Copper Coating of Aluminium Contact Surfaces Using Magnetoplasma Accelerator

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Abstract – The urgency of a task of drawing of a copper covering on aluminium surfaces is proved. The opportunity of use for this purpose pulse magneto-plasma of the accelerator with high-current by the category such as Z-pinch is shown. In atmospheric conditions the copper coverings by thickness ~ 100 microns on aluminium samples are received, high adhesion which is caused by formation of a boundary layer of mutual hashing at influence hipersound of a flow of copper plasma on an aluminium surface. The opportunity of the decision of a problem of overlapping high-current of contact pair Cu–Al and significant reduction of its transitive contact resistance is experimentally shown at use of a copper covering put on an aluminium surface with the help magneto-plasma of the accelerator.

The problem of the decrease of transitional resistance and the combination of electrical link copper - aluminum meeting in industrial electrical engineering, is well-known. There are, at least, two methods of combination of such contact couples. At using of one of them, bimetallic layings, the number of contact transition is increased, that results in increase of transitional resistance of contact. The most effective method of the solution of these problems is the usage of special lubrication on the basis of copper powder. However, such demerits as aggravation of properties at protracted exploitation with cyclic loads proposed and impossibility of repeated at usage of contact. In this work a new method of the solution of is this problem – the copper coating of aluminium contact surfaces using impulsive coaxial magneto-plasma accelerator (CMPA). During the work of the accelerator in plasma structure of the accumulation up ~ 10 g of a material, eroded from the surface of its electrodes and involved accumulates in movement. The speed of the front of the stream at the beginning of its influence on the surface of the target is ~ 1 km/s. At such speeds of flows with density of substances ~ 1 g/cm^3 it is necessary to expect a plastic deformation, a heating and melting of the surface layer of the aluminium substrate – target [1]. The pressure of the impingement should be higher than 100 кBar and result in to an intermolecular interaction. The totality of these factors should ensure the appearance of the boundary layer of mutual mixture of the material of the stream form coating, and material of substrate. For one cycle the copper coating on the circular aluminium surface by the area of ~ 80 cm^2 is put. From the aluminium substrates with the put copper coating the samples of the vertical cut with slices were produced. Research of the structure of surface slices was held on a raster electron microscope Jeol-840 with the attachment Link for the X-ray photo electronic spectroscope (PES). It determined that the average thickness of the coating not less than 100 microns. The structure him is homogeneous and almost has no pores.

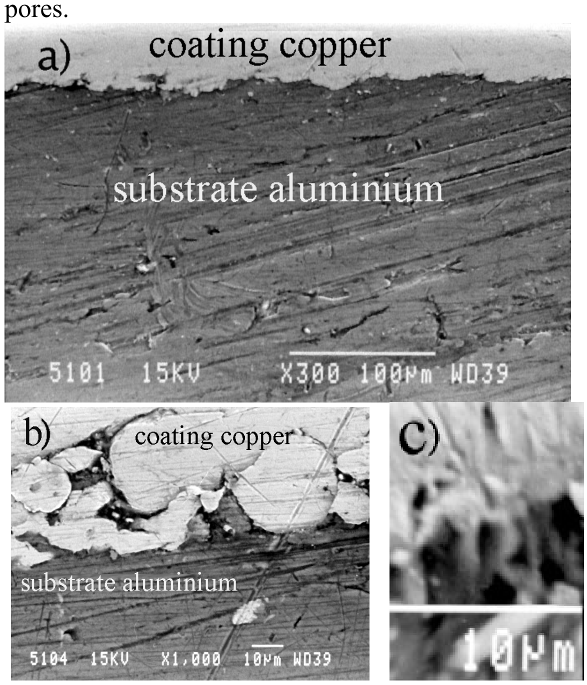

Fig. 1. Microphotograph of slices of the vertical cut of an aluminium substrate with copper coating: *a*) boundary a coating-substrate at increase ×300, *b*) fragment of a boundary layer with mutual mixture of materials of a covering and substrate, *c*) fragment with microcumulative effect

The copper coating is densely interfaced with the surface of the aluminium substrate (Fig. 1*a*). The copper segments with the size of up to ~10 microns are visually found in the substrate on the depth up to ~ 50 microns, that is confirmed by datas of X-ray PES. On such depth at aluminium there is up to 1% copper. The character of mutual hashing both couplings of materials of a coating and substrate in a boundary layer is clearly seen on the microphotograph (Fig. 1*b*) and can be explained by melting of aluminum. On separate parts of border discover the fragments reminding on an outline microcumulative configurations (Fig. 1*c*) similar submitted in [2]. The introduction of microcumulative copper stream in an aluminium substrate is probable and it is the mechanism of the penetrance of copper on the depth in some tens micrometers. For conducting comparative analysises of characteristics and properties of contact transition executed the assembly from four models of the toroidal form with contact ring surfaces by the area of 600 mm^2, by one coupling bolt (Fig. 2) with by copper thorns which bring up current.

