Metallophysics and Advanced Technologies
Металофіз. новітні технол.
Metallofiz. Noveishie Tekhnol.
2021, vol. 43, No. 3, pp. 425–433
https://doi.org/10.15407/mfint.43.03.0425
Reprints available directly from the publisher

MATERIALS IN EXTREMAL CONDITIONS

PACS numbers: 05.60.Cd, 81.40.Pq, 81.70.Bt, 89.20.Kk, 89.40.Bb

Theoretical and Experimental Research of Contact Wire and Pantograph Contact Elements Wear

A. V. Antonov and V. G. Sychenko*

Dnipro National University of Railway Transport
named after Academician V. Lazaryan,
2 Academician Lazaryan Str.,
UA-49010 Dnipro, Ukraine
**Branch of PJSC 'Ukrzaliznytsia'*
'Research, Engineering and Design Institute of Railway Transport',
39 Fedorov Str.,
UA-03038 Kyiv, Ukraine

The goal of the work is substantiation of using the proposed method of sliding high-current contact wear prediction by comparing the forecasting results with the experimental ones. In conditions of ensuring high quality services transportation of passengers and cargo, the issue of ensuring reliable operation of the high-current contact 'contact wire–pantograph contact element' becomes especially relevant. The reliability of the traction system as a whole depends of the high-current contact reliability. The feasibility of using the proposed method for predicting wear of sliding high-current contact is substantiated. This method differs from the existing ones due to possibility of taking into account the set of factors, which influence on current collection process, by comparison the predicted wear values of the sliding high-current contact with the data obtained experimentally. The results show a possibility of reducing the wear of the contact wire up to 11% in its interaction with graphite contact elements and increasing the efficiency of the use of contact elements up to 25%.

Key words: current collection, wear rate, contact wire, pantograph, contact elements.

Метою роботи є обґрунтування доцільності застосування запропонованого

Corresponding author: Andrii Vladyslavovych Antonov
E-mail: a.v.antonov91@gmail.com

Citation: A. V. Antonov and V. G. Sychenko, Theoretical and Experimental Research of Contact Wire and Pantograph Contact Elements Wear, *Metallofiz. Noveishie Tekhnol.*, **43**, No. 3: 425–433 (2021), DOI: 10.15407/mfint.43.03.0425.

методу прогнозування зносу ковзного сильнострумового контакту, шляхом зіставлення результатів прогнозування з результатами експерименту. В умовах забезпечення високої якості послуг перевезення пасажирів та вантажів особливої актуальності набуває питання забезпечення надійної роботи елементів сильнострумового контакту «контактний дріт–струмознімальний елемент», від працездатності якого залежить надійність роботи системи тягового електропостачання в цілому. Запропоновано та обґрунтовано доцільність застосування методу прогнозування зносу ковзного сильнострумового контакту, який відрізняється від існуючих можливістю врахування сукупності впливаючих на процес струмознімання факторів шляхом зіставлення прогнозованих значень зносу ковзного сильнострумового контакту з даними, отриманими експериментальним шляхом. Результати досліджень показують можливість зменшення зносу контактного дроту до 11% при його взаємодії з графітовими струмознімальними елементами та підвищення ефективності використання струмознімальних елементів до 25%.

Ключові слова: струмознімання, величина зносу, контактний дріт, струмоприймач, струмознімальний елемент.

(Received December 9, 2020)

1. INTRODUCTION

In Ukraine, improving the quality of current collection on electric transport, which is powered by the contact network, is a particularly pressing issue. This is due to the fact that most current collectors of electric rolling stock are equipped with carbon contact elements [1]. And because of its mechanical strength and electrical characteristics [2] not always meet existing requirements [3] there is a problem of appearance pantograph damage and the wasteful use of contact elements that are constantly increasing in value.

Throughout the existence of electric transport that receives power from the external network through sliding high current contact, there is a issue of ensuring high quality of current collection [4–7].

The process of current collection is a complex electromechanical process, which is accompanied by the wear of contact wires and pantograph contact elements [8, 9] and depends on a number of parameters of both the friction pair elements themselves and the external influencing factors.

