6.3 MACHINES FOR UNCONVENTIONAL MACHINING TECHNOLOGIES

This commodity has experienced a great boom during the recent years in various industrial application branches. The material removal is based at these machines on another principle than the chip machining is.

Because the demands put on the high machining performance, environment friendly machining of materials and on the high strength (nickel, titanium, their alloys, composites,...) increase still more and more, the unconventional machining technologies come into foreground. These unconventional machining technologies find their utilization especially in the cases, when the conventional machining methods are less efficient or unsuitable. Various physical or chemical principles are used to machine the particular material (Fig. 6.3.1).

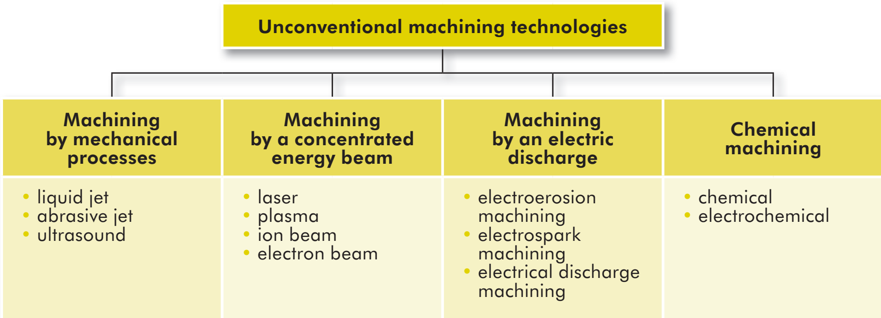


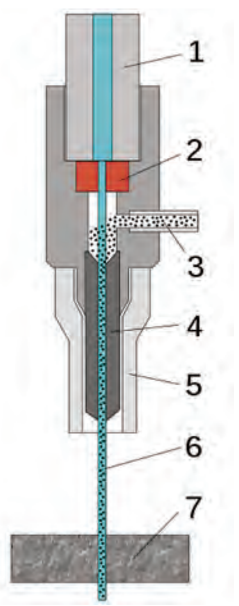
Fig. 6.3.1: Machining principles of unconventional technologies

Machines for machining by a water jet

The utilization history of a water jet for cutting reaches up to the thirties of the 20th century, when the water jet was used to cut stone and coal. Subsequently, the technology was improved by addition of abrasive material to the water jet – the high speed liquid jet with addition of abrasive substances came into existence (Abrasive Water Jet – AWJ). The high speed of the flowing water stream with addition of abrasive substances enables to machine in fact all materials used in the industry in the economic and ecologic way. It is possible to machine wood, paper, plastic materials, metals and their alloys, hard metals, composites, stone and other materials. The water jets can be divided in dependence on the used liquid, pressure intensity or used abrasive material.

Cutting with the pure water jet (WJM) is suitable for extremely detailed geometries, especially at softer materials (plastic materials, cork, wood, rubber). The water jet with abrasive material (AWJ, Fig. 6.3.2) is able to cut stone, metals, glass and other materials. Garnet sand or olivine is usually used as the abrasive material.

The main advantage of the water jet can be seen in the cut without a thermal influence on the cut material. No physical, chemical or mechanical changes take place due to this. The workpiece can be subsequently machined very easily. The water jet has the minimum force influence on the cut material, no microcracks appear. It is possible to divide the majority of materials at a large thickness range. This technology enables to leave the gaps only of 3 mm between the products – small material waste. No harmful products arise during the cutting process. The water consumption is relatively small (it depends on the nozzle size and pressure). Dirt is excluded from the waste water during sedimentation. Nontoxic substances are used as the abrasive material and these substances can be recycled for the next utilization.



1 – highpressure water supply
2 – ruby or diamond nozzle
3 – supply of abrasive material
4 – mixing tube
5 – holder
6 – jet
7 – cut material

Fig. 6.3.2: Principle of cutting using the water jet with abrasive material [www-1]

The main disadvantage can be seen in the unavoidable contact with water and with the abrasive material. Moreover, it is the limitation in relation to the manufacture of very small workpieces. If the cut has a worse quality degree, the cut contour may be deformed on the lower edge at materials having a bigger thickness, which is caused by the jet outlet.

