Development and Testing of New Solutions of Overhead Contact Line Accessories

Grzegorz KIESIEWICZ[1], Tadeusz KNYCH[2], Paweł KWAŚNIEWSKI[3], Artur ROJEK[4]

Summary

The overhead contact line (OCL) consists of various kinds of supporting structures and elements that allows the installation of the contact wire horizontally to the track. OCL is a complex mechanical and electrical system, that has to ensure the proper electric power transfer to the traction vehicle. During the exploitation of contact line accessories (extension arms, cantilevers, tensioning devices etc.) different kinds of problems appear, significantly affecting the railway traffic. Furthermore, the outdated design is the reason for difficulties with assembly and daily use.

Research results, stress characteristic numerical analyses, clamping force relaxation experimental results and contact line equipment corrosion resistances of present in-use devices are presented. An OCL new generation concept was developed. Stress distribution and safety factor tests were conducted at operationally loaded construction.

Obtained results showed that currently used equipment at the operational loads has effort close to the material yield strength. Tested elements have also different kinds of design defects, low corrosion resistance and rheological resistance at a level of 8–10% degree of relaxation. Conducted research showed that newly designed elements have a safe level of effective stress and high safety factor – all tested under an operational load regime.

A new solution of no-load tensioning device was designed and tested. The contact wire or catenary wire tensioning force is generated by device spiral springs. Properly designed elements application – cams – allowed to obtain a constant tensioning force in full contact wire length variation range.

Keywords: overhead contact line, contact line accessories, numerical research

1. Introduction

Properly designed and well done catenary provides high operational features which directly determine the speed and safety of passenger and cargo rail transport. Due to the rail infrastructure's operation time, including traction line, damage is more often detected, which may lead to the train's traffic difficulties, delays and dangerous accidents threatening passengers' health and lives. The railway overhead contact line can be divided on three basic component groups:

- support structures,
- catenary wires, contact wires and their accessories,
- electrical and mechanical connection elements.

Safety, speed and reliability of the railway transport may be guaranteed when each overhead and bottom catenary components have features dedicated to the system. In the last few years two modern overhead catenaries, YC120-2CS150 and YC150-2CS150, were implemented. Due to them trains can move flawlessly up to 250 kilometers per hour [2, 6, 7].

Using these contact lines in the normal operation was conditioned by the invention and production of two new component elements. The first one related to modern contact wires made from copper silver. Its resistance against abrasive wear and the heat resistance is much higher than in currently used CuETP copper wires. The second one involved modern high conductive and high resistant accessories made of CuNi2Si alloy [10]. Moreover lately, new light support structures (poles and gates) have been designed and deployed to production. They have high safety factor with controlled destruction area dedicated to the new line types system [4].

[1] Dr inż.; Akademia Górniczo-Hutnicza, Wydział Metali Nieżelaznych, Kraków; e-mail: gk@agh.edu.pl.
[2] Prof. dr hab. inż.; Akademia Górniczo-Hutnicza, Wydział Metali Nieżelaznych, Kraków; e-mail: tknych@agh.edu.pl.
[3] Dr hab. inż.; Akademia Górniczo-Hutnicza, Wydział Metali Nieżelaznych, Kraków; e-mail: kwas@agh.edu.pl.
[4] Dr inż.; Instytut Kolejnictwa, Zakład Elektroenergetyki; e-mail: arojek@ikolej.pl.

The last group of the contact line elements, which were never included in research work leading to their thorough modernization, are the overhead contact line (OCL) cantilever systems with catenary wires constituting conductive elements and support structures connection.

For this reason, new type messenger connections with high operating properties were designed. They are dedicated to new catenary types and serve as a replacement to the current solutions with 3kV DC power system. The FEM stress distribution simulation was conducted on the designed elements. They were laboratory and operationally tested on a real catenary cantilever model. Described work was carried out within project number INNOTECH-K2/IM2/28/182120/NCBR/13 co-financed by the National Centre for Research and Development.

2. Current state

Currently, these elements are produced in Poland from simple sections (pipes, brackets, channel sections) made of structural steel S235JR. This steel is characterised by low corrosion resistance [8] and the only corrosion protection in discussed elements is the zinc layer applied in an igneous way. In connection with the fact that the galvanizing process is often curried in a careless way, first corrosion points on this type of elements may be visible already a year after an installation. Another problem is the entire system high mass, which is the reason of many complications during the installation and exploitation. Additionally, series of omissions in production facility are reflected in numerous geometric and technological defects. Many foreign manufacturers produce different kinds of catenary connection elements made of different materials technologies. Main materials used by European manufacturers include: structural steel, aluminum alloy and composite materials. These elements are mainly dedicated to the catenary powered by alternating current (AC). This power system is used in most European countries. Because of that, these elements do not have optimal properties from the viewpoint of catenary powered by direct current 3kV (DC), which leads to a number of operational problems. The knowledge compendium of European solutions with different elements to mount the catenary can be found in the publication [3].

Currently operated on railway network tensioning devices are the type of weight devices. Because of frequent thefts the cast iron loads are replaced by the polymer-concrete loads. However, they are also stolen or destroyed and it causes the contact line parameters deterioration (when a few loads are absent) or its destruction in case of complete tensioning device's weights cutoff. The exemplary contact line equipment and weight tensioning device solution is shown in Figure 1.

Fig. 1. T-profile catenary equipment and weight tensioning device [photo P. Kwaśniewski]

3. New overhead contact line accessories conception

Within this work a number of different type systems conceptions were designed and analyzed that could fulfill the established bearing capacity criterion in a mechanistic approach resulting with such a system work parameters in real static and dynamic loads conditions. The basic criterion adopted in the beginning was the dependability and reliability of a new system, its high corrosion resistance, fast and simple assembly using one key. This work resulted in the development of a new overhead catenary cantilever conception, whose scheme is presented in Figure 2. The new conception is based on the main profile (1), on which cantilever support (3) is fixed. A support (2) is mounted in the cantilever's support's middle length. Elements (1) and (2) are fastened to the support structure by a package of insulators and handles. A registration arm (4) is mounted to the main profile (1) for the tension arms. Constructions (1–4) are fixed between each other by special slide holders. After putting them into guides located in both profile sides and positioning correctly afterwards they are twisted tightening up immobilizing the whole construction. An idea of profiles connection system is shown in Figure 3. Elements (1, 3, 4) and the handlers are made of highly strength aluminum alloy EN-AW 6082.

