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The development of railway transport engineering in the Russian Empire in the second half of the nineteenth century

Abstract. *The article is devoted to the consideration of the features on the development of railways and railway engineering in the second half of the XIX th century. It is well known that railway transport in European countries emerged in the eighteenth century, and the nineteenth century was a period of rapid development of raiway systems, railway technology and the creation of operation technologies. The author of the article shows that the development of railway transport engineering in the Russian Empire began in the 30s of the XIX century and went on at a rapid pace. It is clear that foreign technology was used at first, and foreign technology thought was significantly influenced by technology. As the whole policy of the tsarist government was aimed at reducing the country's dependence on potential opponents, the idea of forming a Corps of national transport engineers was greatly supported. Among its graduates were such well-known engineers as P. P. Melnykov, M. I. Lypyn, V. P. Sobolevskyi, M. A. Beleliubskyi, D. I. Zhuravskyi and others who managed to create a national scientific school in the field of railway transport. Almost all problems were solved independently without the help of foreign specialists. Among them, according to the author, the most significant were "Track bed structure", "The development of signalling systems, centralization and block signal system" and "The development of rolling stock". Based on the analysis of a large number of sources, the author concludes, that in the second half of the nineteenth century the development of industry in the Russian Empire went through capitalist reforms. Expansion of domestic and foreign markets, active domestic and foreign trade led to the need to develop means of communication. The railways proved to be the most powerful and economically effective. They connected different regions, places of production and consumption, facilitating, speeding up and reducing the cost of delivery of raw materials and goods. In the 60-80's of the XIX century there was a significant increase of the railway network. The construction was mainly carried out at the expense of private joint stock companies. During that period, foreign specialists who were not interested in the qualitative development of the Russian railway network played a major role in the construction and management of the* *railway tracks. With the increasing demand for this new type of transportation, there was a need for technical modernization of the entire industry.*

Keywords: *railway transport; engineering; track bed structure; railway bridges; railway engineering; scientific research*

Introduction

The development of railway transport engineering in the Russian Empire began in the 30s of the XIX century and went on at a rapid pace. At first, a significant influence of foreign technical thought was felt in this direction, but later a national school of railway engineers was formed.This was largely due to the opening of the Institute of the Railway Engineers Corps. Among his graduates there were such famous engineers as P. P. Melnykov, M. I. Lypyn, V. P. Sobolevskyi, M. A. Beleliubskyi, D. I. Zhuravskyi and others who managed to create a national scientific school in the field of railway transport.

Due to their fruitful work, entire directionsof the national railway science were formed and successfully developed. Almost all problems were solved independently without the help of foreign experts.

The purpose of this article is to analyze the development of railway transport engineering in the Russian Empire in the second half of the XIX th century.

Research methods

The methodological basis of the work comprises the scientific principles of research, such as objectivity, historicism, systemic, complexity. The principles of objectivity and that of historicism enable consideration of the studied historical events in their interrelation and development, giving the grounds to a comprehensive analysis and reliable assessment of historical facts. The application of the systemic method to the work allowed investigating comprehensively railway transport engineering in the Russian Empire in the second half of the nineteenth century (Pylypchuk & Strelko, 2016; Pylypchuk & Strelko, 2017; Pylypchuk & Strelko, 2019).

Results and discussions

Track bed structure

In the Russian Empire works on improving basic elements of the railway track were carried out in the first years of construction and operation of railways. A variety of topographical and climatic conditions made the builders use different constructive techniques in the construction of the roadbed.

The ballast layer on the railways of the Russian Empire was created from various materials. On the railway line Petersburg-Moscow, the prism of the ballast layer was two-layered (crushed stone and sand pad), and on many other railways – with sand and gravel materials. In the construction of railways in the southern regions of Ukraine, shell rock was used as a ballast layer. The thickness of the ballast under the sleepers was 30-40 cm. The desire to save some money forced railways to reduce this amount, which later led to numerous injuries of the main plane of the roadbed. In this regard, in the late 90's of the nineteenth century, the thickness of the ballast layer was at least 55 cm.

