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Abrasive Water Jet Machining

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***Abstract* - This paper gives an Insight on various research and activities carried out on the process of Abrasive Water Jet Machining (AWJM). AWJM process is briefly explained in the introduction section of the paper. This whole research is based on the process of material removal in AWJM as researched by various scholars. The last part of the paper gives the conclusion framed by us after reviewing the research papers on AWJM.**

Keywords: Abrasive Water Jet Machining, Material Removal rate.

I. Introduction

Water Jet Machining (WJM), or in other words water jet cutting, is a mechanically advanced unconventional machining process where water having a very high velocity is used to erode away small portions of materials from the workpiece surface. WJM was initially used for cutting soft materials, cleaning and removal of coating in early 70s. Softer materials like wood, plastic and rubber were cut using this technique. It does not encounter any vibration problems. However, in order to machine hard materials like metals and granite, another machining process called Abrasive Water Jet Machining (AWJM) was developed.

Figure 1: Water jet machining

AWJM is an unconventional machining process which gets results by the combined efforts of abrasive jet machining and water jet machining (WJM) such that the drawbacks of each individual process is overcame . It enhances and betters the capability of WJM for machining hard or strong materials.

In AWJM, jet of water having very high velocity is mixed with abrasive particles to improve the efficiency of the process in terms of material removal rate and making it possible to cut all the materials (NO matter hard or soft). Here , the high velocity and high pressure of water is mixed with small abrasive particles on the workpiece which erodes the material due to impact causing material removal .This process is environmentally friendly and does not affect the properties of the materials (or its internal structure) as it has no thermal effects. Both WJM and AWJM are modern machining process that do not create any heat affected zone or residual stress on the machined surface or workpiece.

II. History

Using high pressure water for hydraulic mining until mid 1800s. It wasn't until the 1930s that small water jets became an industrial cutter. A paper metering, cutting and rolling press was developed in 1993 by Wisconsin's paper parents company which used a water jet pin to cut a horizontally moveable sheet of continuous paper. The early applications were low and limited to soft materials such as paper.

In the year 1958, North American aviation swach of Billie invented a high-pressure fluid-based system to cut hard materials.

John Olsen along with George hurlburt and Louis kapcasandy at flow research further improved the commercial potential of the water jet.

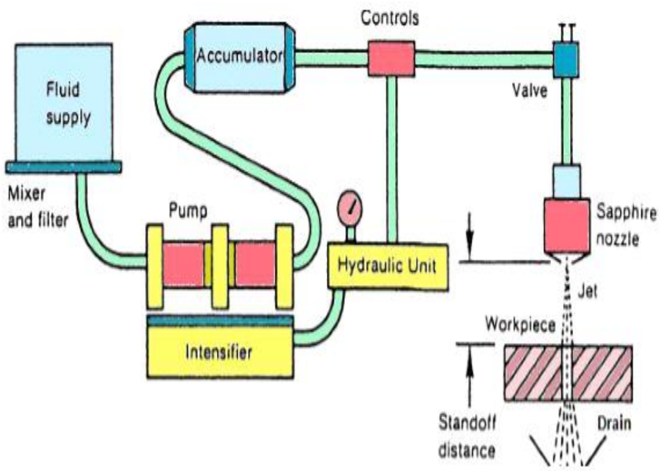

Figure 2: Schematic diagram of WJM

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III. Process of Material Removal

The basic principle involved in material removal process is as follows:

A Hydraulic pump pumps water from a reservoir to a intensifier. The pressure of water is increased to desired level in the intensifier. Generally, water is pressurized to 200 to 400 MPa. Accumulator then receives the pressurized water, and stores it temporarily. The flow regulator and control valve allows the pressurized water to enters the nozzle .The direction and pressure of water is kept under check using control valve , while the flow rate of water is regulated by the flow regulator. Pressurized water entering the nozzle expands with a huge increase in its kinetic energy, thus creating a very high velocity water jet. Stresses are induced on the workpiece, as the jet of water hits and strike the surface of the workpiece. Material removal is achieved as a result of these stresses acting on the workpiece surface, without creating any Heat Affected Zone.

