PLASMA HARDENING AND RECONDITIONING OF THE WORN DETAILS

G.GELENIDZE, T.GOCHITASHVILI, G.GOGIA

In the presented work the combined method of Plasma hardening and reconditioning is described. Method considers a preliminary zoned heating of the processing surface by a plasma torch, building-up manually with a wear resistance electrode, and further building-up of a surface again with plasma torch for burning-off and levelling of a surface. Finally, a plasma jet will make tempering a built-up layer. This technology is developed for one of the most complex case of deterioration – hydroabrasive deterioration of driving wheels of turbines and earth pumps.

Key words: Turbine, plasma torch, plasmatron, cycle-converter, matching transformer.

The most widely widespread method of hardening and reconditioning of the details, undergone to hydro-abrasive wear, is manual electric arc building-up of the structural materials (especially in the field conditions). However this method is accompanied by occurrence of cracks and roughness on built-up surfaces, which significantly reduces efficiency of rehabilitation. In the presented work the combined method of Plasma hardening and reconditioning is offered. Method considers a preliminary zoned heating of the processing surface by a plasma torch, building-up manually with a wear resistance electrode, and further building-up of a surface again with plasma torch for burning-off and levelling of a surface. Finally, a plasma jet will make tempering a built-up layer.

This technology is developed for one of the most complex case of deterioration – hydroabrasive deterioration of driving wheels of turbines and earth pumps.

The two variants of the technique of plasma restoration of driving wheels turbine and earth pumps is developed as well:

1. Plasma technology of restoration of driving wheels turbine and earth pumps with manufacturing of new blades.

The technology includes the following technological receptions of plasma restoration:

- **Removal of blades from the driving wheels turbine and earth pumps. It will be used a technique of the preliminary cutting of blades with the special plasma torch and then turning on the mechanical machine tool.**
- **Blades of a corresponding design will be castled separately.**
- **Blades will be fixed on the processed wheel mechanically.**
- **Preliminary zoned heating by a plasma torch will be made.**
- **Blades will be welded on a wheel.**
- **Built-up of a surface will be proceeded with plasma torch – burning-off and levelling of a surface.**
- **The plasma jet will make tempering of a built-up layer.**

2. Plasma technology for restoration of driving wheels turbine and earth pumps with repairing of the worn out blades.

The technology includes the following technological receptions of plasma restoration:

- **Plasma processing of roughness of the worn out surfaces of blades.**
- **Cutting of facets from the broken segments of blades with the plasma torch.**

- **Manufacturing of a fire-resistant pattern for erection of welded walls of blades.**
- **Drawing of a welded seam.**
- **Plasma processing of each welded seam before drawing the following welded seam.**
- **Plasma processing of all welded surfaces - burning-off and levelling of a surface.**
- **The plasma jet tempering of a built-up layer.**

For performance of these purposes is elaborated the mobile arc plasma device with high - energy efficiency, self-stabilizing and self-cleaning arc plasma torch (further plasmatron), power source with cycle-converter and voltage multiplier, or inductive-capacitive converter the voltage source in the current source.

Advantages which one ensure broad application and broad volume of sales to the offered plasma device are:

1. The operate reliability, which one is ensured with raise of resource of a plasmatron by means of the mobile composite pivotal cathode of the compacting, made by a method, by a blast wave or magnetic impulse of high intensity (USSR Invention Certificate №332963) and applying of the power supply with properties of an current source: the inductive-capacitive converter of a voltage source in an current source (Patent of USA 4378522).

2. By mobility of the plasma device, which one is ensured by development of self-cooled and stabilizing plasmatron eliminating necessity of an external water-supply and gas supply, and also applying of the power supply with doubling frequency (cycle-converter) and voltage multiplier or power supply with properties of an current source: the inductive-capacitive converter of a voltage source in an current source.

3. With energy-efficiency of the plasma device - that is ensured by development of a plasmatron in which the heat taking off from a plasmatron for cooling is reverted in a plasma jet. Thus the efficiency of a plasmatron is increased on 10-15 %.

4. By ecological purity plasma device - which is ensured by them, that the plasma jet forming gas, instead of air, is formed by the steam, getting at cooling of units of plasmatron.

The developed plasma device is focused on developing the simple, inexpensive, reliable, high energy efficiency, ecological and low running cost mobile plasma device for the hard materials treatment.

To achieve such goals some very novel technical solutions have to be used and developed like (a) new composite (bi-component: shell-core) cathode made by the explosive welding method, (b) automatic, self controlled feeding of the cathode into the torch area to compensate the erosion due to metal consumption; (c) special dual feed air jet arc stabilization method where design requires strong theoretical modeling effort, (d) new plasmatron's power source with cycle-converter and voltage multiplier teamed together characterized by low cost and low weight (weighing three times lesser than any traditional power source and costing about ten times lesser that inverter power sources) or inductive-capacitive converter the voltage source in the current source.

