Tổng quan thông tin trao đổi

An introduction to Abrasive Waterjet (AWJ) machining

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Introduction

AWJ machining is a recent unconventional machining process. It has been developed from Waterjet machining. The earliest use of the water beam in coal mining was in the former Soviet Union and New Zealand [1]. This mining technique was also used for removing blasted rocks from working areas into collection drifts or tunnels.

From 1853 to 1886, pressurized water was used for excavating soft gold rocks. The pressurized water for coal mining was also used in Prussia in the early 1900s and then in Russia in the 1930s [1].

In 1936, Peter Tupitsyn, who was working for the Donetsk Coal Basin in Ukraine, proposed the idea of using waterjet beam to cut boreholes in the coal bed [2].

In the 1950s, Dr. Norman Franz, a forestry engineer, was the first who studied the use of a waterjet beam as a cutting tool for wood processing [3]. However, the first patent of a waterjet cutting system was granted for the staff of McCartney Manufacturing Company, a division of the Ingersoll-Rand Corp. [4]. In 1971, the first commercial waterjet machine was introduced into the market by this company [4].

In 1979, Dr. Mohamed Hashish, who was worked for Flow International Cooperation, invented the abrasive waterjet cutting method by adding abrasives into the pure waterjet [3]. Soon after this, in 1980, abrasive waterjet was first used to cut glass, steel, and concrete [3]. The invention of AWJ led to a huge expansion of applications of cutting with high-pressure water. Since then, AWJ has been widely used in various industries such as cutting of a wide variety of sheet materials, cleaning of contaminated surfaces, polishing of hard-to-machine materials, etc.

This paper introduces about AWJ system as well as about AWJ process parameters. Also, advantages and limitations of this type of machining are given.

AWJ cutting system

There are two types of waterjets: pure (or plain) waterjet and abrasive waterjet. In pure waterjet cutting, only a pressurized stream of water is used to cut through materials. This type of cutting is used to cut soft materials such as cardboard, leather, textiles, fibre plastics or thin plates of aluminium. In AWJ cutting, an abrasive waterjet entrainment system (Figure 1) mixes abrasives with the waterjet in a mixing chamber following an orifice. The abrasive particles are accelerated by the water stream and then come out the focusing tube (or the nozzle) with the stream. AWJ cutting is used for cutting harder materials such as stainless steel, glass, ceramics, titanium alloys, composite materials, and so forth.

A typical AWJ entrainment system (as shown in Figure 1) consists of four main parts: the water preparation system, the pressure generation system, the jet former, and the abrasive supply system. A brief description of these parts is given below:

- The water preparation system:

The water preparation system is used for supplying purified water for the pressure generation system. Generally, particles larger than 1 μm have to be filtered out to prevent unacceptable wear of the critical parts of the pressure generation system [5].

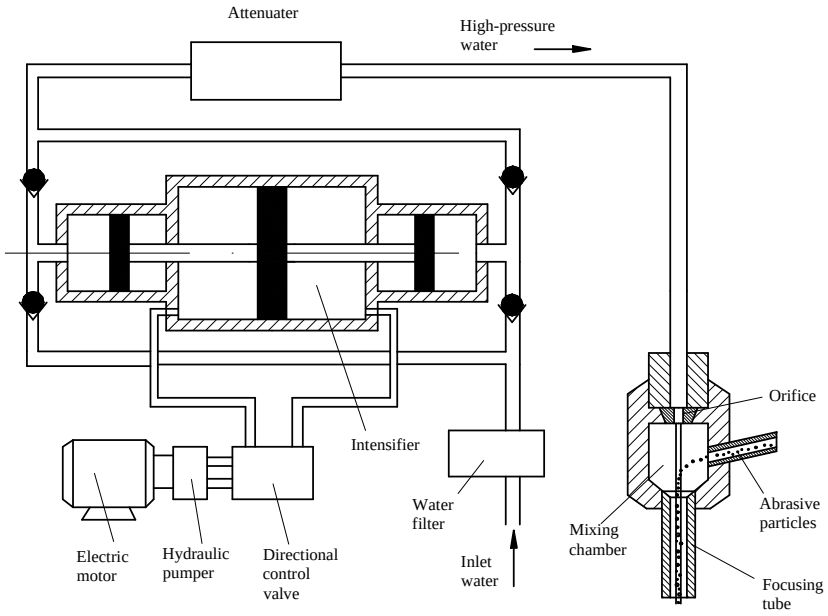

Figure 1: Schema of an AWJ system

- The pressure generation system:

This system is equipped with a pump to ensure a continuous and stable flow of high pressure. Three types of pumps including intensifier, crankshaft and direct pumps can be used.

Figure 2: Direct pump (Courtesy of Flow International Cooperation)

Direct pumps (Figure 2) are used for applications with low pressure such as cleaning, or washing a desk or a work place etc. In a direct pump, the movement of three plungers is transmitted directly from the electric motor.

