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D. Yu. ZHURILO, PhD (tech.), associate Professor
orcid.org /0000-0002-0015-9412
E-mail: zhurilo.dm@gmail.com
M. V. GUTNYK, PhD (hist.), associate Professor
ORCID: orcid.org / 0000-0002-2723-2755
E-mail: marinazoza@gmail.com
A. G. ZHURILO, PhD (tech.), associate Professor
orcid.org /0000-0003-4084-4622
E-mail: zhurilo.alla@ukr.net

National technical university «Kharkiv Polytechnic Institute»
2, Kirpicheva Str., Kharkiv, 61002 Ukraine

GEORGE BOTHEZAT AND HIS CONTRIBUTION INTO THE WORLD AVIATION AND ASTRONAUTICS

The article dedicated the life and scientific way of George de Bothezat, the first Doctor of Sciences in the field of aviation. Together with Nikolay Zhukovsky, Igor Sikorsky, Stephen Timoshenko, Alexander Fan-der-Flit, and Alexey Lebedev, he was one of the organizers of the Air Fleet of the Russian Empire. He is the author of various inventions: gyroscopic sight and other types of aviation equipment. We analyze works by G. Bothezat on the impulse theory of propellers. In particular, the scientist derived formulas for ensuring the flight stability of airplanes and helicopters. He developed training ballistic tables, which allowed making corrections for the speed of the flight and the direction of the wind.

We briefly described a biography of G. Bothezat, focusing on the student period of his life in Kharkiv, Ukraine, and the reasons for G. Bothezat's departure to the United States in 1918. It is stated that it was there that his talent as a designer and creator of helicopters of the original system was disclosed in the best way. In 1922, George Bothezat obtained the financial support of the American government to build a workable helicopter model without prototypes and experiments, only based on the results of calculations. The reasons why G. Bothezat did not manage to achieve the launch of the serial production of helicopters are analyzed. We also mention the activities of the company founded by G. Bothezat, which was engaged in the production of fans of a new type for the US Navy. The Bothezat system fans were installed at the Rockefeller Center in New York as well as in American tanks. It is emphasized that I. Sikorsky also used the works of G. Bothezat in his research. It is stated that the flight trajectory calculated by G. Bothezat in air and airless space was used in the development of the American program of a manned landing on the Moon using the "Apollo" system.

Keywords: *Personalities: George Bothezat, Igor Sikorsky, Nikolay Zhukovsky; helicopter, history of aviation, Kharkiv Institute of Technology.*

INTRODUCTION

One of the main achievements of world astronautics is the flight and landing on the Moon. The implementation of the ideas of science fiction writers took place in July 1969. This result was not immediately obtained: several lunar stations and ships failed. One of the reasons for this was the incorrectly chosen flight trajectory. To calculate the correct trajectory, the works on the study of flight trajectories in air and airless space found in the archives of NASA

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were applied. In particular, it was these developments that were used in the preparation of the American program for a manned landing on the Moon by the "Apollo" system. The author of these calculations was George Alexandrovich Bothezat [3].

Despite the significance of scientific discoveries, the name of this scientist is still little known in Ukraine. In the scientist's homeland, in Moldova and Ukraine, there is not a single memorial plaque to G. Bothezat. The authors failed to find any publications in Ukraine similar to the fairly thorough monograph by V. Mikheev [15], dedicated to the figure of George Bothezat and published in the Russian Federation. Because the authorship belongs to a Russian, the text itself has an ideological slant, and it is emphasized in it that Bothezat was a Russian scientist, referring to his scientific activity during his life in the Russian Empire. Also, the period of George Bothezat's studies at the Kharkiv Technological Institute was out of the author's attention, namely his teachers, who in one way or another influenced the formation of his personality during his student years.

Some information about the scientist is contained in the review article "Pioneering works of Kharkiv technologists in the field of aviation technology" by Nazarenko and Pavlova [17, p. 45–46]. It is only mentioned here that G. Bothezat was a graduate of KhTI and defended his first doctoral dissertation in the field of aeronautics.

Numerous photos of the designs developed by Bothezat are included in the Smithsonian National Air and Space museum album [3] and are posted on American aviation websites. In particular, the website of the Association of the United States Army posted an article by Bruce H. Charnov "The Flying Octopus': The Forgotten Beginning of Army Helicopter Aviation" [12]. The author describes in some detail the tests of the "H-1" helicopter and the failures of G. Bothezat during its tests. However, Bruce H. Charnov noted: "The de Bothezat helicopter cost too much, performed too little and was too complex to be reliable. While it was not the first military project to go over budget and promise more than it delivered, it was the first rotary-wing project to do so".

