



OVERVIEW OF MATERIAL PROCESSING MECHANISMS IN UNCONVENTIONAL MACHINING METHODS

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Abstract: From the point of view of the concept itself, technology is a set of processes, rules and habits used in the production of various objects in the most diverse spheres of production, or human activity itself. Therefore, there are several designations and naming of production technologies in the professional literature. Historically, probably the oldest systematic designation and division of production technologies and processes is given as early as 1963 in the German standard: Begriffe der Fertigungsverfahren DIN 8580. The standard defines production processes for the production of geometrically certain solids. In the paper is shown explanations of mechanisms of machining when is used unconventional machining technologies.

Key words: Unconventional technologies, mechanisms, workpiece, processing material.

Pregled mehanizama obrade materijala kod nekonvencionalnih postupaka obrade. Sa stanovišta samog koncepta, tehnologija je skup procesa, pravila i navika koji se koriste u proizvodnji različitih predmeta u najrazličitijim sferama proizvodnje ili same ljudske delatnosti. Stoga u stručnoj literaturi postoji nekoliko oznaka i imenovanja proizvodnih tehnologija. Istorijski gledano, verovatno najstarija sistematska oznaka i podela proizvodnih tehnologija i procesa data je još 1963. godine u nemačkom standardu: Begriffe der Fertigungsverfahren DIN 8580. Standard definiše proizvodne procese za proizvodnju geometrijski određenih čvrstih materija. U radu su prikazana objašnjenja mehanizama obrade kada se koriste nekonvencionalne tehnologije obrade.

Ključne reči: Nekonvencionalne tehnologije, mehanizmi, obradak, obrada materijala.

1. INTRODUCTION

1.1 Characteristics of individual machining procedures

In English-speaking countries, the name (Advanced Method of Material Removal) is used and promoted, ie as a progressive, modern or advanced machining method [1, 2, 3]. In the initial designation, it also encounter the name in our literature as non-traditional or unconventional technologies. The American Society of Mechanical Engineering (ASME) refers to a group of these technologies as the Nontraditional Method of Machining. The name Unconventional Technology is also used by CIRP, based in Paris, in the periodicals: Annals of the CIPR.

Where the medium acting as a production tool - is a formless substance, liquid or gaseous, which various forms of energy, such as. it acts on the workpiece by mechanical energy, heat, radiation, etc., or by a chemical reaction. Shapeless substances are gases, liquids, powders, fibers, granules and the like. For the purposes of this standard, free particles with a geometrically determined shape are also considered to be formless substances [4].

Unconventional technologies are expanding into areas where other types of machining fail many times, whether they are not economically efficient, etc. An important factor in the material removal process is its mechanism. These can be: - induction of mechanical stress by means of a tool; - use of thermal energy, where the material evaporates; application of

electrochemical reactions induced by an electric field in the electrolyte that disrupts the atomic lattice of the workpiece material; - chemical reactions that break down atomic bonds. Figure 1 shows the testing and separation of structural materials by appropriate treatment.

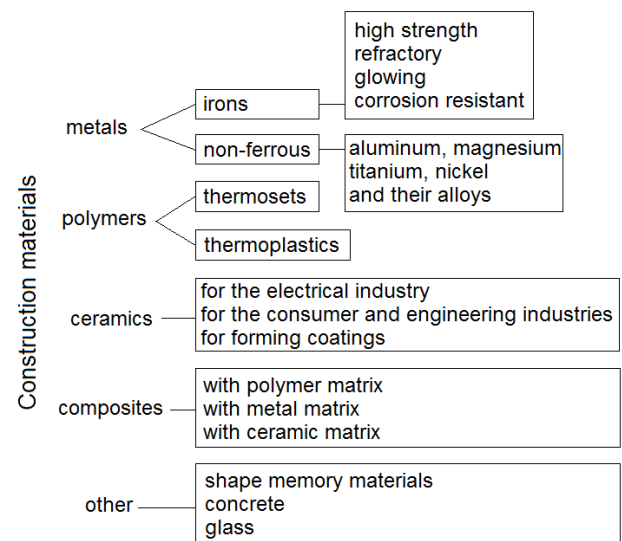


Fig. 1. Examination and separation of structural materials by treatment [5]

Due to the increasingly current lack of energy, respectively. Rising energy prices and ever-increasing demands on components and equipment in terms of

their properties, be it the condition of vehicles, aviation, chemistry or the construction sector, or medicine efforts are still being made to develop new materials and qualify them. At the same time, production must keep pace with developments and new ways and technologies must be sought, tested and introduced to process these materials. An important group of materials that has achieved particular importance in this regard in recent years are e.g. composite materials. Especially in aviation, there is a growing need for composites with carbon and synthetic fibers. The materials are characterized by high strength, high hardness, low specific weight and stability against thermal expansion. Based on these specific properties, these materials began to be used as the first plastics in the primary area of aircraft structure. This consists of essential load-bearing elements. This makes it possible to achieve a weight reduction of up to 10, depending on the aircraft type, which results in a significant increase in the payload or a significant increase in the radius of action, ie. range due to lower fuel consumption. No other material has achieved such an improvement in aviation in the last 30 years. Similarly, apparently positive experiences are also used in the construction, engineering and chemical industries, etc. [6].

