Automatic Laboratory Test Bench for Experimental Study of Moveable Contact Joint Characteristics in Power-Distribution Equipment

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Abstract

The paper is devoted the laboratory test bench and results of laboratory tests of the moveable contact joints. The principles of operation and apparatus of the laboratory test bench is described. Contacts without protective coating are compared with contacts with the protective light-alloy-based coating applied according to the authors' technology in process of automated experiment.

Keywords: laboratory test bench, measuring, coating, electrical contact, contact joint, contact electrical resistance.

I. Introduction

Ambient factors (e.g., temperature, humidity, aggressive substances) provoke oxidation and corrosion of the contact surfaces of the contact joints in electrical equipment. These factors result in greater losses in contact joints (because of increasing contact electrical resistance) and in emergency failures of the contact joints [1-11].

The main parameter indicating the condition of a contact joint is its contact electrical resistance [12-16]. In fact, the only way to monitor the condition of contact joints in operation is to periodically measure the contact electrical resistance of the joint under load.

The technology uses protective metal coatings based on the low-melting alloys providing simple application on the contact surfaces and stable characteristics of the contact joint in the longer term [17, 18, 19]. The protective metal coating on current-carrying contact surfaces was produced on the basis of the contact melting process supposing that solid and liquid metals interact below the autonomous melting point of the solid metal [20].

When wetted with the liquid metal, the solid metal is melted. After that, the solid body atoms from the melted volume move to the remaining volume of the liquid phase - the dilution (diffusion) process takes place [20]. After hardening, a layer of a metal coating remains on the solid metal surface. The physical and chemical properties of this metal coating differ from those of the solid metal and the solder metal applied on the surface [20].

II. Laboratory test bench

To hold laboratory wear tests and observe the contact electrical resistance value and stability, we constructed a test bench including a knife switch with a nominal current of 400 A and an actuator that switched on/off the system with a predefined periodicity. A loading device was used for the load test.

The test bench (Fig. 1) consisted of a control unit and a contact joint unit. The control unit consisted of a control panel, a microcontroller and a power unit. The contact joint unit consisted of the following elements:

- a knife switch;
- a linear actuator Hiwin LAS-1 (an electric drive with an integrated DC motor, a reduction gear, and a retractable rod);
- position sensors.

The knife switch and the actuator were mechanically connected. The knife switch got "closed", when the actuator rod was extracted, and "open", when the actuator rod was retracted. The user specified the necessary number of knife switch closing/opening iterations. When all the iterations were complete, the process halted, and the user saw a notification. Also, the manual mode is possible.

The LCD display shows which operation mode was selected, how many automatic cycles were defined, and how many cycles were complete at the moment.

For test bench control, Arduino hardware computing platform was selected due to its open architecture and moderate price. An Arduino board consists of an Atmel AVR microcontroller, elements for programming and integration with other circuits, and a linear voltage stabilizer. The linear actuator was connected through an extension board - a driver of the DC motor.

The experiments measuring contact electrical resistance relied on the standard voltmeter-ammeter method: measuring voltage drop at the measured resistance resulting from stable current. The measurement used a 4-wire circuit preventing the instrument resistance from affecting the measurement accuracy. The measurement range of the applied microohmmeter was 1 μohm to 10,000 μohm. The absolute measurement error amounted to 1 μohm.

