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Performance Evaluation of Working Model of Abrasive Jet Machining

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ABSTRACT

Primarily focuses on the analysis the performance and design of the machine that uses mixture of air and abrasive particle to flow it at high pressure to hit work piece at high velocity to perform process, and is entitled as Abrasive Jet Machine. The basic objective of this paper is to come up with mechanical machine that can be operated easily and reliably with the help of simple elements, to provide appropriate amount of efficiency in a quick response and easy way. As abrasive jet machine (AJM) is the equally consider as sand basting process and effectively capable of removing hard and brittle materials. It's the future crucial machine because work on fabric and brittle material is increasing day by day. It is verified for micro machining. There are various factors which are analysed while processing such as the type of abrasive materials, material removal rate (MRR), diameter of holes, nozzle tip distance (NTD), and erosion rate.

1. Introduction

The concept of removing from a work piece with an edged cutting tool is ages old. The cutting tool is moved relative to the work piece for the purpose. The mechanism of material removal is related to plastic deformation and the consequent chip formation. The cutting tool is traditionally hardened than the work material. Use of such tools and processes of machining are satisfactory in most cases However, there are hard and brittle work materials for which the conventional cutting processes for material removal can not fill the requirements. For example, the production of fine holes of intricate shapes on thin brittle jobs is very difficult by conventional methods. The techniques of piercing, stamping and extrusion do not work satisfactory on brittle materials because of their limited plasticity. Thses materials may develop cracks or may even crumble under such processes. Even the drilling of circular holes on brittle materials is a difficult task, if conventional drills are employed. Techniques like electro- discharge machining (EDM), laser beam machining (LBM), electron beam machininh (EBM), ultrasonic machining (USM) and abrasive jet machining (AJM) are some of the methods which are suggested for such situations. These processes are called unconventional machining processes. The abrasive jet machining (AJM) is one of the unconventional machining processes. Conventional grinding, Honing, lapping and super finishing are some of the other processes in which powered abrasive is used.

2. Abrasive Air Jet Machining

2.1 Desired properties of abrasives for abrasive jet machining

I. Abrasive grits must have sharp edges- For simple miniaturized scale cutting activity. In spite of the fact that for demonstrsting reason corn meal are thought to be of circular shapes, for all intents and purposes sharp edges are crucially fundamental generally MRR will be low and surface completion will be poor.

II. Abrasive grits should have irregular shape- Be that as it may, variety of size inside the general mass ought to be low, generally appraisal of MRR and surface quality won't coordinate. Bigger coarseness makes bigger depression and in this manner high MRR with poor surface completion is gotten, while littler corn meal will in gereral stay inserted on work surface prompting poor surface completion.

2.2 Effects of abrasives on AJM performance

As talked about before, shape, size, quality, material and stream pace of abrasive can impact machining execution. Unpredictable shape abrasives having sharp edges will in general produce higher MRR when contrasted with round corn meal. Littler size corn meal produce profoundly completed surface however diminish material expulsion rate (MRR) and hence profitability slips. Bigger corn meal can again make inconvenience while blending and coursing through the pipeline. In any case, variety in size in the whole volume ought to be low generally estimation or appraisal won't be exact. Abrasive materials have changing quality or hardness. The harder is the abrasive regarding work surface hardness, the bigger will be the volume evacuation rate. It is essentially the relative hardness among abrasives and workpiece that decides machining capacity and efficiency.

Table 1: Process Parameters on the Alumnina specimen of different thickness

S.No.	AJM Parameters	Condition
1	Type of abrasive material	alumina
2	Abrasive size	0.25-1.35
3	Jet pressure	4.5-6.5 kg/cm2
4	Nozzle tip distance	5-20 mm

2.3 Effects of abrasive flow rate on AJM performance

Mass stream pace of abrasive is characterized and distinguished by a particular term called Mixing Ratio. It is the proportion between the mass stream pace of abrasives and the mass stream pace of transporter gas. In the event that blending proportion is expanded by expanding abrasive stream rate (keeping gas stream rate unaltered) at that point an expanding pattern in MRR will be taken note. Nonetheless, after certain most extreme breaking point, further increment in abrasive stream rate will let down MRR.

