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The “Engineer” publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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CONTEXT / MUNDARIJA

Improving monitoring and diagnostics of wear of contact wire of electrified railways

M. Yakubov[1][a], S. Norjigitov[1][b], I. Karimov[1][c], U. Mukhtorov[1][d]
[1]Tashkent state transport university, Tashkent, Uzbekistan

Abstract: The article presents information that facilitates monitoring and diagnosing wear of contact wires in traction electrified railways. Classifications of the causes of damage and the corresponding types of wear of the contact wire are given. A method is proposed for calculating wire wear by the measured width of the worn surface or height from the base line, which are entered into a mobile phone, which contains a program for calculating wear as a percentage, during maintenance of the contact system. An algorithm for calculating wear is given [2].

Keywords: amount, contact wire, electroerosion, mechanical erosion, abrasive erosion, bearing cable

1. Introduction

The contact network in the traction system is among the most damaged facilities. The operational surveys carried out by JSC "O³zbekiston temir yo¹llari" showed that the intensity of failures in the contact network from the total number of failures in the last five years (2016-2021) is 8.7%. It should be noted that while the number of failures on the contact network has generally decreased, their relative level is stable.

2. Methodology

Set of structural parameters (current collector, contact suspension, track, XPS speed), physical properties of the contact wire (hardness, density, electrical resistance, heat capacity) [7] and environmental conditions (temperature, humidity, dust, air speed) are the main factors influencing the wear of the contact wire [3][6].

Failure of the devices of the contact network is caused by imperfection of the design of elements and parts, errors in its assembly and operation (40-50%), wear of their parts (10-20%). This can be explained by insufficient or total absence of commonly used means of technical diagnostics of the condition of the contact suspension [1]

The question of ensuring the reliable operation of the devices of the contact network - to study the causes and consequences of damage, external and internal modes, determination of criteria for assessing their technical condition, development of methods and means of control and diagnostics is a priority and their solution is topical of this article. Wear of the contact wire can be gradual, continuous or instantaneous. For example, if the contact wire is exposed to electrical wear and heat, the wire may melt. Mechanical or electro-erosive wear on the wire cross-sectional surface lengthens it and, to some extent, also depends on the load and external forces. As a result of thermal destruction and stretching of the contact wire, it can break. Gradual thermal destruction creates an extended "cervix" [8] in the wire. The most studied causes of contact wire wear are given in Figure 1.

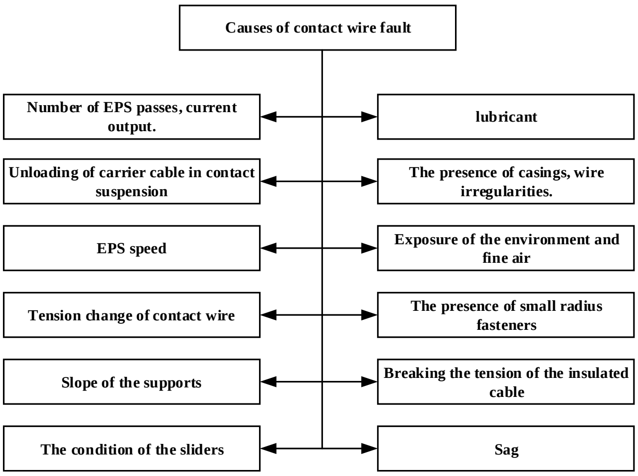

Fig. 1. Classification of the causes of wear of contact wires

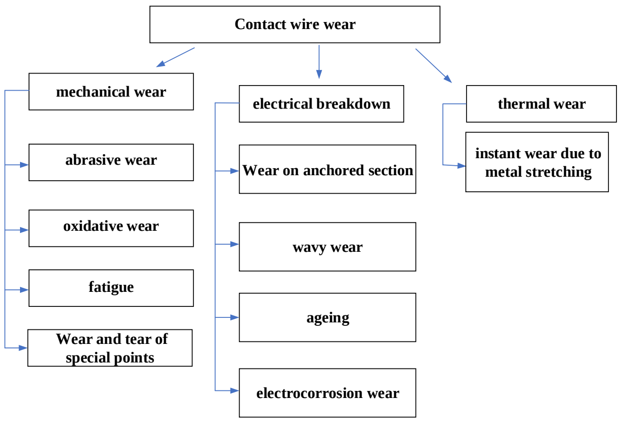

Fig 2. Classification of types of wear of contact wire

The most common wear measurement method is the measurement of the wire by the height of the base line of the remaining contact wire and the width of the worn friction

[a] https://orcid.org/0009-0005-4912-1772
[b] https://orcid.org/0009-0005-0999-7032
[c] https://orcid.org/0000-0002-5221-0443
[d] https://orcid.org/0009-0002-6036-9857

pad, which are known in the development of devices in the monitoring and technical diagnosis process.