However, compared to metal production, the degree

of mechanization and automation in machining difficult-to-machine materials (composites) was still very low. This was also true when cutting uncured prepregs and laminates. The problem was apparently relatively high processing costs and environmental pollution during their processing. Unconventional technologies (eg water jet technology) have proven to be a suitable tool for machining such specific materials (apart from the initial problems with the absorbency of these materials). Similarly, unconventional technologies have preferably been used where sticky materials need to be cut, in which the blade or saw is quickly clogged with the material and blunted very quickly. A significant advantage was also the elimination of dust during the machining of asbestos, plastics, ceramic materials and other.

The high versatility of unconventional technologies is due, among other things, to a wide range of applications and different machining methods and their combinations. The inclusion of unconventional technologies in a wide range of production processes is elaborated in the following text.

1.2 Methods of machining materials

The following figure shows the division of production processes of material processing, Figure 2.

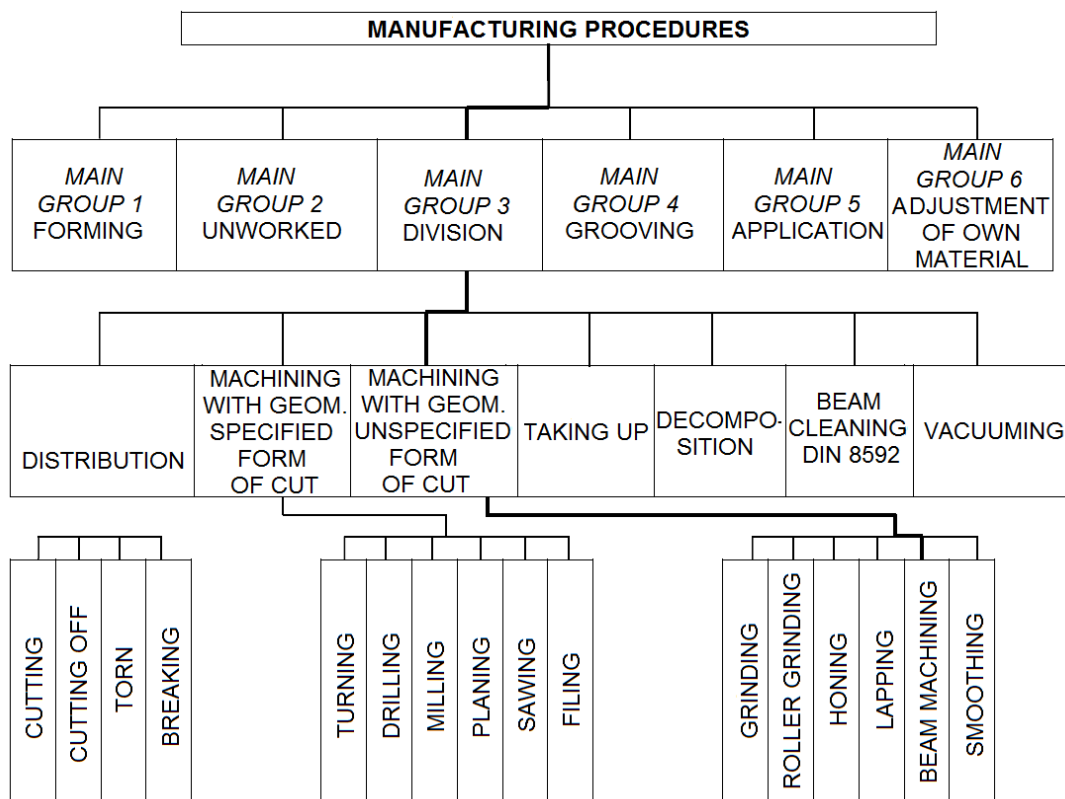


Fig. 2. Division of material processing production processes [7]

2. DISTRIBUTION OF UNCONVENTIONAL TECHNOLOGIES

Competition and scientific and technological development in the world increase the quality requirements of various products in every area of human activity. Increasingly, construction materials

with top performance properties are required, i. construction materials with high mechanical, physical and chemical properties. Also design, technological, design and other product innovations, requirements for reliability and long life of structures, requirements for reducing the weights of structures, design and ergonomics of products gradually directly and

indirectly require the development and application of new materials many times with qualitatively different properties than those of the materials used so far.