Some of the required development solution are already protected by USA patents and 28 USSR Invention Sertificates.

The commercial value of such novel development has already been proven by the fact that German company " Ferrostall AG " has acquired the exclusive license on operational principle of the welding cycle-converter (the technical solution partially used in proposed project), restricted to German territory.

The manufacturing techniques of the cathode of the plasmatron will consist in the following:

Nowadays, the routine technology for embedding zirconium or hafnium rods into the copper hoop does not fully meet technical requirements since there does not exist any transient zone between the hoop and embedded rod and because of it the lifetime of the plasmatron's cathode is reduced.

The increase of the heat-resistance of long composite cathodes is provided by the formation of a transient zone between the hafnium or zirconium rod and copper hoop.

The applications of the hot explosive compression technology and experiments under heated conditions permit to obtain composite cathodes without any crack and porous with simultaneous formation of the wide transient zone upon the whole length of the cathode. This provides a significant improvement of the cathode's heat-resistance and increases the lifetime.

There is to be taken into consideration that in the Mining Institute was developed and put into operation semi-automatic explosive robot-device enabling to consolidate and treat long compound samples within the wide field of loading conditions (T=20-1200C, loading intensity - 5-30 GPa).

Also important factors for the mobile plasmatron are its weight, complexity and the power source's cost as the application of the plasma apparatus. Below is described the core of the technical solution of the problem:

Welding AC/DC converters at present being in use for feeding the plasmatron may be divided into two types: traditional converters the main transformer of which is being fed by the supply-line with 50 Hz, and inverters the main transformer of which is being fed by the preliminary converted voltage with the bigger frequency (1000-1500 Hz).

Traditional AC/DC converters are simple and inexpensive, however they have huge weight and dimensions while inverters have small weight and dimensions but are complicated and expensive.

The cycle-converter with the voltage multiplier occupies the intermediate position between traditional AC/DC converters and inverters. In the AC/DC converter instead of the inverter is used cycle-converter - simple direct frequency converter from 50 Hz to 100 Hz, which at the same time is a regulator of the welding current. The cycle-converter is simple to such extent that it is simpler than the common thyristor regulator of welding current of traditional AC/DC converters. So, without complicating the circuit there is achieved the double reduction of weight dimensions. Besides, it is foreseen to install on the AC/DC converter's output the voltage multiplier that will allow decreasing by 1/3 the voltage of idle running of the AC/DC converter's main transformer. Consequently, weight and dimensions of the main transformer will be decreased by 1/3. The simplicity and cheapness of the voltage multiplier also is provided by the simplicity of the circuit that allows using small-size and cheap DC capacitors. As a result, the proposed cycle-converter with the voltage multiplier has a weight three times as smaller than traditional AC/DC converters and two times lesser cost.

The principal diagrams of developed plasma devices and their basic units, and also technology providing receiving of these results are explained below.

On Fig.1 the plasma device a containing self-blown plasmatron and power supply with the cycle-converter and voltage multiplier is exhibited.

At operation of a plasmatron the arc 1 burns between the composite pivotal cathode 2 and treated item 3. Air entering either from the micro fan or from the micro compressor 4

chills the cathode 2. The cathode 2 has a multiple thread for air delivery in an arc forming spaces 5 in a twisted form and also metric thread for feed the cathode 2 to an arc to forming space in accordance with its burn-up. Air entering from the micro fan after blowing of the cathode 2 is partitioned on two parts: one part enters in an arc forming space and other part blows in an anode 6 and follow-up crimps an arc 1. Thus all heated air enters in a spray of plasma.

The cathode is contained a copper socket sleeve 1 and cathode insert 2 (Fig-2). A cathode insert 2 can be a metal hafnium either zirconium or powdered mixture (Fig.3).

