DRIFT OF TRANSPORT TECHNOLOGIES AND PROCESS LEADERS

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ABSTRACT

The authors consider the issues of scientific and inventive activity of Russian scientists and engineers in the field of transport in the late 19th–early 20th centuries. It is shown that the increasing role of engineering and technical education in the country was associated with challenges of industrialization, in particular, development of the transport system. Domestic science has made a great contribution to creation of a vehicle on electric propulsion – main railway, city trams, and electric vehicles. Experimental work on the use of urban rail transport were performed by F. A. Pirotsky, a theoretical rationale for transfer of direct electric current over long distances was given by D. A. Lachinov, pioneering works of I. V. Romanov on creation of a suspended monorail. The Imperial Russian Technical Society organized the first international congresses and exhibitions in the world, which presented the engines for road transport and aircraft construction.

Keywords: engineering education, Imperial Russian Technical Society, rail transport, transport on electric propulsion, internal combustion engines, history of science and domestic invention.

Background. *At the present stage of development of society, when the Russian state solves the problem of modernizing the economy, historical experience is of particular importance. In domestic historiography, not so much space is devoted to the study of the activities of private and public organizations aimed at creating and strengthening industry. Separate studies of Russian historians [1] and foreign ones [2] are devoted to formation of branch associations in the form of congresses of industrialists of mining and manufacturing industries, as well as transport workers at the end of 19th century. The problems of the national intelligentsia, including technical ones, development of engineering education in Russia [3, 4] were also touched upon.*

Over the past two centuries, the country has faced the task of creating a powerful domestic industry that does not have a solution without developing a transport system. It is not by chance that engineering education in Russia dates back to the opening of the Institute of Railway Engineers in 1810 in St. Petersburg. Its graduates were specialists with the military rank of lieutenant to serve in the interests of the state. The vast empire needed arrangement of numerous and convenient traffic and development of all types of transport. Due to Russian engineers in 19th century a unique system of communications was built, which included several water systems, extensive railways and highways [4].

Pic. 1. D. A. Lachinov (1842–1902).

During this period, a new social and professional community began to take shape in Russia – the technical intelligentsia. Institutionally since 1866 there was a public organization in the country – the Imperial Russian Technical Society (IRTS). It was created at the initiative of scientists and teachers of St. Petersburg higher educational institutions, engineers and representatives of the state apparatus and industrial capital. For the members of IRTS, the main feature was characteristic, that of connection of higher technical education and the desire to serve the Motherland, to promote development of its industry and economic independence. At the turn of the century, these qualities were especially needed: industrial technologies underwent revolutionary changes, the classical steam era ended, and the process of electrification of the power apparatus of the whole industry began, it was followed by wide use of internal combustion engines.

Objective. *The objective of the authors is to consider drift of transport technologies and process leaders.*

Methods. *The authors use general scientific methods, historical method, comparative analysis.*

Results.

Electric traction progress

Representatives of the Russian scientific and technical community made a significant contribution to development of electric propulsion – electric railways, city trams, electric vehicles. At the end of 19th century in Russia, unique developments of suspended monorails were carried out, there were projects of high-speed traffic. Simultaneously with the projects of new vehicles and the inventions of talented engineers, scientific understanding of innovations at the interface of related technical disciplines was under way to study the theoretical issues of power and heat engineering.

In the journal «Electricity», published by IRTS, in 1880, an article by D. A. Lachinov «Electromechanical work» on the use of electric motors and transmission of electrical energy was published. Certain issues were resolved by him and received an explanation earlier than this was done by the major European

scientists. Dmitry Aleksandrovich, a professor of physics at St. Petersburg Forestry Institute, was the first to substantiate the conditions for transmitting direct electric current over long distances (Pic. 1). He proved that the useful effect of transmission is in no way connected with resistance of the circuit, but depends on the ratio of the number of revolutions of a generator and an engine.

In order to increase the distance to which energy is transmitted, it is necessary to increase the speed of both machines by an amount inversely proportional to the square root of their resistance. The increase in the number of revolutions of the generator leads to an increase in voltage at its terminals. Therefore, to achieve the desired effect when transmitting energy over long distances, it is required to increase voltage in a power line.

The findings of Russian electrical engineering were called the «law of power transmission» and laid the foundation for development of modern high-voltage equipment. About a year later, French engineer Marcel Depret came to similar conclusions. In 1882, he organized transmission of 200 V electricity between the cities of Miesbach and Munich, which are 57 km away from each other. In the future, on the basis of the development of Lachinov and Despres, power lines with voltage of more than 1000 V were built, which stimulated the emergence of power transformers. For many years, Lachinov worked as an expert in the department of trade and manufactures, which issued Russian privileges to inventors. His signature is under many conclusions about novelty in inventions and improvements proposed in the field of electrical engineering.