Technological processing of these materials brings a number of problems, so they are referred to as difficult-to-machine materials. Classical machining methods are then supplemented and in many cases successfully replaced by the so-called unconventional machining technologies [8].

They are based on physical, chemical and electrical phenomena. In contrast to mechanical machining methods associated with the removal of material in the form of chips, in these methods the material is removed mostly by thermal, chemical, electrical, electrochemical and other, or combined processes, with almost exclusively force-free action on the material being

machined and without chip formation. Clear division of unconventional technologies according to the used principal resp. method of energy use is given in Table 1 [9]. In this table, for completeness, they are listed together with the designation. Slovak technical terminology also names used abroad, which are also in accordance with the designation and division of production methods according to the ISO standard, while several foreign sources assign to the group of concentrated energy beams also solar beams (SBM - Solar Beam Machinig). This technology is quite specific and is also given by suitable climatic conditions. Due to its perspective and importance, and also due to the fact that it has not been published in this sense in our country so far, it is also elaborated in a separate chapter [10].

BASIC DISTRIBUTION OF NON-CONVENTIONAL MACHINING METHODS				
ELECTRO - THERMAL PRINCIPLES				
the air abrasive	BEAM MACHINING - CONCENTRATED ENERGY			
Electro discharge machining „EDM“	Laser beam machining „LBM“	Elektron beam machining „EBM“	Ión beam machining „IBM“	Plasma beam machining „PBM“
ELECTRO - CHEMICAL PRINCIPLE	CHEMICAL PRINCIPLE	MECHANICAL PRINCIPLE		
		ABRASIVE PRINCIPLE		
Electro-chemical machining „ECM“	Chemical machining „CHM“	Ultrasonic machining „USM“	Water jet machining „WJM“	Abrasive jet machining „AJM“

Table 1. Specific characteristics of unconventional machining methods

The basic tendencies and causes of the introduction and expansion of unconventional machining methods can be summarized in the following trends [9, 11]:

1. Growing demands on the construction of machine parts, leading to an increase in the proportion of difficult-to-machine materials. The causes of difficult workability of these materials result from:

- microstructure (high-strength, heat-resistant, refractory, anti-corrosion, antimagnetic and other materials, eg based on austenitic steels, titanium alloys, etc.),
- macrostructure (composites), or their special construction structures (honeycombs, layered materials, sandwiches, rigid foams, prepreg, composite materials, etc.)

2. Growing demands on the shape complexity of cutting and forming tools, die-casting molds and molds for molding plastics, etc.

3. Increasing demands on the shape complexity of high-speed steel and sintered carbide cutting tools (eg monolithic sintered carbide shaped tools).

4. Growing requirements for the complexity of machined mold shapes and dies for forming, caused by a completely new design concept of products.

5. Growing demands on the production of precision miniature components.

6. Growing demands on productivity in order to create preconditions for the introduction of automation and automated production systems in the above-mentioned special areas of production.

7. As well as the preconditions for a very good integration of these production method systems with NC control and CAD / CAM systems, resp. CIM.

From the technical point of view, a different approach to the concept of machinability emerges from the stated technical and economic assumptions when

using unconventional machining methods. In the vast majority of applications of these methods, the machinability of materials is not limited by mechanical properties (hardness, strength), but is mainly related to physical properties of the material such as thermal conductivity, melting point, electrical conductivity, electroerosion resistance, chemical composition and the like. When evaluating the mentioned machining methods, the factor of non-force machining is also not important, which creates the preconditions for the formation of a surface without mechanical reinforcement. Said force-free machining factor is accompanied by a minimum thermal load on the workpiece. In the case of methods using the thermal effect of an electric current for machining, the heat amount is concentrated in the microvolume of the material and affects only thin surface layers ranging from a few hundred micrometers to a few millimeters, depending on the chosen method and the intensity of material removal [12]. The total warming of the workpiece is in the order of degrees or tens of degrees, which of course do not have a significant effect on changing the properties or structure of the material. With regard to the required production accuracy, it does not significantly affect the thermal stabilization of the machine tool.

