

Study on Water Jet Machining and Its Future Trends

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Abstract—The water jet cutting is very old techniques initially it has limited application. But now days its application increases in almost every sector of the science like mechanical parts development, civil construction, transportation, bio medical applications, electrical motor parts making, efficiently used for rock breaking and food beverages. So this process got very much attention from the researcher. The many experiment were conducted on different process parameter of the water jet cutting and abrasive water jet cutting like on the impact pressure, nozzle diameters and velocities, Jet velocity and cutting depth. But now the researcher moved their experiment towards the jet angle and material properties. This process still has scope for advance development in its control system and process parameters relation with machining quality. There is no constraint on applications of water jet machine when material properties are taken in record which makes it most wonderful procedure. This is open field for new era educated people to utilize it in various range all alone reason. In this paper author try to understand the basics of water jet cutting process and parametric effects. Searching for its utilization as water-jet grinding, water-jet milling and water-jet turning also.

Keywords—water jet; abrasive, turning, milling, grinding

I. INTRODUCTION

In the manufacturing technology, machining is an important technique however there are different techniques for different applications in which water-jet machining system is one of them. The purposes that are not easy to accomplish by different procedure can be smoothly achieve by water-jet system. Water-jet system can be used to machining of metal as well as non-metal materials, generally where cure form heat affected zone is required. In water jet system machining is done by means of high pressure jet of water with or without use of abrasive particles.

When water streams from a high pressure pump at 300 MPa (approximately 40,000 PSI), out through a tube with small opening at Mach 2 (680 m/s or 2,450 Km/hr) while it may over Mac 3 (1,021 m/s or 3,676 Km/hr) when pressure goes up to 400 MPa (roughly 60,000 PSI), the water stream ways out called as water jet. This amazing high speed water jet transforms into high strengths flexible tool for cutting, scoring, trimming, and cutting, slitting and cleaning etc.

Water jet machine can cut almost any material with attractive results. But water jet and abrasive water jet are used at large level to cut glass, stone, clay, metal, amalgam, plastic, elastic composite material, dispensable diapers, tissue paper, car insides, extended materials, for example, froth, paper and cardboard etc. The materials which are best feasible to machined with water jet and abrasive water jet are listed as Acrylics, Alloy steel, Aluminum, Alumina 95, Alumina 99, Armor plate Boron, Bronze, Armor glass, Carbon fiber, Cast iron, Ceramics, Ceramic Tile, Cobalt, Copper, Exotic alloys, Expanded metal, Fiberglass, Foam, Glass, Granite, Graphite Hard face Polymers, Hardened steel, Hot rolled steel, Inconel, Kevlar, Limestone, Linoleum, Magnesium, Marble, Mild steel, Molybdenum, Mylar laminates, Neoprene, Nickel alloys, Niobium, Nylon, Phenolics, Plastics, Plexiglas,

Polycarbonate, Polyethylene, Porcelain, PVC, Rubber, Silicone, Stainless steel, Tantalum, Teflon, Thermoplastics, Tile bonded metals, Tin, Titanium, Tool steel, Tungsten, Urethane, Vinyl, Wood, Wrought iron and Zinc etc.

There is no constraint on applications of water jet machine when material properties are taken in record which makes it most wonderful procedure. This is open field for new era educated people to utilize it in various range all alone reason. Hence water Jet applied in nearly all kinds of industries but widely used in Automotive, Marine, Solar, Elevators, Film, Gasket, Glass, Carpentry, Lighting, Computer, Optic, Wood, Metal, Chemical, Medical, Semiconductor, Sporting goods, Communication, Food processing, Plastic and rubber, Machining and tool, Education facilities, Musical instrument, Recreational equipment, Prototype development, Electrical and electronic, Architectural and construction etc.