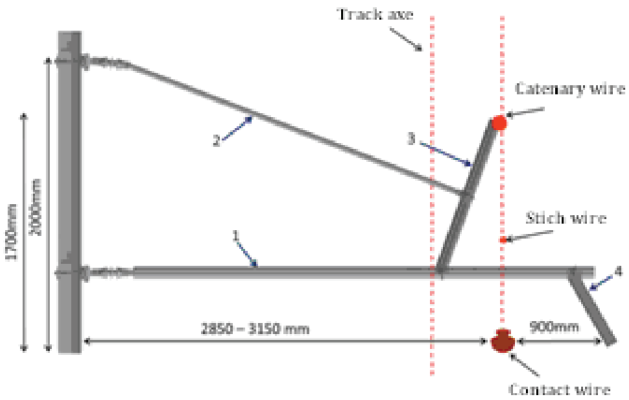

Fig. 2. A new generation cantilever catenary system to the support structures scheme [5, pp. 429–436]

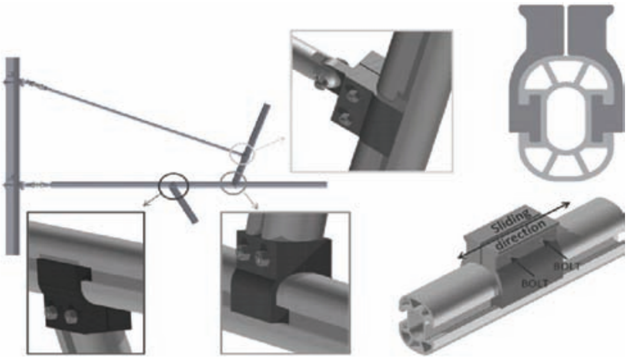

Fig. 3. Connection of a new overhead contact line (OCL) cantilever system elements [5, pp. 429–436]

One of more important problems to solve was to develop the main profile, optimal in terms of bearing capacity, stiffness and economic reasons. In order to accomplish this task, about 30 different shapes of a new profile were elaborated and numerically tested, which helped to achieve the final optimal geometry shown in Figure 4.

Fig. 4. Shape of an aluminum alloy EN-AW 6082 profile used as a main profile, cantilever support, registration arm [5, pp. 429–436]

The basic assumption for a new tensioning device solution was to eliminate the tension weights. As a part of progress, a number of constructional solutions were analyzed to be used as a base to develop a modern no-load tension device. Additionally, taking into account the future manufacturer's technological possibilities and the claims of patent it was decided to carry on work leading to develop a new tensioning device that uses the flat springs power.

4. FEM analysis results

The currently used catenary equipment analysis started from pipe fixture numerical calculations in terms of the stresses distribution and displacements for assumed operational loads. The value and power balance were chosen according to the Normative Document PKP Polskie Linie Kolejowe S.A. number 01-1/ET-2008 [1]. Figure 5 shows the arrangement of forces to which it is the biggest stress values.

Exemplary calculation results are shown in Figures 6–8. An effort of cantilever support bracket was noted at 100 MPa level, and the pipe mounting bracket as 70 MPa. The highest tension value, reached 200 MPa, was recorded in the connections system: tube slash – handle tube slash – registration arm and tension bracket arm – registration arm. Bending downwards the entire structure in the end of registration arm reached over 200 mm value.

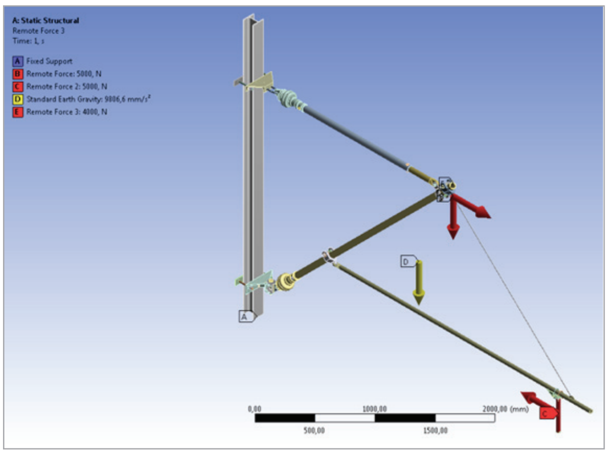

Fig. 5. The overhead contact line cantilever system load [8, pp. 421–428]

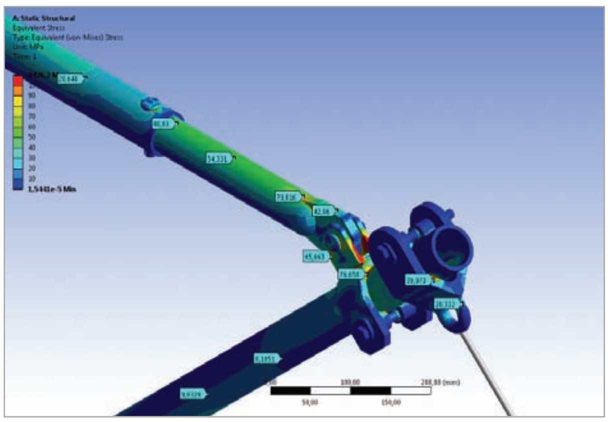

Fig. 6. Stress intensity of the system: cantilever support – support handle – cantilever mounting handle [8, pp. 421–428]

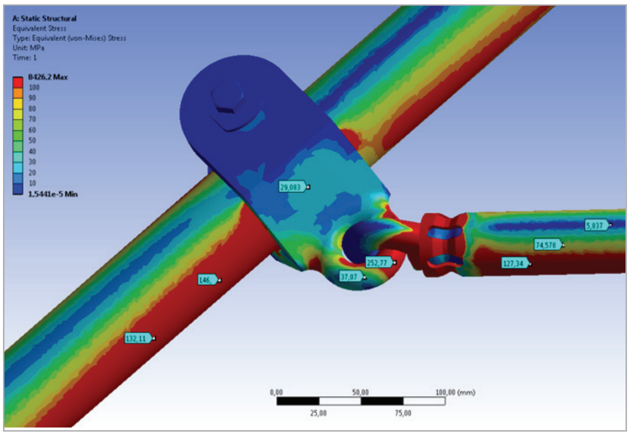

Fig. 7. Stress intensity of the system: cantilever support – support handle – registration arm [8, pp. 421-428]

