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Research on the Operational Properties of the New Generation of Railway Carbon Contact Strips Designated for Pantographs. Part II

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Summary
Along with the continuous expansion and modernization of railway lines in Poland, there is a need for new solutions designed to transfer electricity in the traction contact lines. One of the key elements of the electricity transfer from the traction contact lines to locomotives is the carbon contact strip. In Poland until 2011, contact strips made of copper were used which caused much faster wear of contact wires. The order to use carbon contact strips, due to the lack of domestic solutions, meant that foreign solutions in this area were adopted. Due to the type of Polish railway lines, which are supplied with 3 kV DC, adapted contact strips show a number of problems during operation in traction lines in Poland. This article is the second part of the study of the new generation of contact strips and has been focused on the research of exploitation properties that enable their use in railway lines managed by PKP PLK S.A., namely the President of UTK List.

Keywords: carbon contact strips, carbon composite, pantograph, railway, contact system

1. Introduction

The railway traction lines consists of two main elements which are the overhead contact lines and return circuit. The overhead contact line is a set of wires and carrying ropes suspended on supporting structures together with various traction fittings. Electricity is transferred to locomotives via direct contact of contact strips placed on pantographs with contact wires of traction lines [7, 8]. In Poland until 2011, contact strips were made exclusively of copper. The use of copper strips directly affected the quick abrasion of the contact wires and the contact strips themselves. In addition, rolling stock equipped with copper contact strips were not allowed to travel in other European Union countries. Due to the existing need to change copper strips for carbon contact strips, foreign contact strips have been adapted to domestic requirements.

In Poland, the overhead contact line is powered by a 3 kV DC system and an electric intensity of up to 2.5 kA. This system under high power of vehicles and high traffic density is characterised with voltage drops and high current loads [2, 6]. Therefore, contact strips should exhibit strength and electrical properties that enable continuous operation with no malfunction for all types of network lines in a given area and in all weather conditions. The contact strips used in locomotives show various types of operational problems that cause failures, which directly affects the efficiency of the traction line, as well as the comfort of traveling passengers [11].

In order for the contact strips to be used in traction lines managed by PKP PLK S.A., they must meet a number of requirements, which are recorded in the TSI LOC & PAS document (EU Commission Regulation No. 1302/2014) [10] and "List of the President of the UTK on the relevant national technical specifications and standardization documents, the use of which makes it possible to meet the essential requirements for interoperability" from January 19th, 2017 (document on contact strips – attachment TE-1) [9, 12]. Attachment TE-1 regarding the requirements for pantograph's pans used in Poland includes such requirements as:

- temperature increase of contact wires at the place of contact during a stopover for a minimum of 30 minutes: ≤ 80°C,

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- the weight content of metal in the carbon composite: <40%,
- hardness of carbon composite: ≤ 120 HRB,
- width of carbon contact strips: ≥ 60 mm.

As a part of this article, the study of contact strips manufactured by Carbo-Graf company was presented, the tests were carried out in accordance with the above mentioned normative document.

2. Research methodology

The subject of the research were three types of carbon contact strips manufactured by Carbo-Graf Sp. z o.o. from Racibórz made in various technologies of metal impregnation of a carbon composite, summarized in Tab. 1, while the model of the contact strip is shown in Fig. 1. The testing of contact strips was carried out in the laboratory of the Faculty of Non-Ferrous Metals at the Department of Metal Working and Physical Metallurgy of Non-Ferrous Metals.

Table 1

List of contact strips

Contact strip i.d.	Type of carbon composite	Estimated amount of metal in carbon composite
F20E10 Scu	Impregnated with liquid copper	35–39 wt. %
F20E10 20Scu	Impregnated with liquid copper and copper powder	35–39% wt. (in equal parts)
F20E10 Cu40	Impregnated with copper powder	39% wt.

[Elaboration by author]

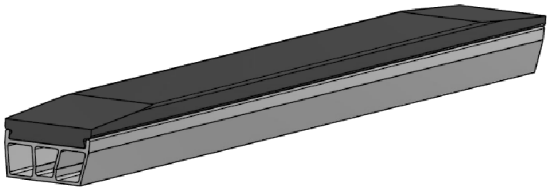


Fig. 1. The 3D model of a contact strip manufactured by Carbo-Graf [own work K. Franczak]

Tests of metal content in the carbon composite of contact strips were carried out in accordance with annex TE-1 of the List of the President of UTK. The measurement of metal content in the carbon composite was made by atomic absorption in five selected points of the carbon composite spaced 5cm apart. Samples for testing were cubes with dimensions of 10x10x10mm. According to the standardization document, the contact strip should not contain (in any of the tested places) the weight content of the metal above 40%. A scanning electron microscope HITACHI SU-70 was used for the tests (Fig. 2). The hardness measurement of contact strips carbon composite was carried out in accordance with annex TE-1 of the President of UTK List using the Rockwell method in the HRB scale. The hardness test was performed using a KP15002 P type hardness tester in five points of the carbon composite (Fig. 3). Research on the increase of contact wires temperature at the place of contact during a stopover was conducted on a specialist stand, which is located in the laboratory at the Railway Institute (Fig. 4). The measurement of contact strips width was conducted with the use of digital caliper MITUTOYO CD-15APX.