As the speed of the electrical rolling stock (EPS) increases, the wear on the contact wire can be reduced. [4] This phenomenon is explained by increased resistance of metal to deformation. It is known that the density of wear distribution of the wire especially on the anchor section along the wire changes according to the Weibull formula.

$$S_{wear}(x) = \frac{\beta}{\eta}\left(\frac{x-x_o}{\eta}\right)^{\beta-1} * exp\left[-\left(\frac{x-x_o}{\eta}\right)^{\beta}\right], \qquad (1)$$

where, x-current value of wire length; x_o -minimum initial value; $\beta > 0$ -form parameter, $\eta > 0$ - scale parameter.

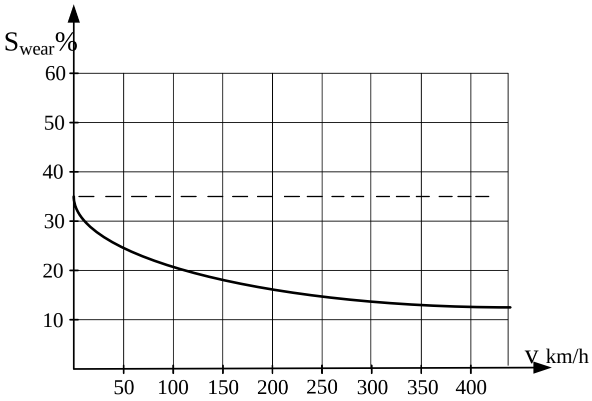

Fig. 3. Contact wire wear graph on anchor section from EPS speed

And the intensity of failure caused by wear is defined as:

$$\lambda(t) = \frac{\beta}{\eta}\left(\frac{x-x_o}{\eta}\right)^{\beta-1} \qquad (2)$$

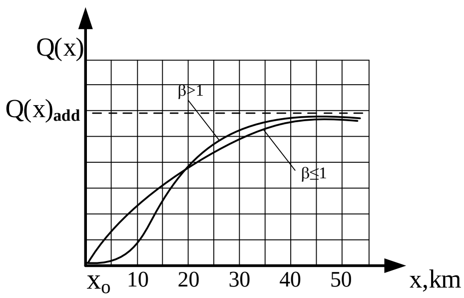

Fig. 4. Contact wire wear distribution curve in anchor section

Often the wear of the contact wire is measured by tools with a handle (caliper, measuring range 150 mm, micrometer, 0.01 mm, etc.) and an automated device. The measured parameters of the contact wire are proportional to the wear (height of the section h, width of the grinding surface a) and are transmitted to the calculation of Sm to computer programs or by means of a table of nomograms [2], [4]. Further, the process of monitoring and diagnostics of wear during maintenance of contact wires is carried out in the technical service. The cross-section surface of the contact wire is complex. (Figure 5). Usually the contact wire is replaced at wear of 30% of the lower and full surface of the cross section of the wire. If the lower radius of curvature R=6.5 mm, the original cross section area of the contact wire MF-100 is 100 mm^2.

The section of the worn cross section of the contact wire represents a segment whose area can be defined by the following expressions (Figure 5).

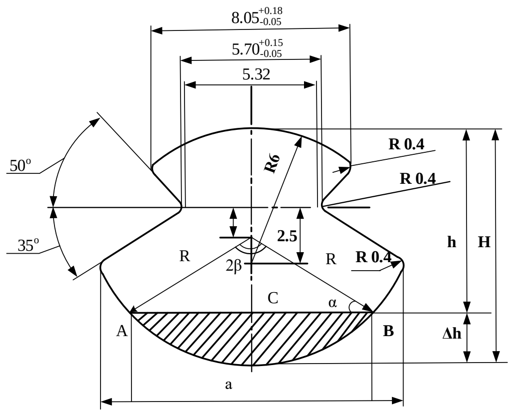

Fig. 5. Cross section of contact wire MF-100

From Figure 5 we know:

$$2 * \frac{a}{R} = 2sin\alpha; \ \alpha = arcsin\frac{a}{R}; \ \beta = 2\alpha = 2arcsin\frac{a}{R}; \quad (3)$$

