N. GRECHANYUK, I. MAMUZIĆ, P. SHPAK

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MODERN ELECTRON-BEAM TECHNOLOGIES OF MELTING AND EVAPORATION OF MATERIALS IN VACUUM, BY USED "GEKONT"-COMPANY, UKRAINE

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In this reviews modern ways, examples of operational use of electron-beam technologies are shortly submitted. Also are described of its advantage and prospect for its development. In the article examples of successful operational use of electronbeam technologies in applied material science and industry are adduced.

Key words: *electron-beam technology, protective coatings, composite materials, electrocontacts material*

Suvremene elektrono-lučne tehnologije topljenja i isparavanja materijala u vakuumu, rabljenih u tvrtki "GEKONT", Ukrajina. U članku su ukratko prikazani primjeri praktične primjene elektrono-lučne tehnologije. Dane su prednosti i perspektive razvitka. Navedeni primjeri njihove uspješne primjene u industriji.

Ključne riječi: *elektrono-lučna tehnologija, zaštitne prevlake, kompozitni materijali, materijali za elektolučne kontakte*

The development of economics of any state bodily depends on a level of development of science and application of high and modern technologies. One of newest, dynamically developing and perspective technologies widely used in applled materials technology, is the electron-beam technology.

Modern concept the electron-beam technology are includes:

- electron-beam melting;
- electron-beam evaporation (EB-PVD) and subsequent condensation in vacuum of metallic and non-metallic materialss by covers or massive bars, unbound from a substrate, of composite materials, powder and etc.;
- electron-beam welding;
- electron-beam treatment.

The modern level of development of EB-technologies, which have used in the Research and Producing Company "GEKONT", Ukraine has reviewed.

ELECTRON-BEAM MELTING

Electron-beam melting is widely applied in the world practice to producing metals high-melting, high-reactionary and precision alloys of high purity [1,2]. It is one of the most effective ways of increase of metal purity from parasitic and non-metallic impurity, and also elimination of a chemical and structural non-uniformity.

In the "GEKONT"-company the industrial electron-beam equipment permitting to produce ingots of metals and alloys by diameters from 60 up to 140 mm, length up to 2000 mm and slabs by the sizes 140x160x2000 mm.

The new generation of the electron-beam equipment, designed in the "GEKONT" company, allows to produce ingots by diameters up to 300 mm, length up to 2000 mm and slabs 300x300x2000 mm.

Exploited in the "GEKONT"-company the electron-beam equipment will be widely used:

- for producing ingots and slabs of copper of heightened purity used hereinafter for manufacturing of essential parts of nuclear power engineering;
- of ingots of zirconium also used in the nuclear power engineering;
- of ingots of alloys MeCrAlY, where Me-(Ni, Co, Fe), for protective coatings, used for deposition, on turbines blades;
- of ingots and slabs of titanium and its alloys by used in an aeronautical and chemical engineering;
- of ingots of a high-speed steel R6 (W6-Mo5-V2) for effecting a high performance cutting tools [3, 4].

N. Grechanyuk, P. Shpak, Scientific Production Enterprise, Gekont, Ukraine, I. Mamuzić, Faculty of Metallurgy, University of Zagreb, Sisak, Croatia

In stage of industrial approbation there are new technology of production of ingots:

- of alloys: nickel-chromium, nickel-chromium-aluminium - for the producing of strand for heating elements;
- of alloys: a chromel-copel, chromel-alumel - for the producing of thermocouples strand.

In a development stage there are also other technologies of obtaining of ingots and slabs by the electron-beam melting.

ELECTRON-BEAM DEPOSITION OF PROTECTIVE COATINGS

In economically developed countries electron-beam evaporating and the subsequent condensation of metallic and non-metallic materials in vacuum has used for creation protective and, first of all, heat-protective coatings on turbine blades.

The modern heat-protective coatings, having the greatest operational resource, put on a defended item basically by the two-steps of technology. On such ways, in particular, there was the American company "Pratt and Whitney". An internal metallic layer Ni(Co)CrAlYHfSi- deposits by the plasma spraying, and external ceramic layer (ZrO_2-Y_2O_3)- by electron-beam deposition.

