STRUCTURE AND EROSION RESISTANCE OF SINTERED HEAVY-CURRENT Mo - Cu CONTACTS

M. A. Zhavoronkov, G. V. Levchenko, R. V. Minakova, and O. K. Teodorovich

UDC 621.3:620.18

The switching device of any modern high-voltage electric circuit is one of its key elements. The operating parameters of current switching units are governed chiefly by the performance of their contact systems, in particular by the reliability and useful life of the contacts themselves. The choice of materials for contacts is dictated by the characteristics of the processes taking place during contact operation.

When heavy currents are interrupted in high-voltage circuits, severe arcing is induced between the elements of the contacts, and a number of complex physical phenomena occur on the contact surfaces under the gas-dynamic, mechanical, and thermal actions of the electric arc. During arcing, the contacts heat up, particularly high temperatures being reached in the arc base spot and in its immediate vicinity. Under the base spot, a crater forms and fills up with molten metal [1, 2]. When the contact material is homogeneous, the molten metal may completely disappear from the crater as a result of evaporation and spattering, and contact elements experience rapid wear under such conditions.

To reduce the intensity of the processes leading to electroerosion rupture, contact materials can be synthesized by powder metallurgy methods to give special composites of heterogeneous structure. The structure of such composites consists of two phase components. Agglomerates or bands of grains of a refractory component (for example, tungsten or molybdenum) form the main skeleton of the composite, while a second component (copper or silver), having a relatively low melting point, fills all the empty voids in this skeleton.

The increased electroerosion resistance of such materials may be ascribed to the fact that, in a heterogeneous system composed of two elements differing widely in their melting points, only the low-melting-point constituent melts under the action of an arc, so that the contact temperature in the base spot cannot rise above the boiling point of this constituent. The refractory phase remains in the solid state and forms a capillary system, in which the molten metal is retained by capillary constriction forces. This prevents the liquid phase from splashing and reduces its rate of evaporation.

The present work was undertaken with the aim of studying the effect of composition and structure on the electroerosion resistance of arc-break contacts made of sintered composite materials. Molybdenum-copper composites alloyed with various amounts of cobalt were chosen for investigation.

Starting materials for the preparation of molybdenum-copper composites were provided by a molybdenum powder of 0.01-mm max. particle size, produced by the reduction of ammonium molybdate, and copper and cobalt nitrates. The materials investigated contained 70 wt. % molybdenum, 0-10 wt. % cobalt, and copper (the remainder). Powder mixtures for the manufacture of contact specimens, prepared by the method of "chemical" mixing, were subjected to drying, after which cobalt and copper oxides on the surfaces of the molybdenum powder particles were reduced with hydrogen in two stages, at 450 and 850°C. Contact specimen blanks were compacted from these mixtures under a pressure of 3-5 tons/cm², sintered at 1000°C, and infiltrated with molten copper at 1250°C in a reducing atmosphere. Determinations were made of the density, hardness, and electrical resistivity of the composites, and also of the microhardness of their phase constituents.
Fig. 1. Crust formation on surface of Mo–Cu composite contact, ×300.

Fig. 2. Formation of double crust on Mo–Cu composite with 10 wt.% Co, ×300.

Fig. 3. Structural changes caused by arc in surface layer of Mo–Cu–Co (5 wt.% Co) composite contact, ×300.

Electroerosion tests on contact materials were conducted using endtype contacts fitted in a model of a VMG-133 low-oil-capacity switch [3]. The tests involved current interruption with a freely burning arc, that is, an arc whose base spots can migrate under the action of its own field and of oil and gas flows. Power was supplied by a two-section capacitor bank. With the two sections connected in series, the current supplied had a first half-wave amplitude of 3 kA, a second half-wave amplitude of 2.7 kA, a third half-wave amplitude of 2.4 kA, and so forth. Connecting the sections in parallel almost doubled the current. During each interruption cycle, oscillographic records were obtained of the arc current, arc voltage drop, contact separation velocity, and arc burning time. Each pair of contact elements was subjected to 150 interruption cycles. After each 50 cycles, the installation was dismantled to examine the wear of the elements. The extent of arc-induced erosion wear was determined by weighing specimens before and after testing. At the same time, the variation of contact resistance was determined, by the ammeter-voltmeter method, during the passage of a direct current of 20 A, as a function of the number of interruption cycles. For each pair of contact elements and each contact pressure, the arithmetic mean of the results of 10 contact resistance measurements was computed.

The character of electroerosion wear was studied under an MIM-8 metallographic microscope, using oblique sections through working contact surfaces.

Test Results and Discussion

The mechanism of formation of a material consisting of components exhibiting no solid- or liquid-phase reaction is determined by the processes occurring on their interfaces, namely, wetting and adhesion. In the formation of a composite such as molybdenum–copper, a porous molybdenum powder compact is subjected to solid-phase sintering and subsequent infiltration with molten copper.

In the course of low-temperature sintering, a refractory skeleton forms through recrystallization of the contact zones of grains deformed during pressing and grain coalescence during sintering in the presence of a liquid phase [4-7]. The absence of reaction between the components of a molybdenum–copper composite and incomplete spreading of the low-melting-point component over the molybdenum surface (the angle of contact becomes zero at a temperature as high as 1350°C) make it difficult to obtain nonporous, dense parts.

To stimulate interaction at the liquid copper/molybdenum interface with the aim of ensuring that, ultimately, dense parts were produced at 1100–1150°C, cobalt was added to the composites investigated. The presence of this metal, inducing a partial solubility of the molybdenum in the resulting copper–cobalt melt, modifies the structure of such a composite: The grains of the refractory constituent undergo partial spheroidization and increase in size, while the skeleton loses to a certain extent its continuity. However, even in the presence of this alloying element, the refractory component continues to control the mechanical strength of the composite [8]. The addition of cobalt (up to 10 wt.% Co) has virtually no effect on the density of the composite, but increases its hardness and electrical resistivity (Table 1).