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Parametric Investigation of Abrasive Jet Machining

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ABSTRACT

Abrasive Jet Machining (AJM) is a non-traditional machining process that removes materials through the erosive action of a high-velocity gas jet, causing fine-grained abrasive particles to impact the work surface. This technique is ideal for cutting intricate shapes in hard and brittle materials, which are sensitive to heat and easily chip. AJM is applied to rough working, debarring, and finishing, and has become a useful technique for micromachining in various industries, including ceramics, semiconductors, electronic devices, and L.C.D. The top surface diameter and bottom surface diameter of the hole increase as the nozzle tip distance (NTD) increases, as is typical of the abrasive jet machining process. The material removal rate (MRR) increases along with the pressure.

Introduction

Abrasive jet machining (AJM) is a non-conventional machining technique employed for the purpose of achieving precise cutting, cleaning, and surface preparation of various materials. The process entails the application of a forceful stream of abrasive particles that are targeted at the surface of the workpiece, resulting in the removal of material via erosion. The procedure encompasses several key components, namely a nozzle assembly, pressurization, precise focusing and control, as well as the removal of material. AJM provides several benefits, including the absence of heat-affected zones, the ability to work with non-conductive materials, and the achievement of high levels of precision [1]. Nevertheless, this technique exhibits certain limitations, including a relatively low rate of material removal, the production of rough edges, and the requirement for expensive equipment and operational expenses. The AJM process is well-suited for the machining of non-conductive materials and for applications that priorities the prevention of thermal damage [2]. However, it is important to acknowledge that this manufacturing method also possesses inherent challenges. The aforementioned factors encompass a range of challenges, such as reduced rate of material removal, surface impairment, nozzle degradation, obstruction caused by abrasives, ecological considerations, and restricted control over depth [3]. The process of AJM necessitates multiple iterations in order to attain the desired level of depth or shape, thereby resulting in potential time constraints within manufacturing operations. Additionally, there may be instances of surface damage, nozzle wear, abrasive clogging, and environmental considerations that can emerge [4]. The development of nozzle design, abrasive selection, and process control has effectively addressed these challenges, rendering AJM a feasible choice for targeted material removal needs. Abrasive water jet machining (AWJM) factors affect surface roughness in squeeze-cast Al-graphite composites [5]. Water pressure outweighed traversal speed and standoff distance in L9 Taguchi trials. Surface roughness was predicted via linear regression. A high-velocity water jet containing generated abrasive particles erodes in AWJM, a non-traditional machining method used in different industrial applications [6]. Water pressure lowered kerf tapper angle and surface roughness. AJM micro machines ceramics, semiconductors, electronic devices, and L.C.D. The study covers process parameter research and abrasive jet machining advancement [7]. Abrasive jet machining (AJM) employs high-velocity gas to dissolve material from work pieces. Manufacturing uses it to cut costs without sacrificing quality. A high-pressure water jet with fine abrasive particles erodes hard surfaces in AJM [8]. Air quality, pressure, abrasive grain size, nozzle material, nozzle diameter, and work surface standoff distance affect metal removal rate [9]. This paper models how applied pressure, standoff distance, nozzle diameter, and particle grain size affect AJM machining performance. MRR is largely reliant on abrasive particle kinetic energy, and applied pressure is the most important parameter affecting material removal rate [10]. Water jet pressure affects Material Removal Rate and Surface Roughness in abrasive water jet machining (AWJM) for cutting brittle surfaces [11]. For experiments, the new AJM has a heating jacket and rotational mechanism, and the MRR and SR rise with pressure, temperature, and mixing chamber speed. Abrasive water jet (AWJ) is one of the most advanced and lucrative non-traditional machining methods because it removes metal from hard and soft metals. The Taguchi method was used to conduct tests and determine the process parameters that affected material removal rate [12]. The main objective is to study the parametric investigation of abrasive jet machininig.

