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# Processing of flat glass

**Abstract.** The article discusses the issues of sheet glass processing and provides information about the application, advantages, disadvantages and technological capabilities.
The technological parameters of waterjet processing that affect to the cutting quality: the jet speed, the grain size of the abrasive, the angle of jet inclination, the distance from the nozzle to the treated surface.
The water cutting method or waterjet cutting can significantly increase the speed and quality of material cutting. From an economic point of view, the consumption of material and energy is significantly reduced (by 20-30%), due to the use of water energy as the cutting tool in this method. The consumable material is only water and abrasive material.
By modeling, when using software, it is proved that during waterjet cutting, lower stresses are formed in the glass compared to mechanical roller cutting, thereby ensuring minimal heat generation and accurate cutting with an edge roughness of Ra 1.6 microns.
**Keywords:** waterjet processing, sheet glass, abrasive, jet, CAE.

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## Introduction

The uniqueness of the waterjet cutting technology lies in the fact that it can be used to cut almost any kind of materials and is an alternative not only to mechanical, but also laser, plasma, and ultrasonic cutting, and in some cases is the only possible one.

In modern mechanical engineering, very often high requirements are imposed on the quality of metal cutting, which makes it impossible to use traditional equipment: guillotines or plasma cutting and other methods [1-5]. Cutting metal with water has been used since the 60s of the XIX century by the US aircraft company and is optimal for cutting metal, etc. high-strength materials [6, 7].

There is considerable experience in processing a complex profile by mechanical methods, ultrasound energies, plasma, laser, water jet, etc. [2, 4, 8]. They predict a high average annual growth rate of the world market of hydraulic cutting equipment [9].

When packet cutting sheets in mass production, waterjet processing is used. The expediency of using packet cutting is determined by the following advantages: the ability to cut thin-sheet parts along any contour without melting edges and warping sheets; reduction of abrasive consumption compared to cutting single sheets; high productivity; identity and accuracy of the detail shapes which cut from a one packet [10].

Despite the high productivity, the method of waterjet processing has not been sufficiently studied, which is pretty much holding back its use. The works [11-14] are aimed at studying this method and one or more technological parameters are being investigated: the speed of the jet, the size of the abrasive grain, the angle of inclination of the jet, the distance from the nozzle to the treated surface.

The most common modern technology for cutting float glass is cutting with cutting rollers (Figure 1). The glass cutting rollers have a wedge-shaped obtuse-angled section and are made of hard alloys. The sharpening angle of the used roller depends on the thickness of the glass. In this case, the cutting takes place in two stages: first an incision is made, i.e. a scratch is formed with a chain of cracks appearing under it, and then a bending force is applied across the cutting line. Such glass cutting is the creation of microcracks in the glass under the action of a cutting roller, along which the glass then splits.