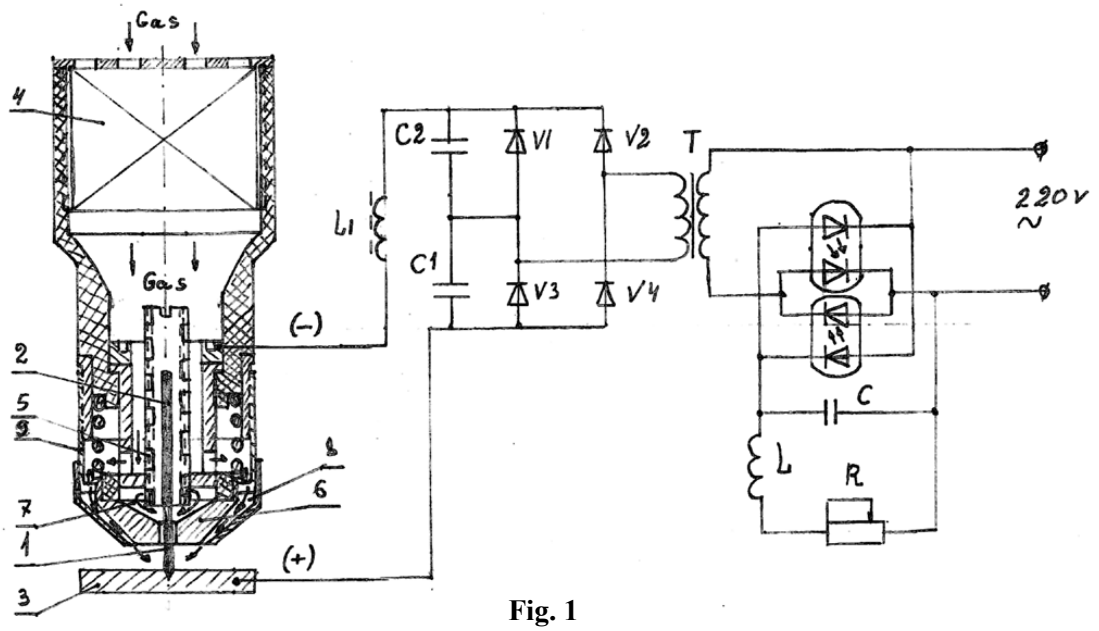

Fig. 1

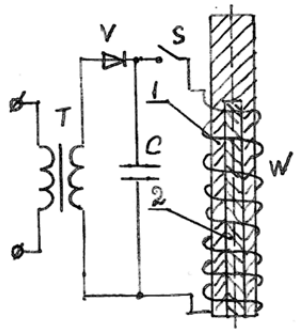

Fig. 2

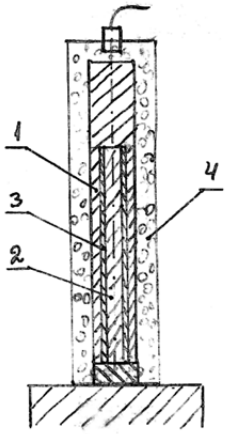

Fig. 3

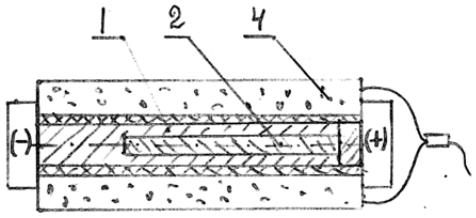

Fig. 4

The production process of the cathode is follows:

In first case the composite cathode is place inside the magnetic concentrator W (Fig.2) of magnetic pulse installation, composed from the transformer T, rectifier V, capacitor bank C and contactor S. At closing of a contactor S through the magnetic concentrator W there is an impulse the magnetic field of high intensity, the insert 2 is pressed by a wall of a socket sleeve 1. - In the other case the composite cathode is located in an explosive (Fig.3

and 4). At detonating the shock blast wave compacts the cathode. The composite cathode previously can be heat up to definite temperature (Fig.4). The plasma device, schematic drawing which one is exhibited on Fig.1, is supplied with the power supply, which one differs by the small cost price and simplicity of the schema that is obviously considered on Fig. 1. In a primary circuit of a power transformer T two optrons (V5 and V6) are included; on control electrodes which one enters impulses clocked with a web (assigning is R, L and C). The optrons alternately are unlatched approximately by angle of opening $=90^0$. Coefficient of self-inductions of the transformer T is selected so, that the optron is locked at coal of lockout $=210^0$ -240^0. It equivalently to that the transformer feeds a current by frequency of 100 Hz, that twice reduces bulk of the transformer. Same R, L and C serve a current controller of a plasmatron. On an output of the transformer the rectifier with a voltage multiplier (C1 and C2) is established, that twice augments no-load voltages of the power supply. It also approximately twice reduces bulk of a power transformer. In result the minimum is three times reduced bulk both dimensions of the power supply and minimum 2 times the cost price of its manufacturing.

The best weight-dimension factors have inverter power supplies, but they at 5-10 of time more dearly offered power supplies. Is developed of the plasma device introduced on Fig.1 in two alternatives: a) of an independent arc and в) of a dependent arc.

Advantages of this form of developed plasma devices are: mobility (absence external water and gas supply); service life of a plasmatron is some times increased (that is ensured with a construction and production process of the cathode); the small weight, dimensions and cost price of plasma setting (it is ensured with applying of the power supply with the cycle-converter and voltage multiplier).

On Fig. 5 the plasma device to the containing self-stabilized and self-cooled own ferry of water a plasmatron and power supply with properties of an current source inductive-capacitive converter of a voltage source in an current source is exhibited.

