The analysis and selection of methods and facilities for cutting of naturally-deficit materials

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Abstract
The comparison of perspective methods is done in the article, such as laser, plasma and combined electro-diamond methods of hard processed materials cutting. There are the review and analysis of naturally-deficit materials cutting facilities. A new electrode-tool for the combined cutting of naturally-deficit materials is suggested. This electrode-tool eliminates electrical contact between the cutting electrode-tool and side surfaces of the channel of cutting workpiece cut, which allows to obtain coplanar channels of cut.

Introduction
The rapid development of mechanical engineering, instrumentation, aviation, space industry, led to widespread use of hard, natural-deficit materials and their compositions, such as wolfram, cobalt, molybdenum, zirconium, niobium, as basic materials in the manufacture of load-bearing structures of products, where it is necessary to ensure high standards of accuracy and surface quality at an acceptable process performance.

Efficient processing of output parameters of technological processes of obtaining products from the hard and naturally-deficit materials is an important task in the conditions of modern production.

Analysis and comparison of separating materials methods
In modern industry for cutting natural-deficit, hard metals there are used traditional, such as mechanical processing, and new kinds of cutting, such as ultrasound, laser, plasma, and others [1].

Laser and plasma cutting of materials are the most modern and advanced and perspective methods which are being found more in practical use in the manufacture of hard materials.

These methods provide high efficiency of the production process and the possibility of cutting the curved contour of the workpiece, but have some disadvantages that prevent their use in the case of stringent requirements on the quality of treatment. For example, in laser cutting the grooves of certain depth, frequency and shape could occur, which together defines microgeometry of cutting area unallowable in the specific conditions of process requirements. In the case of treatment at low speeds there is the possibility of cutting mode automatically (autogenous) cutting, when there is a significant increase in the width of cut caused by the diameter of the jet of oxygen and not by the diameter of the focused laser beam.

During laser cutting it is also a probability of burr occurring on the lower edge of the workpiece as a result of surface wetting of the solid metal liquid metal and its oxide. Quantity of burrs is
depended on parameters such as the power of the radiation, the thickness of the metal, the cutting speed and the pressure of the oxygen. Moreover, it is difficult to achieve minimal heat affected zone by laser cutting [2].

During laser cutting of large thickness workpieces there is slag can be formed in the cutting zone caused by the presence of alloying elements in the material being processed. The alloying elements in compositions influence the melting point of both the composition and its oxide. In some cases, refractory oxides of the alloying elements is above the melting temperature of the base material blank, which prevents the cutting process.

As well one of the technological features of laser cutting of large thickness materials is a need for deepening the focal spot of the radiation to cut the workpiece. The consequence of deepening of the focus is the increase of the hole diameters at the inlet to cauterize the material and therefore increase the gas inside the material in the melt zone [3].

A plasma cutting is another method of separation of materials which is used in modern production. The plasma cutting process consists in the local intensity of melting metal to be cut in the volume of the cavity cut by heat generated compressed arc, and removing molten metal from the cavity high speed plasma stream resulting from the channel of the plasma torch nozzle. During plasma cutting the quality and performance of the processing are depended on the composition of a plasma environment.

The disadvantages of plasma cutting are: low resistance of electrodes; possibility of saturation of the surface of cut by air gases; dependence of deterioration of consumables cleanliness and air humidity, the thickness of metal to be cut and value of operating current. The best indicators of plasma cutting is achieved by plants, which are equipped with a contour copy, tracking and control of technological parameters of the process of cutting devices to stabilize the working distance of the plasma torch. Such devices and systems are expensive, and in many cases their use is inappropriate for cutting difficult-to-deficient and naturally-deficit materials [4].

Based on an analysis of the advantages and disadvantages considered above methods it can be concluded:
- when cutting metal materials with thickness less than 6 mm it is mostly efficient to use laser cutting;
- when cutting metal materials with thickness more than 20 mm it is more efficient to use plasma cutting;
- due to the difficulty to ensure the constancy (stability) of the parameters of laser and plasma cutting changes occur in the material layer at a considerable depth after treatment;
- possibility of a grid of cracks due to stress-strain state in the thermal overvoltage;
- use of laser and plasma cutting in the manufacture of products from naturally-deficit materials is undesirable because of the increased amount of material due to remove the altered layer;
- from economical point of view the most acceptable method is the use of combined electro-diamond cutting method, because the cutting is done with a thin disc, which is less than 1 mm and has diamond coating.

To illustrate that the proposed combined electro-diamond method is the most effective method for the separation of naturally-deficit and hard materials, there are shown in Table 1 the main differences in quality of cut between laser, plasma and combined electro-diamond cutting [5]:

Table 1. The main differences in quality of cut between laser, plasma and combined electro-diamond cutting methods.

| Indicator of quality               | Laser cut | Plasma cut | Combined electro-diamond cut |
|-----------------------------------|-----------|------------|-----------------------------|
| Taper edge                        | 0–2       | 0–10       | 0                           |
| The surface roughness $R_{\alpha}$, $\mu$m | 1.25–2.5  | 6.3–12.5   | 0.03–0.05                   |
Facilities for cutting of naturally-deficit materials

Technical problems solving of cutting deficit and hard materials by using combined electro-diamond cutting method are reflected in the derived with the participation of the authors of patents for inventions SU 1016129, SU 1641539, SU 1641540, RU 2432240, and used in the development of the machine SR 902M that enables adaptively manage the process of cutting in overall and individual components of the combination of mechanical, electrical discharge, electrochemical, hydraulic and cavitation treatments.