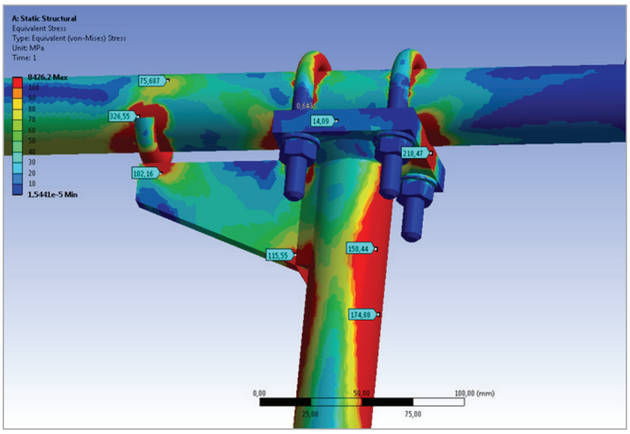

Fig. 8. Stress intensity of the system: tension arm bracket – registration arm [8, pp. 421-428]

Numerical studies have shown that under the loads established in the Normative Document [1], in currently used contact line cantilever system elements there are stresses up to 200 MPa or close to structural steel yield strength S235JR (235 MPa). After crossing that, it comes to a permanent deformation, which may result in loosing contact line parameters.

The first step of research procedure and each element geometry choice was to make numerical stress distribution calculations of a new cantilever system in simulated operating loads conditions. Material properties were assigned to built 3D models. Contact conditions were given to the connection systems and the fixed constraints with load conditions compatible with the Normative Document PKP Polskie Linie Kolejowe S.A. number 01-1/ET-2008 [1]. These obtained models were split as finished elements by putting a grid. After a material research wide analysis two main materials were chosen as new constructional system elements, whose qualities are shown in Table 1. Pole mounting holders and a support will be built from a stainless steel 1.4301 but the other elements from highly strength aluminum alloy in EN-AW 6082 type. The boundary parameters adopted in the calculations are shown in Figure 9. This system of forces occurs in the case of stagger to the pole.

Table 1

Materials qualities adopted in the analysis and new constructional connection elements system production

Parameter	Aluminum alloy – EN AW 6082	Stainless steel 1.4301
Yield strength [MPa]	310	190
Ultimate tensile strength [MPa]	340	500-700
Young's modulus [GPa]	70	200
Density [g/dm3]	2,7	7,9
Poisson's ratio [-]	0,33	0,3-0,31

Source: [5, pp. 429-436], [9, pp. 57-60]

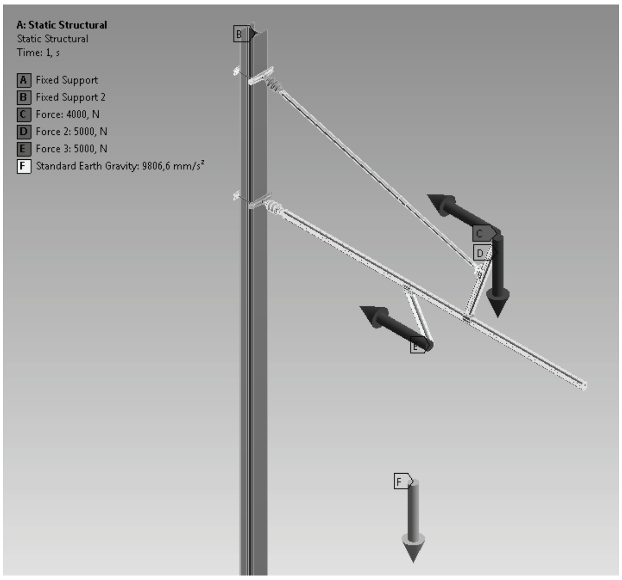

Fig. 9. The cantilever's catenary's load according to the Normative Document PKP Polskie Linie Kolejowe S.A. number 01-1/ET-2008 [5, pp. 429-436]

Stress distribution research results in analyzed general view are shown in Figure 10. The calculations show that the stress intensity maximally till 235 MPa occurs in the analyzed loaded by operating forces system. The highest stresses level is located in cantilever support with main profile connection area where the highest bending moments are found. Other areas are located in the range of 50-100 MPa stresses (screws and support structures holders areas, support's endings and the registration arm with tension arm mounting points). The rest areas demonstrate stresses at 10-50 MPa level.

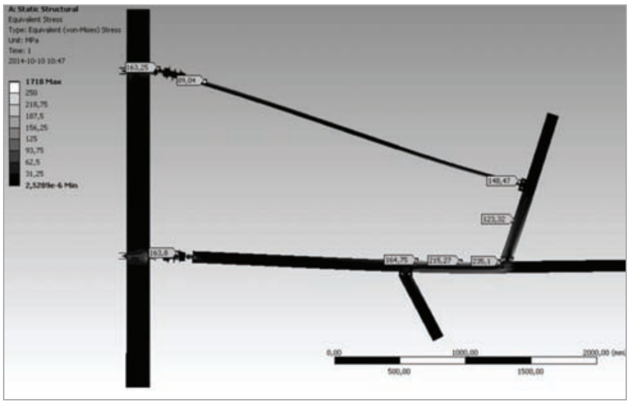

Fig. 10. The stress distribution in new construction type of cantilever catenary system [5, pp. 429–436]

The new construction's safety factor distribution understood as stresses in the node ratio on determined load, referred to the stresses value plasticizing the material from which the element was made (Figure 11). Calculations show that all of the elements have high safety factor at minimal level 1.3 considering that loads used in calculations included safety factors already applied in railway applications.

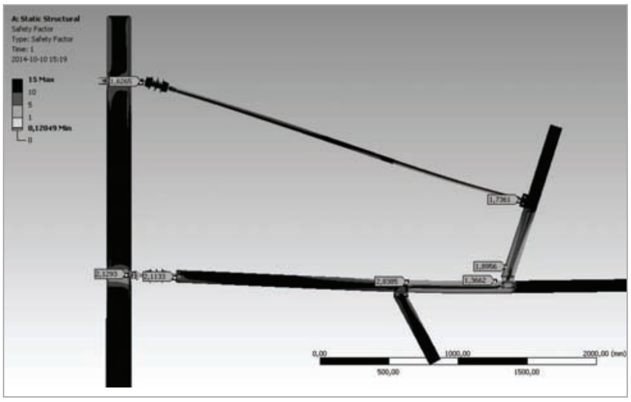

Fig. 11. Safety factor distribution for new cantilever type system – general view [5, pp. 429–436]

5. Laboratory test results

Components of the contact line cantilever system are mounted by screw connections. Because of that, except skid forces tests, the screw connections stress relaxation tests were conducted for M12 and M16 screws. Figure 12 shows a sample graph with a stress degree relaxation change in time.