The works and ideas of another Russian engineer, Fyodor Appolonovich Pirotsky, preceded the works of Lachinov. He conducted the first experiments on the use of electric traction in public transport, as a result of which, for the first time in the world in St. Petersburg in 1875, a motor tram car was launched on rails of horse-drawn railways. The transmission of electricity from a generator to an engine according to the project was to be carried out by one iron wire laid on insulators fixed on wooden poles.

«In other words, this wire, its bond with the pillars, as well as the pillars themselves, and their mutual distance, all these objects are the same as those used in ordinary telegraphs,» wrote Pirotsky in a petition to issue a privilege. Pic. 3 shows a diagram of this petition for transmission of energy over a distance. At the same time, the return wire, as in the telegraph, was supposed to be the ground. Electric energy was transferred from a small Gram generator to an electric motor that was removed at a distance of about one kilometer. On July 24, 1874, the author filed an application with the Department of Commerce and Manufactures for a 10-year privilege on his invention.

At the beginning of 1880, Pirotsky wrote a report for IRTS «Transferring power to any distance using galvanic current (conductors – rails and wires), including for movement of trains». Understanding the unsuitability of the use of wire for transmission of high power over long distances, the engineer suggested using rails with a significantly larger cross section as a conductor. Despite the fact that the proposal to increase the wire cross-section with an increase in

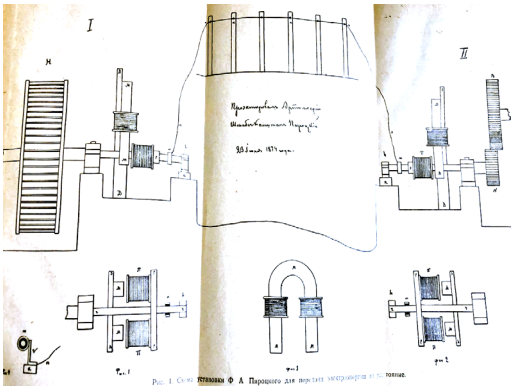
Pic. 2. F. A. Pirotsky (1845–1898).

the transmitted power or transmission distance is erroneous (it will later be possible to reduce losses by increasing the transmission voltage when using wires of a relatively small cross-section), any amendments do not detract from the merits of the inventor.

In 1876, Pirotsky presented the results of his work in an article published in «Engineering Journal». Among his readers was Werner Siemens – the head of the German firm Siemens and Galske. In 1879, the idea of transferring electricity through rails for movement of a toy railway was demonstrated by this company at the Berlin Industrial Exhibition [5]. The engine of the exhibition locomotive was powered from the third, contact wire.

At the first in the world electrical exhibition in St. Petersburg on March 26, 1880, organized by IRTS, a great attention was paid to arrangement of the electric railway offered by Pirotsky. The experts and opponents were respected scientists and engineers, among whom were D. A. Lachinov, O. D. Khvolson, P. N. Yablochkov. At the same time, the issue of using electric traction for transport was considered solved, no one disputed it, only details of electric braking, signaling, etc. were discussed.

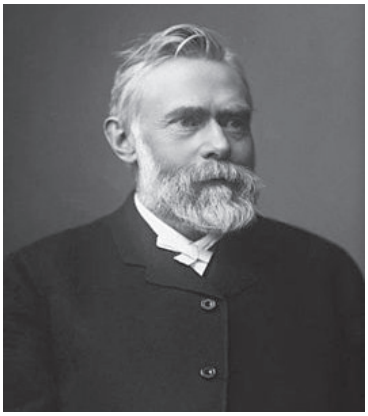
For a wide practical application on the main railways of the invention, Pirotsky's, as well as Lachinov's theoretical positions on the use of direct electric current were not suitable. Only as a result of appearance of the work of another Russian engineer,



Pic. 3. Scheme of F. A. Pirotsky for transmission of electric energy over a distance.

Pic. 4. G. D. Dubelir (1874–1942).

Pic. 5. I. V. Romanov (1864–1944).



Pic. 6. L. E. Nobel (1831–1888).

M. O. Dolivo-Dobrovolsky, the inventor of three-phase current, in the years 1889–1891 it was possible to use electricity on the main railway lines [6]. A retrospective look at the operation of electric traction systems in railway transport on both direct current and alternating current is presented in the article [7].

The ideas of Pirotsky were embodied in the construction of the city tram, which was launched in Kiev in June 1892. The implementation of the first tram project in Russia is entirely the merits of Russian engineers who did it without any participation of foreign capital and foreign specialists.

A major contribution to development of electric transport was made by the professor of Kiev Polytechnic Institute, Grigory Dmitrievich Dubelir, who graduated from Petersburg Institute of Railway Engineers in 1898 and studied the tram business in Germany, Belgium and England (Pic. 4).

