"Victoria" Plant Design

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Abstract – In the given article we consider different variants and characteristics of plants for combined vacuum ionic implantation and ionic plasma methods hardening of steam turbine blade of steel and titanium alloys and also constructive and technological peculiarities of the universal plant allowing to apply combined technologies to harden both steel and titanium blades of steam turbines.

The combined vacuum ionic implantation and ionic plasma technologies are used to harden steam turbine blades (STB) made of steel and titanium alloys what helps to increase their steam wet erosion resistance in more than 3 times.

To apply these technologies for STB of titanium alloys L = 1315 mm long we have designed and produced "Maria" vacuum plant and introduced it into industry at FSUE "SPE "Motor" (Ufa city). The vacuum chamber from ЭЛУ-9Б used in the plant was supplied with a manipulator mechanism for horizontal fastening, positioning and transportation of two STB, two sources of gas and four sources of metal plasma (see Fig. 1).

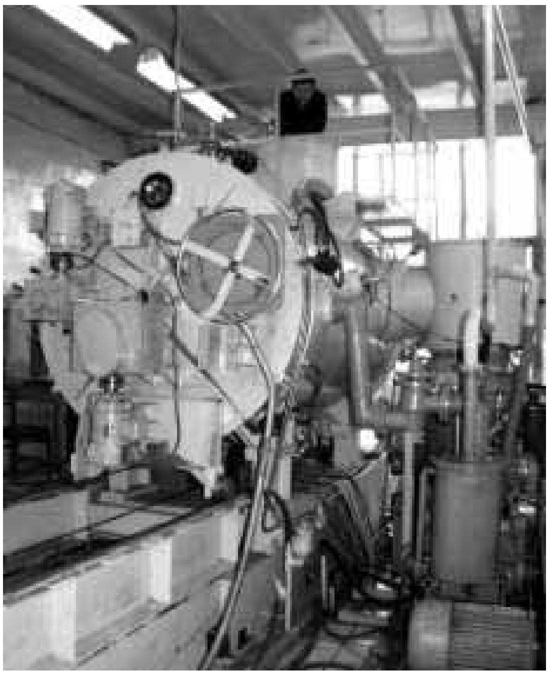

Fig. 1. Outer view on "Maria" plant for titanium STB treatment

For STB of steel 20X13 and 15X11MФ L = 640–960 mm long the treatment in a vacuum plant with horizontal fastening would be inaccessible because of the following:

– deposition of neutral plasma particles, droplet phase and other flying particles on STB fan profile that would disturb surface uniformity and as a result would lead to activation of erosion and corrosion processes when being operated;

– location of metal plasma sources and their simultaneous spraying on the whole length of a blade fan that would lead to creation of zones with high thickness and zones with deficient coating thickness failing to provide corrosion and erosion resistance.

To apply steel blades hardening with combined ionic implantation and ionic plasma treatment, we have designed and produced "Victoria" vacuum plant (see Fig. 2). The plant allows to increase service properties of STB of steel by way of ionic implantation and protective coating deposition in a single technological cycle.

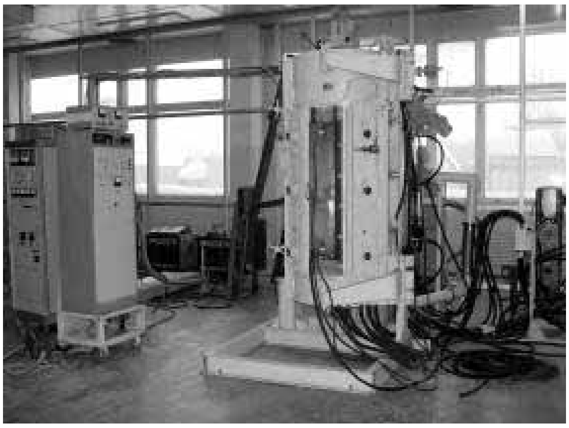

Fig. 2. Outward appearance of "Victoria" plant

As the sources of gas and metal plasma we applied a planar electroarc evaporator (EAE) with a flat cathode 1000 mm long providing two-stage vacuum arc discharge (TVAD) of gas plasma with high concentration of charged particles (Ar^+, N^+). Planar EAE provides the following characteristics:

– current of arc discharge 150–1000 A;

– displacement speed in the area of cathode spot along the cathode length up to 10 m/s;

– opening angle of metal plasma ~ 90°;

– consumption of cathode material (Ti) – 30–140 g/h;

– density of net current – 5–25 mA/mm^2;

– irregularity of ion current density at 1000 mm length – no more than 10%.

