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Prerequisites of the Development of Applied Sciences in Russia in the 17th – 18th Centuries. The First Attempts to Train Mechanics and Engineers in the 18th Century

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Abstract. The article describes the directions of the development of applied mechanics in Russia in the 17th – 18th centuries and focuses on the first attempts to train specialists in these areas. These are the construction of roads, bridges, fortification and hydraulic engineering constructions, practical ballistics. Water and land means of communications are being improved, the industries that served the army and the fleet are developing, and the first attempts are being made to educate mechanics and technicians. Educational institutions are being opened, in which elements of mechanics are beginning to be taught. However, mechanics occupies an auxiliary position in relation to technology.

Keywords: construction and applied mechanics, training, 18th century, Saint-Petersburg Academy of Science.

Research area: history.

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Russia of the 14th-17th centuries is of undoubted interest for historians of science and technology. It was a time when Russia, cut off from Europe, at the same time under the influence of the Tatar-Mongol invasion, is trying to create its own architectural and technical traditions. For about two centuries Russia was under Horde domination, with a constant threat from the south and the west. However, even the liberation from oppression and the growth of national self-consciousness did not allow the full development of Russian culture and technology, which would have seemed natural since the second half of the 16th century. The fact is that the 17th century cannot be called calm for Russia. The time of troubles, internal and external wars – the Bolotnikov uprising, the Razin uprising, the movement of the Old Believers, almost continuous wars with Poland – all these made the development of Russia difficult.

Practical mechanics was developed in several directions in the country. These are construction mechanics of buildings, roads, bridges and fortifications, practical hydraulics – building ships, dams, the strength of cast products – primarily bells and cannons, practical ballistics, machine mechanics – mainly the construction of water and windmills, watchmaking. The construction art was the most common and studied field of practical mechanics. Of course, the construction mechanics itself was not developed in the 17th century yet, but still, Russian architects and builders achieved some success in this direction. A certain style of Russian architecture was developed. Apparently, this was due to the fact that the builders did not very willingly change the design and structure of their erections, since the strength and size of the buildings were associated, first of all, with their geometric dimensions. But besides the new construction and restoration work was carried out. Fortresses were restored and built – walls and towers, then temples. This is not limited to the list of work done. For example, estimates for the repair of buildings of the Nizhny Novgorod Kremlin indicate that the laying of the main walls suffered from water, therefore, the foundation needed to be replaced. Perhaps this later led to the development of new types of foundations.

During the 17th century, new fortresses were built in Russia, and old ones were repaired. For example, new fortresses were built in Mozhaisk and Vyazma on the outskirts of Moscow, the fortifications of the Solovetsky Monastery were improved, new fortress walls were built in the Ipatiev Monastery in Kostroma, in Kirillo-Belozersky, etc. The constructive elements of buildings – arches and vaults – have received significant development. For example, during the construction of the Moscow Church of the Intercession in Rubtsov (1619-1626), a peculiar construction of the arches was used. With the same height of the interior and a much smaller thickness of the walls, the cross-vault in the Rubtsov church covers twice the area compared to the old cathedral of the Donskoy Monastery" (Bessonov, 1956: 175). In general, the overlap of large spans in the 17th century was not so rare. For example, the White Chamber of the Rostov Kremlin (1672), which is a single pillar hall of about 300 square meters, premises in the Trinity-Sergius Monastery. Thus, the construction mechanics of the 17th century not only prepared the ground for the development of this science in the subsequent time but also naturally affected the state of the road and hydraulic engineering construction.

Since ancient times, there were land and waterways in Russia. The formation of Moscow Rus' laid the foundation for the creation of the first network of land roads – unpaved roads. They began at the outposts of Moscow and went towards the major cities – to Smolensk, Kharkov, Vologda, Nizhny Novgorod, and others. On these paths, wooden or stone artificial structures were built. The waterways or the so-called "winter roads" were often used. Roads between navigable rivers were called "tracks" or "drags" (These words are still preserved in place names, for example, Vyshniy Volochek station). Communication through permanent waterways was carried out using floating bridges or ferries. And in Russia, floating bridges have been used since ancient times. It is known, for example, that already in 1115, under Vladimir Monomakh, a floating bridge was built across the Dnieper in Kiev, similar bridges were later built across the Volga (1380) and through the Volkhov (Nikolai, 1898: 2). In general, Velikiy Novgorod received an important state significance precisely because of its favorable location on the navigable river Volkhov, not far from the watershed between the basins of the Baltic, Black and Caspian seas. In the conditions of ice drift and freeze-up floating bridges were, undoubtedly, simple, cheap, and convenient. However, permanent bridges and even lifting bridges were built. "The first indication regarding the use of lifting bridges refers to 1229" (Nikolai, 1898: 4).