The electrification of urban public transport in Russia kept pace with the times and fully corresponded to the state of scientific thought and the level of technological progress at that time. In 35 cities of the empire, the tram became the main form of public transport [8]. In 1902, Dubelir made a report to the commission headed by the Chief Inspector of the Russian Railways A. I. Gorchakov, «On the basic principles of the design of the profile of railways with an electric burden». Developing the scientific positions of urban planning, he published the books «Design and repair of the Russian tramway» (1902) and «City electric trams» (1908), which for many years were the most common manuals for students of higher technical educational institutions on urban electric transport [9]. A world-class scientist, Dubelir participated in construction of the first in Russia Lodz–Zgierz and Lodz–Pabianice electric railway, was involved in urban planning issues, and was one of the organizers of the highest automobile education in the country.

At the end of 19th century, a large number of projects for construction of an electric tram appeared, both from individuals and from joint-stock companies. Among these projects, the work of the Russian engineer Ippolit Vladimirovich Romanov, who is known as the inventor of the first electric cars, electric omnibuses for urban transport, deserves special attention (Pic. 5). Simultaneously with the design of electric vehicles, he developed the idea of creating a suspended monorail with electric drive.

The main element of a road – a lattice track beam was suspended on L-shaped, lattice supports. On the beam were two two-axle chassis trolleys, to which an ordinary tram car was suspended with spring shock absorbers. The trolley was designed so that it covered the beam from three sides. An electric motor (power 6 kW, constant current supply voltage of 100 V), as well as running and runner wheels were mounted on its upper platform. On the side surfaces of the trolley, two guide wheels were placed horizontally one above the other. Due to this design, the cart was securely held on the beam. The trolley speed did not exceed 15 km/h (this was achieved by choosing a small diameter of the running wheel – 12 cm), the weight of the car was 100 pounds (1638 kg), with a load (ballast) – 200 pounds, height from ground to the bottom of the car – 75 cm. In 1900, near Petersburg, successful tests of a suspended electric tram, made entirely according to the drawings of the author and with his direct participation, passed. Suspended monorail railway with electric drive was called «the road of the system of engineer Romanov», it was granted in 1900 a Russian patent, and later an American one.

Romanov proposed to build three types of monorails: for transportation of mail and light parcels; for transportation of goods of large volume and weight: bread, ore, stone, earth and cement, as well as for the transport of passengers and large goods. In 1905, in IRTS, the railway engineer V. S. Melentyev made a «Report on implementation of a suspended railway with an electric traction of Romanov system between St. Petersburg and Moscow». It discussed in detail the option of building a highway along the line of the existing Nikolaev railroad [10]. The project was approved by the Ministry of Railways, but its financing became an unsolvable problem in the conditions of the beginning of the Russian-Japanese war, and then Russia's entry into the First World War.

Development of ICE

In the history of the technological development of the country there are many examples of the contribution of foreign nationals who have long lived and even subsequently accepted Russian citizenship, whose engineering, inventive and commercial

activities have contributed to the progress of domestic transport. These include Ludwig Emanuilovich Nobel and Gustav Ivanovich List. Active members of IRTS, they participated in educational activities, increased their business for the benefit of the Russian economy.

Ludwig Nobel is known as the founder of the Nobel Brothers Petroleum Production Association, one of the best companies in Russia and Europe for extraction, processing and transportation of oil (Pic. 6). He made an enormous contribution to the development of IRTS, was the initiator of introduction of the metric system of measures in our country, was noted by a number of inventions. After his death, the Nobel Brothers Petroleum Production Association appealed to the IRTS Council with a proposal to establish a gold medal named after L. E. Nobel for «the best essay or study on the metallurgy or the oil industry, or for any outstanding inventions or improvements in the technique of these industries, taking into account their greatest practical application to the development in Russia». And it was the first Nobel Prize, long before Alfred Nobel founded the one now awarded by the Royal Swedish Academy.

Sons of L. E. Nobel continued the business of the partnership of petroleum production, and their activities in IRTS were associated with the development of engine-building. Having acquired a patent for the manufacture of internal combustion engines (ICE) of the Diesel system, «Ludwig Nobel Plant» began their production, competing with the best foreign enterprises. Merit of L. E. Nobel was that he found the original solution for the operation of a diesel engine on crude oil, created his version, which became known as the «Russian engine». Georgy Depp, a professor at St. Petersburg Institute of Technology, spoke about the Nobel engine in IRTS report: «Such good results obtained with engines built at one of our Russian plants are quite remarkable... perfectly executed Russian oil engines are not inferior to those abroad» [11].