The process involves various equipment or units namely:

3.1 Hydraulic pump unit

The main objective of this unit is the momentum transfer from the water jet having high pressure to the abrasive particles, which when strikes a workpiece causes material removal .It consists of 5 sub components namely:

a) Electric motor: An electric motor of typical capacity of 20 - 75 HP is used, to drive the hydraulic pump.

b) Hydraulic pump: An electric motor drives the pump generating the hydraulic pressure of the order of approximately 15–30MPa. It has typically main 2 types: Hydraulic intensifier pump and/or a Crankshaft pump. The crankshaft pump is more efficient and hence achieves faster cutting when compared to hydraulic intensifier pump.

c) Intensifier: The pressure of water is increased to more than 40 times the hydraulic pressure in the Intensifier, as it uses larger size of oil piston over the normal water piston. Mathematically the square of diameter ratio of oil and water piston is equal to water pressure divided by hydraulic pressure. The pressure of water can be easily manipulated by controlling the lower pressure oil.

d) Accumulator: The accumulator stores the high pressurized water temporarily, until very high amount of pressure energy is required. The fluid is then supplied to eliminate any variations in pressure producing uniform water flow at the output.

e) Tubing: Water and the abrasive particles are mixed within a vacuum chamber called tubing. Flexible tubing is preferred for pressure <24 MPa . For pressure >24MPa another method called rigid tubing is employed.

3.2 Water Feeding Unit

Pressurized water (<500 MPa) is made to pass through a nozzle resulting in a jet of water with velocity as high as 900m/s. Both WJM and AWJM methods have similar units usually Synthetic sapphire and tungsten carbide form the material for the nozzle of water jet.

3.3 Abrasive Feed Unit

Abrasive particles are delivered in a regulated manner and precisely using a hopper and flow control system within the feed unit to the nozzle. Mainly there are 2 particle delivery methods namely:

a) Dry abrasive delivery: It is suitable when the distance of delivery is less.

b) Abrasive slurry feed: It is possible to introduce particles over a large distance, however this method requires more power per cut and commercial availability is limited.

3.4 Abrasive Water Jet Nozzle

In general, the characteristics and direction of the flow of a fluid as it comes out of a pipe can be controlled using a device called Nozzle. Here high velocity water is emerged from the nozzle after conversion of high pressure water into it. Here water and abrasives are blended thoroughly to form a coherent mixture. The two major configurations that are adapted are:

a) Single-jet side feed: Here, water jet is located centrally and abrasives are added on the periphery of the water jet. It is relatively easy to machine using this configuration. It however does not provide optimal mixing of the water jet with the abrasives and wears out at an increased rate, thus making it less desirable.

b) Multiple-jet central feed: Here, abrasives are introduced centrally with multiple water jets being added on the periphery of the abrasive jet. It provides optimum mixing and an increased nozzle life but it is costly and more difficult to fabricate.

The movement of nozzle is controlled using computer based motion controllers.

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3.5 Worktable

Accurate cutting is ensured by providing easy and precise motion to abrasive water jet nozzle relative to the workpiece along all the three axes using computer numerical control systems. Worktables of many shapes and sizes are easily available, where it varies from small to very large and can be chosen as per requirements.

3.6 Drain and Catcher System

Here the energy of abrasive water jet is dissipated to reduce noise to the lowest possible level and prevent jet from leaving the workpiece.

- When the abrasive water jet nozzle is in rest and workpice is in motion (moving) a catcher is used.
- When the abrasive water jet nozzle is in motion (moving) and workpiece is in rest a settling tank is used.

IV. Working of Abrasive Water Jet Machining Process

As seen in the above schematic diagram , water is pumped to the intensifier from the reservoir with the aid of a hydraulic pump .The intensifier increase the low pressure water to high pressure water, of pressure upto 3000 to 4000 bar (300MPa to 400MPa). This high pressure water is sent to both the accumulator as well as the nozzle. The accumulator stores the high pressure water and supplies it at the moment it is required. It is used to eliminate the fluctuation of high pressure requirement of machining hard materials. Then the high pressure water is sent to the nozzle, where the high pressure energy of water is converted to high kinetic energy of water (*water expands with tremendous increase in its kinetic energy or velocity*), resulting in a very high velocity water jet leaving the nozzle in the form of a narrow beam.