The basic shortcomings of unconventional machining methods include the low productivity of own production. Comparison of achieved volume outputs (removal) Q_r [$\text{cm}^3 \cdot \text{min}^{-1}$] of chip machining technology is given in [5, 7, 13], together with the values of the specific work E [$\text{J} \cdot \text{mm}^{-3}$], which characterize the energy intensity of individual technologies. Despite the low productivity of the actual removal, resulting from the applied physical principle, suitable approaches (another evaluation criterion) allow to achieve high savings of labor and costs in the production of very complex shapes (in the order of hundreds of percent). The problem in the introduction of unconventional technologies may be ignorance of the issue, for their relevant evaluation, higher energy intensity of some production methods as well as e.g. higher set-up price for quality machine tools. Other issues of productivity, energy intensity and surface condition after machining, etc. are discussed in more detail in the relevant chapters devoted to each

production method. Due to the fact that the EU-STN standard does not cover the whole area of unconventional technologies of material processing, it will continue to use the international designation of these technologies.

3. CHARACTERISTICS OF INDIVIDUAL MACHINING PROCEDURES

3.1 Electro-thermal principles of machining

3.1.1 Electroerosive machining

Called ISO standards as Electro Discharge Machining for short - EDM. It is based on the removal of particles of surface layers of material by the effect of thermal and pressure action of controlled electric discharges. All electrically conductive materials can be machined by electroerosion. In EDM, no force is applied to the workpiece, i. the workpiece does not have to be fixed during machining. The following technological applications of electroerosion have found application in technical practice:

1. Electroerosive excavation of cavities.
2. Electroerosive surface polishing.
3. Electroerosive wire electrode cutting.
4. Electroerosive microdirection.
5. Electrocontact machining

3.1.2 Laser beam machining

The greatest application of the laser beam is in the shape division of thin plate-like materials, in the production of miniature precision holes, slits, etc. At present, the use of lasers in combination with conventional machine tools is also effective. The combination of mechanical embossing of precise simple holes and precise laser cutting of complex and complicated shapes found the greatest application. The area of local laser preheating of difficult-to-machine material during mechanical machining is also successfully developing (Fig. 3). When heating difficult-to-machine material to a temperature of around 600°C , the cutting resistance decreases (by up to 50%), which facilitates chip separation and allows both an increase in cutting speed and a significant increase in cutting edge durability [8, 14, 15].

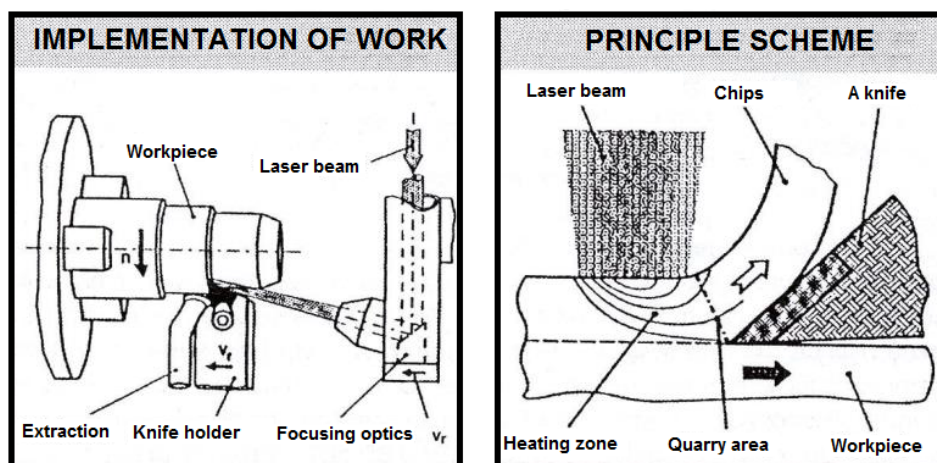


Fig. 3. Laser beam assistance scheme for machining

3.1.3 Plasma beam machining

The designation of the ISO standard is PBM, i. Plasma Beam Machining. The principle of plasma machining consists in melting the cut material at an extremely high temperature (more than 15,000 ° C). Such a high temperature is created by the decomposition of gas molecules when passing through an electric arc, which burns between the non-melting electrode (cathode -) and the cut material (anode +). Plasma torches of such a design are generally referred to as transfer arc torches (Fig. 4.). From these torches emits a high-velocity narrow beam of plasma - a gaseous state of matter, which is characterized by strong ionization and, as a result, good conductivity for electric current. Due to the high temperature, the material melts and the molten material is pushed out of the cut by the kinetic energy of the stream.

Due to some negative properties of plasma machining, such as: high noise, dust and flue gases, the effect of UV radiation, plasma torches with water injection called Hydroterm are currently used. The schematic diagram is shown in Figure 5. The cutting head has several additional channels through which water is injected directly into the plasma beam. This significantly extends the life of the plasma torches in addition to eliminating the above negatives. Due to the principle, the whole machining process can be realized below the water surface, which also significantly reduces noise (below 80 dB). Operating currents of up to 600 A enable high machining speeds to be achieved.