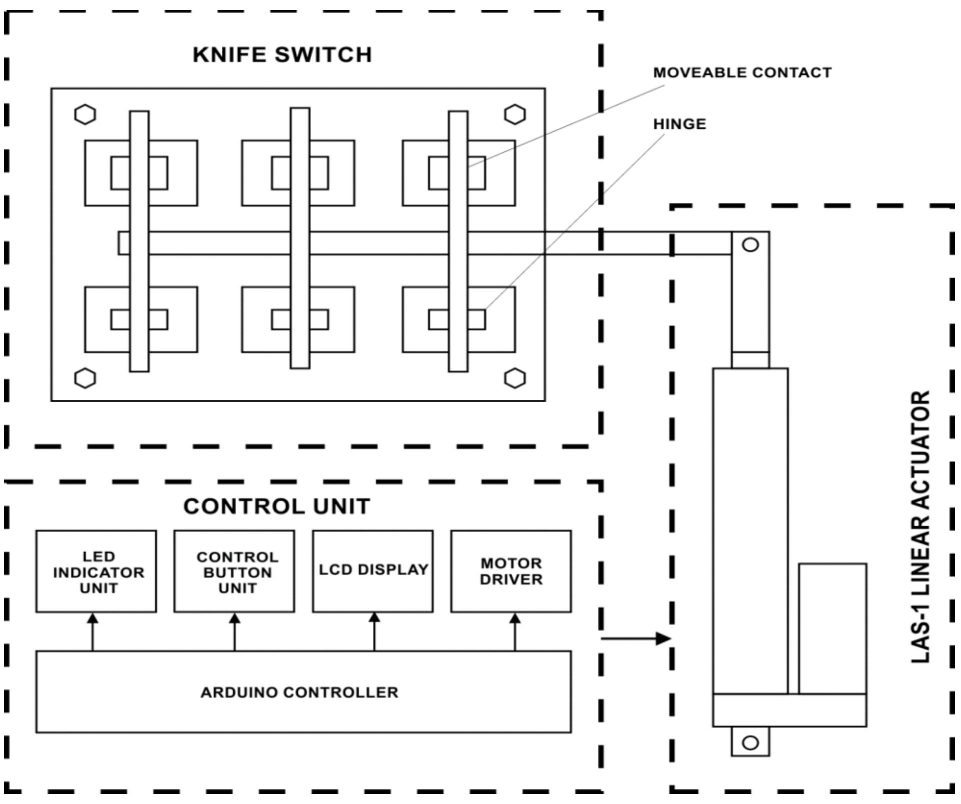

Fig. 1. Test bench structural circuit

III. LABORATORY TESTS

The moveable copper contact joints of phase A and phase C of the knife switch were coated according to the proposed technology. The phase B joint remained intact, i.e. tin-coated at manufacturer factory. Before phases A and C were coated, the manufacturer's coating had been removed.

Resistances were measured at ambient temperature with a microohmmeter. The results are presented on fig. 2. During the load test, heat monitoring was performed.

On the basis of the laboratory tests, the following conclusions were suggested:

- the contact electric resistance of the contact joints after application of the protective coating reduced 1.5-2 times;

- with the coating applied, the knife switch closing force reduced by 12%, from 80 N to 70.4 N. Therefore, a friction ratio decrease in the moveable contact can be assumed;

- as soon as after 200 closing/opening cycles of the knife switch contact system, the contact electrical resistance of the contact joint with manufacturer's tin coating increased 1.9 times; after 500 closing/opening cycles, the contact electric resistance grew 2.9 times.

- after 500 closing/opening cycles, one could see minor wear of the protective coating of the switch knife; the main metal, copper, was not visible though (Fig. 3). The surface of the pretinned switch knife was in far worse condition; there were attritions and dimmed surface segments (Fig. 4).

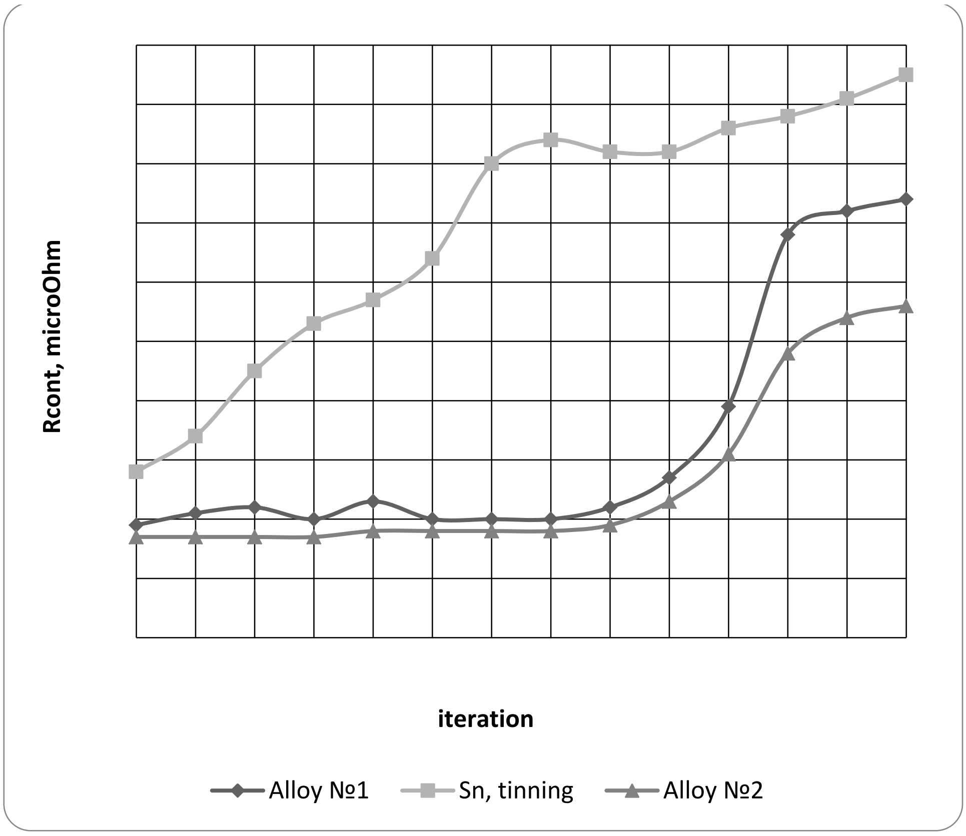

Fig. 2. Test results of laboratory test objects

- after 700 closing/opening cycles of the knife switch contact system, the contact electrical resistance of the coated contact joints remained stable and showed just a minor increase. In real operational conditions, it may take 5-7 years to use such electrical mechanism as knife switch 700 times;

- after 750 cycles, the contact electrical resistance of all the contact joints grew considerably, i.e. the protective coatings were almost worn off.

