The Scientific Background of the Russian Revolution and Some Origins of TMM

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Abstract. This paper is an attempt to present and discuss the scientific context prior to the outbreak of the Russian Revolution in 1917 also emphasizing some important origins of TMM. General aspects of the scientific milieus of the eighteenth and nineteenth centuries are described, including the period of Peter the Great, the foundation of the Academy of Science, and the influence of great figures of science, both Russian and foreign. In the eighteenth century Leonhard Euler (1707–1783) was chosen as symbolic and representative figure of Mechanics and TMM, while in the nineteenth century, Chebyshev (1821–1894) was looked at by the same reason.

Keywords: History of Russian science · History of TMM
History of Russian revolution · Russian scientific biographies

1 Introduction

The Russian revolution in 1917 was one of the most radical turning points in Russia history. It affected economics, social structure, culture, international relations, and industrial development, amongst other transformations. The revolution opened the door for Russia to enter the industrial age and consequently to achieve modernity [4].

Before 1917, Russia was an agrarian nation, with only very limited industrial development. However, the pre-1917 scientific base was of fundamental importance for propelling the country forward and for technological advances, such as electrification and new urban-industrial regions which appeared almost immediately [10]. Education also played a major role, with illiteracy being practically eradicated.

Using the scientific background from the pre-revolutionary period, during the 1920s the Soviet state changed research organizations into an institute system 1920s [7]. From the revolutionary viewpoint, the term scientific-research institute had another meaning and structure. Almost all outstanding scientists and engineers were members of, or had a commitment to, an institute. Another very impressive characteristic of the history of Russian science, mainly in the nineteenth century, is the role and the participation of women [11]. In fact, Russia had the highest contribution of women to scientific activities in the world, looked at in terms of doctorates in mathematics, physiology, zoology, chemistry, and in many other fields.

B. Zhang and M. Ceccarelli (Eds.): *Explorations in the History and Heritage of Machines and Mechanisms*, HMMS 37, pp. 338–349, 2019.
https://doi.org/10.1007/978-3-030-03538-9_27

2 Russian Science in the Eighteenth Century

The two major traditions in Russian science in the above period were mathematics and studies of natural resources. Furthermore, these traditions have continued until the present. In both, but especially in mathematics, foreign researchers dominated, notwithstanding many works written by Russians at the end of the eighteenth century. The most famous case is Leonhard Euler who came to St. Petersburg to study mathematics and physics [13]. He arrived in 1727 as an assistant professor of physiology. Other examples of foreign academics include Daniel and Nicolaus Bernoulli.

The contributions of Euler and the Bernoulli brothers alone gave St. Petersburg prestige and honor in the history of mathematics. They came from Basil. Euler spent two long periods in St. Petersburg, from 1727 to 1741 and from 1766 until his death in 1783. The majority of his works was written in St. Petersburg. Euler arrived young in Russia, twenty years old and received his professional education there. With respect to the Bernoullis, Nicolau's career was interrupted by his death with the age of thirty-one. Daniel stayed only seven or eight years in St. Petersburg, before returning to Basil, but in Russia he started writing his famous book *Hydrodynamics* (1738) which contains the Bernoulli principle [2].

Critics of Russian science in the eighteenth century have argued that these contributions are much better described as Russian carried out by European scientists, and some of whom actually returned to their original countries. Another comment that appears is that the high-level mathematics studies encouraged were far from the educational necessities of the country and were at the very least a distortion of priorities. However, these studies consolidated the Russian mathematical tradition [9].

The second great scientific heritage in the eighteenth century were studies of natural resources, often obtained through expeditions. The American historian of Russian science Alexander Vucinich has found 161 published studies that came from these expeditions in Russia in the period 1742–1822. The eminent German naturalist Peter Simon Pallas (1741–1811) became a member of the St. Petersburg Academy and spent almost his entire adult life in Russia, from the age of 26 until 69.

Moscow University, founded in 1755, made few contributions to science in this period despite providing the organizational foundations for the development of science in the next century [3].