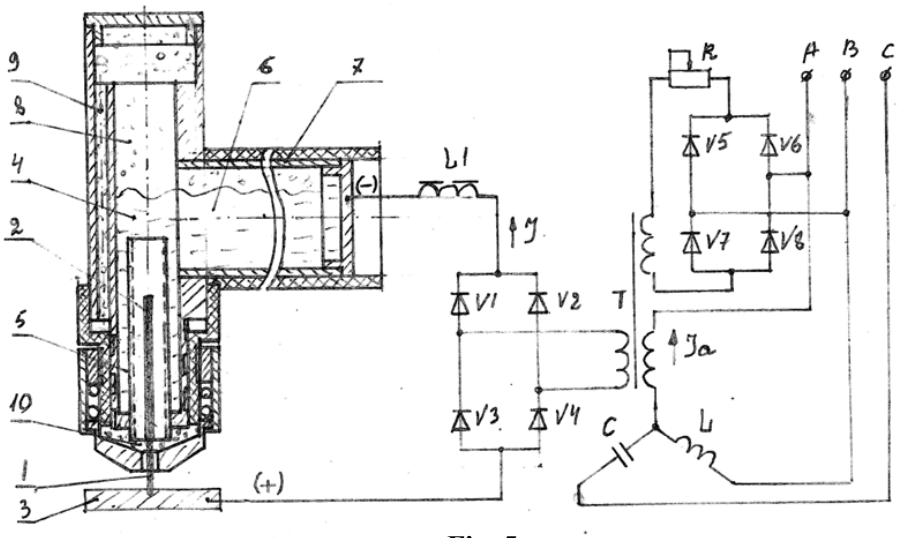

Fig. 5

By operation of a plasmatron (Fig.5) the arc 1 burns between the composite pivotal cathode 2 and treated item 3. Cathodes 2 are chilled by water 4, by which one the plasmatron previously charges also which one occupies cavities 5 and 6 plasmatrons and its hand levers

7. At burning an arc by 1 heat acting from the cathode 2 waters boil and evaporates. At boiling the water samples heat for the cathode and chills it, and the vapor 8, formed thus, through openings 9 enters in an arc forming space 10 and there is a plasma jet forming gas. The plasma jet 1 forming from vapor of water is applied to processing a material. Necessity the external water and gas supplies thus passes.

Thus the plasmatron feeds from an adjustable current source (Patent of USA №4378522), containing the inductive-capacitive converter the voltage source, in a current source. It consists of a matching transformer T and reactance components L and C, which one are included in a star by one shoulder which one is the matching transformer T, we echo lagging from maiden on a phase a choke L, and third - bank of condensers seconds. At what a choke L and capacitor bank with are selected thus that their reactance X_L and X_C are equal one another. It is known, that thus the current branches I_A does not depend on magnitude of a load and on this the current of an arc I remains invariable.

Advantages of applying of the power supply of this type is encompass by following: It is known, that at burning an arc of a plasmatron of an indirect action it is possible to supervise three characteristic frequencies of oscillation of a voltage: low frequency oscillation with frequency of the order of 300 Hz; large-scale oscillation with frequency of the order 10 кHz; and small-scale oscillation with frequency of the order 100 kHz. Thus amplitude of oscillation of a voltage with frequency of the order of 300 Hz and 100 kHz (5-10) % from rated voltage lay in limits and influence repeatability of operation of a plasmatron a little. However amplitude of oscillation of a voltage by frequency 10 kHz can reach (50-60) % from nominal and have the relevant significances for a stable operation of a plasmatron.

The respective amplitudes of variation of a current of a plasmatron thus depend on static and dynamic properties of the power supply. On this the relevant significances is attached to development of the power supply at which one of amplitude of variation of currents thus will be minimum. It can be reached by applying of a theoretical current source having theoretically rigid static and dynamic characteristic on a current. The analysis of experimental processes of operations of miscellaneous types of power supplies of plasmatrons, and also on dates preliminary study most eligible is the inductive-capacitive converter of a voltage source in a current source (ICT).

Analysis of electromagnetic processes of operation of systems: ICT- the plasmatron demonstrates that at any perturbations on an arc (miscellaneous instability and emergency operation) the current of an arc cannot exceed rating value. Any current oscillation thus are confined and this safeguards the cathode and anode of a plasmatron from destroying.

In the introduced plasma device such schema ICT is offered, in which one between a phase of a load and circuit of an arc the transformer with a magnetic biasing is included. In this schema the current of an arc sets by a current magnitude of a magnetic biasing, that is impossible at a voltage source, as, in the latter case magnetizing of the transformer calls magnification of a primary current. At a current source the primary current will be changed can not and therefore the transformation ratio of a current is changed. Thus applying of the new schema ICT ensures smoothly varying regulation of a load current that is current of a plasmatron.