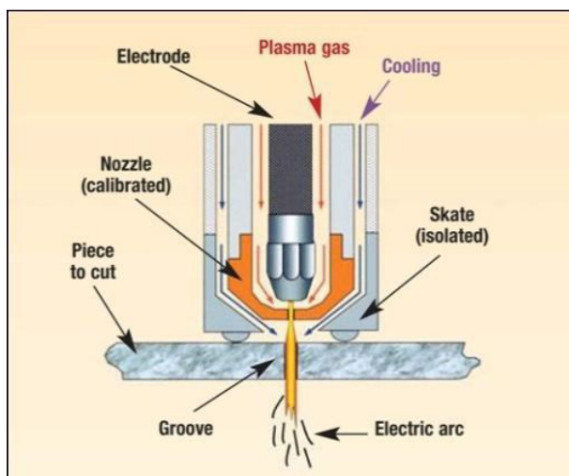


Fig. 5. Principle of plasma torch with water injection

3.1.4 Electron beam machining

It is known by the abbreviation (EBM) or ELECTRON BEAM MACHINING. Electron beam machining began to be used in technical practice in the early 1940s. It is mainly used for melting materials, welding, cutting, drilling or burning holes. So far, the largest industrial application has been welding and melting of materials as well as drilling holes of small diameters into coarse materials. The device for generating an electron beam is called an electron gun. The electron beam burns in a vacuum of 10^{-4} to 10^{-5} Pa (this eliminates oxidation of the machining process), Figure 6.. The beam has a large specific energy output (ratio of power to beam cross section). The beam can be easily controlled and focused, so the material heats up

Effect of N_2/H_2O Plasma on Non-Ferrous

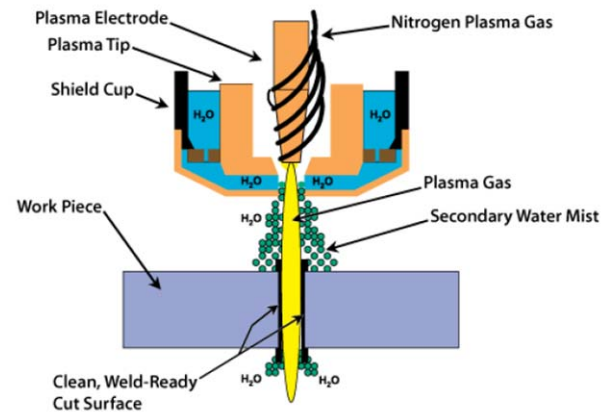
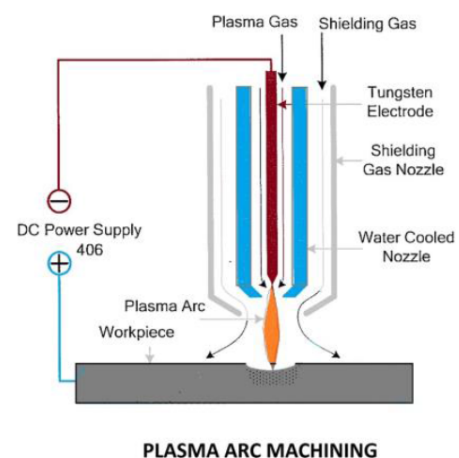


Fig. 4. The principle of plasma machining

Plasma cutting systems are preferably used in particular for cutting materials. Plasma cutting devices are manufactured as automated and robotic systems. The most modern machines are already commonly controlled by a computer. In addition to cutting, the plasma beam is preferably used for welding materials, heat treatment of surfaces and application of new surface layers. The plasma beam, like the laser beam, is preferably used to improve machinability by heating the chip root. Especially for difficult-to-machine materials. The scheme of the machining process is identical to Figure 3.



very quickly and at a specific location [16, 17].

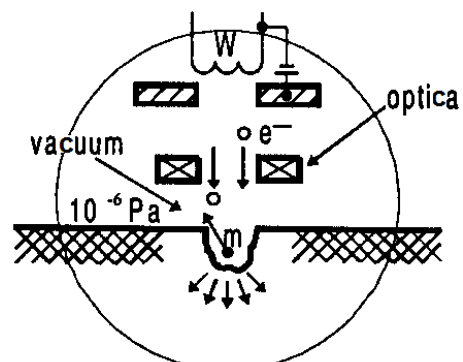


Fig. 6. Electron beam machining

Promising prospects for the use of the electron beam are also in space, where the pressure is also 10^{-4} Pa. A major step in the development of space technology was taken by scientists in 1984. Soviet cosmonauts (SOJUZ -7, S.E. Savická and V.A. Džanibekov) successfully completed a unique experiment in open space. They performed various technological operations - welding, cutting, soldering and also coating by thermal evaporation and condensation. An electron beam can machine any material, regardless of its mechanical or physical properties. Holes and slits with a diameter below 0.1 mm can be drilled with the beam, while the accuracy of cutting or grooving is ± 0.0015 to ± 0.0025 mm.