Bridge construction as the most important branch of the art of building began to develop relatively quickly from the second half of the 17th century. Already in 1687, the Bolshoy Kamenny Bridge over the Moskva River was built in Moscow. It was an arched bridge of 140 meters long, 24 meters wide, leaning on powerful bulls and foundations. It received its name, unlike the small stone bridges that existed across the Neglinnaya River at those times, across the ditch at the Kremlin. The name of this bridge is still preserved. This direction of practical mechanics in the field of road and bridge engineering was further developed rapidly in connection with the transfer of the capital to St. Petersburg. The words of L.F. Nikolai, the bridge builder in the 19th century in Russia, about the construction work in Russia are worthwhile noting: "... the abundance of forests led to the ubiquity of wooden buildings, which gradually achieved a high degree of perfection, despite of the fact that they only used an ax while working. The saw was introduced only at the time of Peter the First. That was due to the administration's measures due to the representation of Leblond (French engineer, invited by Peter I on Lefort's recommendation), who pointed out at the useless waste of material when cutting logs with an ax" (Nikolai, 1898: 2). He also notes that the first time the word "engineer" is mentioned by Alexey Mikhailovich. This title was intended for foreigners only, whereas the Russian builders were called "city masters" (Nikolai, 1898: 10).

Here is another example of building a road. In 1702, Peter I arrived in Arkhangelsk, where, on his initiative, two combat frigates were built. From here, at the head of the five battalions of the Guard, he set out on the march along the road, which was later called the "sovereign". This road (170 km long and 6.5 meters wide) was built at an extraordinary speed by guards soldiers and officers. Frigates were moved along it, which then went to Lake Ladoga for the siege of the Swedish fortress Noteburg (Oreshek), founded by Novgorodians in 1323. The fortress was taken by the storm and renamed Shlisselburg (Petrokrepost). Thus, this White Sea-Povenets road contributed to the solution of the most important issue – Russia's exit to the Baltic Sea. Here, in the delta of the Neva River, the city of Petersburg was founded.

An interesting direction of Russian mechanics is casting bells. They were made in Moscow, Pskov, Nizhny Novgorod and other cities of the country. Their weight was different. For example, 13 tons on the Assumption Belfry of the Moscow Kremlin (1652), 32 tons – on the Belfry of the Rostov Kremlin (1688). In 1654, by the order of Alexey Mikhailovich, the New Assumption Bell was cast, its weight being 128 tons. It was raised to the belfry in 1678 and rang until 1701 when it was damaged by the fire. Yet, regarding the bells, it was necessary to solve very important problems of mechanics, the problem being the development of the bell profile, which ensured the strength and purity of the tone, the construction of the mold, the casting process, the development of the mounting structure on the belfry, the lifting of the bell, and the bell suspension. The strength of the bell body was also achieved by the absence of shells and stresses in the metal during the cooling of the bell.

Similar questions were also raised in the course of the production of guns. At the Moscow cannon yard in the 17th century guns of various calibers were cast, weighing from 2-3 to several hundred pounds. Gunmakers had found original technical solutions. For example, in 1615, a screw gun was created for the first time there. Screw threading was also used for handguns.

We must not forget about the energy of the 17th century either. This is, first of all, the power of water, wind, animals, and man. The technique of building water mills was changing. Now they served not only for the production of flour but also for driving various machines and mechanisms. The construction of motion transmission was gradually becoming more complex, branching gears appeared, for example, for iron mills, as well as gears. Of course, there is no need to talk about any curves yet, the quality of the gear wheel depended on the skills of a particular master. It is interesting that precisely at the same time clock mechanisms appeared in Russia. Already at the end of the 16th century, the tower clock stood on the three towers of the Moscow Kremlin and the palace premises. In the 17th century, they were already in several cities and monasteries, the masters began to make pocket watches (Pipunyrov, Cherniagin, 1977: 21, 34, 37). Thus, it can be said that the Russian masters were familiar with the technique of building machines. The installation of the mills themselves proper and the associated hydraulic engineering works required knowledge of practical mechanics.

