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

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Summary

The system of supplying railway traction vehicles with electricity is carried out through direct contact of the contact wires with contact strips of the pantograph of the locomotive. Since 2011 in Poland, in accordance with the interoperability specification of the TSI LOC & PAS, the previously used copper contact strips have been prohibited and the use of carbon contact strips has been forced. Due to the lack of domestic solutions dedicated to railway contact lines powered with DC 3 kV, foreign solutions were adopted. In order for the contact strips to be used in Polish railway lines managed by PKP PLK S.A, they must meet a number of requirements regarding their operational properties. The first part of the article presents research on the new generation of carbon contact strips manufactured by Carbo-Graf in accordance with EN 50405:2006, which is specified in TSI LOC & PAS.

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

1. Introduction

The development of railway infrastructure in Poland observed in recent years is dictated by the continuous improvement of passengers' travel comfort along with shortened travel time and the increase in the tonnage of transported goods by rolling stock. Transfer of electricity from the overhead contact line to locomotive is carried out by direct contact of the contact wires with pantograph's contact strips. The efficiency of electric energy transmission in the railway contact lines depends on the quality of contact strips, contact wires, catenaries and used overhead line fittings [3, 4, 5]. Since 2011, the obligation to use carbon contact strips has been introduced in Poland, at the same time prohibiting the use of copper contact strips. Due to the lack of domestic solutions adapted to the conditions prevailing in Polish railway lines, where the traction is supplied with DC 3 kV, foreign contact strips have been adapted, which were adjusted to the local network conditions, which are AC 15 kV or AC 25 kV [2]. The currently operated carbon contact strips cause some operational problems, disrupting the transfer of electricity in the railway contact lines. The most common problems during the operation of carbon contact strips include, among others: chipping and breaking of carbon material, melting of support profiles caused by electric arc flashover, uneven wear of carbon contact strips resulting from improper assembly of the contact strips on the pantograph pan [8].

In to allow the use of contact strips in Polish railway 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) [7] 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 regarding contact strips – attachment TE-1) [6, 9]. According to the TSI LOC & PAS, carbon contact strips should be assessed in accordance with EN 50405:2006 [1][4]. This standard defines the

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method of testing in the following clauses referred to TSI LOC & PAS:
- 5.2.2 – Test for deflection and extension of the carbon contact strip under extremes of temperaturę;
- 5.2.3 – Test for flexural characteristic of the carbon contact strip;
- 5.2.4 – Test for shear strength of the contact strip;
- 5.2.6 – Test of mechanical fatigue resistance of the carbon contact strip;
- 5.2.7 – Test of the electrical resistance of the contact strip.

The first part of the article presents testing of contact strips manufactured by Carbo-Graf, which were tested in accordance with EN 50405:2006.

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 Department of Metal Working and Physical Metallurgy of Non-Ferrous Metals at Faculty of Non-Ferrous Metals being a part of AGH University of Science and Technology in Krakow.

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. %

In accordance with clause 5.2.2 of EN 50405:2006, test for deflection and extension of the carbon contact strip under extremes of temperature has been carried out. The standard does not adapt any criteria, but requires the determination of extreme operating temperatures, –40°C and above zero according to the value specified by the manufacturer, which is 200°C at which the connection of the carbon strip from the support profile is broken. A climatic chamber was used for the tests to lower the temperature to –40°C and heating rods to heat the contact strip to 200°C.

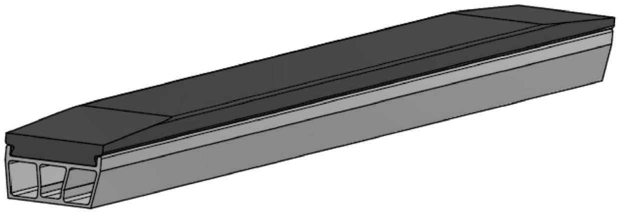

Fig. 1. The 3D model of a contact strip manufactured by Carbo-Graf [own work K. Franczak]

Determination of the deflection characteristics of the contact strip was carried out on a specialist stand, which was equipped with a force sensor type EMS-150-50 kN and a transmitter path HBM WAL 50 to determine the characteristics of force in the function of displacement (Fig. 2). The tests for determining the deflection characteristics were performed on one type of contact strip due to identical geometries of the bearing profile and carbon composite for each type of contact strip.

