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The Laboratory Equipment for the Prompt Functional Properties Measurement of Electrocontact Materials

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The automated laboratory equipment for efficient interrupting electrocontact materials testing with respect to their general functional properties during their development and/or improvement is presented. The equipment for estimating erosion resistance, transient resistance of loaded pair contacts and also welding resistance during on-off cycles by break force measurement (380/220 V, current is 15-30 A, power factor φ=0.8, frequency of on-off cycles is 0.01-10 Hz, controlled duty cycle). The equipment control, monitoring, recording and primary processing of parameters taken from the detecting device are performed using specialized software. The equipment was tested on two type contact materials, Ag and Ag/(15%CdO). The results and appropriate correlation are presented in this article.

Keywords: automated laboratory bench, contact resistance, arc erosion performance, electrical conduction measuring.

Introduction

Control and operative assessment of the functional material properties is required at studying new materials. Presence of the measuring means in the form of the specialized laboratory benches allows to effectively and operatively solving a problem of the material synthesis with demanded properties. In development and perfection of the new serial electrocontact materials there is a problem of the operative estimation of the basic functional properties of the materials for the purpose of culling and making of corrections in the composition and technology. Serial equipment for measurements of the electrocontact material functional properties is practically absent. It is a serious obstacle for studying such materials.

The main causes of the interrupting contacts failure in switching low-voltage electrical equipment working in air (as a part of the automatic circuit breaker, contactors, solenoid starters, relays) are:

- oxidation of the contact surfaces and formation a low conductive layers of operation that is characteristic for materials with the significant content of the ignoble components;
- wear of contact elements under the influence of an electric arc – spark erosion;

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- welding of contacts (including so-called "cold welding" and welding under the influence of electric arc of interruption).

Therefore, testing of such indicative characteristics as long stability of intercontact resistance in the loaded contact pairs, electric wear resistance of a contact material and resistance to welding are necessary.

We developed and used the laboratory bench for measurement of erosion properties of materials, contact resistance on working contacts in the presence of "operation layers" and resistance to welding during performance of cycles I-O (input – output). The detailed description of this equipment is presented below.

The similar equipment for the certification of electrical contacts is represented in [1-4]. One used for testing as at ac voltage (U=220V and I=20A [2] or 90A [3]) and other at dc voltage [4], but at much lower voltage, 42V.

The bench for measurement of properties of electric-contact materials

Main purpose of the equipment: the control of a transitional voltage drop on working contacts (in the presence of "operation layers"), the evaluation of erosion properties of materials (the erosive wear as a result of the arc breaking), as well as the resistance to contact welding during repeated I-O cycles. This bench imitates the work of the AC contactor (general diagram of installation is similar to that described in [1]). The electrical scheme of the bench for measurement of erosion properties of materials is given in Fig. 1. The bench consists of 3 parts: power block, I-O device of testing contact tips and control block.

The power block involves an isolating transformer T1 (380/380V, 30 A), a ballast choke L1 with the value of inductance of 30 mH, the rated current is 30A and rheostat R1, with the aid of which the current control is produced. In the power block the contactor CM1 is also mounted, with the aid of which turning off of the voltage supplied to the contact tips is carried out.

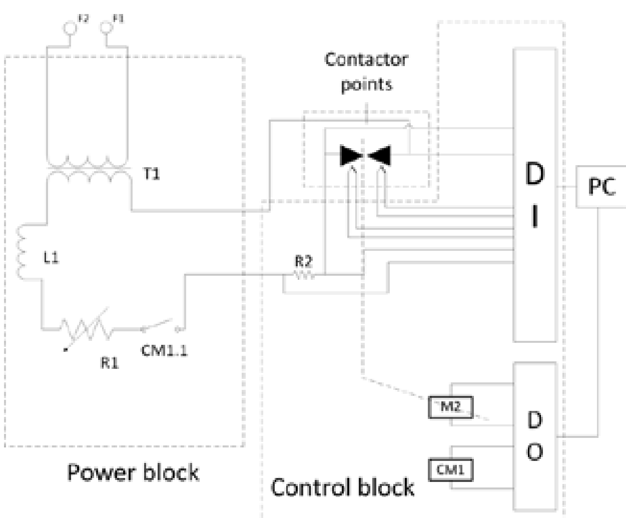


Fig. 1. The block-scheme of the equipment

The control block includes the shunt R2, where according to a voltage drop the current magnitude passing through the contact pair is determined. The electromagnet M1 closes and breaks the contact pair moving a mobile contact. The analog-to-digital converter represents 2 modules (made by Advantech) for measuring the temperature and voltage and a module of strain gauge by means of which the effort of pressing and breaking of contacts is defined. The digital-to-analog converter represents the module of a discrete output of data (made by Advantech).