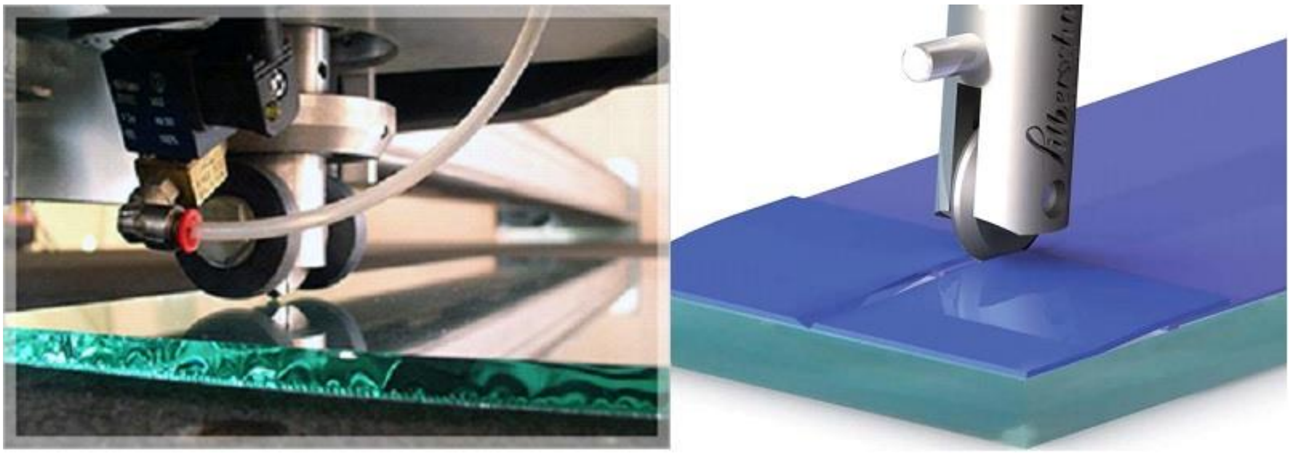


**Figure 1. Automatic cutting of glass with a cutting roller**

Various factors, such as the type of cutting tool, its position, type of glass, applied pressure, speed, glass surface quality, temperature affect the cutting quality. To perform a sufficiently good cut, the roller speed (up to 160 m/min) and its pressure on the glass must be sufficiently large and constant. These factors are interrelated: as the speed increases, the pressure should be reduced and vice versa. But the main criterion for cutting is not so much the number of fragments when applying scratches and various surface defects, as the stresses created by these defects in the glass. The deepest crack, which occurs under the action of the tensile stress created by the pressure of the cutting tool, is crucial.

## Research methods

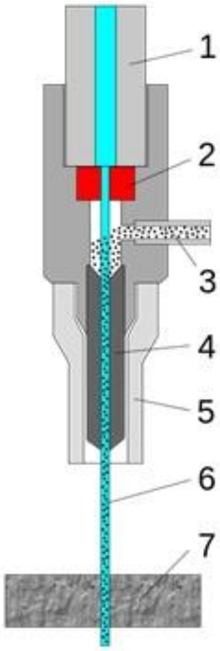
In modern mechanical engineering, finishing operations have the main influence on the quality and performance of details [13-17]. The task of improving the quality of products is associated with the improvement of well-known and the development of new, effective finishing methods, among which the leading place is occupied by methods of abrasive processing. Abrasive processing allows to ensure the required accuracy and quality of details with high productivity, as well as high reliability and durability of machines during operation, therefore the role of abrasive operations in modern mechanical engineering is continuously increasing.

Waterjet processing is one of the varieties of processing details by free abrasives, allows to process shaped details that are difficult to process on machines.

The process is insufficiently studied and the result of which is influenced by many technological parameters: cutting jet pressure, nozzle feed, grain size, hardness, abrasive consumption, distance from the nozzle to the waterjet processing surface, physical and mechanical characteristics of the processed material.

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 along the depth of section, as well as deterioration in quality with increasing nozzle feed [13-18].

Figure 2 shows a diagram of the installation of waterjet glass cutting. Water compressed by the first main system component, the multiplier pump, to a pressure of more than 4000 atm, passes through a water nozzle forming a jet with a diameter of about 0.5 mm, which enters the mixing chamber. In the mixing chamber, the water jet "pull in" the abrasive (for example, garnet sand with particles about 0.4 mm in size) and then passes through a second, carbide nozzle with an inner diameter of 1 mm. From this nozzle, a jet of water with an abrasive exit is poured at the speed of about 3M (about 1200 m /s) and is directed to the surface of the cutting material. Upon 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.




1 – high pressure water supply, 2 – nozzle, 3 – abrasive feed, 4 – mixer, 5 – casing, 6 – cutting jet, 7 – cut material.

**Figure 2. Scheme of waterjet processing**

In the process of waterjet cutting the following is consumed: electricity; air; abrasive; water. The consumption of abrasive is about 300-350 g/min. As an abrasive material, it is recommended to use only a natural abrasive - garnet, which has good strength indicators. The grain size of the abrasive material should be from 200 to 600 microns.

The service life of the nozzle is about 50 hours, and the tube is 100 hours. The cutting width can be easily compensated by CNC. Thus, it will not affect the accuracy and quality of cutting [17].