Metallurgical production was one of the most important areas of using water energy. In the 17th century, only 9 factories operated in the Tula-Kashira region. Then the plants were built in the Moscow region, in the Olonets region, Voronezh, and the Urals. At these plants, iron was mined from local ore, processed, and sometimes weapons were made there as well. The technological scheme of these plants was essentially the same. The river was blocked by a dam and, thus, the obtained difference in levels was used to supply water to the top-wheel. The energy received from one or several wheels was used to propel the working equipment of the manufactory. The construction of dams was quite a complicated matter and at that time there was even a special profession of "dam masters".

Waterways were still the most accessible means of communication in the country. The main artery of the country was the Volga, and the main seaport was Arkhangelsk. It was both the only Russian export-import port and a major center of the fishing industry. Shipbuilding also developed here. The design of the ships at that time was a spatial wooden truss on which a wooden planked trim was fastened outside. In the 17th century, vessels for the transportation of goods appeared on the Volga, some of which can also be considered passenger vessels. This was the Frederick ship built in 1636 in Nizhny Novgorod, with an overall length of over 40 meters and a draft of about 2 meters. The ship was adapted for sailing and rowing, it had 3 masts and 24 oars. On the Oka River, in 1667, the ship "Eagle" was built, which had a length of 24.5 m, a width of 6.5 m, a draft of 1.5 meters and was armed with 22 cannons (Shershov, 1952: 265).

The ships, which were built in Arkhangelsk, went mainly under sail. The construction of such vessels required a great deal of knowledge in mechanics – the vessels had to have good streamlining, speed, and good submission to management. Steering was carried out with the help of an unequal arm with a fulcrum on the stern. The steering wheel turned 60-70 degrees. Gradually, its design was improved, a second control lever was added (later it was transformed into a wheel), and the steering angle decreased to 25-30 degrees. The control of sails on large ships was carried out with the help of blocks and tackles. Regarding many dissimilar structures related to mechanical engineering, the rules of simple machines were applied; the strength of the structures was taken into account, based on the geometric dimensions. In all this, the builders were helped by the experience (both inherited and their own).

In general, in Russia, although they were familiar with some achievements in various fields of science in other countries, the attitude towards them was rather negative. Science hardly fits into the life of the country in the 17th century. The situation began to change due to Peter I, as well as to the foundation of St. Petersburg and the transfer of the capital from Moscow to St. Petersburg in 1712. First of all, the development of railways, large industrial enterprises, the creation of the Russian Navy, the emergence of new types of transport are connected with these events. At that time, large ships, built at the Olonets shipyard on the Svir River, could not get to St. Petersburg due to the presence of rapids on the Neva River. Therefore, already in 1704, they began to build the Admiralty Shipyard. (It subsequently became the largest enterprise in the shipbuilding industry of Russia). At the same time, the Admiralty was intended not only for the construction of ships. It also performed the defense functions, as it was built as a fortress on the left bank of the Neva. Along with the Admiralty cannon, foundry yards, powder factories, tar, rope, sailing, and other workshops were built. In 1715, over 10,000 people already worked at the enterprises of the Admiralty. In 1706, the first 18-gun ship was launched, and in 1712, the first linear 54-gun ship, the Poltava, named after the 1709 victory, was built by Peter I and the Russian engineer Sklyaev. Until 1715, almost a third of all ships built in Russia in the first quarter of the 18th century was built at St. Petersburg shipyards (Shershov, 1952: 265).

Simultaneously with the Peter and Paul Fortress and the Admiralty, Peter I began to build a fortress on the island of Kotlin in the Gulf of Finland – Kronstadt. It was in 1704 when a fort was already built there and an artillery battery was installed to protect the fairway leading to St. Petersburg. A few years later Kronstadt turned into a well-equipped port with a harbor and ship repair shops. The arrangement of the grand canal-dock – "Petrovsky" – became widely known. It was introduced into service in 1752 and was an engineering structure, which had no equal in Europe. The system of hydraulic facilities made it possible to free the dock from water in 24 hours. The water flowed into an artificial pool, and from there it was pumped out first with wind-driven pumps, and then with a steam engine.

