Advances in Engineering Research, volume 188
International Conference on Aviamechanical Engineering and Transport (AviaENT 2019)

Automated Measurement of Engaging and Separating Forces of Electrical Connector Contact

Fedonin O.N.
Department of Automated Technological Systems
Bryansk State Technical University
Bryansk, Russia
rector@tu-bryansk.ru

Akulov P.A.
Department of Automated Technological Systems
Bryansk State Technical University
Bryansk, Russia
e-mail: akulov.paul@mail.ru

Petreshin D. I.
Department of Automated Technological Systems
Bryansk State Technical University
Bryansk, Russia
dipetreshin@yandex.ru

Handozhko V.A.
Department of Automated Technological Systems
Bryansk State Technical University
Bryansk, Russia
e-mail: vichandozhko@gmail.com

Abstract – **The automated system is proposed that allows to control and measure forces of engaging and separating electrical connectors. The structure of the mechanical and electrical parts of the developed device is described. The use of the system will increase the productivity and accuracy of the operation under control.**

Keywords – connectors, testing methods, tests, engaging force, separating force, measuring equipment.

I. INTRODUCTION

The quality of electrical connectors supplied to the ultimate consumer greatly depends on the proper tests at all stages of design and production. The importance of the tests is due to the fact that modern electronic systems, which include electrical connectors, must perform complex functions with high degree of accuracy, quality and reliability. During the production process, the electrical connector passes many tests, including control of engaging and separating forces.

Automation of technological operations, which are at least essential and labour-intensive, eliminates the human factor from the process. The use of automated testing methods together with the testing equipment of a new generation and relevant technical standards base make it possible to improve the quality and efficiency of production significantly by monitoring the current state of production and timely introduction of anticipatory changes in the technological process [1].

In the production the electrical connector passes many tests, including control of engaging and separating forces.

The automated control of engaging and separating forces of electrical connectors allows to reduce the labour-intensive characteristic of this operation and to eliminate the influence of the human factor on the objectivity of the control results.

The purpose of the study is to increase the productivity and control accuracy of engaging and separating forces of the electrical connector through the use of an automated system.

The engaging force of an electrical connector is defined as the force that must be applied to a plug-socket pair of the mateable connector for their full engagement. The engaging force depends on the engaging forces of some contact pairs, friction forces created by centering, guiding, fixing, coding and other elements of the connector design, taking into account the errors of their location in the connector [1].

The separating force of electrical connectors is determined in the same way.

There are quite a lot of works of both Russian [1-3, 8-9] and foreign scientists [4-7] devoted to measuring of engaging and separating forces of separate contacts of electrical connectors with the testing pin.

However, insufficient attention has been paid to the development of equipment that allow measuring engaging and separating forces of electrical connectors as a whole.

There are regulations specifying tests to control engaging and separating forces of electrical connectors and setting requirements for such tests, including:

1) permissible values of engaging and separating forces are specified in the technical regulations for a specific type of a connector. In technically justified cases, minimum and maximum value of engaging and separating forces can be specified for a particular type of connectors;

2) engaging and separating forces are controlled by any method providing measurement of the force directed along the axis of punch-through and breaking;

3) traverse speed of the plug and the socket concerning each other should not exceed 10 mm/s and the traverse is without accelerations;

4) the value of engaging and separating force should be the arithmetic mean value of five successive measurements.

Nowadays, in many domestic enterprises engaging and separating forces of electrical connectors are measured manually by means of specialized equipment (fig. 1).

II. Methods and materials

The test algorithm is as follows: the connectors are placed in the appropriate seats, the design of which depends on the type of electrical connectors tested, after that the operator uses the handle to engage and separate the pair under test, visually controlling the test indications of the dial dynamometer.