The cutting process of the machine starts with the formation of holes (like the punching before drilling) on the author's certificate SU 1016129. When applying the electrolyte in the electrode gap and the voltage of the additional current source available on the machine with adjustable law $V = k \times h$, where $V$ - voltage, $h$ - electrode gap, $k$ - empirical coefficient equal to 70V / mm [6].

| Reflow frames, corners | min | present | absent |
|------------------------|-----|---------|--------|
| Slag                   | min | absent  | absent |
| Grid cracks            | possibility | possibility | absent |

The essence of the invention lies in the fact that to improve cutting precision due to the decrease of the beat tool electrode, an electrolyte pressure change by a signal proportional to the amplitude of the beat converter beats tool electrode through one nozzle - in phase and in antiphase via another.

![Figure 1 Installation scheme by inventor's certificate SU 1016129](image1.png)

Figure 1. Installation scheme by inventor's certificate SU 1016129

Figure 1 shows an installation scheme for carrying out the proposed method. The scheme includes an abrasive tool 1, workpiece 2, source of operating voltage 3 power supply 4.

Stable introduction of a rotating tool made of thinsheet material, the body blank being cut, an apparatus is described in the inventor's certificate SU 1641539. The apparatus comprises a disc electrode-tool 1 for cutting the workpiece 2, the injector 3, inverters 4 beats, beats secondary converter 5, the generator 6 Supply pressure regulators 7, 8 technological current source (Figure 2).

![Figure 2. Installation scheme by inventor's certificate SU 1641539](image2.png)

The essence of the invention lies in the fact that to improve cutting precision due to the decrease of the beat tool electrode, an electrolyte pressure change by a signal proportional to the amplitude of the beat converter beats tool electrode through one nozzle - in phase and in antiphase via another.
The disadvantage of this invention is the fact that the processing of the material produced single cutting wheel, being in constant contact with the workpiece that does not provide an intensive electrochemical dissolution of the surface of the material and the evacuation of the dissolution and removal of beating tool electrode, then all this leads to rapid deterioration of electrode-tool and as a result in poor cutting (processing). Another drawback is the complex system of converters and regulators [7].

To improve the processing conditions by increasing the amount of electrolyte in the treatment zone and strengthening the electrochemical metal removal and cavitation components of the combined cutting process proposed "Extra electrode tool cutting electro-abrasive" copyright certificate SU 1641540, containing a set of disks of 1.2 combined with each other eccentrically relative to the axis of rotation of the tool-electrode (see Figure 3).

Figure 3. Installation scheme by inventor's certificate SU 1641540

Figure 3 shows a diagram of the device's certificate SU 1641540, where 1 and 2 - discs (an electrode-tool), 3 - blank, 4 - current source technology, A1 and A2 axis of the instrument.

The disadvantages of this device the collecting electrode tool is the following: when introducing an instrument into the body of the preform there is a "bump" plunge, which causes vibration of the tool and the workpiece, which reduces the quality of processing, and can also cause damage as the tool and the workpiece that generally leads to a decrease in the quality of processing [8].

To exclude the impact the introduction of the instrument into the body of the preform proposed collecting electrode-tool combination elektroalmaznoy cutting Copyright certificate RU 2432240. Extra electrode composite tool made in the form of a set of combined eccentric disc is characterized in that a set of eccentric disks introduced an additional drive, which is located relative to the axis of rotation of the tool-electrode without eccentricity and mounted between the disks with the possibility of permanent mechanical contact with the workpiece, allowing to produce smooth infeed, the eccentric wheels located on mutually perpendicular axes (Figure 4).

Figure 4. Installation scheme by inventor's certificate RU 2432240

Figure 4 shows a diagram of the device's certificate SU 2432240, where 1 - a disc without eccentricity, 2 and 3 - wheels with eccentricity, 4 - preparation, 5 - power supply E1, E2 - the axis of rotation of the tool.
Because of the disc 1 without eccentricity, located in the center of the disks with an eccentricity of 2 and 3 is provided by constant contact between the disk 1 and the workpiece 4, it promotes "unstressed" (smooth) plunging alternately drives 2 and 3 of the workpiece. When this vibration tool electrode does not occur.

Disadvantages tool electrode Copyright certificate RU 2432240 are: the introduction of an instrument into the body of the preform, an electric interaction between the side peripheral metal conductive strip holding diamond granules and cut the side surface of the workpiece, which causes non-uniform electric metal removal and receipt of the inclined cut surface, which reduces the surface quality and requires additional processing and increases the complexity of the process [9].

**New electrode-tool for naturally-deficit materials cutting**

The above illustrated methods have given some positive results, but does not completely eliminate the problem of uncontrolled removal of metal from the side surfaces of the channel cut. Design features of the buildings considered diamond discs (whole-metal material) does not allow the process to locate an electric pickup to a point and carry out the process at the minimum clearances.

We are offering fundamental solution to the problem of an uncontrolled removal of metal from the side surfaces of the channel of cut. The essence of the new method is described in the patent’s application "Electrode-tool for combined cutting of conductive materials." The design of a new electrode-tool has nanomaterials and composites. In the present option, there is no uncontrolled permanent electrical contact between the electrode-tool and the workpiece, so that the side surface of the channel obtained by coplanar cut.

The principal difference between our method from the existing ones that due to the design of the proposed tool, it excludes side etching, which is present in all previous studies. Due to the presence in the electrode-tool conductive composites of carbon fiber processing is provided on a soft mode (microcurrents). A positive result of a new electrode-tool is the exclusion of additional processing operations to eliminate uncoplanar surface channel cut that does not require additional costs.

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