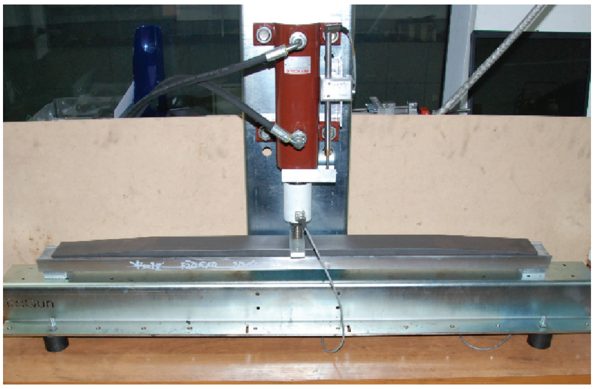

Fig. 2. The view of the stand to determine the deflection of characteristic of the contact strip [photo. K. Franczak]

The measurement of shear strength of the contact strips was made using a static material testing machine equipped with a force sensor EMS-150-50kN and instrumentation for fixing samples of contact strips. The profile of the contact strip was fixed in the instrumentation, while the force was set through a carbon com-

[4] At the time of research being conducted (2017/2018), TSI LOC & PAS regulations clearly indicated that all tests should be carried out in agreement with EN 50405:2006 standard in order to allow the use and sell of new types of contact strips. At this time a EN 50405:2016 was already published showing some variations in particular tests methodology and general requirements for contact strips, but it was not obligatory from the TSI LOC & PAS regulations point of view. For that reason all research works carried out showed in the article are related to EN 50405:2006 standard only.

posite in accordance with the EN 50405:2006 clause 5.2.3 (Fig. 3). This standard gives the criterion that the connection in the contact strip should be at least 5 N/mm² at room temperature (20°C). In addition, the shear strength of the contact strips at temperatures of –40°C, 100°C, 200°C and 250°C should be determined.

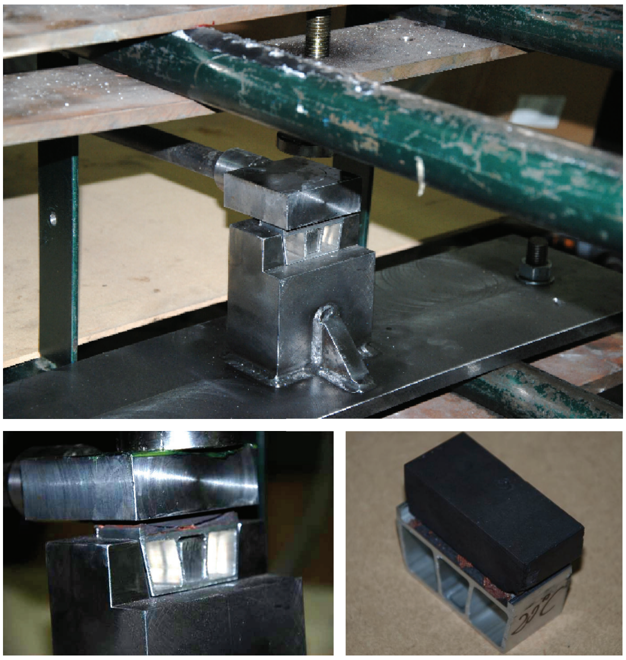

Fig. 3. The view of the test stand for shear strength research of the contact strips [photo. K. Franczak]

According to the clause 5.2.6 of EN 50405:2006, which assumes 11.2 million loads induced in the central place of the contact strip, test of mechanical fatigue resistance of the new generation of carbon contact strip were performed. In the first part of the tests, 1.2 million cycles should be carried out with a maximum force of at least 220 N, while the minimum force after unloading the contact strip is max. 15 N. In the second part of the test, the contact strip must be subjected to 10 million of additional cycles with a maximum force of at least 160 N and the minimum at the level of 15 N. These tests were performed using a specialist fatigue testing device for contact strips (Fig. 4).

The last test carried out in the first part of the article was the test of the electrical resistance of the new generation of contact strips which were carried out in accordance with clause 5.2.7 of EN 50405:2006. The standard however does not impose any criteria at this point, but the resistance of the system should be determined between a carbon contact strip, adhesive connection and aluminum support profile in order to demonstrate consistent manufacture [1].

