Problems of interaction of contact wire and current collectors of electric transport with different contact materials

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Abstract. The reliability of the current transfer process depends on the reliable sliding contact between the current collector and the contact wire; the value of the resistance of the contact element of the current collector; the value of the contact wire's contact and the contact element. Graphite inserts for operation on electric transport of railways of alternating current operate at low values of current, on electric trains of a direct and an alternating current at high speeds, and on electric locomotives of a direct current at large values of a current. They are good lubricate the contact wire, but have a high resistivity and are rapidly mechanically erased. Copper and metal-ceramic lining have relatively less resistance, but due to the high hardness of the material, they quickly wipe off themselves and the contact wire. When using all materials in open and closed mines, dust and dirt on contact plates, high temperature and the presence of gas, which is dangerous when the spark is in contact, must be considered additionally. It is proposed to use the new contact material of BRZG from bronze, graphite and iron. The effectiveness of this material is confirmed by the operation of electric locomotives and electric trains of direct and alternating current on railways and trolleybuses.

1. Introduction

Reliability of electric transport, which receives electric energy from the contact network, depends primarily on the reliability of the electricity supply system. The main problems arising in the operation of the electric transport of the railways are not enough reliable contact in the "pantograph-contact wire" sliding contact, and the contact wire hanging system is not always properly selected or not adjusted according to the requirements. Providing electric rolling stock with high-quality current-drawing is one of the most difficult tasks [1].

The problem of reliable contact on current collectors is important for railroad electric transport, and for the electric transport of the city – the tram and trolleybus. Even more complicated problems exist in electric transport, which works in open and closed mines, where, in addition to large currents, there is gunpowder and dirt on contact elements of the current collector. When operating high-speed lines it is confirmed that ensuring reliable interaction pantograph and contact wire is even more difficult technical task than ensuring the reliable interaction of the rolling crew with rails [2-5].

2. Purpose and objectives of the research

The purpose and tasks of the research is to analyse the work of pantographs on various types of electric transport and to find a solution to the problem of contact between the contact wire and current collectors of electric transport by using modern contact material.

3. Analysis of pantograph work on various types of electric transport

To determine the dynamic characteristics that are included into the indices, with help of which the dynamic properties of the mechanical part of the diesel train are estimated, the analysis of the car design and its spatial mechanical model should be carried out [6, 7].

Reliability and the required quality of current-picking are determined by the velocity of the rolling stock and the structural parameters of the contact pendant and current collector, and their interaction is a complex oscillatory process that causes different intensity of mechanical and electrical wear of the contact wire and current-drawing elements [8]. In the process of oscillation various vibrational systems participate. Special influence on this process is made by oscillations of the locomotive and self-oscillation of the contact wires caused by the air flow.

Most researchers in their studies to improve the interaction of contact pairs "current receiver - contact wire" are considering different directions: improving the systems of hanging contact network; tension adjustment of the contact wire; changes in the type of compensation of contact hanging; replacement of conductor materials of the contact network. The research of individual scientists is aimed at the invention of new structures of current collectors of electric transport. However, in the operation of the railroad main and industrial transport, there are only two main types pantographs – symmetrical heavy type, Figure 1, symmetrical light type, Figure 2, and pantograph asymmetric, or semi-pantograph, Figure 3.

Figure 1. Heavy symmetric pantograph, electric locomotive.

Figure 2. Light symmetrical pantograph, electric locomotive.

Figure 3. Asymmetrical pantograph, electric locomotive.

Sometimes different models of current collectors are used depending on the conditions of the electric locomotive – for example, the speed (Figure 4), or the energy supply system – one phase, or three phases at different levels (Figure 5). Pantographs of electric pushers may have several sections (Figure 6). In industrial electric locomotives, when loading in the carriages from above, side current collector is used, and in the main section the upper pantograph is used (Figure 7).

For rail electric transport in cities use symmetrical pantographs (Figure 8), asymmetrical pantographs (Figure 9), and bugeli (arcs) (Figure 10).In some cities, a current collector is used in the form of a rod (Figure 11). To protect against wandering currents, two rods were used instead of a rail (Figure 12). There are various types of current collectors on trams – pantograph and rod (Figure 13).

Figure 4. Different types of pantographs, one electric locomotive.