Yet, not only shipbuilding was developed in St. Petersburg. Peter I paid great attention to the improvement of artillery affairs. In 1712, the Foundry Business and Cannon Yard was built on the bank of the Neva. It was headed by the Arsenal famous figure of the time – Yakov Vilimovich Bruce (James Daniel Bruce). Under his leadership, the first copper cannons with a barrel channel were cast. Then the Arsenal began to cast the so-called "deaf" guns, that is, without the receiver channel, which was then drilled. Thus, the foundations of internal and external ballistics were laid. Skillful workers were needed for work. Peter I also paid much attention to this. It is interesting to note that even at the time of the Second World War the gunners were the most educated part of the army. Powder factories were built in St. Petersburg, and they worked not only on horse-thrust but also used water engines. Thus, in 1720, Yakov Batishchev, a specialist of the Tula Arms Plant, became the head of the Okhta plants. Under his leadership, a powder production system was set up at the factories, driven by water wheels. During these years, St. Petersburg became the second center for the production of gunpowder in the country after Moscow.

The transfer of the capital to Petersburg meant that Russia was turning into a maritime state and Petersburg itself – into a military and commercial port. The population of the city was also constantly increasing and by 1725 it was over 40 thousand people. Naturally, there was an urgent need to create improved means of communication for the new capital with the whole country. First of all, waterway communications were developed as the cheapest. So, almost simultaneously with the foundation of the city, the construction of a connecting canal between the Tvertsa and the Tsna rivers of the Volga and the Ladoga basins was begun. The works were completed in 1798, and later the canal became known as the Vyshnevolotsk water system. With its discovery, a direct waterway was established between the Neva and the Volga rivers, that is, the connection between the northern capital and the whole country. In 1719, the Vyshnevolotsk system was redesigned. This was done by the prominent Russian hydraulic engineer Mikhail Serdyukov, Kalmyk by his origin. He built reservoirs for artificial feeding of the system and, thus, provided water for the navigable depths on the Tvertsa, Tsna, and Msta rivers.

Strong winds and storms on Lake Ladoga, during which many ships were sunk, were a major obstacle to shipping. Therefore, in 1719, between the mouth of the Volkhov and the source of the Neva, the construction was begun on a canal bypassing Lake Ladoga. The construction of the canal with a length of over 110 kilometers was completed in 1731. The water horizon in the canal was higher than the water horizon in the Volkhov and the Neva. Therefore, at the ends of it in Shlisselburg and in New Ladoga the locks were built. The construction of a canal of this size was the largest engineering structure of the time. Thus, the first canal in England, not counting the canals built during the time of Roman rule, was built in 1761. In North America, it is only in the 1980s when two small canals were built around the rapids on the Potomac River (Gershelman, 1892: 35, 46).

In addition to waterways, Peter I also took steps to develop land communications between cities. So, by his orders, they began to lay a route between Petersburg and Moscow, the route being a direct direction. Peter I attributed the speed of movement to the category of the economic and strategic. Therefore, despite of the merchants' objections to the construction of a road leading to rich Novgorod, Peter, nevertheless, preferred the direct option. However, the construction of the tract (road) went slowly, and after Peter's death it was stopped altogether. The construction was resumed only in 1733 when the Office of the perspective road was formed and the provision "On the construction of the road and bridges from Moscow to St. Petersburg" was developed. According to the document, the road had to be built "with extreme joy while looking for the treasury so that it would break even, and in the passage, it had to be more capable and timely and stand firm in the future" (Full set of laws, 1739). Naturally, this principle is important and fair for any time and any country. The construction of the tract was completed in 1746. Its length was 778 km, since the road was still built with a call to Novgorod. Since that time, regular communication between the capitals began. Later, in 1755, the Office of the perspective road was transformed into the Office of the State Road Structure, which in 1786 became known as the Commission on Roads in the State, and at the end of the century – the Expedition of the Construction of Roads in the State. These bodies were engaged in the construction of tracts coming from Moscow to the inner cities of the country. In the second half of the 18th century, stone bridges and pipes were built for the first time on a massive scale (that is, according to standard designs), especially at St. Petersburg-Moscow tract.