The corrosion resistance tests were conducted on currently exploited equipment using the salt chamber. The first corrosion appearance was observed after 24 hours and after further 7 days the corrosion process was intensified. It shows a low corrosion resistance of these tested elements, especially when they work in an aggressive environment. Figure 13 shows an anchor holder after 24 hours of salt fog exposure.

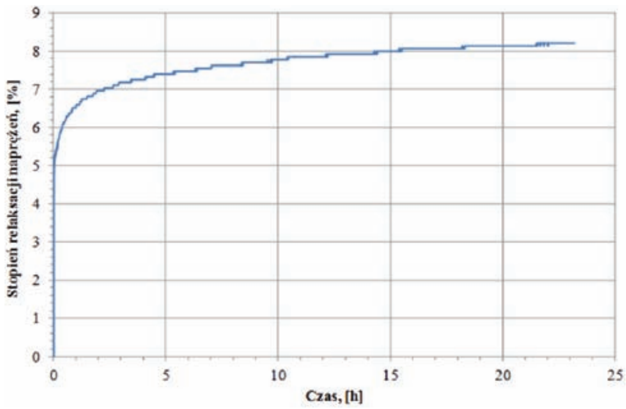

Fig. 12. Stress relaxation degree as a time function in 60 Nm moment the M12 tightened screw joining: cantilever support handle – cantilever support [8, pp. 421–428]

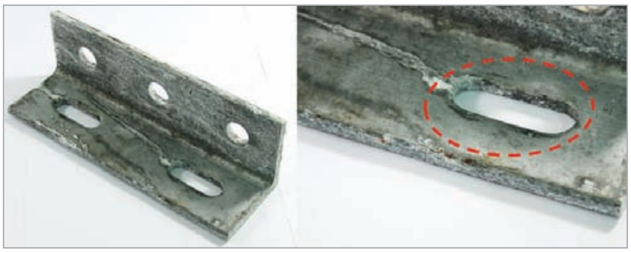

Fig. 13. An anchor holder after 24 hours of salt fog exposure [8, pp. 421–428]

The next stage of the new OCL cantilever system tests consisted of manufacturing a real scale prototype model and a strain gauge tension test. The model was manufactured and mounted on the support structure at MABO company premises. Having applied FEM analysis there were selected nine areas of manufactured OCL cantilever model expected to be most exposed to stresses. Those areas were properly prepared and wired with the strain gauges. The object was equipped with a set of compensed strain gauges and a specially created measurement and data acquisition system. Tension measurement areas are shown in Figure 14. The real scale prototype model with mounted strain gauges is shown in Figure 15. The tension level in specific areas of the new railway overhead contact line cantilever system was examined during the test.

Tension tests were conducted for several different load schemes of the test model. Then, after detailed analysis two were typed, which most suitably represented conditions met in overhead contact line. The load scheme is shown in detail in Figures 15 and 16. During test no. 1 cantilever system was loaded with force F_1 = 4.9 kN, while during test no. 2 it was additionally loaded with forces $F_2 = F_3$ = 0.98 kN.

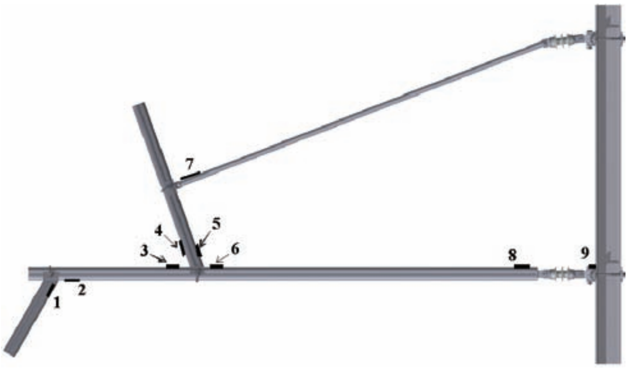

Fig. 14. Overhead contact line new generation accessories mounted on the pole with tension measurement areas marked [11]

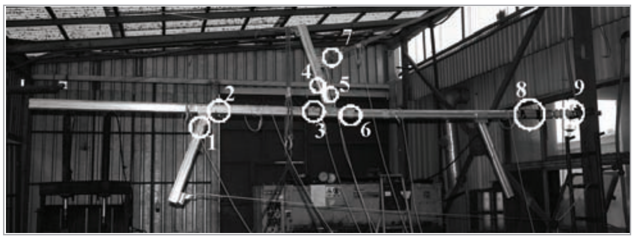

Fig. 15. Real scale prototype model with marked tension measurement areas [11]

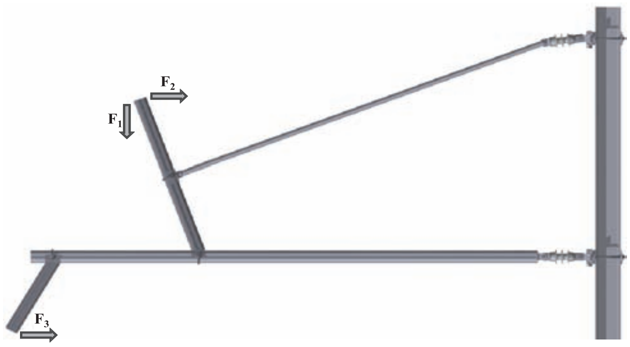

Fig. 16. Real scale prototype model with marked loading forces [11]

Figures 17 and 18 show stress distribution at preset loads respectively during test no. 1 and no. 2. At the load scheme no. 1, where only force F_1 = 4,9 kN was set, the highest tension values in tested object were observed in contact area of cantilever support and main profile (point T6 – value about 85 MPa, point T5 – value about 50 MPa, point T4 – value about 40 MPa) and contact area of cantilever support and support (point T7 – tension values about 50 MPa).

The introduction of two additional forces caused certain changes in the tension scheme. Still the most stressed area was the connection of the cantilever support and the main profile (point T6 – tension value about 85 MPa, point T5 – value about 70 MPa, point T4 – value about 50 MPa, point T3 – value about 35 MPa) and contact area of cantilever support and support (point T7 – tension value about 50 MPa). The introduction of forces F_2= 0.98 kN and F_3=0.98 kN causes an additional load in the contact area of the main profile and registration arm (point T1 – value about 20 MPa, point T2 – value about 22 MPa).