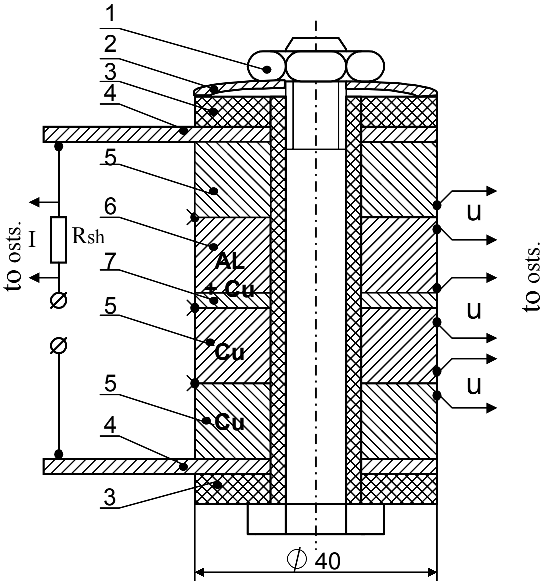

Fig. 2. The schema and construction of contact assembly for study of transitions contact. *1* – coupling bolt with a bolt with a nut; *2* – plate a spacer; *3* – glasstextolit of a spacer; *4* – current brought trunks; *5* – copper contact elements; *6* – an aluminium contact element with a copper covering (*7*). *I* – load current; *U* – fall voltage on contact transitions

Thus, equal efforts of compression of all contact transition thus were ensured. The researches were held in conditions of loading the models by pulse current and long cyclical loading by an alternating current. The pulse-regime was created by a discharge of one molecular capacitor an MIG-100 (C = 2 F, R = 0.05 Om, U = 100 V). The amplitude of current of impulse (with the duration of ~ 10 ms) changed from 760 A up to 1040 A at the expense of change of charging voltage of the capacitor. During the one impulsive loading the temperature of transition remains practically constant ~ 20 °C. Definite by volt-ampere method the mean values of resistance of transition, at different currents and identical temperature have shown, that the resistance of contact couple Cu–Al is equal to $1.83 \cdot 10^{-6}$ Ohm, by contact couple Cu–Cu – $0.61 \cdot 10^{-6}$ Ohm, by contact couple Cu–Al (with copper coating) – $1.06 \cdot 10^{-6}$ Ohm. The different of values of resistance of contact couple Cu–Al and Cu–Cu can be accepted for an estimate of magnitude of electric resistance of boundary of transferring between a copper coating and aluminium substrate.

From the Fig. 3 it is visible, that the contact couple Cu–Al (with copper coating) is less sensitive to the effort of compression in comparison with the usual contact couple Cu–Al (the curve *2* is more gently sloped, than the curve *1*), it is probably because of the greater hardness of an aluminium surface of the sample with the coating. Close to the real the conditions of

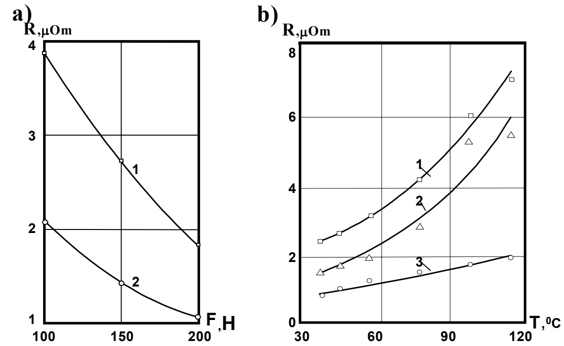

Fig. 3. Dependences of resistance of contact transitions: *a*) from amount of effort of compression R (F), *b*) from temperature *R* (*T* °C). *1* – for transitions Cu–Al, *2* – for transitions Cu–Al with a copper coating, *3* – for transitions Cu–Cu

long loading by an alternating current of the industrial frequency were created with the help of the load transformer. According to [3] the contact elements were compressed with an effort 230 N. The current loading of 470 A and density current of on contact transition were determined with the allowance for the demand GOS-434-53. The temperature of the researched is a model was determined at the constant level ~ 50 °C in ~ 3 hours after switching on of a current. The natural growth of temperature of models under loading is accompanied by increase of resistance of contact transitions. In experiments the temperature of models was up to 115 °C both by heating from the external heater at a constant nominal level of current, and at the expense of a increase of a current density over nominal (Fig. 2). The analysis of the experimental data dependences, introduced in a Fig. 2 demonstrates, that the resistance of contact transitions Cu–Al is more sensitive to the growth of temperature, than transitions Cu–Cu. However, the resistance of transitions Cu–Al with coating on a constant ΔR ~ 0.67 μOhm is lower than the resistance of customary transitions Cu–Al in the whole investigated temperature range. The model of contact couple Cu–Al with copper coating was exposed to long cyclic loads by nominal current (10 cycle for 12 h). In breaks occurred a natural cooling of assembly up to room temperature. Thus it was not revealed of appreciable increase of transitive resistance and change regime of heating of contact pair, the change did not occur and at cooling contact pair in breaks.

Conclusions

1. The principle possibility of creation of technological installation by deposition of copper coating on aluminium contact surfaces on the basis of impulsive coaxial magneto-plasma of the accelerator.

2. High adhesion of coating and low transitional electric resistance are conditioned by deep introduc-

tion of coating material (copper) into aluminium substrate and by formation of the boundary layer of mutual mixture both coupling materials of coating and substrate.

3. The copper coating on an aluminium contact surface gives a possibility for solving problems of contact couple Cu–Al and the decrease of its transitional resistance. It provides the increase of reliability of contact connections and the decrease of losses of the electric power at long exploitation.

References

[1] A.A. Sivcov, L.V. Korolkov, A.S. Saigash, Electrical Engineering **8**, 41–46 (2003).
[2] A.A. Sivcov, Letter in GTF **16,** 60–65 (2001).
[3] V.V. Afanasev, *The reference book on account and constructing of contact parts of high-current electric vehicles,* Leningrad, Energoatomizdat, 1988.