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ABRASIVE JET DRILLING AND CUTTING MACHINE

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ABSTRACT
An efficient method of processing a range of hard and brittle materials is abrasive jet machining. Additionally, it differs significantly from other non-traditional cutting techniques in that it offers high machining versatility, minimal work-piece stress, high flexibility, no thermal distortion, and low cutting forces. The abrasive jet machine is a non-traditional machining technique where a high-velocity abrasive particle is made to impact the work material. Air or a carrier gas carries the jet of abrasive particles. By converting the carrier gas or air's kinetic energy to pressure energy, a high velocity stream of abrasive is created. The fragile material is removed by micro cutting caused by the high velocity abrasive particles.

Keywords:
Abrasive material, Compressed Air or gas, Glass

INTRODUCTION

A specialized instrument known as an abrasive jet drilling and cutting (AJDC) machine is used to drill and cut through a range of materials by firing a high-velocity jet of abrasive particles suspended in a pressurized gas stream. This introduction gives a general overview of AJDC machines while emphasizing its advantages, uses, and operating principles. Industries including aerospace, automotive, electronics, and manufacturing, which call for exact drilling and cutting of complicated forms, frequently use AJDC machines. AJDC machines work without direct contact between the tool and the workpiece, in contrast to conventional drilling and cutting techniques that depend on it. Instead, they erode the material with a concentrated stream of abrasive particles, enabling high-precision machining. Precision drilling and cutting of delicate shapes is required in industries such as aerospace, automotive, electronics, and manufacturing. Instead, they erode the material with a focused stream of abrasive particles, allowing for high-precision machining. An AJDC machine works by pressurizing a mixture of abrasive particles, such as garnet or aluminum oxide, with a carrier gas, commonly air or nitrogen, to produce a supersonic abrasive jet. The abrasive particles are then driven towards the workpiece at extremely high speeds, ranging from a few hundred meters per second to several thousand meters per second. Precision drilling and cutting of delicate shapes is required in industries such as aerospace, automotive, electronics, and manufacturing. AJDC machines function without direct contact, in contrast to typical drilling and cutting procedures that require on physical contact between the tool and the workpiece. As the abrasive particles strike the material's surface, small particles are removed, eventually drilling or cutting through the material. Because of its versatility, AJDC machines may work on a wide range of materials, including metals, ceramics, composites, and even fragile materials like glass and semiconductors. As a result, they are appropriate for applications such as hole drilling, slotting, contouring, and precision cutting in a variety of sectors. Furthermore, there is no unifying knowledge on how abrasives work in their various applications, which range from polishing to cutting off, rough machining to precision grinding. Milton Shaw of the University of Arizona has done much to uncover the basic fundamentals of abrasives as they apply to metalworking. The vast bulk of other technical literature on the subject, on the other hand, is fundamentally empirical, reporting on initiatives involving specific items and materials under specific conditions. As a result, there is a substantial body of accumulated knowledge and a huge number of process variables. Controlling a grinding process, then, necessitates a system approach that emphasizes the interdependence of the grinding wheel, machine tool design, grinding fluids, process and parameters, and other system elements.

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OBJECTIVES

i. Develop a low-cost abrasive jet machine: The major goal is to produce a low-cost abrasive jet machine capable of providing efficient and precise cutting capabilities. This goal seeks to make abrasive jet technology more accessible to a broader variety of users by lowering the machine's overall cost without sacrificing performance.
ii. To build and test the machine: This goal entails building the abrasive jet machine according on the design and specifications set throughout the development process. After the machine is completed, it will be thoroughly assessed and tested to determine its functionality, performance, and dependability. This phase guarantees that the machine satisfies all of the necessary specifications and functions optimally throughout abrasive jet drilling and cutting operations.
iii. Removing material from a workpiece (glass) using a high-speed stream of abrasive delivered in a gas stream medium from a nozzle: The goal is to successfully apply the abrasive jet cutting technique, which involves using a high-speed stream of abrasive particles transported by a gas stream medium. The emphasis is on removing material from the workpiece, notably glass in this case.
iv. To cut heat-sensitive and delicate materials without causing harm: This goal emphasizes the abrasive jet machine's capacity to cut heat-sensitive and delicate materials, such as glass, without causing damage or distortion. The machine should be built and optimized to cut precisely and precisely, allowing for complicated forms and profiles while minimizing temperature effects on the workpiece.
v. The tool should be user-friendly and ergonomic: This goal emphasizes the need of developing an abrasive jet machine that is both user-friendly and ergonomic. To ensure simplicity of use and to reduce the danger of accidents, the equipment should be constructed with intuitive controls, clear operating instructions, and safety measures. Ergonomic considerations strive to provide the operator with a comfortable and efficient working environment, increasing productivity and decreasing operator fatigue.