Intensifier pumps (Figure 3) are used for applications with the water pressure up to 600 MPa. In an intensifier pump, a double-acting cylinder in which the movement of the piston is driven by a hydraulic system is used. Two small diameter cylinders at each end of the hydraulic cylinder help to pressurize the water alternately as the hydraulic piston moves back and forth.

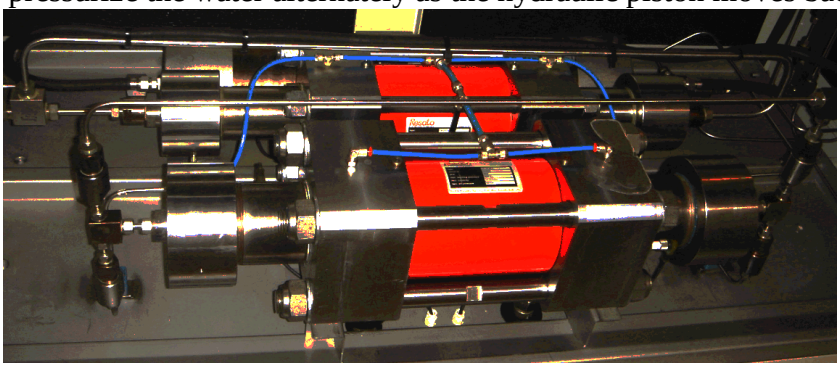

Figure 3: Double-acting intensifier

The third type is the crankshaft pump, which can provide the pressure up to 345 MPa [2]. An example of this pump is shown in Figure 4. It is known that the efficiency of crankshaft pumps is higher than that of intensifier pumps because crankshaft pumps do not require a power-robbing hydraulic system.

Figure 4: Crankshaft pump (Courtesy of OMAX Corp. Kent, WA)

- The jet former:

The jet former is used to transfer part of the hydraulic water energy into the kinetic energy of water, and then into the kinetic energy of abrasive particles. Figure 5 shows a typical jet former for AWJ cutting [6]. To form the abrasive waterjet, first, the high pressure water is forced through an orifice to create a high speed waterjet. Then the high speed waterjet passes through a mixing chamber, which is installed downstream of the orifice (see Figure 5). Because of the Venturi effect, a vacuum is created in the mixing chamber. As a result, the abrasive particles and some air are pulled into the mixing chamber through a feed line. After entering the mixing chamber, the particles are accelerated by the high-speed waterjet (velocity about 600 to 900 m/s) and then passed through a focusing tube (or nozzle).

As mentioned above, the orifice, the mixing chamber and the focusing tube are the main parts of a jet former. Orifices can be sapphire, ruby or diamond with a diameter ranging from 0.08 to 0.8 mm [5]. The lifetime of a diamond orifice is about 1000 to 2000 hours while it is only 40 to 70 hours for sapphire [7]. However, sapphire orifices are most commonly used because they are much cheaper than diamond orifices (the price of a diamond orifice can be $450 while it is only $14.5 for a sapphire one).

Most of AWJ nozzles are made from composite carbide materials with two famous products ROCTEC 100 and ROCTEC 500 from Kennametal Inc. ROCTEC composite carbide is a very dense, sintered, tungsten carbide based hard metal. The common inner diameter of the focusing tube is from 0.5 to 1.5 mm, and the common length is from 70 to 100 mm.

- The abrasive supply system:

The abrasive supply system is used for accurate supply of abrasives with a pre-required mass flow rate. Generally, when cutting with the abrasive waterjet, the abrasive mass flow rate is about 0.08 to 0.5 kg/min (15 to 30 kg/h –[8]) and the abrasive size of 0.1 to 0.3 mm (garnet #150 to #50).

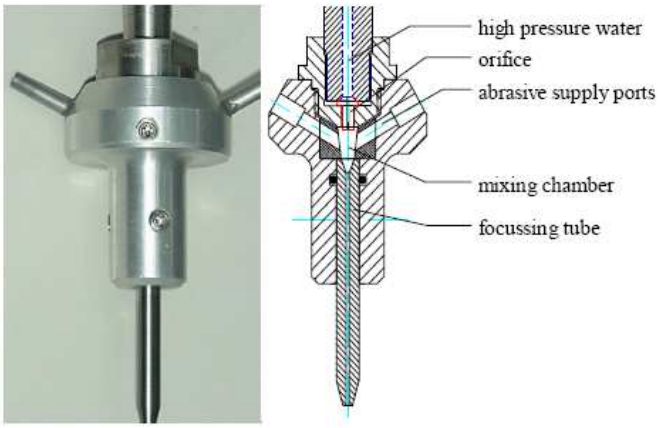

Figure 5: A typical jet former for AWJ cutting [6] AWJ machining process parameters

There are many parameters involved in an AWJ machining process. In general, these parameters can be divided into two groups: process parameters and target parameters (see Figure 6) [9]:

- Process parameters:

The process parameters include parameters relating to the forming of the AWJ beam. These parameters can be sorted into four following sub-groups [9]:

-*Hydraulic parameters* including water pressure p and orifice diameter d_0 .