II. LITERATURE

A. development of water jet machining

Water jet machining idea has come when someone absorbed the falling of water from a tap and that water gains some kinetic energy ($.5mv^2$) hit to the floor. In a long length it will cut the floor surface make some burrow. This destructive phenomenon was converted into constructive use and subsequently, the conceived of new innovation happens. Low pressure water jets were firstly used for gold mining as a part of California, USA in 1852. Steam and high temp water jets were utilized for cleaning purposes in mid 1900s. Start using in mining industries for removing stone and coal in 1930s. Necessity arose in aerospace industries for cutting advanced materials. High pressure water jets were utilized for mining in the year of 1960. After various trials and mistakes, in mid 1970s, it was found that water pressure at between 276 MPa and 414 MPa (40,000 PSI to 60,000 PSI) at roughly 0.1mm

water jet stream could flawlessly slice everything from cardboard to dispensable diaper and hence the attempt was made in aerospace applications for advanced composites using Water Jet Process. This progressive innovation was created for modern purposes and was connected in those zones that had been disused to cut with blades or mechanical procedures.

head. The abrasive water jet turns out from nozzle with higher cutting capacity. This abrasive trademark empowers the water jet to cut any sorts of hard, sensitive and thick materials. Abrasive water jet can cut as hard as aluminum oxide clay or alumina and tungsten also. Preferences of abrasive water jet because of , extremely versatile process, no heat is generated, no mechanical stresses, thin stream, thin and thick material cutting, little cutting material wastage, low cutting force, little or almost no burr, One jet setup is almost applicable for all abrasive jet jobs, Quickly switch between abrasive water-jet to pure water-jet.

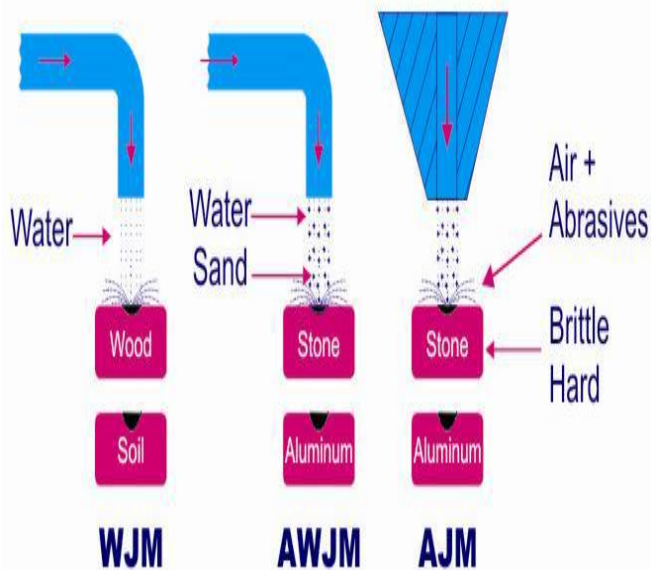


Figure 1: Evaluation of water jet

The first commercial AWJ machines were started in 1980s. Water jets were then widely connected in other applications like Cardboard, Disposable diaper, Insulating material, Foam rubber, Gasket material, Food products, Fabric, Leather and Carpet for automotive applications.

This was in light however inadmissible for the cutting of hard materials, similar to glass, metal, stone and mud only limit to soft material. Industrialists and analysts continued analyzing and in mid 1980s, uncommon spout was created and little measure of abrasive powder abrasive (garnet) was mixed with the water jet, launched out from the nozzle as quick as the water jet. This, supposed "abrasive water jets", could cut any hard and intense materials, for example, titanium, stainless steel, glass and earthenware production with acceptable results.

B. Two types of water jet machining

Pure water jet—In early stage of evaluation of water jet procedure only water steam at very high speed was used as flexible tool to cut any material and water jet cutting procedure was firstly dispatch in the business sector in mid of 1970s. Pure water jet is for the most part used to cut thicker, gentler and lighter materials like tissue papers, folded cardboard, car insides, dispensable diapers and so fiber glass protection up to 24" thick or slight but now a day's exponentially used in food and beverages industries. Preferences of water jet machine to the others because in this very minimal material wastage and no heat is produced during cutting, can cut thicker materials, fast cutting, extremely low cutting power, very reasonable for light and delicate materials cutting.

Abrasive water jet—In this Abrasive water jet abrasive material(garnet) are sucked into cutting head when vacuum create due to high velocity flow of water through the tube, they are combined legitimately with water inside the cutting

III. MACHINE & COMPONENT

Water jet machine is consists of different components and accessories.

