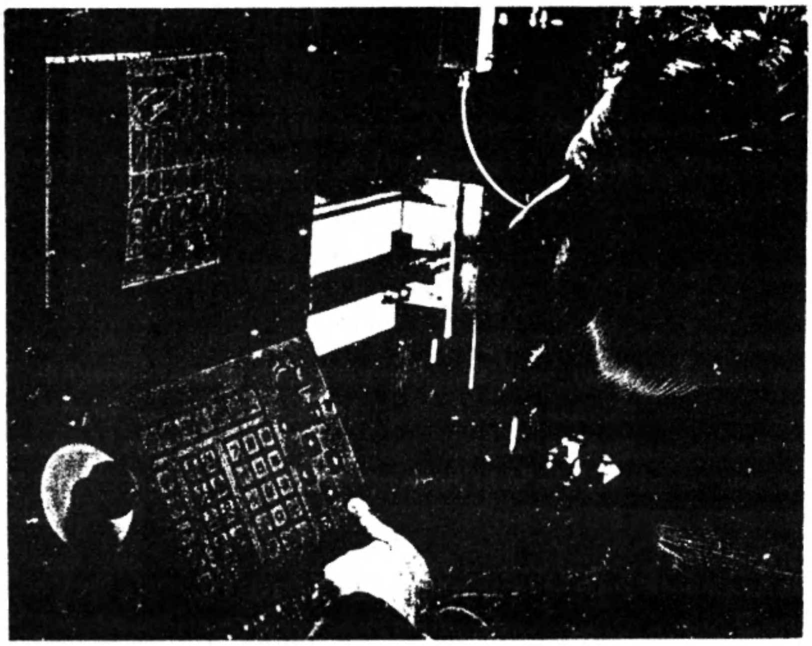
Continuous-path controlled water-jet cutting

by Thomas Kerst

The fact that water is able to release immensely high levels of energy was already known in the 1940s, when water jet technology was used in underground mining operations. Following the increasingly sophisticated level of technology and the constantly developing innovative capacity of the industrial sector, the decisive reason for using water-jet technology in industrial production was provided by the aviation and aerospace industry.

The water-jet process has become more interesting through the use of modern materials. The cutting tool used in this process is a concentrated water jet which is released from a fine nozzle at three times the speed of sound and at a pressure level of several thousand bar.



Programming station for the production of cutting programs

In no way should water-jet cutting be seen as a competitor to the conventional cutting processes; instead it offers a technical and economical alternative whenever thermal cutting is not possible and mechanical processes would necessitate extensive and expensive finishing.

Construction of a water-jet system

The cutting system consists of a treatment system for the cutting water a high-pressure pump with one or two pressure intensifiers which raise the pressure of the cutting water to the level of the system, a flexible high-pressure piping system, the cutting head and a CNC-controlled guide machine adapted to the specific application.

Down-life from this system there is a special cutting table, which neutralises the high level of residual energy of the water jet.

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The local water quality, i.e. the type and concentration of dissolved minerals, is the decisive criterion when it comes to the working life of the nozzles and high-pressure equipment. The use of a neutraiising gravel bed ion exchange system or separation of the dissolved components, by means of reverse osmosis is recommended, in order to obtain a high level of efficiency. Filtration of suspended matter in the cutting water to 0.45 micron is carried out in all cases, in order to protect the high-pressure components of the pressure-intensifying pump and the jet-producing sapphire from wear.

The unit which produces a water pressure level of 2000-4000 bar is a hydraulically-powered, double-acting plunger pump. An adjustable hydraulic axial or radial piston pump acts on the low-pressure part of this pressure intensifier. The oil is supplied alternately to either side of the double-acting position via controllable distribution values. This oscillating movement is transferred to the cutting water via the plunger and the required operating pressure is produced.

The pressure for the cutting water is determined by the intensifying ratio, using the adjustable pressure level of the hydraulic system.

On its way to the cutting nozzle, the cutting water which has been compressed to the required operating pressure passes through a buffer/filter system, in which the final microparticles are filtered out and the pulsation is damped.

The safe, reliable connection of the pump to the guide machine is guaranteed by a special high-pressure piping system with valves, hinges, crossing points, branch lines and flexible pipes.

Pure water-jet cutting

With a jet diameter of 0.1 mm and at a pressure of 4000 bar, the pure water-jet cuts through materials such as paper and board, rubber and leather, textiles, foam, glass wool and carpeting. The process also offers tremendous advantages when working with fibre glass reinforced plastic, carbon fibre fabrics and other laminates.