-*Mixing parameters* including focusing tube (or nozzle) diameter d_F and focusing tube length l_F .

-*Abrasive parameters* including abrasive type, abrasive particle size d_P, abrasive shape, and abrasive mass flow rate $\dot{m}_A$.

-*Cutting parameters* including standoff distance x, impact angle φ, feed speed v and number of passes n_P .

- Target parameters:

The target parameters consist of parameters related to the target of the machining. These parameters are the work material, the depth of cut h and the cutting quality.

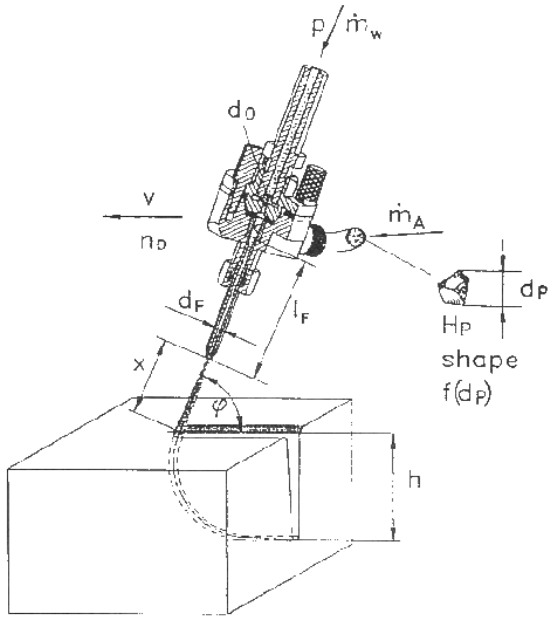

Figure 6: AWJ process parameter [9] Advantages and disadvantages of AWJ Technology

AWJ cutting has various advantages over other unconventional techniques such as laser and Electrical Discharge Machining (EDM). The advantages of this type of machining can be described as follows:

-AWJ can machine a wide range of materials including titanium, stainless steel, aerospace alloys, glass, plastics, ceramics, wood, and so on.

-AWJ can cut quickly net-shape parts and near net-shape parts (see Figure 7).

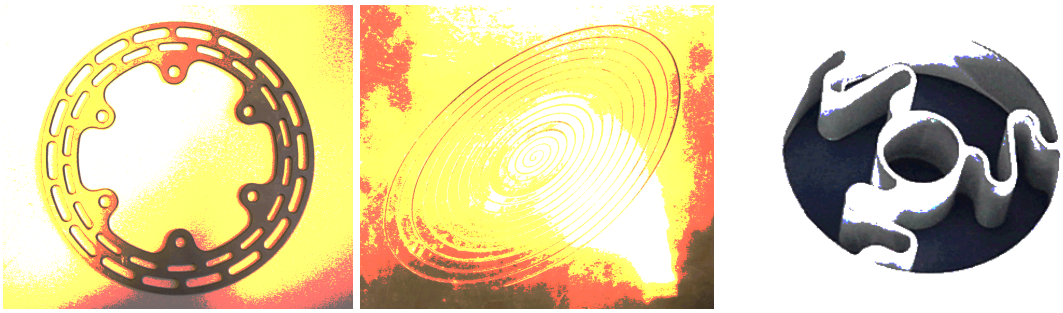

Figure 7: Pictures of several parts made by AWJ cutting

-No heat is generated in the cutting process. As a result, there is no heat-affected area that makes structural changes in work materials.

-AWJ cutting is particularly environmentally friendly as it does not generate any cutting dust or chemical air pollutants.

-The abrasives after cutting can be reused which allows for possible reduction of the AWJ cutting cost.

-Only one nozzle can be used to machine various types of work materials and workpiece shapes.

-AWJ machining can be easily automated and therefore can be run with unmanned shifts.

Although AWJ cutting is a truly useful machining process and it can be used for various applications, the technology still has several disadvantages:

-The total cutting cost is high;

-The cutting quality is not so high and unstable.

5. Conclusion

- In the paper, an introduction to AWJ machining is carried out. The AWJ system including the water preparation system, the jet former, and the abrasive supply system are described. Several advantages and drawbacks of AWJ machining are also given.

- Although AWJ machining has many advantages and it has been used for many applications, its high cutting cost is the major disadvantage of the technology. As a result, the reduction of the total cutting cost and cutting time as well as the increase of the profit rate in AWJ machining in order to increase the profitability of AWJ users are big challenges for this technology.

Summary

This paper presents an introduction to Abrasive Waterjet machining. In the paper, a short history of AWJ technology is given. The AWJ cutting system which includes the water preparation system, the jet former as well as the system for abrasive applying are introduced. In addition, the advantages and disadvantages of this technology are shown.

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