- High Pressure Pump
- Cutting Head
- Plumbing
- Control System
- Abrasive Delivery System
- Water quality
- Misslenious

A. High pressure pump

High pressure pumps guarantees consistent pressurized water at lowest running and maintenance costs. High pressure pump is the heart of water jet framework. The pump pressurizes water and conveys it ceaselessly through plumbing and blending tube until a supersonic water jet stream exits out from gem opening. There are two types of pump utilized for water jet production, direct drive based pumps and intensifier based pumps.

1) Direct drive based pumps

In this high pressure pump, pressure is generated by the help of plungers specifically from the electric engine. This kind of pump has capacity to develop pressure 138 MPa to 345 MPa (20,000 PSI to 50,000 PSI). Because of its straight forwardness and cost focused, direct drive based pump is broadly utilized for universally useful applications.

2) Intensifier pumps

With this kind of pump ultra high water pressure is delivered. There are two fluid circuits generally runs in an intensifier pump. They are water circuit and pressure driven fluid circuit.

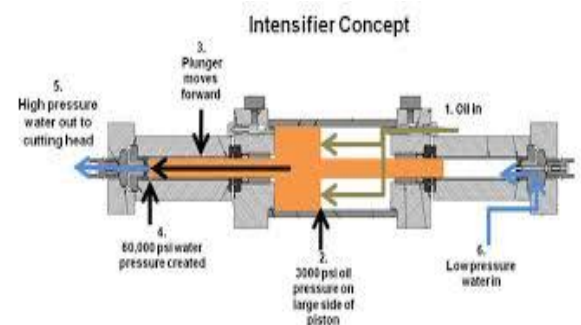


Figure 2: Intensifier

a) Water circuit

Whether the water continues running, through a channel structure, into the water circuit which is comprises of supporter pump, intensifier pump, and stun attenuator. After the filtration, the water goes into the promoter pump with channel water pressure kept up at around 0.7 MPa (100 PSI) ensuring the intensifier is continually stacked with water. By leaving from the bolster pump, the water goes to the intensifier pump and then pressurized to 400 MPa (around 60,000 PSI). The forward and reverse action of intensifier chamber produces the stream of water at high pressure. The shock attenuator chamber is basically high pressure surge vessel and is used to help to keep the water stream more uniform and realizing a smoother cut.

b) Hydraulic circuit

This circuit is comprises of an electric engine, pressure driven pump, oil repository, complex and cylinder bread and plunger. Oil is powerfully pumped from the store and is then pressurized to 20 MPa (around 3,000 PSI) and this pressurized oil is conveyed to the complex's valves where this produces stroking activity of the intensifier by pushing the oil to the other side of the plunger. The intensifier pump comprises of a two way acting chamber. It is a complementary such that the bread and plunger has to responds together forward and backward. A progression of check valves permits low pressure water into the plunger barrel when the plunger withdraws and pressurized the water into the outlet complex when the plunger moves into its pressure stroke. This plunger pressurizes water to a level that is corresponding to cross-sectional zone of the cylinder. The pressure generally generates is 20 MPa (around 3,000 PSI) to 400 MPa (around 60,000 PSI). This shows that the increase of pressure is in the ratio of 20:1.

B. Cutting head

Cutting head makes possible to perfect self-alignment.

1) Jewel orifice

It has a tiny opening and pressurized water from the pipes will stream into this hole. This tiny hole is used to change pressurized water into a very high speed stream of water. Depending upon various applications, openings are from 0.2 mm to 0.35 mm are taken. There are three regular nozzles available depending on the materials sapphire, ruby and precious stone.

a) Sapphire

This one is mostly utilize today. For waterjet process with greater water quality, it ensures between 100 to 200 hours life for any operations. The life may be reduced to half for abrasive waterjet machining.

b) Ruby

This one is more suitable for abrasive waterjet. However this not appropriate for pure water jet applications. It has comparative life time to sapphire one.