LITERATURE REVIEW

S. Naveen and Aslam A. Hirani (2014) AJM is mostly used to cut shapes in hard and brittle materials such as glass, ceramics, and so on. The machine was designed, built, and tested for several factors such as material removal rate, abrasive particle size, and fabrication material type. Stream Utilization the principle of material erosion while fine abrasive particles carried in high velocity air or gas impinge on the work-piece surface.
S. Wang and C.H. Li (2012) The current state of development and recent advances in high efficiency abrasive machining technologies related to high speed and super high speed grinding efficiency deep cut grinding and abrasive belt grinding were summarized in this study. Abrasive machining processes' efficiency and parameter range were compared. The fundamental technologies of high efficiency abrasive machining were studied. It was concluded that high efficiency abrasive machining would be a promising future technology.
Gagandeep Singh, Raminder Singh (2014) The following AJM process parameters were validated in this paper: pressure, nozzle tip distance, and nozzle diameter. The Taguchi Method's L9 orthogonal array is utilized for optimization and finding the optimum value for maximum Material Removal Rate. The Al2O3 abrasive particle achieves a maximum material removal rate of 37.5. The ideal air pressure for increased MRR is 55 psi. It is worth noting that the Al2O3 abrasive particle produces the smallest overcut, 0.14.
Punit Grover, Sanjay Kumar, Qasim Murtaza (2014) This study discusses the manufacture of AJM and machining on tempered glass, as well as the calculation of material removal while adjusting various performance factors using the Taguchi Method.
Fabrication of the AJM and machining on tempered glass, calculating material removal while altering performance parameters such as pressure angle and abrasive grit size, and so on. For MRR analysis, the Taguchi method and ANOVA are utilized. L9 orthogonal arrays were used in statistically constructed experiments based on Taguchi methods to analyze the MRR as the responsible variable. The concepts of S/N ratio and ANOVA for data analysis yielded similar results.
J.M. Fan, C.Y. Wang, J.Wang (2008) An experimental research encompassing a range of common process characteristics was used to examine and validate the predictive power of the models. It demonstrates that model predictions agree well with experimental results.
The models are developed using a dimensional analysis technique as functions of particle impact parameters, target material qualities, and important process parameters known to affect the erosion process of brittle materials.