The bench is the independent system implementing the mode of repeated I-O cycles of the contact pair. The control of transient resistance (with user-defined periodicity) and overheat temperature of tested contacts is performed. The bench control is carried out by means of the specialized software. This software allows to control and store data, time and force from the strain gauges. It also allows to switch off equipment at the end of the experiment and in case of overheating of contact tips and to specify operating frequency.

The main characteristics of the bench

1. Standard size of contact tips for a tested material is PP0820 (d= 8 mm, h= 2-3 mm).
2. Voltage on contacts – variable, 380 V, 50 Hz.
3. AC rated current of test is 15-30 A.
4. Power factor is fixed, φ=1-0.3.
5. Contacting by an electromagnet. The contact breaking by a spring with adjustable effort.
6. The intercontact distance is regulated in the range of 0…15 mm.
7. The operating frequency is specified in the range of 0.01 to 10 Hz. The load cycle is changing with a maximum load of 50 % (0.25 s ON and 0.25 s OFF) at the unlimited minimum value.
8. Total number of I-O cycles in the test is adjustable; automatic switching-off after completion of the expected number of cycles.
9. Work of mechanical system (I-O) occurs both when the AC circuit is switched on and without operating current.
10. Switching on AC is carried out at the opened contacts or simultaneously with the starting of the electromagnet.
11. Measurement of transient resistance is made at AC.
12. Sequence of measurements of transient resistance is made automatically with the set number of I-O cycles after several I-O cycles at no-load operation. The transient resistance is estimated as an average value from several measurements (the divergence of measured values is also fixed).
13. The information is loaded into a data file. It is compatible with the "MS Excel" program in which processing of results is made. The interface to a computer – RS232.
14. The measurement of erosive wear is made via the weighing of contact tips with the holders on the analytical balance before and after of tests.

The photographs of installation, contacts and control block are given in Fig. 2. In actual measurements the force of clamping of contacts was 10 N. This duty ratio is possible because of low current on which the testing is carried out, the current that does not cause strong heating of contacts.

Fig. 2. The elements of the laboratory equipment for measuring the erosion wear of contact materials: a – the main frame of the bench, b – the control block, c – the element of the device for fastening and moving the contact tips and view of a contact surface after testing

The transient resistance was measured after every 100 I-O cycles, the total number of cycles of the experiment was usually 10000 times that is sufficient for the evaluation of the erosion wear for non-optimized materials.

Example of received data

For illustration of test equipment (laboratory benches) exploration, silver samples which were made with powder metallurgy method and industrially manufactured widely used – Ag/15CdO. The comparison of the results is represented in the Fig. 3-5.

Results demonstrate positive influence of CdO additive on erosion resistance of arcing electrocontacts. Difference is measured more than one degree in mass loss. Observations, including visual, show that after about 1000 I-O cycles all work surfaces had contact with arc (Fig. 3). That point explains abrupt rise of wear rate in the beginning for silver contact surface. Surface, which has interaction with arc, has a layer development. This layer is hardened with oxides and tempering. Then presence of such layer leads to linear rising of wear from I-O cycles number.

The rates of electrocontacts from I-O cycles number are represented in the Fig. 4, and demonstrate the material tendency to welding. The break force rates of silver pair reduce about up to 1000 I-O cycles, what is explained with running-surface of electrocontacts. As opposed to silver contacts, SCO-15 has higher gap force rate (Ag ~3N, Ag/15CdO ~6N)

Variation dependence of contact resistance R_i on I-O cycles number is shown in Fig. 5. For contact pair containing silver R_i value rises after two first tens I-O cycles and further possess the value about

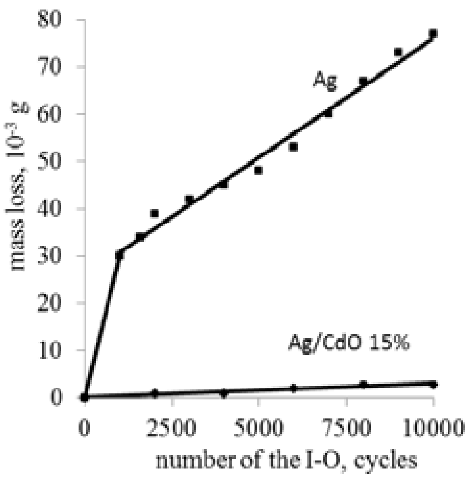


Fig. 3. Dependence of mass loss from number of the I-O cycles for Ag and Ag/(15CdO)