3.1.5 Ion beam machining

Ion beam machining is also referred to as ION BEAM MACHINING (IBM). Ion beam machining is one of the latest technologies, which has been used mainly in recent decades, especially in connection with the rapid development of semiconductor and integrated circuit production. Today, the ion beam is mainly used to form matrices in the production of integrated circuits and in cleaning and polishing surfaces. Milling (engraving) using an ion beam through a special mask creates the basic technology for the production of integrated circuits. Non-traditional approaches to plasma etching and reactive ion beam etching have been fully adopted by industry in the field of submicron semiconductor manufacturing. Machining compared to e.g. chemical etching achieves significantly higher accuracy than 100 nm, it is also possible to machine almost all materials, achieves a higher removal rate, is characterized by good control of beam scattering and achieves higher quality of the machined surface and perpendicularity of the walls of machined grooves.

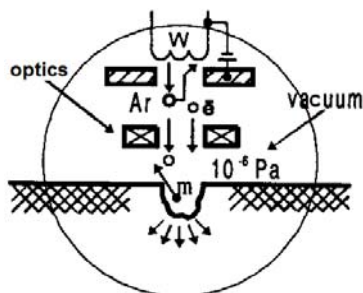


Fig. 7. Ion beam machining

Ionic devices are based on the action of ions (use of kinetic energy) in a vacuum on the material being machined. The intensity of the removal depends on the density of the ion current. The usual source of ions is argon and the operating voltage for ionizing the environment ranges from 300 to 500 V. The normal machining speed is 0.5 to 1.5 nm.s⁻¹.

3.1.6 Solar beam machining

Solar beam machining It is also included by some authors [10] among the thermal and electrothermal principles of machining. It is referred to as SOLAR BEAM MACHINING (SBM). Due to its nature, this

method of machining can be a very interesting alternative way of machining materials, especially in the future. Solar machining includes several machining procedures: cutting, welding, drilling, melting materials, etc. Due to the low awareness of this technology and its perspective as well as the fact that it is based on the so-called A separate subchapter is also devoted to this technology. Experimental verification of the structural and technological parameters of the PKS was done by authors [18].

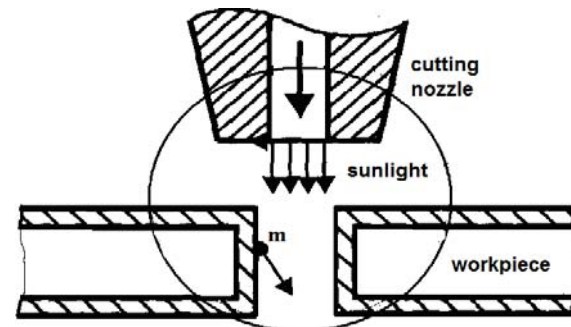


Fig. 8. Solar beam machining

3.2 Electrochemical principle

1. Electro-chemical (EC) machining with forced removal of reaction products,
 - 1.a. EC machining with flowing electrolyte,
 - 1.a.1 EC excavation of shapes and cavities,
 - 1.a.2 EC digging of small diameter holes,
 - 1.a.3 EC deburring,
 - 1.a.4 EC cutting of materials, performed by: rotating disk, wire electrode and slotted tool.
 - 1.b. EC machining with mechanically removed reaction products (often referred to as anodomechanical machining).
 - 1.b.1 EC grinding and lapping,
 - 1.b.2 EC honing,
2. Electrochemical (EC) surface treatment without removal of reaction products
 - 2.a. EC polishing of material surfaces,
 - 2.b. EC surface marking.

Normally achieved dimensional accuracy in EC machining is ± 0.03 mm, but an accuracy of up to 0.005 mm can be achieved. The commonly achievable surface roughness is $Ra = 0.2 \mu\text{m}$. Research into the laws and characteristics of electrochemical, electroerosive and mechanical methods creates preconditions for the emergence of completely new machining processes. Due to the superposition of various effects with basic anodic dissolution, a substantial intensification of the process is possible. In technical practice, of the combined methods, the principle of the so-called anode - mechanical cutting of difficult - to - machine materials. In this case, the removal takes place mainly by electric arcs by discharge, to a lesser extent also by electric spark discharges and anodic dissolution of the material. During anodomechanical cutting, the rotating tool electrode touches the workpiece at uneven locations. At

these contact points, a mechanical failure of passivation and an increase in current density occur. This melts the material at the contact surface. At the same time, however, it also occurs in places of broken passivation, which no longer touch the tool electrode. If the working fluid has a low passivating capacity and a relatively low power source, electrochemical material removal predominates. In this way, various profile materials are preferably divided up to a cross-sectional area of 600 mm². Similarly, steel strips or wires can be divided. Depending on the machine parameters, removal rates of up to 6000 mm³/min can be achieved for steel machining and up to 2000 mm³/min for sintered carbide cutting - HM.

