General Ideas of Academician V. P. Goryachkin Concerning the Construction of Agricultural Mechanics

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Abstract – The paper considers the contribution to the development of applied mechanics, namely, the creation of a new discipline, agricultural mechanics, by the Academician V. P. Goryachkin (1868 - 1935), apprentice of N.E.Zhukovskii and graduate of the Moscow University and of the Imperial Higher Thechnical School.

Key words Theory of Mechanism and Mashines, Agricultural machinery engineering, Agricultural Mechanics

1 Biographical Notes about V. P. Goryachkin

The heritage of Academician V. P. Goryachkin refers to the history of the theory of mechanisms and machines. Nevertheless, his works were the basis for the very large-scale development of the theory and practice of creating new, high-production and effective machines and systems of machines. Creation of these machines has already helped to solve many problems of the national economy and the exploration of natural laws and will be used for this purpose in the future.

V.P. Goryachkin, a remarkable scientist and theoretician of the agricultural machinery engineering, laid foundations of a new scientific discipline called Agricultural Mechanics. Goryachkin was an Honorary Member of the Academy of Sciences of the USSR and Academician of the All-Union Academy of Agricultural Sciences (VASKhNIL) [1].

Fig. 1. Goryachkin Vasilii Prokhorovich (1868—1935)

Vasilii Prokhorovich Goryachkin (Figure 1) was born in Moscow on January 29th, 1868 in a family of craftsmen.

He graduated with honors from the mathematical division of the Department of Physics and Mathematics of the Moscow University in 1890 and the Imperor's Moscow Technical School (nowadays, Bauman Moscow Technical University) in 1894. In both higher institutes, his teacher and tutor was Nikolai Egorovich Zhukovskii (Figur 2).
At the end of XIX century in Russia needed specialists in applied mechanics, in particular on agricultural mashinam. Departament of Agriculture dispatched him abroad to prepare for the academic and scientific work.

When he was on his business trips in Germany and France, Goryachkin understood that there was no actual science of agricultural machines and tools there. At that time, the science of agricultural machinery was just a description of the structure of machines and tools and a compilation of practical instructions on their usage, assembly, setting, and adjusting, containing also information on their performance and cost, the number of needed working people and moving force. The content of such a "descriptive machine building" was far from being a true scientific knowledge needed for understanding the technological principles of operation and mechanical basis of the machine construction.

After arriving from abroad in 1896, Vasilii Prokhorovich was appointed an acting associate professor at the chair of studying the agricultural machinery, tools, and engines at the Moscow Agricultural Institute (Figur 3). From the very beginning of his scientific and educational activity as a professor, Goryachkin aimed his efforts at searching for and developing theoretical principles for the calculation and construction of machines. He had to make his own way in the science. He faced a huge number of very different machines and tools of many kinds and types aimed at a wide variety of purposes. Plows, horse drives, grain binders, mowers, different threshers, separators, and many other machines, which had hardly anything in common, were a huge conglomeration of stuff that were neither touched by science, nor examined, nor even described technically.

2 The creation of "Agricultural Mechanics"

First, it was necessary to look at all this machinery from the point of view of its diversity, to carefully consider and classify different kinds of machines, to clarify main tasks of studying every type of tools and machines, and to find out fundamentals for constructing the theory and calculation methods for all of them; that is, it was necessary to identify the questions the answers to which would be a subject of the science dealing with agricultural machines and tools. Later, Goryachkin laid out the fundamentals of this new science and called it Agricultural Mechanics.

He laid the foundation for the agricultural branch of technical sciences, a new engineering speciality, and a new kind of engineer education.

Vasilii Prokhorovich was surely an outstanding specialist on agricultural machinery but the most principal merit of his was creating a philosophy of agricultural mechanics as a domain of science and technology. He was the best in both our country and the whole world in formulating
scientifically valid requirements to constructions and types of agricultural machines and to directions of explorations needed for their development.

Scientific works of Academician V.P. Goryachkin are still classical in the field of technical sciences. Apart from the development of the theory of agricultural machinery, some fundamental theoretical aspects such as the theory of masses and velocities, impact and destruction of materials, a wedge, cutting, similarity, and a general scheme of natural phenomena and processes were developed in his works. For testing machines, he created instruments used in agriculture, metalwork, and machine building: a soil hardness tester, profilographs, dynamographs, etc.