Figure1. **General view of electron-beam equipment for deposition of protective coverings**
Slika 1. **Pogled na elektro-lučno postrojenje za nanošenje zaštitne prevlake na lopatice turbine**

The similar engineering solution is conditioned also by that until recently indispensable quantity of yttrium, hafnium, silicon and zirconium in an internal metallic layer by electron-beam technology, vaporization from one crucible was not possible. The new generation of the electron-beam equipment was designed by "GEKONT"-company for a deposition of heat-protective coatings (Figure 1.) allows to decide a problem of the introducing practically of any quantities of addition elements in standard heat-resisting alloys MeCrAlY, including Hf, Si, Zr, Y etc. It opens new feasibilities of electron-beam technology for perfecting heat-protective coatings:

- at the approximately equal cost of the plasma spray and electron-beam equipment and material inputs on a deposition heat-protective coating, the application of EB-PVD technology will be more economically expedient, as the deposition of composite two-layer coating, such as MeCrAlYHfSi/ZrO_2-Y_2O_3 implements on one type of equipment and, probably, for one work cycle;
- this type of facility allows to obtain the concentration graded heat resistant metallic layers more easier in comparison with plasma spraying technique;
- in the case of getting two-layered coatings the EB-PVD technology allows also to obtain the dispersion strengthened metallic first layer with oxide, carbide or boride particles;
- it is possible to obtain heat-protective multi-layer coatings with alternating micro-layers such as Me/Me, Me/MeO, Me/MeC, Me/MeB_2, MeO/MeO, MeO/MeC with a micro-layer thickness within a range 0.001 ... 10.0 - 30.0 μm;
- the available equipment allows to start the development of new types ceramic materials for thermal barrier coatings with an increased toughness and with a self curing effect at the expense of fine particles and micro-layers to cure the micro-cracks formed during thermal cycles in a ceramic top layer;
- using this EB-unit type gives a possibility to develop EB-PVD technology, to deposit new metallic materials (for example, Cr alloys) as the heat resistant coatings. It is also important direction of our further investigations.

Now the "GEKONT"-company has produced heat-protective coatings on turbines blades by electron-beam evaporating of ingots MeCrAlY, MeCrAlYHfSiZr and ceramics on the basis ZrO_2, stabilizing Y_2O_3. [5]

Three classes coatings are designed:

- single-layer metallic such as MeCrAlY, MeCrAlYHfSiZr;
- single-layer micro-laminate composite such as with alternation of layers MeCrAlY (MeCrAlYHfSiZr)/MeCrAlY(MeCrAlYHfSiZr + MeO), where MeO-Al_2O_3 or ZrO_2 + 6 ... 8 mas. % Y_2O_3;
- two-layer coatings with internal metallic MeCrAlY (MeCrAlYHfSiZr) and external ceramic (ZrO_2-Y_2O_3) layers;
- two-layer coatings with internal composite layer MeCrAlY (MeCrAlYHfSiZr) + MeO dispersible-hardened or micro-layer types and external ceramic (ZrO_2-Y_2O_3) in layers;
- three-layer coatings with internal and intermediate in layers on the basis of alloys MeCrAlY (MeCrAlYHfSiZr) and external ceramic layer on the basis of ceramics (ZrO_2-Y_2O_3);
- three-layer coatings with internal metallic MeCrAlY

(MeCrAlYHfSiZr), intermediate composite MeCrAlY (MeCrAlYHfSiZr) + MeO dispersion-hardened or micro-layer types and external ceramic (ZrO_2-Y_2O_3) in layers;

The application of protective coatings allows:

- to increase durability of the workers and guide vanes in 2 ... 5 times;
- to increase an operation temperature of gas and efficiency of the turbine;
- to supply(ensure) more complete combustion of fuel;
- to use low-cleaned fuel.

Productivity exploited in the “GEKONT”-company of the industrial electron-beam equipment: 20 ... 50 thousands coated blades annually, depending on their geometrical sizes. The sizes of coated blades: length up to 400 mm; diameter up to 220 mm.

PRODUCING OF MATERIALS FOR THE ELECTRICAL CONTACTS

Despite of broad application of an electron-beam technology for deposition of protective coatings of a different functionality, until recently there were no claimed unique capabilities of the given technology for obtaining massive materials, semifinished items, sheet bars, powders, metal paper and etc.

The modern electron-beam aggregates allow to receive up to 10 ... 15 kg a vapour per hour and consequently quite actual is obtaining items from the vapour up to 100 kg and more are powerful.