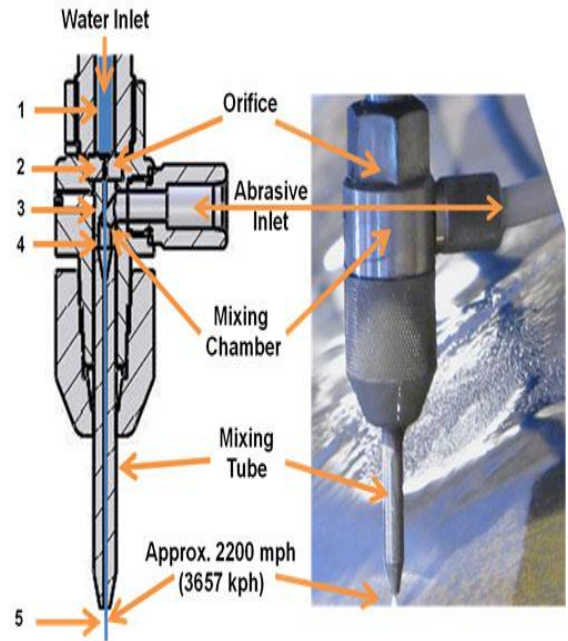


Figure 3: Cutting head

c) Diamond

However the cost is very high nearly 10 to 20 times than sapphire and ruby, it has life from 800 - 2,000 working hours and generally clean by ultrasonic for reuse. Because of long life time this used in specific application when required.

2) Venturi chamber

This chamber is the meeting place for abrasive and the water. After the water stream goes through the opening, it create vacuum and hence the abrasive goes downwards to the venturi chamber at a high speed.

3) Mixing tube

When the abrasive and water goes out of the venturi chamber, by going into a long and empty tube shaped blending tube where they are mix with each other and makes a reasonable stream while leaving the blending tube. This stream increases the power to perform cutting.

C. Plumbing

This is used to deliver the steady pressurized water. Through high pressure plumbing the high pressure water is then transported to the water jet spouts. The pipes are typically of stainless steel and sufficiently long giving flexibility development of the spout.

D. Control system

Control is fast and simple with user friendly programming interface. Design is provided with easily accessible AutoCAD software. Cutting speed and pressure is adjustable according to materials and its thicknesses.

E. Abrasive delivery system

The abrasive act as flexible tool used to cut harder materials at faster speed with better surface finish. Surface finish and cutting capacity depend on abrasive material and its size. Generally abrasive are extreme hard sand olivine sand, aluminum oxide and garnet. Different sizes of garnet are available for various

applications, generally 120 mesh sizes is utilized when smooth surface required, 80 mesh broadly utilized for universally and 50 mesh is utilized when quicker speed is more concerned rather than surface completion. The effective water jet cutting is achieved with 400 MPa (around 60,000 PSI) intensifier pump pressure which consume nearly 0.4 kg/min. to 1.2 kg/min. of abrasive depending on the mesh sizes of abrasive particle. Earlier reuse of the abrasive was not possible but now days so many technology developed by the researcher and reuse becomes possible in-fact some of the machines are also developed. Abrasive particles turn out to be too fine and are ineffectual to reuse to perform cutting appropriately.

F. Water quality

Cold water is needed (4 degree to 6 degree) because the water gets warmed when water is pressurized and also a very good quality (TDS value is nearly 20) of water needed for water jet system. The segments influenced by water quality are seals, gem hole, on/off valve, plunger and check valves. Pollutants in water create effect on the gem hole. These pollutes is by two means suspended solids and broke down solids. When water quality requirement is known then water treatment framework can characterized.

G. Misslenious

1) Finished product

Machining with this machine produces high cutting accuracy and precision. In this the cutting tool behaves as flexible tool and hence it is a cold cutting process which doesn't produce heat affected zones (HAZ). No mechanical stresses are found on waterjet cut surface this means this process relieved mechanical stresses. Produce superior edge & surface quality and hence No secondary finish is required. Very minimal burrs were found. The quality of finished product depends on different parameters as shown in the figure bellow.

