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ON THE ISSUE OF THE USE OF WATERJET TREATMENT I N MODERN MECHANICAL ENGINEERING

The article deals with the application of waterjet abrasive processing (cutting) in mechanical engineering. The data on the application areas, advantages, disadvantages and technological capabilities, as well as the world leaders in the production of waterjet cutting machines with technological characteristics are presented.

In waterjet processing, the process is most influenced by the technological parameters: the speed of the jet, the grain size of the abrasive, the angle of inclination of the jet, the distance from the nozzle to the surface to be treated.

Thus, the use of waterjet processing ensures minimal heat generation and accurate cutting of materials, the equipment is completely versatile and economical compared to plasma processing of the material reaching a cutting speed of 30,000 mm / min without affecting the quality of the cut, as well as the absence of surface heating, the likelihood of sparks make the use of water-abrasive machines as convenient and safe as possible.

Keywords: hydraulic cutting, waterjet cutting, abrasive, non-traditional processing methods, cutting jet, water jet cutting.

Introduction

In modern mechanical engineering, very often high requirements are placed on the quality of metal cutting, which makes it impossible to use traditional equipment: guillotines or plasma cutting. Metal cutting with water (other names are «water cutting», «water cutting», «water jet» or «water jet cutting», as well as» water jet «from the English» waterjet») has been used since the 60s of the last century.

For the first time, the waterjet method was used for cutting metal by an aircraft manufacturer in the United States. Later, the company officially announced that this method is optimal for cutting metal and other high-strength materials. Now it should be noted that American companies are the leader in the use of «waterjet» [1, 2].

In the world practice, considerable experience has been accumulated in cutting materials along a complex contour using mechanical methods, ultrasound energy, plasma, laser, water jet, etc. For cutting blanks from a sheet with a thickness of up to 10 mm, laser cutting is most preferable, as it is more productive and less energy-intensive [3-5].

The global hydraulic cutting equipment market is projected to reach $1.15 billion by 2020, according to analysts at Global Industry Analysts, Inc. The largest player in this

market is the United States. In second place is the EU. Now there is a rapid development of the market in the Asia-Pacific region (APR) (China, Taiwan, India and Vietnam). The average annual growth rate of the market in the Asia-Pacific region in 2006-2012 was 11 %. The latter is due to the relocation of production facilities to these cheaper countries from economically developed countries in Europe and America, the development of the automotive industry, and the overall growth of capital investments in the aerospace, mining, construction, and maritime transport industries. An important role is played by the stable economic development of China, South Korea, India, Malaysia and Taiwan.

The high average annual growth rate of the global hydraulic cutting equipment market from 2013 to 2020 in the amount of 9.3% is also predicted by the research company TechNavio (UK) [6].

When mass cutting of the same type of parts from sheets, batch cutting is used. In this case, the cost of cutting one linear meter of metal with a waterjet jet, as the main competitor to the laser, does not exceed the cost of laser cutting [7].

The feasibility of using batch cutting of materials with a waterjet jet is determined by the following advantages: the ability to cut thin-sheet parts along any contour without melting the edges and warping the sheets; reduced abrasive consumption compared to cutting individual sheets; high productivity; identity and accuracy of the shapes of parts cut from a single package [8].

Despite the high productivity, the method of waterjet processing is currently insufficiently studied, which largely constrains its use. The existing information about the regularities of the process is very fragmented and does not allow us to form empirical dependencies for determining the main parameters of the processing quality with this method. In the works devoted to the study of the method of waterjet processing, as a rule, one or more technological parameters that have the greatest impact on the processing process are investigated. On the basis of the studied literature, it can be concluded that these are the jet speed, the grain size of the abrasive, the angle of inclination of the jet, the distance from the nozzle to the treated surface.

Materials and methods

To date, a number of works devoted to the study of the process of waterjet processing, the study of its basic laws and technological capabilities have been completed.

The greatest interest in the field of studying the method of hydroabrasive processing is represented by the works of Nepomnyashchy E. F., Provolotsky A. E., Shmanev V. A., Shulepov A. P., etc. [9-12] These works are devoted to the study of the essence of the method of hydroabrasive processing, some of them present the results of theoretical and experimental studies of the influence of technological parameters of the process on the removal of metal and the roughness of the treated surface.

