A review on abrasive water jet machining process and optimization of its parameters

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It is certified that this project report **““A review on abrasive water jet machining process and optimization of its parameters”** is the bonafide work of“**Prabhat Ranjan & Pradumn Chaubey”** who carried out the project work under my supervision.

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APPROVAL SHEET

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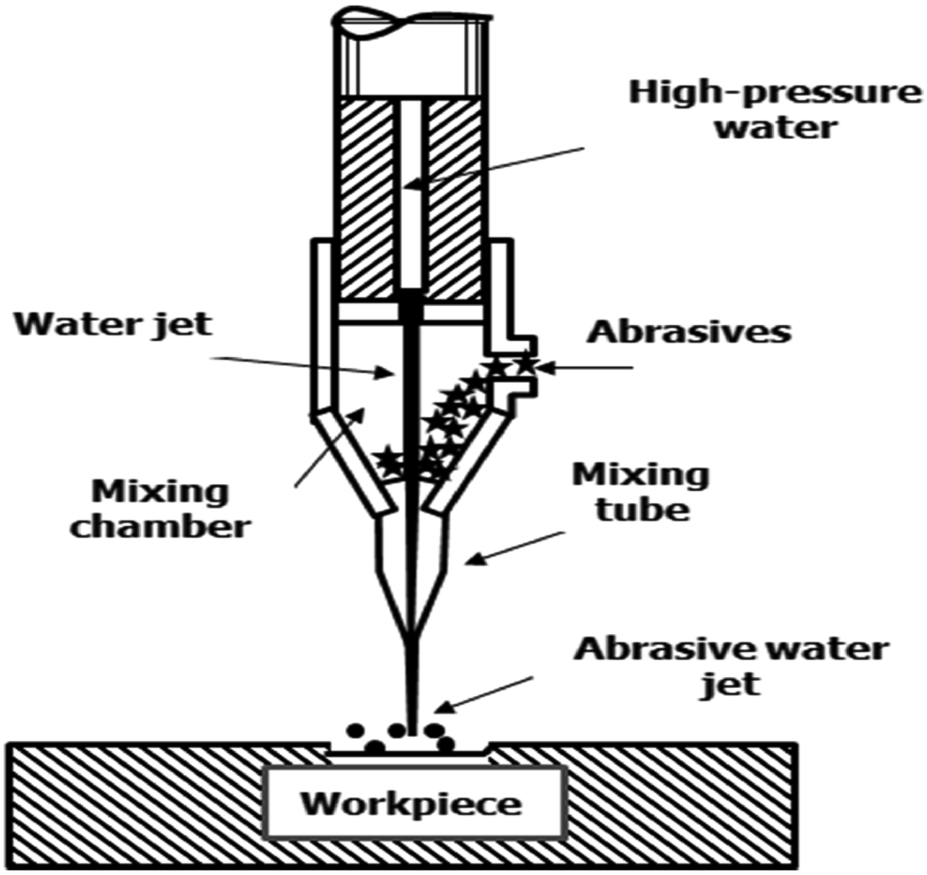
ABSTRACT

Abrasive water jet (AWJ) machining is one of the best non conventional machining processes are being used in modern industries. Operations like cutting, polishing, deburring etc. are often done successfully with the help of AWJ machining processes. This paper reviews latest techniques being applied in this machining and also discusses the complex issues associated with machining. Also this review paper highlights various materials and methods being utilized in different conditions .Various optimization techniques for the betterment of the material removal rate (MRR) and Surface roughness (SR) are also discussed. This review paper could point out the scope for the research of abrasive jet machining**.** This study examines the research that has been done on AWJM over the last decade, from its inception through its development. It summarises AWJM research on increasing performance measurements, process monitoring and control, and process optimization.the variables A wide range of AWJM industrial applications for various material categories have been recorded.


High-pressure water
Water jet
Abrasives
Mixing chamber
Mixing tube
Abrasive water jet
Workpiece

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List of abbreviations

1.	AWJM	Abrasive water jet machining.
2.	MRR	Metal removal rate.
3.	SR	Surface roughness.
4.	MO	Manufacture Order.
5.	ANOVA	Analysis of Variance.

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Chapter 1

1.1 Introductions

Waterjet cutting machines were originally used to cut wood and plastics in the early 1970s, and abrasive waterjet cutting was the firstmethos used.marketed as a pioneering product in the late 1980s.

Technology for processing AWJ (American Women's Journal) was founded in the early 1980s.Machining was once seen to be a waste of time.use Cutting-edge abrasive jets are now available.

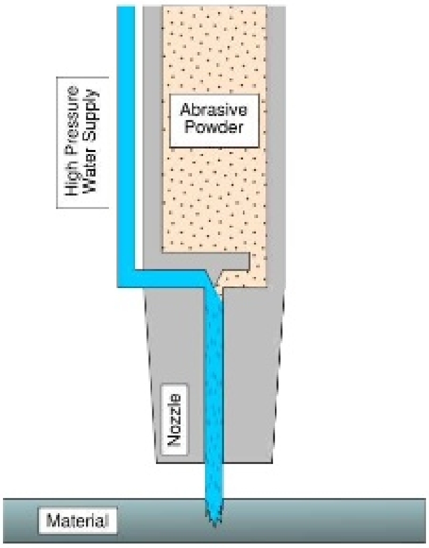
1.2 Objectives

The work piece material is removed by the action of a high-velocity cutter in the AWJ machining process.The work piece material is removed by the action of a high-velocity cutter in the AWJ machining process.based on a spray of water combined with abrasive particles the erosive principle of the substance on which it is built When the water jet lands.