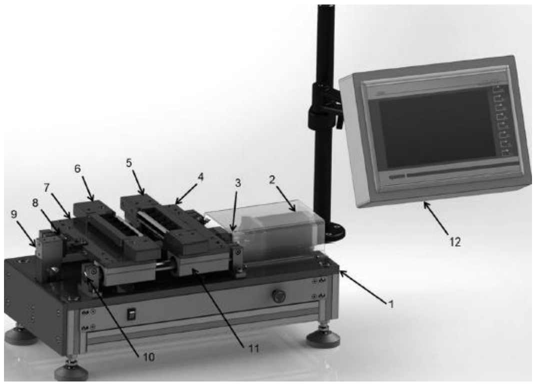
It is obvious that the use of hand-operated equipment cannot guarantee either the required speed of engaging and separating the tested electrical connectors, or a clear maximum value of the force during the tests. In addition, the dynamometers currently used are capable of displaying the value of the force applied only in one direction, so that different modifications of the units are used to record the engaging force and separating force of the electrical connectors, which greatly complicates the testing process.

Fig. 1 Equipment for measuring engaging and separating forces of electrical connectors

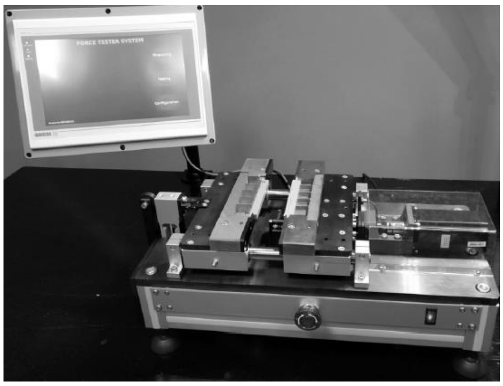
At present, an installation [10] has been developed and manufactured for automated control of engaging and separating forces of electrical connectors. This installation is basic (universal) for connectors under test, i.e. for testing a particular type of connector appropriate test equipment (clips) must be installed on the main mounting base.

Let us consider the key units and operating principle of the proposed automated testing system (Fig. 2). The installation has a base plate with a frame (1) made of aluminum structural shape, moving (4) and fixed (7) mounting base plates, step motor (2) with a leadscrew (3), strain gauge (9) and a control module (12) with a touch panel. The fixed and movable base plates are mounted on guides (10) by means of linear rolling bearings (11), while the moving base plate is rigidly connected to the ballscrew nut (not shown in the figure), and the fixed plate is connected to the strain gage transducer by means of a crank mechanism (8), which allows to transfer force to the strain gauge with minimal friction losses in the linear bearings of the fixed base plate and compensate for the bend of the strain gauge during measurements. The location of the moving and fixed base plates on the same guides ensures a high alignment of shifting base plates relative to each other. Tested connectors are installed into clips (5, 6).

Since this installation belongs to the class of measuring equipment, it should be certified and inspected. To do this, its design uses a special calibration device (not shown in the figure).



a)



б)

Fig. 2. Automated installation to control engaging and separating forces of electrical connectors: a – 3D-model; б – installation appearance

This device is a bracket with a roller acting as a block through which the cable is pulled, to which the calibrated load is attached. The software of the installation uses mode *Calibration* for this purpose, in which the user must enter the value of the calibrated load, and the installation itself calculates the transformation ratio of the strain gauge signal into the value of the measured force. Then, the resulting transformation ratio and the calibration date and time block are recorded in a special log of calibrations located in the non-erasable non-volatile memory of the control unit.

The use of single point strain gauge allows measuring engaging and separating forces of the tested connector in a single cycle engagement and its subsequent separation.

Applying a specialized step motor controller provides high accuracy maintenance of the parameters of moving base plate shifting and positioning relatively fixed one by commands from the control module. At the same time, the user has the opportunity to set not only the shifting speed of the moving plate, but also the required parameters of acceleration and braking, the current in the step motor windings, the parameters of step breakup and the parameters of step motor transition to *sleep* mode to reduce heat generation in its windings during downtime.

Strain gauge signal processing is realized with the help of a specialized ADC module of our own design. The features of this module include:

1) implementation of alternating supply of the strain gauge, which minimizes the influence of thermal EMF and contact potential difference in the connecting wires on the measurement results;

2) subsequent digital filtering of the data flow to minimize interference from the industrial supply voltage network.

