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Innovative technologies of electrical contacts for electrical devices in energy construction: contact materials

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The article considers the electrical contacts used in power systems and networks of electric rolling stock of railway transport, taking into account the operating modes and traction characteristics of a traction electric motor. The main types of contacts and contact materials used for the manufacture of con-

tacts operating in electrical and electronic devices of ERS (electric rolling stock) are given.

Today, innovative technologies in hydraulic engineering, energy construction, water and railway transport are relevant. The requirements for a modern live part are special and therefore different cermet materials are used to manufacture new contacts.

Contacts in devices are called current-carrying parts, when they come into contact with an electric circuit during operation of the device. The contacts of devices used to close and open a circuit without current are usually called disconnecting or disconnecting.

Despite the wide variety of geometric shapes of traction apparatus contacts, they can be divided, depending on the type of contact surface at the point of electrical contact, into three varieties, conventionally called surface, linear and point. Fig. 1 shows some types of contacts [1].

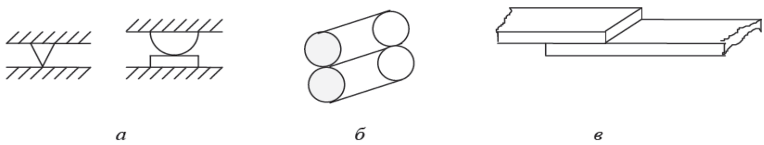

Fig.1. Types of contacts:
a – point; *b* – linear; *c* – surface

In addition, the devices have detachable contact connections, which do not open during operation of the devices, but serve only to disconnect part or the entire device during replacement or repair. Such connections are made by means of clamps (bolts, nuts, etc.) and therefore they are called contact clamps.

The contact connections carried out by soldering are called non-removable. At the point of contact of the contacts, additional contact resistance of the gc and loss of Rp energy occur. These losses mainly determine the heating of the contacts [2].

The physical nature of the contact resistance is revealed when considering the point of contact of the contacts, depicted with a high degree of magnification. Regardless of the quality of the processing of the working surfaces of the contacts, they have micro-dimensions, as a result of which the contacts do not touch each other over the entire surface, but in a limited number of points [3]. As the pressure of the contacts increases, the microscopic protrusions at the contact points deform, shorten, and the area and number of contact points increase, which leads to a decrease in contact resistance. This dependence is confirmed by theoretical and experimental studies.

The electrical resistance of the contacts is inversely proportional to the contact pressure and does not depend on the area of their contact. This explains the predominant use of linear and point contacts, in which a large specific pressure contributes to a better cleaning of the contact surface from oxide.

Surface contact is formed by the contact of two flat surfaces. The surface contacts allow very large depressions without damage, so that the contact resistance is reduced to a minimum. In particular, this is why they are used in some powerful circuit breakers.

The linear contact is formed by current-carrying parts touching along the line. In fact, the contact surface is a narrow rectangular strip. High specific pressures are created in such contacts and therefore it is easy to crumple the oxidized contact protrusions and obtain a relatively low contact resistance with relatively small pressures. Linear contacts are used in most traction devices.

Point contact. The two spherical surfaces touching form a point contact, which, due to the crumpling of the metal of the contacts, practically has the shape of a small circle. Point contacts provide high specific pressures and low contact resistance even in the case of very small pressure. Therefore, point contacts are especially widely used in devices where the pressing force is low (relays, locking contacts) [4].

Contact materials. The main necessary properties of the contact material — high electrical conductivity and arc resistance - cannot be obtained due to alloys of materials such as silver and tungsten, copper and tungsten.

Silver. Positive properties: high electrical and thermal conductivity, the silver oxide film has low mechanical strength and quickly collapses when the contact point is heated [3]. The silver contact is stable, due to the low mechanical strength, small presses are sufficient (used when pressing 0.05 N and above). Contact stability and low transient resistance are characteristic properties of silver.

Negative properties: low arc resistance and insufficient hardness of silver prevent its use in the presence of a powerful arc and with frequent switching on and off.

It is used in relays and contactors at currents up to 20 A. At high currents up to 10 kA, silver is used as a material for the main contacts operating without an arc.

Aluminum. This material has a sufficiently high electrical conductivity and thermal conductivity. Due to the low density, the current-carrying part of the circular section made of aluminum with the same current as the copper conductor has almost 48 % less mass. This allows you to reduce the weight of the device.

Disadvantages of aluminum:

1) formation of films with high mechanical strength and high resistance in air and in active media;

2) Low arc resistance (melting point is much lower than that of copper and silver);

3) Low mechanical strength;

4) upon contact with copper, steam is formed, which is subject to severe electrochemical corrosion.

In this regard, when combined with copper, aluminum must be coated with a thin layer of copper electrolytically, or both metals must be coated with silver.