The main difference that waterjet metal cutting has from other methods of cutting sheet metal is that there is no mechanical impact on the material. 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: marble, granite, stone and other rocks; glass, ceramics; steels and metals, including: titanium, stainless steel; reinforced concrete; plastic, textolite, ebonite and paronite plates, rubber [7].

Cutting is carried out by a supersonic jet of water, which is obtained by concentrating the flow of water through a calibrated hole. As a result, the waterjet cutting speed is almost three times the speed of sound (810 m/s). Cutting can be with or without abrasive material, depending on the type of material being processed on a Primus 202 machine with one or two 3- or 5-axis heads to ensure maximum productivity and continuous cutting without compromising flexibility.

Due to the fact that the table is divided into two cutting zones, there is the possibility of working in a pendulum mode: unloading/loading workpieces in one part of the table while the machine is working in another part [13, 18].

Figure 3 shows samples of products made on a waterjet glass cutting machine.

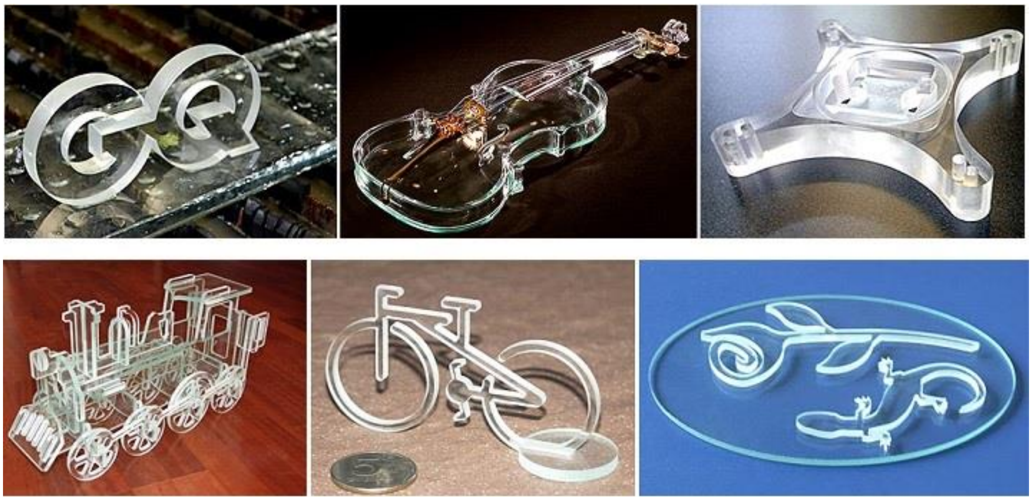


**Figure 3. Product samples**

## Results and discussion

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

1. A unique method of processing material using a narrowly directed water jet 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 chipped and heating surface which present during the usual cutting of objects.

Thanks to modern technologies and the improvement of machines, 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 slope of the cut does not affect the cutting quality. The precision of metal cutting at an angle allows the use of the resulting blanks without further processing [18].

We will perform modeling and comparison of two methods of processing transparent glass with a thickness of 10 mm and a size of 1 × 1 m: mechanical cutting with a cutting roller and waterjet processing.

Figure 4 shows a 3D model of mechanical glass cutting with a cutting roller.

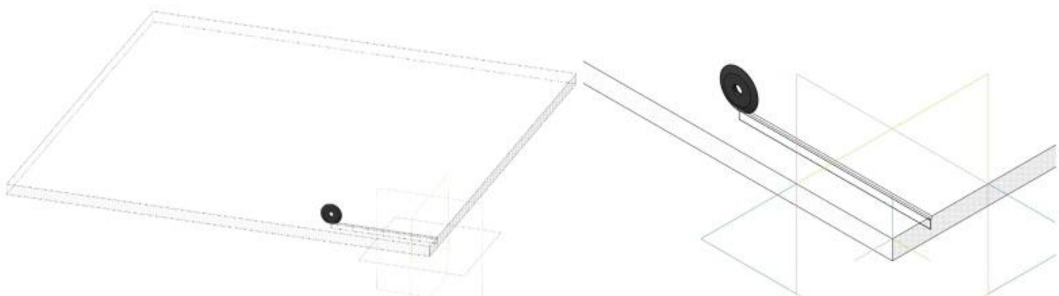


**Figure 4. 3D model of mechanical glass cutting with a cutting roller**

Using the resulting 3D model, we create a finite element grid and perform a static calculation, the results (equivalent Mises stress, total linear displacement, yield strength factor, strength margin factor) which are shown in Figure 5.