An interesting and original fact is the solution to the problems of moving large loads. So, in 1769, in St. Petersburg, a special railroad was built to move the "stone of thunder" for the pedestal of the monument to Peter the Great. This stone with a weight of about 100 thousand pounds was found on the Karelian Isthmus, 9 km from the Gulf of Finland. The transportation of the stone over the land to the bay was carried out on a special platform, moved with the aid of winches on portable rails, which were laid on a specially arranged road. The platform with the stone moved on the balls-rollers nested in the gutters of the rails. The speed of movement averaged 400 m per day. The monolith was relatively quickly delivered to the shore of the Gulf of Finland, and from there it was transported to its destination on raft ships. In honor of this, a medal was stamped with the inscription "Daring like" (Kabanov, 1955: 30). Besides, in 1788, in Petrozavodsk, the head of the Aleksandrovsky cannon factory, Anikita Sergeevich Yartsev (1737-1819), built a 173-meter-long railroad to move the guns from one shop to another. Its track was a solid cast-iron rail grille with a width of 800 mm. It is believed that this road marked the beginning of the development of industrial transport in Russia (Voronin, Voronina, 1994: 60).

The tremendous changes in the country at the beginning of the 18th century naturally required a large number of skilled artisans, engineers, and workers. There was an acute task of forming the technical and administrative intelligentsia, and Peter I took on this task. Training is placed at the service of political, military, and economic goals. Various schools are starting to open in Russia: first in Moscow and St. Petersburg, then in other cities. So, in 1699, the Moscow Pushkar school was established. Peter's decree on this issue says: "to teach verbal and written literacy, tsifir (arithmetic) and other science". However, first of all, mathematical knowledge was necessary. The task was to prepare a large number of people with the knowledge of elementary mathematics and statics. In 1701, there was a decree on the establishment of the "Moscow School of Mathematics and Navigation, that is, Navigationally Cunning Art of Teaching" to train specialists in maritime and shipbuilding business. For teaching at school, Peter invited foreign mathematicians: Prof. Farvarson, Stefan Gwyn, and Richard Grace. At the same school L.F. Magnitsky, the author of the first Russian printed scientific and technical book "Arithmetic, in other words, is a numeral science" (Magnitsky, 1703: 3261) published in 1703, worked. From this school young people were released into all kinds of services – military and civilian. The program included arithmetic, geometry, trigonometry, and practical applications of them to geodesy and navigation.

During these years, numerous new schools were opened. "Small admiralty schools" in St. Petersburg, Revel, Kazan, and other cities, schools for training in shipyards in Voronezh, later in Arkhangelsk, engineering school in Moscow (1711) were established. In 1714, by Peter's decree, the so-called "digital" schools were opened in a number of cities, the students of the navigation school teaching there. "... in all the provinces of the nobility and the order of orders, children and children of ages from 10 to 15 years, learn tsifir and some of geometry". Since the above-mentioned children were very reluctant to do so, the decree clarified that without written certificates of graduation from these schools "the students were not allowed to marry" (Decree No. 2778 of February 28, 1714).

Gradually, it was Petersburg, as the capital of Russia, that became the scientific center of the country. In 1715, the Maritime Academy or, as it was then called, the "Academy of the Marine Guard" was established. Farvarson and Gwyn were moved from Moscow to teach here. The journal of the College of Farvarson says: "... due to then, the first mathematics education in Russia was introduced, and almost all of the Russian subjects, from the highest to the lowest, were trained in navigation sciences in Naval sciences" (Journal of the College, 1737). Farvarson distributed time to study subjects: arithmetic – 1 year, geometry – 8 months, flat trigonometry – 3 months, spherical trigonometry – 3 months, geodesy – 4 months, navigation – 9 months, astronomy – 4 months, geography mathematical – 1 month, artillery – 1 year, fortification – 1 year, painting and training on rapids – 1 year. Although the course seems to be complete according to the list of sciences, only short rules which were necessary for practical application were studied, and there was no connection between the subjects.