In TVAD mode the planar source provides:

– ion density of gas plasma – 5–20 mA/cm^2;

– irregularity of net current density at 1000 mm length – no more than 10%;

– current strength at electronic heating makes up 40–60% out of current strength of arc discharge.

The planar electroarc evaporator comprises an expanded rectangular cathode fixed on a cooled “bed” detached from plasma steam with a screen. The auxiliary arc is lighted by way of pressure supply to the cathode through a resistor. The lighting device is located on a cathode butt. Two probes with alternating pressure supply on every probe carry out the dislocation control on cathode spots. The lighting device operates in an automatic impulse mode with frequency no less than 10 Hz that provides arc repetitive stimulation at its quenching.

As a high voltage source for negative removal supply on blades we have chosen a source with a block of microarc suppression with the following characteristics:

– capacity – 30 kVt;

– range of pressure adjustment – 50–1000 v;

– ion current strength:

at I = 1000 v – I_i = 25 A,

at I = 150 v – I_i = 160 A;

– operating speed of microarc detection system – 3–50 mks.

To increase the efficiency of plasma application and increase the production capacity the article holder of the given plant consists of separate insulating sections according to the number of EAE possible to connect by means of switches both to the independent negative outlets of a source of removal potential and to the positive pole of TVAD power supply independently of one another.

The above gives the opportunity to treat simultaneously one article group with plasma electrons and the other with plasma ions. In addition both electron and ionic plasma components are used simultaneously that economizes power and material consumption. The articles installed into the section of article holder connected to the positive pole of TVAD power supply turn out to be anodes to TVAD and are subjected to efficient heating by electrons. The articles installed into the section of article holder connected to the negative outlets of a source of removal potential are subjected to ionic implantation.

The article holder of the given plant can be produced to have a possibility to install sets of articles into it. Thus, at a single cycle we can observe treatment of several small-sized articles instead of one long-sized one. This provides high production capacity of the plant at small-sized article treatment.

The device is illustrated with Fig. 3. In Fig. 3,a there is a constructive scheme of the given plant. In Fig. 3,b there is a vacuum chamber with a connected section. In Fig. 3,c there is a set of articles installed into article holder.

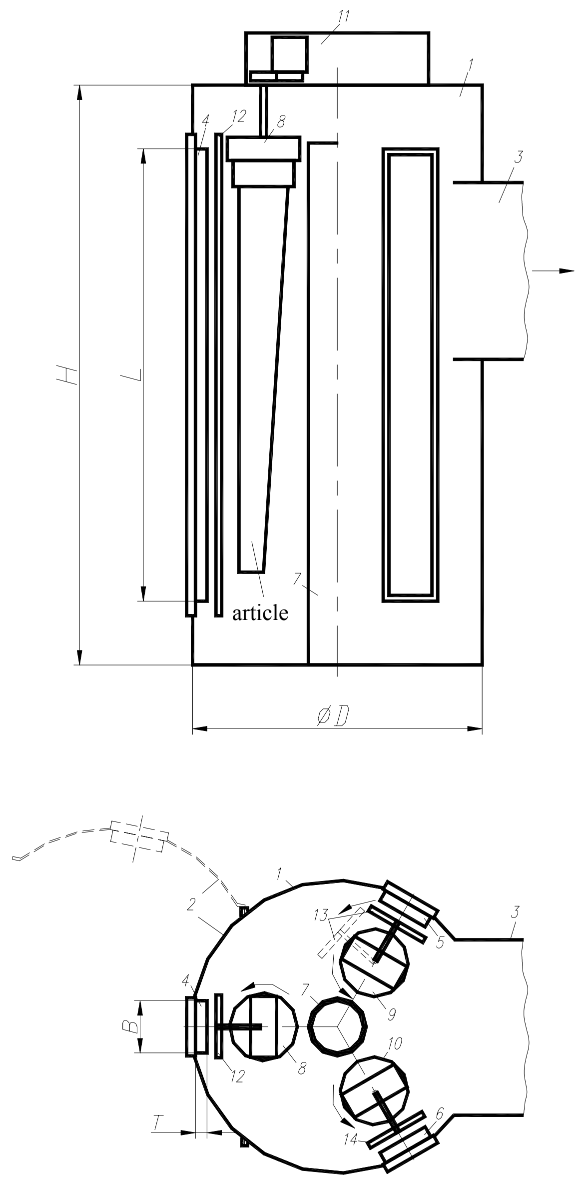

Fig. 3. “Victoria” plant device. *3a* – constructive device scheme; *3b* – vacuum chamber with a connected section; *3c* – set of articles installed into article holder