An article "The Flying Octopus" [10] by C. V. Glines is available on the Air Force magazine website. In this publication, the work of Bothezat in the United States in the early 20s of the XX century is also considered. The author talks about Bothezat's work in Dayton and notes: "After de Bothezat arrived in Dayton, Maj. Gen. Mason Patrick, Chief of the Air Service, authorized a contract with him, without open bidding, for the construction of a helicopter. This unusual procedure was authorized because no other qualified bidders existed. However, de Bothezat first had to produce a written proposal to make the transaction legal". The information on the "Octopus" helicopter testing is also provided.

Bogdan Boreschievici, a researcher from Romania, in his publication [2, p. 112–120], analyzes the ethnological origin of the Bothezat family, and he posted the works by George Bothezat since 1913. However, in this article, the researcher ignores the Ukrainian period of the scientist's life.

The purpose of the publication is to conduct a comprehensive historical and scientific study of Professor George Bothezat's contribution to the world development of aviation and astronautics. Based on archival materials, in particular, the personal file of George Bothezat, we intend to reveal the formation of Bothezat, as a scientist, to show the socio-political conditions in which the formation of his scientific worldview took place in his student years.

SELECTED FACTS OF BIOGRAPHY

The future scientist was born on June 7, 1882, in St. Petersburg in a family of hereditary nobles of Moldavian origin [21, p. 7]. The literal translation of the surname from the Moldavian language meant "baptized". The boy's father, Alexander Ilyich, served in the Ministry of Foreign Affairs of the Russian Empire. The family lived in Paris until the death of Alexsander Ilich in 1900.

In 1902, George graduated from the Chisinau Real School and tried to enter the St. Petersburg Technological Institute of Emperor Nicholas I. The applicant passed the exams successfully but did not score the necessary points for admission: the competition in the capital's universities was high. With such a number of points, it was possible to enter other institutes. George chose the Kharkiv Technological Institute of Emperor Alexander III (KhTI) [21, p. 2].

At that time, the Institute had two departments: Mechanical and Chemical. At the Mechanical de-

Fig. 1.George Bothezat, 1905, from the open sources

partment, engineers were training in a wide variety of specializations: from metal cutting and mechanical engineering to construction and electrical engineering. The young man became interested in electrical engineering. This science at KhTI was taught by the leading figures of Russian engineering of that time: Professor Alexander Pogorelko, teachers Mykola Klobukov and Pavlo Kopniaev, laboratory assistant Alexander Ilyev [12, p. 157; 22, p. 1262–1263].

George Bothezat studied not just well, as it is written in his personal file, "with impeccable behavior, he showed excellent success" [21, p. 36]. In Bothezat's record book, there was only one grade: "excellent" in all disciplines! Painstaking and serious work was behind such success. The training program for an engineer in Russian universities was extremely varied. It should be mentioned that within the 5-year educational period part of those who entered KhTI, no more than a third of students managed to finish it. (For example, from 101 entrants to the KhTI's Mechanical Department in 1908, only three graduated from the Institute in 5 years [22, pp. 33–34]. Next year from 98 entrants, none of them graduated from the KhTI in 5 years [22, pp. 35–36]).

But, in the level of knowledge and diversity of scientific and applied interests, Ukrainian engineers far surpassed their counterparts around the world. But by the end of George Bothezat's third year of education, in 1905, the KhTI of Emperor Alexander III was closed due to "Schiller's history" and the Russian Revolution.

Many teachers negatively assessed the Director's administrative pressure on students and faculty. As a result, the dismissals began, in particular, of two professors, two teachers, two laboratory assistants, and later of others. In total, 24 teaching staff remained at the institution [23, p. 87]. 239 students were fired from KhTI for participating in the riots, 25 of them without the right to enter any other educational institution [24, p. 8]. That was the only year in the history of the Institute when no one engineer graduated from this institution [29, p. 58].

G. Bothezat believed that the Russian Empire should be transformed, not through shaking the air at rallies and shooting at windows, but through selfless work. An attempt to transfer to the capital's institute did not succeed: turmoils seized St. Petersburg. Not wanting to waste time, the student turned to the institute administration for permission to "go abroad to continue his studies".

At the end of August 1905, he left for Belgium (Fig. 1). In Liege, he graduated with honors from the Electrotechnical Institute of Montefiore, and in 1908 returned to his homeland with a diploma in electrical engineering. On the one hand, an engineering degree almost guaranteed a well-off future. On the other hand, foreign diplomas were not considered prestigious: the course of study in Russian institutes was more extensive than in foreign ones. Not wishing to lag, G. Bothezat graduated in 1908 with honors from the Kharkiv Technological Institute. The list of graduates of the Institute says: "Bothezat Georgy Alexandrovich (with honors), foreign engineer" [22, p. 33]. At KhTI, Bothezat completed a graduation project on the design of a power plant. In the same 1908, the former teacher of Georgy at KhTI – the Holy Father Vasyl Dobrovolskyi baptized Pavlo – the first-born of Lidiia Alexandrovna and Georgy Alexandrovich Bothezat [25, p. 209].