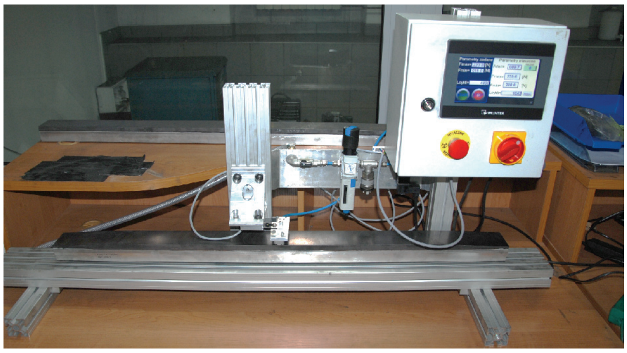

Fig. 4. The view of the specialist fatigue testing device for contact strips [photo. K. Franczak]

3. Research results and analysis

Within this article selected tests of contact strips, which are the basis for their admission to operation on railway lines managed by PKP PLK S.A., were presented.

Research of deflection and extension of the carbon contact strip under extremes of temperature have shown that as a result of heating two different materials connected together by means of an adhesive joint, the deflection amounted to 6.5 mm. Research on heating the carbon contact strips has shown that at temperatures between 125°C and 135°C, a gradual process of peeling the carbon strip from the support profile begins. In the case of cooling contact strips down to –40°C, the tests showed that the deflection was 2.5 mm in the opposite direction than in the case of above zero temperatures.

The tests results, which were presented in Fig. 5, showed that the F20E10 Cu40 contact strip (as an representative sample) tested at a given force of more than 9.3 kN was not damaged, and the carbon composite – bearing profile remained untouched. The maximum deflection of the contact strip was 19.47 mm. At the value of 8.1 kN permanent plastic deformation of the aluminum support profile occurred. After unloading the system, the permanent deformation of the contact strip was 2.22 mm. In Fig. 6 below the view of the contact strip under a load of 9.3 kN is presented.

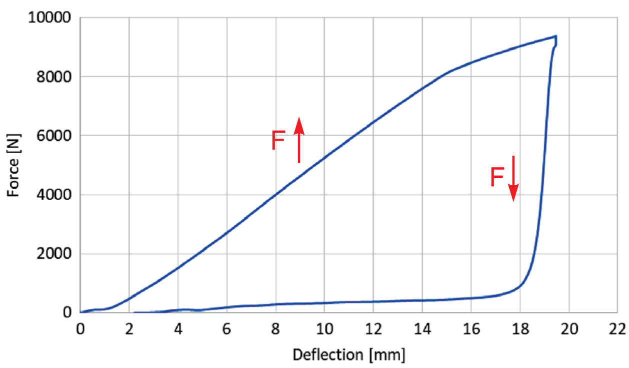

Fig. 5. Force / deflection diagram of the contact strip F20E10 Cu40 type [own work]

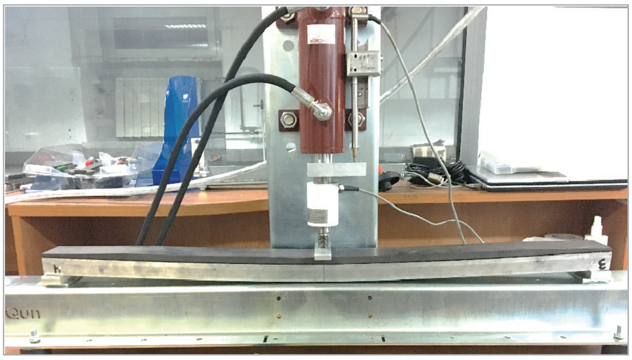

Fig. 6. The view of the contact strip under a load of 9.3 kN [photo. K. Franczak]

Test for shear strength of the contact strip – aluminium support profile joint was carried out in accordance with EN 50405:2006 clause 5.2.4. The tests were carried out using a force sensor with an accuracy of 0.01% configured with the Spider8 measuring device. Samples with total length of 30 mm were made for the tests, while the width of the carbon composite joint with the support profile was 60 mm. The tests were conducted on three types of contact strips: F20E10 SCu, F20E10 20SCu and F20E10 Cu40. The results of the conducted shear strength tests of contact strips are presented below in Fig. 7.

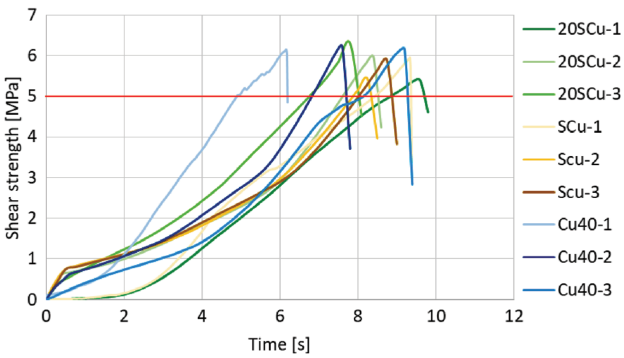

Fig. 7. The results of the conducted shear strengths tests of contact strips (3 samples of each type) in room temperature (20°C) [own work]

The shear strength tests' results of contact strips types F20E10 SCu, F20E10 20SCu and F20E10 Cu40 show that all contact strips have shear strengths above 5 N/mm^2, and therefore meet the criterion in EN 50405:2006. The summary of the shear strength of the contact strips at temperatures such as –40°C, 100°C, 200°C and 250°C is shown below in Fig. 8.