The author [13] showed that at a low speed, a jet of liquid directed at the metal surface for a short period of time does not leave a noticeable trace on it.

In modern mechanical engineering, finishing operations have a major impact on the quality and performance of parts. The task of improving the quality of products is associated with the improvement of well-known and the development of new, effective finishing methods, among which the leading place is occupied by methods of abrasive

processing. Abrasive processing allows you to ensure the required accuracy and quality of parts with high productivity, as well as high reliability and durability of machines during operation, so the role of abrasive operations in modern mechanical engineering is constantly increasing.

The development and implementation of new technological processes of abrasive processing are subordinated to the general task of further improving the quality of products while ensuring high production efficiency.

Hydroabrasive processing is one of the varieties – processing parts with free abrasives, allows you to process shaped parts that can not be processed on machines.

One of the most modern and promising methods of cutting and producing finished parts is the method of waterjet cutting. Wide ranges of processed thicknesses of materials, the ability to cut almost any materials, high productivity, obtaining a high quality of the cutting surface, the ability to process complex geometry makes this method of processing the most popular in modern production conditions. The absence of thermal effects on the material, low cutting force, and the erosive nature of the destruction do not contribute to the development of internal stresses in the cutting zone.

The process of waterjet cutting is complex, insufficiently studied, the result of which is affected by many technological parameters, such as the pressure of the cutting jet, the nozzle feed, grain size, hardness, abrasive consumption, the distance from the nozzle to the surface to be processed, the physical and mechanical characteristics of the material to be processed. The complexity of designing the cutting process is to choose the optimal cutting modes, which will ensure the desired quality of the surface layer of the part at the lowest cost.

In addition to the advantages, there are disadvantages of this technology, one of which is the uneven distribution of the roughness of the cut surface over the depth of the section, as well as the deterioration in quality with an increase in the nozzle feed. The cut surface is conventionally divided into a zone of smooth and wavy cuts [14].

The essence of waterjet processing

Waterjet cutting is a type of material processing by cutting, where a jet of water or a mixture of water and abrasive material is used as a cutting tool instead of a cutter, emitted at high speed and under high pressure. The method of waterjet cutting of metals and materials has been around for 20 years. The essence of the method is simple. The principle of waterjet cutting is based on the method of separating metals and materials using a high-pressure water jet. Water compressed by the first main component of the system, the multiplier pump, to a pressure of more than 4000 atm, passes through a water nozzle that forms a jet with a diameter of about 0.5 mm, which enters the so-called mixing chamber. In the mixing chamber, the water jet «sucks» the abrasive (for example, garnet sand with particles about 0.4 mm in size) and then passes through a second, hard-alloy nozzle with an internal diameter of 1 mm. From this nozzle, a jet of water with an abrasive comes out at a speed of about 3M (about 1200 m / s) and is directed to the surface of the cut material. After cutting this material, the residual energy of the jet is extinguished by a special water trap. The cutting material is usually located on the coordinate table [15].

The main difference that waterjet metal cutting has from other methods of cutting sheet metal is that the material is not mechanically affected (Table 1). The absence of friction, heating of tools affects the quality of the cut and possible applications. Waterjet cutting of metal with a jet of pure water or an abrasive mixture is also successfully used for cutting the following materials:

1 Marble, granite, stone and other rocks;

2 Glass, ceramics;

3 Steels and metals, including: titanium, stainless steel;

4 Reinforced concrete;

5 Plastic, textolite, ebonite and paronite plates, rubber.

Table 1 – Advantages of waterjet technology

№	Advantage of waterjet cutting technology	Brief description (explanation)
1.	Wear Resistance	The cutting element of waterjet cutting technology – water jet-has no wear
2.	Minimization of production waste	Due to the variation in the diameter of the water jet, it is possible to cut at any point of the processed material, which reduces the waste generated in the process
3.	Preservation of the original physical and mechanical parameters of the processed material	It is achieved due to the absence of deforming (mechanical or thermal) effects
4.	Environmental friendly and fire-proof technology	The formation of unsafe fumes, melting or burning of the processed material is excluded Gorenje.
5.	Uniqueness	It is the only cutting technology for materials such as ceramics, multilayer and honeycomb structures, composites
6.	Versatility	It has a large range of the thickness of the processed surface, which has made the waterjet machine widely in demand in many industries

Thus, the water cutting method or waterjet cutting can significantly increase the speed and quality of cutting the material. From an economic point of view, the material and energy consumption is significantly reduced (by 20–30 %), due to the use of water energy as a cutting tool in this method. The consumable material here is only water and abrasive material. The most expensive consumable material can be considered the type of abrasive and the nozzle that changes after a certain time. Practice shows that this method is economical, environmentally friendly, and has a number of advantages.