After receiving his diploma, Georgy Alexandrovich at once became an intern at the Göttingen and Berlin universities. There he was going to stay for two years. In Göttingen, G. Bothezat was lucky – he had the opportunity to listen to lectures by one of the

founders of world aerodynamics, Professor Ludwig Prandtl, and then under his leadership to engage in research work. But, politics intervened in the work of the engineer. Relations between Germany and Russia became more and more complicated. That began to affect his work, and in 1910 G. Bothezat moved to France (Russia's military ally in the Entente). In this country, Georgy Alexandrovich began to use the prefix "de" to his surname and signed all his printed works "de Bothezat". In democratic France, the ancient nobility was still looked upon with respect. True, the prefix "de" usually indicated the presence of a castle, identical to the surname of a nobleman. Of course, there is no Bothezat's castle either in Russia or in Moldova.

G. de Bothezat continued his work on aircraft flight dynamics at the Sorbonne. The aerodynamic laboratory of the university was well equipped: the leaders of the Sorbonne did not spare money for it and did not hide anything from their Russian colleagues. France has long sought to have Russia as an ally. Russian military agents also contributed a lot to this. The most famous of them was Count Aleksei Ignatiev.

At that time, aviation was only in the process of formation. Practical research was significantly ahead of theoretical one, and scientific ideas about many classical flight phenomena have not yet existed. For the first time, G. de Bothezat decided to use the accumulated theoretical knowledge of the dynamics of objects movement. It should be mentioned that the scientist could do similar research in Russia.

But the Russian bureaucracy could drive anyone crazy. Paul Painlevé himself, an academician, a world-renowned scientist, invited the Russian engineer to study the problem of application of classical knowledge in the theory of object dynamics to aviation problems, which he had long been interested in. As a result of two years of research at the Sorbonne, G. Bothezat, under the guidance of P. Painlevé, prepared and in 1911 successfully defended his thesis on the topic: "Study of the airplane stability". The book was written in French, and it was divided into two parts. The first was "Les Forces Agissantes sur L'Aeroplane", and the second was titled "Le Probleme General de la Stabilite de L'Aeroplane". The candidate considered his main goal: "a mathematical analysis of the general phenomena of the stability of an airplane with the derivation of necessary and sufficient conditions for its equilibrium and the study of the possibility of fulfilling them to a degree sufficient for practice" [10]. This was the first doctoral dissertation in aviation in the world! Bothezat was one of the first who divided the system of equations of airplane motion into equations of angular motion around the center of gravity and equations of linear motion of the center of gravity of the airplane and then investigated them separately. This approach is still used today as a first approximation to the analysis of aircraft stability. The main conclusion of the dissertation was one about the need to equip the airplane with an automatic stabilizing device.

Of course, G. Bothezat's work, like any other dissertation, had several shortcomings. The father of Russian aviation, Nikolay Zhukovsky, put attention on them, but he also pointed out the undoubted advantages of the work. G. A. de Bothezat's dissertation on the topic "Study of the airplane stability" is the first work in the world devoted to deep and complex mathematical research on this issue, significantly ahead of all previous ones in this area.

Botezat can rightfully be considered one of the founders of the science of aircraft flight dynamics. N. Zhukovsky positively assessed the work of the young scientist as a whole: "Bothezat, in his dissertation on the stability of an airplane, gave a good-looking geometric method for dynamic stability analyzing" [28]. Later Professor N. Zhukovsky, in his educational course "The theoretical Foundations of Aeronautics", referred to the calculations of George Bothezat.

At the end of the summer of 1911, after defending his dissertation, the young doctor of mathematics returned to Russian Empire. He went to Petersburg, where the main aviation institutions of the Empire were concentrated. But G. Bothezat's plans for teaching and for obtaining the title of professor did not come true. There were many qualified scientists in Petersburg, and it was not easy to become one of them. To obtain in Russia the title of not only a professor but at least an adjunct professor, it was necessary to submit a significant number of works of a high professional level to the Council of the university. It also required many years of teaching experience. To have only a dissertation was not enough. In 1911, the Polytechnic Institute of Peter the Great was the only

educational institution in Russia that prepared certified aeronautical engineers. G. Bothezat was offered to give several trial lectures there. On December 20, 1911, at a meeting of the Council of the Institute, G.A. Bothezat was elected to the position of a teacher "for hire" in the aeromechanics course. It was a temporary position, as the teacher was re-elected every year, but it was also a great success.

In addition to teaching, G. Bothezat also worked in the aerodynamic laboratory of the Polytechnic Institute. In the laboratory, he took part in the research of some parts of the C-6B airplane designed by I. Sikorsky [20]. In September 1911, G. Bothezat received a Safety Certificate (Priority Certificate) no. 49706 for "Automatically absolutely stable airplane".