Somewhat later, an engineering school was opened in Petersburg (1719) as well as an artillery school (1722). In 1724, by the decree of Peter the Great, the Academy of Sciences was founded. Moreover, according to Peter's plan, the Academy was to become a half-technical educational institution. Arithmetic, geometry, astronomy, geography, navigation, mechanics, optics, architecture, physics, chemistry, etc. were taught here. J. German, D. Bernoulli, H. Goldbach (in mathematics), Nikolai Bernoulli (on mechanics), and others were invited for lecturing at the Academy. The establishment of the Academy immediately brought Russia to one of the leading places in the world science. In 1727, Leonard Euler came to St. Petersburg. He was the person who played a particularly large role in promoting the Petersburg Academy as one of the main centers of scientific research. Euler devoted a number of his works to the science of machines. He wrote that the theory should be such that with its help "among all the machines used to perform a certain work, one could find the best one that would do this work in the shortest possible time or with the minimum expenditure of real forces, or, otherwise, will be able to ensure the best result" (Bogoliubov, 1976: 77-78).

Nevertheless, in the course of the 18th century, the Academy of Sciences remained an isolated scientific island in the life of the country. For the time being, Muscovite Russia needed not general ideas, but practical knowledge. That is why in the time of Peter the Great, and, then, Catherine the Second, so many different schools were opened, many talented people were sent abroad to study, as mastering the techniques of Western countries was still easier than the corresponding science. At the same time, foreign specialists were invited to teach in the field of technical sciences. For the following years Moscow University (1755), which initiated the development of natural sciences in the center of the country, Land (1731), Marine (1752), Artillery and Engineering Corps (1758) were formed in Russia.

M.V. Lomonosov also wrote about the need for serious study of the mechanics in them. For an artilleryman, to use the machines in the manufacture of guns it is needed to calculate their parts, to account for friction, etc., for an engineer – to construct machines, large bridges, sluice gates, during the construction of ceilings on powder cellars and barracks, which must withstand the hit of artillery shells. It is curious to read that one should "as much as possible explain to him [the student] the property of that curved line that a bomb in the air can describe, show him the effect of the air resistance on the solid body moving in it, from which some differences in the flying bomb occur and can occur, and, finally, show him the ways, how to throw a bomb from a mortar, and how the blow can be applied to the vaults or what kind of structure can be calculated and determined" (Bogoliubov, 1985: 230).

In 1800, the Land Corps was renamed the First Cadet Corps, and the Artillery and Engineering Corps – the Second Cadet Corps. These were secondary schools. They provided the course of mechanics, which included the elements of the theory of machines. A bit later, in 1773, the Mining Engineers Corps was formed along with the Mining School, which played an important role in the development of mining engineering. There were also the first organizations and schools for training specialists in the matter of the actual means of communication. In 1782, the Hydraulic Corps was created. It was intended "to compose plans, to produce and manage works ... such as locks, canals, marinas, and the like" (PSZ, 1782). In the cadet engineering corps, they began to train hydraulics specialists. The first hydro-technical schools for training the masters were opened, and in 1798, the Ship Architecture School was established in St. Petersburg.

However, it should be noted that in the 18th century there was a gap between "academic" mechanics and mechanics taught in schools. The classes were practical, that is, knowledge in the field of mechanics was presented as a collection of ready-made recipes for various situations. The theory has not been developed yet. Although L. Euler, D. Bernoulli and others worked at the St. Petersburg Academy of Sciences on the development of the ideas of mechanics, this mechanics could hardly find a consumer inside the country. There were almost no mechanics-creators yet, and applied mechanics achieved the most important results. For example, Russia came out on top in the world in the production of iron; mining, canals, and roads were built. Gradually mechanics terminology was developed. The work of mechanics practitioners, such as I. Polzunov, A. Knartov, I. Pulibin made a significant contribution to the development of mechanics in Russia (for example, the model of an arched bridge across the Neva River). Their experience survived them themselves and often served as a model for further research. The problem of educating mechanics-engineers in Russia was solved within the walls of a high school of the 19th century.

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Предпосылки развития прикладных наук в России XVII – XVIII веков. Первые попытки подготовки механиков и инженеров в XVIII веке

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Аннотация. В статье рассказывается о направлениях развития прикладной механики в России в XVII – XVIII веках и о первых попытках подготовки специалистов в этих областях. Это строительство дорог, мостов, фортификационных и гидротехнических сооружений, практическая баллистика. Улучшаются водные и сухопутные пути сообщения, развиваются отрасли промышленности, которые обслуживали армию и флот, делаются первые попытки воспитания механиков и техников. Открываются учебные заведения, в которых начинают преподавать элементы механики, однако механика занимает подсобное положение относительно техники.

Ключевые слова: строительная и прикладная механика, обучение, XVIII век, Санкт-Петербургская академия наук.

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