1.3

WORKING PRINCIPLE OF AWJM

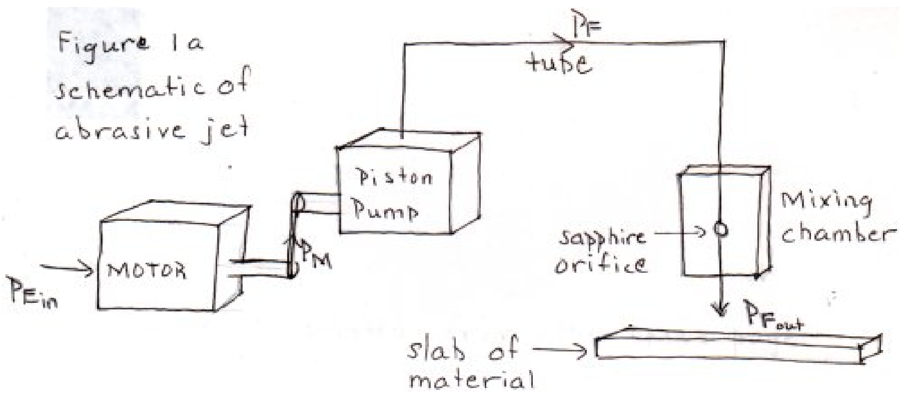
- The cutter is commonly connected to a high pressure water pump where the water is then ejected from the nozzle, cutting through the material by spraying it with the jet of high speed water.
- Additives in the form of suspended grit or other abrasives, such as garnet and aluminum oxide can assist in this process.



AWJ is one of the most advanced current systems for material processing in the industrial business. AWJ has a small number of members.Features such as a high degree of machining versatility and a small footprint cutting forces, a high degree of flexibility, and no thermal conductivity Distortion When compared to other complementary services No heat impacted zone (HAZ) on machining processesa work piece is created.

AWJM is widely used in the processing of titanium, steel, brass, aluminium, stone, inconel, and all types of glass and composites.Abrasive blasting is a modern manufacturing procedure.Waterjet machining has yet to go through enough testing.supremacy in order to realise its full potentialattained.

This report gives an overview of the numerous research activity on AWJM throughout the last decade. It starts with a high-level summary of the procedure.Based on the well established high-velocity premise erosion, as well as some of the applications for which it can be used.