In 1906, at the XXIV Congress of Railway Engineers it was decided to improve the ballast quality through the use of crushed stone and gravel. The outline of the main plane of the roadbed had a trapezoidal shape on single tracks, and a triangular one on double tracks, which provided a favorable environment for water drainage. The width of the main plane on single lines was from 4.7 to 7.6 m, on double-track lines – from 9.4 to 11.5 m. The slopes of the roadbed, depending on the soil, were taken as follows: 1:1, 2, 2:2. The roadbed in the transverse profile represented embankments and excavations. For surface water runoff, ditches with a longitudinal slope of at least two degrees were arranged (Kraskovskij & Uzdin, 1994).

Wooden railroad sleepers, as well as ballast prism, served as a rail track base for national railways. The application of wooden sleepers was due to their relatively low cost, simplicity of forms and advantages in operation. The dimensions of the cross section and the length of the sleepers were determined empirically. In the concession period of railway construction, the dimensions of sleepers were determined by the technical conditions that were produced for each line separately. The most common were flat sleepers, in some cases, rectangular sleepers were used. In 1886, the first circular was issued, establishing six sizes of sleepers. Mostly these were rectangular sleepers; flat sleepers were allowed to produce only from the oak. As joints it was recommended to use only square-edged from four sides rectangular sleepers.

Three years later, a new circular was issued. It added to the previously established types of sleepers six more, trimmed only on two edges, including joint sleepers. In 1900, the Ministry of Railways trying to put things in the sleepers economy in order, allowed the use of five more types of flat and rectangular sleepers.

Wooden sleepers rot, so it became necessary to impregnate wood with various antiseptics - resin, and later with creosote oil, zinc chloride, etc. For this purpose, treating plants were built in Mykolaivska, Moscowsko-Nizhnohorodska, Orlovsko-Vitebska, Katerynynska, Kursko-Kharkivska-Azovska, and other railways. Sleepers treating allowed increasing their life term from four to eight years. To reduce sleepers cracking some railways tied them with various kinds of brackets, or used sleepers' reinforcement with metal parts (Pershyn, 1978). The rail is one of the most important elements of the permanent way. In the first years of railway operation the rails were iron, weighing 24-35.5 kg/m, with a joint on the sleepers. Their length was from 4.6 to 6.1 m. Iron rails quickly wore out.

Therefore, they soon turned to more economical double-layer rails: the upper part of the head was made of steel, the web and the bottomwere iron.For the first time steel rails appeared in 1868. Since 1875 they have become widespread. In the late 90's of the nineteenth century steel rails were laid down on all mainlines.

The rail joints were originally arranged on sleepers, the ends of the rails were combined with a covering cast-iron rail-chair that was fastened to the sleepers. In 1858, rail-chairs were abandoned and switched to the joint on the tie, but with base plates and strap bars, and since1868 they have begun to use suspended joints.

With this type of joint, strap bars were first used, and then splice-bars (angular fishplates). At first they were placed on the outside of the joint, and since 1883 they have began to move on joints with splice-bars on both sides of the rail.

In the Russian Empire, earlier than in other states, the practice came to the necessity of creating unified rails for the whole country. In 1874 the Ministry of Railways adopted three types of iron and four types of steel rails. The main feature of the type was the linear weight of 1 foot (30.5 cm) of the rail. In 1903, four types of rails were introduced to organize the rail economy – I, II, III, IV. A major step forward in the unification of rails was the approval in 1908, the four common types of rails under the index “a” (Ia, IIa, IIIaa, IVa), they had been a standard until 1947. The heaviest was the rail Ia, which weighed 43.6 kg/m, and the lightest was IVa – 30.9 kg / m. The rails were made in length 10.68 m. Such rails existed on the railways of the Russian Empire for four decades and withstood a six-diameter magnification in carrying load (Zapysky RTO, 1867, p. 51). In 1903 the Ministry of Railways issued a circular which established the maximum axle load of the rolling stock, depending on the type of permanent way. In 1914, the circular was supplemented by Interim guidelines, which, in turn, regulated the ratio of the most acceptable speeds of the trains and the type of the permanent way. Thus first additional speed limit was introduced in small radius curves. As we see, during this period, work on typing the permanent way of the track depending on the conditions of its operation was done (Zhurnal Obshcheho sobranyia chlenov-uchredytelei KO RTO po sveklosakharnoi promyshlennosty ot 8 yanvaria 1871 h.).