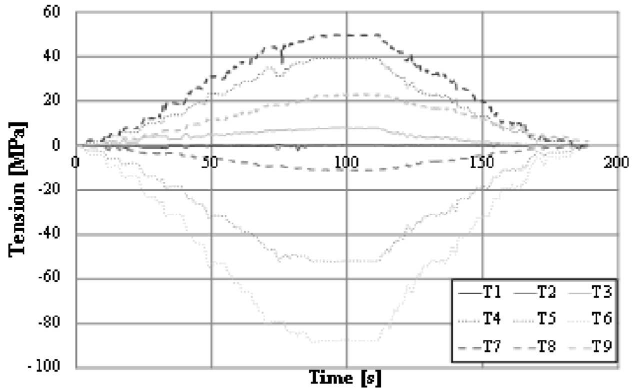

Fig. 17. Plot of tension versus time – test no. 1 [11]

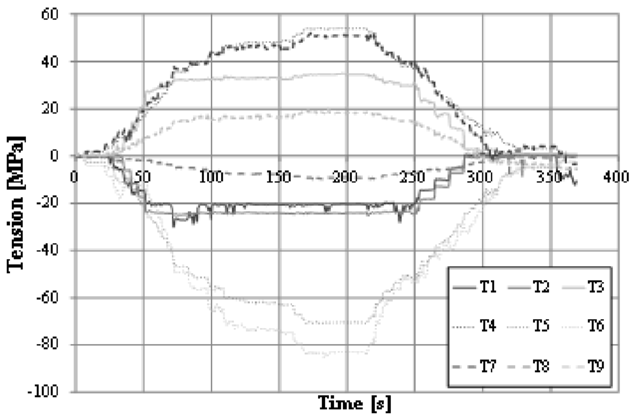

Fig. 18. Plot of tension versus time – test no. 2 [11]

Test results confirm numerical analysis results, according to which the connection of the cantilever support and the main profile was selected as the most stressed area. An additional test was performed, during which the real scale model was loaded according to the test no. 2, for 12 hours. The experiment provided that the vertical deflection of the construction in its extreme position does not change in time and equals 30 mm. The low tension level and low elastic deflection met in the new construction proves its high rigidity and mechanical endurance.

The achievement of linear characteristics of force as a function of spring torsion degree is the basic problem connected with springs application in tensioning devices. Initially sloped characteristics shall be processed to become flat. A number of various spiral spring geometries (Fig. 19) were designed, and tested in respect of exploitation characteristics of no-load overhead contact line tensioning devices. As a result of the tests, the spring linear characteristics, shown in Fig. 20, were obtained.

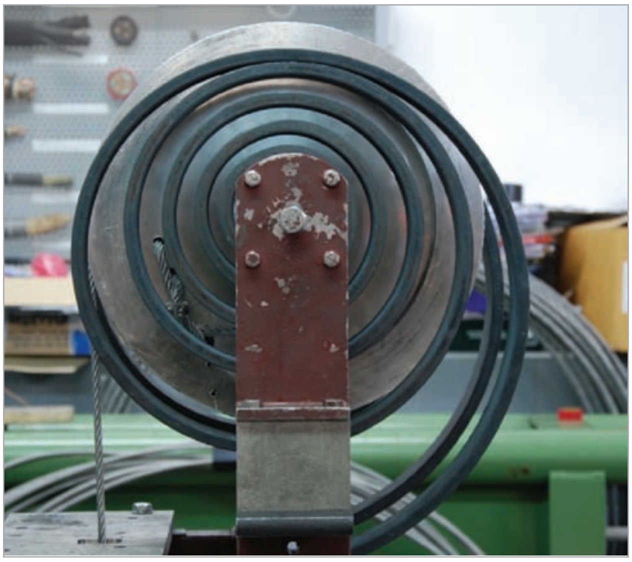

Fig. 19. Spiral spring during test [11]

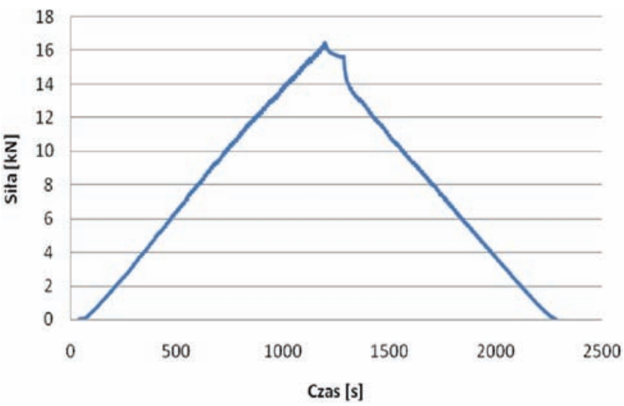

Fig. 20. Spiral spring characteristic [11]

The obtained results became a basis to the project system capable of generating a determined force on the contact wire or catenary wire at their variable extension. In order to obtain such an effect there was designed a cam of precisely determined geometry that allows receiving and keeping the required force. As a result of the test and design work the device characteristics was received, shown in Fig. 21.

The complete tensioning device was laboratory tested (Fig. 22). The force characterisitcs tests of the prototype no-load tensioning device and catenary wire displacement (elongation) were conducted under the research program. An example of the test result is shown in Figure 23. The test was carried out in order to: check the correctness of prototype operation, perform a possible setup correction of the cam with respect to the shaft, and test the tensioning device in its full operation range.

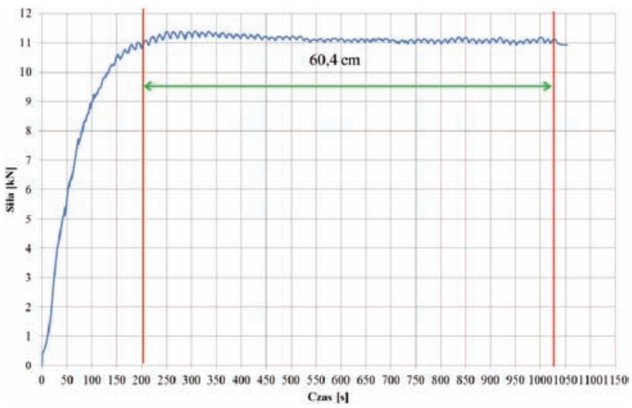

Fig. 21. Spiral spring with cam characteristic [11]