Waterjet Cutting Equipment

The following companies are world leaders in the production of waterjet cutting machines: Flow (USA), OMAX (USA), Jet Edge (USA), PTV (Czech Republic), Waterjet Sweden, Resato (Holland), Bystronic (Switzerland), Caretta Technology (Italy), ALICO (Finland) [16].

In the process of machine tool production, these plants use the highest quality and reliable components and spare parts manufactured by KMT, AccuStream (ultra-high pressure pumps, cutting heads, abrasive feeders, etc.), as well as UHDE, Thueringer,

BHDT. Currently, manufacturers produce mainly waterjet machines with numerical control (CNC).

One of the most modernized machines in recent years is the Flow Mach 4 waterjet cutting machine, which has a modular design and combines all the necessary components for operation. This ensures the most comfortable conditions for its operation and easy access to all working units. Flow Mach 4 is used to solve a wide variety of cutting tasks [16].

The use of waterjet cutting machines is not limited only to the possibility of cutting rolled metal, yet the majority of the equipment continues to be used directly in this area of production. The possibility of using programmable machines with numerical control (CNC) for waterjet cutting of stainless steel, aluminum, copper, and other types of ferrous and non-ferrous metals of different strengths, allowed us to significantly increase and expand the scope of application of the equipment. Thanks to CNC machines, it is possible to produce precise parts with a minimum deviation from the specified dimensions, which is almost impossible to achieve with traditional cutting methods.

The principle of operation of waterjet cutting equipment with CNC is as follows: Software for waterjet cutting on CNC machines is installed. Each material has its own software that automatically selects the composition of the cutting mixture, the jet pressure and other necessary parameters. The program allows you to provide curly cutting of the material. Additional processing – usually after processing the material with the machine, such is not required.

But with the wrong selection of the cutting jet composition, there may be a slight surface roughness after the GAR. The roughness of the cut is practically eliminated when using machines with software. The CNC machine analyzes the cut quality and automatically adjusts the selected mode. In addition to cutting the material, the CNC waterjet metal cutting machine allows you to drill holes of the required diameter. Some CNC waterjet machines contain additional equipment for performing certain operations. After processing the workpiece, a completely finished part is obtained, which does not require additional work on grinding or refining the cutting site.

The most well-known equipment for waterjet Waterjet Sweden AB (Sweden) is the European leader in the production of high-tech precision waterjet cutting machines [17].

The main technical characteristics of some Water jet Sweden waterjet cutting machines are shown in table 2.

Table 2 – Technical characteristics of some Waterjet Sweden waterjet cutting machines

Car model	NC 1010B	NC 3015E(B)	NC 4020E(B)	NC 2560S
Table size, mm	1050x1150	3200x1750	4200x2275	2700x6700
Cutting area, mm	950x1010	3100x1510	4100x2010	2510x6470
The range of movement on the X,Y,Z axis	950 1010 175	3010 (2250) 1510 175	4010 (3010) 2010 250	2510 6470 175 или 250
Positioning accuracy	±0,025	±0,025	±0,025	±0,025
Feed rate on the X-Y axis, mm/min	0….12000	0….10000	0….12000	0….10000

Feed speed along the Z axis, mm / min	0….4000	0….4000	0….4000	0….4000
Minimum possible distance between the nozzles, mm	90	90	90	-
Maximum possible distance between the nozzles, mm	500	400 (1500)	400 (2010)	-

Results and discussion

Waterjet cutting capabilities:

1 The unique method of material processing using a narrowly directed jet of water under pressure has found its place in many areas of production and art. One of the main advantages of the waterjet cutting method is the complete absence of chipping and surface heating, which are present during the usual cutting of objects.

Thanks to modern technologies and the improvement of machine tools, it was possible to expand their functionality and scope of application;

2 The ability to perform non-standard cutting of the material. Moreover, the change in the incline of the cut does not affect the quality of cutting. The precision of cutting metal at an angle allows you to use the resulting workpieces without further processing. There are machines that are able to operate in a completely autonomous mode without human intervention. At the same time, it is required that a certain program is set up, which regulates the operation of the equipment [18].