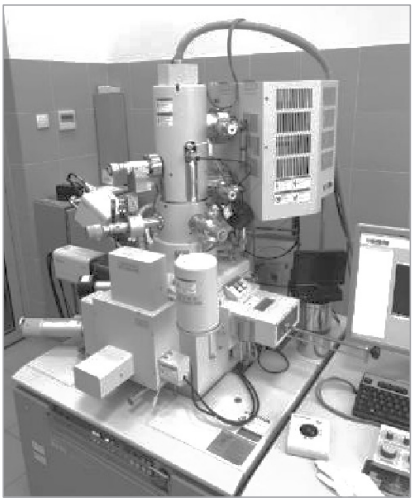


Fig. 2. Scanning electron microscope used for the research – HITACHI SU-70 [photo. K. Franczak]

Fig. 3. Hardness tester KP15002 P [photo. K. Franczak]

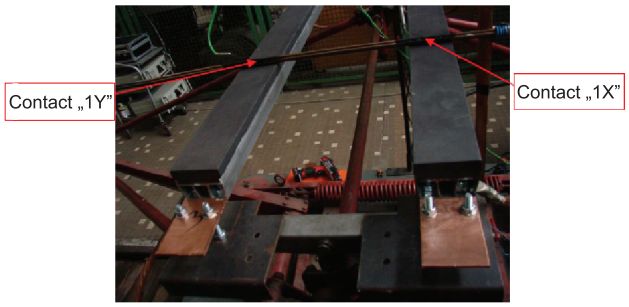
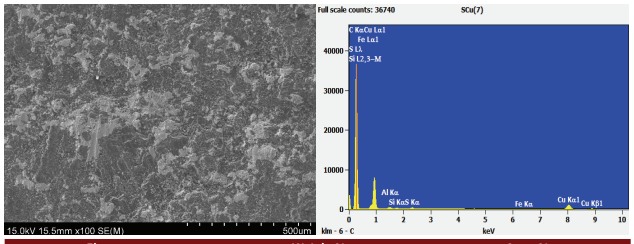


Fig. 4. Specialist stand designated to test the increase of contact wires temperature and contact strips at the place of contact [photo. K. Franczak]

3. Research results and analysis

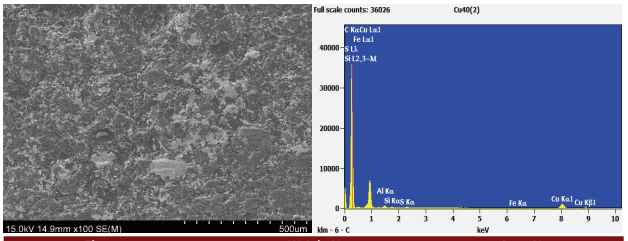
Tests of metal content in carbon material were carried out in accordance with annex TE-1 of the List of the President of UTK. The tests of the metal content in the carbon composite show that all Carbo-Graf contact strips: F20E10 SCu, F20E10 20SCu and F20E10 Cu40 do not contain more metal than 40%. Depending on the type, carbon composites have a copper content of 18–20% wt. and traces of impurities originating from the production process of carbon composite, i.e.: Al, Si, S, Fe, which do not exceed 0.5% of weight. Thus, all types of contact strips meet the requirements of annex TE-1 of the List of the President of UTK regarding content of metal in carbon composite. See Fig. 5–7 below for an example of the Energy Dispersive X-ray Spectroscopy (EDS) analysis of carbon based contact strips.



Element Line	Weight %	Atom %
C K	79.28	95.15
Al K	0.24	0.13
Si K	0.07	0.03
S K	0.24	0.11
Fe K	0.08	0.02
Cu K	20.10	4.56
Total	100.00	100.00

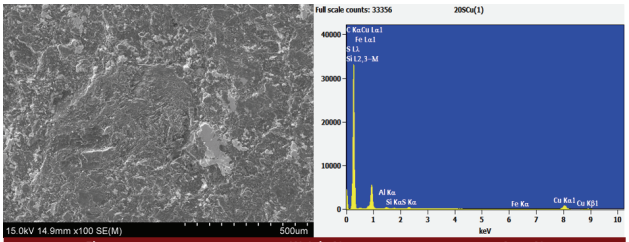
Fig. 5. The results of the analysis regarding content of metal in carbon composite of the contact strips F20E10 SCu „Sample 1” [own elaboration]

Conducted hardness tests, which are presented in Tab. 2 show that the hardness of the carbon composite in the tested points in all three types of contact strips, i.e.: F20E10 SCu, F20E10 20SCu and F20E10 Cu40 is lower than the criterion contained in annex TE-1 of the List of the President of UTK which is 120HRB. Therefore, all types of contact strips meet the requirements set out in annex TE-1 of the List of the President of UTK regarding the hardness of carbon composite.