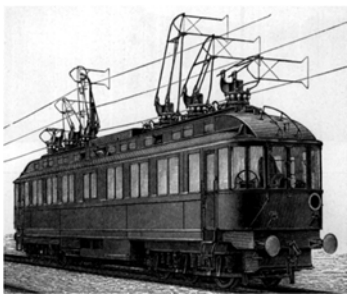

Figure 5. Three-phase current collectors.

Figure 6. Multi-sectional current collector for pusher carriages.

Figure 7. The upper pantograph and the lateral half-pantograph, industrial electric locomotive.

Figure 8. Symmetrical pantograph, tram.

Figure 9. Asymmetrical pantograph, tram.

Figure 10. Bugle (arc) current collector, tram.

Figure 11. Tram current collector – rod.

Figure 12. Two rods of the tram.

Figure 13. Various current receivers, tram.

Figure 14. Two current tram receivers.

For the reversal of the bore current collector, a special network of air arrows and contact wires is developed, which allows the trolley to unfold without lowering the current collector (Figure 14). If only one track is used to work in different directions of motion, use two rods (Figure 15), or two arcs (Figure 16).

Some cities have experience sharing the contact network for different modes of transport. For example, tram and trolleybus used common contact wires and rod current collectors (Figure 17). Together with passenger trolleybuses, cargo trolley buses (Figure 18) and trolley bus trucks (Figure 19) worked.

Figure 15. Two bugle current tram.

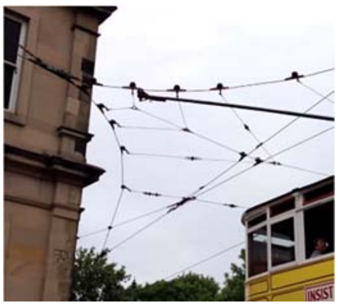

Figure 16. Contact wire for turning current collector.

Figure 17. Tram and trolley bus network.

Figure 18. Cargo trolleybus.

On the lines of the trolleybus trucks were used, which used a barge current collector (Figure 20). On heavy duty trucks, the bore current collectors are coupled and replace the contact heads on the skis (Figures21 and 22). The painted pantographs were replaced by semi-pantographs (Figure 23).

Figure 19. Trolley car.

Figure 20. Diesel-trolley car.

Figure 21. United pantograph.

Figure 22. Pantographs.

Figure 23. Semi-pantographs.

Figure 24. Carbon car inserts.

Figure 25. Hybrid bus collector.

At the moment, special contact networks have been created for use by their cars. At the same time, pantographs (Figure 22) and semi-pantographs (Figure 23) with copper, composite and coal strips and inserts remain in the structure of current collectors (Figure 24). Modern is the use of a hybrid bus with current collectors. At the end stops, the tumbler automatically raises to the contact wire (Figure 25).

Certain companies produce current receivers made of aluminum tubes to ease weight and reduce the weight of pantograph, which improves the process of screw-in. But the cost of such a pantograph is large. Most manufacturers use steel pipes, which makes the pantograph heavier, but its cost is lower. This causes the static and dynamic characteristics of the pantograph to deteriorate. The process of transferring electrical current from the mains to the electrical equipment becomes worse. As a result, we get worse traction characteristics of electric transport. Some scholars try to combine different designs of pantographs (Figure 28). Leading manufacturers make an asymmetrical current collector with two rows of contact elements made of graphite (Figure 29).

Figure 26. Contact roller current collector.

Figure 27. Trolley contact element.

Figure 28. Hybrid pantograph by tram.

Figure 29. Modern pantograph.

In current collectors there should be minimal friction in the hinged knots, stable pressure on the contact wire, the minimum moving weight. They should provide minimal abrasion of the contact wire and contact elements. Qualitatively selected dynamic indicators characterize quality, reliability and profitability.

Contact elements should be reliable, environmentally friendly, and ensure long-term operation of the pantograph. Qualitative and reliable work is possible only with reliable contact of current collector and contact network. Minimize short-circuiting current collector from a contact network can lead to negative consequences. First of all, tearing leads to damage to the contact element and its rapid wear and contact wire. The poor contact between the contact wire and the current collector in the closed mines not only leads to the wear of not only contact elements but can cause sparking on the pantograph, which is a threat of explosion and a danger to life. The sparking of the contact elements indicates the unsatisfactory condition of the contact inserts, and worsens the current removal rates, and as a result, the traction characteristics of the electric transport deteriorate, and the consumption of electricity increases (Figures30-32).

Figure 30. Spark on pantograph trolley bus.