The process of wear of the contact wire and contact elements during the current collection is characterized by the mechanical (friction) and electrical (erosion) components of wear.

The electrical (erosion) component of wear occurs only when electrical erosion of the contact material occurs. As a result, craters and overlap of copper appear on the contact wire surface. Electrical erosion depends first of all on the current density flowing through the contact point and on the hardness of the material, which determines the contact area of the friction pair elements ‘contact wire–contact element’.

The mechanical component of wear is crucial in places where no electrical erosion occurs and depends on the strength parameters of the contact elements.

The quality of the current collection can be estimated by a large number of indicators. In general, it is described by the minimal cost of maintenance of pantographs and contact suspensions.

Contact suspensions and pantographs evolution [6] allows more power to be transmitted to the electrical equipment of the rolling stock and to realize higher speeds of movement. But the question of minimizing the cost of its maintenance and repair remains relevant to this day.

2. THE MAIN MATERIAL

It is possible to increase the efficiency of sliding high-current contact operation between the contact wire and the contact elements of the pantographs, using the proposed in the work [10] method for predicting wear of sliding high current contact. The essence of the method in the rational placement of contact elements on the pantograph. For this purpose, its parameters are pre-determined and compared with the corresponding results of experimental studies on wear, with various influencing factors [11]. It should be noted that the results of experimental studies, which are partially presented in [11], are analysed by a whole set of parametric methods of statistics [12].

To assess the adequacy of the proposed method of predicting the wear of current collection friction pairs [10] was predicted the wear of the friction pairs ‘contact wire–contact element’ for a number of real current collecting elements. A sample of contact elements from a batch

TABLE 1. Contact elements parameters with hardness sorting.

No.	Contact elements parameters	
	HB	ρ, μΩ·m
1	43.1	32.5
2	38.2	30.1
3	34.5	28.4
4	30.3	26.6
5	26.9	25.2
6	24.5	24.3
7	22.4	23.5
8	20.2	22.7

TABLE 2. Output parameters of the current collection system.

Parameter	Value
Pantograph contact force P, N	80
Current in contact I, A	200
Simulated movement speed V, m/s	10
Ambient air humidity, φ, °C	50

was selected and its parameters were determined using a developed device [13]. Tables 1 and 2 show the study results of the contact elements parameters with decreasing ranking.

Prediction of contact wire wear with interacting with contact elements was performed for two variants of its location on the pantograph:

– at arbitrary location (contact elements were located on the position of the pantograph without taking into account its parameters), Fig. 1, *a*;

– according to the proposed scheme Fig. 1, *b* [10].

When modelling, the condition was determined that the contact wire is rigidly fixed. Assessment of wear of the contact wire was carried out after 10 thousand passes through it contact elements and the assessment of wear of contact elements during its run of 10 thousand km.

The prediction of wear of the contact elements and contact wires was performed at the initial parameters, which are shown in Table 1.

The presented comparative results of predicting the contact wires with carbon contact elements wear at its location on the slide arbitrarily and according to the scheme (Figs. 2–4) show, that the wear of the contact elements along the length of the slide can be offset. This is achieved by positioning the contact elements using the predicted method of sliding high-current contact wear.

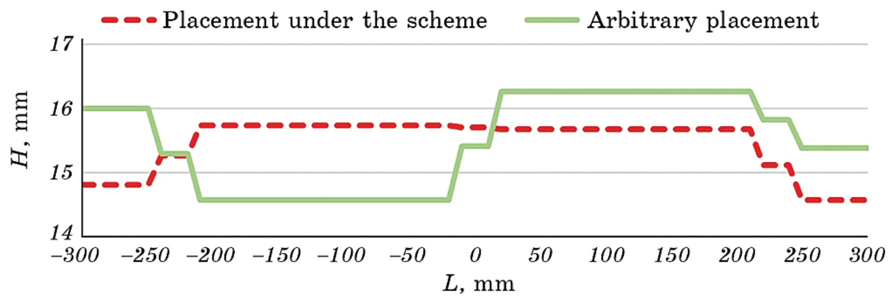

Fig. 1. Slide pantograph schemes at placement of contact elements arbitrarily (*a*) and according to scheme (*b*).