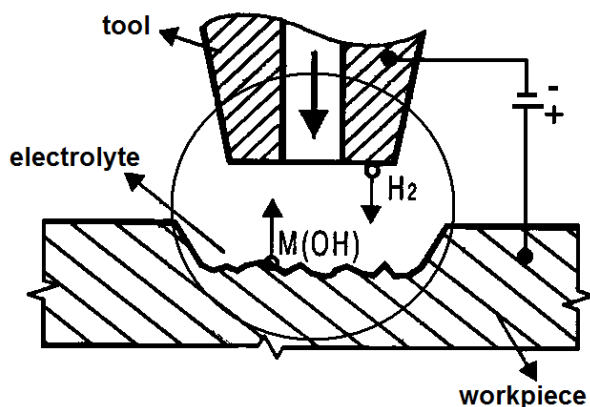


Fig. 9. Electrochemical chemical principle

3.3 Chemical machining

The name CHEMICAL MACHINING (CHM) was used in practice for chemical machining. Currently, there are two basic application directions for the use of chemical engineering in the field of machining. The essence of the first direction lies in the use of chemical reactions between the workpiece and the chemical for directional machining. Today, this technology is referred to as chemical machining - etching.

The essence of chemical machining is the controlled etching of layers of material with a thickness of a few hundredths of a millimeter to a few millimeters from the surfaces of workpieces. Etching is based on the chemical reaction of the material being machined with the working environment, most often by acid or hydroxide. A protective coating of suitable resins or varnishes is applied to the workpiece areas that are not to be etched. 0.15 to 2 mm. Or a rubber mask is glued with a special protective sealant. The depth of the etched layer depends on the resistance of the protective coating or mask, usually up to 12 mm and more. The accuracy of the dimensions depends on the depth of the etched layer and can be in the range of a few hundreds to tenths of a millimeter. When etching to a depth of 1 to 3 mm, an achievable accuracy of 0.05 mm is given. The material is etched evenly in all directions, ie also under the mask, which must be taken into account when designing the dimensions of the mask (Fig. 10).

It is not possible to create sharp transitions and edges by etching. The transitions of the two surfaces are rounded with a radius equal to the etched thickness

h (Fig. 10). Chemical etching technology is especially suitable for machining aluminum and its alloys (these materials are most often machined in NaOH solutions). Chemical machining is economically advantageous for removing small thicknesses in thin-walled parts (especially sheet metal), low-rigid parts that could be deformed during machining, for parts of broken shapes and large areas for making flat small parts, surface polishing and the like. Chemical machining can be used for steels (also stainless), titanium, nickel and their alloys.

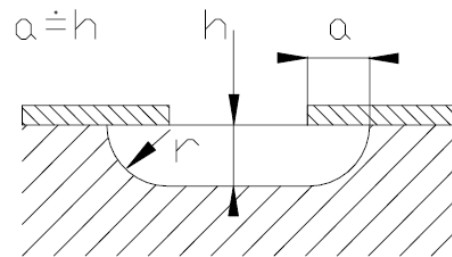


Fig. 10. Shape of etched cavity during chemical machining

Thermal deburring is a chemical-thermal process in which a flammable gas mixture is most often ignited with an electric spark in a closed chamber (in which the workpiece is stored), e.g. 2: 1 hydrogen and oxygen. During the ongoing chemical reaction, water and a high temperature are formed, which reaches a value of up to 3500 °C. This temperature affects the entire surface of the part. Due to the fact that the burrs have a substantially lower weight to surface area ratio relative to the entire workpiece, this causes the burrs to heat up to the reaction temperature in a short time and burn with the excess oxygen to metal oxides. To fully justify this method, a difference between the surface and the weight of the workpiece and the burr is required. As a result of this condition, the workpiece surface does not exceed 100 °C. This method is widely developed, but in no way can it be considered as a universal replacement for previously used mechanical methods. In any case, it is exclusively intended for deburring and cannot be used for chamfering.

The technology of thermal deburring is immediately followed by washing of products in ultrasonic washing machines. Said method of thermal deburring represents one of the possible ways of mechanization and automation of a very demanding method of mechanical, often manual method of deburring. On this occasion, it is appropriate to mention the method of deburring by the latest introduced procedure, namely high-pressure water jet, where the process is cold and no subsequent washing of the products is necessary.