In September 1912, the S-6B became the winner of the military airplane competition. Then, Igor Sikorsky's "Russian Vityaz" airplane model and the designer's masterpiece "Ilya Muromets" airplane model were tested in the wind tunnel. For today, aviation historians pointed out that the rapid-fire cannon was installed on this world's first passenger airplane for the first time. And they emphasized that among almost a hundred such airplanes that took part in World War I, only one was shot down. Of course, in the creation of the first multi-engine aircraft, there was a lot of work of G. Bothezat too, because he advised I. Sikorsky in the problems of flight dynamics.

Despite his fruitful scientific and pedagogical activity, G. Bothezat could not wait for the Professor's rank. In early 1914, Bothezat applied to the Don Polytechnic Institute with a request to provide him with work. Soon he received an invitation to Novocherkassk with the appointment of an extraordinary professor and an offer to start work in the 1914/1915 academic year.

Brilliant prospects opened up before him to head the creation of the third (after Moscow and St. Petersburg) scientific aviation base in the Cossack capital. G. Bothezat arrived in Novocherkassk and immediately became actively involved in the educational and scientific processes of the established institution. Soon, an introductory lecture by G.A. Bothezat "The Great Law of Inertia" was published in the Bulletin of the Alekseevsk Don Polytechnic Institute [4]. It was materials of the lecture he had read to first-year students in the fall of 1914.

Soon, G. Bothezat received the title of an ordinary professor and the corresponding high rank of State Councilor.

The outbreak of World War I messed up all the grandiose plans. At the end of 1915, G. de Bothezat returned to the northern capital, while his position and rank at the Novocherkassk Polytechnic were retained. Soon, the Head of the Training Department of the Ministry of Trade and Industry, to which all polytechnic institutes were subordinate, received a petition from the Head of the Air Force Directorate (AFD) on the permission of G.A. Bothezat to join the Technical Committee, because he was the most appropriate for the position of "specialist in the theory of aeronautics" [15, p. 43].

In addition to George Bothezat, Professors Stephen Timoshenko, Alexander Fan-der-Flit, and Alexey Lebedev were approved by the members of the Technical Committee of the AFD. A commission headed by A. Fan-der-Flit, consisting of professors N. Zhukovsky, G. Bothezat, and S. Timoshenko, engineers Vetchinkin, Lukyanov, Tupolev, Florin, and other scientists, developed the first aircraft Strength Standards in the Russian Empire [19, p. 241].

In 1916–1917, G. Bothezat and S. Timoshenko, for the first time, organized comprehensive strength tests of aircraft parts and components, as well as aviation materials, in the mechanical laboratories of the Central Scientific and Technological Laboratory and Petrograd university. To determine the stresses in the wing bracing of aircraft, G. Bothezat used his tensiometers, which were ten to fifteen years ahead of the methodology of foreign researchers.

G. Bothezat becomes an authoritative scientist: I. Sikorsky, listing the most prominent figures of Russian pre-revolutionary aviation science in his work "Air Way", put G. Bothezat in second place after "the father of Russian aviation" N. Zhukovsky.

George Bothezat's huge contribution to the victory in World War I was the creation of bombing tables for all types of airplanes of that time. Understanding well the resource intensity of the technical component of his work, Georgy Aleksandrovich was very careful about state money. So, in the spring of 1916, Bothezat, the first in the world, developed formulas for the preliminary calculation of the cost of aviation products and the payback of aircraft manufacturing enterprises.

Only in 1917, the scientist has got the title of Professor of the Petrograd Polytechnic Institute, which he had long deserved. Before the war, Georgy Alexandrovich wrote and published the book: "Introduction to the study of the stability of airplanes" (SPb., 1912) [3]. According to the results of his work in the Technical Committee, the books "Study on the phenomenon of the blade rotor operation" and "The theory of a flat-radial blade propeller" were published too (Pg., 1917) [5, 6]. Named books became the most important contribution to aviation science during these years. From a single point of view, all propeller operating modes were analyzed by the scientist. The impulse theory of Bothezat propellers was developed in 1916 and was highly appreciated by both domestic and foreign experts. During all his future life, Georgy Aleksandrovich was engaged in its improvement.

Under his supervision, gyroscopic sight and other types of aviation equipment were built, and airplanes for various purposes were designed. Since 1915, Bothezat's ballistic tables have been successfully used in aviation units, which made it possible to make corrections for flight speed and wind direction. The first airplane designed by G. Bothezat was built in October 1917 [15, p. 81]. The revolution in October interrupted the construction of other machines by engineer G. de Bothezat.

Namely, thanks to the impulse theory of propellers, G. Bothezat was able to derive formulas for ensuring the stability of the flight of not only an airplane but also a helicopter. According to the designer's idea, four propellers, installed in pairs longitudinally and transversely (rhombus) and also inclined relative to each other, were supposed to provide static stability. It should be noted, that the scheme turned out to be not only working but today it is widely used in practice in quadrocopters and drones. And their small size and weight significantly complicate the stability of their flight. But, thanks to the technical genius of George Bothezat, the problem of the stability of such aircraft has been successfully solved.