Figure 31. Spark on an electric train.

Figure 32. Spark on electric locomotive in mine.

The main problem with the AC system is the rapid action of the carbon insert, which during operation leads to a reduction in electrical contact and the emergence of an electric arc. This causes intense wear of the contact wire both on the railroad and on the city electric transport. As a result, there is a breakdown of wires, breakage of current receivers and other damage that violates normal movement.

At present, most of the locomotive depot for contact areas of DC uses copper-based contact materials. In this case, there is a major problem of the mutual wear of copper wire and contact element. To reduce the harmful effects of frictional forces between the pantograph pad, the dry graphite oil is pressed and baked, and in the course of operation to reduce the wear, the lining is greased with a graphite-based liquid lubricant [9] (Figure33).

Comparing contact elements on the basis of copper and graphite, it is evident in their electrical properties. It is known that the specific electrical resistance of copper is 1.75×10^{-5} Ohm × m, and the specific electrical resistance of graphite is 10^{-6} ... 10^{-4} Ohm × m [10]. Since we do not use either pure copper or pure graphite in the form of contact elements of the current collector, we are creating the problem of using contact materials in the contact lens of the pantograph. By placing graphite on copper, we worsen the electrical properties of the sliding contact. That is, using the expensive material for the contact wire and the contact plate, we increase the electrical component of the transient resistance, which complicates the problem of the use of the overlays.

For the depot, which operate the electric transport of alternating current railways, the main material for inserts of current collectors is graphite. Here again the question arises - which graphite inserts is better to use? If you look at the problem from the point of view of electrical engineering, then it is necessary to use those inserts, which have less specific electrical resistance. According to manufacturers, the specific resistance of coal inserts should be within 4.5 ... 22×10^{-5} Ohm × m. In practice, these values range from 8×10^{-5} to 30×10^{-5} Ohm × m [10].

The European Union regulations [3-5] contain requirements and recommendations for the use of contact inserts and overlays on different models of current collectors of electric locomotives and electric trains. If we consider the main problem of the resource of work, it is better to take carbon inserts with the smallest hardness to not rub the contact wire. For example, in the contact inserts of the sign “A” (coke), the hardness is 70 HS. In the most common contact inserts of artificial “B” graphite hardness should be 50 HS. They should be washed faster than the contact wire. But in reality, the insertion of wear occurs too quickly, which leads to the formation of zones of local wear, or the degree of wear of the inserts (Figure 34).

Figure 33. Lining of pantograph on the basis of copper with graphite lubricant.

Figure 34. Carbon inserts of the pantograph of the electric locomotive.

As a result of such a quick and improper work, there are cases of piercing pantographs with the help of a contact wire (Figure 35); hacking the pantograph (Figure 36); department of pantograph from the roof of the electric locomotive (Figure 37); and breakage of the contact wire (Figure 38).

Figure 35. Sawing the pantograph with a contact wire.

Figure 36. Hacking the pantograph of the electric locomotive.

Figure 37. Disruption of pantograph.

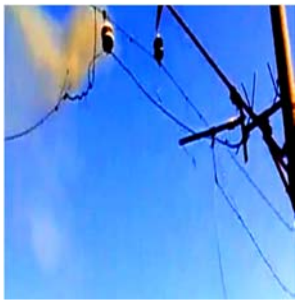

Figure 38. Break of the contact wire.

The most dangerous is the drop in the contact wire on the body of electric transport, which may be the cause of death of people (Figure 39). A similar situation is possible with the breakdown of current receivers of the tram and the trolleybus. When the contact wire of the tram or trolleybus contact network breaks, the traffic of the city electric transport stops, which leads to the accumulation of passengers, the failure in the schedule of traffic or individual routes, or the whole area (Figure 40).

It is obvious that the best in terms of maintaining the contact wire would be the use of contact inserts of artificial graphite mark “O”, hardness of which should be 25 HS [10]. They also satisfy the electrical part of wear because they have a specific electrical resistance of 5×10^{-5} Ohm × m.

For urban electric transport – trolleybus and tram, graphite contact inserts are used, which have a high specific resistance of 8 ... 30×10^{-5} Ohm × m, and significantly less work life, compared with the coal inserts of rail transport. This is especially noticeable in the case of significant precipitation, sticking wet snow (Figure 41), and large ice on the contact wire and in areas where energy recovery is used [11] (Figure 42).

