Opportunities for waterjet cutting using modern pressure-measurement equipment

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Published on hbm.com: http://www.hbm.com/en/menu/applications/test-measurement/technical-articles/
ID number: 793_en

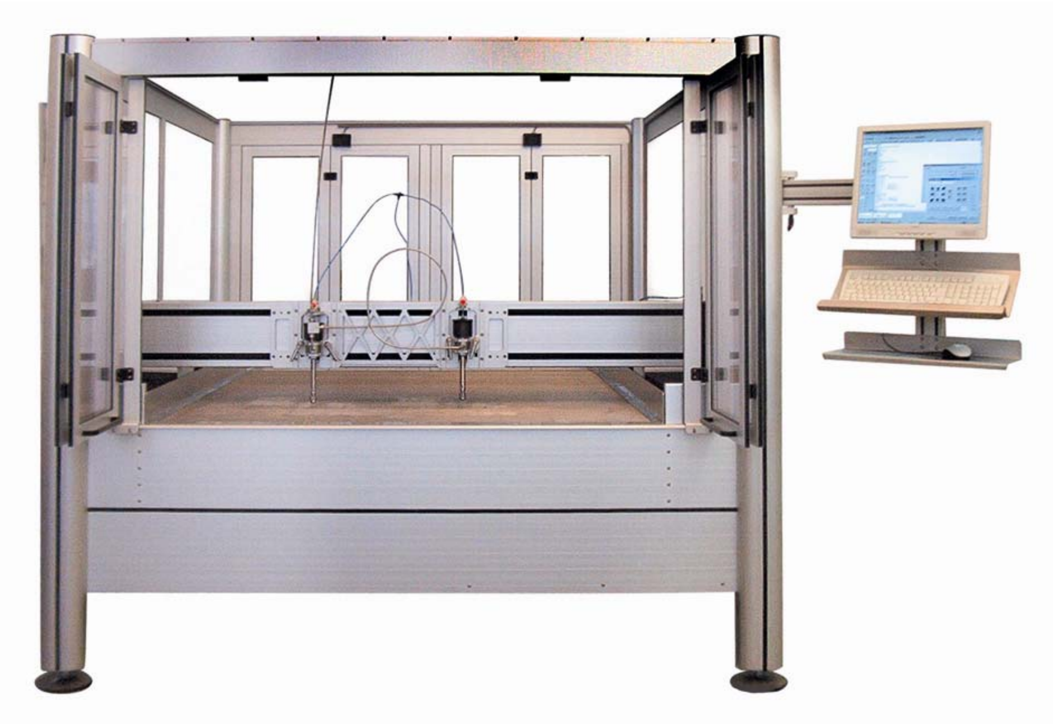

Fig. 1: Waterjet cutting machine

Introduction: Waterjet cutting – a cost-effective and capable alternative to the laser method

Waterjet cutting is an innovative field of measurement technology in manufacturing. The more cost-effective waterjet cutting has numerous advantages compared to the normal laser method. For waterjet cutting, the required, extremely high water pressures of 3000 to 5000 bar have to be precisely regulated and measured. HBM provides the relevant sensors for this purpose. This article shows how the correct application of modern measurement technology can improve waterjet cutting to such an extent that many new fields of application are opened up.

Fig. 2: P2V pressure transmitter for installing in the high-pressure lines of waterjet cutting machines, for example

In the eighties, the addition of solid particles to the stream improved waterjet cutting so much that metals up to 200 mm thick can be machined. With this method, which is called “abrasive waterjet cutting”, far deeper cuts are possible than with laser cutting. For example with a laser, it is only possible to cut stainless steel up to a material thickness of 20 mm, but with a waterjet, up to 100 mm is possible. The high precision achievable with the waterjet method also allows cutting accuracies of approx. +/- 0.1 mm. The cut edges do not require any after-treatment either. There is no pollution burden from toxic gases. The laser method, on the other hand, produces combustion residue. When working with plastics, acrylics, rubber or foams, for example, toxic vapors are produced.

In general, the waterjet cutting method is a sensible alternative to conventional cutting and removal methods, as it can also be used in situations where other technologies, such as laser cutting, do not work (applications under water, involving explosive substances or in full fuel tanks, for example). Waterjet cutting is a cold-cutting method which works with virtually all materials. This also includes composite materials, such as laminates or fiber-reinforced plastics. The workpiece is not subjected to thermal and chemical stresses. Possible warping of the workpiece from the thermal effect of using a laser, for example, does not happen here.