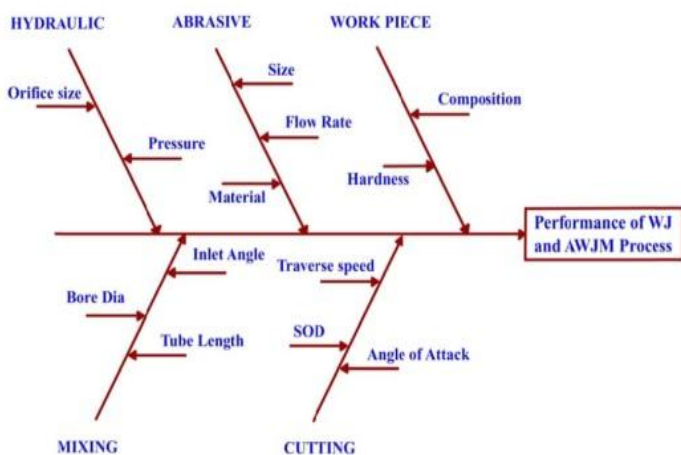


Figure 4: Process dependency

2) Costs

Relatively to the other processes low capital investment and operating costs. Low fixturing cost and almost no tooling cost. Low maintenance cost and Job change over cost. Abrasives are the only the thing which is consumable but available at low cost that's why no issue.

3) Effects on environment

No toxic liquids or gases are used. No any vapours are created during water jetting. Noise can be suppressed simply by putting the small machine inside or by filling the water in the catcher tank and this process is absolutely environmental friendly.

H. Comparision with other technologies

1) Laser

Laser cutting is basically used for cutting of flimsy metal sheet. In this cutting warm influenced zone is produced and blazed imprints are left at of cutting surfaces. Laser cutting can't perform on some of the amalgams and ferrous metals, for aluminium and copper, especially when they are thick laser is not suitable to cut thicker material. Accuracy to $\pm 0.001''$ (± 0.025 mm) or better in flimsy material.

2) Plasma

In this plasma cutting it is evident that warmth influenced zone are found at the cutting surface. The cutting resilience is low and the cutting thickness also restricted. In this capital expenses is relatively low. Very quick generation rates in slight sheet metal.

3) Diamond tool

In the field of Jewellery the instruments are actually connected in different materials like stone, glass and artistic commercial ventures. There may situation which restricted to basic bend or straight line cutting and of precious stone apparatus cutting resistance is not as good. However the cutting by waterjet is exact. Waterjet can cut any shape or profile that jewel apparatuses can't accomplish. Cutting completion is great and no optional completions are required for universally useful applications.

4) Wire EDM

Especially low cutting speed and requirement of electrically conductive material are the limitations of EDM wire cutting. Heat affected zones produced limit over the workable and work piece sizes are also demerits of this process. Some advantages over the water jet are extremely precise (± 0.025 mm) and very thick parts (over 30 cm) can be made.

5) Oxy-fuel

Oxy-fuel is basically utilized for metal cutting especially for thicker metal. In this also heat impact is marked.

6) Water jet

Warm influenced zone is not produced. Water jet can cut materials like plastic and elastic which are warmth delicate. Waterjet cutting is adaptable to all the materials, thick, delicate or hard, extreme or fragile. Low working and support costs. By this process any one can produce parts up to 5 cm thick and also can machine conductive, non conductive, intelligent, and thicker materials, for example, stainless steel and aluminium copper and metal etc. this can cut materials without softening, produces smooth and uniform surface with negligible burrs. No harmful gas or vapours delivered amid cutting.

IV. CONCLUSION

Author absorbed the detailed and specification of the component of water jet and its effect on the machining. It has been absorbed that property of water jet (pressure, abrasive type and size) process parameter (nozzle diameter, standoff distance, angle of water jet,) and properties of work piece material (compressive, tensile strength, density, hardness) all these comes under affecting parameters. By concluding all the results of different researcher and available literature rate of material removal is directly proportional to the power of the water jet and area of the orifice. During the process there may occur some loss of energy which leads to the kerfs formation. Thus the kerf is wider at the top and lesser at the bottom. As we see in the comparison with another technology the abrasive water jet machining is an effective technique for slicing materials and it's additionally the test of the more up to date era peoples to make new control of it and customized for simply computerized for selecting ideal parameter.

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