The digital filter is a cascade connection of FIR-filter and sinc3-filter, the operation of which is synchronized with each other and with switching of the supply voltage direction of the strain gauge. In addition, a stepwise change of the measured parameter results in the reset of accumulated sinc3-filter results for accelerated processing of newly obtained data. This use of digital filtering makes it possible to reject signals with 50 Hz frequency of the supply network and multiple frequencies (100, 150 and 200 Hz) significantly while maintaining a high-speed response to the stepwise change in the force parameters recorded by the strain gauge.

A specialized strain gauge processing module (when working with a strain gauge of a maximum recorded force of up to ±500 N) provides an accuracy of force measurement not worse than ±0.1 N. Despite this, the resulting error of the installation increases to ±1 N as a whole due to the friction force in linear bearings of the fixed base plate.

III. Results

A block diagram of the electrical part of the developed automated installation to control engaging and separating forces of electrical connectors is presented in Fig. 3.

A touch panel controller is used as a control module of the installation. The control module software is done in CoDeSys 3.5.5 environment.

The shifting of the moving base plate is monitored by the step motor controller according to the commands coming from the installation control module. Input, editing of parameters of shifting and measurement of engaging and separating forces, indication of current parameter values and measurement modes are carried out by means of the touch panel controller.

To fix the initial position of the moving plate, the installation construction has a precision sensor, which ensures the accuracy and repeatability of 1 μm.

The interaction of the control module with the touch panel and the signal processing module from the strain gauge is implemented using a high-speed USB bus (FullSpeed), and the interaction with the step motor controller is via RS-485 bus over Modbus RTU protocol.

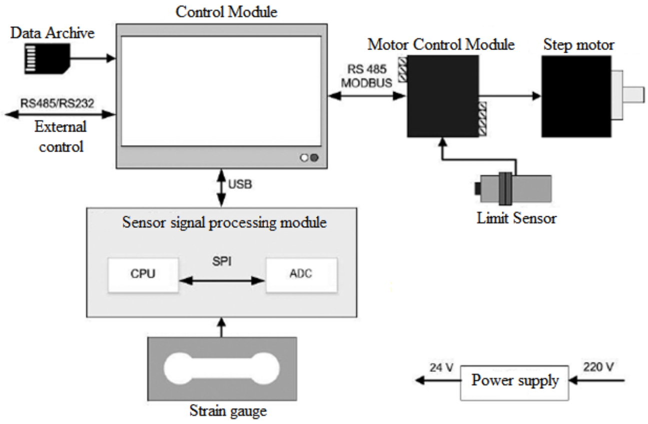


Fig. 3. A block diagram of the installation electrical part

L6N strain gauge used in the developed installation with maximum load ±500 N provides testing of all major types of electrical connectors of good contact connection.

If necessary, the strain gauge can be simply replaced by another one (of the same series) with a bigger, maximum permissible value of the recorded force. An incremental transducer recording angular movements of ballscrew with high accuracy can be additionally installed if bigger engaging and separating forces of electrical connectors are needed to be implemented and in order to eliminate possible "missing steps" of the step motor and to increase the shifting accuracy on the ballscrew shaft.

Before conducting the tests, it is necessary to fasten on the moving and fixed base plates appropriate clips for the tested electrical connectors, which are positioned using pins and screws. Standardization of mounting bores in the base plates and clips greatly simplifies the process of changing the tooling for different types of tested connectors. Due to the fact that the clips installed on the base plates are uniquely associated with the type and design of the electrical connector under test, they can be installed with identifiers, for example, a non-volatile memory chip (EEPROM), which will inform the control module about the type of an installed clip and the required parameters for testing the selected type of an electrical connector.

Each time the installation is turned on, the operation of separate units and modules is checked, and the procedure for automatic search of engaging point (zero point) of the base plates is performed [11].

After defining the position of the moving and fixed plate, the operator must insert the tested connectors (plug and socket) into the clips, select the type of the tested electrical connector on the operator panel and press the start button for measurements.

