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Investigation of the Physical and Mechanical Parameters Interconnection of Pantograph Contact Elements

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Abstract **– The aim of the work is to establish the relationship between hardness and volume resistivity of the current collectors contact elements of electric rolling stock. Was conducted statistical analysis of the data result of numerous experimental research obtained of the physical and mechanical parameters of carbon contact elements. The theoretical and empirical methods of research used in this work. As a result of the conducted research was found statistical interconnection between contact elements hardness and volume resistivity described by the analytical expression. Taking into account the design features of the contact elements and the requirements for their operation, were established more accurate correlations of the measured values. Using the results obtained in the work will increase the operational reliability of the sliding high-current contact of electric transport.**

Keywords – electric transport, traction power supply system, catenary, current collector, contact element.

I. Introduction

The reliability of the Railways Traction Power Supply System in general depends on the reliability of its components. The catenary is perhaps the most important element of the Railways Traction Power Supply System. Catenary has no reserve and when it fails, the electric rolling stock is stops [1–6]. This leads to substantial losses money of carriers and delayed cargo and passengers. Transmission electric energy from the traction substation to the electric rolling stock carried out through the sliding contact between the contact wire and contact elements of the current collector. This process called current collection.

The current collection quality and the transmission of electric energy to the electric rolling stock depends directly of the contact network operational performance [6 – 10].

The hardness instability of the current collector contact elements in the party and between the parties negatively affects the resource characteristics of the contact wires and current collector contact elements.

The main factor that determines the physical and mechanical parameters of carbon contact elements is the density of the material. The density of current collector contact elements directly related to a mechanical parameter such as hardness and eclectic parameter – volume resistivity. Volume resistivity and hardness are parameters that investigated at the stage of contact elements production and when they received in of locomotive depots [8, 11]. However, the method of their verification has certain disadvantages.

The perspective direction of increasing the contact elements resource is using devices that allow determining the parameters of each separate sample contact element and determining the location of their installation on the current collector to achieve the highest efficiency of the current collecting. [12, 13].

II. The main material

In the work, a research carried out on the existence of a relationship between hardness and volume resistivity, for a combination of carbon and graphite contact elements from different manufacturers, selected from different parties.

Determination of the contact elements volume resistivity carried out in accordance with [11] on the working surface using the ammeter-millivoltmeter method.

The maximum permissible value of the volume resistivity, for carbon and graphite contact elements in accordance with [11] is 30 and 15 μΩ·m, respectively.

Set of experimental studies [14] carried out to determine carbon and graphite contact elements parameters to determine the possible statistical relationship between the hardness and volume resistivity of carbon and graphite contact elements, resulting in data arrays.

The obtained data analyzed for normality using the software package STATICTICA. For that selected descriptive statistics selected: average, median, asymmetry coefficient and its standard error, excess and its standard error.

For the aggregate of data analyzed for normality, has been established (Table 1) that the mean and the median are close to each other by value.

TABLE I. Results of Checking Data on Normality

Variable	**M**	**Me**	**Min**	**Max**	**As**	**σ(As)**	**Ex**	**σ(Ex)**
Carbon contact element								
HB, (N/mm^2)	32,553	32,994	17,364	48,643	-0,076	0,221	-0,936	0,438
ρ, (μΩ·m)	27,704	27,587	21,451	35,738	-0,093	0,221	-0,672	0,438
Graphite contact element								
HB, (N/mm^2)	15,572	17,751	11,498	19,2	-0,245	0,219	0,85	0,437
ρ, (μΩ·m)	18,548	18,57	10,815	25,56	-0,104	0,219	0,877	0,437

The asymmetry coefficient is negative and relatively close to zero. The standard error of the asymmetry does not exceed more than three times the absolute value of the asymmetry coefficient. Excess has a rather significant negative value, but its standard error also does not exceed more than three times its absolute value. The check on selected descriptive statistics shows that the hypothesis not rejected by normality.