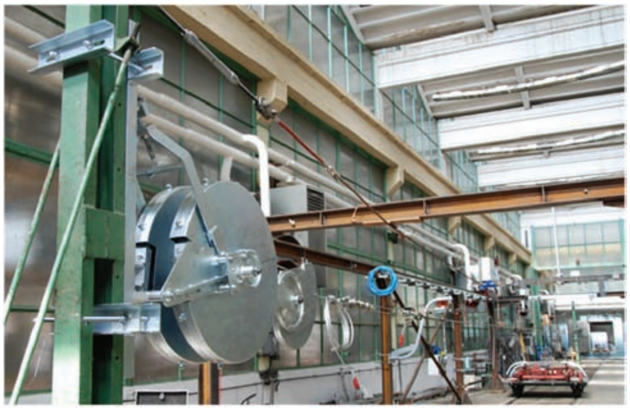

Fig. 22. No-load tensioning device during laboratory tests [photo P. Kwaśniewski]

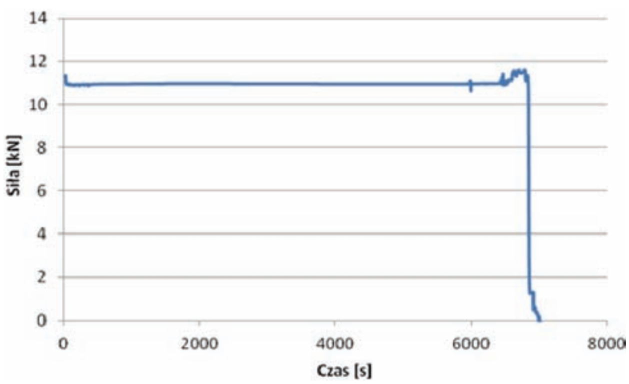

Fig. 23. Tensioning device characteristics during arrangement relieving [11]

6. Field tests

Field tests started in October 2014 at the IK Test Track Centre near Żmigród. In order to perform these field tests several of the previously used cantilevers were removed from the poles and replaced with new OCL cantilever systems. New constructions worked with YC150-2C150 overhead contact line, consisted of the copper contact wire – crossection 150 mm^2, and two catenary wires – crossection 150 mm^2 each. Apart from the mentioned YC150-2CS150, it is the heaviest overhead contact line used in Poland. Assembly works are shown in Figure 24. The OCL cantilever system mounted on the pole is shown in Figure 25.

Fig. 24. Assembly of the new OCL cantilever system at IK Test Track Centre near Żmigród [photo P. Kwaśniewski]

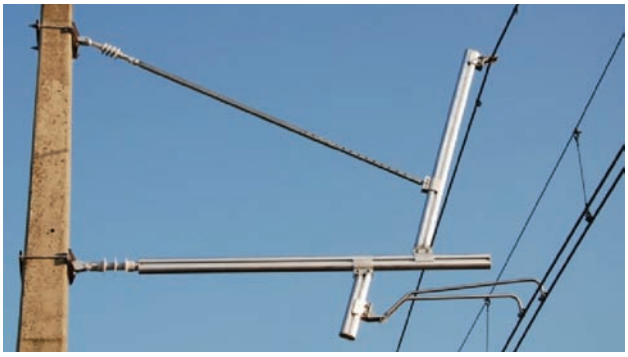

Fig. 25. New OCL cantilever system mounted at IK Test Track Centre near Żmigród [photo P. Kwaśniewski]

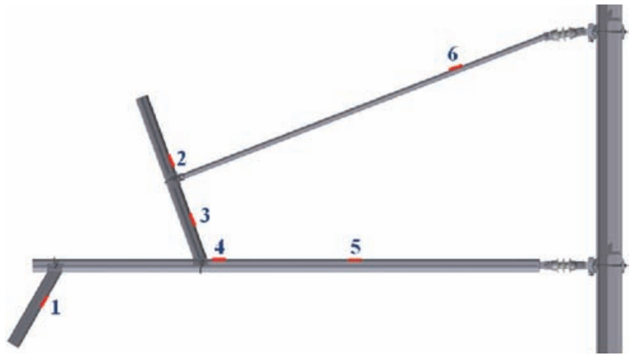

Fig. 26. Tested OCL cantilever system scheme with marked tension measurement areas [11]

Due to the number of elements, a cantilever in which contact line is ousted from the alignment track and the pole was chosen for the test. Measurement areas were properly prepared and wired with six strain gauges, which is shown in Figure 26. Those areas were selected basing on previous research. The object was equipped with a set of compensed strain gauges and a specially created measurement and data acquisition system. Due to the 3 kV electric potential met on the elements of OCL cantilever system and strain gauges, a part of the measurement system was also mounted on the 3 kV potential at a specially prepared platform (Fig. 27). The measurement system consisted of data acquisition from strain gauges module, power supply module and communication module. The data was recorded on a personal computer via Wi-Fi link. During the test the stress level was examined in particular areas of the new OCL cantilever system, caused by trains passage.

Fig. 27. Tested OCL cantilever system with visible mounted strain gauges and measurement equipment [photo P. Kwaśniewski]

The tension values caused by passing train were recorded during performed tests. In a series of the measurements the traction vehicle passed under the tested cantilever system with different speeds, ranging from 40 to 160 km/h (with step speed change 10 km/h), and one pantograph raised, and speeds ranging from 40 to 120 km/h and two pantographs raised. The photos of the traction vehicle with raised one and two pantographs passing under tested cantilever system, are shown in Figure 28.

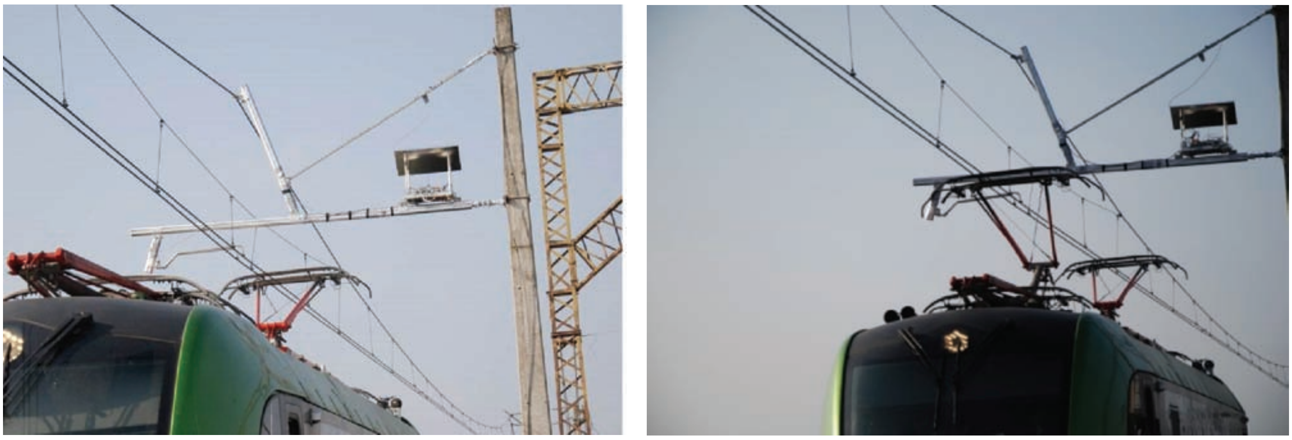

Fig. 28. Traction vehicle passage under tested OCL cantilever system with raised one (left) and two (right) pantographs [photo P. Kwaśniewski]

