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# WATER JET TECHNOLOGY USED IN MEDICINE

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Subject review

Abrasive water jet technology has been recently used mainly in industrial areas. This technology provides several advantages in comparison with conventional methods. At present, it is used in medicine. This paper discusses the possibility of using water jet technology in medicine. The paper describes the benefits and usage in orthopedic surgery, plastic surgery, neurosurgery, dermatology, urology, and in dental surgery.

***Keywords:*** *abrasive water jet, medicine*

## Tehnologija vodenog mlaza koja se koristi u medicini

Pregledni članak

Tehnologija abrazivnog vodenog mlaza od nedavno se koristi uglavnom u industrijskim područjima. Ova tehnologija pruža nekoliko prednosti u usporedbi s konvencionalnim metodama. Trenutačno, to je uporaba u medicini. U radu se razmatra mogućnost korištenja tehnologije mlaza vode u medicini. U radu su opisane prednosti i uporaba u ortopedskoj kirurgiji, plastičnoj kirurgiji, neurokirurgiji, dermatologiji, urologiji te u oralnoj kirurgiji.

***Ključne riječi:*** *abrazivni vodeni mlaz, medicina*

## 1
## Introduction
Uvod

Rapidly expanding industry, along with its increasing requirements for production quality, demands continual implementation of technologies that meet demanding criteria given by market environment and its requirements [12, 13, 14, 15]. Today, the production technologists encounter the need to adapt the existing technologies for the specific properties of new materials or for developing new ones. The water jet is one of the few instruments able to cope with the technologists' requirements and to adapt to the trend of development of engineering materials with specific properties. Water jet cutting is currently characterized as an alternative method of cutting sheet materials. The principle of hydroabrasive cutting consists in blooming hydroabrasive stream where only water, divided by the material leading to it, is disintegrated. The impact of mixture on divided material causes its cut. Permeate, which is the carrier of kinetic energy abrasive, drains the removal products from the kerf and provides cooling kerf. That is precisely the space cooling section that gives an advantage to the technology division over conventional materials technology division which involves adding of unwanted heat to shared materials with subsequent change in the structure, deformation, and change in visual appearance. The abrasive water jet technology is currently used for cutting a wide range of materials. The main advantages of this technology include the lack of thermal effect on machined material. Water jet is applied to all kinds of industries. However, possibilities of its further usage have not been exhausted yet. Medicine is a field where this technology is used very little.

## 2
## State of the art
Prikaz stanja

Water jet cutting device consists of a pump which serves for creating a working fluid pressure of cutting fluid (in medicine it is a sterile saline – 0,9 % aqueous solution of sodium chloride-NaCl), the cutting head forming a fluid flow and a mixing chamber in which the abrasive is added into the fluid. Fig. 1 shows the technological scheme of AWJ (Abrasive Water Jet) place of work. The cutting high pressure water has been used in industry for a long time. Lately, this technology has also found its application in medical field such as: trombektomy, artoscopic backbone operations, as well as in plastic surgery for removal of tattoos or liposuction for endoscopy and surgical ophthalmology. Papachristou and Barters [8] were the first who described the usage of water stream in medicine. Four patients had a liver resection through physiologically saline. They came to the conclusion that the usage of the water jet led to the reduction of blood loss during the surgery.

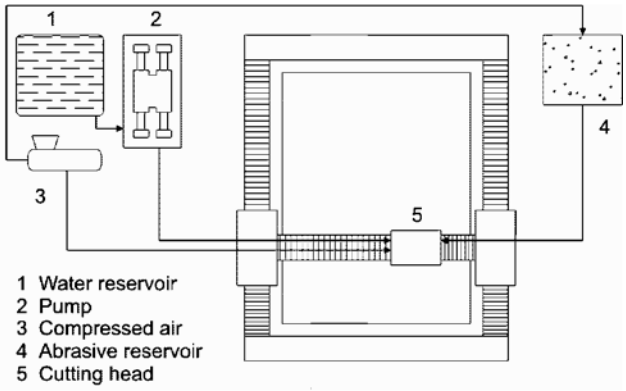


***Figure1*** *Scheme of AWJ technology group*
***Slika 1.*** *Shema tehnološke grupe abrazivnog mlaza vode*

## 3
## Water jet used in clinical conditions
Vodeni mlaz koji se koristi u kliničkim uvjetima

The first medical use was in 1980, when this kind of technology was used for cutting bodies and endoprothesis

[5]. Since there is no heat which affects the cut material during the abrasive water jet cutting, this technology is suitable for applications where the structural change of material is not permitted. The critical temperature is much lower for medical applications than for industrial usage. Biscup [1] dealt with this issue at using the abrasive water jet cutting bone. Bones are very sensitive to heat. Damage of tissue depends on temperature and time of exposure. The damage is irreversible even after 10 seconds at 57 °C when there is necrosis and poor healing of a bone. Pude [6] dealt in his work with the appropriate abrasive at knee endoprosthese surgery. As abrasive, the soluble substances are used during this surgery which ensures better removal of abrasives from the operated area. Sugar proved to be a suitable material. Pude et al. (2003) [6] dealt with the investigation of these substances: sucrose, xyilitol, lactose, sorbitol. Sorbitol reached the highest value regarding the depth of cut achieved. Fig. 2 shows comparison of the results. In addition, dividing bone liquid stream is dealt with by Schwieger et al. [18].