The Kolmogorov-Smirnov and Shapiro-Wilk tests for graphite and carbon contact elements (Fig. 1–4) indicate that the significance level for the Kolmogorov-Smirnov test is more than 0.2 - this suggests that the hypothesis of normality not rejected by it. In the Shapiro-Wilk test, for carbon contact elements, the significance level is less than 0,05 for hardness - the hypothesis about normality is rejected, for a volume resistivity greater than 0,05 - the hypothesis is taken. In addition, the hypothesis of normality for the test Shapiro-Wilk accepted for graphite contact elements.

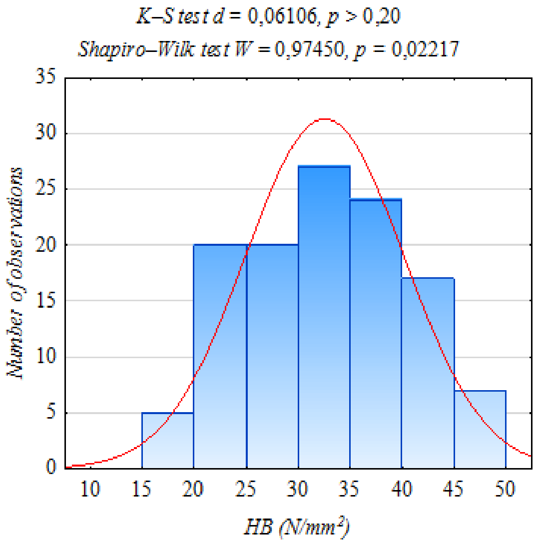

Fig. 1. K-S test and Shapiro-Wilk test for hardness carbon contact elements

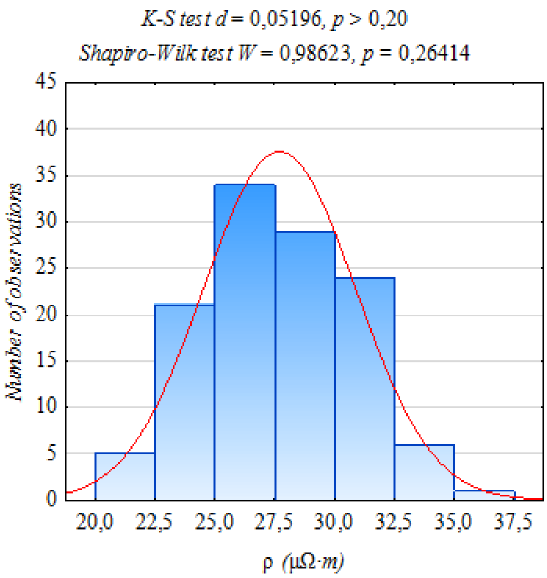

Fig. 2. K-S test and Shapiro-Wilk test for volume resistivity carbon contact elements