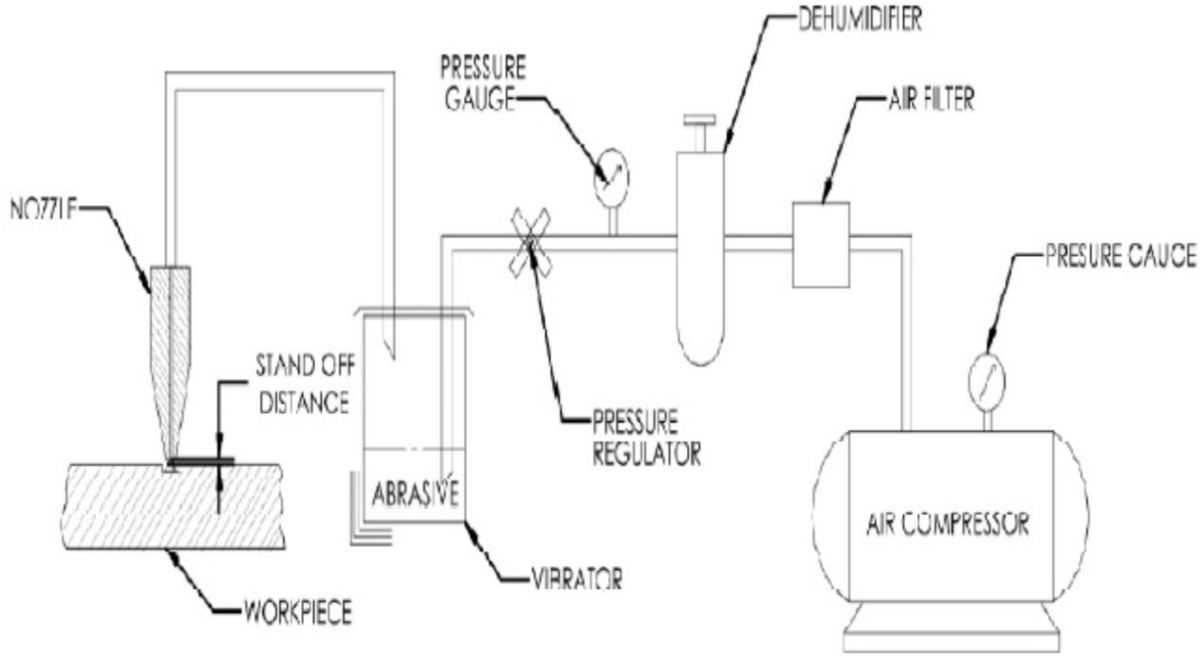
1.4 AWJM Process

Water jets that contain an abrasive component are known as abrasive water jets. Aluminium oxide, silicon carbide, sodium bicarbonate, dolomite, and/or glass beads are examples of abrasives that come in a variety of grain sizes. Cutting using a high-pressure abrasive water jet is essentially a two-step erosion process. A rough water fly is a water fly that is made up of rough material. Abrasives are particles of extraordinary materials with varying grain sizes, such as aluminium oxide, silicon carbide, sodium bicarbonate, dolomite, and glass dots. High-pressure grating water stream cutting is a disintegration technique that consists of two parts.High-pressure grating water stream cutting is a disintegration technique that uses two different techniques depending on whether the disintegrated material is brittle or pliable.

Differences between WJM and AWJM

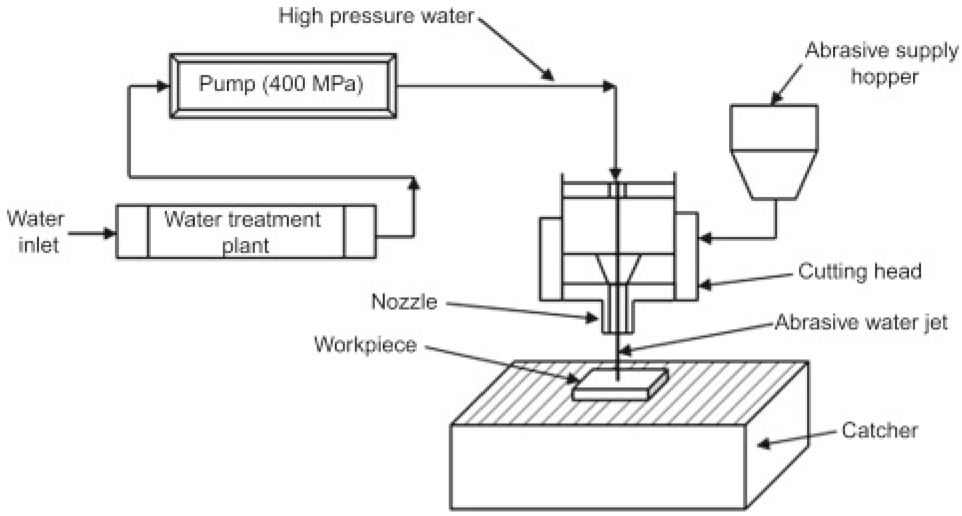
Water Jet Machining (WJM)	Abrasive Water Jet Machining (AWJM)
1. A high velocity jet of pure water (sometimes with stabilizer) is used to erode material.	1. A high velocity jet of water-abrasive mixture is used to erode the workpiece material.
2. Material removal from the workpiece takes place only due to the erosive action of water jet.	2. Material removal takes place due to the micro-cutting action of abrasives (water does not directly participate in cutting the material).
3. No mixing chamber is desired as abrasive is not mixed with water.	3. A mixing chamber (focused tube) is required for mixing abrasives with pressurized water.
4. The jet of water does not possess high power, and thus it cannot be advantageously applied for cutting metals, alloys, etc.	4. The jet of abrasive-water mixture possesses enough power to slice metallic plates of thickness up to 10 mm.
5. It is free from the risk of abrasive embedment on the finished surface.	5. There exists a risk of abrasive embedment, particularly for ductile workpiece materials.
6. WJM can be employed in food industries for slicing food items like frozen meat, fish, etc.	6. Presence of abrasive particles makes WAJM process unhygienic for application in food industries.

Water enters the blending chamber at an extremely high speed (about 900 m/s) and passes through the slim hole with a very high pressing factor (about 4,000 bars). Rough particles and water fly are transported into the spout from the blending chamber. This mixture of water, coarse particles, and air erupts as a spout. When the grating particles sway the work piece surface, they create wear and machining because they have gained a lot of active energy and speed from the water stream.



1.5 AWJM VARIATIONS

Cleaning, piercing, turning, 3D machining, and processing are all part of the AWJ machining process. Zhu et al. discovered that by using a flexible disintegration approach with a low pressing factor and a small disintegration point, AWJ can perform accurate surface machining and subsequent lapping. Due to the material's fragility and hardness, boring progressed materials with strong bores is typically unrealistic. Regardless of material properties, mechanical piercing has difficulty producing openings with a breadth of less than 0.04cm and a shallow point to the surface. It is possible to manage the stream's pressing factor time profile and the grating stream rate by adjusting the stream's pressing factor time profile and the grating stream rate.