The highest tension values were recorded at maximum speed. It occurred in points 2 and 6, therefore in support and cantilever support to which catenary wire is mounted. Figures 29 and 30 show tension values recorded during the traction vehicle passage with speed 160 km/h and one pantograph raised (Fig. 29), and speed 120 km/h and two pantographs raised (Fig. 30). The recorded characteristics show that stresses met in the new OCL cantilever system do not exceed 3 MPa (which is 4% of maximum tension values caused by static loads), even during cooperation of overhead contact line with two pantographs spaced apart from each other at 8 m distance.

The no-load tensioning device tests were conducted at IK Test Track Centre near Żmigród. The device was assembled on C95-C overhead contact line, tensioning contact wire at length of half section 800 m. The device installation is shown in Figure 31, and the mounted device is shown in Figure 32. Force measurement, device characteristic measurement and device setup for environment temperature were performed during installation (Fig. 33). The no-load tensioning device has been continuously operating since the spring of 2015. During one year service no device malfunctions or inappropriate operation of tensed overhead contact line were noted.

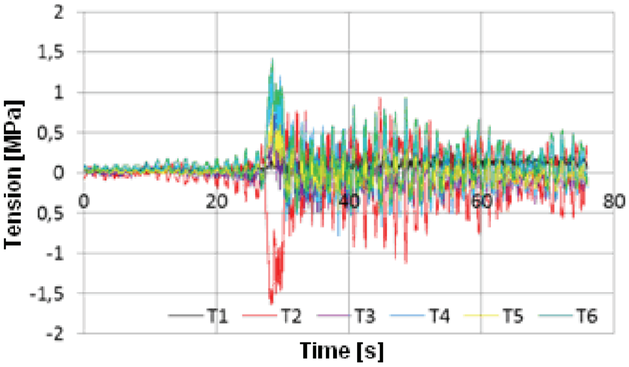

Fig. 29. Tension values in new OCL cantilever system elements during traction vehicle passage at speed 160 km/h and one pantograph raised [11]

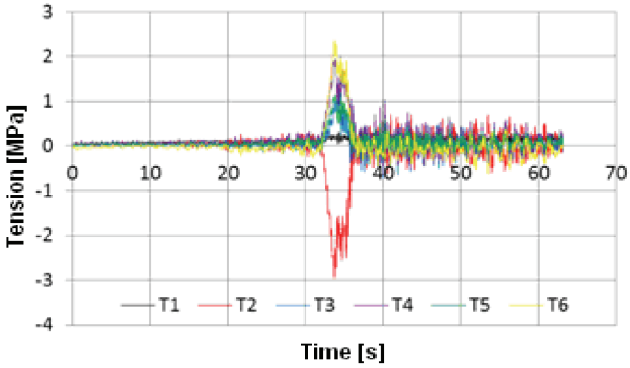

Fig. 30. Tension values in new OCL cantilever system elements during traction vehicle passage at speed 120 km/h and two pantographs raised [11]

Fig. 31. Assembly of the no-load tensioning device [photo P. Kwaśniewski]

Fig. 32. Mounted no-load tensioning devices. Commonly used tensioning device with loads is visible in the background [photo A. Rojek]

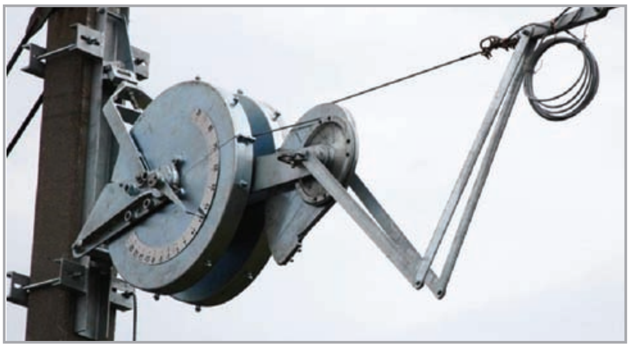

Fig. 33. No-load tensioning device with visible assembly temperature scale [photo P. Kwaśniewski]

7. Conclusions

The performed tests showed, that tension values met in the new OCL cantilever system are at the safe level and do not endanger the newly constructed cantilever system operation. The laboratory and field tests performed on the real scale model confirmed that numerically pointed contact area of cantilever support and main profile is the most stressed area. However, the tension value in this area equals about 90 MPa, which is significantly lower than yield strength of an EN-AW 6082 alloy (tensile stress value at 30% level). The tests confirm that the constructed elements are safe in operational load conditions from the viewpoint of a load capability. Advantages of the new OCL cantilever system:

- high elastic properties – rigidity,
- high corrosion resistance,
- high rheological resistance,
- reliable operation,
- low weight – lower gravitational load of the poles,
- simple assembly and regulation,
- simple and cheaper transport,
- lower number of elements,
- high aesthetics,
- product lifetime – minimum 30 years.

The advantages of the new OCL cantilever system compared to currently used tube cantilevers are shown in a the Table 2.

The performed laboratory and field tests of no-load tensioning device showed that spiral springs application allows obtaining a constant tensioning force in the required wires variation length range. The resignation of loads in tensioning device increases operation reliability in comparison to the presently used solutions, in which load theft or destruction leads to a change of tensioning force.