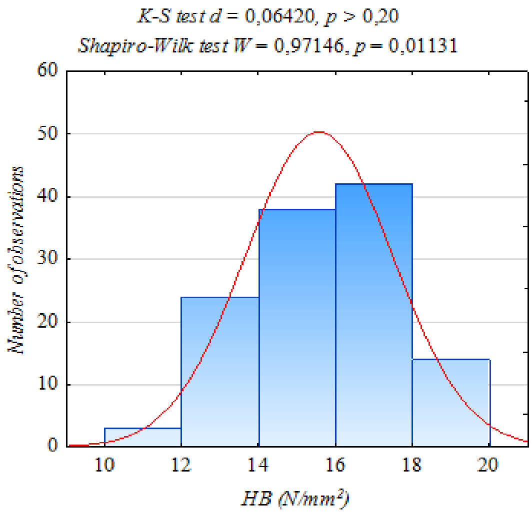

Fig. 3. K-S test and Shapiro-Wilk test for hardness graphite contact elements

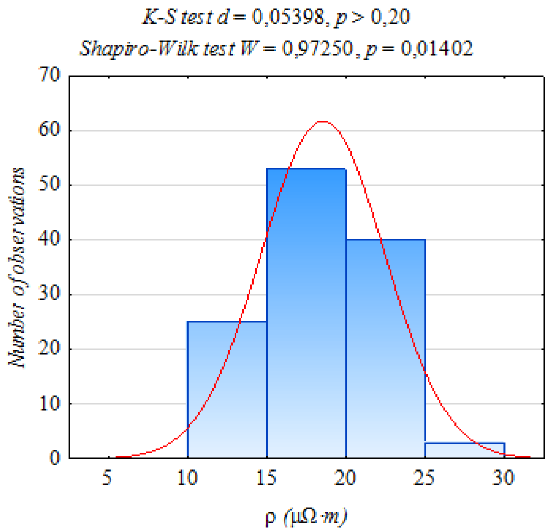

Fig. 4. K-S test and Shapiro-Wilk test for volume resistivity graphite contact elements

The analysis of normal-probable graphs (Fig. 5, 6) showed that there are unsystematic deviations, but the hypothesis of normality does not deviate, since the main part of the actual data is located along the theoretical normal line.

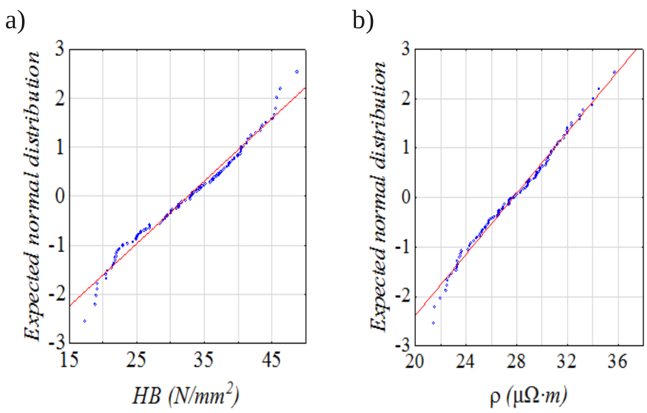

Fig. 5. Normal-probable data distribution graph for carbon contact elements

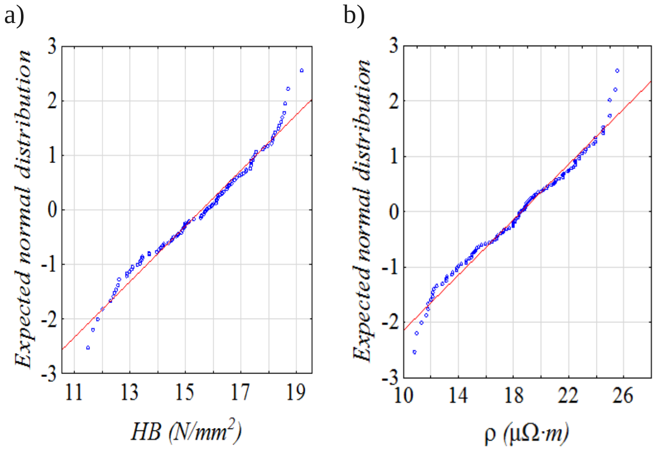

Fig. 6. Normal-probable data distribution graph for graphite contact elements

The boxplot (Fig. 7, 8) show that there are no emissions, the box and whisker are symmetric, and the median centered, indicating the normal distribution of data.