With the development of railways consistently improved and qualitatively changed a very important element of the track structure, allowing moving the rolling stock from one track to another – railroad switch. It consisted of switches and toes. First, switches with movable rails were used, then switches with point rails and switch points appeared. At the same time point rails were located on continuous metal switch slide plates. The first toes were movable, consisted of short rails, later fixed cast toes began to use instead of them. Later they began using prefabricated toes from conventional rails with steel cast tongue pieces. On most railways, two types of switches were used: the first one was longer and the toe brand 1/11, the second of the smaller length and with the toe brand 1/9.

Since 1886, the railways began to lay down bent switch blades, which were produced from Williams’ rails. English lap switches were widespread. This made it possible to reduce significantly the length of the switch lead.

Structurally the toes were of three types: continuous cast, prefabricated from Williams rails, and prefabricated cast tongue pieces of Camlim system (Kraskovskyi & Uzdyn, 1994, p. 213).

The development of signalling systems, centralization and block signal system

For the first time, signals on the railroad were introduced by J. Stephenson at the Manchester-Liverpool Railroad in 1834. He suggested placing signalmen at a certain distance that could to give signs to the engine driver. The first signals were points that could be rotated, at night the signals were given using lanterns. In 1841, Englishman Gregory designed a semaphore. Just then the transition from the movement of trains with time-interval system to the space-interval system became possible. Means of communication were the telegraph and later telephone.

In Russia, the engineers Jacobi and Shilling worked on the problem of an optical telegraph (semaphore). In 1849, the famous inventor Werner Siemens was invited to Russia, who took part in the installation of the first telegraph on the St. Petersburg-Moscow railway. From the 50s of the nineteenth century Siemens systems began to be spread on all national railroads (Vyrhynskyi, 1938, p. 205).

A major step forward in ensuring the safety of train movement was the introduction of a block signal system, with which the track semaphores closed for a while, until the the train was on the relevant section of the track. The main rule of the railway safety emphasized that there might be only one train on the crossing. Previously, the next train was let out for a crossing only when the time required for the previous train to pass was over. However, this system was not reliable, because it was not possible to make sure that the previous train has already passed over the crossing. Therefore, in 1844 the English engineer Cook proposed the principle of blocking the track, better known as a block system. Its essence was that the track between the stations was divided into small sections. The train could occupy a crossing or a section of the track between the stations only if the previous train had already fired this crossing. Thus, the space-interval system and not time-interval system was maintained between two trains. In order to notify that the crossing was free special devices were used. This innovation became widespread after the invention of devices for block systems in 1859 by a French engineer Thayer. They were first used in France on the Paris-Saint-Germain railway. A turning disk served as a block signal which was connected with the moving tire to the running rail with the help of the arms and levers.

When passing the train flanges of the wheels pulled the tire from the rail. This caused the disc to be closed. At the same time, the piston installed in the mercury brake disc raised, which kept the disk in the closed position. After a certain time (about 6 minutes) after the passage of the train, the piston, overcoming the viscosity of mercury, returned to its place, and the disk was closed.

After the invention of the Tayer machine, the first attempts were made to apply automatic blocking of sections by the steam locomotive by means of electric current. For this it was proposed to place special pedals along the track at the points of section division. Arriving to the section the train automatically informed block post that the section was busy. Clearing the line, the train pressed another pedal, giving signal on the empty track. In 1867 William Robinson suggested using running rails as conductors of electric current and created a special design of the wayside signaling system. In 1869, he developed the first model of electric automatic block signaling, which was demonstrated at an exhibition in New York.

In 1872, engineer Lathrih improved blocking devices by proposing electrical semaphores. The principle of their operation was in the fact that the value of the signal was dependent on the position of electrical devices that were at the shunting towers. Later, electrical systems of Siemens, Reno, Shaperon, and others appeared (Stolpovskyi, 1891, p. 249).