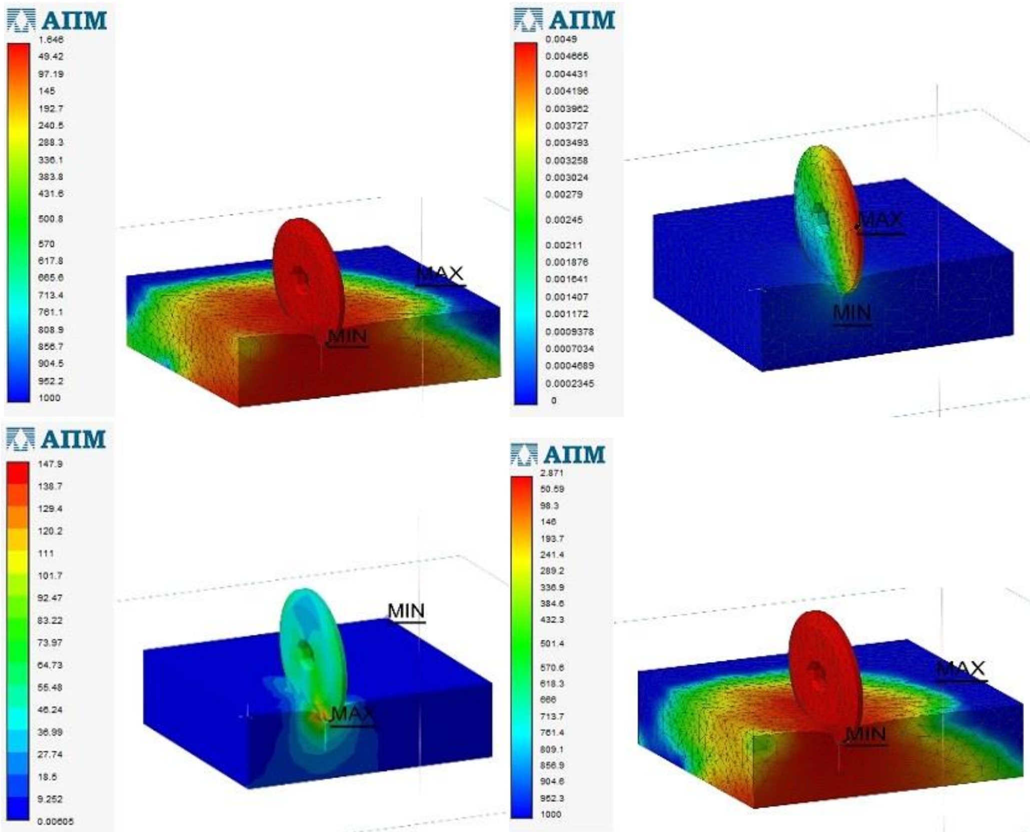



**Figure 5. Results of statistical calculation of mechanical glass cutting with a cutting roller**

Similarly, we will perform a statistical calculation of waterjet processing, the results (equivalent stress by Mises, total linear displacement, yield strength factor, strength margin factor) are presented in Figures 6, 7.