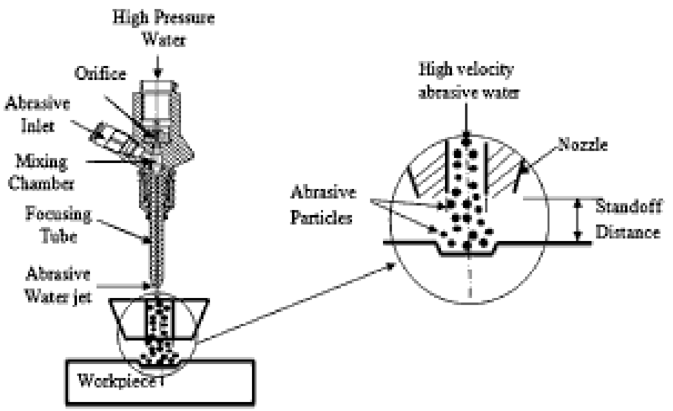

Figure 3: Abrasive water jet machining process

Abrasive particles such as garnet, olivine or aluminum oxide is mixed with water within the nozzle. A mixing chamber is present in the nozzle where the abrasives get mixed with the high pressure water using either of the configurations i.e single-jet side feed or multi-jet central feed. The high velocity jet of water emerging from the nozzle is directed towards the workpiece, when the jet of water strikes the workpiece it removes the material due to erosion, stresses induced on the workpiece and fracture of small parts of the workpiece at the contact point. The water jet after machining is gets collected by the drain and catcher system. Here the debris, metal particles from the water is removed and it is supplied to the reservoir tank. This is how the entire process of material removal takes place using Abrasive Water Jet Machining.

V. Abrasive Water Jet Machining Process for Various Materials

Advanced Composite Materials also known as advanced polymer matrix composites are advanced composite materials (ACMs). Compared to other materials, these materials have high strength, dimensional stability, light weight with low rigidity, temperature and chemical resistance and are easy to process. D.V. D.V. Srikanth et al carried out research into the impact of various parameters such as Pressure

Granite / Marbles Granite is a common type of felsic intrusive igneous rock that is granular and phaneritic in texture. Granites may be predominantly white, pink or grey, depending on their mineralogy. Investigation of the behavior of five artificial rock-like materials subjected to abrasive water jet cutting. The effects of the AWJ operating variables on the width of the kerf have been studied

Advanced Ceramic Materials The most recent ceramic materials, which offer high-performance features as opposed to unconventionally built products, are silicon carbide, alumina, silicon nitride, zirconia, alumina and titans. D. V. Srikanth et AL, work conducted to determine effect on MRR and Kertf of fibre glass of the Abrasive jet machining process parameters. Lalchhuanvela, H.; Doolin, B.; Bhattacharyya, researched Alumina ceramics process machining by varying parameters of the ultra-sonic process, such as abrasive grain sizes, slurry concentration, power rating, tool feed rate and slurry flow rate. C-H. C-H. Tsai H.-W. Chen, done experiments by laser machining for shaping ceramic, defocused laser beam is applied throughout the length of the groove-cracks to generate a great thermal stress, which makes the two groove cracks link together. The material removal is due to the linkage of the groove-cracks. From the

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experimental results they observed surface roughness and the inspection of crack defects.

Glass is a solid amorphous substance, which is not crystalline. This is commonly used for decorative applications in tableware, windows and decorative applications. The youngest one is the bottle of silicate. Axinite, Glass products can solve several specific problems and can have applications in design engineering. Such products can operate in conditions in which plastics and metals struggle and have to form part of the arsenal of the manufacturer. N. Jagannatha, Investigations have been performed in order to find the effect on MRR and Ra on soda lime through abrasive hot air jet machinery. Mathematical model for micro-hole boiling and micro nutrition on glass, developed by J.M. Fan. They contrasted predictive models with experimental results and concluded that they are well in line with experimental findings.

An alloy is a metal and a different component combination. A metallic bonding character distinguishes alloys. A solid metallic solution (singles phases) or a metallic combination of phases (two or more solutions) Alloys may include brass, silver, solder, iron, long-lasting aluminum and bronze. Vasanth's analysis of titanium alloy machinability has been carried out. They consider an effect on surface roughness and topography by the process parameters to improve the process. The experimental results have shown the most important part in determining surface quality is the abrasive flow rate and stagnation. M. Uthayakumar et al. have been studying the machinability of super alloys based on nickel. The system parameters selected include the water jet pressure, jet nozzle speed and stopping distance. Differences of throat length, brazing wall inclination and removal rate (MRR) are assessed by adjusting the selected system parameters. They found that the jet pressure is the most important factor affecting surface morphology and surface quality from experimental results.