The most important aspect is that the initial outlay for waterjet-based methods is less than it is for the laser method. Waterjet cutting machines are nowadays certainly within everyone’s reach. So this inexpensive technology has maximum potential for the future.

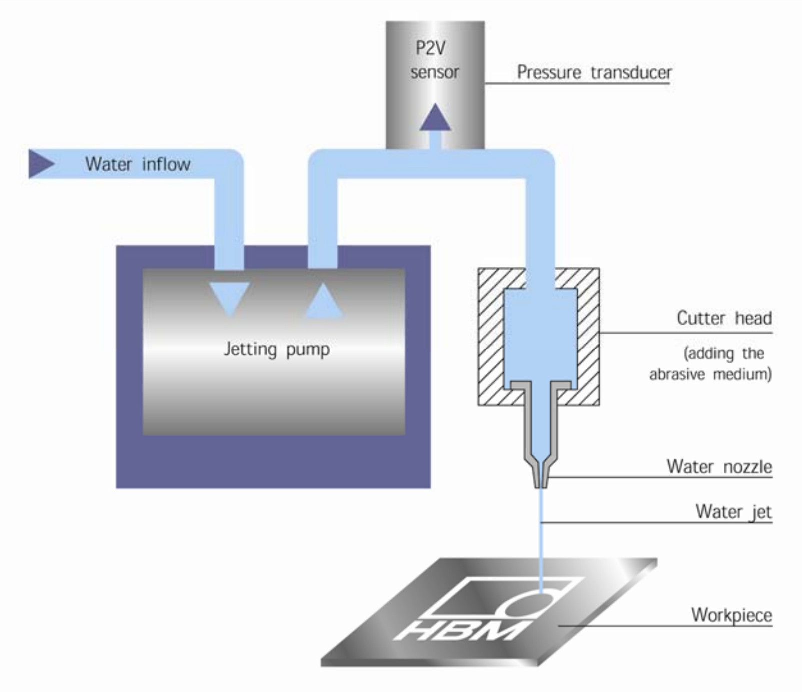

Fig. 3: Schematic diagram of waterjet cutting

Growing demand for precision measurement tools to increase process safety when waterjet cutting

A waterjet cutting system comprises a cutting table and a high-pressure pump, which provides the requisite water pressure of 4000 bar, for example. The high pressure is generated by a pressure intensifier from the low pressure which is in turn generated by an oil hydraulic pump. The hydraulic pump allows the pressure to be adjusted and stabilized. Additional pressure fluctuations are caused by the discontinuous operation of the pressure intensifier. Whereas signs of wear on the high pressure intensifier cause additional pressure penetrations. None of these pressure fluctuations are corrected. The water pressure is an important process parameter for waterjet cutting and is vital for determining quality.

Although experience shows that it is absolutely essential for at least one pressure indicator to be attached to a waterjet cutting machine, price dictates that this is not always the case. If the pressure is measured at all, it is traditionally done by a mechanical pressure gage, although recently, electrical measurement technology has also been used. With the first of these two methods, there is considerable measurement uncertainty. Experiments have already revealed differences between electrical and mechanical pressure measurement technology of greater than 5 percent in the operating range, that is to say between 3000 bar and 4000 bar. The negative effects that this produces are apparent primarily in wear, but also in quality.

Fig. 4: Conventional pressure gage on a high-pressure pump for a waterjet cutting machine