The “GEKONT”-company has designed and patented the new industrial technology of obtaining of materials for electrical contacts, which are not having of clones in the world [6, 7]. General view of the industrial electron-beam installation for obtaining materials for electrical contact has shown in a Figure 2..

Figure 2. **General views of electron-beam installation for obraining composite materials for electrical contacts**
Slika 2. **Pogled na elektro-lučno postrojenje za pridobivanje kompozitnih materijala za elektrolučne kontakte**

The materials (Cu- 8 ... 4 mas. % Mo- 0.05 ... l mas. % Zr- 0.05 ... 0.l mas. % Y), not keeping extremely scarce argentums, tungsten, cadmium oxide, receive by highvelocity electron-beam evaporating of dilute coppers alloy and molybdenum and subsequent condensation of a blended steam flow in the vacuum on the substrate, heated up to 580 ... 600 °C. The previously marked adherent provides mild separation of the condensed sheet from a substrate. The condensed materials represents disk sheet bar a diameters up to 1000 mm and depth up to 4 mm, from which one was carving the working section of a contact and soldering on the its basis. The specificity of new technology is formatting special micro-layer structures with depth of alternating layers from 0.1 up to 0.4 microns, owing to what the contacts have higher complex physical-mechanical and service properties as contrasted to by used now materials has received powder metallurgical techniques.

The main advantages of new materials:

- it do not contain argentums and consequently are rather cheap;
- its durability surpass in 1.5 ... 3 times compositions an argentums-cadmium oxide;
- provide high reliability of actuation of contacts;
- its maximum switched current up to 4200 A.

The materials are well treated by cutting, extrusion, drilling, are easily soldered by any of known ways of soldering with usage standard argentums and non-argentums of solders.

General view of contacts, which has produced by “GEKONT”-company, has shown in the Figure 3..

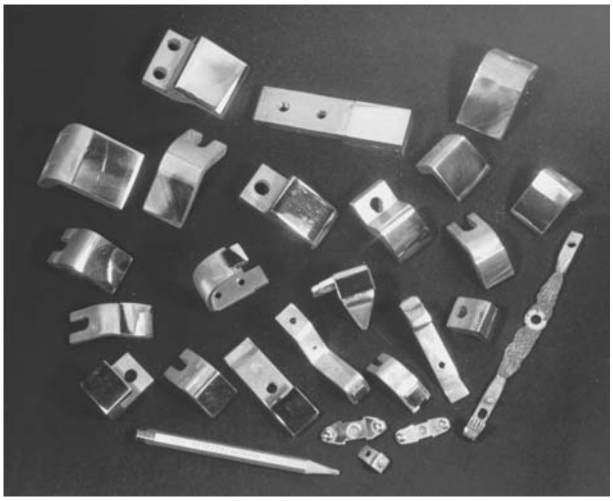

Figure 3. **General view of contacts made with application of composite materials for electrical contacts**
Slika 3. **Pogled na kontakte prigotovljene s rabljenjem kompozitno elektrokontaktnog materijala**

Most effective fields of application of contacts, which has produced on the basis of new materials for electrical contacts:

- the electrical transport (contacts used in electric locomotives, trams, trolley buses, underground trains);
- lifts facilities (passenger and goods lifts);
- ports and ships cranes and other handling gears;
- electric carts of all types;
- mining equipment;
- industrial and household electrical devices, keeping relay assemblies, contactors, single-switches etc.;
- welding rods of contact welding machines.

The new generation of the industrial electron-beam equipment for producing materials for electrical contacts has designed by the "GEKONT"-company. It allows to make up to 10 tons of the condensed materials annually, from which one it is possible to produce up to 2.5 millions pieces of contacts.

Built in the "GEKONT"-company the new generation of the industrial electron-beam equipment is universal and can be utilised for obtaining sheets of composite materials with the unique physical-mechanical charcteristics on the basis of copper; aluminium, chromium, iron, cobalt, titanium, molybdenum and other materials, and also for deposition wear-resist and high-hard of coatings on a cutting tool, title block, etc.

Now already designed materials on the basis of copper, which one under the physical-mechanical characteristics surpass beryllium bronze. Also has designed the materials on the basis of copper and chromium for electrical contacts for arc-extinguish chambers, [8] on the basis of aluminium and boride of zirconium for an aeronautical engineering and etc.

This not full list of different directions of an electron-beam technology indicates its sufficient universality and economic feasibility of its application in different branches of science and engineering.

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