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A dimensional analysis technique was used to construct predictive mathematical models for the erosion rate in hole and channel machining on glasses by micro abrasive air jets.
Jukti Prasad Padhy, Shailesh Dewangan, Gangadharudu Talla. (2013) Drilling experiments were conducted on AJM using glass as the workpiece and aluminum oxide (AL2O3) as the abrasive powder. The effect of overcut and MRR of glass was discovered using an orthogonal array created by Taguchi. Pressure has the greatest impact on MRR and OC. It is proportional to the replies (MRR, OC).The ideal AJM parameter settings for highest MRR and minimum OC were discovered to be SOD=1mm, P=4bar.
T. Gavaskar, c. Devabalan, M.A. Revanth, G. Sakthiseelan, A. Rajivranjan, K. Ashok Kumar, H. Vishwanathan. (2016) This research investigates the process factors that are used to determine the surface roughness of a machined surface. Process parameter analysis entails determining the surface roughness of the machined surface. The effect of various parameters on the surface roughness of the material is investigated, and the best circumstances for achieving the best surface finish are identified.
D.V. Srikanth, Dr. M. Sreenivasa Rao. (2014) This study presents Taguchi methodology for optimizing process parameters of Abrasive Jet Machining of Glass .The Taguchi Analysis results were compared to the Analysis Variance (ANOVA).Taguchi methodology was used to optimize the process parameters of ajm of glass, which were then compared using analysis of variance anova. The ideal levels of performance were established as air pressure (8kg/cm2) sod (10mm) nozzle diameter (4mm). The ideal levels of performance were established as air pressure (6kg/cm2) sod (9mm) nozzle diameter (3mm). Taguchi's results are substantially identical to anova's results.
Ivan Sunit Rout, Kasturi Panigrahi, Banishree Pardhan. (2014) The report describes how AJM works on brittle materials by using a high-speed stream of abrasive particles delivered by a gas medium via the nozzle. It also discusses the effect of gas pressure on the material removal rate AJM. The application of a high-speed stream of abrasive particles carried by a gas medium through the nozzle to brittle material, such as glass, and the impact of gas pressure on mrr in ajm experimental results and graphs show that gas pressure has a direct impact on material removal rate. when a result, when the pressure rises, so does the rate of material removal.
Massimiliano Barletta, Stefano Guarino, Gianluca Rubino, Vincenzo Tagliaferri. The internal finishing of tubular components composed of a high strength aluminum alloy (AA 6082 T6) utilizing a Fluidized Bed aided Abrasive Jet Machining (FB-AJM) system is the subject of this paper. Using a fluidized bed aided ajm system, internal finishing of tubular components manufactured of a high strength aluminum alloy (aa 6082 t6) was achieved. The proposed fb-aim system's machining capabilities is validated by constant material removal and average roughness trends based on the primary operational variable. According to this finding, fluidized bed hydrodynamic enhances the properties of the jet fluid and, as a result, the abrasive design and distribution to the workpiece, resulting in superior overall finishing outcomes.
Rajeev Kumar, Gurdeep Singh Deol, C.S. Kalra, Vijay Kr Sharma. (2014) The impacts of micro AJM settings on Material Removal Rate (MRR, gm/sec) and Overcut (mm) during micro machining of Silicon Glass are presented in this research. A mini AJM setup has been made. Consider a tungsten carbide nozzle with diameters of 1.3mm, 1.5mm, and 2.3mm. The SIC abrasive with grit size 70 micrometer is chosen. Another parameter range evaluated includes pressure: 50 psi, 55 psi, 60 psi, and nozzle tip distance: 8mm, 10mm, and 12mm. The ideal parameters for increased MRR are found to be 60 psi pressure, 8 mm Nozzle tip distance, and 1.5 mm Nozzle diameter. The best parameters for decreased overcut are likewise discovered to be 50 psi pressure, 8 mm nozzle tip distance, and 1.2 mm nozzle diameter.
N.S. Pawar, R.R. Lakhe, R.L. Shrivastava (2013) The current study examines the performance of Sea Sand in Silicon Carbide and Mild Steel Nozzles, as well as their estimated life of nozzle diameter. Glass was employed as a workpiece in this experiment.
The performance of sea sand in silicon carbide nozzles and mild steel nozzles, as well as their estimated life of nozzle diameter, are investigated. Glass is utilized as a working material. The hardness of the nozzle material is important in terms of erosion wear in the AJM process. Silicon nozzles have a longer life than mild steel nozzles.
Parteek Vijay Kumar Year- (2015) This paper discusses the creation of an Abrasive Jet Machine and machining on tempered glass, as well as estimating Material Removal while adjusting various performance parameters such as pressure, angle, and abrasive grit size. The Taguchi technique and ANOVA are used to analyze the material removal rate. The rate of material removal rises with pressure and abrasive size in microns. The rate of material removal increases as the angle value decreases. Taguchi's optimization approach calculates the maximum MRR as 0.0099 gm/sec.