Finally, since the beginning of the eighteenth-century Peter the Great had tried to bring European science and technology to Russia having a remarkable role to do this regarding the top of the Academy. His critics did not always agree with his methods, but he always replied saying that his successors would continue and complete his project.

2.1 Science in the Peter the Great Period

Peter the Great (Fig. 1), the 'Reformer Tsar Reformer,' whom the Russians generally call Peter I (Pyotr Pervy) was born in Moscow, on June 9, 1672. He died in St. Petersburg, on February 8, 1725 and is entombed in Cathedral of Saints Peter and Paul, located in St. Petersburg [1].

Fig. 1. Peter the Great (Portrait by P. Delaroche)

The reign of Peter the Great (1689–1725) has a special importance in Russian history, mainly due to the introduction of Western European science in the country. It is possible to argue that many of these reforms were suggested by his father Alexis. Moreover, Moscow had previously received foreign influences and culture from other European countries which had left their marks. Nevertheless, in spite of these previous influences, it is generally accepted that the process of disseminating European culture in Russia began with Peter the Great.

At the end of the eighteenth-century Russia did not have scientific organizations, although religious institutions existed in Kiev and Moscow for teaching languages and religion.

The first prominent Russian scientist was Mikhail Lomonosov (1711–1765), educated in these institutions. In 1701, Peter the Great created a navigation school in Moscow and a naval academy in 1715, in St. Petersburg. In addition, an artillery school, an engineering school, and a medicine school were also founded during his reign.

Peter thus created a favorable atmosphere for the penetration of European science and culture in Russia, in contrast with his predecessors. Hence, in his reign a small part of the Russian population, mainly belonging to the nobility but also including some academics and literati, began to see West European culture as something desirable.

2.2 The Foundation of the Academy of Science

In contrast with other European countries Russia did not have any universities at the time of the foundation of the science academy. This increased the prestige of the academy for a long period. At the end of nineteenth century Russian universities overtook the Academy of Science (Fig. 2), a trend that led to the decline of prestige and research effort in this institution, making it more of an honorific place [8]. This transition was not complete when Russian Revolution radically changed the political context in 1917. The Soviet government adopted a policy of increasing the prestige of academies after 1917, something which reminds us of the Peter the Great period.

Fig. 2. Original building of the Imperial Academy of Science

Peter the Great, inspired and advised by Leibniz (1646–1716), founded the Academy of Science in St. Petersburg by means of the Senate decree of February 8, 1724. Originally called The *Saint Petersburg Academy of Science*, it changed name various times during the years. In 1836 it was named *the Imperial Saint Petersburg Academy of Science* which lasted until the end of the empire in 1917.

When Peter decided to create a scientific society, there were several models from other European academies to choose from, many of which he knew personally. He maintained fruitful correspondence with Leibniz, founder and president of the Berlin Academy. He also exchanged opinions and experiences with Christian Wolff, professor at Halle University and later in Marburg. He was helped by Lavrentii Blumentrost (1692–1755), the court physician charged with designing a final plan for this organization. Blumentrost's model was approved by Peter the Great before his death, adopting many details of foreign academies.

One goal of this new orientation was to cultivate native Russian science [12]. Its structure permitted the presence of foreign academics at the top, offering the possibility of scientific investigations at the highest level and providing professors in special scientific fields.

From the administrative viewpoint, the Academy was treated as a branch of government and naturally submitted to imperial command. The original project drafted by Blumentrost and approved by Peter allowed for self-government including the right to elect their own members and the president. However, this was obtained late, because the right to elect the president was hidden from the members. This right was maintained until the provisional government in 1917.

2.3 Great Scientists in the Eighteenth Century

Leonhard Euler (1707–1783)

Leonhard Euler [14] is undoubtedly the most important mathematician of the 18th century (Fig. 3). He was born in vicinity of Basel, in northern Switzerland near the French border, on April 15, 1707, the son of Paul Euler and Margaret Bruchner. After first being taught by his father, Euler went to University at the age of thirteen, where he demonstrated a rare aptitude for mathematics. In addition, he studied with Jean Bernoulli and was directly influenced by Leibniz (1646–1716) and Descartes (1596–1650), mainly in mathematics and philosophy. From Newton (1642–1727) he received mechanical theory and the concept of force. From Leibniz he adopted mathematical theory for finite and infinitesimal quantities but diverged with the first in relation to the idea of absolute space.