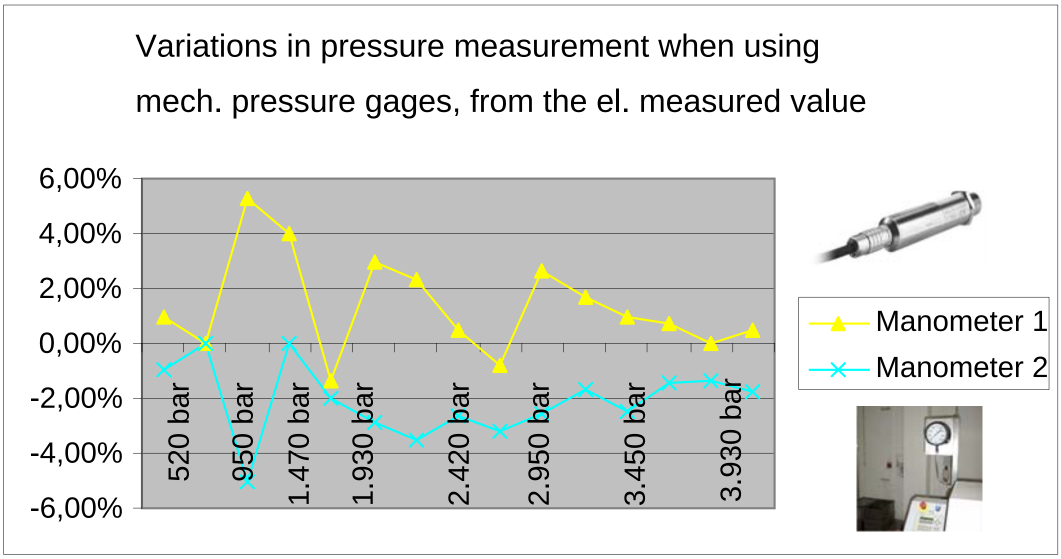

Fig. 5: Comparing mechanical pressure gages with electrical measurement technology

Ideally, up to two pressure measuring points should be provided on a waterjet cutting machine. One of these should be at the high-pressure pump, to monitor the pressure characteristic on the high-pressure generator.

Fig. 6: Use of P3MBP/5000 bar on a high pressure pump

The second measuring point is at the cutting table within view of the operator, as close to the cutting head as possible, so that the effective pressure is actually measured at this point. Traditionally an analog display is preferred for pressure measurement at the cutting table, as this makes the tendencies clear. Although this type of display is not satisfactory for absolute precision. Because of the increased liquid friction at such a high pressure level, there is a considerable drop in pressure along the line. Measurement at the cutting head is essential, especially when there are long supply lines or distribution systems. There are many advantages to electrical measurement at the high-pressure pump.

The big advantage of electrical pressure measurement is that if required, limit values and fluctuations can also be recorded a long way away, such as centrally, in the control room. This is an important contribution to increasing process safety.

Options to improve the process by means of a pressure control loop

One of the problems with the workpiece quality of parts cut by waterjet is so-called “lag”. This is caused by the resistance of the material deflecting the stream. Cutting grooves appear in the opposite direction to the direction of feed. The large dimensional tolerance that results is something to be avoided. Stream lag has a bad effect on dimensional accuracy, especially when there are abrupt changes in direction.
The following options can counteract this effect:

- A lower feed rate
- Waterjet cutting machines with more than three degrees of freedom
- The control loop concept

Currently, the way to counteract this effect is to reduce the feed rate, although this does increase the cost per piece. A second option is to use waterjet cutting machines with more than three degrees of freedom. This can reduce the effect of stream deflection, which would give a better cut surface at the same cutting speed. Although systems of this type are expensive.

A far simpler way to counteract this effect is to increase the pressure momentarily, to minimize lag at the critical contours. This presupposes that with the electrical pressure transducer, the process can be monitored - in practically the same way as for a machine tool with numeric control (such as Simatic). The input value here can be supplied via a 0 - 10 V analog input or also via a 4 - 20 mA current signal. A signal, triggered by the cutting table control, is given to the pump in critical areas of the cutting contour to increase the pressure of the active media to the maximum value.

With the control loop concept, lag is avoided far more cost-effectively by an immediate increase in pressure in critical areas, such as the deflection points of the stream (the sharp angle of a contour). This does not require the speed of the process to be reduced, either. As, with this method, this increase in pressure is only momentary, there is only minimally more wear. It is possible to achieve the required control dynamics with the electrical measurement technology described here. This gives you the opportunity to use the applied pressure to gear the cutting conditions to optimum workpiece quality and help to improve the process.