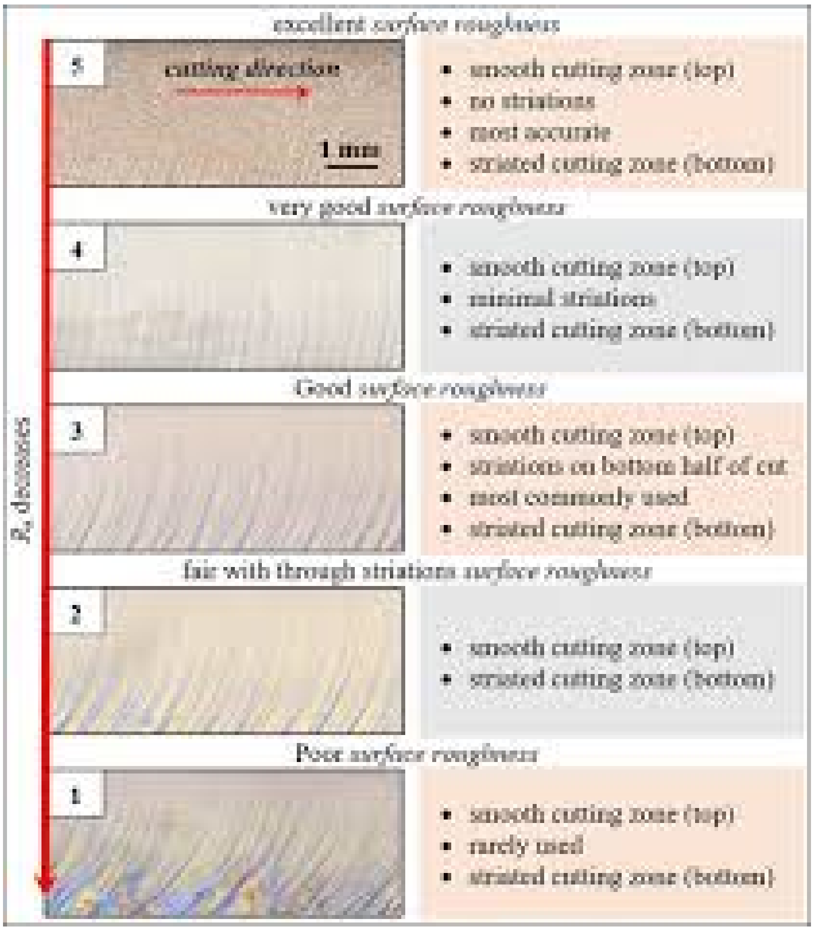
AWJ is superior to other handled instruments such as lasers and Electro Discharge Machining (EDM) for penetrating small measurement and large perspective proportion openings, especially at shallow points. The work piece is turned while the AWJ is crossed pivotally and radially to produce the required turned surface when turning with AWJ. The use of a grating waterjet to turn difficult-to-machine materials has been demonstrated as a viable cycle. The AWJ turning boundaries were investigated, including the fly pressing factor, grating stream rate, grating molecule size, opening size, and feed rate. In AWJ turning, an alternative methodology that takes into account the shifting local effect point introduces

1.6 AWJM APPLICATIONS

The practicality of the AWJM method in the machining of various materials used in industrial applications is discussed in this section.

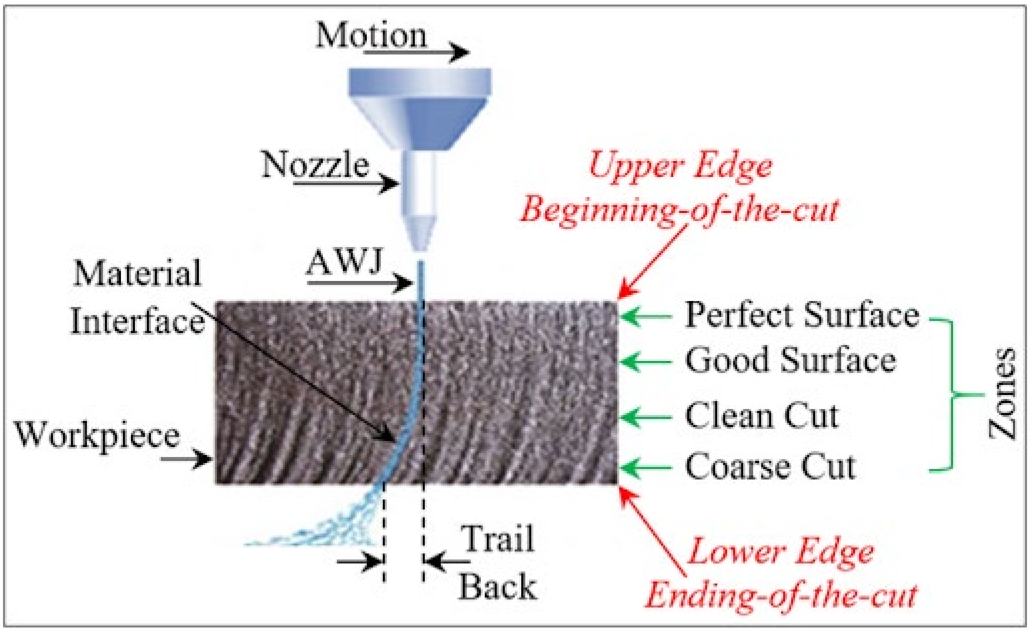
(1) Advanced ceramics materials

Earthenware materials' tremendous hardness and strength make them extremely difficult to handle with conventional tools, resulting in significant machining costs. As a result, non-traditional cutting technologies such as lasers, ultrasonic machining, and electro release machining have been used to handle earthenware production. Despite the fact that these cycles have been successfully used for machining earthenware manufacture, each has its own set of drawbacks. Plasma and laser cutting leave a thick, hard exterior, and these methods can't achieve the precision required on a 13mm thick plate. For intelligent and efficient cutting, the AWJM measure extends the capabilities of EDM and laser.