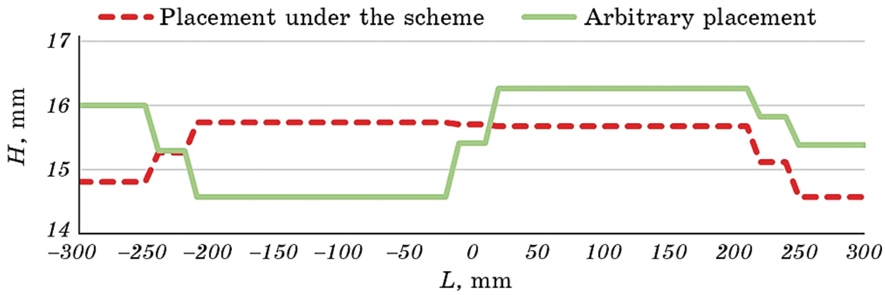

Fig. 2. Predicting residual height of the first-row carbon contact elements along the length of the double row slide pantograph.

The prediction of the contact wire and contact elements wear was performed for the contact wire stagger ±300 mm to compare predicted wear with contact wire and contact elements wear in operation.

The amount of contact wire wear along the span, when using the proposed method, is significantly reduced and evened. That is especially important in operation. In operation is possible to extend the life of the contact suspension without having to replace the parts of the contact wire in the contact network section due to excessive wear. To confirm the adequacy of the data obtained from the prediction at the Department Intelligent Power Supply Systems an experimental setup was developed that allows to study the process of contact wires interaction with pantographs, Fig. 5.

Investigations at the experimental setup were conducted for a double row slide pantograph, it was equipped with carbon contact elements with arrangement according to the scheme Fig. 1, *b*. The parameters of the current collection system, during the experiment, corresponded to the values in Table 2. The trajectory of the contact wire at the experimental setup was determined by the methodology [14] and taking into account the design of the catenary [15–18].

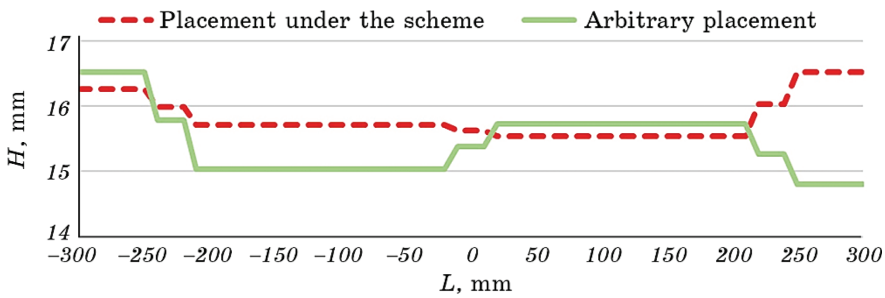

Fig. 3. Predicting residual height of the second-row carbon contact elements along the length of the double row slide pantograph.

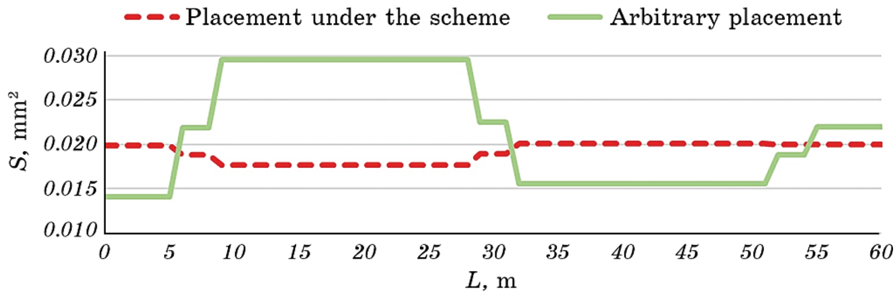

Fig. 4. Predicting residual cross-section of the contact wire after interaction with the double row slide pantograph equipped with carbon contact elements.