2.4 Effectsi of abrasive type on abrasive jet machining performance

AJM can be done utilizing different abrasives, among them aluminum oxide, silicon carbide, grass globule, squashed glass and sodium bicarbonate are every now and again utilized. It is important that different abrasives get diverse MRR and the equivalent extensively fluctuates with the procedure parameters moreover. Diverse MRR for various abrasives is ascribed to the hardness of abrasive particles (when procedure parameters and geometrical highlights are unconcerned). When affecting abrasive hardness is significantly high, crack durability of work material ends up transcendent.

2.5 Effects of abrasive size on abrasive jet machining performance

Alongside the kind of abrasive, its size additionally impacts cutting execution. Littler size corn meal produce profoundly completed surface however decrease material evacuation rate (MRR) and in this manner efficiency corrupts. Bigger corn meal can again make inconvenience while blending and coursing through the pipeline. Higher blending proportion may machine gear-piece the spout, particularly when abrasives contain generous dampness. Normal grain size of abrasives changes from 10 – 50μm. Littler grain size is utilized for getting high finish just as for low obligation tasks, (for example, surface cleaning). Bigger grains are utilized for rock solid applications for the most part with harder materials.

2.6 Size of abrasives suitable for AJM

Alongside sort, abrasive size additionally impacts cutting execution. Littler size corn meal can deliver exceptionally completed surface however corrupt material evacuation rate (MRR) and subsequently efficiency hampers. Bigger corn meal can again make inconvenience while blending and coursing through the pipeline. Higher blending proportion may machine gear-piece the spout, particularly when abrasives contain considerable dampness. Normal grain size of abrasives fluctuates from 10 – 50μm. Littler grain size is utilized for getting high finish just as for low obligation activities, (for example, surface cleaning). Bigger grains are utilized for rock solid applications more often than not with harder materials. In abrasive jet machining (AJM) process, fine abrasive particles entrained in gas stream are permitted to strike the work surface at high speed (100 – 300m/s) to step by step disintegrate material.

Table 2: Process Parametrs of Abrasive

S.No.	Abrasive	Process Parameter
1	Grain size	150-250 microns
2	Pressure	8-15 kg/cm2
3	Standoff distance	constant
4	Tungsten carbide Nozzle	5 mm dia
5	Work piece	Alumina and Thickness= 8 mm

I. Reason-1: Contamination by wear debris

At the point when abrasive particles are made to strike the work surface, they dissolve material as strong minor particles and both get stirred up. The blend of wear flotsam and jetsam and abrasives is thusly detracted from the machining zone by pressurized transporter gas. Size of the expelled modest particles is normally like the size of abrasives corn meal (both in the scope of 10 – 100μm). In this condition, it turns out to be hard to isolate one from another.

II. Reason-2 : Loose of cutting ability

After the main effect, abrasive particles lose its sharpness. Sharpness is one of the ideal properties of abrasive particles as it helps simple and productive cutting (dissolving). So reuse of abrasive particles may result low material evacuation rate (MRR) and poor surface quality.

2.7 Various ways of improving MRR in Abrasive Jet Machining

I. Enhancing abrasive flow rate

It is clear from diagnostic model of material evacuation rate in AJM for malleable or weak materials that MRR is corresponding to abrasive stream rate. Not surprisingly, expanded abrasive stream rate can prompt obvious improvement in disintegration rate as increasingly number of abrasives will encroach the work surface per unit time.However, last speed of jet diminishes since bearer gas stream rate and weight are kept unaltered. Therefore, jet rapidly misfortunes its motor vitality as a result of spreading while at the same time traveling through showdown separation (SOD), and at last disintegration ability corrupts. A relentless improvement in MRR can be seen if gas stream rate and weight are likewise expanded with abrasive stream rate; be that as it may, such activities depend incredibly on set-up ability as tight joints, thicker pipelines, solid structures, and so on are totally important to withstand high weight without disappointment.