(2) Modern composites materials

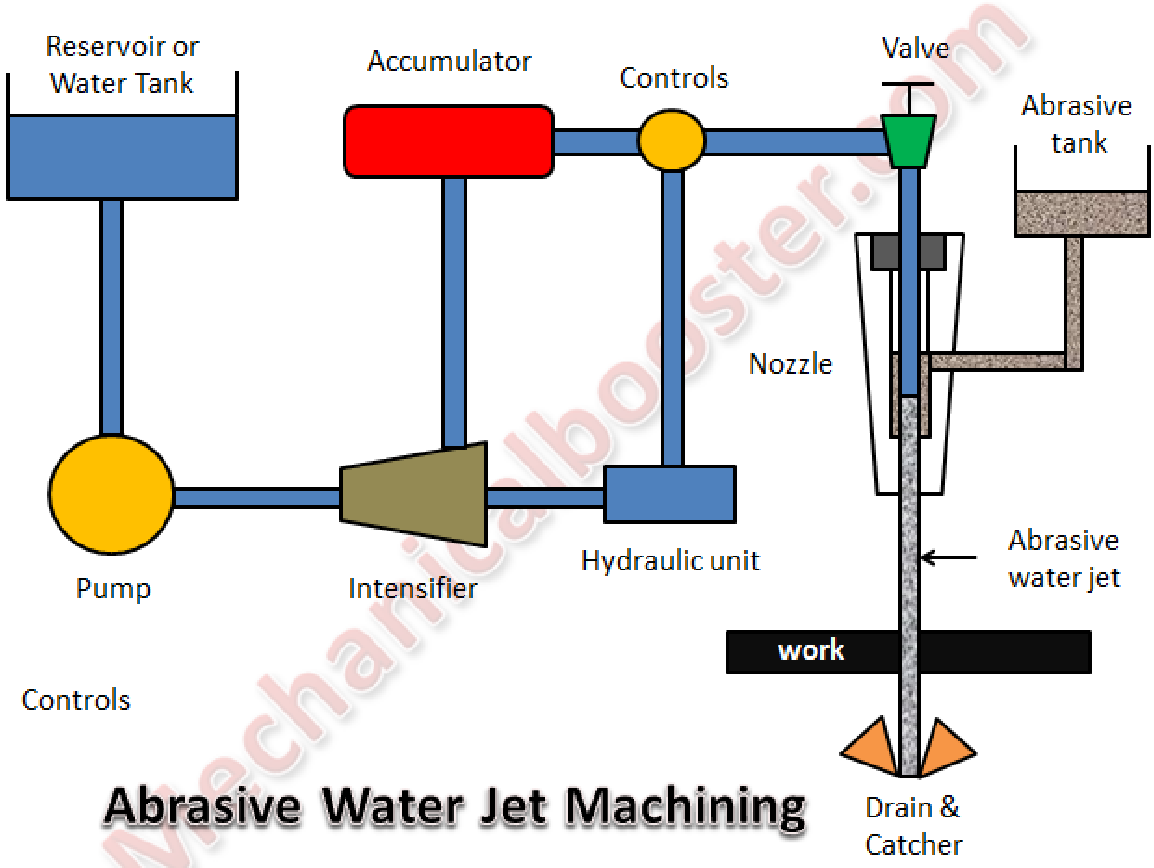
Because of the significant device wear caused by the presence of the hard support, Molecule Reinforced Metal Matrix Composites (PRMMCs) have become extremely difficult to process using traditional manufacturing methods. For the machining of molecule supported MMCs, electro release machining, laser cutting, and rough water stream (AWJ) machining are increasingly being used. Muller and Monaghan compared the AWJM of molecular supported metal grid composite (PRMMC) to those of other non-traditional machining cycles including LBM and electro release machining (EDM).



The results reveal that AWJ cutting does not cause any thermal damage to the composite, and there is no evidence of a burr connection.

(3) Marble and granite

Stone has been widely used as dimensional stone openly and commercially in recent years due to properties such as strong solidity and resistance to scratches, cracks, stains, spills, heat, cold, and wetness. Another ingenious instrument for cutting rocks and rocklike materials is the rough water fly (AWJ). It is commonly used for rock cutting, preweakening, and penetrating. Because of its obvious advantages of precise form cutting, a decent surface finish, more modest kerf widths, and expanded instrumentation, the innovation is a promising tool not only for assembly ventures but also for other businesses, including common and mining designing industries.