So, in 1917, G. Bothezat managed to develop the basic methods of creating a flying helicopter. Employees of the aviation department of the DECA plant (today it is Motor Sich JSC), under the leadership of G. Bothezat, began to design parts and components of the apparatus. It was planned to complete the assembly of the helicopter by 1918.

But the Bolshevik Coup took place. The first thoughts of G. Bothezat, like many Russian intellectuals, were that this revolution was temporal. Among the new leaders were good acquaintances: his former students, colleagues at work, and social activities. However, as events have developed, Bothezat's hopes for a new authority remained less and less.

Illiterate people made their way to the management of the industry and the Armed Forces. At the end of January 1918, the scientist was officially dismissed from the Technical Committee. The Bolsheviks mockingly recommended to G. Bothezat to find another state for himself to apply his remarkable abilities and even provided him with a document exempting him from any obligations to Russia: "We hereby certify that there are no obstacles on the part of the AFD for Professor G.A. Bothezat entering into agreements with the Allied authorities regarding the use of his discoveries and inventions". Other members of the Technical Committee received the same paper. Outstanding scientists and patriots of Russian aviation were left without means of survival.

Institutes did not work, laboratories were looted, and factories were closed. Gangs of drunken sailors roamed the streets of Petrograd, killing everyone they didn't like. The Red Terror began, hunger, cold, and unemployment. Unfortunately, G. Bothezat had nowhere to use his talents under the new government. Throughout Russian history, most scholars have either died or emigrated.

G. Bothezat received invitations from diplomatic representatives of several countries with a proposal to continue his work abroad. The US naval attach was persuading more than others, and this was not surprising. Military aviation in America was in its beginning, and research on flight theory was in its initial stage. Initially, G. Bothezat moved from the northern capital to Odessa, closer to his estate and the main airfield that was in the process of construction.

After Odessa had been captured by the Austro-Hungarian troops, at the invitation of the King of Romania, Bothezat visited the temporary capital of the country, Iasi city, where he made reports on various problems of aviation. Local officials promised "mountains of gold" to the professor and persuaded

him to stay in the "historical homeland", but to no avail [15, p. 91].

Having sold all his property, G. Bothezat returned to Petrograd. The American naval attaché and contacts in the Bolshevik government helped to obtain permission to travel abroad. In May 1918, G. de Bothezat sailed on a British warship from Arkhangelsk. He managed to take out not only all his scientific works and working papers but also most of his technical library. Together with him was his faithful assistant Ivan Yeremeev.

The journey to the USA took two weeks. In the USA, G. de Bothezat was met by representatives of the oldest and most prestigious higher technical institution in America, the Massachusetts Institute of Technology. They immediately invited a Russian professor to read a series of lectures. At the same time, the scientist began to teach at Columbia University in New York.

In the United States, the most prestigious universities invited G. de Botezat to visit them. In 1919 he was elected as a professor of the University of Chicago, and a few years later – of Michigan one. After his arrival to the United States, Georgy Alexandrovich again changed his surname to "de Botezat" and wrote it in such a way for the rest of his life.

Three weeks after arriving in the United States, de Bothezat was invited as a scientific advisor on aerodynamics to the newly formed center of American aviation science – the National Advisory Committee for Aeronautics, or, for short, NACA. The US government appropriated $ 5000 to the scientist, a considerable sum at that time, to continue the work begun in Russia, primarily on the theory of propellers [15, p. 103].

Surprisingly, Russian pre-revolutionary science was ahead of American one in many areas for many years. The majority of Russian emigre scientists began their scientific activities overseas with the reprint of their works, published in their homeland in the previous years. Reprinted in English, Botezat's "impulse theory" made a stunning impression on American and European aerodynamics. They were surprised: it turned out that "wild Russia" had not only advanced aviation technology but also science.

The knowledge and natural talent gained in the Russian Empire allowed de Bothezat to quickly ascend to the Olympus of American science. However, it was not so difficult because the general level of training of American engineers was low. Another outstanding Ukrainian scientist S. Timoshenko, who arrived in the USA a little later, wrote in his memoirs: "Thorough training in mathematics and basic technical subjects gave us a huge advantage over the Americans [26, p. 238].

Later, when I became more familiar with the setting of education in America, I learned that insufficient requirements in mathematics begin in high school. An American graduating from the high school knows no more in mathematics than what is taught in the first four grades of Russian real schools" [26, p. 241].

It should be emphasized that after signing a memorandum on the prospects of helicopters, in 1921 the US Congress appropriated the astonishing sum of $ 200 000 for work on the project. G. de Bothezat was hired as acting chief of the Engineering Division's Special Research Section at an annual salary of $ 10 000 [10]. (For example, a Ford car in those years cost about $ 250).

The government specified that G.de Bothezat had to prepare "drawings and data for the design, construction, and control of the helicopter flight tests". In turn, the government had to provide engineers, materials, equipment, hangar areas. When the Engineering Division received the first set of drawings and computations from G. de Bothezat, he was to receive $ 5 000. When the machine was fully constructed, he would receive another $ 4 800. If it actually left the ground, climbed to 300 feet, and returned to its takeoff point without mishap, he would receive further payments totaling $ 20 000. The craft was to be ready for flight by January 1, 1922 – that is, in seven months [10].