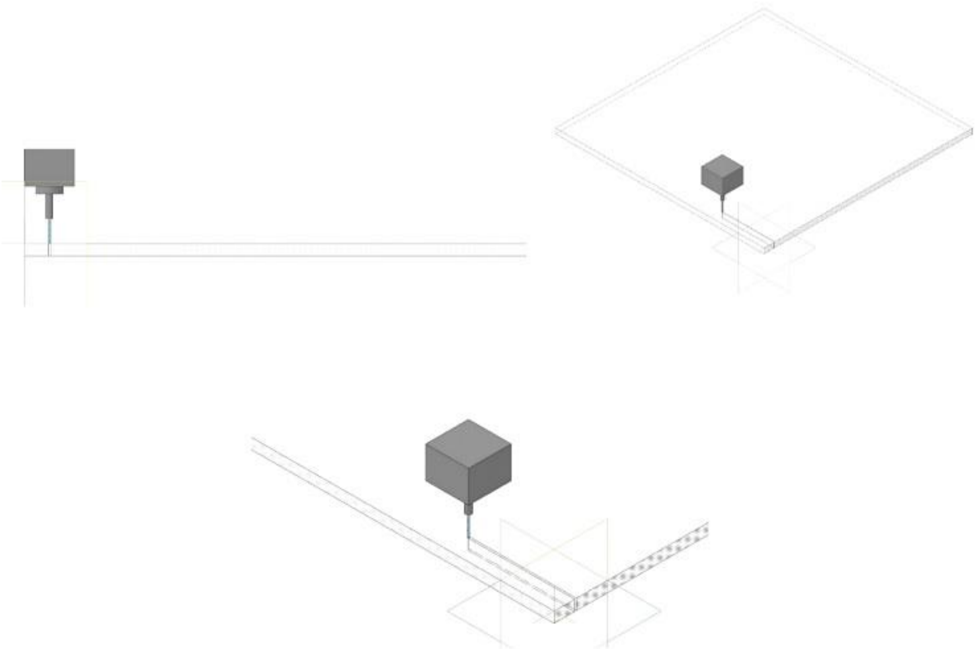


**Figure 6. 3D model of waterjet glass processing**

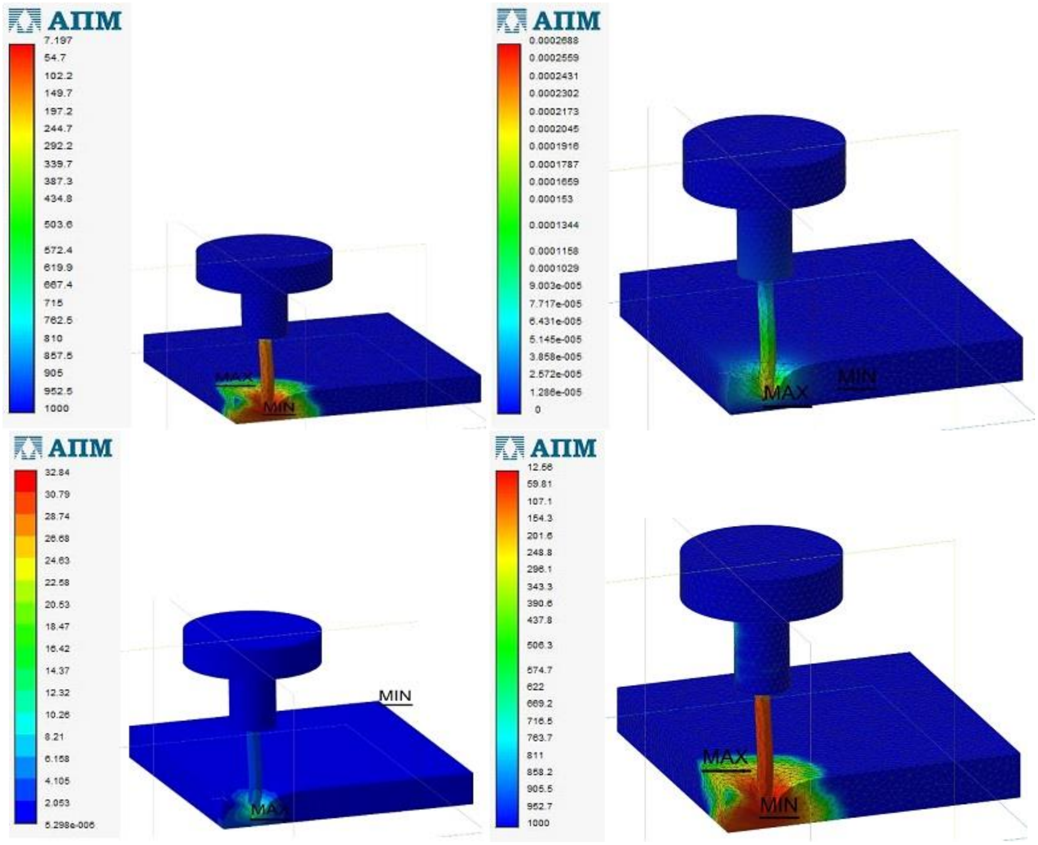



**Figure 7. Results of statistical calculation of waterjet glass processing**

Analysis of the results of computer modeling has shown that with waterjet cutting, less stresses are formed in the glass, i.e. a higher-quality cut and a more efficient and less marriage-forming method of cutting glass.

## Conclusion

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 consumption of material and energy is significantly reduced (by 20-30%), due to the use of water energy as a cutting tool with this method. The consumable material is only water and abrasive material.

Practice shows that this method is economical, eco-friendly, has a number of advantages: minimal heat generation ensures accurate cutting of materials; cutting speed can reach 30,000 mm/ min; accuracy and full compliance of finished products; the possibility of cutting out parts of complex shape; ordinary water can be used as a working fluid or with a small proportion of abrasive particles; no thermal effect on the material (temperature in the cutting zone 60-90 ° C); a wide range of cut materials and thicknesses (up to 200-300 mm or more); no melting and burning of the material on the edges of the machined parts and in the adjacent area; environmental cleanliness and complete absence of harmful gases; high cutting quality (edge roughness Ra 1.6 microns).

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**Табақ шыныны өңдеу**

**Аңдатпа.** Мақалада табақ шыныны өңдеу мәселелері қарастырылған және қолдану, артықшылықтар, кемшіліктер және технологиялық мүмкіндіктер туралы ақпарат берілген.

Кесу сапасына әсер ететін су абразивті өңдеудің технологиялық параметрлері: ағынның жылдамдығы, абразивтің түйіршіктілігі, ағынның көлбеу бұрышы, соплодан өңделетін бетке дейінгі қашықтық.