The plant for complex vacuum ionic implantation treatment comprises vacuum chamber *1* designed in the form of hollow rotation cylinder with H height and D inner diameter having door *2* and exhaust tube *3*. EAE are installed on the walls of vacuum chamber *1* with EAE cathodes *4*, *5*, *6* arranged in vacuum chamber *1*. Additional electrode is installed in the form of rotation cylinder in the center of vacuum chamber *1*. Sections of article holders *8*, *9*, *10* are possible to rotate and are connected to gear *11*. Rotary optically opaque screens *12*, *13*, *14* are installed between every EAE cathodes *4*, *5*, *6* and the correspondent section of article holder *8*, *9*, *10*.

EAE cathodes *4*, *5*, *6* are connected to the negative poles of VAD power supply, which positive poles are connected to the earthed vacuum chamber. Additional electrode *7* is possible to be connected to the positive pole of TVAD power supply by way of a key. Sections of article holders *8*, *9*, *10* are possible by means of switches to be connected independently of one another both to the independent negative outlets of the removal potential source and to the positive pole of TVAD power supply. The vacuum chamber, negative pole of TVAD power supply and positive pole of the removal potential source are earthed.

The plant vacuum chamber is possible to connect additional sections 24.

The plant operates in the following way. The treated articles are installed into sections of article holders. When the door of the vacuum chamber is closed, vacuum is pumped into the vacuum chamber, and the gear of article holders is switched on.

After, the articles are treated in one of the following ways: heating, ionic implantation, coating deposition and their combination.

The articles are heated to treat them thermally and to prepare them for subsequent treatment, for example, for coating deposition. The articles are heated in the following way. Working gas is pumped into the vacuum chamber. Rotary optically opaque screens cover EAE cathodes. VAD is switched on between EAE cathodes and the vacuum chamber that serves as VAD anode. By means of switches articles are connected to the positive pole of TVAD power supply and TVAD is switched on between EAE cathodes *4*, *5*, *6*, and the articles. In this case the articles, which are EAE anodes are heated intensively by TVAD plasma ions.

Ionic implantation is carried out in the given plant in the following way. Working gas is pumped into the vacuum chamber. Rotary optically opaque screens cover EAE cathodes. VAD is switched on between EAE cathodes and the vacuum chamber that serves as VAD anode. Connecting an additional electrode to the positive pole of TVAD power supply TVAD is switched on between EAE cathodes and the additional electrode that serves as TVAD anode. As a result of TVAD combustion gas plasma is produced in the chamber that contains working gas ions, electrons and neutral particles. The articles subjected to ionic implantation are supplied by means of switches with negative potential from the removal potential source sufficient for ionic implantation. In this case plasma ions of working gas are accelerated in the article electric field and are introduced into their surface.

Coating deposition in the given plant is conducted in the following way. Working gas is pumped into the vacuum chamber. EAE cathodes are opened and rotary optically opaque screens are put aside. VAD is switched on between EAE cathodes and the vacuum chamber that serves as VAD anode. As a result of TVAD combustion metal gas plasma is produced in the chamber that contains working gas ions, metal ions of EAE cathode, electrons and neutral particles. The articles are supplied by means of switches with negative potential from the removal potential source. In this case plasma ions of working gas are accelerated in the article electric field and are deposited on their surface forming a coating. When active gases are applied as working gas, working gas ions are connected with metal ions to create a coating of metal and non-metals combination.

The worked out plant allows to conduct thermal treatment, coating deposition and also ionic implantation of articles. Due to technological enhancement the given plant replaces several devices: a heating treatment furnace, a device for chemical thermal treatment, a device for ionic implantation and a device for coating deposition. When combining in a single cycle different processes, for example, ionic implantation and coating deposition or ionic implantation and thermal treatment we can get complex vacuum ionic plasma treatment that one the one hand increases the quality of treated articles, on the hand decreases treatment cost. Due to one-cycle treatment combination of ionic implantation and coating deposition, the quality of treated articles greatly increases: coating adhesion, fatigue limit of treated articles. Due to process alternation of heating, soaking, ionic implantation, coating deposition in a single cycle, it is possible to get new physical, mechanical and service properties of article surface.