To keep the curious away and allow G. de Bothezat and his assistants to work unmolested, the project was given "top secret" status. Work began in a tin-roofed hangar. When the machine began to take shape and outgrew the hangar, a wall of canvas was erected outside to enclose it from view.

Engineers assigned to work with G. de Bothezat enjoyed the task, despite the Russian's angry outbursts when things didn't go his way. He hovered over their workbenches, watching them turn his drawings

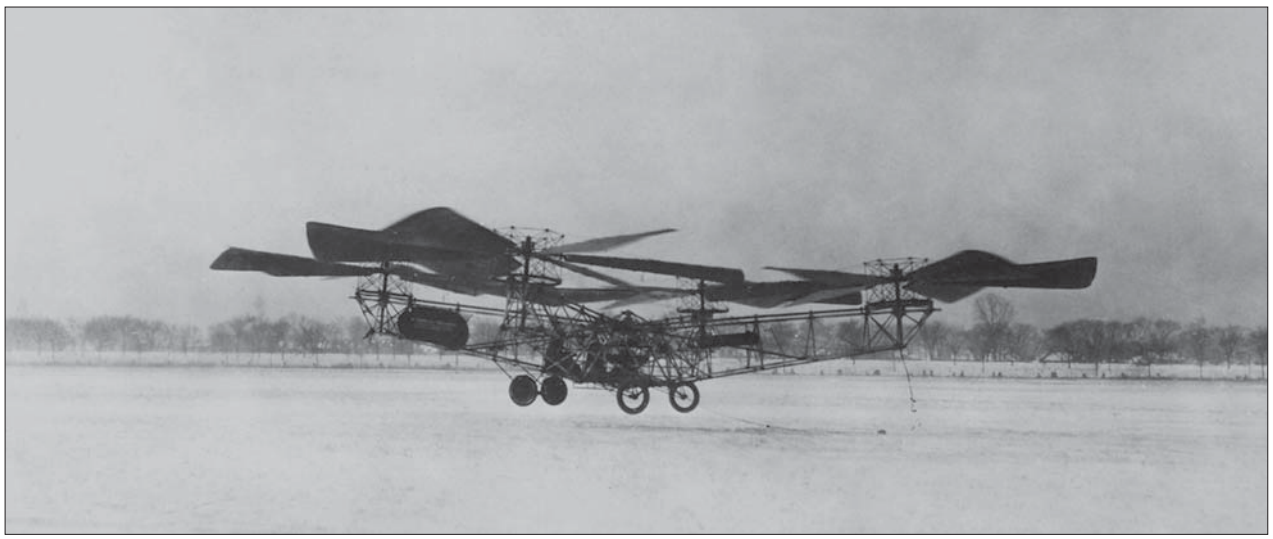

Fig. 2. Bothezat's helicopter "Flying Octopus", 1922, USA, from [12]

into strangely shaped pieces of metal. He spent his waking hours tinkering, figuring, and writing furiously. There were many problems. It is interesting that G. de Botezat, himself an ascetic man, was in great need of money because he supported several families of scientists who had immigrated to the United States but had not yet found a job.

Toward the end of 1921, G. de Bothezat realized he could not meet the deadline and pleaded for more time. He got an extension, and he and his assistants worked through the winter, spring, and summer. By the fall of 1922, the Air Service's first helicopter was near completion. On December 18, 1922, the machine was ready for the world to see. It was the first helicopter on the planet capable of manned, stable, and controlled flight! [10, 14, p. 29]. The first flight of the new helicopter lasted less than two minutes, but it was a huge leap forward in world helicopter engineering.

After all, when it comes to the history of helicopter construction, Paul Cornu using the ideas of Leonardo da Vinci, created the first helicopter capable of lifting a person but succeeded in remaining airborne for about 20 seconds at a height of 30 cm on November 13, 1907. Thus it was he who was officially recognized as having made the first free flight [16, p. 12]. Later, P. Cornu improved his achievements, but he failed to achieve a stable and controlled flight. It must be said that Bothezat's helicopter differed significantly from the later helicopters of the classical scheme. It was a giant quadcopter with propellers over 8 meters in diameter and a 180 hp engine. The Americans nicknamed Bothezat's helicopter "Flying Octopus" (Fig 2). In 1922–1923, Bothezat's helicopter made more than 100 flights. On January 23, 1923, it left the ground with two people aboard and lifted a payload of 450 pounds (~204 kg) to a height of four feet (~1.2 m). In April 1923, it lifted four men off the ground (Fig 3) [27, p.13].

Subsequently, Igor Sikorsky created in 1940 the first helicopter of the classical scheme: with one main propeller and with a tail propeller. The overwhelming majority of helicopters are built today according to this scheme.