Table 3: Mechanics of Meterial Removal

S.No.	Mechanics of Metal Removal	Brittle Fracture by Impinging Abrasive Grains at High Speed
1	Carrier gas	Air, carbon- dioxide
2	Abrasive	Alumina, Sic
3	Pressure	4-10 atm
4	Nozzle dia.	WC, sapphire
5	Critical Parameters	Abrasive flow rate and velocity, nozzle tip distance abrasive grain size
6	Material Application	Hard and brittle metals, alloys, and non metallic

II. Using high carrier gas pressure and flow rate

As talked about before, a high gas stream rate gives arrangement of using high abrasive stream rate and in this way upgrading material expulsion rate without giving up machining quality and spout life. For same blending proportion and spout measurement, speed of abrasive jet can likewise be expanded by expanding transporter gas weight. Notwithstanding, every set-up has certain impediment and appraised capacity past which gas weight can't be expanded.

III. Reducing stand-off distance (SOD)

At the point when gas-abrasive blend jet travels through SOD (hole between spout tip and work surface) it encounters generously lower encompassing weight and subsequently it starts spreading prompting increment in width and loss of speed. At the point when jet strikes workpiece in the wake of passing however longer SOD, it needs dynamic vitality to proficiently dissolve material.

IV. Using proper impingement angle

In the vast majority of the cases a vertical jet (impingement point = 90º) gives better outcome; notwithstanding, in numerous occurrences it was seen that 70º – 80º edge gives most extreme MRR. In spite of the fact that it relies upon numerous different variables, when all is said in done any deviation in impingement edge from 90º can prompt machining mistake. Additionally a point of underneath 60º can significantly debase material expulsion rate. situation.

2.8 Nozzle Material and Design

Nozzle directs abrasive jet in a controlled manner onto work material maintaining the desired nozzle tip distance from the workpiece. The high velocity Abrasive particles remove the material by microchipping action as well as brittle fracture of the work material. Abrasive jet machining (AJM) is one of the advanced machining processes (mechanical energy based) where a high velocity jet of abrasives is utilized to remove material from work surface by impact erosion. The abrasive jet is obtained by accelerating fine abrasive particles in highly pressurized gas (carrier gas). A nozzle is used to convert this pressure energy into kinetic energy and also to direct the jet towards work surface at a particular angle (impingement angle).

3. Functions of nozzle in Jet Machining

In general, nozzle is an isentropic steady flow device that produces a high velocity jet by converting static pressure of fluid to kinetic energy (while a diffuser slow down fluid velocity and increases static pressure).

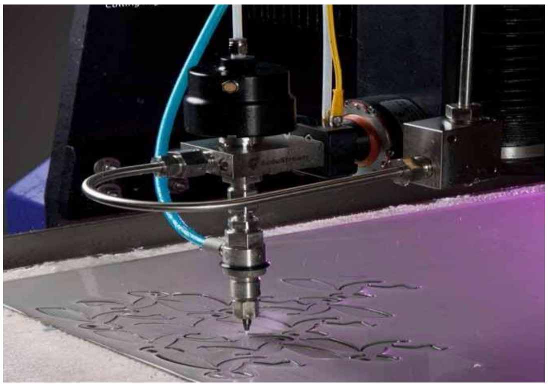


Figure 1: Abrasive and mixing chamber position in AJM

It also delivers fluid at particular angle.In Abrasive Jet Machining also, a nozzle is used to produce high velocity jet (100-300m/s) and deliver it at a particular angle to strike the work surface.When such high velocity jet strikes the work surface, it removes material by impact erosion, sometime assisted by brittle fracture. Basic functions of nozzle by brittle fracture. Basic functions of nozzle in Abrasive Jet Machining are discussed 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. The spout shape, size, spout tip separation are the most significant parameters in rough air-fly machining hardware. Materials with high wear obstruction will have incredible potential as grating air-stream spout materials.