Abrasive Water Jet Machining

Chapter 2

Literature Review

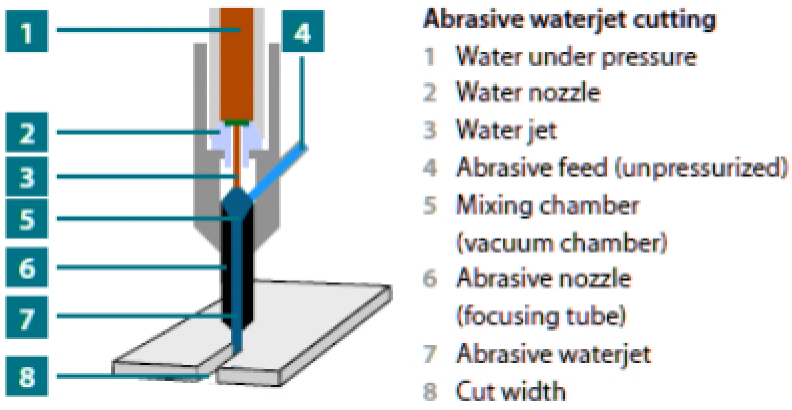
2.Introduction

Using traditional machining, components are machined to the expected component geometry. Turning, milling, grinding and forming processes have very little advantages [1-2]. Also they have limitations like heat-affected zones and the need to configure a cutting tool for each applications and work materials.

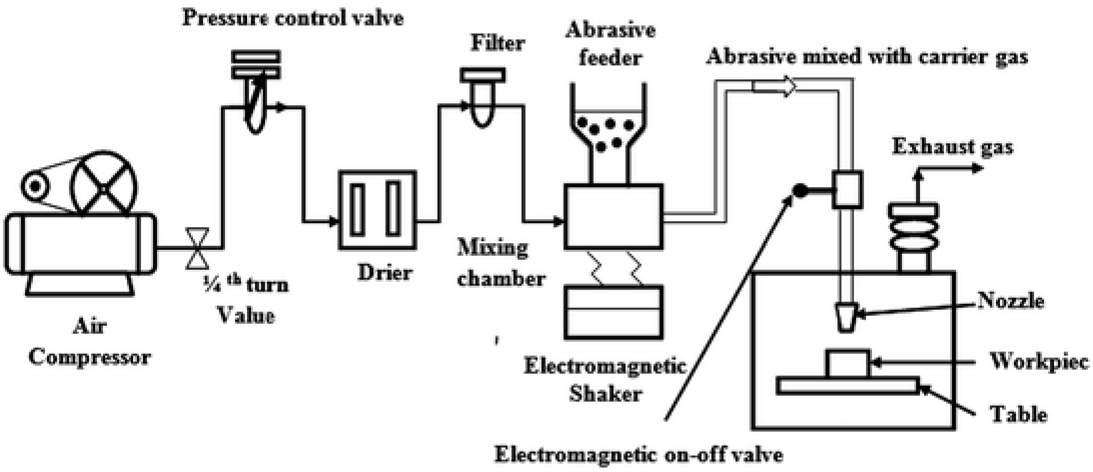
2.2Literature review

Water jet machining was introduced in the middle of 1800 and later it was converted in to Abrasive water jet machining (AWJM) with the help of abrasive particles such as silicon dioxide, Silicon carbide, aluminium oxide in order to speedy the material removal rate [3]. Abrasive water jet (AWJ) is indeed a widely desired unconventional manufacturing technology used throughout modern industries [4]. Its uses in the manufacturing industries for the processing of different materials, especially those that are difficult to cut, are commonly used [5]

AWJ machining is highly favored because it produces little to no heat in the cutting field, as well as the material percentage removal is higher relative to other unorthodox machining such as WEDM, etc., [6-9].Surface roughness is minimal with AWJ and as it does not generate much heat near the cutting zone, it causes very little micro structural changes to the surface of the work piece [10-11].

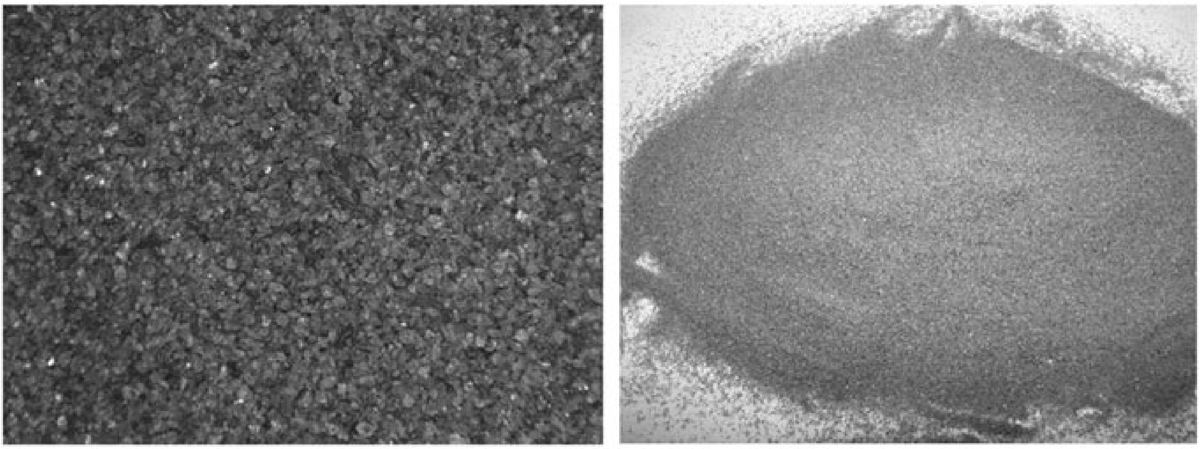


However it still has some disadvantages such as high initial cost and more noise associated with machining [12-14]. AWJM, in which abrasive particles are mixed with a high speed jet of water and hit the work surface [15-16]. As the cutting movements of the AWJM are controlled by the computer, their operations are efficiently executed. AWJM are often employed in automotive industries, aerospace, sports, mining industries and electronics industries [17-20]. Figure 1[21] shows a schematic diagram of the AWJM process.