It took many years to work out and develop the agricultural mechanics, while it was necessary for Vasilii Prokhorovich to hold the course Theory of Agricultural Machines and Tools starting from the first year (Figur 4). Nevertheless, the earliest lithographic prints of Goryachkin's lections on this course appeared as far back as 1897 and all the remaining lists came out in 1898.

The Moscow Agricultural Society organized exhibitions of agricultural machines and tools in 1896, 1897, 1898, 1903, 1908, 1909, and 1910. These exhibitions were held at Butyrskii Khutor, a property of the Society, located in the vicinity of the Moscow Agricultural Institute. Goryachkin actively participated in these exhibitions since 1897, being a supervisor during tests of the machines at show. Since 1903, he was a chairman of expert commissions at these exhibitions. These exhibitions and tests of machines and tools carried out by Vasilii Prokhorovich gave him an original material for studying constructions and finding out theoretical principles of their work and structure.

The first printed work by Goryachkin, Moldboard, came out in 1898. It was written as a result of studying the shapes of working surfaces of plow bases using profilometer measurements at the 1897 exhibition. A short time later, Goryackin's small books and brochures began to come out: Different Sorts of Plows, Plows, Threshers, etc. (Figur 5). Each work clarified theoretically the structure and work of a machine; in each of the works, the author sought to identify the laws of mechanics that were responsible for the machine operation and that had to be observed while constructing the machine. Under his guidance and with his direct participation, a theory of tractor plow mechanisms was developed. Owing to this theory, raising mechanisms of national plows were higher in their characteristics than mechanisms of the best foreign plows.

In 1913, Mower, Harvester, and Binder Drawing Atlas was published (Atlas kept in the museum Goryachkina). Engineers could find in the Atlas strictly systematized and the most voluminous data characterising the then existing harvester constructions, in their totality and in the most compact and particular form. Goryachkin made up an instruction for writing the Encyclopedia of Agricultural Machine Building (he edited four volumes, 263 author's sheets). He created working models with original cuts and sections for demonstrations at studies.

This wonderful book was published in 1919 and served as a textbook at the rate of agricultural mechanics. This course is taught himself Goryachkin.

Fig. 6. V.Goryachkin "Agricultural Mechanics". M. 1919

The basic content of the book includes the description of those parts of the analytical mechanics, theory of mechanisms, theory of elasticity, and mathematics, which should be a basis when studying agricultural machines and their operational processes and constructing the theory of every kind of agricultural machines.

Goryachkin revised thoroughly the whole material and developed it deeply to resolve a special task - to make it to serve as a theoretical basis for studying agricultural machines. Many parts of his remarkable work were independent contributions to those disciplines of which some principles and laws were described by the author in his book. For example, Vasilii Prokhorovich mentioned that most tools were based on the use of a wedge. In the chapter "General theory of tools", the theory of materials failure is immediately followed by the description of a friction wedge (dihedral and trihedral) and its effect on the processed material. In this chapter, Goryachkin significantly elaborated the friction wedge theory in comparison with what had been achieved in this direction earlier.

Besides their direct targets, the books *Forces of Inertia and their Counterpoising* [3, v.1, p. 69-178; v.2, p. 107-114] and *Agricultural Mechanics* [3, v.2] achieved another important result. They illustrated to what extent the agricultural machinery was a deep, complicated, specific, and serious subject of investigation and what kind of scholarly apparatus was needed to study these machines. In particular, it was shown that some branches of mechanics turned out to be not developed well enough to master such objects as agricultural machines and tools, as well as different technological processes executed by these machines. It became clear that it was not right to consider agricultural machines as elementary instruments since these were not primitive at all.

*Forces of Inertia and their Counterpoising*, Vasilii Prokhorovich selected and layed out branches of kinematics and dynamics of mechanisms for studying forces of inertia in mechanisms in his book of agricultural machines. He also described the corresponding methods of kinematic and dynamic analysis with regard to specific features of mechanisms in agricultural machines. In general, when characterizing the book, it may be said that Goryachkin selected and adapted the scholarly apparatus for studying agricultural machines, constructing their theory and calculation methods. Meanwhile, only the the range of questions concerning the calculation of velocities, accelerations, forces of inertia, as well as counterposing these forces, was considered in the book. "Agricultural Mechanics" by Goryachkin was translated into English, Arabic, and Bulgarian.