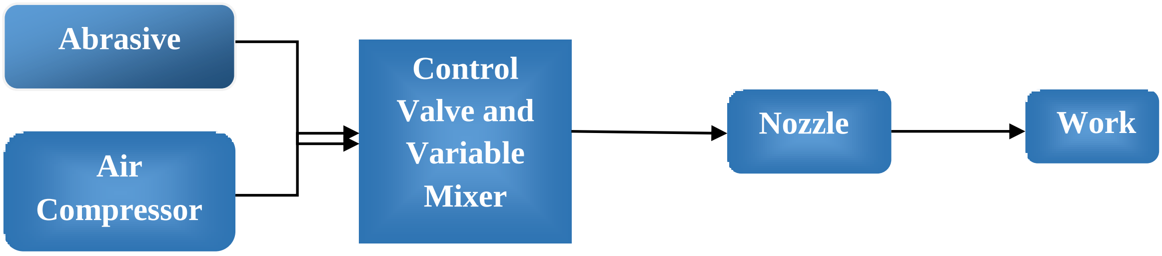


Figure 2: Nozzle in Jet Abrasive Machining

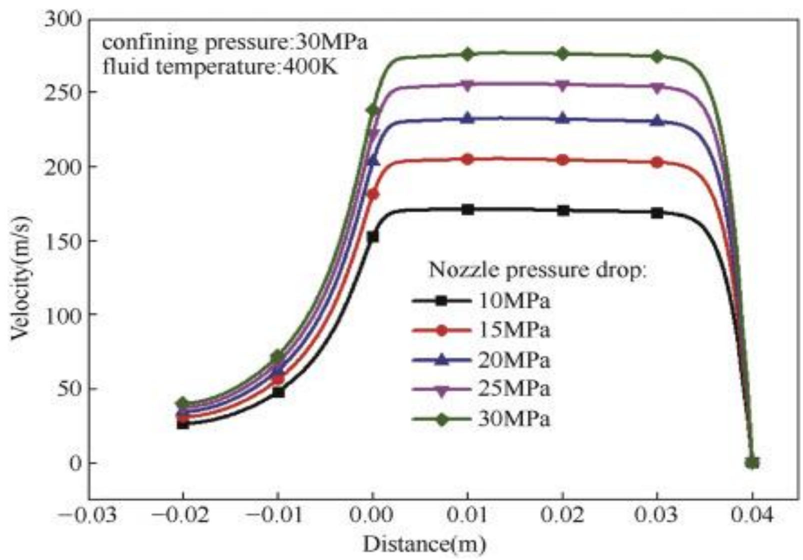
The size differs from 0.2 to 0.7mm distance across. Spouts are made with an outside decrease to limit optional impacts because of ricocheting of rough particles. Spouts made of tungsten carbide have a normal existence of 12 to 30 hours while spouts of sapphire keep going for around 300 hours of activity. In this paper, a (W,Ti)C/SiC angle caly composite was vreated to be utilized as spout material. The disintegration wear conduct of the (W,Ti)C/SiC inclination spout was explored and contrasted ordinary artistic spout.

3.1 Different Material of Machining Chamber

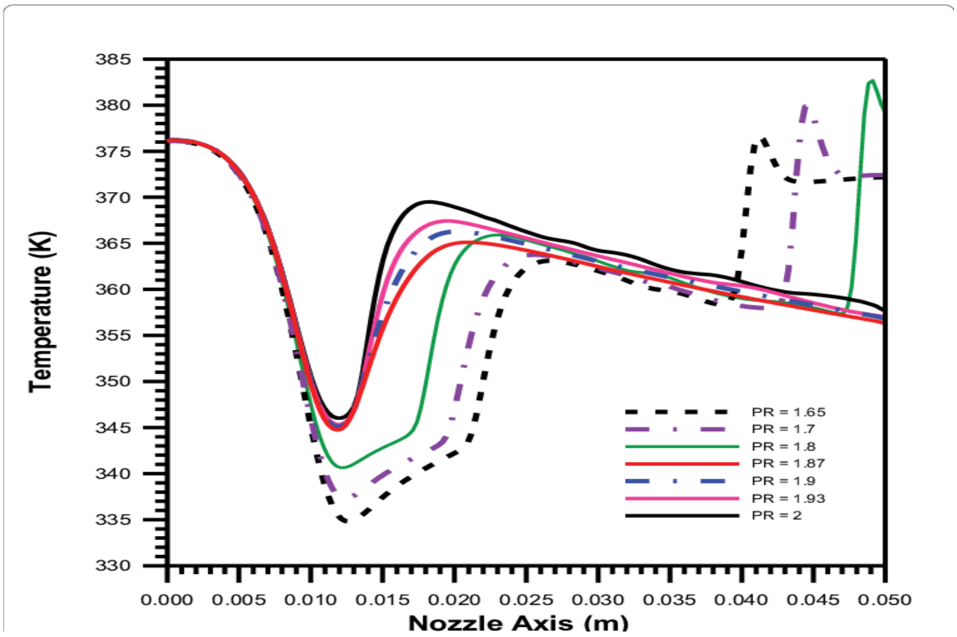
There are different materials by which we can make Machining Chamber like-Wood, Glass, Fiber glass, and different types of metals. There are some factors that we need to take into account like- The work piece should be visible if work piece is not visible to the operator than how he should know that when he need to stop machine or how he know that machine is doing a proper work or not and to check the harm tomachine. The other factor is what kind of abrasive particles we are using if we using sand then we can take glass but we taking some kind of metal as abrasive particles then we cannot use glass these kind of particles can easily break the glass so for such particles we need a machining chamber which is more harder than glass like some kind of metal or some other material.