Fig. 3. Leonhard Euler (1707–1783)

When Euler was twenty-one he was nominated by Daniel Bernoulli to the St. Petersburg Academy of Sciences. In 1733 he succeeded him as mathematician in that Academy. Here he improved integral calculus, developed the theory of trigonometric and logarithm functions and worked hard to simplify analytical expressions in mathematics.

In 1741 Frederick the Great invited him to the Berlin Academy. He left Russia and stayed in Berlin for 25 years. During this period Euler produced a significant amount of scientific work. In 1776 he returned to St. Petersburg to the court of Catherine II (1729–1796). Euler was now practically blind.

Euler died on September 18, 1783. He left on his desk some manuscripts and calculations on the problem of aerostatic balloons. This was his last scientific concern

Euler's contribution to the theories of machines and mechanisms can be summarized as follows:

- In 1750 he discovered that the principle of linear momentum could be applied to all mechanical systems independent of their specificity, in other words, whether they were discrete or continuous. In a work called "Discovering a new mechanical principle", published in 1752 he showed the equations:

$$F_x = Ma_x;\ F_y = Ma_y;\ F_z = Ma_z \tag{1}$$

  where the mass M could be finite or infinitesimal. Later, he called these equations "the first principles of mechanics". Obviously, those equations are Newton's second law and thus we can call them Newton-Euler equations.
- In his 1744 work Euler states: "In the trajectories described by bodies under the action of central forces, the integral of the velocity multiplied by curve element, is always a maximum or a minimum." In this way Euler postulated an expression for the least action principle, as follows:

$$\int mvds,\ \text{is an extremum.}$$

  where m is the mass, v the velocity and ds, the infinitesimal element of the trajectory.
- In 1760, Euler published "*Theoria motus corporum solidorum seu rigidorum*." This work was improved by Euler's son Johann Albrecht in a new edition in 1790. In the introduction to the original work Euler confirmed the principles he had stated in 1736. He defines the main characteristic of a rigid body by the invariability of distances between any two points belonging to a body. In addition, Euler defined a "mass centrum" or an "inertiae centrum" for every body; he emphasizes that the "center of gravity" of a rigid body implies a more restricted concept than a "mass center" or an "inertia center". The last two concepts are better defined by the inertia itself when the system of forces acting on the rigid body is neglected.
- Euler introduced the concept of moment of inertia of a rigid body, which simplifies the language and the solution of problems. He also calculated the moments of inertia of several homogeneous bodies. In addition, he adopted a system of reference attached to the rigid body and discovered the principal axes of inertia (Euler's equations). The next step was to study the rigid body dynamics by means of the decomposition of motion into two elements: the translation of the center of mass and the rotation about the center of mass. In this context he considered Euler angles and studied rotational problems motivated by the precession of the equinoxes.
- In 1755 Euler prepared for the Berlin Academy the "Principes généraux de l'état d'équilibre des fluides", which discussed fluid equilibrium. He considered two types of fluids, the compressible and the incompressible, both submitted to any system of forces. The mass of the fluid is taken into account assuming a 3D infinitesimal parallelepiped with dimensions dx, dy, dz. If the forces components acting on the

body are P, Q, R and the body density is q, then the fluid element of volume $dxdydz$ has force components $Pqdxdydz$, $Qqdxdydz$ and $Rqdxdydz$.
- Euler derived from this a general equilibrium equation:

$$\frac{dp}{q} = Pdx + Qdy + Rdz \tag{2}$$

The forces P, Q, R must be such that the differential form $Pdx + Qdy + Rdz$ either becomes integrable when the density q is constant or uniquely dependent on the elasticity p, or becomes integrable when multiplied by some function.
- Starting with the above-mentioned 1755 paper, Euler considered the original state of the fluid as the configuration of particles and their velocities. This state is assumed to be known at a given time as well as the forces acting on it. The problem to be solved is to calculate at any time the pressure in each point of the fluid, the density and the velocity of the fluid elements that pass through that point.
To study the present state of the fluid, Euler used the components of the accelerative force, P, Q, R which are known functions of x, y, z and t. The density q, the pressure p and the components u, v, w of the velocity of the fluid element that is at point Z are at time t unknown quantities.