Test of mechanical fatigue resistance of the new generation of carbon contact strips showed that during the first part of the research, 1.2 million cycles with a maximum force of at least 220 N (Fig. 9) no damage to the contact strip was found. In the second part of the tests, the contact strips has been subjected to 10 million additional cycles with a maximum force of at least 160 N (Fig. 10), which shows that the total of 11.2 million cycles did not cause damage to the structure of the contact strip.

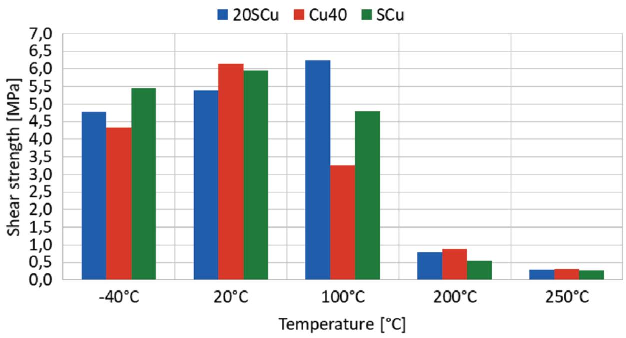

Fig. 8. The results of the shear strengths tests of the carbon contact strips in various temperatures [own work]

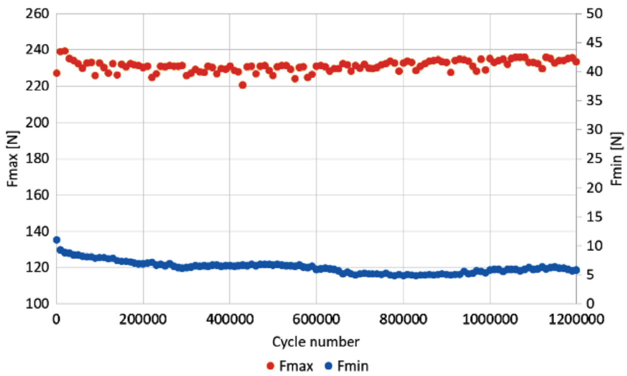

Fig. 9. The diagram of the first part of the mechanical fatigue resistance of the carbon contact strip (1,2 million cycles) [own work]

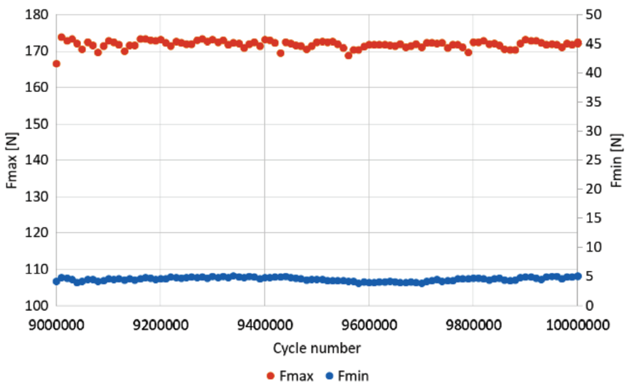

Fig. 10. The example of the second part of the mechanical fatigue resistance of the carbon contact strip (9–10 million cycles) [own work]

According to clause 5.2.7 of EN50405:2006 standard, electrical resistance of the contact strip of various types was determined as part of the project. For the SCu contact strip, the resistance of the transition through the entire system, i.e. the carbon contact strip, adhesive connection and aluminum support profile, is on average 63,4 mΩ, 20SCu contact strip 130,9 mΩ and Cu40 contact strip 79,5 mΩ.

4. Conclusions

The article presents research on the operational properties of the new generation of contact strips manufactured by Carbo-Graf made in accordance with TSI Loc & Pas (EU Commission Regulation No. 1302/2014), in reference with the EN 50405:2006 standard. The standardization document mentioned above is one of the two that give the basis for allowing the use of contact strips on railway lines managed by PKP PLK S.A. Carbo-Graf contact strips of the following types: F20E10 SCu, F20E10 20SCu and F20E10 Cu40 meet the criteria for their properties.

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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,
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