In the late 80's of the nineteenth century English engineer Webb-Thomson invented traffic wands for regulating trains movements of on single-track lines. Since 1897 they have spread on the railways of the Russian Empire. In the 80s of the nineteenth century, the first national installations of mechanical centralization appeared. One of the most common was the system of mutual point and signals locking of professor Ya. M. Hordienko, first applied in 1885, first with rigid connecting-rod, and later with flexible. Y.M. Hordienko's invention was awarded a prize at the All-Russian Exhibition in Nizhnyi Novhorod in 1896 and at the World Exhibition in Paris in 1900.On the South-Western railways, the Sikes interlocking system systems with rugged drive, the wired of Siemens and Halske, the hydraulic of Bianki and Servantes, and the electric of Siemens and Halske were common.

The development of rolling stock

The first commercialize locomotives for national railways were imported from England and Belgium. The design of these locomotives was of the same type: in the general rigid frame they had one driving wheel set of large diameter (within 1700-1900 mm), pilot wheel sets and supporting, as well as wheel sets of smaller diameter. Complete evaporation boiler heating surface was 50-60 m^2, the vapor pressure reached 6-7 bar, capacity 70-75 hp, the maximum speed reached 60 km/h. Steam locomotives were named “Strila”, “Bohatyr”, “Orel”, “Lev” and “Slon”.

Subsequently, steam locomotives began to be assembled in Russia, at the Oleksandrivskyi plant in St. Petersburg, since 1844. By the time the plant had unique equipment. Steam hammers, a lathe for pulling pipes, a gear cutting machine, a special installation for testing metal structures, as well as mechanical and hydraulic presses were installed in the workshops. Thanks to these technical capabilities, the Oleksandrivskyi plant became advanced in locomotive engineering. Since 1850, in addition to the construction of new ones, the plant has started to repair old cars and manufactured spare parts for them. In 1846 the first cargo steam locomotive was produced. In addition to cargo steam locomotives, during 1848-1850 years 43 passenger locomotives were built. In general the Oleksandrivskyi plant had produced 164 steam locomotives by 1851.

Further growth of the railway network required the development of locomotive building. So, in 1869 Kolomenskyi and Kamsko-Votkinskyi plants began to build steam locomotives, and since 1870 Maltsevski plants and plants in St. Pereburg. Since 1892 the locomotive building began at the Briansk plant, in 1894 at the Putilov plant, and since 1898 at the Sormov plant. These enterprises formed the basis of locomotive development in the late XIX and early XX century.

For the first time on the territory of Ukraine, locomotives began to be built at Kharkiv (1897) and Luhansk (1898) locomotive works. The Mykolaivsk shipbuilding plant was partly engaged in the production of steam locomotives. New locomotives were also built at railroad workshops in Kyiv and Odessa. By repairing the rolling stock and studying operational deficiencies, the workshops created the design of locomotives and cars, which by operational qualities could serve as models for specialized plants.

The rates of locomotive building development can be traced from the following data: in 1846-1868 in Russia 227 locomotives were built, and in the period from 1875-1880 – 1439 locomotives were built. It was approximately 239 locomotives per year. The construction of wagons also grew. In the period from 1875 to 1880 39280 freight wagons and 1005 passenger cars were built (Kraskovskij & Uzdin, 1994, p. 25).

The first locomotive built at the Oleksandrivskyi mechanical plant of the Petersburg-Moscow railway was a passenger locomotive of type 2-2-0 (the number of uncoupled wheel pairs, the number of driving wheel pairs and the number of trailing idle wheel pairs), later this type of locomotive received the designation of the "B" series. It had two spooked wheels, cast iron, without counterweights, driving wheel pairs with a diameter of 1705 mm, of which driving was the first pair. The internal eccentric steam distribution mechanism set in motion double (expansion) spools, which allowed reversing the machine and changing the degree of filling the cylinders with steam. This design was a significant step forward compared with those used on steam locomotives of the Tsarskoye Selo railway. Taking into account the flat profile of the St. Petersburg-Moscow railway such locomotives could drive six wagons trains at a speed of 40 km/h. Furthermore, the plant built locomotives with wheel arrangement 1-2-0 and 1-2-1.

The first locomotives were without booths and platforms; the locomotive crew was under the open sky. Blow-off valves opened from the outside when the locomotive was started. The freight train developed a speed of up to 22 km/h, and a passenger train up to 30 km / h. But at first, the locomotives were not divided into freight and passenger. In the future, these locomotives were upgraded by installing booths, platforms, spur gears, injectors, and buffers.