4. Result and Discussion

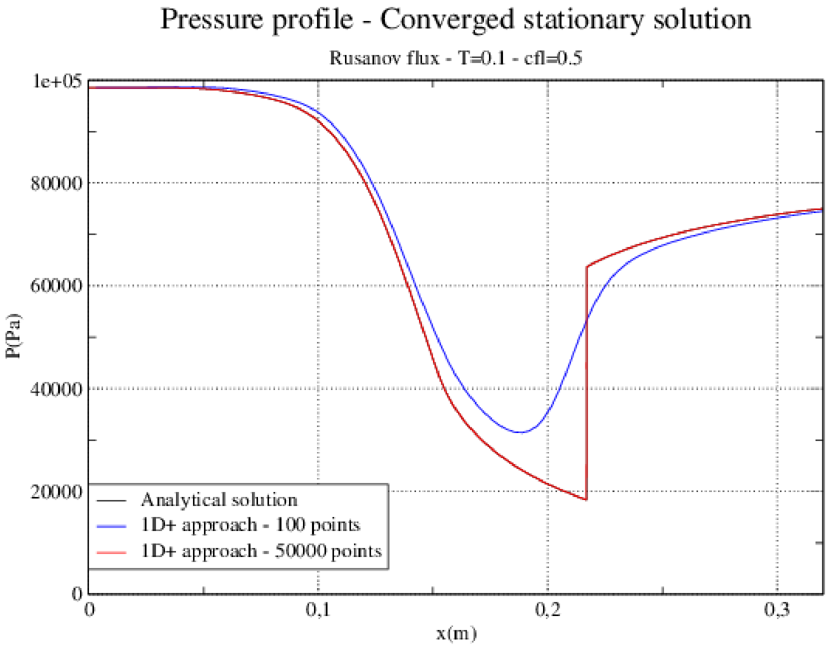
The design and fabrication of AJM is presented. The embedment of the abrasive particles was found to be the major reason of decrease in machining efficiency. In fabrication of AJM, abrasive feeder chamber and mixing chamber are incorporated in such a way that they receive the air separately through the air distribution system.



Graph 1: Nozzle Pressure at confining pressure 30 MPA and fluid temperature 400K.



Graph 2: Effect of pressure ratio on the temperature along nozzle axis.



Graph 3: Steady flow in Laval nozzle: pressure profile.

This allows the restriction of abrasive particles from mixing in air when required. This air which does not contain the abrasive particles remove the embedded abrasive particles which will result into better machining efficiency. AJM is basically which could utilized for cutting, drilling and removal of surface particle.

Table 4: Abrasive Particle with Process Parameters, Air Pressure, Temperarure and RPM.

S.No.	Pressure (Kg/cm2)	Temperatrure (^{0}C)	RPM	MRR (gm/sec)	SR (µm)
1	5	50	120	0.05	2.05
2	5	60	150	0.0032	2.08
3	5	100	180	0.0872	1.75

4	10	50	200	0.099	3.16
5	10	60	100	0.0104	4.1
6	10	100	150	0.0118	4.32
7	12	50	200	0.0126	4.52
8	12	60	120	0.0142	3.98
9	12	100	150	0.0179	4.74

- Suitable for remoc]val of deposites on surface
- Wide range of surface finish can be obtained
- High degree of flexibility
- Process is independent of electrical or thermal properties
- Suitable for nonconductive brittle materials.