Material removal and accuracy of manufacturing are greatly connected to the type of abrasive used in the AWJM process [22]. Hardness of the abrasive materials plays major role. Most widely used abrasives are Silicon dioxide

(Silica), Boron carbide, Silicon carbide, Sodium bicarbonate, and Garnet and Aluminium oxide. Abrasive materials with high hardness could reduce the surface roughness and increase the MRR [23-25]. Abrasive grain particles size determines the operations of the AWJM [26]. For polishing operations, very fine particles abrasives are used and for cutting operations coarse grain particle size is used. Fig 2 shows the coarse garnet and fine garnet.



a) Coarse Garnet b) Fine Garnet

Agus et al. [27] identified the parameters to evaluate the abrasive particles such as abrasive material hardness, abrasive particle shape, abrasive material density, abrasive particle diameter and abrasive mass flow rate. They also stressed that for cutting the hard materials such as granite and porphyry, hardness of the abrasive materials plays the major role and for cutting the soft materials such as marble, particle shape plays the vital factor.

Momber et al. [28] identified that the material removal rate improves greatly with an optimum grain size distribution which is shown in the Fig.3.The AWJM performs machining under the influence of high pressure water mixed with abrasive particles, which facilitates environmentally safe and eco-friendly machining process.

Most widely used abrasives are Silicon dioxide (Silica), Boron carbide, Silicon carbide, Sodium bicarbonate, and Garnet and Aluminium oxide [29].Mardi, K. Bimla, et al. [30] investigated “the influence of the jet traverse speed on the surface of the Alumina nano particle reinforced with the metal matrix composite (MMC) machined by the AWJM”. They concluded that hi level of transverse speed could damage the surface of the work piece machined by the AWJM.

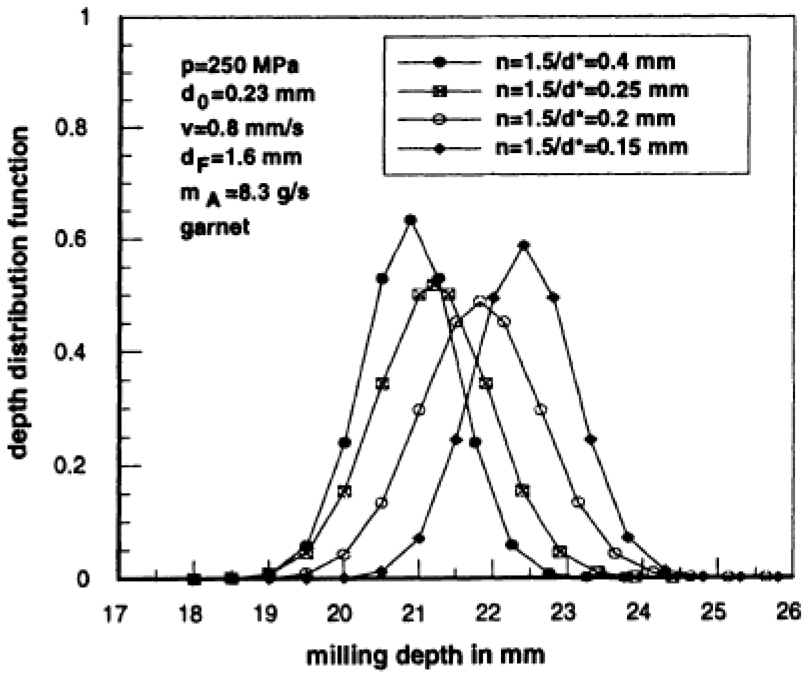


Fig.3 Influence of particle distribution parameter on milling depth variations.[28]

Arola, D., and M. Ramulu et al. [31] “Investigated the material removal rate in AWJM of metals surface integrity and texture”. They also conducted the micro hardness test and carried out microstructure analysis. Their results suggest that the deepness of the surface plastic deformation is inversely relative to the co efficient of the strength of the metals.

Zhao, Wei, and Chuwen Guo [32] studied the “topography and microstructure of the cutting surface machined with abrasive water jet”. They observed that the very high smooth surface is more possible with the hard materials and erosions on the soft materials pose very serious problems. Vigneshwaran et al. [33] studied the “AWJM of fiber reinforced composite materials” as composite materials are vital parts in the manufacturing industry. They found that the AWJM is very suitable methodology for machining the fiber reinforced composite materials.

Wang et al. [34] investigated the “Cutting performance and erosive process of AWJM of polymer matrix composites”. They reported that the cutting parameters can decide the good quality kerf with high production rate. Traverse speed and pressure of the water play the key role in the depth of the cut and kerfs taper angle. Scanning electron microscope (SEM) revealed the intergranular cracking. They also created the mathematical model for verification.