Process parameters of AJM

The carrier gas options for this experiment include carbon dioxide, nitrogen, and air. Air is commonly employed on a widespread basis. However, the use of oxygen as a carrier gas is avoided due to the inherent risks associated with fire hazards. Abrasive materials are offered in a variety of dimensions, spanning from 10 microns to approximately 1.3 millimeters. The smaller dimensions of these sizes yield a refined cutting outcome, rendering them appropriate for applications such as polishing, cleaning, and grooving. The larger sizes exhibit enhanced suitability for cutting and peening tasks due to their heightened cutting efficiency. Aluminium oxide is a suitable material for performing cutting, grooving, and deburring operations. Silicon carbide is employed for analogous operations, albeit with the intention of processing more rigid materials. Sodium bicarbonate demonstrates utility in performing light-duty tasks such as cleaning, cutting, and deburring of soft materials. Dolomite is primarily suitable for the purposes of fine etching or polishing exclusively. Glass beads have the potential to be utilized in the process of surface polishing, resulting in a matte finish, as well as in the removal of burrs during deburring work. The velocity of the abrasive is determined by the nozzle pressure and design. The velocity range of jets is observed to be between 150 and 300 meters per minute. The subject matter at hand pertains to the materials utilized in the context of work. The utilisation of this method is advised for the processing of materials that possess characteristics of hardness, brittleness, and glass-like properties. The nozzles used in Abrasive Jet Machining (AJM) are typically constructed from materials such as Tungsten Carbide (WC) or Sapphire in order to effectively withstand the erosive effects caused by the high-velocity abrasive stream. The nozzle possesses either a right-angled or straight-edged configuration. The Nozzle Tip Distance (NTD) refers to the measurement of the distance between the nozzle tip and the work material. The term "Standoff Distance (SOD)" is another commonly used designation for this concept.

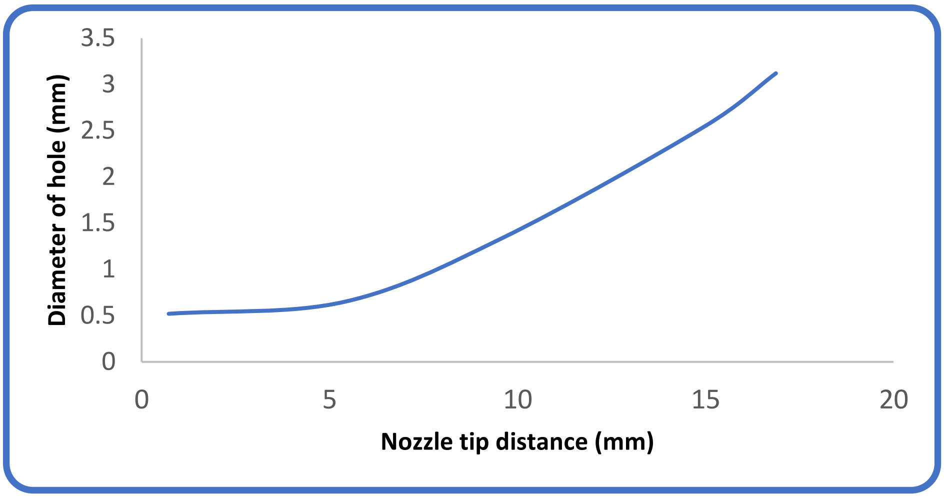
Process

The test specimen utilized in this study was composed of glass, which was prepared by cutting it into square and rectangular shapes in order to facilitate machining using the Abrasive Jet Machining (AJM) technique. The specimens underwent a cleaning process utilizing an air jet and were subsequently weighed using a highly precise scale with an accuracy of 0.001 grammes. The compressed air originating from the compressor is introduced into the mixing chamber, which is partially preoccupied with fine-grained abrasive particles. The mixing chamber generates vibratory motion in the air, which facilitates the transportation of abrasive particles to the nozzle. From there, the particles are directed onto the work-piece. The nozzle and the work-piece are contained within a working chamber, which is equipped with a Perspex sheet on one side to allow for observation of the operation. The abrasive particles employed in the study consisted of silicon carbide (SiC), Aluminium oxide (Al_2O_3), and sodium bicarbonate, with grain sizes of 60 microns and 120 microns. The material of the nozzle employed in the experiment was stainless steel, while the nozzles themselves were of varying diameters. The aforementioned configuration offers the benefit of a straightforward approach in terms of design, manufacturing, and functionality. The cost of the equipment is significantly lower, with the exception of the compressor. Subsequently, the work-piece of the machine was extracted, subjected to a cleansing process, and subsequently re-weighed in order to ascertain the quantity of material that had been eradicated from the work-piece. The dimensions of the aperture at the upper and lower surfaces were measured and subsequently recorded in a tabular format.