3 Russian Science in the Nineteenth Century

During the nineteenth century Russian science developed enormously. All education levels were rising, from elementary to the universities, as well as the highest level of scientific research. However primary education continued to be a problem until the following century.

In the nineteenth century Russia had a great number of figures and a certain level of scientific leadership, even in the international context, including Nikolai Lobachevski, F. G. W. von Struve, Dimitri Mendeleev, Pafnustii Chebyshev, Illia Mechnikov and Ivan Pavlov, amongst others.

At the beginning of the reigns of Alexander I (1801–1825) and Alexander II (1855–1881), the most innovative periods, great advances were made which were partially reversed in subsequent periods of reaction. Nevertheless, even in these periods many advances continued to be made in science and technology education.

The Russian empire had only one city with university, Moscow, when Alexander acceded to the throne, but he added more three universities: in Kazan, Khar'kov (1804), and St. Petersburg (1819). With the help of the Academy of Science, the system worked as a lever to move forward the development of science and scientific education in Russia. This model, to some extent was inspired by the Polish system, but it went beyond this because of its classical education elements.

Despite the written rules, this system did not work. No woman went to university during Alexander's reign. Social pressure was much stronger than official rules.

In the second part of Alexander's reign the cost of the Napoleonic wars became too heavy for his government to support the educational system. At the same time the tsar became more conservative and mystic. French Revolution ideas were left aside, and nationalist thought became dominant.

Nicolaus I (1825–1855) was a conservative and militarist tsar who imposed his ideas on Russian intellectual life using strong bureaucratic control. Paradoxically, in this period there flourished original literature, including writers such as Pushkin, Lermontov, Gogol, Dostoievskii, Nekrasov and Turguenev. In the sciences a similar wave of eminent scholars appeared: Lobachevskii in mathematics, Struve in astronomy, von Baer in zoology, Hess in chemistry, Lenz in physics and many others. Yet in Nicolaus' reign the reforms of Count S. S. Uvarov introduced many changes to the educational Russian system. He promoted a renaissance in the Academy of Science with the introduction of a new system of scholarships in universities. In addition, he created a tradition of excellence to evaluate student performance and strongly supported mathematical studies.

A second great period of reforms in Russian science came with the Crimea War during the reign of Alexander II (1855–1881). This war highlighted Russian technological weakness, which had been much behind Western European states since the Napoleonic period, when Russia demonstrated its power to Europe. The government concluded that with social and economic system modernization of Russia was impossible. However, educational reforms had a greater impact on the scientific system. University admissions increased significantly, but the privileges of social class implied a decrease in student participation in the applied sciences. Foreign travel for studying was again permitted, while the education of women up to the secondary level was stimulated. New rules for universities established in 1863 eliminated the majority of restrictions created by rules introduced in 1835.

Some reformers proposed that women should be admitted into universities, but this suggestion was not accepted. Instead of this, a few years later special higher-level courses were created for women, in special faculties separate from universities. In the 1860s and 1870s a remarkable generation of Russian women looked for more advanced educations in those courses or in Western Europe. This encouraged women to receive doctorates in several scientific fields. The mathematician Sofia Kovalevskaia became a leader in the field of partial differential equations. She was the first famous Russian mathematician and one of the most important since antiquity.

3.1 Great Scientists in Nineteenth Century

Pafnuty Lvovich Chebyshev (1821–1894)

Chebyshev [5] was born in Okatovo, on May 16, 1821 and died in St. Petersburg in December 8, 1894 (Fig. 4). He was descended from a minor noble family. His father, Lev Pavlovich Chebyshev, was a retired army officer who had fought in the war against Napoleon. Agrafena Ivanovna Pozniakova, his mother, had raised nine children; the youngest Vladimir Lvovich became a famous general and professor in the Artillery Academy of St. Petersburg.