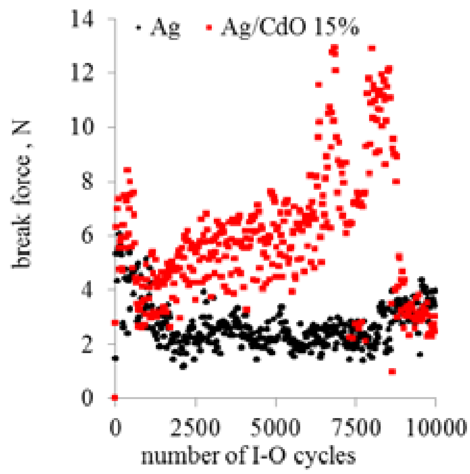
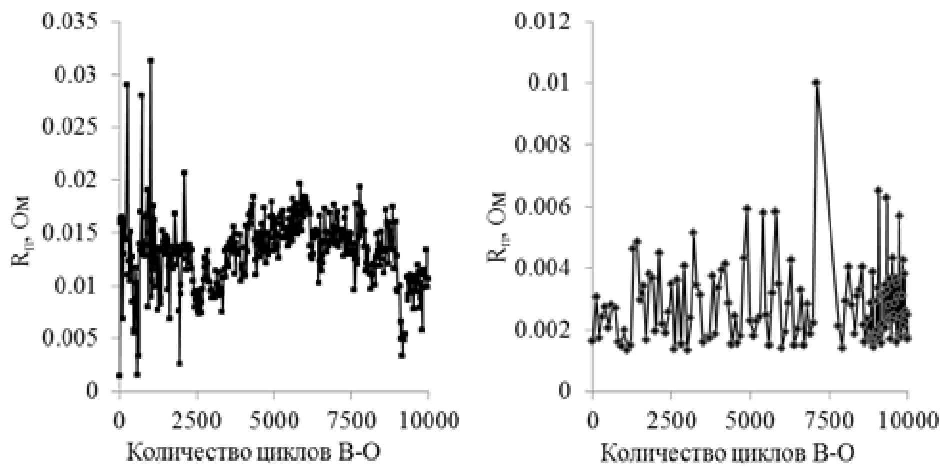


Fig. 4. Dependence of the break force from number of the I-O cycles for Ag and Ag/15CdO electrocontacts



a) b)

Fig. 5. Contact resistance for a symmetrical contact pair: a – Ag, б – Ag/15CdO

0,012-0,015 Om. The intermediate resistance value of Ag/15CdO possess the value R_i = 0,003 Om, that is considerably lower than for pure silver, although resistivity of composite considerably higher [5]. Lower intermediate resistance for Ag/15CdO apparently is provided with inclination to welding, what entails better contact of the electrocontact's surface opposed silver pair.

Conclusions

The laboratory bench for efficient interrupting electrocontact materials testing with respect to their general functional properties during their development and/or improvement is presented. The main properties of materials for testing are: transient voltage drop on closed contacts under the rated current; erosion wear resistance, break force. This equipment was tested on traditional contact materials and it was used for comparison test of new materials to form corrective actions to composition or technology.

Measurement of the whole range of functional properties of the material at the same time provides the profound knowledge of the nature of each property. This knowledge allows conscious controlling of chemical and phase composition of the electrocontact material.

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Лабораторный стенд для оценки функциональных свойств материалов разрывных электроконтактов

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Представлен автоматизированный лабораторный стенд для оперативного тестирования материалов разрывных электроконтактов по основным функциональным свойствам при их разработке и/или совершенствовании. Оборудование служит для оценки величины электроэрозии, межконтактного сопротивления работающей пары, а также усилия сваривания (посредством оценки усилия разрыва) в течение заданного количества циклов включения-отключения (380/220 В, ток 15-30 А, коэффициент мощности φ=1-0,3, частота циклов В-О 0,01-10 Гц, возможность задания параметров циклической нагрузки). Управление оборудованием, контроль процесса тестирования, регистрация и первичная обработка данных осуществляются с помощью специализированного программного обеспечения. Стенд апробирован на ряде традиционных, а также новых разрабатываемых материалов. Характерные результаты представлены на примере тестирования изготовленных авторами порошковых образцов Ag и Ag/15CdO в симметричных контактных парах.

Ключевые слова: электроконтактный материал, разрывные электроконтакты, функциональные свойства, лабораторный стенд, электроэрозия, контактное сопротивление, усилие сваривания.