Automatic engaging and separating of electrical connectors is carried out by shifting the moving plate, which is driven through the ballscrew torque of the step motor. The moving plate approaches the fixed plate, i.e. there is engaging the connectors. The generated force is recorded by the strain gauge. After full engaging of the connectors, the moving plate shifts in the opposite direction, and that is the process of separating with force registration. Upon successful completion of measurement, a pop-up window with the measurement results appears on the touch panel (Fig. 4). It displays the average values of engaging and separating forces, the maximum values of engaging and separating forces recorded during measurements.

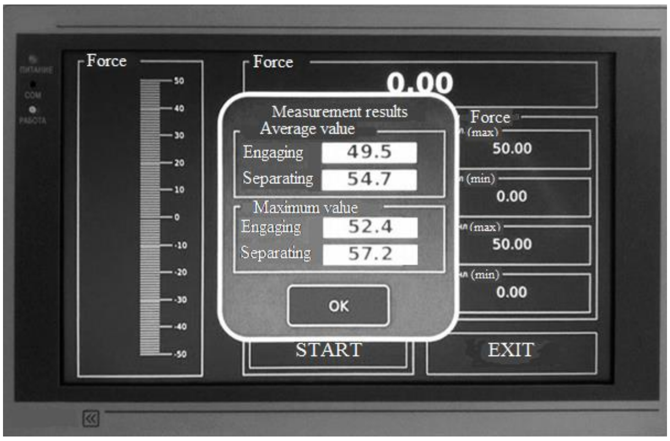


Fig. 4. Rendering a window with measurement results

In addition, in the cases of engaging and separating forces, exceeding the permissible values before measuring the parameters: engaging (min.) – engaging (max) and separating (min) – separating (max.), a red warning flag is displayed at the corresponding value to draw the user's attention to the measurement results which are beyond the permissible values.

TABLE I. EXPERIMENTAL VALUES OF MEASURED ENGAGING AND SEPARATING FORCES OF AN ELECTRICAL CONNECTOR

Measurement number	**Engaging force, N**	**Separating force, N**
1	47.7	54.1
2	48.5	53.8
3	48.9	53.8
4	50.0	54.6
5	52.4	57.2
Average force value	49.5	54.7
Maximum force value	52.4	57.2

Table 1 shows the values of engaging and separating forces of one of the electrical connectors obtained by means of an automated installation. According to the technical specifications, this connector should provide engaging and separating forces ≤45 N. Since the registered arithmetic mean values of engaging and separating forces exceed the permissible limit, it can be concluded that the tested connector is not suitable.

A similar automated system was developed to control the engaging and separating forces of a single contact of an electrical connector.

While the system is operating, the data obtained from the measuring diagram were processed by an external computer. The data are written into a text file and then imported into MS Excel for constructing a graph. Fig. 5 represents engaging and separating contact forces along the axis of ordinates, and the ordinal number of the measurement point - on the abscissa axis. The time of measuring engaging and separating forces for one contact is 1.5 - 2 s, and the speed of engaging/separating is 10 mm/s.

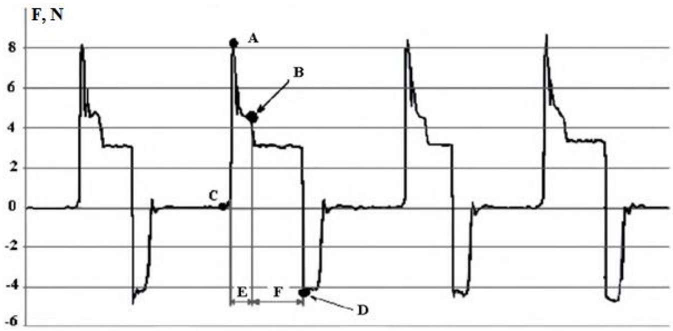


Fig. 5. Results of measuring engaging and separating forces of a single contact

The analysis of the results of measuring engaging and separating forces of a single contact (Fig. 5) shows that engaging of the connector pin with a single contact occurs in E area from C point to A point. In this area, engaging force increases sharply and reaches its maximum at A point, and a unit pin penetrates into the contact. Engaging force is a sum of Fy force of elastic contact elements on a unit pin and Ftr friction force of the pin on the elastic contact elements:

$$Fc = Fy + Ftr$$

In A-B area, a unit pin moves inside the contact and experiences Ftr friction force. The depth of pin penetration into the contact is set in the gaging unit and depends on the type of an electrical connector. The depth of pin penetration into the contact during the test is controlled by the gaging unit.