Worst of all, when the influence of the dynamics of the rolling stock is added to the question of a stable electrical contact [12, 13]. Due to the poor contact between the contact elements of the current collector and the contact wire, an electric arc arises which, during a certain time of combustion, warms the contact wire, it stretches under the influence of temperatures and ruptures. If on a railway rolling stock you can move from a place to burn a thin layer of ice, then on trolleybus lines it almost fails (Figure 43). Since the voltage level in the contact network is only 600 Volts, and with significant transient resistance and with a high specific resistance of the carbon inserts, there is not enough current to move from place. This is especially true for trolley buses of new models, in which static converters are sensitive to voltage drop [14]. Under such difficult operating conditions, the insertion of the current collector is eroded sharply, as well as the elements of the contact network are spoiled.

Figure 39. Fall of the contact wire on the body.

Figure 40. Drop current receiver tram.

Figure 41. Sticking wet snow.

Figure 42. Ice on the contact network.

Figure 43. Electric arc on the trolley bus network.

4. Presentation of new material

Increasing the speed and weight of trains requires the use of electric transport of higher power, which corresponds to world trends. The main requirements for current collectors and contact elements are reliability and durability. To ensure high-quality current formation, it is necessary to use contact elements with high load capacity and wear resistance. Unfortunately, at present, none of the known contact elements guarantees full safety in the operation of electric transport and does not have large operating resources within the cost of material contact.

Most manufacturers in the European Union have focused on carbon contact elements. Some manufacturers add copper to carbon. In the manufacture of metal-ceramic contact elements, various metal compositions are used. But the main contact material is copper.

In order to comprehensively evaluate the problem of interaction of receivers of electric transport currents with different contact materials and contact wire in different conditions of operation of railway and industrial transport, contact elements were most often used: contact inserts of type of pantographs "A" and "B"; carbon inserts of pantographs of trams; copper tire for current collectors; metal-ceramic plates; copper contact plates with graphite inserts NMG-1200; copper-graphite contact plates MG-487; PCD-4-2 copper-based contact plates; Contact plates BRZG (Figure 44) [15].

For such studies, the most common carbon contact inserts, metal-ceramic inserts, contact plates BrzG-Tr (Figure 45) [16] were used in the conditions of trolley operation.

Figure 44. Contact inserts of type BRZG.

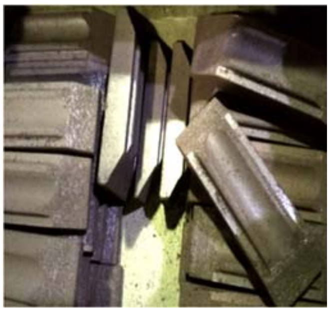

Figure 45. Contact inserts of trolleybus type BRZG-Tr.

Figure 46. Patent for the invention of the composition of the BRZG.

Having considered the problems that are common in the process of wear of contact elements of pantographs of electric trains and locomotives, electric transport of the city, industrial enterprises, we have improved Brzg contact plates on the basis of bronze, iron and graphite. They provide reliable work on a constant and alternating current. After all laboratory tests, the effectiveness of the new Brzg material has been confirmed during operation on electric locomotives and electric trains of direct and alternating current on railways and trolleybuses. Inventions are provided with patents (Figure 46).

Compared to copper-graphite inserts, which use DC in electric locomotives, the lifetime of the inserts of the BRZG is greater 1.7-2.5 times.

Compared with graphite inserts used in trolley buses and electric trains and locomotives on AC, the lifetime of the inserts of the BRZG is greater 21-26 times.

5. Conclusions

On the reliability of a moving electrical contact pantographon the contact network is affected by many factors. The main material is the contact element, the kinematic circuit of the current collector, its dynamics and the mobile mass.

For rail, industrial and urban transport, there is a big problem with the choice of contact materials for current collectors. Given the problems of contact between contact and current collectors of electromotive transport, it is necessary to choose the contact material for the elements only after the test.

When using all materials in open and closed mines, dust and dirt on the contact plates, the high temperature and the presence of gas that is dangerous when contact with the spark should be taken into account additionally. The contact material should be strong but not destroy the contact wire.

The article proposes to use the new BRZG contact material in bronze, graphite and iron. The efficiency of this material is confirmed by the reliable operation on pantographs of electric locomotives and on electric trains of direct current and alternating current, as well as on current receivers of trolleybuses.

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