Assessing of the impact of different factors on erosion in the initial phase of the disconnection arc.

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The degree of influence of totality of factors(current, time of ignition of arc, gap, polarity of electrodes) is considered on electro-erosive firmness and transitional resistance of interconnect vehicles in the process of their exploitation.

Influence of interpin interval, strength of disconnecting current and material of electrodes on the size of electric erosion of contacts are investigated.

Electric erosion, interpin interval, electrodes, bursting contacts, energy, cathode, anode, commuting current, overheating.

The purpose of the research. Study of influence of electric disconnection arc factors on erosion's resistance of contacts and identifying of characteristics of contact's material mass transfer.

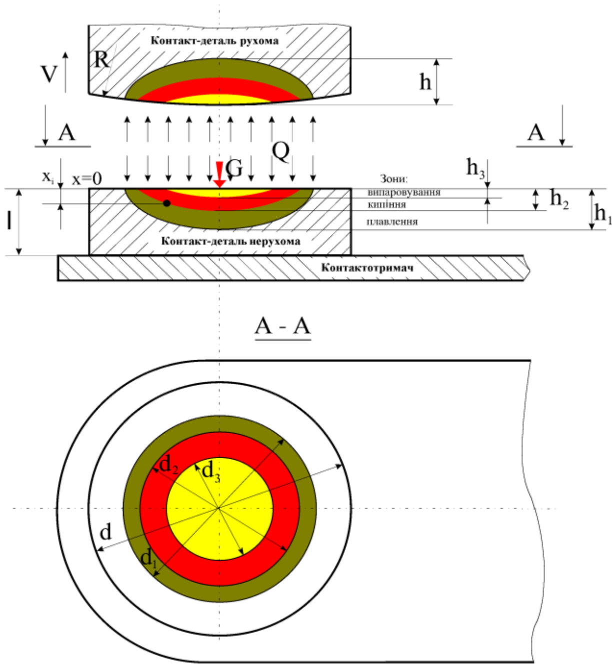
Materials and Methods of research. Conditions of operation and the set of factors of electric arc of disconnection (gap, material and state of electrodes 's surface) affect significantly the term of operation of switching devices that constitutes in average 1-3 years. The reason for the small operating term of contact details of the relay is an electrical erosion with directional mass transfer from cathode to anode with the switching circuits of constant current. The electrical erosion is influenced by such factors as an amount of current, kind of the load, arcing time, the environment of the arc functionning, the shape of the contact details and its material, the speed of releasing and the technology of contact details production. The influence of numerous factors on erosion can be expressed as follows:

$$\Delta V_{\Sigma} = f(I^{\alpha}; t^{\beta}; \delta^{\gamma}; H^{x} \dots),$$

where: I - current A; t - combustion of arc, sec; δ - clearance, mm; H - magnetic field's blast strength, A / m; α, β, γ, χ - coefficient.

To assess the effect of a factor on erosion we need to have the results of experiments in which this parameter acts as the independent variable, while the other effects must be reduced to a minimum or remain constant.

Qualitative independent variables in our experiments are: the duration of the arc and the switching current. However, the obtained pattern of the changes $\Delta V_{\Sigma} = f(t)$ complicates the assessment of the extent of their participation, as depending on the area of examination the impact is different, so we assess the impact factors according to a particular area: $\Delta V_{\Sigma} = f(t)$.



Img. 1. Schematic image of penetration depth *h* of contact details with switching current

Effect of the interval. With the small distances between contacts almost all energy that is released during arc discharge is given to the electrodes. This causes the heating of the metal to high temperatures in the reference points of interaction channel discharge electrodes, resulting in evaporation, which provides access to the appropriate number of neutral atoms in the discharge gap. However, to maintain the level of discharge only a small portion of the total number of "neutrals" received is involved. The rest diffuses into the environment and deposites on electrodes. In establishing the quasi-stationary conditions the required number of "neutrals" to support the discharge channel length with consistency of environmental conditions will be constant. With increasing of length of the discharge channel the required number of "neutrals" must increase disproportionately. This is due to the following factors:

Firstly, with the increasing of the gap size in the case of direct current arc, the energy released in inter-contact’s gap increases proportionally. The energy from the increasingly growing degree will start to discharge into the environment and to a lesser extent - in contacts.