Fig. 6.3.3 shows the principle of cutting with the water jet. The main components of the device for cutting with the water jet include the highpressure water pump, the intensifier, the highpressure tube system, the pressure accumulator, filters, the two way pressure relief valve, cutting heads, feeds in the particular axes, the tank catching water and dirt, the supporting grate and water treatment.

The devices work with the water pressure from 60 MPa to 400 MPa at the water jet velocity of 600–900 $m.s^{-1}$. The water consumption depends on the cutting parameters. The material removal intensity and the quality of the machined surface are influenced by many factors. The cutting process velocity is mainly influenced by the water pressure, by the nozzle diameter and by the flow velocity. The machined surface quality is influenced by the distance between the workpiece and the nozzle and by the kind and size of the abrasive material. Fig. 6.3.4 shows the qualitative cut degrees. Tab. 6.3.1 mentions the quality degree of cutting surfaces and their character.

The nozzle distance from the surface is another factor influencing the quality of the machined surface. If the nozzle is too near to the surface, there is a danger

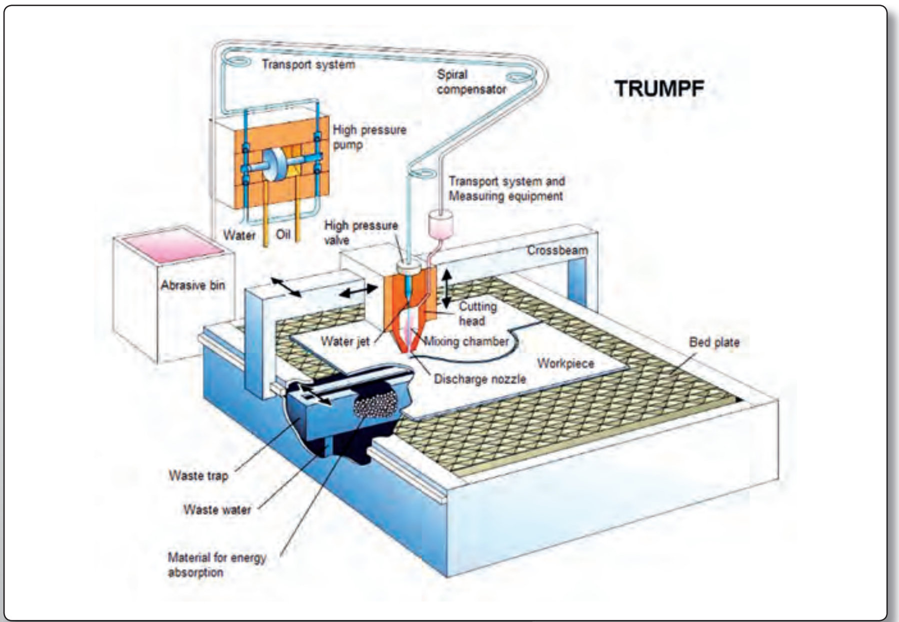


Fig. 6.3.3: Principle of cutting with the water jet [Humár 2005]

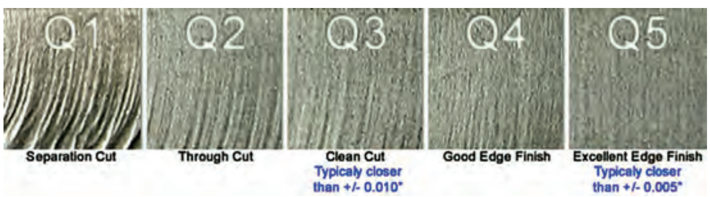


Fig. 6.3.4: Qualitative cut degrees [www-1]

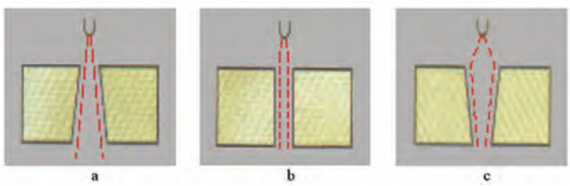


Fig. 6.3.5: Cutting gap shape [www-2]

that the nozzle can be broken off in the case that wavy material is cut and no height sensor is used. If the nozzle is too far away from the surface, the water jet with abrasive material is scattered and the surface of the edges of the cut workpieces will be destroyed.