The four-rotor scheme has not become widespread in the creation of manned helicopters, but now it is very actively used for unmanned aerial vehicles! All current drones and quadcopters are the embodiment of George de Bothezat's ideas.

The flights of the Flying Octopus were followed not only by the public but also by officials. Among them were Herbert Hoover – Minister of Trade and the future President of the United States; General William Mitchell – founder of the United States Air Force; Newton Diehl Baker – US Secretary of War at the time.

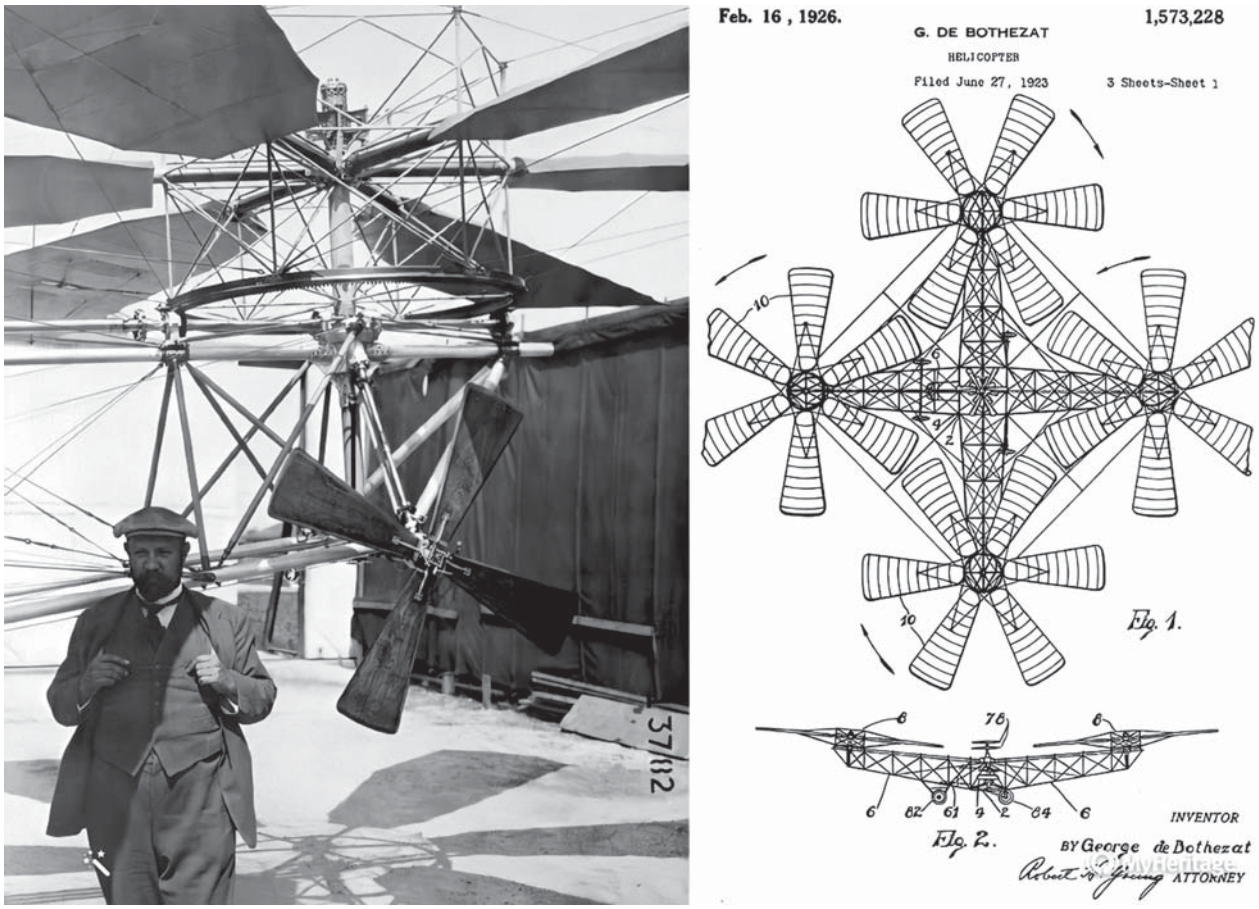

Fig. 3. G. de Bothezat beneath one of the rotor arms of his helicopter in 1923 at Wright Field, Ohio [5]

Despite the obvious successes, Bothezat failed to achieve the launch of serial production of helicopters. "Flying Octopus" by George de Bothezat remained, albeit an outstanding but single, experimental model. Bothezat's greatness lies in the fact that his helicopter was built without preliminary experiments, without prototypes, only based on of mathematical calculations of a brilliant designer. And this was done even before the advent of computers.

After creating his "Flying Octopus", Bothezat was engaged in the design of airplanes and experimental helicopters. In 1926, he founded the "G. de Bothezat Impeller Company", which started the production of new types of fans for the US Navy. Subsequently, Bothezat fans were installed at the famous Rockefeller Center in New York, and, in addition, they were installed on American tanks. The outstanding engineer I. Sikorsky also used them in his developments [7].

