Waterjet cutting

How does the power of water prevail?

The destructive power of water in the context of erosion has been known for millions of years. We know many examples of the impact of this force even in our immediate environment. The canyons, river valleys that delight in their sight today are, in fact, the products of the immense power of water.

The exploitation of the aforementioned properties of the jet of water goes back several decades. In the 1930s, American and Soviet engineers took first steps in the direction of using high-pressure water jets for mining stone and brown coal. Since then, the technology has been constantly evolving. This process was significantly boosted by the involvement of the American aviation industry through which it was made possible to incorporate materials that had never been used before. In addition to previous cutting procedures, waterjet cutting allowed for the machining of new types of technical materials, which was not previously possible.

In the late 1960s, American aircraft factories used this technology to cut fibre-reinforced, cellular, and sandwich materials. These substances, often subjected to significant mechanical interventions, are particularly sensitive to high-temperatures. Traditional flame cutting, sawing, shear procedures can significantly damage the structure of these materials.

What are the benefits of waterjet cutting over other procedures?

The greatest advantage of waterjet cutting over other technologies is that it is a cold cutting process, suitable for cutting virtually all materials.
Other procedures fall short in certain areas.
Heat intake procedures for example can involve combustion and melting along the cutting surface.
During laser and plasma cutting, tensions can form in the material, leading to hairline cracks, damage to the material connection in alloys as well as the creation of toxic gasses that need to be neutralised.
In contrast, when cutting with waterjet, there is no gas, no surface strain, no conicity and no deformation caused by heat. It is the only procedure that works for hard plastics and plastic-coated metals as it does not damage the surface. It is also a number one choice when cutting thicker and tougher metals such as titanium, acid-resistant steel, copper and aluminium, as tool wear during other procedures represents a significant cost.

What can you expect of cutting procedures?

Demand for industrial cutting has increased dramatically in recent years. Better productivity and higher cutting speeds are the focal point of today’s development as well as accuracy when dealing with complex forms and an increasingly good surface quality.

What solutions does waterjet cutting provide?

- high precision parts
- cut edges are not damaged
- a high-quality surface that does not require further machining
- the normal homogeneous cutting surface is easier for any further machining
- cutting any complex shape
- the small size changes and the unique patterns can be handled flexibly
- the machine can start cutting anywhere
- improved material utilization thanks to minimal cutting gap

How is the waterjet cutting equipment built?

The equipment is basically made up of two units: the booster equipment and the cutting machine with the control designed to meet the needs. The high-pressure pump produces a water pressure of around 360 MPa, water stream comes out on a special sapphire stone, converting the pressure energy into kinetic energy, with the approximate speed of 800-900 m/s. The resulting energy is sufficient for the jet of water to cut different materials in a highly precise, economical and speedy manner. The performance requirements of the equipment are determined by the pressure produced and the amount of water required. To produce a pressure of 360 MPa, a water volume of 3,5 l/min, and a 30 KW equipment is required.

Water is received from a network water system. The system requires water preparation to prevent calcification. A conventional equipment produces the pressure value already mentioned in two stages:

1. First, an axial piston pump with hydraulic oil produces a pressure of 27 MPa,
2. The oil is placed in a piston pressure booster through the valves, using control, where the 13x difference in the pressure surfaces of pistons gives the final pressure of the water entering the system

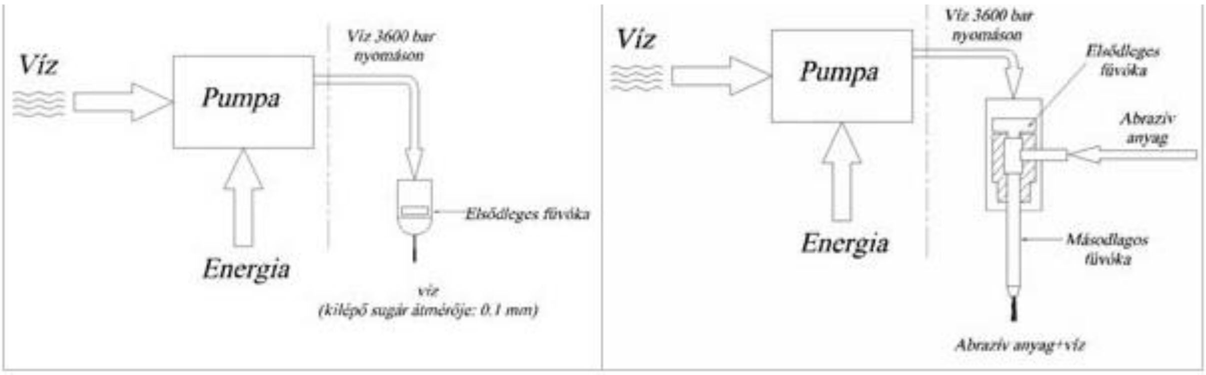
It is also clear from the description of the conventional pump that the isolation of the oil and water circuit from each other is a constant source of error, therefore the efficiency is low. These reasons prompted developers to build a better-performing system. This is where the idea of a direct-drive pump, which circumvents the oil circuit, was born.

These pumps operate directly using an electric motor and produce the water pressure required for cutting in one step. Eliminating the oil circuit reduced the number of production errors as well as production costs.

In fact, the cutting machine must be controlled at the same time between two, three or even 5-6 axles, depending on whether you want to achieve 2D or 3D machining. The possibilities of 3D application are significantly reduced by the objective fact that the absorption of the remaining energy of the outlet beam must be solved. Thinking about 2D, this is not a problem, as energy is absorbed by a tub filled with water.

How can water cut?