More accurate pressure measurement reduces waterjet cutting costs

If you want to ensure that the process can be easily reproduced, then the water pressure for waterjet cutting must be accurately controlled and also accurately measured. The specification of a waterjet cutting machine often indicates a maximum pressure of 4000 bar, for example, although the permissible sustained pressure loading is only 3800 bar. The seals of the high-pressure pump (pressure intensifier) that is needed to generate the pressure are under great stress, especially at maximum pressures. These must be designed as moving, plastic parts. A set of seals costs at least 200 euro. If, instead of working at 3800 bar, you only work at 3000 bar, the difference is a quarter of the wear costs.

In practice, there are clear variations between the target pressure and the actual pressure. This is particularly drastic if the volume of the anti-pulsator (pressure accumulator) is insufficient.

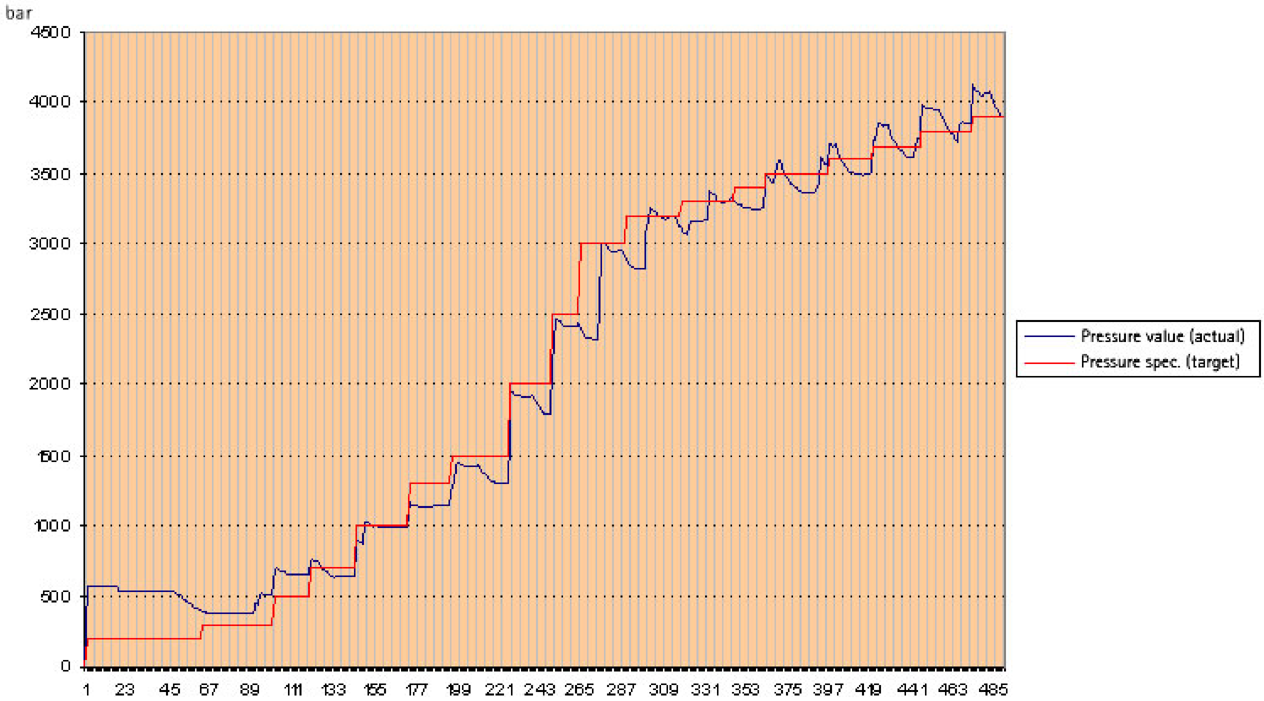

Fig. 7: Typical variations between target pressure and the actual pressure.

It must be possible to measure the pressure accurately, as pressure fluctuations are squared in the capacity of a high-pressure pump and thus in the cutting capacity. The capacity has a crucial effect on the possible feed rate and on the possible depth of cut.

The electrical measurement technology described here makes it possible to use the applied pressure to gear the cutting conditions to the required workpiece quality. Manufacturing associates attach great significance to effectiveness. A high feed rate is essential for efficient manufacturing and this can lead to rough quality, grooves and corners. What would otherwise be a very slow cutting process is ruled out on the grounds of effectiveness. This correlation previously meant that waterjet cutting only played a minor role in metal-working processes in the automotive industry. But now, with fast, electrical measurement technology and innovative pumps, both high quality and high speeds are possible. Investment costs are reduced.