Abrasive cutting

When used for processing metals, particularly titanium/aluminium alloys and highly tensile steel, as well as ceramics, granite, glass and composite materials, an abrasive is added to the water jet as a grinding agent. The abrasive is drawn in by means of an injector in the mixing chamber and is mixed with the highly compressed water at the nozzle head, in order to increase the kinetic energy of the jet.

This means that the problems involved in conventional cutting processes are a thing of the past—structural changes, material deformation, tension, tearing or strain hardening no longer occur.

Applications

These advantages are already being put to use today in various branches of industry :

The foundry industry uses the abrasive water jet to debur extruded products, open-die and drop-forged parts, particularly when extremely expensive special alloys are involved.

No other cutting process enables profile cutting to be carried out on special steels, nonferrous heavy metals and titanium without any structural change, heat affected zones or mechanically-affected zones or cutting edges.

The temperature in the groove or the cut is no more than 100°C and the cut surface is similar to a sand-blasted surface. It is free of burrs and tension and tapers relatively slightly towards the bottom.

The width of the cut depends primarily on the selected cutting nozzle, and is normally between 1.2 and 2.5 mm for abrasive cutting.

Cutting data

The cutting rate date shown in the table has been established under standard conditions. The cutting rate is calculated on the basis of the thickness of the material and the feed rate. The rate may be considered to be constant for material thicknesses of between 4 and 30 mm.

Material	Cutting rate P (cm^2/min)
Special steel	10— 20
Titanium	10— 25
Copper	15— 30
Brass	20— 50
Aluminium	20— 50
Lead	80—120
Glass, 100—200	
Plexiglass	120—300
Rubber	200—400
Fibreglass reinforced/chemical-fibre reinforced/plastic	120—300
Ceramics	100—300
Natural stone, 50—300	

The cutting speed can be estimated for a specific material thickness, D, on the basis of the cutting rate, P:

$$V(\text{cm/min}) = \frac{P(\text{cm}^2/\text{min})}{D(\text{cm})}$$

Titan part cut with water jet

The estimate can only be used for orientation purposes and is no substitute for a trial cut.

CNC-controlled guide machine

The technology involved in water-jet cutting imposes extremely rigorous demands on the guide machine. High levels of contour precision at precision at precisely defined feed rates have an important effect on the quality of the cut.

To meet the special requirements of this cutting process, ESAB-HANCOCK GmbH has developed continuous-path controlled guide machines which enable full use to be made of the potential offered by water jets.

Servo drive units run the abrasive cutting machine in a speed range of 10-6000 mm/min. For pure water-jet cutting a highly dynamic guide machine is available, for speeds of up to 50,000 mm/min.

All the guide elements on the machines are made of non-ferrous material and the moving parts are also equipped with special covers to protect the bearings from abrasive deposits.

The customer's requirements in terms of precision are covered by the appropriate machine. The system is designed on a modular basis, so that the user's various requirements can be fulfilled. The system basically comprises coordinate machines in a portal design which can be equipped with two to five controlled axes. The portal is a stable, rigid and low-vibration structure. The space inside the portal is available for cutting or changing tables.

Continuous path control system

The continuous-path control systems of the portal guide machines are the logical result of many years of cutting experience and the call for a favourably priced CNC continuous-path control system with a diversity of applications.

The integrated interface of the microprocessor-controlled continuous-path control system permits communication with the electronically-controlled high-pressure pumps, thereby meeting CIM production requirements.

This provides the highest possible level of process monitoring, automatic diagnosis of the pumps and extremely flexible production.

All the cutting parameters are programmed directly on the continuous-path control system.

The contous data can be produced by means of editable macro programmes, or can be converted from drawings into numerical data by means of teach-trace conversion. It is also possible to produce cutting contours with programming stations and CAD systems, and subsequently to have these into the CNC control system.

The control and servo system controls all the drives by means of a closed position control loop with subordinate rotational speed control. The synchronization control system provides extremely smooth running and guarantees optimal compliance with the required path geometry by means of angular analysis.

The integrated cut-groove compensation system shifts the water-jet by one half of the jet diameter in the positive or negative direction, thereby enabling a precisely profiled finished part to be produced.

Cuts in the material can be started in accordance with a programmable dwell time. These location points are programmed outside the contour to be cut by subsequently approaches the contour to be cut by circular or linear interpolation.

The coherence of the water jet is constant over an area of 10 mm. The distance between the nozzle and the surface of the materials is controlled by a capacitive height control system when it comes to electrically conductive materials. For more complex cutting operation, this distance is regulated by a controlled third axis. ■