The distance between the nozzle and the workpiece at WJM cutting ranges from 2 up to 70 mm. If AWJ cutting is used, this distance ranges from 2 up to 10 mm [Řasa 2001]. As a standard, the accuracy is ±0,2 mm.m^{-1}.

The cutting gap with the bevel of 1–1,5° usually arises at cutting with the water jet. Fig. 6.3.5 shows the cutting gap shapes. At a very slow cut or if soft material is cut, the water jet is able to "grind through" its natural conical trace, see Fig. 6.3.5a. If the optimum equilibration is among the cutting speed, resistance and material thickness, the jet is kept in the cylindrical shape all the time while it passes through the material and no bevel arises, see Fig. 6.3.5b. If the cutting is performed very quickly or if some more resistant material is cut, the jet is not able to "grind through" the material even in its input diameter and the cut is closed downwards, see Fig. 6.3.5c [www-2].

Examples from practice

Fig. 6.3.6 shows the waterjet cutting machine with which is able to cut in 3D. The Dynamic Waterjet XD technology with active tolerance control is utilized for cutting in 3D. This brings the possibility to cut the parts more quickly and more precisely in comparison with the standard cutting with the water jet. The cutting speed is up to 25 m.min^{-1}. The machine is equipped with the control system Siemens 5 Axis CNC. The machine accuracy is stated by the manufacturer as ±0,127 mm, the repeatability is ±0,0762 mm. The Dynamic

Qualitative level	Basic characteristics	Roughness Ra in the upper contour	Roughness Ra in the lower contour	Dimensional accuracy in the upper contour (mm)*	Dimensional accuracy in the lower contour (mm)*	Chamfer
Q5	Excellent edge finish	under 3,2	about 3,2	±0,1	±0,1	Mostly slight undercutting
Q4	Good edge finish	about 3,2	about 6,3	±0,1	±0,2	Mostly minimal
Q3	Clean cut	about 4,0	to 12,5	±0,15	Depending on the type and thickness of material	Depending on the type and thickness of material
Q2	Throught cut	about 4,0	to 25	±0,2	Depending on the type and thickness of material	Depending on the type and thickness of material
Q1	Separation cut	4,0-6,3	to 40	±0,2	Significantly inaccurate	Significant chamfer to+
(*) Values are indicative only and they may vary according to the type of material						

Tab. 6.3.1: Quality degree of cutting surfaces

6.3 MACHINES FOR UNCONVENTIONAL MACHINING TECHNOLOGIES

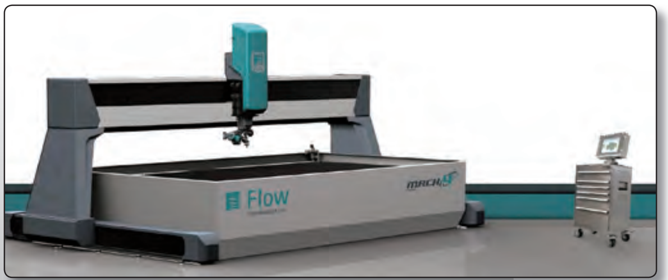


Fig. 6.3.6: Water jet cutting machine – Mach 4 series [Flow]

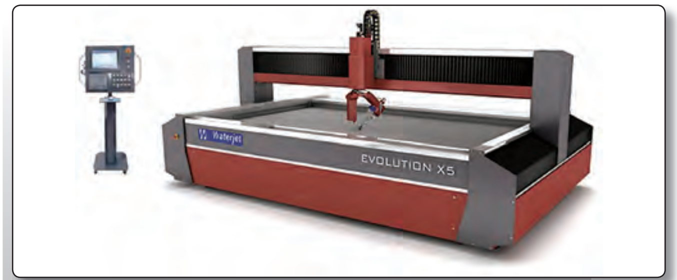


Fig. 6.3.7: Water jet cutting machine – Evolution X5 series [WaterJet]

Waterjet XD technology tilts the cutting head automatically by means a small joint in an arbitrary direction up to by 60°. Therefore, the water jet has no delay and there is no error at the groove bevel. The result is represented by the minimum tolerances and the maximum cutting speeds. Maximum cut lengths: X axis – 4 000 mm, Y axis – 14 000 mm, Z axis – 305 mm [www-3].