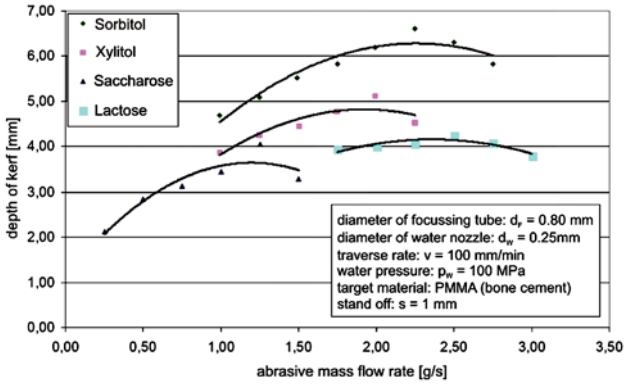


***Figure 2*** *Dependence of depth of cut and type of abrasives* [6]
***Slika 2.*** *Ovisnost dubine reza i vrste abraziva* [6]

Fig. 3 shows an operating device for a knee joint replacement surgery with the assistance of hydroabrasive jet. Fig. 4 shows a bone cut by the water jet.


***Figure 3*** *Operating device (A); detailed cassette with abrasive (B)* [6]
***Slika 3.*** *Operacijski uređaj (A); detalj kasete s abrazivom (B)* [6]

Dental surgery is another medical area [2, 4] where the cutting and grinding of dental materials is used with AWJ. In addition to water jet, the so called air grinding with the water jet assistance is used. Fig. 6 shows the head of device used in

***Figure 4*** *Division of a bone by the water jet* [6]
***Slika 4.*** *Rezanje kosti vodenim mlazom* [6]

dental surgery. Using this technology brings the following benefits:

- no generation of heat, sound or pressure,
- reduces the need for anesthesia,
- gives much more healthy dental tissues,
- leaves a relatively dry work area, which is an advantage for the subsequent hole filling,
- reduces the risk of micro-cleavage and jagged teeth.

Ciancio [17] deals with the use of AWJ in dental surgery.


***Figure 5*** *Liver resection through the water jet*
***Slika 5.*** *Resekcija jetre vodenim mlazom*

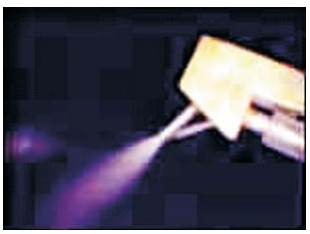

***Figure 6*** *Air grinding with the water jet* [2]
***Slika 6.*** *Glava uređaja za brušenje vodenim mlazom* [2]

The water jet is applied also at cleaning of traumatic wounds. The healing process of these wounds has been codified with the abbreviation "TINE". Tissue necrosis (T) indicates dead tissue. The entire dead and damaged tissue, including the lack of blood supply, must be removed. Mark (I) denotes infection. Bacterial burden must not be greater than 100 000 bacteria/g. Moisture balance (M) indicates the balance of moisture for the best healing of wounds. Edge (E) indicates the wound edge, which must be protected. Using of the water jet as a scalpel resulted in more healthy tissue than using the conventional methods. This technology (versajet) also allows good cleaning of wounds from foreign elements (earth, sand, silicone gel from the implants), which would otherwise be incorporated into the healing of the skin and it would create a traumatic tattoo. It is a useful tool for degreasing of skin grafts. Another field where the water jet can be used is liposuction. Water Jet Liposuction (WJL) is

non-edema method which maximizes the benefits of the old methods. WAL (Waterjet Assisted Liposuction) uses a thin fan-shaped stream by which it releases fat cells while saving blood vessels and nerves. Fat cells are removed and drifted out by saline. Benefits of WAL are as follows:

- results can be achieved with greater accuracy, without edema and contour changes,
- better mobility of patients, optimized access to the treated area,
- greater comfort of the patient and postoperative wound infiltration is less than 24 hours,
- number of medications for patients is reduced and the residual volumes are kept at minimal level.

Further, the hydroabrasive jet is used in dermatology for dead skin removing. Water flow is dosed with various drugs, such as anesthetics, for the elimination or reduction of pain, antiseptics to disinfect violation of the skin integrity, or medications coagulation preparations for better coagulation of blood.