Secondly, the allocation of energy will be accompanied by increasing diffusion of "neutrals" into the environment and, at the same time, the reverse process of penetration of "cold" particles from the environment into the discharge channel.

Thirdly, the degree of external factors (magnetic or air blast) on the canal discharge increases.

Fourth, with the increasing of a gap and of the size of the interval the probability of variation and deviation from the direction of the discharge channel of flare jets, emanating from the anchor points on the electrodes, will increase.

In addition, after installing of quasistationary state any additional energy supply must lead to disproportionate (explosive) growth rate of evaporation, indicating a disproportionate impact on erosion interval.

Growth losses of electrode material with interval increasing may continue to a certain extent. This is determined by power relations, as the gap increases with the increase of the energy that is given to the environment, on the other hand, there is an increase in the degree of environmental support level, which leads to an increase in energy released in the interval, and the maximum is reached at the moment $\Delta V_{\Sigma} = f(t)$.

Thus, the absolute change in arc length, placed inside inter-contact gap electrode material costs will continue to increase until the arc increases to large sizes and doesn’t leave electrodes. In the case of fixed reference points of the arc the wear will increase by hydro-and gas-dynamic processes, leading to significant reduction of the liquid phase and depend on the capacity of the arc of disconnection.

Effect of current shutdown. According to the analysis of the results of numerous experiments, the impact of current shutdown has the largest range of 1.2 to 3.0.

Due to the complex pattern of erosion changes in the initial phase, the results of the impact of current are carried on the verge of transition of respective areas. Results of analytical evaluation are kept to Table 1, which shows even a greater range of variation exponent of 0.36 to 3.12.

1. Value of exponent α depending on the time of existence of the initial phase of the arc

Groups of tracts			
I-II	*II-III*	*III-IV*	*IV-V*
1,31-1,8	0,36-2,02	0,36-2,42	1,28-3,12
1,38 – 1,86	1,45 - 2,59	1,54- 2,62	1,6- 2,66

Depending on the switching arc the break off occurs at that time point, which leads to the corresponding limits of the development of the initial phase of the disconnection arc. Depending on the switching conditions the extinguishing of the arc will be held at different values of the interval.

2. The value of exponent α depending on the duration of the existence of an arc

Time, *t*, msec										
1,0	2,0	3,0	4,0	4,5	5,5	8,5	9,5	10	13,0	17,0
1,35-1,85	1,385-3,34	2,05-1,80	2.48-1,58	1,97-2,14	0,31-4,00	1,385-3,4	2,12-3,09	2,34-3,09	1,795-3,09	1,23-3,09

These estimations indicate the impact of variability on power switching erosion. This is due to a change of the mechanism of destruction of the electrode material in the vapor, liquid and solid phases, drip, so the appliance of the specific value [$см^3/(кА * с)$] to calculate erosion should very careful.

Influence of polarity of the electrodes on the wear. In close contact with a homogeneous material due to tunneling, there is the overheating of the anode. This results on a large areas of penetration on the anode with the disconnection of contacts, and with increasing of anode material in the formation of rare bridge. As a consequence there is a transfer directed bridge from the anode to the cathode, which causes a change in the geometry of the contacting surfaces with forming of a "peak" on the cathode and "craters" on the anode.

Experimentally it was found out by the ratio between constant thermophysical material contact pairs, under which the transfer will occur at the self-regulatory disconnected contact with small load currents. That is, when switching circuit with a spark or short-arc discharge forms by the selection of materials for juxtaposition of contact pairs can reduce and equalize the wear of the contacting elements.