VI. Advantages and Disadvantages

The **advantages** of AWJM are as follows:

- Water is cheap, non-toxic, readily available, and can be disposed easily. It is eco-friendly process as no hazardous gases are produced.
- It has the ability to machine workpiece without leaving any mechanical stresses or change in microstructure of workpiece as there is no heat affected zone.
- Complex geometry and intricate cuts can be achieved easily with excellent surface finish and in relatively clean and dust free environment.
- Maintenance and operating cost is low as there are no moving parts associated in this process.
- Both hard and soft materials can be machined using AWJM, however very thick materials cannot be machined.
- The precision of machining is excellent. The tolerances of the order of ± 0.005 inch can be achieved easily.
- It has multidirectional cutting capacity.
- No heat is produces though it is continuously fooled by supply of water.
- Grinding and polishing are eliminated which reduces secondary operational tools.

The **disadvantages** of AWJM are as follows:

- The equipment is quite expensive, making the initial investment too high. Due to high cost it becomes unsuitable for mass production.
- Though it is possible to machine hard materials, but to do it satisfactorily (with required precision and surface finish) requires reducing the material removal rate to a great extent, thus increasing the time for each cut.
- Very thick materials cannot be machined with required accuracy; the water jet dissipates in such cases and may result in wider cut at the bottom of workpiece than at the top of workpiece.
- The narrow kerf allows tight nesting when multiple parts are cut a single blank.
- Very thick parts cannot be cut with this operation.
- Slow material removal rate.

Applications of WJM:

- It is very useful in fields where cutting and drilling soft materials is required
- It used in turning operation and also in paint removal
- Pocket milling and cutting
- Textile, lather industry and cleaning
- Penning and surgery

Optimal tracing or numerical control allows more complicated profiles to be cut at optimum rates and it is particularly suitable for difficult-to machine materials.

Steel and brass can also be cut by water jets. Jet cutting is employed over Sheet cutting in shoe industry.

VII. Conclusion

Various materials can be machined using process. BHRA has successfully cut materials using high pressure water jets. Efficiency of Abrasive Water Jet Machining process is

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impacted by nozzle wear, which intern depends on certain process as well as geometrical parameters such as nozzle length, nozzle diameter, orifice size, nozzle inlet angle. From the literature point of view compared to all parameters, transverse speed is the most effective parameter for MRR. Another important parameter for increase in MRR is Abrasive flow rate. It is required to find suitable condition for the process parameter to give better quality of cutting surface. A safer and more effective tool is expected to emerge in the coming years for quality cutting with WJM opening the door to a new era in modern machining.

REFERENCES

[1] Dixit, A., Dave, V., & Baid, M. R. (2015). Water jet machining: an advance manufacturing process. *Int J Eng Res Gen Sci,* 3(2), 288-292.

[2] Nanduri, Madhusarathi, David G. Taggart, and Thomas J. Kim. "The effects of system and geometric parameters on abrasive water jet nozzle wear." *International Journal of Machine Tools and Manufacture* 42.5 (2002): 615-623.

[3] Jegaraj, J. John Rozario, and N. Ramesh Babu. "A strategy for efficient and quality cutting of materials with abrasive waterjets considering the variation in orifice and focusing nozzle diameter." *International Journal of Machine Tools and Manufacture* 45.12-13 (2005): 1443-1450.

[4] Srinivasu, D. S., and N. Ramesh Babu. "A neuro-genetic approach for selection of process parameters in abrasive waterjet cutting considering variation in diameter of focusing nozzle." *Applied Soft Computing* 8.1 (2008): 809-819.

[5] Momber, Andreas W., and Radovan Kovacevic. Principles of abrasive water jet machining. *Springer Science & Business Media*, 2012.

[6] Parikh, Pratik J., and Sarah S. Lam. "Parameter estimation for abrasive water jet machining process using neural networks." *The International Journal of Advanced Manufacturing Technology* 40.5-6 (2009): 497-502.

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