Table 2

Tube and new OCL cantilever system selected parameters and properties

No.	Properties	Tube cantilever	New OCL cantilever system
1.	**Material**	Hot-dip galvanized steel	Aluminium/stainless steel alloy
2.	**Weight of all elements**	90 kg	41 kg
3.	**Number of elements to connect**	18	~13
4.	**Necessary assembly tools number**	5	2
5.	**Assembly time (preparatory works not included)**	100%	30–50% of current time

Source: based on [11]

Literature

1. Dokument Normatywny PKP PLK S.A. nr 01-1/ET-2008-Osprzęt sieci trakcyjnej, let-110, Warszawa 2008.
2. Kaniewski M.: *Sześćdziesiąt lat badań sieci trakcyjnej i odbieraków prądu*, Problemy Kolejnictwa zeszyt nr 152/2011, Instytut Kolejnictwa, Warszawa 2011, s. 155–171.
3. Kiessling F., Puschmann R., Schmieder A.: *Contact lines for electric railways*, Munich 2001.
4. Knych T., Kwaśniewski P., Rojek A. i inni: *Analiza numeryczna kolejowych konstrukcji wsporczych na bazie profili zamkniętych*, Semtrak 2010, s. 91–102, Zakopane 2010, s. 91–102.
5. Knych T., Kwaśniewski P., Rojek A. i inni: *New generation of railway overhead line equipment system*, Rudy i Metale Nieżelazne, R60 2015 nr 9, s. 429–436.
6. Knych T., Kwaśniewski P., Rojek A. i inni: *Nowa generacja wysokoobciążalnych sieci trakcyjnych – YC120-2CS150 i YC150-2CS150*, Założenia techniczno-konstrukcyjne, Technika Transportu Szynowego TTS 1-2/2007 s. 56–63.
7. Knych T., Kwaśniewski P., Rojek A. i inni: *Nowa generacja wysokoobciążalnych sieci trakcyjnych – YC120-2CS150 i YC150-2CS150 (5)*, Badania nowej sieci trakcyjnej, Technika Transportu Szynowego TTS 7–8/2007 s. 50–55.
8. Knych T., Kwaśniewski P., Rojek A. i inni: *Theoretical and experimental studies of overhead railway line equipment – current state*, Rudy i Metale Nieżelazne,R60 2015 nr 9, s. 421–428.
9. Knych T., Kwaśniewski P., Rojek A. i inni: *System nowej generacji elementów połączeń nośnych kolejowej górnej sieci trakcyjnej*, Technika Transportu Szynowego TTS 1-2/2015, s. 57–60.
10. Knych T., Mamala A., Kawecki A., Kwaśniewski P.: *Nowoczesne krajowe rozwiązania materiałowe i konstrukcyjne elementów górnej sieci trakcyjnej*, Elektro-Info 11, 2008 (69), s. 64–71.
11. Projekt NCBiR INNOTECH II (Firma MABO) pt: „Opracowanie technologii i uruchomienie produkcji nowej generacji elementów nośnych kolejowych sieci trakcyjnych", nr: INNOTECH-K2/IN2/28/182120/NCBR/13.

Rozwój i badania nowych rozwiązań wyposażenia sieci elektrycznej

Streszczenie
Sieć trakcyjna (OCL) składa się z różnych konstrukcji i elementów nośnych, które umożliwiają instalację przewodu jezdnego poziomo w stosunku do toru. Sieć trakcyjna jest złożonym systemem mechanicznym i elektrycznym, który musi zapewnić właściwe przekazywanie energii elektrycznej do pojazdu trakcyjnego. W trakcie eksploatacji urządzeń sieci trakcyjnej (wysięgniki, wsporniki, urządzenia napinające itp.) pojawiają się różne problemy znacząco wpływające na ruch kolejowy. Ponadto przestarzałe konstrukcje utrudniają ich montaż i codzienną eksploatację.
Przedstawiono wyniki badań, analizy numeryczne właściwości naprężeń, eksperymentalne wyniki relaksacji siły nacisku i odporności na korozję urządzeń sieci trakcyjnej w obecnie używanych urządzeniach. Opracowano koncepcję sieci trakcyjnej nowej generacji. Przeprowadzono badania rozkładu naprężeń i współczynnika bezpieczeństwa na konstrukcjach obciążonych eksploatacyjnie. Uzyskane wyniki pokazały, że obecnie używane urządzenia przy obciążeniu eksploatacyjnym pracują blisko granicy wytrzymałości materiału. Badane elementy miały również wady projektowe, niską odporność na korozję i odporność reologiczną na poziomie 8–10% stopnia relaksacji. Wykonane prace przeprowadzone w obciążeniu eksploatacyjnym wykazały, że nowo zaprojektowane elementy mają bezpieczny poziom naprężenia efektywnego i wysoki współczynnik bezpieczeństwa. Zaprojektowano, przetestowano i zbadano nowe rozwiązanie urządzenia naprężającego bez ciężarów naprężających. Siła naprężenia przewodu jezdnego i sieci trakcyjnej jest generowana przez spiralne sprężyny urządzenia. Użycie właściwie zaprojektowanych elementów – krzywek, pozwala uzyskać stałą siłę naprężającą przewodu jezdnego w całej długości przęsła naprężenia.

Słowa kluczowe: sieć trakcyjna, przewód jezdny, urządzenia sieci trakcyjnej, badania numeryczne

Развитие и исследования новых решений для тягового оборудования

Резюме
Контактная сеть (OCL) состоит из разных конструкций и несущих элементов, которые делают возможным установку контактного провода горизонтально по отношению к рельсу. Контактная сеть является сложной механической и электрической системой, которая должна гарантировать правильную передачу электрической энергии для единицы подвижного состава. Во время эксплуатации тягового оборудования (кронштейны, опоры, натяжные устройства и др.) возникают разные проблемы существенно влияющие на железнодорожное движение. Кроме того, устаревшие конструкции вызывают сложности в монтаже и ежедневной эксплуатации.
В статье представлены результаты исследований, численный анализ свойств напряжений, экспериментальные результаты релаксации силы давления и устойчивости к коррозии тягового оборудования в ныне используемом оборудовании. Была разработана концепция контактной сети новой генерации. Были также проведены исследования напряжений и коэффициента безопасности на конструкциях подвергающих эксплуатационной нагрузке. Полученные результаты показали, что ныне используемое оборудование подвергающие эксплуатационной нагрузке работает близко к пределу прочности материала. У исследуемых элементов обнаружено разного типа проектные дефекты, низкую устойчивость к коррозии, реологическую устойчивость на уровне 8-10% степени релаксации. Выполненные работы, которые были проведены полностью при эксплуатационной нагрузке показали, что недавно разработанные элементы обладают безопасным уровнем эффективного напряжения и высоким коэффициентом безопасности. Было разработано и протестировано новое решение натяжного устройства без груза компенсатора. Сила натяжения контактного провода и контактной сети генерируется спиральной пружиной устройства. Употребление правильно разработанных элементов – кулачков – позваляет получить постоянную силу контактного провода по всей длине мачтового опорного участка.

Ключевые слова: контактная сеть, контактный провод, тяговое оборудование, численные исследования