The scheme of fixing the contact wire on the moving part of the experimental setup is shown in Fig. 6.

In experimental studies, the contact wire was fixed rigidly, the assessment of the contact wire wear was carried out after 10 thousand passes through the pantograph, and the assessment of the contact elements wear during its run of 120 km (due to the structural features of the experimental setup).

Prior to the experimental study, the friction surface of the contact wire and contact elements was cleaned to ensure the purity of the experiment.

The results of experimental studies of the contact elements and contact wire wear with the superimposed results of predicting its wear un-

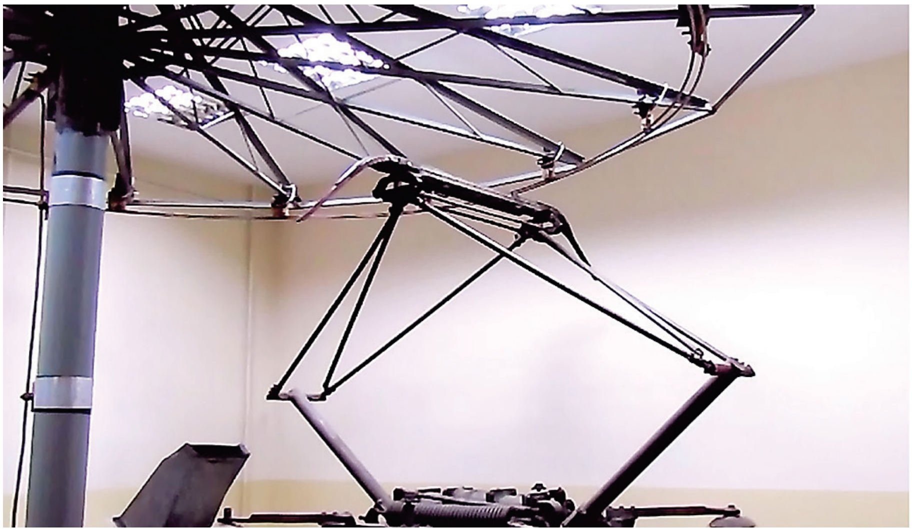

Fig. 5. Experimental setup for the study the process of contact wires interaction with pantographs.

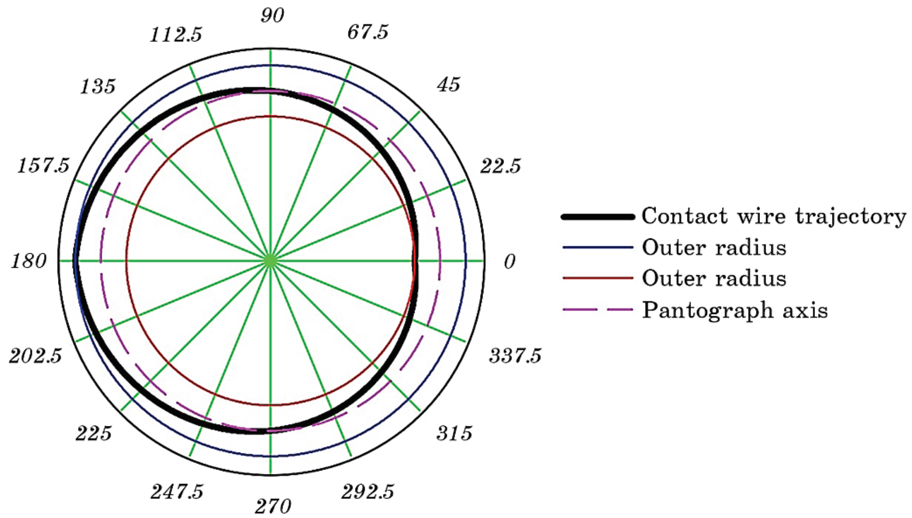

Fig. 6. Scheme of fixing the contact wire.

der the corresponding experimental conditions are shown in Figs. 7–9.