Element Line	Weight %	Atom %
C K	79.65	95.24
Al K	0.28	0.15
Si K	0.09	0.04
S K	0.19	0.09
Fe K	0.12	0.03
Cu K	19.67	4.44
Total	100.00	100.00

Fig. 6. The results of the analysis regarding content of metal in carbon composite of the contact strips F20E10 Cu40 „Sample 1” [own elaboration]



Element Line	Weight %	Atom %
C K	81.15	95.65
Al K	0.19	0.10
Si K	0.06	0.03
S K	0.32	0.14
Fe K	0.28	0.07
Cu K	18.01	4.01
Total	100.00	100.00

Fig. 7. The results of the analysis regarding content of metal in carbon composite of the contact strips F20E10 20SCu „Sample 1” [own elaboration]

Table 2

The results of hardness tests of the carbon contact strips

Contact strip type	No. of hardness test [HRB]				
	1	2	3	4	5
F20E10 SCu	83	70	87	85	82
F20E10 20SCu	87	85	88	86	83
F20E10 Cu40	72	80	76	75	79

[Own elaboration].

In the next stage of research, the contact strips were subjected to the tests of temperature's increase

in the place of the contact strip – contact wire under the current flow of 200 A. According to the criterion, the temperature increase should not exceed 80°C. All three types of contact strips have passed the test of temperature's increase. The temperature increase for F20E10 SCu contact strips was ΔT1X = 76.9°C and ΔT1Y = 66°C, for F20E10 20SCu contact strips ΔT1X = 73.1°C and ΔT1Y = 72.2°C and for contact strips F20E10 Cu40 ΔT1X = 74°C and ΔT1Y = 75.9°C (Fig. 8–9).

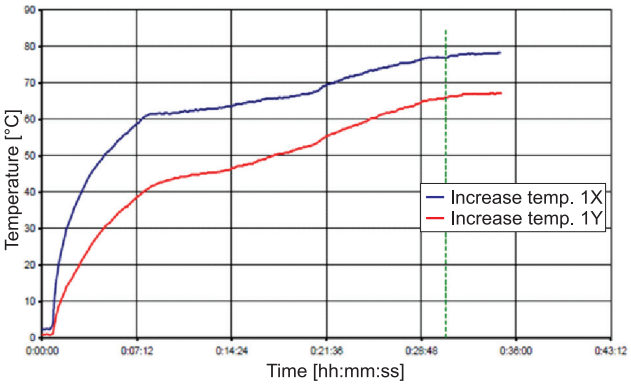


Fig. 8. Characteristic the increase of temperature for contact strip F20E10 SCu [own elaboration]

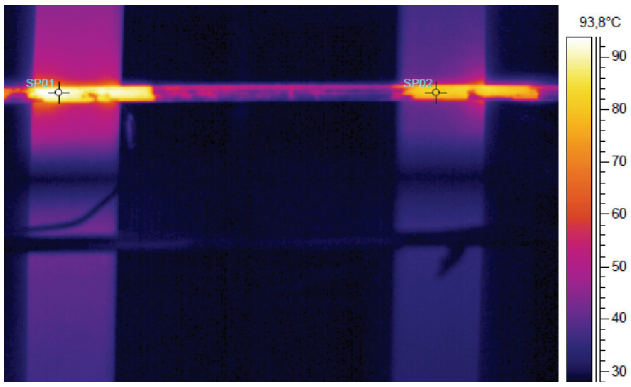


Fig. 9. The photo made using the thermal camera showing the increase of temperature for contact strip F20E10 SCu [own elaboration]

The conducted widths tests of contact strips made by Carbo-Graf type F20E10 SCu, F20E10 20SCu and F20E10 Cu40 show that all tested contact strips meet the criterion of width of over 60mm. The width of the new generation of contact strips is 67.3mm ± 0.2mm.

4. Conclusions

The article presents the research of exploitation properties of the new generation of contact strips manufactured by Carbo-Graf accordingly to "List of the President of the UTK on the relevant national technical specifications and standardization documents, the use of which makes it possible to meet the essential requirements for interoperability" from January 19th, 2017 (document on contact strips – attachment TE-1). The research shows that the three types of carbon contact strips, i.e.: F20E10 SCu, F20E10 20SCu and F20E10 Cu40 manufactured by Carbo-Graf meet the criteria for their properties, which are included in the annex TE-1 of the List of the President of UTK.

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Krystian Franczak, MSc, Eng. – conducting tests, analysis of the test results,
Grzegorz Kieniewicz, PhD, Eng. – analysis of the literature, translation of the manuscript,
Prof. Tadeusz Knych, PhD, Eng. – research methodology, analysis of the test results,
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Szymon Kardaszewski, MSc, Eng. – conducting tests,
Wojciech Ścieżor, PhD, Eng. – analysis of the literature,
Radosław Kowal, MSc, Eng. – conducting tests,
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Wiesław Majewski, MSc, Eng. – conducting tests,
Marek Kaniewski, MSc, Eng. – conducting tests,
Roman Majnusz – manufacturing materials for tests,
Romuald Wycisk – manufacturing materials for tests,
Michał Śliwka, Eng. – manufacturing materials for tests.