Improvements for weather protection of the locomotive brigade began to appear from about 1865. At first these were metal sheets for protection against headwind, than umbrellas, and finally closed booths, which was especially important in the conditions of the northern climate. At the same time, instead of hand pumps, simple and compact devices − injectors − began to be set up to supply water to the boiler.

In 1868-1870 the first technical specifications were made, providing for the stipulation the type of work of the engine being designed: its type, the number of axles in the tender, the most allowable pressure on the rail from the wheel band. Locomotives began to divide into passenger, freight and shunting. The greatest pressure from the wheel bands of one wheel set on the rail was allowed up to 10 tons and in the 70s up to 21.6 tons. The capacity of freight trains of type 0-3-0 and passenger type 1-2-0 was 300-440 hp, the weight in working condition − 32-37 tons. The design speed of freight locomotives was 40-45 km/h. and passengers − up to 80 km/h.

The boilers of locomotives were built horizontally cylindrical, with a diameter of 1200-1400 mm, riveted from sheet steel, with 160-180 smoke tubes, mainly brass, flat-section fireboxes, made of red copper. The total heating surface was 85-133 m^2, the area of the firebox grate was 1.27-1.58 m^2. The boiler was provided with two injectors. Maximum steam pressure in the boilers was 8-10 at. The two-cylinder steam engine of single-stage expansion was installed on the engine frame. On each side on the outer side of the frame there was one cast-iron cylinder with a diameter of 394-460 mm, the piston stroke length was 553-620 mm. The valves were flat of box members with internal steam distribution. The diameter of the wheels of freight trains was 120-1418 mm. The diameter of the passenger trains wheels was 1520-1728 mm, bolster springs. The locomotives were provided with trailers for fuel and water. In 60-90, the XIX century plants built freight locomotives mainly of triaxial - type 0-3-0 or 0-4-0. Passenger locomotives were built according to type 1-2-0 or 2-2-0 (Artobolevskyi & Blahonravov, 1975 , p. 27).

At the end of the XIX century on domestic steam locomotives evaporative heating surfaces of boilers reached 150-160 m^2. The heating surface of the furnace reached to 11 m^2. and the firebox grate area up to 2.2 m^2. To reduce steam condensation, the insulation of the boiler and piping has improved. In order to reduce heat loss in the steam engine the principle of double steam expansion (compound) was used. In 1850, English engine driver John Nichols proposed a draft of a locomotive system compound James Samuel. In 1852, the system of D. Nichols was applied to freight and passenger locomotives, the results of the application were quite satisfactory. The locomotives of the compound Samuel system were equipped with two cylinders, having a ratio to the piston area of one to two. From a small cylinder, the steam was blown off to the large by means of a special valve. At a certain point in the stroke of the piston, steam passed from a small cylinder to a large one, and expansion took place in both cylinders simultaneously. It should be noted that steam was turned on into the large cylinder from the side of the piston working part of the small cylinder, and not from the side of the non-working part.

In England, the most authoritative supporters of the compound system were the chief engineer of the rolling stock of the London-North-West Webb Railway (Webb) and the chief engineer of the rolling stock of the North-Eastern Railway (Worsell). In 1878, by way of experiment Webb remade one of the old steam locomotives in the compound of Mallet system. This locomotive has worked 5 years. The results have been so satisfactory that Webb decided to introduce this system in widespread use. For this purpose in 1881 he constructed a new compound locomotive in his workshop. It had two outer high-pressure cylinders with a diameter of 11.5 inches and a low pressure inner cylinder diameter of 26 inches. The diameter of the driving wheels was 6.5 ft and the steam distribution of the Joey system. The high-pressure cylinders operated on the rear wheels, and the low-pressure cylinder on the driving wheels. The driving and rear wheels were not coupled with each other. Due to this, there was no need for coupling rods, and the locomotive had the same freewheeling as a locomotive with one pair of driving wheels, but having the same coupling on the wheels with rails as that of a locomotive with coupled wheels. Designing this system, Webb tried to achieve the following results:

1. Development of a large locomotive power.
2. Savings in fuel consumption.
3. Utilization of all steam force.
4. More even distribution of forces affecting on the parts of the mechanism.
5. The same freewheeling, as in locomotives with one driving axle, but with the same coupling of wheels with rails, as in locomotives with coupled axle. New steam train went into operation on April 3, 1882 another 29 locomotives of the same type were built later (Stolpovskyi, 1891, p. 219). In Russia, the steam engines of the compound system began to be used on the initiative of O. P. Borodin. The first six such steam locomotives of the type 2-2-0 PB series were built in 1885 by Odessa workshops for the South-Western railways. In 1868, the Vladykavkaz Railway designed a six-axial 1-4-0 type steam locomotive with a boiler equipped with a powerful two-cylinder compound machine. These locomotives could drive large-weight trains, and the pressure on the rail was maintained up to 13 tons. Later, locomotives of this type were built at the Briansk and Kharkiv plants and received a series of”C”. The use of such locomotives gave up to 15% fuel economy. By the end of the 1890s, about 13% of the locomotives were compound machines mainly in the two-cylinder version.

In 1905, the Kharkiv plant designed a compound-locomotive of type 1-4-0 of the “Sch” series. During the period of the greatest distribution of compound steam locomotives (1906-1909), the Kolomna and Luhansk plants built locomotives not only for native, but also for foreign railways.

Compound-machines were used in passenger steam locomotion. Among them are steam locomotives of type 1-3-0, designed by engineers of the Nikolaiev railroad and the Aleksandrovskyi plant and produced by the N^d series in 1892. The diameter of the driving wheels of a locomotive was 1900 mm, the pressure on the rail was up to 15 tons. The vapor pressure was up to 12 at. With minor design changes, these locomotives were built in other factories under the series of V^s, N^v, well, and N^p. They ran on wood, coal and oil at the beginning of the First World War.

The increase of the passenger trains speeds required more steam-producing boilers of steam locomotives, with a steam pressure of 11-12 at, and a further increase in the diameter of running wheels. Such requirements are related to the fact that the “Rules of technical operation of railways” limited the number of turnings of the driving wheels: for passenger locomotives – up to 260 r/min, for freight locomotives up to 225 r/min. High speeds of trains were used on some railways, so there was a need to build high-speed locomotives with large moving wheels (up to 2000 mm in diameter for passenger and 1300 mm for freight), although this reduced the traction force of locomotives to some extent. By reason of the necessity to improve traffic safety in 1891, the “Rules for the Design, installation, maintenance and inspection of steam boilers” were enacted, and the “Rules for testing action of velocimeter” were introduced. According to the circular of the Ministry of Railways on the frontal part of high-speed trains' locomotives, it was supposed to put fanlights on with a silver-plated or nickel-plated reflector.

Constant contradictions between the requirements of the growth of traction and the limitation of loads from moving wheels on the rails forced the designers to look for new solutions. One of them was the combining of several wheels with a thrust (driving rod). By the end of the XIX century passenger locomotives had up to three coupling axles, and freight - up to four; the load from the wheel set on the rails was 13 tons.

In 1902, on the initiative of Ye. Ye. Noltein, the Kolomna Plant equipped the first locomotive in the country with a superheated element (series Zh of type 2-3-0). With the start of use of superheated steam, which provided savings of up to 25% of fuel and about 35% of water, round piston throttle that reliably maintained the temperature of saturated steam at 300 - 350 degrees Celsius became widespread. The increase in the size and weight of the boilers, which accounted for the majority of the total weight of the locomotives, led to an increase in loads on the rails, which were limited by norms. In this regard, coupling wheel sets, the number of which reached five were introduced additionally. However, placing them in one rigid frame made it difficult to fit locomotives into curved sections of the track. To solve this problem, engineers and designers of steam locomotives went for some complications of the crew part: the introduction of flangeless wheels, acceleration of axles in axle boxes, axle boxes in the frame, and thrust bearings on the axial pins. Also, there appeared designs of duplex locomotives with two steam engines. The heating surface of the boilers was 200 m^2; the vapor pressure was 12-13 atm. The use of superheated steam contributed to the operation economy of the machines. The diameter of the wheels of locomotives with the aim of increasing the traction force was set in the optimal dimensions: passengers 1830-1920 mm, freight − up to 1320 mm. Passenger locomotives had a design speed of 115-130 km/h, and freight up to 70 km/h. The load from the movable wheel sets on the rails was 16-17 tons. Capacity at the calculated boost of the boiler overload operation and the machine reached 1500 h.p. From January 1913, in order to identify locomotives, a single series system was introduced for the entire railway network. Prior to that, railways ordering steam locomotives at the plants, independently assigned series in an arbitrary manner, as a result of which, on different railways, locomotives had the same types of series, but different in characteristics and wheel arrangement (Artobolevskyi & Blahonravov, 1975 , p. 30).