In the late 1932, Goryachkin began to compile a multivolume collection of works, the *Theory and Calculation of Agricultural Machines*. He managed to prepare for print four volumes and he saw only one of them to have come out of print.
Further Goryachkin's works were devoted to the development of the theory of agricultural machinery. As a result of his long efforts, he managed to arrange the first machine-test station at his department that became a center of scientific work and a managerial basis of his further activity. This machine-test station was actually a scientific research institute where intense scientific explorations were carried out under the guidance of Goryachkin (Figure 7).

![Fig. 7. The Machine-test station. 1913.](image)

3 Teacher and a organizer of science

Vasilii Prokhorovich Goryachkin received a rank of an associate professor in 1899 and became a full professor in 1913. Since 1913, he was in charge of the machine-test station, a project of his. Goryachkin brought into being a branch of the Engineering Department (1915) and the Department of Agricultural Machine Building (1928) at the Moscow Agricultural Institute.

As an outstanding scientist and social activist, V.P. Goryachkin was elected and appointed a principal of the Petrovskaya Agricultural Academy (1919-1922), the former Agricultural Institute. He was a director of the All-Union Institute of Agricultural Mechanics since 1929. He organized a council under the All-Union Institute of Mechanization of Agriculture.

After organizing the All-Union Academy of Agricultural Sciences (VASKhNIL), Goryachkin became an Academician and later an Honorable Member of the Academy of Sciences of the USSR. V.P. Goryachkin was a very modest man. When he was nominated for the title of a full member of the Academy of Sciences of the USSR in 1932, he refused to be a candidate: he reckoned that he had not made enough for becoming an academician. He was elected an honoured Academician of the Academy of Sciences of the USSR. Here is the text from his application (Figure 8):

![Fig. 8. "To the permanent secretary, Academy of Sciences. Since I cannot recognize my works to be deserving of the Academy, I strongly object to be a candidate for the Academy. Professor V.Goryachkin. 26.02.1932"](image)
In 1935, the Academician Goryachkin was awarded the Order of the Red Banner of Labour. He was awarded the title Honoured Master of Sciences and Engineering of the Russian Soviet Federated Socialist Republic. The Moscow State Agricultural University and the All-Union Institute of Agricultural Mechanics were named after him. He died in Moscow on Sept. 21, 1935. In Machine-test station was opened Memorial Museum V.P. Goryachkina (Figure 9).

Fig. 9. Memorial Museum V.P. Goryachkina

After Goryachkin's decease, seven volumes of his collected works were published [3]. On the 100-th anniversary of his birth in 1968 was published Collected Works in three volumes [4] and was translated into English [5].

Almost every theoretical work that appears abroad mentions the name of V.P. Goryachkin as an unquestioned authority in the field of agricultural mechanics.

The role of Vasilii Prokhorovich was not restricted to the creation of a new scientific discipline. He not only left behind the scientific works but also brought up a whole scientific school of apprentices and followers. Among these were: V.Yu. Gann, the author and constructor of the Rostselmash project, the corresponding member of the Academy of Sciences of the USSR; the academicians I.I. Artobolevskii and V.A. Zheligovskii; the VASKhNIL academicians N.D. Luchinskii and I.F. Vasilenko; many doctors of sciences, candidates of sciences, and engineers. The scientific school created by V.P. Goryachkin affected the development of the agricultural machine building in other countries. Many his foreign followers called themselves his apprentices, although they never met Vasilii Prokhorovich personally. Thus, it was in no way fortuitous that Dr. Giordano, the professor of the Milan State Higher Engineering Institute, wrote to his Russian colleagues: "With a deep emotion I received, along with two volumes of the Theory, Construction, and Production of Agricultural Machines, sad news about the decease of Mr. Professor Goryachkin. You have lost the remarkable scientist whose works will attest his great significance. I have lost a great friend, very kind, who was attentively watching my work, who inspired me and helped me from the first steps in activity of the experimental institute of agricultural mechanics I founded in my country. Glory to his memory".

4 Goryachkin and His Idea in the Theory of Mechanisms and Machines: Human - Machine - Environment

When trying to formulate the ideas, which were posed and developed by V.P. Goryachkin in his works, in terms of modern concepts, the set of these ideas can be determined as a global problem: Human - Machine - Environment.
In our century of scientific and technological revolution, this problem is developed on the basis of four general scientific directions: biomechanics of working processes, mechanics of machines, theory of machine control, and theory of technological processes.