Aluminum and its alloys (duralumin, silumin) are mainly used as a material for tires and structural parts of vehicles.

Tungsten. The positive properties of tungsten are high arc resistance, high resistance to erosion, welding. The high hardness of tungsten allows it to be used with frequent switching on and off.

The disadvantages of tungsten are high resistivity, low thermal conductivity, and the formation of strong oxide and sulfide films. Due to the high mechanical strength and film formation, tungsten contacts require a lot of pressure.

Corrosion—resistant materials such as gold, platinum, palladium and their alloys are used in electromagnetic relays for low currents with a slight push.

Metal-ceramic materials. Consideration of the properties of pure metals shows that none of them fully meets all the requirements for discontinuous contacts. For contacts of high-voltage devices, the most widely used cermets are KMK-A 60, KM KL 61, KMK-B20, KMK-B21 [4].

In low-voltage devices, KMK-A10 cermets made of silver and cadmium oxide CdO have become the most widespread. A distinctive feature of this material is the dissociation of CDOs into cadmium and oxygen vapors. The released gas causes the arc to move rapidly over the contact surface, which significantly reduces the contact temperature and contributes to the deionization of the arc.

Металлокерамика, состоящая из серебра и 10 % окиси меди, КМК-А20 еще более стойка к износу, чем КМК-А10.

Silver-nickel contacts are well processed and have high resistance to electrical wear. The contacts provide a low and stable transient resistance in operation. However, they are easier to weld than contacts made of KMK-A60, KMK-B20, KMK-A10 material. Fig. 2 shows some contact designs.

When the device is operating, electrical energy losses occur in its current-carrying circuit, insulation and structural parts, which are converted into heat. Thermal energy is partially consumed to increase the temperature of the device and partially released into the environment.

As the temperature increases, the insulation of the conductors ages rapidly and their mechanical strength decreases. So, for example, if at a given permissible long-term temperature, the service life of the conductor insulation is reduced (with prolonged operation and an increase in temperature of only 8 °C, the service life is reduced by 2 times). When the temperature of copper increases from 100 to 250 °C, the mechanical strength decreases by 40 %. It should be borne in mind that in case of a short circuit, when the temperature can reach the limit values (200–300 °C), the current-carrying parts are exposed to large electrodynamic forces.

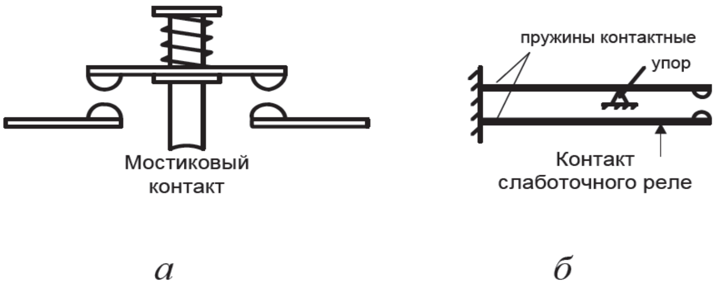

Fig. 2. Contact designs:
а – bridge contact; *б* – low-current relay contact

The operation of the contact connections is also highly dependent on temperature.

Heating of the current-carrying parts and insulation of the device largely determines its reliability. Therefore, in all possible operating modes, the temperature of the parts of the device should not exceed such values at which its long-term reliable operation is ensured. In direct current devices, heating occurs only due to losses in the active resistance of the current-carrying circuit.

For a homogeneous conductor, the resistance *R*, knowing the properties of the material, the length and cross-section of the conductor, is easy to find.

At alternating current, the active resistance of the conductor differs from the resistance at direct current due to the appearance of the surface effect and the proximity effect.

In high-voltage alternating current devices, in addition to losses in conductive and ferromagnetic materials, it is necessary to take into account losses arising in insulation. These losses are determined by the formula

$$P = 2nfCU^2 \mathrm{tg} a,$$

where f = 50 Hz is the network frequency; C is the insulation capacity; U is the effective value of the insulation voltage; tg is the tangent of the dielectric loss angle.

The insulation of the device is heated both due to losses in the current-carrying circuit and due to losses in the dielectric.

Methods of heat transfer inside heated bodies and from their surface:

There are three types of heat transfer: thermal conductivity, convection and thermal radiation [5].

Thermal conductivity. Thermal conductivity is the process of heat propagation between directly touching particles caused by the thermal motion of molecules or atoms of a substance, and in metals - free electrons.

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Innovative technologies of electrical energy conversion system with regulation in electric drive

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This system explores innovative technologies in the field of electrical power conversion with a focus on control in the context of electric drive. The abstract covers advanced methods and tools aimed at efficient and controllable electrical energy conversion to improve the efficiency and functionality of electric drive systems.