The results are presented in Figs. 7–9 indicate sufficient quality prediction of contact wire and contact elements pantograph wear by the method predicting wear of sliding high-current contact. There is a slight deviation of the prediction result from the experiment, the relative error: for first row contact elements 2.21%, for second row contact elements 1.31%, for contact wire—1.28%.

3. CONCLUSION

1. The use of the method predicting wear of sliding high-current contact in operation and contact elements placement according to the scheme allows to reduce the wear of the contact wire to 11% and to in-

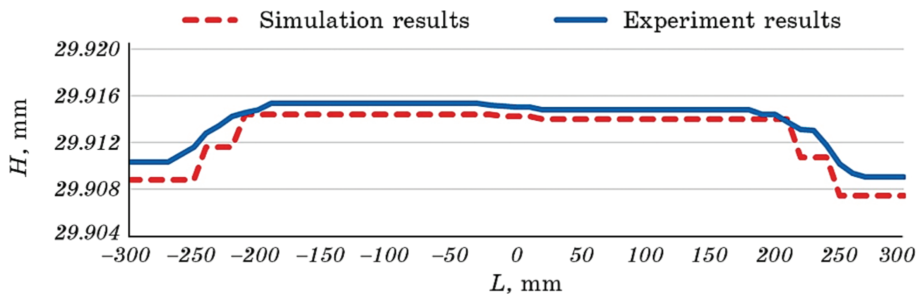

Fig. 7. Residual height of the first row carbon contact elements along the length of the double row slide pantograph.

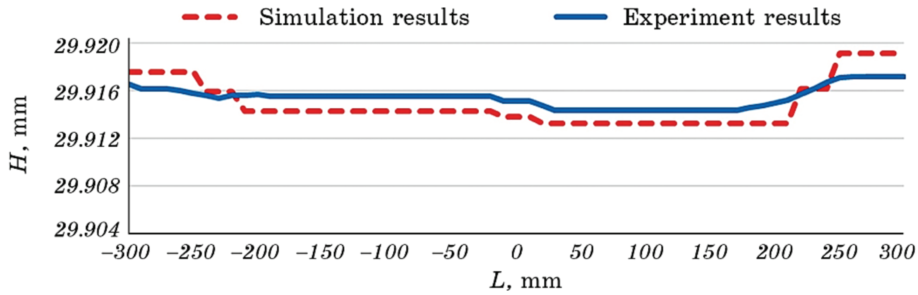

Fig. 8. Residual height of the second row carbon contact elements along the length of the double row slide pantograph.

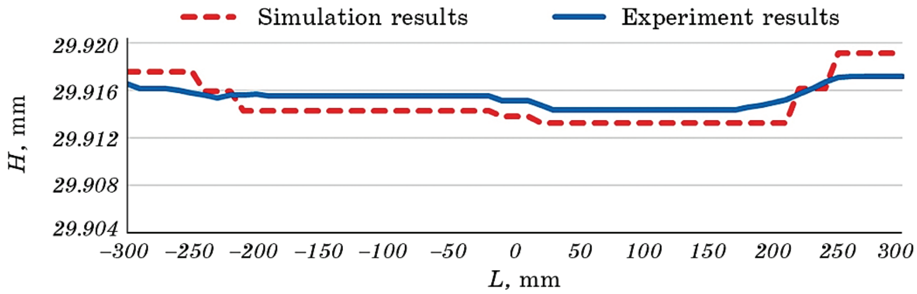

Fig. 9. Residual cross-section of the contact wire after interaction with the double row slide pantograph equipped with carbon contact elements.

crease the use efficiency of the contact elements up to 25%.
2. Aligning the wear of the contact wires along the span will increase the life of the contact suspension with a given speed mode without completely or partially replacing the contact wire.
3. Absence of contact elements cuts will allow to increase its mileage and lead to reduction number of repairs, which will positively affect the cost of pantograph maintenance.
4. Positive experience of conducting theoretical and experimental researches of elements sliding high-current contact wear at the experimental setup of the Department Intelligent Power Supply Systems testifies to the necessity and importance of such researches.