Fig. 6.3.7 shows the water jet cutting machine which is also able to cut in 3D. This machine is able by means of the self positioning using the contact probe to keep the constant jet distance from the surface during interpolation up to the rotation of ±69° (Fig. 6.3.8). The cutting speed is up to 20 m.min^{-1}. The accuracy stated by the manufacturer is ±0,05 mm, the repeatability is ±0,005 mm, the accuracy of the axes A, C is ±0,01° the repeatability of the axes A, C is ±0,005°, he rapid traverse of the axes A, C is 90°.s^{-1}. The machine is equipped with the anticollision system. Maximum cut lengths: X axis – 3 350 mm, Y axis – 6 100 mm, Z axis – 300 mm.

Fig. 6.3.8: Cutting head [WaterJet]

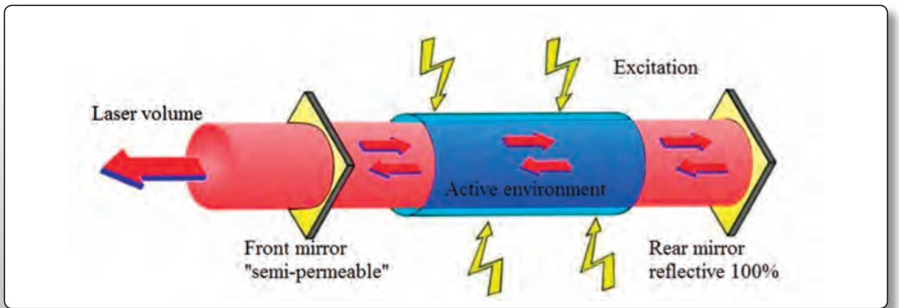


Fig. 6.3.9: Laser chart [Novák 2012]

Machines for machining by laser

Laser technology was utilized in the industry for the first time in 1965. Western Electric Company built the functional laser determined to drill diamond dies. The laser device determined to cut steel metal sheets was put into operation in 1967 in Great Britain. This laser device used oxygen as the assistance gas. The devices specified to cut nonmetallic materials came later. Laser cutting by means of CO_2 started to be used in the industry more extensively in the seventieth in the last century [Kořán 2012].

Fig. 6.3.9 shows the chart of the general laser principle. The basis of every laser consists of the active medium which is excited (electrically, optically,....). The excitation supplies energy to laser and this energy is then emitted by means of the stimulated emission process in the laser beam form. For this purpose, it is necessary to create the so called optical resonator which usually consists of the reflecting mirrors. The laser beam is collimated (i. e. it does not diverge), monochromatic (unicolour, generated photons have the same frequency or wave length), coherent (generated photons are in the same time and spatial phase) [Novák 2012]. The laser cutting principle can be seen in Fig. 6.3.10.

Lasers are most often divided in dependence on the active medium type.

Gas lasers – the active medium is here represented by gas which can be excited e. g. electrically, optically, by radiofrequency waves, etc. The active medium of gas lasers consists of atoms (He-Ne laser), ions (Ar laser), molecules (CO_2 laser) or of their mixture in the gas phase. Gas lasers most often work in the continuous mode. There are also pulse lasers available. Their indisputable advantage can be seen in their high efficiency (CO_2 approx. 40 %). The disadvantage of these lasers can be seen in the small output which can be obtained from the volume unit of the active medium. It follows from this that the highduty gas lasers have considerably big dimensions. CO_2 lasers are used in cutting applications.

Solid substance lasers – the active medium consists here of a solid substance, usually of single crystals. The excitation is usually performed optically (discharge lamps or laser diodes). The most commonly used and best mastered solid substance laser is the laser designated Nd:YAG (Fig. 6.3.12). The active medium is represented at it by yttrium