In 1832, Chebyshev's family moved to Moscow, where he completed his secondary studies at home. He learned mathematics with P. N. Pogorelski, the author of many popular elementary mathematics books.

Fig. 4. Pafnuty Chebyshev (1821–184)

In 1837, Chebyshev entered the Department of Physics and Mathematics of Moscow University. Mathematics was taught by N. D. Brashman and N. E. Zernov. The first had a great influence on Chebyshev's scientific development. In a letter addressed to the latter, Chebyshev acknowledges the importance of his guidance in the classroom as well as many dialogues and profitable discussions. This letter was read in a session of the Moscow Mathematics Society in September 30, 1865. It also appeared in the first issue of *Matematichesky sbornik* (Mathematical collection) Chebyshev was one of the first members of the society, Professor Brashman was a founder and its first president.

While still a student, Chebyshev wrote *Vychislenie korney uravneny* (Calculus of roots equations) in which he proposed an iterative and original method for calculating approximately real roots of algebraic equations, y = f(x) = 0. The method was based on a series expansion of the inverse function x = F(x). In terms of the numerical results obtained, comparing the first order approximations, it is equivalent to the well-known Newton-Raphson method. In addition, his method also provides for error estimation.

In the spring of 1841, Chebyshev received his degree in mathematics from Moscow University, but continued his studies under the guidance of Brashman. He began a MSc program in 1843 and at the same time published a paper on multiple integrals theory in *Journal des Mathématiques Pures et Appliquées,* edited by the famous French mathematician Liouville (1844). Another paper about the convergence of Taylor series appeared the *Journal für die reine und angewandte Mathemati.* In 1846 he presented his MSc dissertation: *Opyt elementarnogo analiza teorii veroyatnostey* (Essay and analysis of the elementary theory of probability).

He moved to St. Petersburg University as an assistant professor. In September, 1847, Chebyshev began to teach advanced algebra and number theory. Later, he taught other disciplines including integral calculus, elliptic functions, and finite difference calculus. At this time in St. Petersburg, Chebyshev began to work with Bunyakovski on a new edition of Euler's works about number theory. This was demanded by the

Russian Academy of Science. It was published as: *L. Euleri Commentationes arithmeticae collectae*, 2v. (St. Petersburg, 1849). This project encompassed not only Euler's articles on number theory, but many archives and manuscripts provided by Academy.

Number theory drew the attention of Chebyshev. He entered deeply into it and developed congruence theory (*Teoria stravneny*) which was chosen and presented as his PhD thesis in mathematics at St. Petersburg University, May 27, 1849. He won a prize from the Science Academy for this work. In addition, his findings were extensively used, and many books propagated his ideas for a long time in Russian universities.

In 1850, Chebyshev was elected extraordinary professor in mathematics at St. Petersburg University. In 1860, he became full professor. It is important to emphasize that during this decade he wrote his famous studies on mechanisms which implied important improvements in the theory and a better approximation of functions.

These developments in mechanisms led him to Moscow University, where he increased his interest in technological problems, especially mechanical engineering. Between 1849–1851 he taught courses on applied mechanics in the Department of Practical Knowledge, a kind of engineering department in St. Petersburg University. Among his many technological concerns, Chebyshev studied the steam engine and propeller mechanisms using articulated levers. As a consequence, he began to develop a general theory of mechanisms, arriving at some analytical problems, not previously known or even studied by his contemporary mathematicians. These problems led him to new achievements related to find a better approximation of functions. We can also summarize his main contributions to theories of machines and mechanisms [6]:

- He was the founder of theory of planar mechanisms, which appears in the paper *On parallelogram* (1869) where is postulated a formula for linkage with rotational kinematic pairs. This approach is known as Chebyshev's formula.
- In 1887, Chebyshev's disciple, Pavel Somov extended Chebyshev's formula for spatial mechanisms.
- Using his method of synthesis, he created then forty new mechanisms and about eighty modifications of those, with applications in cars, motocycles and instruments.
- One of the most known and famous Chebyshev's mechanisms is the *plantigrade machine* that simulates the walking animal motion.