A specific property of most agricultural machines, including modern ones, is the fact that a human operator is needed to control these machines. Many manual tools are applied up to present, especially in gardening, horticulture, vineyard processing, and cultivation of specialty crops. Starting from his very early works in agricultural mechanics and theory of agricultural machinery, Goryachkin explored working movements of a human operator in search for optimal forms of these movements, which would minimize the burden on arms and legs of an operator. He examined also aspects of comfortability, convenience in the machine control, and questions connected with service zones, as these are called nowadays.

While solving these questions, a problem arose how to determine interrelationships between required operator movements and human phisiology. And Goryachkin introduced the course called Theory of Live Engines into the curriculum on agricultural mechanics. The course was given by academician A.V. Leontovich, the outstanding physiologist. He considered some questions of human physiology, which are developed now as biomechanics of working movements of humans and animals. Leontovich set forth also the physiology of humans and animals paying special attention on the role of muscles of nervous system and brain in generating and controlling working movements. Further, energy characteristics and adaptive properties of live engines were considered to determine their ability to adjust to different working conditions, in particular, to find out an effect of the position of an operator relative to the machine (upstanding or sitting positions, moving nearby the machine, etc.).

In 1930s, V.P. Goryachkin was eagerly engaged in studying the theory of manual tools. He carried out his explorations together with the Central Institute of Labor, involving his apprentices in the work. For example, I.I. Artobolevskii determined mechanical parameters of hammers, mattocks, spades, scythes: their masses, barycenters, moments of inertia, centers of oscillation, etc. Simultaneously, more complicated tasks were solved, for example, how the position of a barycenter of a human operator affected operator's movements. These tasks were solved using the simplest, although unique at that time, experimental installations. All these works were based on remarkable results obtained by Goryachkin in the kinematics and dynamics of manual tools, the theory of impact processes produced by these tools, etc.

The organization of works on standartization of tractor plows was carried out at that period of time too. Vasilii Prokhorovich requested his friend, professor N.I. Mertsalov, who was reading courses of the theory of mechanisms and machines and the kinematics of spatial mechanisms at the Moscow Agricultural Institute (since 1921), to carry out the study of kinematics and kinetostatics of elevating mechanisms in tractor plows. N.D. Luchinskii, who became an Academician of VASKhNIL afterwards, and I.I. Artobolevskii, a future Academician of the Academy of Sciences of the USSR, were also involved in these works. N.D. Luchinskii defended his graduation project called American Thresher, in which the problem how an operator could control a machine using handles was considered. The same problem of the relations between a human operator and a machine arose when designing new reaping machines (these questions were examined by professor P.I. Borodin and I.I. Artobolevskii under the guidance of V.P. Goryachkin).

A machine is the second item of the Human - Machine - Environment problem. Goryachkin considered different aspects of machines in his works, focusing mostly on the study of the mechanics of machines. Firstly, his works on kinematics and dynamics of plane and spatial mechanisms should be mentioned here. Vasilii Prokhorovich often said: "Mechanisms are flowers of technics". He paid huge attention to the development of the theory of mechanisms. Goryachkin was the first to have posed the question on the necessity of developing the methods of kinematic and dynamic studies of spatial mechanisms for agricultural machinery. He encouraged professor N.I. Mertsalov to create and read the course called the Theory of Spatial Mechanisms. Stimulated by Mertsalov's lecions and on the recommendation of Goryachkin, Artobolevskii also devoted himself
to the theory of spatial mechanisms. He began with studying mechanisms used in agricultural machines and then got interested in other machine building branches.

Goryachkin studied many different aspects of mechanics of machinery: kinematics of mechanisms, dynamics of machines, theory of oscillations in machines, theory of control over machines and technological processes.

The common thread running through all his works was an idea that mechanics of agricultural machinery could not be considered without taking into account the technological process. In this context, there appeared his papers devoted to cutting and reversing furrow-slices, works on the theory of cutting herbs and grasses, fragmentation of agriproducts, etc., connected with specific technological processes involving the environment that was processed using a tool or a machine.

The necessity of considering the theory of agricultural machinery in terms of the Human - Machine - Environment system, an extremely profound conception of Goryachkin, has become widely recognized today, in the current theory of machinery. Indeed, all the three factors are taken into account when designing separate automatic machines and systems of automatic machines (automated sequence machine systems), machine tools, and other programme-controlled machines, as well as industrial robots and walking machines.

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