Microwave Waterjet scalpel is another application of the water flow in medicine. It is used for minimally invasive removal or resection of tumors. It is a combination of a microwave scalpel and a jet system. It allows control of a flow directly into the saline, directly into the workspace. Then it reduces the risk caused by heat from the microwave radiation. The direct usage of the water jet scalpel in surgery has brought several advantages compared to other methods. It uses sensitive pressure of sterile saline in order to resect tissue. The applicator consists of a nozzle jet with a diameter of 120 micrometers. The sensitivity of saline jet may vary in dependence on the type of shared tissue (nerve tissue, ligaments, blood vessels, etc.). Fig. 7 depicts applicators of ERBEJET 2 used in surgery.

***Figure 7*** *Applicators of system ERBEJET 2*
***Slika 7.*** *Aplikatori sustava ERBEJET 2*

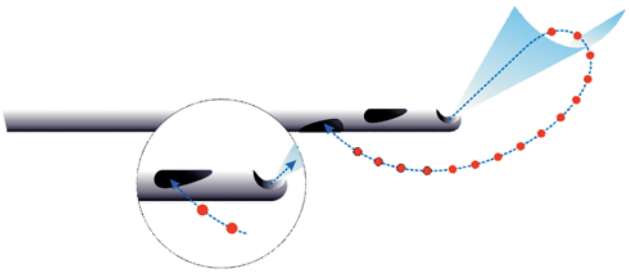

***Figure 8*** *Body-Jet Water-Jet Assisted Liposuction applicator*
***Slika 8.*** *Aplikatori sustava ERBEJET 2*

This system is used in surgery, for example at liver resection [7], blood vessels and biliary channels. During the cut, these are cleaned of neighboring tissues and they can be treated individually. The necessary time for this kind of operation by this method is significantly reduced and also blood loss is limited. A continuous flow of saline provides a clear operating field for the surgeon. Rau et al. [10] describes the comparison of results of liver surgery with 61 patients. 31 patients were operated through the water jet and 30 patients were operated through the CUSA. The resection time was shorter with the water jet (28 ± 11 min) in comparison with CUSA (46 ± 19 min). Duration of ischemy was also markedly reduced [10]. Liver resection is shown in Fig. 5. The operation can be performed in a laparoscopic way or by an open method. While using the water jet technology at the cholecystectomy, there was a gallbladder perforation in the amount of 15 % of cases, whereas while using the traditional methods, it was 30 %. There was less damage of neighboring tissue at the open operations of patients who were diagnosed with kidney tumor or with kidney stones in vacuolization from 100 to 300 micrometers comparing to thermal methods (laser, electric cautery). The operation by the water jet lasted from 14 up to 35 minutes and an average blood loss was 60 ml [9]. In urology, the water jet resection reduces the risk of sexual dysfunction [16]. Neural connections and blood vessels remain almost untouched during prostatectomy. In neurosurgery, this tool does not leave any necrosis along the edges of the cut. It is applied to elimination of metastases and glioma. Tumor resection is performed selectively, without traumatizing of the healthy brain parenchyma, while saving the brain structure. Oertel et al. [11] describes the experience with brain metastases resection with the water jet. Water flow is a particularly useful tool while separating the soft poorly demarcated brain metastases from the surrounding brain parenchyma. The removal of these metastases is very difficult by conventional methods [11]. The following Table 1 shows an overview of using water jet in medicine.

***Table 1*** *Overview of using water jet in medicine*
***Tablica 1.*** *Pregled uporabe vodenog mlaza u medicini*

| Area | Use | Benefits |
|---|---|---|
| **Orthopedics** | Cutting endoprosthese and bone | Below the critical temperature by cutting |
| **Dental surgery** | Cutting and grinding of dental materials | Reduces the risk of jagged teeth and reduces the need for anesthesia |
| **Surgery** | Resection of soft tissues: liver, gall bladder, brain, kidney, prostate, cleaning wounds | Blood vessels and nerve fibers remain in the defined pressure maintained, minimal bleeding, intact edges and precise cuts, lack of necrotic edge, reduce the duration of myocardial ischemia |
| **Plastic Surgery** | Cleaning skin graft, removal of tattoos, liposuction | Separation of the layers of tissue, higher accuracy of results without edema and contour changes |
| **Dermatology** | Removing dead skin | Possibility of direct dose medications in a water jet |

## 4 Conclusion
## Zaključak

The operating parameters for surgical applications are very different from industrial applications. Sterility of working fluid is the most important requirement in medicine. This problem is managed by using a special bag with a sterile cutting fluid. In medicine, water jet has several

benefits compared to the traditional methods. It reaches only a low temperature during cutting and therefore it does not damage surrounding tissue. Depth of cut can be controlled by fluid pressure; it enables high-precision cutting, provides a constant cutting force in changing the distance, leaves a clean cut as it immediately flushes out the tissue separated from the cut, reduces bleeding at surgery, shortens the duration of ischemy, shortens the time of hospitalization; operations can be made even in laparoscopic way.

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## 5
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