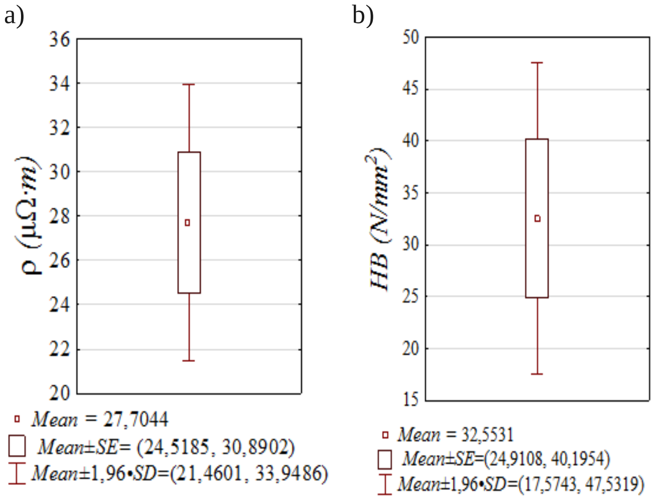

Fig. 7. Boxplot for carbon contact elements

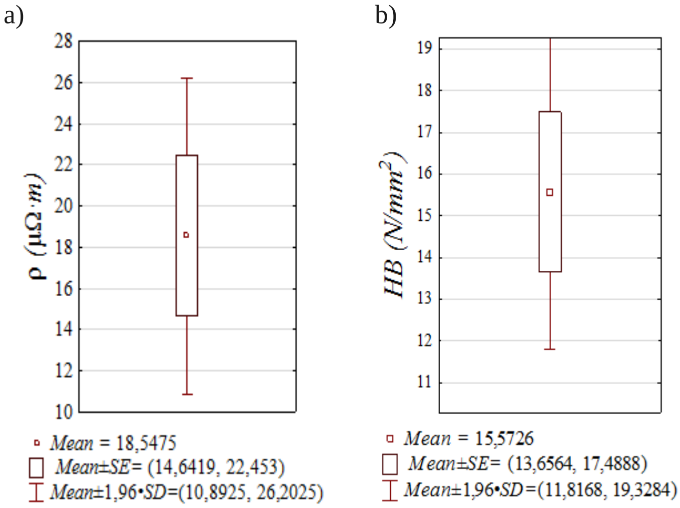

Fig. 8. Boxplot for graphite contact elements

The distribution of data can considered normal, since only one of the five tests (mediated, graphical and estimated) showed a sign of abnormality.

The hypothesis of normal data not rejected, and the data as a whole are subject to the normal distribution law.

A correlation matrix constructed to determine the statistical relationship between the investigated parameters of carbon and graphite contact elements, which showed that there is a strong correlation between hardness and volume resistivity (more than 0.95 for carbon contact elements and more than 0.97 for graphite contact elements).

The histograms of the excesses (Fig. 9), which show that the excesses are concentrated in the middle part of the interval, is symmetric, the hypothesis about the normality of their distribution not be rejected.

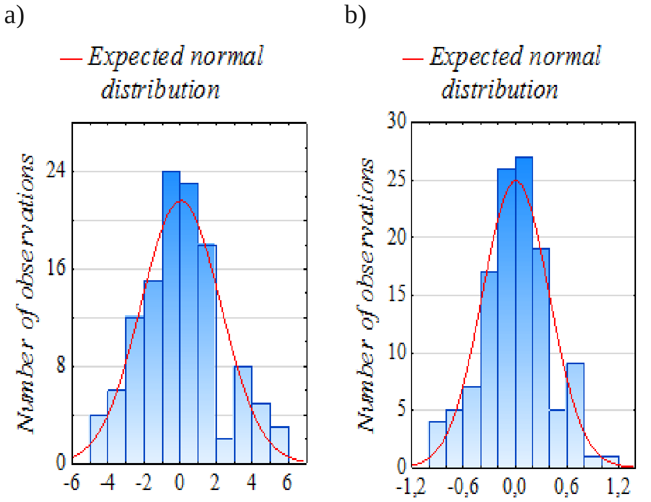

Fig. 9. Histograms of the excesses for carbon (a) and graphite (b) contact elements

The constructed normal-probable graphs of excesses (Fig. 10) indicate the absence of systematic deviations of factual data from the theoretical line, which also indicates the normality of the distribution of excesses.