In addition to his inventive activity, being a versatile scientist, he did not stop doing science. Georgy Alexandrovich published several papers on a new method for solving differential equations, criticism of Einstein's theory of relativity, fundamental research on the theory of helicopter stability, the study of flight trajectories in air and airless space, and even works on philosophy and overcoming the economic depression of the 1930s [12, p. 8; 11].

Of course, Bothezat's first helicopter was hardly a successful design. But, he had no one to rely on: he was the first. So it happened in the history of aviation. It turned out that, perfect from a theoretical point of view, in practice, aircrafts were of little importance.

A striking example is the relatively insignificant practical application of the NEZH wing profiles, developed by N. Zhukovsky.

On February 1, 1940, George de Bothezat died in Boston after undergoing emergency heart surgery. He was fifty-eight. Bothezat was buried with military honors in New York. The archive of the scientist and designer is kept in the library of the US Air Force Academy [3].

One can only regret the untimely death of an outstanding engineer. How much more he could give to humanity!

CONCLUSION

Georgy Alexandrovich Bothezat was undoubtedly an outstanding scientist-theoretician and practitioner of aviation, one of the founders of the theory of stability of aircraft and the theory of propellers.

He was the first in the history of aviation to build a flying model of a helicopter. George de Bothezat's work in the field of dynamics, stability, and theory of flying vehicles has become classic. Subsequently, in practice, Bothezat's helicopter schemes were applied in the form of quadrocopters and drones. The flight trajectory in air and airless space was used in the development of the American Apollo manned lunar landing program.

At present, in Kharkiv, the problems of aviation science and technology, as well as training of scientific and engineering personnel for aviation, are handled by the Kharkiv Aviation Institute (now the NAU "KhAI") that 90 years ago separated from the Kharkiv Polytechnic Institute (name of Kharkiv Technological Institute from December 1929).

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Д. Ю. Журило, канд. техн. наук, доцент
orcid.org / 0000-0002-0015-9412
E-mail: zhurilo.dm@gmail.com
М. В. Гутник, канд. істор. наук, доцент
ORCID: orcid.org / 0000-0002-2723-2755
E-mail: marinazoza@gmail.com
А. Г. Журило, канд. техн. наук, доцент
orcid.org / 0000-0003-4084-4622
E-mail: zhurilo.alla@ukr.net

Національний технічний університет «Харківський політехнічний інститут»
вул. Кирпичова 2, Харків, Україна, 61002

ВНЕСОК ГЕОРГІЯ БОТЕЗАТА У СВІТОВУ АВІАЦІЮ ТА КОСМОНАВТИКУ

У статті показано життєвий та науковий шлях першого доктора наук у галузі авіації — Георгія Ботезата. Використано нові архівні дані, що розкривають причину його навчання за кордоном. Наводяться відомості про сім'ю Г. Ботезата. Стверджується, що учений разом із Миколою Жуковським, Ігорем Сікорським, Степаном Тимошенком, Олександром Фан-дер-Флітом і Олексієм Лебедєвим був одним із організаторів Повітряного флоту Російської Імперії. Проаналізовано роботи Г. Ботезата у галузі імпульсної теорії повітряних гвинтів, зокрема зазначено, що на основі своєї теорії вчений зміг вивести формули для забезпечення стійкості польоту літаків і вертольотів. Він автор різних винаходів: гіроскопічного прицілу та іншої авіаційної техніки. Він розробив тренувальні балістичні таблиці, що дозволяли вносити поправки на швидкість польоту і напрям вітру. Показано причини від'їзду Г. Ботезата до США. Стверджується, що саме тут його талант конструктора і творця вертольотів оригінальної системи розкрився найкращим чином. У 1922 р. Георгію Олександровичу за фінансової підтримки американського уряду вдалося побудувати дієздатну модель вертольота без прототипів та експериментів, лише за результатами розрахунків. Аналізуються причини, через які Г. Ботезату не вдалося домогтися запуску серійного виробництва вертольотів. Наведено інформацію про діяльність компанії, заснованої Ботезатом, що займалася виробництвом вентиляторів нового типу для ВМС США. Вентилятори системи Ботезата були встановлені у Рокфеллер-центрі у Нью-Йорку, а також встановлювалися на американських танках. Підкреслюється, що І. Сікорський також використовував у своїх дослідженнях роботи Г. Ботезата. Повідомляється, що розрахована Ботезатом траєкторія польоту у повітрі і безповітряному космосі використовувалася при розробці американської програми пілотованої посадки на Місяць з використанням системи «Аполлон». Розглянуто причину смерті вченого.

Ключові слова: Георгій Ботезат, вертоліт, історія авіації, Сікорський, Жуковський, Перша світова війна, революція, Харківський технологічний інститут.