REFERENCES

1. Yu. L. Bolshakov and, A. V. Antonov, *Science and Transport Progress. Bulletin of Dnipropetrovsk National University of Railway Transport*, **4**, No. 58: 57 (2015) (in Ukrainian).
2. Yu. L. Bolshakov and A. V. Antonov, *Science and Transport Progress. Bulletin of Dnipropetrovsk National University of Railway Transport*, **6**, No. 60: 34 (2015) (in Ukrainian).

3. *HOST 32680-2014. Tokosyemnyye Elementy Kontaktnye Tokopriyemnikov Elektropodvizhnogo Sostava* [Pantograph Current Collectors Contact Elements of Electric Rolling Stock] (Moscow: Standartinform: 2015) (in Russian).
4. Yu. E. Kuptsov, *Besedy o Tokos'eme, Ego Nadezhnosti, Ekonomichnosti i o Putyakh Sovershenstvovaniya* [Conversations about the Current Collection and its Reliability, Efficiency and on Ways to Improve] (Moscow: Modern: 2001) (in Russian).
5. Yu. E. Kuptsov, *Trudy TsNII MPS*, No. 233: 67 (1962) (in Russian).
6. F. Kiessling, R. Puschmann, A. Schmieder, and E. Schneider, *Contact Lines for Electric Railways: Planning, Design, Implementation, Maintenance* (2 Ed.) (John Wiley and Sons: 2009).
7. M. Kaniewski, V. Kuznetsov, P. Hubskyi, V. Sychenko, and A. Antonov, *Proceedings of 24th International Scientific Conference. Transport Means 2020*, No. 24: 260 (2020).
8. Yu. E. Kuptsov, *Uvelichenie Sroka Sluzhby Kontaktnogo Provoda* [The Increase Resource of a Contact Wire] (Moscow: Marshrut:1972), p. 160 (in Russian).
9. V. Ya. Berent, *Materialy i Svoystva Elektricheskikh Kontaktov v Ustroystvakh Zheleznodorozhnogo Transporta* [Materials and Properties of the Electrical Contacts in the Devices of Railway Transport] (Moscow: Intext: 2005).
10. A. V. Antonov, Yu. L. Bolshakov, and V. G. Sychenko, *Problemy Kolejnictwa*, **61**, No. 177: 13 (2017).
11. A. V. Antonov and V. G. Sychenko, *Archives of Transport*, **44**, Iss. 4: 7 (2017).
12. A. V. Antonov, *IEEE 6th International Conference on Energy Smart Systems (ESS)*, No. 6: 273 (2019).
13. A. V. Antonov, Yu. L. Bolshakov, and V. G. Sychenko, *Pristriy dlya Vyznachennya Parametriv Vugilnih Strumoznimalnih Elementiv* [A Device for Determining the Parameters of the Coal Contact Element]: Patent UA, No. 114369 (2017) (in Ukrainian).
14. D. O. Bosiy and V. G. Mandych, *Elektrifikatsiya Transportu*, No. 2: 35 (2011).
15. I. M. Gelfand and E. G. Glagoleva, *Koordinatnyy Metod* [Coordinate Method] (Moscow: Nauka: 1971), p. 87.
16. A. V. Frayfeld and G. N. Brod, *Proektirovanie Kontaktnoy Seti* [Design of a Contact Network] (Moscow: Transport: 1991) (in Russian).
17. V. P. Miheev, *Kontaktnye Seti i Linii Elektroperedachi* [Contact Network and Transmission Lines] (Moscow: Marshrut: 2003) (in Russian).
18. V. O. Diakov, D. O. Bosiy, and A. V. Antonov, *Kontaktna Merezha Elektrifikovanykh Zaliznyts. Ulashtuvannya Kontaktnoyi Merezhi* [Contact Network of Electrified Railways. Contact Network Design] (Dnipro: Standart-Servis: 2017) (in Ukrainian).