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. Bhaskar Chandra Year- (2011) This study discusses several tests that were carried out to evaluate the effect of Abrasive Jet Machining (AJM) process parameters on the material removal rate and diameter of holes in glass plates employing aluminum oxide abrasive particles. Several studies were carried out to evaluate the effect of AJM process parameters on MRR and diameter of holes in glass plates employing aluminum oxide abrasive particles. When the experimental results were compared to earlier data, it was discovered that as NTD rises, so do the top and bottom surface diameters of the hole. MRR rises as pressure rises.
R. Balasubramanium, J. Krishnan, N. Ramakrishnan In this study, a semi-empirical equation is derived to obtain the shape of the surface generated in AJM, and it is demonstrated that the abrasive jet machined surface is reverse bell mouthed in shape, with an edge radius at the target surface's entry side. To acquire the shape of the surface created in AJM, a semi-empirical equation is derived. The equation is based on the AJM surface's reversed bell mouth form, and it matches the experimental data. The MRR near the jet's center line grows dramatically as particle size increases. As the SOD grows, so does the entry side diameter and the entry side h radius.
. Goutam Shriyan, Rohit Shinde, Harshavardhan Ronge (2015) Drilling is performed on a glass piece using silicon carbide as an abrasive powder in this paper. The L18 orthogonal array is chosen based on multiple degrees of controlling factors using the Taguchi method of design of experiment. The L18 orthogonal array is chosen based on multiple degrees of controlling factors using the Taguchi method of design of experiment. ANOVA was used to analyze the results. According to the results of the investigation, pressure and abrasive size are both important for MRR, but only pressure for taper angle.

RESULTS AND DISCUSSION

For our project, we used 2mm thick plain glass. The results of various configurations used for testing are shown below.

Distance between Jet nozzle and Glass	Size of Hole obtained
1 mm	1.5mm
2 mm	2.7mm
3 mm	3.0mm
4 mm	3.6mm

Table no 1: Result

When the distance between the jet nozzle and the glass surface was set to 1 mm, the hole in the glass substance measured 1.5 mm. This suggests that a shorter standoff distance resulted in a smaller hole size. When the distance between the jet nozzle and the glass surface was increased to 2 mm, the hole size increased to 2.7 mm. This implies that as the standoff distance increased, so did the hole size. When the standoff distance was set to 3 mm, the hole in the glass material measured 3.0 mm. This result shows that when the standoff distance increased, the hole size grew larger. Finally, the obtained hole size in the glass material measured 3.6 mm with a standoff distance of 4 mm. This suggests that the tendency of growing hole size with increasing standoff distance was consistent. It is important to note that the reported trend may vary based on other variables such as abrasive material, nozzle design, cutting speed, and material qualities. As a result, more testing and analysis are needed to identify the best standoff distance for certain materials and cutting conditions. The results show that the standoff distance between the jet nozzle and the workpiece surface has a considerable influence on the size of the hole generated during abrasive jet drilling and cutting. The hole size grew in proportion to the standoff distance. This is due to the abrasive particles spreading more widely as they travel a greater distance before reaching the workpiece surface.

CONCLUSION

The material removal rate in low-cost abrasive jet machines increases with rising pressure and decreases with decreasing glass thickness and hole size. Pressure and material removal rate are inversely related. The erosion process removes material as a result of an increase in pressure and the kinetic energy of the abrasive particle. Up to a certain point, the material removal rate increases as hole size increases; however, beyond that point, the rate of material removal decreases as hole size increases. The material removal rate increases as hole size, work piece, nozzle jet, and abrasive mesh size decrease because the abrasive

CONCLUDING REMARKS AND FUTURE SCOPE

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The growth and advancement of abrasive drilling and cutting equipment promise to be fascinating. Current study and experiments have shed important light on the strengths and weaknesses of ADC devices. However, there is a lot of room for further research and development. The creation of advanced nozzle designs will be one future priority. The abrasive jet properties can be optimized through advancements in nozzle arrangements, materials, and geometries, resulting in higher cutting performance and increased material compatibility. ADC machines will function more effectively and efficiently if process variables such gas pressure, abrasive flow rate, and cutting speed are optimized. Another crucial factor is extending the spectrum of materials that are compatible. It is possible to do research on drilling or cutting difficult materials.

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