D.K.Shanmugam et al. [35] studied the “minimization of kerf tapers in abrasive AWJM of alumina ceramics using a compensation technique”. They carried out the experiment to minimize the kerf taper angle with the help of kerf taper compensation (KTC) practice. They also stressed that the KTC angle 4-5^{o} minimize the kerf taper angle to zero. A predictive model with the help of dimensional analysis was used to verify the technique.

Srinivasu, D. S., et al. [36] investigated the “Influence of kinetic operating parameters on kerf geometry in AWJM of silicon carbide ceramics”. They found that by changing α (90°–40°), the kerf geometry is closely reliant on the difference of standoff distance (SOD), abrasive element velocity distributions and their local blow angle. Shukla et al. [37] demonstrated” the application of the optimization technique in AWJM”. They conducted experiment on “AA6351 Al- alloy” with the help of AWJM. Their main aim was to get optimum values of the parameters involved in the machining performance. They also developed the regression model from the experimental results. Their responses were kerf and taper angle. They adopted Taguchi method along with optimization technique.

Kumar et al. [38] reported the "characterization and optimization of AWJM parameters of aluminium /tungsten carbide composite". They optimized the AWJM on machining the aluminium / tungsten carbide (2, 4, 6, 8 & 10 wt %) composite. Response surface methodology (RSM) was applied to explore the significance of the AWJM parameters on MRR. The most vital parameter affecting the MRR was transverse speed followed by the percentage of reinforcement particles and standoff distance.SR was mainly influenced by the percentage of tungsten carbide.

Gupta, Vishal, et al. [39] investigated the "kerf characteristics in AWJM of marble". Water pressure, nozzle transverse speed and abrasive flow rate have been selected ass process parameters.

Experiments were conducted according to Taguchi's design of experiments (DoE) have been carried out for conducting the experiments in their study. Evaluation of data's has been carried out with the help of Analysis of variance (ANOVA) by them. They also identified the most vital factor affecting the kerf characteristics. They concluded with that the transverse speed was the most vital reason for poor kerf width and kerf taper angle.

Maneiah, D., et al Optimized "the machining parameters for surface roughness during AWJM of aluminium/magnesium hybrid metal matrix composites". They chose the parameters such as standoff distance feed rate and flow rate of abrasive grain. The Taguchi method and ANOVA had been taken for optimization purpose to improve surface quality. Their results suggested that the vital factors affecting the quality of the surface were feed rate and flow rate of abrasive grain.

Pros and Cons of Abrasive Jet Machining (AJM)	
Advantages	**Disadvantages**
1. Suitable for removal of deposits (oxides, coating, etc.) on surface. 2. Wide range of surface finish can be obtained. 3. Process is independent of electrical or thermal properties. 4. No thermal damage. 5. Suitable for nonconductive brittle materials. 6. Low capital investment.	1. Not suitable for soft and ductile materials. 2. Abrasives are not reusable. 3. Abrasive collection and disposal are problematic. 4. Tapered and stray cutting and similar effects for drilling. 5. Limited nozzle life.

2.3 Latest Trends

In previous portions, we looked at the major examination regions in AWJM. Specialists have contributed in a variety of ways, but due to the complexity of the interaction, a significant amount of work remains to be completed. The AWJM cycle is an appropriate machining option for meeting the demands of today's applications. The AWJM of advanced composite, glass, and advanced clay materials, which is displaying a growing trend in many design applications, was also put to the test.It has supplanted traditional methods for machining hard and difficult-to-cut materials, such as ultrasonic machining, laser shaft machining, and electro release machining, which not only delay machining but also harm the material's surface uprightness. Furthermore, the AWJM cycle has investigated the advantages of combining with other material expulsion strategies in order to expand its applications and improve machining quality.

Moreover, various exploratory apparatuses used for advancement (such as the Taguchi strategy and RSM) can be coordinated together to combine the advantages of both at the same time.

There is no literature available for multi-reaction progression of cycle variables at this time, and additional work is required around here. To reduce the error caused by the variation in opening and centering tube bore, a few checking and control computations based on express numerical models, master's knowledge, or astute frameworks have been accounted for. So far, there is almost no literature that illustrates the deadlock distance at the optimal value during the AWJ cutting cycle using the produced sound checks and not for any other boundary. As a result, more work in this area is required.

Chapter 3

Conclusions

Conclusion:

This paper details the AWJM processes and attempt have been made to help the researchers who perform non conventional machining operation for application .The various process parameters associated with the AWJM have been discussed in detail. The MRR and its effectiveness improvement have also been narrated. Various optimization technique with significant parameters have been analyzed and presented .Papers based on AWJM of ceramics, AWJM of polymer composite materials and AWJM of metallic materials have been discussed. This review paper would indeed help understanding the researches for their future research.

LIST OF PUBLICATIONS

1. Accepted and presented at ICAPIE – 2021 (6^{th} International Conference on Advanced Production and Industrial Engineering (ICAPIE) 2021).
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   Title "*Current Research Aspects and Latest Trends in Abrasive Water Jet Machining: A Review"*.

   Paper No: 282

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