Calculate the surface of the sector, taking into account the following proportion:

$\pi R^2 \leftrightarrow 360^o$

$$S_{sektor} \leftrightarrow 2\, arcsin\frac{a}{R}, \qquad (4)$$

Consequently:

$$S_{sektor} = \frac{2\pi R^2 arcsin\frac{a}{R}}{360^o} \qquad (5)$$

The worn surface of the cross section of the contact wire shall be determined as follows:

$$S_{segment} = S_{sekt} - S_{AB} = S_{sekt} - a\sqrt{R^2 - a^2} = \frac{2\pi R^2 arcsin\frac{a}{R}}{360^o} - a\sqrt{R^2 - a^2} \qquad (6)$$

By replacing the measured width and the initial parameters of the contact wire, we determine its wear:

$$S_{segment} = \frac{2*3.14*6.25^2 arcsin\frac{1.5}{6.5}}{360^o} - 1.5\sqrt{6.5^2 - 1.5^2} = 0.35mm^2 \qquad (7)$$

In order to determine the percentage of wear, a proportion of:

$100mm^2 \leftrightarrow 100\%$

$035\%\ mm^2$

$$x = \frac{0.35*100\%}{100} = 0.35\% \qquad (8)$$

Since the wear rate is higher than 0.25%, the contact wire must be replaced.

If the cross-sectional surface of the MF-type copper core of the electrified railway contact network is blurred by 25%, this part must be replaced.

In most cases, to determine wear, the height of the contact wire is measured with a caliper. (Figure 5). Specifying the nominal geometric dimensions of the wire: the cross-sectional area S=100mm^2; A= 5.5 mm; H =14.5 mm; S=3.2 mm; If R=7.88 mm and measured height h=10 mm after wear of a certain part, should this part of the contact wire be changed?

According to Figure 5, the worn part of the contact wire can be determined by measuring the remaining height h as follows:

$$\Delta h = H - h \qquad (9)$$

of ΔOBC

$$\alpha = arcsin\frac{R-\Delta h}{R};$$

$$\Delta COB\beta = 90^o - arcsin\frac{R-\Delta h}{R} \qquad (10)$$

The surface of the AOBFA sector corresponding to angle 2 is determined by proportion as follows: β

$$360^o \leftrightarrow \pi R^2$$

$$2\beta \leftrightarrow S_{sekt}$$

Consequently:

$$S_{sek} = \frac{2\beta\pi R^2}{360^o} \qquad (11)$$

From the surface of this sector we subtract the surface area of the triangle SΔOAB as a result we can calculate the surface of the worn part:

$$S_{\Delta OAB} = (R - \Delta h)*\sqrt{2R\Delta h^2 - \Delta h^2} \qquad (12)$$

The wear of the ACBF transverse segment is determined as follows:

$$S_{segACBF} = \frac{2\beta\pi R^2}{360^o} - (R - \Delta h)*\sqrt{2R\Delta h - \Delta h^2} = \pi R^2 \cdot \frac{90^o - arcsin\frac{R-\Delta h}{R}}{180^o} - (R - \Delta h)\sqrt{2R\Delta h - \Delta h^2} \qquad (13)$$

Here is a numerical example of calculation.

Geometrical parameters of contact wire MF-100: S=100 mm2; R=7.88 mm; Height measured with bar. The surface of wear of the contact wire is found as follows: $\Delta h = H - h = 14.5 - 11 = 3{,}5$ мм

$$S_{ad} = 3.14 * 7.88^2 * \frac{90^o - arcsin\frac{7.88-3.5}{7.88}}{180^o} - (7.88 - 3.5)\sqrt{2 * 7.88 * 3.5 - 3.5^2} = 32.25\text{мм}^2 \qquad (14)$$

The worn surface is defined as follows:

$$S_{adll} = \frac{32.25}{100} * 100\% = 32.25\% \qquad (15)$$

The design part of the worn contact wire is above the allowable part, therefore this part must be replaced. Figure 7 provides an algorithm [4] for calculating the wear of a contact wire, oriented to an iPhone type mobile phone.