From a technological point of view, the materials to be cut are divided into two groups: one of which is cut with clean water, and another that uses abrasive material (granite sand) mixed into the water stream. The difference between the two technologies is clearly visible in the two schematics below



Clean water cutting

The high pressure (3600 bar) can cut, including rubber, 3-4 mm foamed PVC, styrofoam, linoleum, foam materials. The cutting gap is 0.1-0.2 mm.

Abrasive cutting

The energy of the water, along with the abrasive effect of the sand leads to the to the material being cut. In this case, the cutting gap is between 0.8 and 1 mm

What factors affect the cutting surface?

There are two factors that largely determine the use of technology and its area of applicability. One is the formation of conicality along the thickness and the other is undercuts from radiation deflection.

- **conicity problem:** the diameter of the radius leaving the nozzle is 0,8 mm, which determines the width of the cutting gap on the material to be cut. However, as we move lower in the material thickness, the beam loses its strength, so the water on the back can only cut a gap of 0.4-0.5 mm. By reducing the speed, you can minimize the conicalness that you can see in the attached photo. However, the visible quality can be achieved by a third of the normal cutting speed. At this point, traces of the beam cannot be seen on the surface.
- **undercuts:** the direction of cut at the corners during the cut suddenly changes, which causes the jet of water to bend and possibly intersect the material in an unwanted manner on the exit side. This may be a problem with size accuracy, but for our new-build machine, these adverse effects can now be eliminated by controlling the minimum decision of the head.

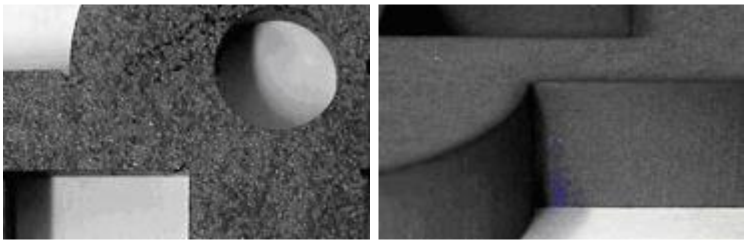
What solutions are possible?

1. To change parameters:

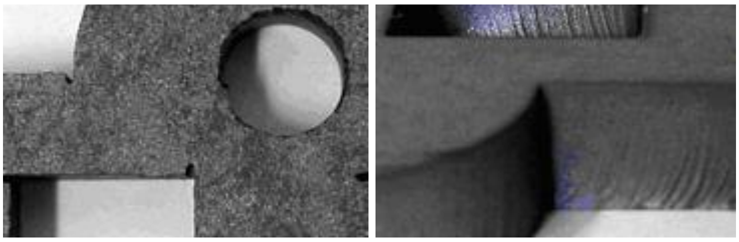
Since the theory of cutting is based on the abrasive effect of the granules, it is necessary to choose a speed that the granite particles in the beam meet the surface of the material to be cut at an ideal angle to produce the "excess" material with as much efficiency as possible. However, the better this efficiency, the more grooved, rougher the cut surface. The appropriate parameters to be set during the cutting should be determined in the knowledge of these edge conditions. Of course, this should be examined for the further processing of the parts.

By changing the different cutting parameters, you can also track changes in the surface and undercuts through a 10 mm KO33 steel component.

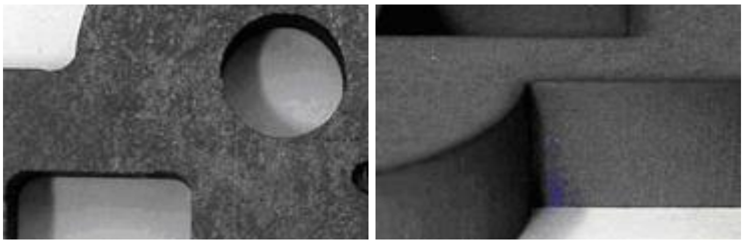
- Quality achieved for cutting out parts requiring minimal post-production and non-functional surfaces:



- In cases where the surface is further worked or where aesthetic aspects are irrelevant



- Avoiding undercuts can be arranged not only by reducing speed, but also by using technological redesign via radius or corner bites, if further use permits.



2 **Machine to compensate for the phenomenon of side skew**

In order to prevent adverse phenomena, the radius of fall must be constantly changed, which can be achieved by installing additional controlled axes. The CAM program moves the head on a specifically modified track so that the side skew of the workpiece is preferably "0", best approaching the theoretical perpendicular.

It is important to note that due to the oblique head position, the distance between the nozzle and the material surface is of great importance. Distance affects the accuracy of the size, so this technique can only be used for properly flat materials.

What factors affect the quality of the production as a whole?

- Type of material
- Water jet diameter
- Water pressure produced
- Cutting process: clean water v. abrasive
- Cutting speed
- Zooming, acceleration factor (corner point approach parameter)
- Quality, quantity, dosage of abrasive material
- Cutting head distance from material

What can and should not be cut with water?

Almost all materials can be machined with this procedure, at least what we have cut so far:

- Heat-resistant, stainless steels and hardenable steels
- In practice up to a thickness of 150 mm (theoretical value), it is no longer recommended to be above 80 mm.
- Aluminium, brass, copper, bronze, armour plate
- Composite materials, with fiberglass and carbon fibre reinforcement
- Sandwich-structure materials (dibond plates)
- Granite 60 mm thick
- Graphite sheet material thickness: 2 mm
- Glass in normal condition
- Industrial rubber sheet
- Foam materials
- Decorative and industrial plastic sheets

Waterjet cutting does not provide a solution:

- Tempered glass
- Cardboard
- Natural wood
- Materials with a higher hardness than granite
- Industrial metal oxide ceramics