3.4 Mechanical principles

3.4.1 Water jet machining

The abbreviation WATER JET MACHINING - WJM is used. High-pressure jet machining is characterized by many interesting advantages and advantages, such as e.g. the place of machining of the material, i. the cut site is cold, i. there is no thermal

loading of the workpieces. The technology is dust-free and thus highly environmentally friendly. Among other things, due to the high degree of automation, it is also highly versatile. The principle of water jet machining consists in the generated high pressure of a liquid (most often water) which, when flowing through a small diameter nozzle, acquires a very high speed (up to 3 times the speed of sound) which then acquires a very high kinetic energy capable of machining almost all known materials [19, 20].

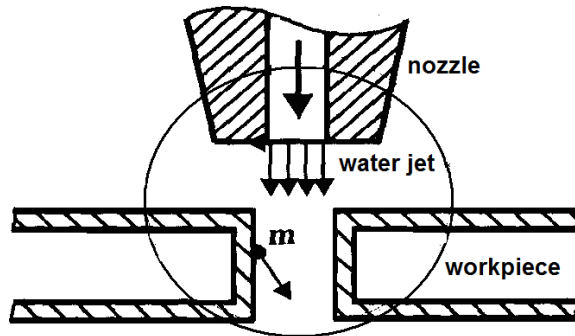


Fig. 11. Water jet machining

In technical practice, several applications of water jet machining are used, e.g. machining with a clean water jet, machining with an abrasive water jet, DIAJET system, ICE JET, etc.

3.4.2 Abrasive jet machining

In accordance with the ISO standard, this manufacturing process is referred to as ABRASIVE JET MACHINING (AJM). The essence of this technology is based on the removal of material by the abrasive effect of an abrasive carried by a stream of air at high speed. The generator of high air pressure (optimal value approx. 5 MPa) is a compressor. The compressor generates air pressure, which is conducted by the compressed air distribution and the nozzle system. The abrasive material is sucked into the nozzles by the resulting vacuum. The abrasive takes some of the energy from the air and is blasted onto the material being machined. As an abrasive, fused aluminum oxide or silicon carbide of grain size 6 is most often used (according to the STN standard it corresponds to a grain size of 60 μm). The diameter of the nozzles is approx. 3.5 mm. The recommended distance of the nozzle from the workpiece surface is approx. 10 mm. The most common industrial applications include the production of grooves and grooves in the electrical industry (silicon machining - semiconductor production) and is also used today to describe and mark car windows.

Among other things, it is also used to remove burrs and corrosion from the surfaces of materials. The application of rounding edges with flowing abrasives in the production of aircraft turbines is also interesting.

In this paper, space will be devoted to the above production process of machining materials not only technical, but also e.g. biological, etc. Many of these unconventional technologies are now well known and widespread in practice. Thanks to their exceptional properties, these technologies have found very rapid

application in the aerospace, automotive, mining, construction, chemical and food industries, healthcare due to their great versatility and in a number of other industries.

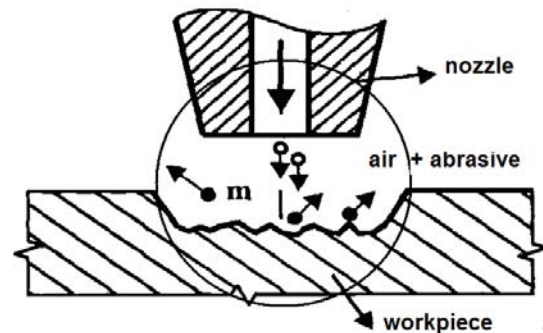


Fig. 12. Abrasive jet machining

Suitability of unconventional technologies for machining difficult-to-machine materials is proved. A summary of the possibilities of performing specific technological operations by individual methods is in [8, 14, 15, 21] shown.

4. CONCLUSIONS

This approach offers a complete short survey of each technology, thus creating a base for understanding and selecting the most appropriate technology for each.

Where the medium acting as a production tool - is a formless substance, liquid or gaseous, which various forms of energy, such as. it acts on the workpiece by mechanical energy, heat, radiation, etc., or by a chemical reaction. Shapeless substances are gases, liquids, powders, fibers, granules and the like. For the purposes of this standard, free particles with a geometrically determined shape are also considered to be formless substances.

It includes processes for the treatment of metallic, ceramic and non-metallic materials, based on polymeric as well as renewable raw materials as well as biological materials. The requirements for miniaturization of products and their components are taken into account not only in the engineering industry.

EDM processes involve transient phenomena occurring in a narrow space (order of micrometers) and in a short period of time (order of microseconds). In EDM, no force is applied to the workpiece, i. the workpiece does not have to be fixed during machining. The indicated technological applications of electroerosion have found application in technical practice.

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