In 1913, the Russian Empire's locomotive fleet was 18695 locomotives (on all private and state railways combined), including 3550 passenger ones. Out of the total number of locomotives, 54% were built in 1900-1913. On average, there were 32 locomotives per 100 kilometers of the network, while private railways, which accounted for approximately 30% of the total network, had 1.5 times less steam locomotives. The average daily mileage was about 112 km. 67% of the total number of steam locomotives operated on coal, spending 7200000 tons a year. 26% used oil and fuel oil (1.8 million tons), some were heated with firewood (5.2 million cubic meters). In general, some series of domestic steam locomotives were at the level of the best examples of world steam locomotive in terms of workmanship and design. This was facilitated by scientific developments, theoretical and experimental studies performed by members of the Mechanics and Construction Department of the Kyiv branch of the Russian Technical Society, O. P. Borodin, L. M. Levi, Ya. V. Shotlander and other specialists in the field of steam locomotive engineering, who gained recognition both in Russia and abroad. During the First World War, the production of locomotives fell sharply; a significant part of the locomotive fleet was disabled, which caused great difficulties in organizing the movement of trains. (Isaienko, 2016, p. 35).

In general, steam locomotion in the Russian Empire has undergone four successive stages in its development. The first stage was from 1834, from the locomotive of the Cherepanovs, to the 60-ies of the XIX century. The need for locomotives of a small number of railway tracks (their total length in 1860 was about 1700 km) was mainly provided by two small factories. The second stage − from 1860 to 1870 − coincided with a significant increase in railway construction. The third stage − from 1870 to 1900 − is characterized by the significant development of Russian steam locomotive building, its formation as an independent industry branch. The fourth stage − from 1901 to 1917 − is associated with significant progress in increasing the capacity of the newly built steam locomotives and the development of scientific foundations of their design and operation (Stolpovskyi, 1891, p. 219).

In view of the above, we can conclude that in the second half of the nineteenth century the development of industry in the Russian Empire went through capitalist reforms. Expansion of domestic and foreign markets, active domestic and foreign trade led to the need to develop means of communication. The railways proved to be the most powerful and economically effective. They connected different regions, places of production and consumption, facilitating, speeding up and reducing the cost of delivery of raw materials and goods. In the 60-80's of the XIX century there was a significant increase of the railway network.Theconstruction was mainly carried out at the expense of private joint stock companies. During that period, foreign specialists who were not interested in the qualitative development of the Russian railway network played a major role in the construction and management of the railway tracks. With the increasing demand for this new type of transportation, there was a need for technical modernization of the entire industry.

Since the 30-ies of the XIX th century the process on creating a national railway with the entire infrastructure started: the formation of a carriage and rolling stock fleet, the development of a track network, the organizational formation of the industry as an economic unit. This process was associated with scientific researches' development in all these areas.

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Розвиток техніки залізничного транспорту в Російській імперії у другій половині XIX ст.