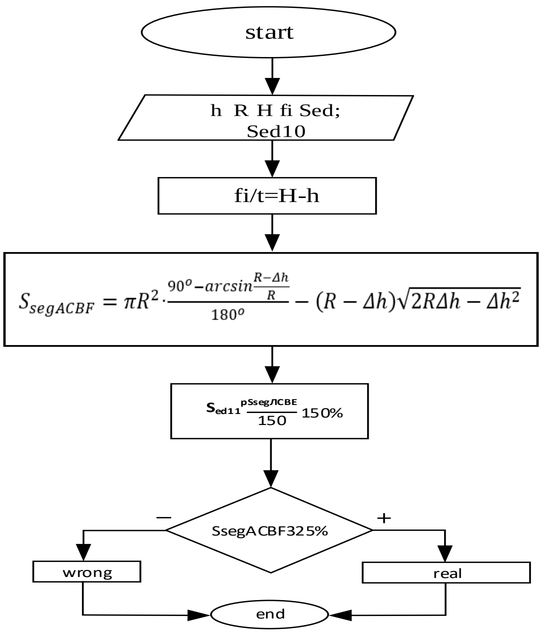

Fig. 7. Algorithm for calculating the wear of the contact wire.

3. Conclusion

The mathematical model for determining the degree of wear of the contact wire, which is the main element of the contact system of electrified railway power supply, has been resulted. The wear measurement of the contact wire is determined by the results of the remaining height after the wear of the contact wire or the width of the worn part of the cross section sector. Currently, the technical control staff determines the wear and tear using a nomogram or table of 4-5 pages.

The proposed method provides a quick and convenient determination of the degree of wear of the contact wire and as a consequence, provides greater economic efficiency due to the use of modern methods and tools in the monitoring and diagnosis processes.

Developed a program created in the language ANDROID, allowing to use mobile phones such as «iPhone», «Samsung», «Mi» and based on modified electronic calculators.

References

[1] Efimov A.V., Galkin A.G. Reliability and diagnostics of railway power supply systems. Moscow: 2000- 512p.

[2] Sadirov O.A., Filippov V.M., Stupakov S.A. Study of electromechanical wear of a contact pair of current collection devices. // Friction and wear. – Tomsk, 2015, Volume 36. No. 5 –390-394p.

[3] Stupakov S.A., Sadirov O.A., Filippov V.M. Modeling of electromechanical wear of a contact pair of current collection devices of electric transport. // Friction and lubrication in machines and mechanisms. -M: "Mechanical Engineering" 2012. No. 4. -23-30 p.

[4] Amirov S.F., Yakubov M.S., Karimov I.A., "Software for decomposing the cross-sectional surface and mass of the contact wire in the contact network" No. DGU 19391

[5] Rules for maintaining the contact network of electrified railways. / Ministry of Railways of the USSR. M.: Transport, 1978. - 92 p.

[6] Konovalov, V. Iron contact wires / V. Konovalov // Railway business. 1991. - No. 6. - p.61-62.

[7] Gat, M. Effect of temperature on the erosion of metals / M. Gat, W. Tabakov, T. Wakeman // Thin Solid Films. 1979. - V.64, №2. -p.219 - 220.

[8] Eyre, T. S. Surface aspects of unlabricated metal-to metal wear / T.S. Eyre, D. Maynard// Wear.- 1971.-V. 18, № 4.-p.301 310.

Information about the author

Yakubov Mirjalil	candidate of Technical Sciences, Professor of the Department of Electricity Supply, Tashkent State Transport University. Email: yakubov1026@gmail.com https://orcid.org/0009-0005-4912-1772
Norjigitov Sayfiddin	senior lecturer, Department of Electricity Supply, Tashkent State Transport University. Email: sayfiddinnorjigitov@gmail.com https://orcid.org/0009-0005-0999-7032
Karimov Islom	senior lecturer, PhD, Department of Electricity, Tashkent State Transport University. Email: nauka.islom@gamil.com https://orcid.org/0000-0002-5221-0443
Mukhtorov Usmonjon	assistant at the Department of Electricity, Tashkent State Transport University. Email: usmonmuxtorov999@gmail.com https://orcid.org/0009-0002-6036-9857