For the first time, the construction of oil-loading motor ships with diesel engines began in Russia at the Sormovsky plant for diesel-electric ships Vandal (1903) and Sarmat (1904). The Nobel Brothers partnership soon transferred its patent rights regarding the engine to the Company of Kolomna Machine-Building Plant, Riga Iron-Casting and Machine-Building Plant, Nikolayevsky Shipbuilding Plant, which led to the rapid expansion of new-type engine production and crowding out the production of steam engines.

At the beginning of 20th century, Gustav List (Pic. 7) was the owner of large machine-building plants that produced fire and mill pumps, chemical fire extinguishers, fire hoses, barrels on horse-drawn carts, steam engines, equipment and pipes for water towers of railway waterworks of the entire transport network of Russia cast iron manholes, pneumatic sirens. For the naval department, its plants supplied turbines, pumps – List's equipment was installed on Varyag, Aurora, Potemkin, Oslyab, Petropavlovsk and other ships of the Russian fleet. In Moscow, he built a machine-building plant, in which there was a unique technical library, design office and school of draftsmen. And he himself, as it turned out, was engaged in creation of new and improvement of existing internal combustion engines. Previously

Pic. 7.G. I. List (1835–1913).

unknown inventive activity of G. I. List and the description of its invention of the two-stroke kerosene internal combustion engine are presented by the authors of the article [12].

Having abandoned the steam boiler, which was the most cumbersome and expensive part of steam power plants, the industry gradually turned to the use of a more economical internal combustion engine. Mass production of cars, as well as the emergence of aircraft are associated with the emergence of ICE. Since 1860, in different countries, the efforts of inventors to create such engines with better parameters have been concentrated around finding the most efficient thermodynamic cycle, the design and location of the pistons, the combustible mixture used, the ignition system and adjusting the supply of the combustible mixture.

E. E. Bromley, a mechanical engineer, one of the owners of the Bromley Brothers Society engaged in engine building, a graduate of the Imperial Moscow Higher Technical School (IMHTS), wrote the fundamental work «Gas, Petrol and Kerosene Engines» (1900). This book appeared in connection with the competition announced by the Polytechnic Society at IMHTS. It contains not only the history of internal combustion engines, but also the analysis of phenomena occurring in cylinders, calculations of various parameters of internal combustion engines – temperature and pressure, combustion rates, cooling surfaces.

In the same period, theoretical work on the thermal calculation of the internal combustion engine of Professor V. I. Grinevetsky of IMHTS [13] is becoming popular. In 1906, he proposed his own design of a two-stroke dual-expansion internal combustion engine.

Setting itself a task of promoting the development of technology and industry in Russia, IRTS promoted the best achievements of domestic engineers. At the meetings of the society, reports were made on new designs of diesel engines, reversible internal combustion engines, their application in urban and railway transport, on sea and river vessels, on the automotive industry and aircraft industry. Domestic engineers were sent to study world experience, their reports were discussed and published in order to provide them with wide access.

So, on April 15, 1904, engineer V. S. Melentyev made a report named «Tsoss experiences of movement at a speed of 200 kilometers per hour» [14]. Acquaintance with German projects and research provided considerable material for assessing the situation in one's own country. In Germany at that time a joint-stock company was created, the goal of which was to organize high-speed traffic in the area between Berlin and Hamburg. For several years, tests of movement of electric trains (they received the name of Tsoss experiments), began at a speed of 80 km/h and then, gradually adding, reached a top speed of 200 km/h.

Much research work was carried out in IRTS on the use of gasoline and kerosene engines for aircraft and automobiles. In 1907, the first international exhibition of automobiles was held in St. Petersburg, where exhibits of the world's largest companies were displayed, including a description of automobile engines, their diagrams and drawings.

In 1909, a permanent automobile and aviation commission, chaired by Professor N. S. Lavrov was organized. Given the leading position of Russia in the world in production and improvement of Diesel engines, IRTS decides to hold from 6 to 15 May 1910 in St. Petersburg the «Congress of personalities engaged in construction and use of internal combustion engines», to which many prominent foreign experts were invited including Rudolf Diesel. About 200 people arrived at the congress. Among them there were famous university professors N. A. Bykov, V. I. Grinevetsky, G. F. Depp, N. R. Brilling, D. S. Zernov, V. P. Arshaulov and representatives of all Russian factories that built engines, and many organizations associated with operation of engines.

Conclusion. *Despite all the efforts and the fact that in the field of inventions and development of the theory of internal combustion engines, Russian engineers did not yield to their foreign colleagues, the automotive industry in Russia did not receive mass development at that time [15]. Many projects and developments of domestic authors have not found practical implementation. This is largely due to the fact that Russian large-scale industry has always developed, focusing primarily on government orders. Russian engineers were and still remain the generators of new ideas and technologies that promise considerable progress in industry and transport, but at the stage of implementation and commercialization, they are often inferior to foreign competitors.*

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