In F area (from B point to D point) the pin and the contact are separated. At this stage, the pin is also affected by the sum of the force from the elastic contact elements and the friction force of the pin and the elastic contact elements.

IV. Conclusion

Thus, the developed automated installation (Fig. 2) allows to measure and control automatically engaging and separating forces of electrical connectors in one cycle with the required test modes (number of engaging-separating, shifting speed, acceleration and distance of moving plate, etc.), which improves the accuracy and performance of the process, and eliminates the impact of the human factor. The installation is universal for tested connectors.

Full-scale experiments to define the accuracy of the installation have shown that the error in determining engaging and separating forces of the connector is ± 0.1 N, the limit of the measured force is ±1 N, and shifting accuracy and repeatability of the moving plate is 0.02 mm and 0.005 mm, respectively.

The developed automated installation for measuring engaging and separating forces of a single contact of the electrical connector showed its efficiency. The error in determining the engaging and separating force of a single contact of the electrical connector is ±0.01 N. The data obtained (Fig. 5) are of interest in assessing the quality of manufacturing electrical connector contacts.

References

[1] A.L. Saphonov, L.I. Saphonov, Some aspects of developing and manufacturing electrical connectors. St.Peterburg, Media Group Finestreet. 2015. 295p.

[2] G.I. Utkin, V.V. Chkan, V.V. Markov, Indexes of electrical connectors identifying contact technical state. Bulletin of Orel State Technical University. 2009. vol. 6/278(577). pp. 114-119.

[3] A.D. Katunin, L.I. Lebedeva, Major problems of controlling commutation forces of rectangular electrical connectors. Bulletin of Orel State Technical University. 2014. vol.4(306). pp. 139-143.

[4] Y-L. Hsu, Y-C. Hsu, M-S. Hsu, “Shape optimal design of contact springs of electronic connectors,” Journal of Electronic Packaging. 2002. Vol. 124(3). p. 178-183.

[5] J. Horn, B. Egenolf, “Shape optimization of connector contacts for reduced wear and reducer insertion force,” AMP Journal of Technology. 1992. 52(2). p. 42-46.

[6] Pan Jun, JIN Fan-jian, CHEN Wen-hua, et al, “Structural analysis of electrical connector contacts and insertion-extraction test,” Chine Mechanical Engineering. 2013. 24(12). p. 1636-1641.

[7] Luo Yan-yan, Yang Jing-yu, Ren Yong-log, Zhank Yuan-lei, Li Wen-jun, “Simulation and experimental study on plug and pull characteristic of electrical connector contact,” Chinese Journal of Engineering Design. 2017. V. 24(2). p. 168-174.

[8] SRS 23784-98. Low-frequency Low-voltage and Combined Connectors. General Technical Conditions. - Minsk: Inter-State Council on Standardization, Metrology, and Certification, 2004.

[9] SRS the RF 51325.2.2-99. Electric Connectors of Domestic and Similar Use. Part. 2-2. Additional Requirements to Plugs and Sockets for Mutual Joint in Devices and Test Methods. - M.: Standards Publishing House, 2000. – pp. 31.

[10] P.A. Akulov, D.I. Petreshin, A.D. Syrykh, Automation of electrical connectors tests. Avtomatizatsiya-i-izmereniya-v-mashinopriborostroenii. 2018. Vol. 3. pp. 100-106.

[11] P.A. Akulov, D.I. Petreshin, Algorithmic support of the control system of force of joint and disjoint of electrical connectors. Proceedings of the Southwest State University. 2018. 224 (79). pp. 94-104.