Сумен кесу немесе су абразивті кесу әдісі материалды кесу жылдамдығы мен сапасын едәуір арттырады. Экономикалық тұрғыдан алғанда, кесу құралы ретінде су энергиясын осы әдіспен пайдалану арқылы материал мен энергияны тұтыну айтарлықтай төмендейді (20-30% - ға). Шығын материалы тек су мен абразивті материал болып табылады.

Модельдеу арқылы бағдарламалық жасақтаманы қолдану кезінде су абразивті кесу кезінде шыныда механикалық роликпен кесумен салыстырғанда аз кернеулер пайда болатындығы дәлелденді, осылайша минималды жылу шығаруы және жиегінің Ra 1,6 мкм кедір-бұдырымен дәл кесуді қамтамасыз етеді.

**Түйін сөздер:** су абразивті өңдеу, табақ шыны, абразив, ағын, CAE

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**Обработка листового стекла**

**Аннотация.** В статье рассмотрены вопросы обработки листового стекла и приведена информация о применении, преимуществах, недостатках и технологических возможностях.

Технологические параметры гидроабразивной обработки оказывающие влияние на качество реза: скорость струи, зернистость абразива, угол наклона струи, расстояние от сопла до обрабатываемой поверхности.

Метод резки водой или гидроабразивная резка позволяют существенно увеличить скорость и качество реза материала. С экономической точки зрения, расход материала и энергии значительно понижается (на 20-30%), за счет использования при таком методе энергии воды в качестве режущего инструмента. Расходным материалом является только вода и абразивный материал.

Моделированием, при применении программного обеспечения доказано, что при гидроабразивной резке, в стекле образуется меньшие напряжения по сравнению с механической резкой роликом, обеспечивая тем самым минимальное тепловыделение и точный рез с шероховатостью кромки Ra 1,6 мкм.

**Ключевые слова:** гидроабразивная обработка, листовое стекло, абразив, струя, CAE.

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