Fig. 3. A metal-coated switch knife after 500 closing/opening cycles

Fig. 4. A pretinned switch knife after 500 closing/opening cycles

IV. CONCLUSION

The research has provided the following main characteristics and advantages of the technology:

- the protective metal coatings of low-melting alloys allow to stabilize the contact electrical resistance of the contact joints and keep it at the initial level for a long time. The contact electrical resistance of the uncoated contact joints gradually grows in the course of operation time;

- as a result, after 0.5-1.5 years of functioning, the average contact electrical resistance of the contact joints without a coating may exceed that of the coated contact joints by 5 times (Al-Al), 2.5 times (Al-Cu), and 2 times (Cu-Cu);

- the coatings improve the wear resistance of the contact member surfaces in moveable contact joints as compared to the conventional tin coatings. The coatings also prolong the resource of switching power distribution equipment in 2-3 times, as proved by laboratory tests at real electrical equipment;

- the protective coatings on the working surfaces of both fixed and moveable contact joints of the contact members can greatly reduce electric energy losses, joint heating, and equipment operational costs.

To develop this technology further, it is proposed to:

- increase the efficiency of the application process (needed by electrical equipment manufacturers);

- experimentally check the effectiveness of the moveable contact joint coatings in the mechanisms for loaded circuit switching and in the conditions of impact interaction of the contact surfaces.

References

[1] M. Braunovic, N. K. Myshkin, V. V. Konchits, Electrical Contacts: Fundamentals, Applications and Technology, first ed., London, New York, CRC Press, 2006.

[2] M. Braunovic, Reliability of power connections, Journal of Zhejiang University, 8(3) (2007) 343-356.

[3] P. G. Slade, Electrical Contacts: Principles and Applications, CRC Press, 2013.

[4] P. F. Preston, An industrial atmosphere corrosion test for electrical contacts and connections, Trans. Instit. Metal Finishing, 50 (1972) 125-130.

[5] M. Braunovic, Aluminum Connections: Legacies of the Past, Proc. of 40th Int. Conf. on Electrical Contacts, (1994) 1-31.

[6] R. Timsit, Some Fundamental Properties of Aluminum-Aluminum Electrical Contacts, Electrical Contacts-1980, (1980) 79.

[7] J. L. Johnson, L. E. Moberly, Separable Electric Power Contacts Involving Aluminum Bus-Bars, Electric Contacts-1975, (1975) 53.

[8] R. S. Timsit, Electrical contact resistance: Properties of stationary interfaces, IEEE Trans. Compon. Packag. Technol., 22(1) (1999) 85-98.

[9] Naybour, R., Farrell, T. Connectors for Aluminum Cables: A Study of the Degradation Mechanisms and Design Criteria for Reliable Connectors, Parts, Hybrids, and Packaging, IEEE Transactions, 9(1) (1973) 30-36.

[10] M. Antler, Survey of Contact Fretting in Electrical Connections, Electrical Contacts-1984, (1984) 3.

[11] Aronstein, J. An updated view of the aluminum contact interface. Proceedings of the 50th IEEE Holm Conference on Electrical Contacts and the 22nd International Conference on Electrical Contacts, Electrical Contacts (2004) 98 – 103.

[12] S. Krumbein, Contact Properties of Tin Plates, Electric Contacts-1974, (1974) 3.

[13] M. Antler, Gold plated contacts: Effects of thermal aging on contact resistance, Proc. 43rd IEEE Holm Conf. Electr. Contacts (1997) 121-131.

[14] Misra, P.; Nagaraju, J. Electrical Contact Resistance in Thin Gold Plated Contacts: Effect of Gold Plating Thickness, Components and Packaging Technologies, IEEE Transactions, 33(4) (2010) 830 – 835.

[15] M. Antler, Gold plated contacts: Effects of thermal aging on contact resistance, Proc. 43rd IEEE Holm Conf. Electr. Contacts (1997) 121-131.

[16] M. Braunovic, Evaluation of Different Platings for Aluminum-to-Copper Connections, IEEE Trans. CHMT-15, (1992) 205.

[17] V.V. Goman, S.A. Fedoreev. Plating Technology for Contact Joint Performance Improvement in Electrical Equipment. Materials Science Forum, Vol. 870 (2016), pp 271-275. doi:10.4028/www.scientific.net/MSF.870.271.
[18] V.V. Goman, S.A. Fedoreev. Experimental Study of Contact Joint Characteristics in Electrical Equipment. Materials Science Forum, Vol. 870 (2016), pp 276-281. doi:10.4028/www.scientific.net/MSF.870.276.
[19] Perelshtein G.N., High-reliability high-efficiency demountable electrical contact joints [in Russian], Industrial Power Engineering Journal, 5 (2010) 30-33.
[20] N. F. Lashko, S. V. Lashko, Contact metallurgical processes during soldering and brazing [in Russian], Moscow, Metallurgiya, 1977.