Effect of nozzle tip distance (NTD) on diameter of hole

The diameter of the hole grows larger in proportion to the distance that can be achieved between the nozzle face and the surface being worked on. This is due to the fact that a greater distance between the nozzle tip and the work surface enables the jet to expand prior to making contact, which may result in the jet being more susceptible to the external drag that is exerted by the environment. The increased kinetic energy that can be produced as a result of a shorter nozzle tip distance is the primary factor contributing to the desirability of having a shorter nozzle tip distance.

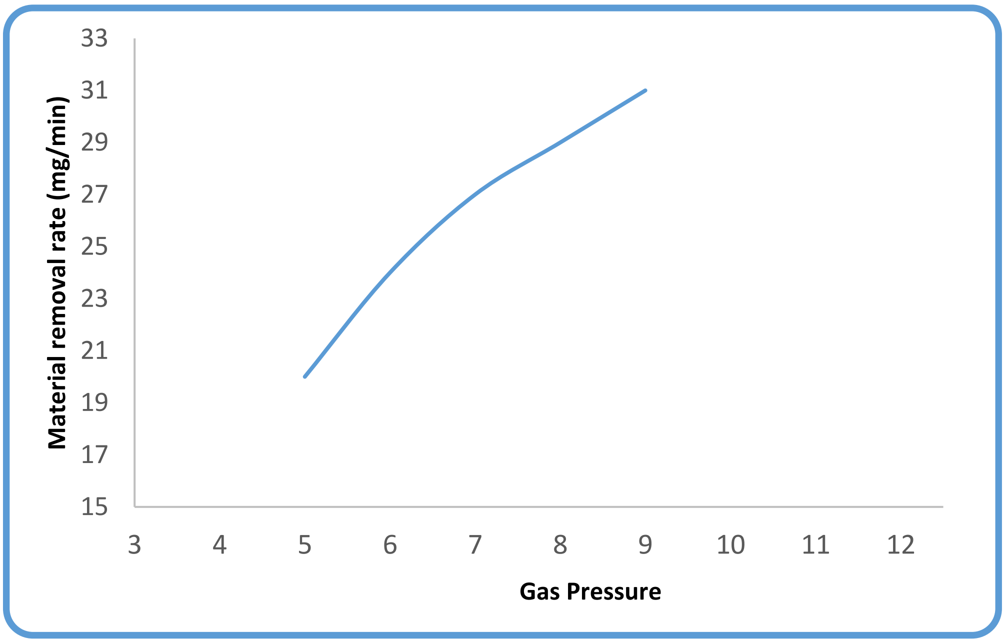
S. No	Nozzle tip distance (mm)	Diameter of hole (mm)
1	0.72	0.52
2	5.4	0.65
3	9.6	1.34
4	14.95	2.54
5	16.87	3.12



Effect of gas pressure on material removal rate

It has been observed that the gas pressure has a proportional relationship to the amount of material removed every minute (mg/min). This is because of the fact that higher gas pressure results in a greater amount of material being taken from the abrasion in the base material. This is the reason for this phenomenon.

S. No	Gas Pressure	Material removal rate (mg/min)
1	5	20
2	6	24
3	7	27
4	8	29
5	9	31



Conclusion

The relationship between the top surface diameter, bottom surface diameter, and nozzle tip distance (NTD) in abrasive jet machining is characterized by an increase in both diameters as the NTD increases. There is a positive correlation between the applied pressure and the material removal rate (MRR). Abrasive jet machining (AJM) is a commonly utilized technique in the fields of coarse machining, deburring, and surface finishing. Micromachining has demonstrated its efficacy as a valuable technique in a wide range of industries, including ceramics, semiconductors, electronic devices, and liquid crystal displays (LCDs).

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