Precise shaped waterjet cutting of metal allows you to use the machines in the production of jewelry items, decorative elements and much more. The quality of the cut and the accuracy of the execution of the figures largely depends not on the experience of the worker, but on the quality of the equipment and software used.

Conclusions

Thus, we can formulate the following conclusions:

1 Minimal heat dissipation ensures precise cutting of materials that can be deformed by high temperature;

2 Processability of the cutting process-the machine is completely universal, if necessary, it can be used for drilling.

It is possible to perform the operation independently of atmospheric and other conditions. Manual installations can be used to cut the material even under water or at a depth of several hundred meters;

3 Cost-effective compared to plasma processing of the material-the advantages of water-abrasive cutting are obvious;

4 The cutting speed can reach 30000 mm/ min. And this does not affect the quality of the cut.

If we take into account that only 0.5–1 mm of material is lost during cutting, as well as the accuracy and full compliance of the finished product with the specified dimensions, it becomes obvious that the high profitability of the waterjet cutting installation is obvious;

5 Safety-the machines can be installed even in production with a high risk of explosion, in the manufacture of flammable materials. The absence of surface heating, the

possibility of sparks and other characteristics make the use of water-abrasive machines as convenient and safe as possible.

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ҚАЗІРГІ ЗАМАНҒЫ МАШИНА ЖАСАУДА ГИДРОАБРАЗИЯЛЫҚ ӨҢДЕУДІ ҚОЛДАНУ МӘСЕЛЕСІНЕ

Мақалада машина жасауда гидроабразивті өңдеуді (кесуді) қолдану мәселелері қарастырылған. Қолдану салалары, артықшылықтары, кемшіліктері және технологиялық мүмкіндіктері, сондай-ақ технологиялық сипаттамалары бар су абразивті кесетін қондырғыларды шығаратын әлемдік көшбасшылар туралы мәліметтер келтірілген.

Су абразивті өңдеу кезінде технологиялық параметрлер процеске үлкен әсер етеді: ағынның жылдамдығы, абразивті дән, ағынның көлбеу бұрышы, саптамадан өңделетін бетке дейінгі қашықтық.

Осылайша, су абразивті өңдеуді қолдану минималды жылу шығаруды және материалдарды дәл кесуді қамтамасыз етеді, жабдық кесу сапасына әсер етпестен 30000 мм/ мин кесу жылдамдығына қол жеткізе отырып, материалды плазмалық өңдеумен салыстырғанда толығымен әмбебап және үнемді, сонымен қатар бетті қыздырудың болмауы, ұшқынның пайда болу ықтималдығы су абразивті машиналарды қолдануды мүмкіндігінше ыңғайлы және қауіпсіз етеді.

Кілтті сөздер: гидрорезка, гидроабразивті өңдеу, абразив, дәстүрлі емес өңдеу әдістері, кескіш ағын, су ағысымен кесу.

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К ВОПРОСУ ПРИМЕНЕНИЯ ГИДРОАБРАЗИВНОЙ ОБРАБОТКИ В СОВРЕМЕННОМ МАШИНОСТРОЕНИИ

В статье рассмотрены вопросы применения гиброабразивой обработки (резки) в машиностроении. Приведены данные об областях применения, преимущества, недостатки и технологические возможности, а также мировые лидеры по производству установок для гидроабразивной резки с технологической характеристикой.

При гидроабразивной обработке наибольшее влияние на процесс оказывают технологические параметры: скорость струи, зернистость абразива, угол наклона струи, расстояние от сопла до обрабатываемой поверхности.

Таким образом, применение гидроабразивной обработки обеспечивает минимальное тепловыделение и точный рез материалов, оборудование является полностью универсальным и экономичным по сравнению с плазменной обработкой материала достигая скорости разрезания 30000 мм/ мин не влияя на качество реза, а также отсутствие нагревания поверхности, вероятности возникновения искры делают применение водно-абразивных станков максимально удобным и безопасным.

Ключевые слова: гидрорезка, гидроабразивная обработка, абразив, нетрадиционные методы обработки, режущая струя, водоструйная резка.

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