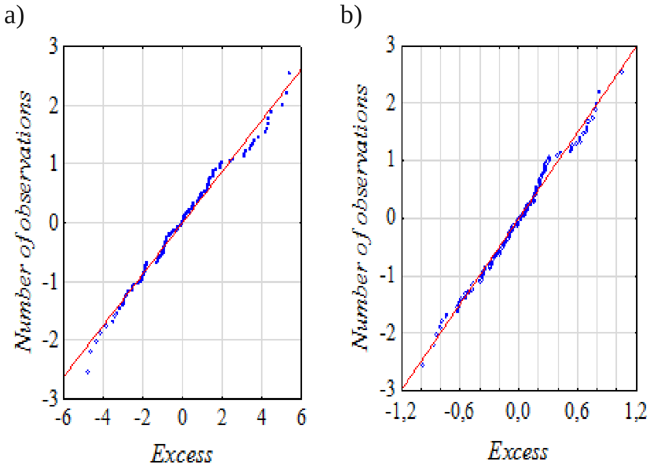

Fig. 10. Histogram of excesses for carbon (a) and graphite (b) contact elements

The diagrams of the dependence of the dispersion of excesses (Fig. 11, 12) on the predicted values have been plotted to indicate the absence of directional distribution of points – they are rather chaotic on the plane; accordingly, it can be concluded that the excesses are independent of the predicted data.

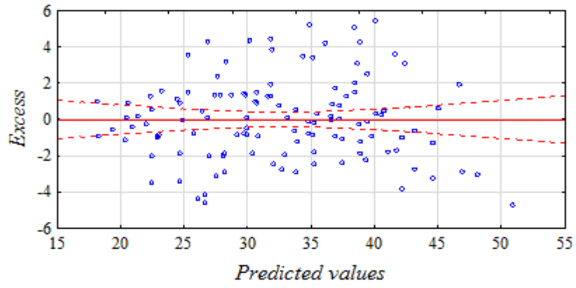

Fig. 11. Scatter of data diagram for carbon contact elements

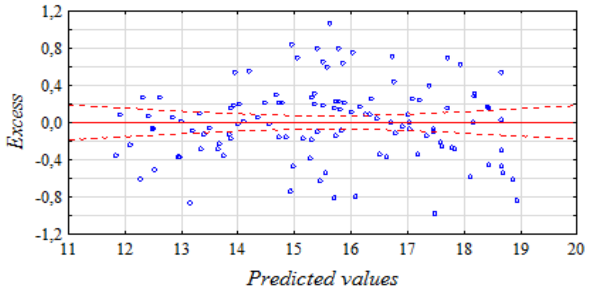

Fig. 12. Scatter of data diagram for graphite contact elements

The analysis of the excesses showed a fairly high quality of models.

To assess the acceptability of the model as a whole, a dispersion analysis (ANOVA) conducted. Since the significance level is less than 0.05, it can said that the model is acceptable.

The value of the determination coefficient for carbon contact elements R^2= 0,928 and graphite contact elements R^2= 0,958 shows that there is a close statistical relationship between hardness and volume resistivity for these types of current collection contact elements.

A model that describes the statistical relationship between hardness and volume resistivity for carbon contact elements type looks like:

$$HB=-0,0066\cdot\rho^2-0,7235\cdot\rho+4,5329 \quad (1)$$

A model that describes the statistical relationship between hardness and volume resistivity for graphite contact elements type looks like:

$$HB=-0,0475\cdot\rho^2+4,94\cdot\rho-67,352 \quad (2)$$

The final stage of model verification was the comparison of the predicted values with the measured values. The relative error of the predicted and actual (measured) value was 3.83% for carbon contact elements and 2.91% for graphite contact elements.

Measurement of the volume resistivity and hardness, for the group of the contact elements, showed that their relationship reflects the structural uniformity of the material.

At the same time, there may be contact elements in the batch with the maximum hardness and volume resistivity, and with the minimum that meets the requirements of the existing normative documentation, but the limitation of this scatter could positively affect the resource characteristics of contact wires and contact elements.

Determination of the contact elements parameters, was also carried out for further research on their wear and determination their influence power on the contact wire wear with variable influence factors and structures of catenary.

III. CONCLUSIONS

1. As a result of the conducted research was found statistical interconnection between contact elements hardness and volume resistivity described by the analytical expression. Taking into account the design features of the contact elements and the requirements for their operation, were established more accurate correlations of the measured values.

2. Using the results obtained in the work will increase the operational reliability of the sliding high-current contact of electric transport.

3. The obtained dependences and results of experimental researches allow to determine the influence of current collection contact elements physical-mechanical parameters on the amount of contact wire wear with variable current collection and environment parameters.

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