Suitable measurement technology for use in waterjet cutting

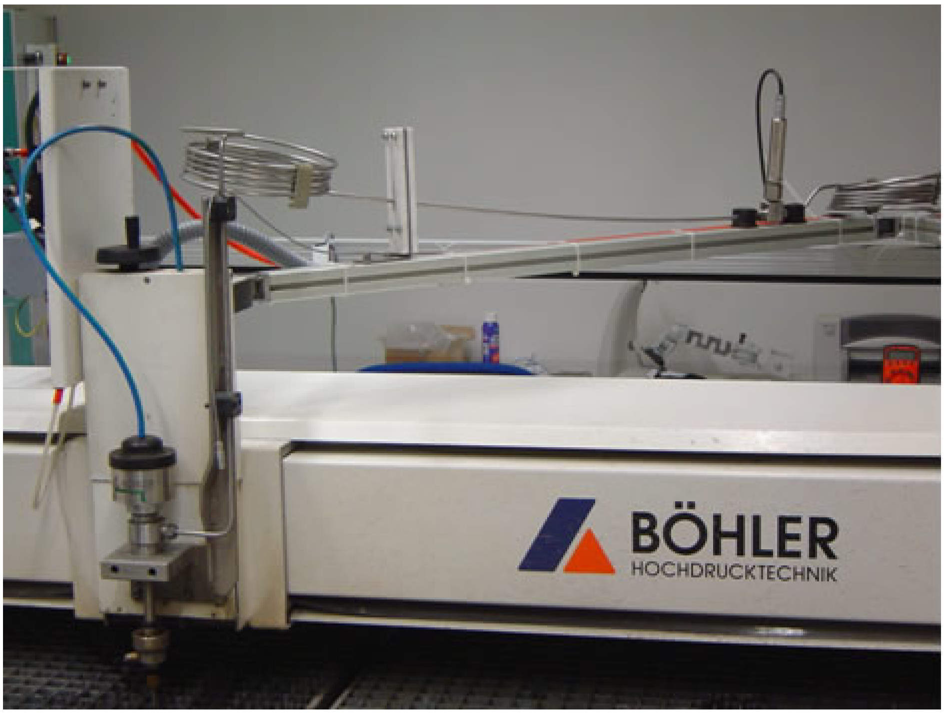

Abb. 8: P3MBP Blue Line 1-P3MBP/5000bar on a Böhler waterjet cutting machine

So far, it has hardly been possible to measure maximum pressures accurately. But with HBM's P3MBP Blue*Line* series of transducers and the new P2V high-pressure transmitters, this is no longer a problem. The special feature of the patented design for pressure transducers up to a nominal pressure of 15000 bar, is the monolithically enclosed pressure chamber. This means that the measuring body is made of one piece, without any weld seams and makes a very high natural frequency available. Foil strain gage technology allows optimum measuring body design and rating, with the measuring grid only being added at the final stage of production.

Since 2006, the P2V high-pressure transmitter has been available in all forms and offers outstanding properties at a very attractive price. Once again, there is a monolithic (one-piece) steel measuring body at the heart of the transducer. With this model, there is also no weld seam or clamping point facing the medium, which means that there is no weak point. This gives maximum reliability and endurance, even under highly dynamic loading. This is a novelty, especially at higher pressures, even if users had to replace the previously available sensor technology very often, depending on the loading. Which is why many users are delighted by the monolithic structure of the P2V, especially when they run high-pressure transmitters under particularly tough operating conditions. Despite the compact size, a high-quality, low-noise amplifier that also includes TEDS transducer identification, is integrated in the device. This means that its most important data are electronically stored in the transducer, from where they can be called. The P2V is equally suitable for the accurate analysis of the process and for fast control loops. Due to its high cut-off frequency of 4 kHz (-3 dB), even transient pressure peaks are reliably mapped. The 0 - 5000 bar measuring range is the optimum for waterjet cutting machine applications. As can be seen from the preceding sections, the P2V can be adjusted for optimum workpiece quality, feed rate and seal wear on the waterjet cutting machine, which makes this method even more suitable for mass-production processes.

Measurement technology is thus making an important contribution to improving the economic efficiency of what is already, in itself, a very capable method.

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