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CONTACT RESISTANCE IN LOW–CURRENT SLIDING CONTACTS

Introduction

The problem of improving the reliability of devices and their complexes sharply put in some modern forms of technology, such as in missile, aircraft, radar, etc.

The successful functioning of the equipment is largely dependent on the uptime for the many electrical items and, in particular, on the sliding electrical contacts.

The trend towards miniaturization of components control equipment caused the need for a low–current sliding electrical contacts, in connection with which faced the problem of ensuring reliable contact.

In some systems, loss of control of contact is allowed up to two milliseconds. The most difficult problem is solved with respect to potentiometric elements and clearly ribbed contact surface, stimulating the dynamic processes in the contact brush. In the paper a practical methodology and formulas for determining the resistance to sliding contacts used in sensors, aerospace engineering.

Formulation and solution of the problem

The contact surface of low–current sliding contacts (CSC) is a terrain with a roughness of coatings of various film kami tarnishing. All hollows and bumps on the surface are filled with wear products. Such a surface, as a component of the electrical contact has a certain resistance to the passage of current, which is called the contact resistance and the height of asperities and the thickness of the insulating oxide layer.

Residual state of the contact surface is estimated static contact resistance, to determine which, even static, there is not a simple task.This is especially true of wire potentiometers, where the background of a high–winding resistance should provide resistance to the transition from the coil to the brush.

There are many articles is devoted to this issue. The analytical and experimental studies of determination of the contact resistance are interesting.

According to Holm [1], contact resistance is an additional resistance in the circuit in the contact area. It is determined by the value of resistance contraction Rc and the resistance of the oxide film Rn.

$$R = Rcm + Rn \qquad (1)$$

Considering that both contacts are made of a metal with circular and symmetrical surface, whereas

$$Rcm = \frac{\rho}{\pi\alpha} \qquad (2)$$

Where ρ is a resistivity of the material contacts, A is a radius of a pole circular surface.

The resistance of the thick film of contact patch is

$$R_{пл} = \frac{\rho S}{\pi a^2} \qquad (3)$$

Then the total value of the contact resistance is

$$R = \frac{\rho}{\pi\alpha} + \frac{\rho S}{\pi\alpha^2} \qquad (4)$$

Holm spent the comparison of the two contact resistances for the two identical spots «α» – without the film and coated film. The effort in touch in some points of contact calls an elastic deformation, in other chances – plastic. Contact resistance is determined, basically, by the real contact area. To determine the actual contact area we can from [2]

$$A_d = \eta A_k \qquad (5)$$

where A_d – is the real area of contact; A_k is the contour area of contact;

η is the curve of the ground.

For the two polished surfaces we have:

$$\eta = 3,4\left(\frac{q_c}{Eh_{\max}}\right)^{\frac{10}{11}} \qquad ((6)$$

where the q_c is the specific contact force; E is the modulus of elasticity;

$h_{\max}$ is the maximum height of irregularities.

Contact resistance depends on temperature and other parameters as

$$R = f(F, \rho, \sigma, E, h, T, \mu) \qquad (7)$$

Where F is the contact force; ρ is the resistivity of material; σ is the surface resistivity; T is the heating temperature in the zone of contact.

Considering the specific case of a truncated cone, the resistance has defined as a

$$R = \frac{\rho h}{\pi\alpha_1\alpha_2} \qquad (8)$$

If we given the contact forces and mechanical strength material, the full contact resistance will be equal

$$R = \frac{2h\rho\sqrt{\sigma}}{\sqrt{A_{\partial}}\sqrt{F}} \tag{(9)}$$

The same expression for the contact resistance is obtained by some form of contacting protrusions. This implies that the contact resistance:

1. Does not depend on the shape of protrusions on the contact surface, and is determined by their height;
2. Is in proportion to the physical characteristics of the contact material – electrical resistivity and mechanical strength;
3. Is inversely proportional to the applied force and real area of contact surfaces.

Conductivity of the electrical contact can be represented as the sum of conductivities of contact spots.

Constriction resistance is equal to one–point contact

$$R_{cmi} = \frac{\rho}{2\pi\alpha} f(\gamma)\,\mathrm{arc}tq\frac{\mu}{\alpha} \tag{10}$$

where ρ is the resistivity of material contacts;

α is the radius of circular area;

$f(\gamma)$ is the coefficient of form, taking into account by the deviation of contact spots from the round.

These surface is the half–ellipsoid which are described by the equation

$$\frac{X^2}{\alpha^2+\mu} + \frac{y^2}{\beta^2+\mu} + \frac{Z^2}{\upsilon} = 1, \tag{11}$$

where α and β are the axis of the ellipse representing the conductive contact spot; μ is the parameter which characterizing the length of the contraction region.

$$\gamma = \frac{a}{\beta} = \frac{\alpha}{a} \to 1 \qquad \mu \to \infty$$

If $\gamma \to 1, \mu \to \infty$ the resistance is approximately expressed by

$$R_{cm.i}(r,h) \approx \frac{\rho\sqrt{2r-h}}{4a\left(\sqrt{2r-h}-\sqrt{h}\right)} \tag{12}$$

The general formula for determining the resistance of the film is

$$R_{пл} = \frac{\sigma_{тун.}}{A_{\partial}} \tag{13}$$

Specific tunnel resistance depends on the voltage drop over the cross section of the film, that is, it nonlinearly and given by

$$\sigma_{тун}=\frac{10^{-22}A^{2}e^{AB}}{2(1+AB)},\quad A=7{,}32*10^{5}\left(S-\frac{7{,}2}{\Phi}\right);\ B=1{,}265*10^{-6}\sqrt{\Phi-\frac{10}{\varepsilon_{\mu}S}}. \qquad (14)$$

Where S is the film thickness; Φ is the electron work function of metal,

ε_{μ} is the dielectric constant film material.

Offers two methods of measuring contact resistance under static conditions using a compensator of constant current.

At the first position, the key to measure the voltage drop U on the resistances Rk and R1

$$U=J\left(R_{k}+R_{1}\right),$$

In the second key position to measure the voltage drop U_1 on the resistance of R_1

$$U_{1}=J*R_{1}$$

In this case, the contact resistance $R_{k}=\dfrac{U-U_{1}}{J}$

Current in the circuit is set within the allowable values for the wire to the potentiometer.

The contact resistance R_k in the second method determines the magnitude of the voltage drop $\Delta U_{k}=J*R_{k}$, which was measured compensator of constant current.

A current which installed on microampermeter is depending on requirements. Thus, the resistance is

$$R_{k}=\frac{\Delta U_{k}}{J}$$

DC power supply is taken Acid Battery U = 6 with large capacity. One such battery fed circuit, the other fed the compensator. Zero device was galvanometer GZP –47 of the magnetoelectric system.

Current strength was set at 700 μά by microampermeter type M109, Class 0,5.

Measurement error for the selected method is determined by the accuracy class of microampermeter and error compensator.

Conclusions

We have explored the behavior of sliding electrical contacts which are necessary for reliable potentiometric sensors. In determining the contact resistance calculation's method has a number of difficulties and inaccuracies in the experimental and theoretical determination of some parameters. The complex processes occurring in the contact zone, some of which disappear after removal of the load, it is impossible to consider all factors affecting the contact resistance. Found that the more realistic assessment of the contact resistance can give practical circuits, to measure its direct or indirect method.

The formulas for determining the resistance of sliding contacts are received. In the future it is expedient to investigate the behavior of sliding electrical contacts under vibration.

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