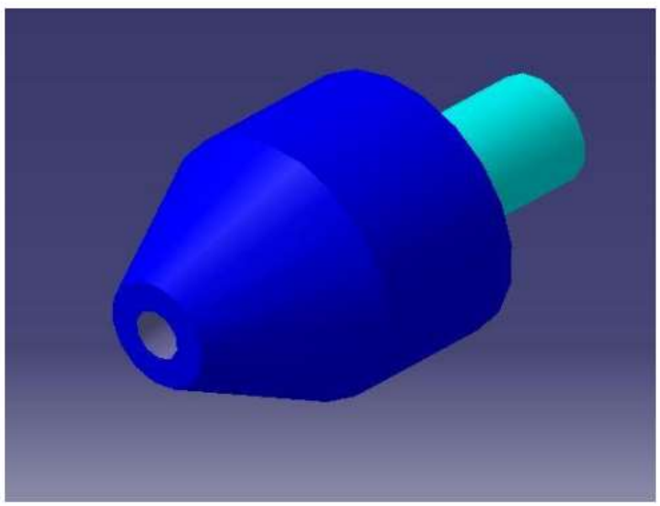

Fig -3: 3D Model of Nozzle

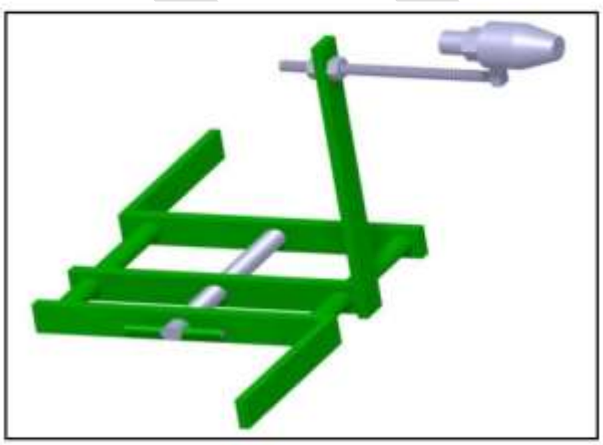

Fig -4: 3D Model of Nozzle Stand Assembly

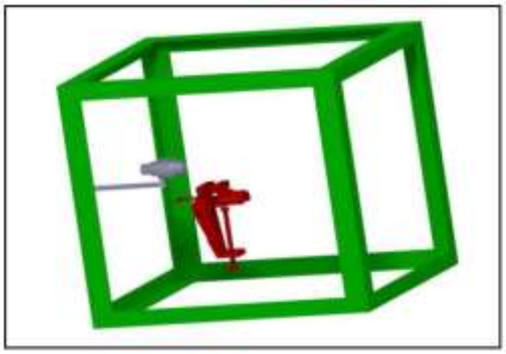

Fig -5: 3D Model of Machining Chamber

Fig -6: 3D model of AJM

2. Fabrication of AJM

The systems were developed as per m The systems were developed as per modeling and then assembled.

3.1 Mixing Chamber

The design of the mixing chamber was done specially for proper mixing of the compressed air and abrasives. For this purpose, we used a seamless mild steel pipe and joined a circular plate, both at the top and bottom ends. Three holes were drilled on the structure, the first at the top; the other two were on the surface. The top hole was used to pass the abrasives into the chamber. From the two holes on the surface, one was used to pass the compressed air from the dehumidifier, and the other brought out the mixture of compressed air and abrasive to the nozzle.

Fig -7: Actual view of mixing chamber

The nozzle was used for the general purpose of increasing the velocity of the mixture of compressed air and abrasives. Due to this purpose, it was tapered in shape. The nozzle was prepared from a cylindrical block that underwent plain turning in the beginning. The nozzle was then tapered for the required use. Inside tapering was done using different drill bits in continuation. The nozzle was fabricated using EDM. The material used was D-2 steel.

Fig -8: Actual view of nozzle

4.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 1.5 mm in the X direction. In the 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 of moving the nozzle in the Y direction was to make a slot in the workpiece.

Fig -9: 3D Model of Complete Assembly

It was cubical in shape. It was basically made up of a 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 workpiece. 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 could be removed by removing the threaded bolt. It was done so to load and unload the workpiece.

After fabricating different components of abrasive jet machining, a frame-like structure was designed and fabricated that supports all the major components of abrasive jet machining. The figure shows the assembly design for abrasive jet machining. All the above components, including the 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.

Fig -10: Actual view of AJM

5.RESULT AND CONCLUSION

In AJM, a focused jet or stream of abrasive particles carried by high-pressure gas (the 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 material get loosened and separated from the workpiece 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. Some of the remarks on the present work are:

- Each part is modeled in CATIA software.
- Each part is fabricated in the workshop.
- Each part is assembled to make a complete AJM setup.

REFERENCES

[1] Amitabha Ghosh and Asok Kumar Mallik,Manufacturing Science, East-West Press, New Delhi, 1985. [2] R. Balasubramaniam and J. Krishnan, "Investigation of AJM for deburring", Journal of Materials Processing Technology, 2014, pp 52-58.

[3] S. Kanzaki and Y. Yamauchi,"Effect of work piece properties on machinability in abrasive jet machining of ceramic materials", Journal of the International Societies for Precision Engineering and Nanotechnology, 2012, pp 193-198

[4] S. Ally, J. K. Spelt and M. Papini,"Prediction of machined surface evolution in the abrasive jet micro-machining of metals", International Journal on the Science and Technology of Friction Lubrication and Wear, 2012, pp 89-99.

[5] N. S. Pawar, R. R. Lakhe and R. L. Shrivasstava,"A comparative experimental analysis of sea sand as an abrasive material using silicon carbide and mild steel nozzle in vibrating chamber of Abrasive Jet Machining process", International Journal of Scientific and Research Publications, Vol. 3, Issue 10, 2013.

[6] Rajkamal Shukla, and Dinesh Singh,"Experimentation investigation of abrasive water jet machining parameters using Taguchi and Evolutionary optimization techniques", Swarm and Evolutionary Computation, 2017, pp 167-183. [7] A. Ghobeity and T. Krajac,"Surface evolution models in abrasive jet micromachining", International Journal on the Science and Technology of Friction Lubrication and Wear, 2014, pp 185-198. [8] Manuba Wakuda and Yukihiko Yamauchi,"Material Response to particle impact during abrasive jet machining of alumina ceramics", Journal of Materials Processing Technology, 2013, pp 177-183. [9] Dong-sam Park, Myeong-Woo Choo and Honghee Lee, "Micro-grooving of glass using micro-abrasive jet machining", Journal of Materials Processing Technology, 2004, pp 234-240.