If strongly overcurrent digits after the destruction of the bridge under the action of the applied voltage between the contacts, the arc develops. The participation of material of the destroyed bridge to support the next level is very low, the main "mass" of neutral particles goes to the discharge channel from the electrodes of the control points of the arc. Since the process of arc development it changes its structure (the share of electronic and ionic conductivity) and size of lesion areas on the electrodes, the ratio of power that is released at the anode to the power emitted at the cathode should be changed.

The differences in the nature of particles, their energy balance and energy transfer mechanism lead to differences in the processes that occur on the surface ofcathode and anode.

Patterns of erosion of the anode depends on the processes that occurs in the region natural arc, and especially the nature of the interaction of electrons with atoms of the anode, which are in the vapor state. The electrons coming from the positive column of the arc and accelerated in the anode fall produce ionization evaporated of anode atoms. Relesing the ionization electrons complement the main current, and their number will be the greater, the lower the ionization energy of the anode. The increase in anode potential drop occurs both by reducing the potential of the positive column of the arc, and by more intensive reduction of positive and negative space charges increase. This is followed by diffusive processes, the electric field of the arc and the anode and cathode flare flow of liquids evaporate from the electrodes. These phenomena suggest that the electrical erosion, and hence the energy that is supplied to the anode, depending on the ionization potential of the anode.

However, the spark erosion of the anode cathode erosion comparable or superior to it. This is observed in electrical discharges that last a very short period of time, or at extremely short distances between the electrodes. Because of the mobility of small ions in the short discharge of only a small part of them reaches the cathode and gives him his power. Reducing the number of ions that bombard the cathode, reduces its erosion.

Thus, the erosion of the cathode and anode in the arc dependent on the elementary processes that occur in the near-electrode area of the arc and the electrode surface, ie, the ionization energy of atoms and their number, as well as the excitation energy of metastable states of atoms. Since thermal process inertia on the relationship between erosion of the anode and cathode electrodes will significantly affect the duration of the discharge. In addition, prolonging the existence of the category in one place reduces the current density in the reference points of the arc, the arc column expansion of the channel to increase the ionic conductivity of the channel share of the arc column. An increase in the number of ions that bombard the cathode, causing it extensive damage.

In addition to external factors, the size and nature of erosion are significantly affected by of electrodes' material. The vast erosion of the anode with the transfer to cathode characterizes the so-called arc of "anode" type, and therefore the vast erosion of the cathode with the transfer to to the anode characterizes the arc of "cathode" type. From the investigated materials the curve of "cathode" type is observed only on molybdenum, in other cases - there is an arch of "anode" type. This fact should be taken into account both when comparing different contact pairs, and in explaining the results of erosion of the anode and cathode electrodes.

The processes at the electrodes of different polarities lead to distinguishing different requirements to the thermophysical properties of materials to provide a minimum of erosion, and these requirements depend on the mode of existence of the arc control points during switching.

Conclusions

1. If you change the length of the arc, located inside inter-contact gap electrode, the material costs will rise until the arc increases to large sizes and does not leave electrodes.

2. The nonlinear dependence of the electrical contacts from the erosion of current, number of switching and physico-mechanical properties of the contact material is found out.

3. The speed of electric erosion is variable, in the first tests - it is maximal, and at certain currents (5-7 A) - minimal, indicating the formation on the surface layer of the material microstructure optimal in terms of resistance to electrical erosion.
4. Erosion of the cathode and anode in the arc depends on the ionization energy of atoms and their number, as well as of the excitation energy of metastable states of atoms.

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Рассмотрена степень влияния совокупности факторов(ток, время возгорания дуги, зазор, полярность электродов) на электроэрозионную стойкость и переходное сопротивление коммутационных аппаратов в процессе их эксплуатации.

Исследовано влияние межконтактного промежутка, силы тока отключения и материала электродов на величину электрической эрозии контактов.

Электрическая эрозия, межконтактный промежуток, электроды, разрывные контакты, энергия, катод, анод, коммутирующий ток, перегрев.

The degree of influence of totality of factors(current, time of ignition of arc, gap, polarity of electrodes) is considered on electro-erosive firmness and transitional resistance of interconnect vehicles in the process of their exploitation.

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