MANUFACTURE OF RESISTANCE ELECTRICAL HEATER BY MICROPLASMA CLADDING PROCESS

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Attempts to develop flat electrical heating elements with application of the technology thermal spraying of electrically insulating and resistive layers were made several times, in order to improve heating effectiveness and save electric power. This work is a study of the process of manufacturing flat electrical heaters by microplasma powder spraying. Al_2O_3 was selected as electrically insulating material in view of its high electric strength (3–5 kV/mm). TiO_2 powder of Metachin company was used to form resistive coatings. Analysis of the produced coating microstructure showed that they are uniform, dense and do not contain foreign inclusions. Investigations of model heating properties conducted in an experimental facility showed that maximum heating temperature was equal to 230 °C, and the achieved specific power of the heater was 75 W. 7 Ref., 1 Table, 3 Figures.

Keywords: *microplasma spraying, electrical heater, aluminium oxide, titanium oxide, heating tracks, heating temperature*

Manufacture of flat electrical heating elements (FEH) by thermal spraying involves several technological difficulties, including substrate distortion, significant losses of spraying material, unstable resistance value, insufficient heat resistance and mechanical strength of the coating, leading furtheron to overheating and destruction of the resistive layer in service [1].

E.O. Paton Electric Welding Institute (Department 73) conducted research on manufacture of FEH heaters by microplasma spraying. This method allows application of a sound coating of various kinds, both from metal and ceramic materials on small-sized parts with minimum losses of spraying material [2–4]. Al_2O_3 aluminium oxide powder (MRTU 6-09-3916–75) with −40 μm particle size was selected as electrically-insulating material owing to its high dielectric strength (3–5 kV/mm) [5]. TiO_2 of Metachin (15–40 μm particle size) was used to form resistive coatings. This material was selected proceeding from the fact that titanium oxide has semi-conductor properties with specific electrical resistance of $(0.42–0.55)\cdot10^{-6}$ Ohm·m and thermal expansion coefficient of $8.6\cdot10^{6}$ °C^{-1} that allows this material to be used for coatings in the form of heating paths, produced by thermal spraying [6]. MPN-004 system, the general view of which is shown in Figure 1, was used for coating application.

Figure 1. General view of MPN-004 system

Unit specification is as follows:

Working gas	argon
Shielding gas	argon
Power, kW	up to 2.5
Current, A	10–60
Voltage, V	20–40
Working gas flow rate, l/min	0.5–5
Shielding gas flow rate, l/min	1–10

Modes of microplasma coating deposition

Parameters	Al_2O_3	TiO_2
Current, A	45	40
Voltage, V	30	28
Spraying distance, mm	150	150
Working gas flow rate Ar, l/min	1.3	1.3
Shielding gas flow rate Ar, l/min	4	4
Coating thickness, μm	300	100
Efficiency, g/min	1.2	2

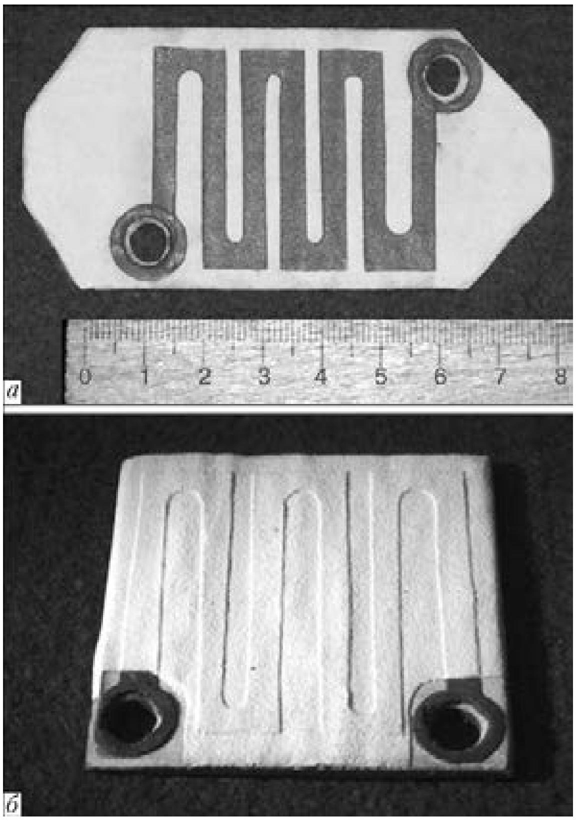

Figure 2. Models of electrical heating elements with two- (*a*) and three-layer (*b*) coatings

Efficiency, kg/h	0.1–2.5
Coefficient of material utilization, %	0.6–0.9
Overall dimensions, mm	500 × 360 × 650
Weight, kg	38.2

Coatings were applied on samples from St3 steel of 70 × 45 × 1 mm (No.1) and 50 × 50 × 2 mm (No.2) dimensions. Modes of deposition of coatings from Al_2O_3 and TiO_2 are given in the Table.

Produced models of heating elements were zigzag paths of 312 and 294 mm length for samples Nos.1 and 2, respectively, of 4 mm width with electrical heating layer thickness (TiO_2) of 100 μm. Figure 2 gives the general view of samples of electrical heating elements. Analysis of coating microstructures showed that the produced coatings are uniform, dense and do not contain any foreign inclusions (Figure 3).

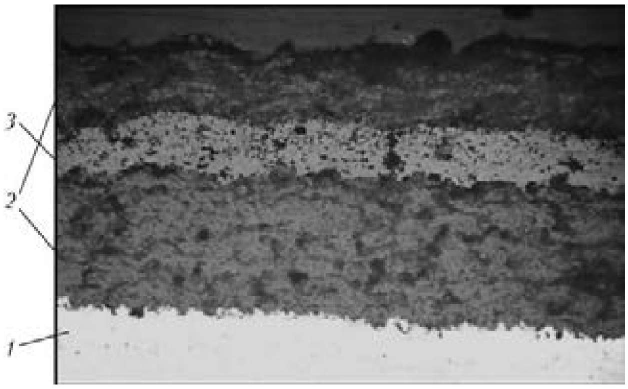

Figure 3. Microstructure (×100) of three-layer coating of a heating element: *1* — base metal; *2* — Al_2O_3 layer; *3* — TiO_2 layer

Investigations of model heating properties conducted in the experimental facility showed that TiO_2 path was heated under the impact of 0.3 A current and applied voltage of 250 V. Maximum heating temperature was 230 °C, and specific power of the heater was 75 W. Further increase of temperature leads to loss of the path electrical conductivity, and interruption of the heating process for the reason of polymorphous transformation of TiO_2 from anatase structure into rutile [7]. At heating up to 230 °C no coating delamination was found, path electrical conductivity was preserved. Thus, the possibility of manufacturing FEH operating up to the temperature of 200 °C by microplasma spraying with application of TiO_2 as resistive material, was demonstrated.

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