5. Conclusion

Most of these models are limited to particular cutting condition and latget materials. Also they have a complex mathematical expression which is difficult for practical use. Some of them include unknown factors needed to be determined by other research. It is concluded that more experimental work is required to fully understand the relationship beween important AJM papmeters, namely air pressure, nozzle size and shape, abrasive mass flow rates and process output in greater detail for aluminum, brass, cast iron, ceramics, copper, composites, granite, mild steel, stainless steel and titanium as the right choice of process papmeters is very important for good cutting performance. As the analyzing and modeling of effect of process papameters are not projected completely with complete optimization by advanced optimization techniques. Extended research works are required to study experimentation and modeling of various papmeters by advanced analysis and medlling techniques, the effect of parameters on AJM, Kerf characteristics. In order to correctly select the process papmeters reliable predictive mathematical models can be developed for the depth of cut in the AJM process of various metals. There is much scope of research in the AJM which can be performed by changing the nozzle design pressure, SOD etc.

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References

[1] Ke, J. H., Tsai, F. C., Hung, J. C., & Yan, B. H. (2012). Characteristics study of flexible magnetic abrasive in abrasive jet machining. Procedia CIRP, 1, 679-680.

[2] Kumar, A., & Hiremath, S. S. (2016). Machining of micro-holes on sodalime glass using developed Micro-Abrasive Jet Machine (μ-AJM). Procedia Technology, 25, 1234-1241.

[3] Bery, S. (1987). Directory of building and housing research and development institutions in India.

[4] D. J. Tidke:Department of Mechanical Engineering, Visvesvaraya Regional College of Engineering, Nagpur, Maharashtra, 440 011, India.

[5] Balasubramanian, M., & Madhu, S. (2019). Evaluation of delamination damage in carbon epoxy composites under swirling abrasives made by modified internal threaded nozzle. Journal of Composite Materials, 53(6), 819-833.

[6] Madhu, S., & Balasubramanian, M. (2018). Effect of swirling abrasives induced by a novel threaded nozzle in machining of CFRP composites. The International Journal of Advanced Manufacturing Technology, 95(9-12), 4175-4189.

[7] V.C. Venkatesh:Faculty of Engineering, National University of Singapore, Singapore 0511, Singapore.

[8] T.N. Goh: Faculty of Engineering, National University of Singapore, Singapore 0511, Singapore.

[9] Wong, K. H: National University of Singapore, Singapore City, Singapore.

[10] Benedict, G. (2017). Nontraditional manufacturing processes. Routledge.

[11] Hours, T., & Marks, W. I. MANAGEMENT AND ENGINEERING ECONOMICS [AS PER CHOICE BASED CREDIT SYSTEM (CBCS) SCHEME] SEMESTER–V.

[12] Jain, V. K. (2009). Advanced machining processes. Allied publishers.

[13] Mishra, P. K. The Institution of Engineers (India) Textbook Series.". Nonconventional Machining" Narosa Publishing House Pvt. Ltd, 22.

[14] Balasubramaniam, R., Krishnan, J., & Ramakrishnan, N. (1998). Investigation of AJM for deburring. Journal of Materials Processing Technology, 79(1-3), 52-58.

[15] Ally, S., Spelt, J. K., & Papini, M. (2012). Prediction of machined surface evolution in the abrasive jet micro-machining of metals. wear, 292, 89-99.

[16] Pawar, N. S., Lakhe, R. R., & Shrivastava, R. L. (2013). 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. Int. J. Sci. Res. Publ, 3(10), 1-4.

[17] Shukla, R., & Singh, D. (2017). Experimentation investigation of abrasive water jet machining parameters using Taguchi and Evolutionary optimization techniques. Swarm and Evolutionary Computation, 32, 167-183.

[18] Ghobeity, A., Krajac, T., Burzynski, T., Papini, M., & Spelt, J. K. (2008). Surface evolution models in abrasive jet micromachining. Wear, 264(3-4), 185-198.