Chebyshev is important in the history of science not only because of his mathematical findings, but also due to the foundation of a great school of mathematics. This school is sometimes known as the *Chebyshev School* but is more frequently called the *St. Petersburg School*, because the majority of its representatives belonged to the St. Petersburg Academy of Science. Some of Chebyshev's older contemporaries, such as Bunyakovski and Ostrogradski, also taught in the mathematical school attached to the Academy. However, Chebyshev founded this school, guided it, and inspired and influenced for a long time the trends of mathematics in St. Petersburg University.

For more than 50 years the professors in the school were Chebyshev's disciples. Moreover, in addition to achieving a high academic level, the school also disseminated Chebyshev's ideas to the other Russian Universities. During this period the St. Petersburg school of mathematics became one of the most important around the world and obviously the best in Russia. The following mathematicians belonged to that school: A. N. Korkin, Y. V. Sohotski, E. I. Olotavo, A. A. Markov, A. M. Lyapunov, K. A. Posse, D. A. Grave, G. E. Voroni, A. V. Vasiliev, V. A. Stelkov, and A. N. Krylov.

4 Final Remarks and Conclusion

Before the 1917 Revolution Russian science, as a whole, lagged behind the leading countries of the West, but was in a process of development. However, in some areas and in some aspects this process was accelerated or even at the same level as the more developed countries. We can underline areas such as mathematics, physiology, astronomy, and some branches of physics, biology and chemistry where remarkable Russian scientists had demonstrated their international capacity. Names as Mendeleev, Lobachevski, Chebyshev, Kovalevskii, Pavlov, and many others progressively occupied places of prestige in the history of sciences.

After 1712, when Peter the Great has moved the capital of the Russia Empire from Moscow to St. Petersburg, this city has contributed to several areas of science and technology, founding scientific institutions and engineering schools. The two outstanding scientists, Euler and Chebyshev were chosen as the most representatives of the theories of machines and mechanisms, thus belonging to this tradition.

References

1. Anderson MS (1978) Peter the Great. Routledge, New York
2. Bernoulli D (1738) Hydrodynamics. Dover Publications, Inc., New York
3. Brooke C (2006) Moscow: a cultural history. Oxford University Press, New York
4. Carr EH (1979) The Russian revolution from Lenin to Stalin 1917–1929. The MacMillan Press Ltd., London
5. Dictionary of Scientific Biographies (2007) Brazilian edition (contraponto), Brazil, vol I, pp 459–469
6. Evgrafov AN, Andrienko PA (2015) The role of St. Petersburg scientists of XVIII-XIX centuries in the development of machines and mechanisms. In: IFToMM workshop on history of mechanism and machine science, St. Petersburg, Russia, 26–28 May 2015
7. Graham LR (1993) Science in Russia and the Soviet Union, 1st edn. Cambridge University Press, Cambridge
8. Graham L, Dezhine I (2008) Science in the New Russia: crisis, aid, reform. Indiana University Press, Bloomington
9. Kerp A, Vogeli BR (2010) Russian mathematics education: history and world significance, vol 4. Series on mathematical education. World Scientific Publishing Co., Pte., Ltd., Singapore
10. Kirchner W (1982) Siemens and AEG and the electrification of Russia, 1890–1914, Seiner

11. Koblitz AH (2013) Science, women and revolution in Russia. Routledge Taylor & Francis Group, London, New York
12. Lieven D (2006) The cambridge history of Russia, vol II: Imperial Russia, 1689–1917. Cambridge University Press, Cambridge
13. Oliveira ARE (2007) Euler's contribution to classical mechanics. In: 12th IFToMM world congress, Bésançon, French
14. Dugas R (1988) A history of mechanics. Dover Publications, Inc., New York