Анотація. *Стаття присвячена розгляду особливостей розвитку залізниць та залізничного обладнання у другій половині XIX століття. Добре відомо, що залізничний транспорт у європейських країнах виник у XVIII ст., а XIX століття було періодом швидкого розвитку залізничних систем, залізничної технології та створення експлуатаційних технологій. Автор статті показує, що розвиток техніки залізничного транспорту в Російській імперії розпочався в 30-х роках XIX століття і проходив швидкими темпами. Зрозуміло, що спочатку використовувались іноземні технології, і іноземна технічна думка суттєво впливала на технологію. Оскільки вся політика царського уряду була спрямована на зменшення залежності країни від потенційних опонентів, ідея утворення Інституту корпусу інженерів шляхів сполучення отримала велику підтримку. Серед його випускників були такі відомі інженери, як П. П. Мельников, М. І. Липин, В. П. Соболевський, М. А. Белелюбський, Д. І. Журавський та інші, яким вдалося створити національну наукову школу у галузі залізничного транспорту. Майже всі проблеми вирішувались самостійно без допомоги іноземних фахівців. Серед них, на думку автора, найбільш значущими були «Верхня будова колії», «Розвиток систем сигналізації, централізації та блокування» та «Розвиток рухомого складу». На основі аналізу великої кількості джерел автор робить висновок про те, що у другій половині XIX століття розвиток промисловості в Російській імперії пройшов шляхом капіталістичних реформ. Розширення внутрішнього та зовнішнього ринків, активна внутрішня та зовнішня торгівля спричинили необхідність розвитку засобів зв’язку. Залізниці виявилися найбільш потужними та економічно ефективними. Вони з’єднували різні регіони, місця виробництва та споживання, полегшуючи, прискорюючи та скорочуючи витрати на доставку сировини та товарів. У 60-80-х роках XIX століття відбулося значне зростання залізничної мережі. Будівництво в основному велося за рахунок приватних акціонерних товариств. У цей період велику роль у будівництві та управлінні залізничними коліями відігравали іноземні спеціалісти, які не були зацікавлені у якісному розвитку російської залізничної мережі. Зі збільшенням попиту на цей новий вид транспорту виникла потреба в технічній модернізації всієї галузі.*

Ключові слова: *залізничний транспорт; верхня будова колії; земляне полотно; залізничні мости; залізнична техніка; наукові дослідження*

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Развитие техники железнодорожного транспорта в Российской империи во второй половине XIX в.

Аннотация. *Статья посвящена рассмотрению особенностей развития железных дорог и железнодорожного оборудования во второй половине XIX века. Хорошо известно, что железнодорожный транспорт в европейских странах возник в XVIII в., а XIX век было периодом быстрого развития железнодорожных систем, железнодорожной технологии и создания эксплуатационных технологий. Автор статьи показывает, что развитие техники железнодорожного транспорта в Российской империи начался в 30-х годах XIX века и проходил быстрыми темпами. Понятно, что сначала использовались иностранные технологии, и иностранная техническая мысль существенно влияла на технологию. Поскольку вся политика царского правительства была направлена на уменьшение зависимости страны от потенциальных оппонентов, идея создания Института корпуса инженеров путей сообщения получила большую поддержку. Среди его выпускников были такие известные инженеры, как П. П. Мельников, Н. И. Липин, В. П. Соболевский, М. А. Белелюбский, Д. И. Журавский и другие, которым удалось создать национальную научную школу в области железнодорожного транспорта. Почти все проблемы решались самостоятельно без помощи иностранных специалистов. Среди них, по мнению автора, наиболее значимыми были «Верхнее строение пути», «Развитие систем сигнализации, централизации и блокировки» и «Развитие подвижного состава». На основе анализа большого количества источников автор делает вывод о том, что во второй половине XIX века развитие промышленности в Российской империи прошло путем капиталистических реформ. Расширение внутреннего и внешнего рынков, активная внутренняя и внешняя торговля вызвали необходимость развития средств связи. Железные дороги оказались наиболее мощными и экономически эффективными. Они соединяли разные регионы, места производства и потребления, облегчая, ускоряя и сокращая расходы на доставку сырья и товаров. В 60-80-х годах XIX века произошел значительный рост сети железных дорог. Строительство в основном велось за счет частных акционерных обществ. В этот период большую роль в строительстве и управлении железнодорожными путями играли иностранные специалисты, которые не были заинтересованы в качественном развитии российской* *железнодорожной сети. С увеличением спроса на этот новый вид транспорта возникла необходимость в технической модернизации всей отрясли.*

Ключевые слова: *железнодорожный транспорт; верхнее строение пути; земляное полотно; железнодорожные мосты; железнодорожная техника; научные исследования*

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