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ON THE WORKS OF S.S. NEZHDANOVSKY IN THE FIELD OF FLIGHT BASED ON REACTIVE PRINCIPLES, 1880-1895[+]

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The history of science and technology knows a number of cases when the ideas of a scientist remained unknown for a long time, becoming the property of humanity only when they were not new any more and had been translated into reality, as well as developed considerably and supplemented by following generations. This was the case with the notes of Leonardo da Vinci on helicopters, with the flying vehicle of N.I. Kibal'chich, the early manuscripts of U.V. Kondratyuk on interplanetary communications, and a number of other materials. The notes of S.S. Nezhdanovsky on the possibility of using jet engines to solve the problem of human flight, notes that date back to the 1880s and 1890s,[+++] should be included among this same group.

Sergei Sergeevich Nezhdanovsky (1850-1940) was a Soviet scientist and inventor rather widely known for his investigations in the field of aircraft science and technology. But his investigations in the field of jet propulsion have been hardly ever mentioned in the scientific-technical or in the historic-scientific literature until the 1950s.[1]

Nezhdanovsky began studying the possibility of using the jet principle in solving the problem of human flight in the 1880s. In July 1880, he first advanced the idea of the possibility of creating jet aircraft, declaring in his working papers: "A jet projectile can be made with the use of an explosive; the products of its burning are discharged from an ejector type device."[2] At the end of 1880 Nezhdanovsky prepared some calculations for jet aircraft using gases from gunpowder as the motive force (Figure 1). He postulated two variants of an engine (under a pressure of gun powder gases equal to

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[+]Presented at the Third History Symposium of the International Academy of Astronautics, Mar del Plata, Argentina, October 1969.

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[+++]The mentioned notes were found in the working papers of S.S. Nezhdanovsky kept at present in the N.E. Zhukovsky Scientific Memorial Museum in Moscow. Unless otherwise indicated, all further references refer to the materials of the scientific archives of the N.E. Zhukovsky Museum.

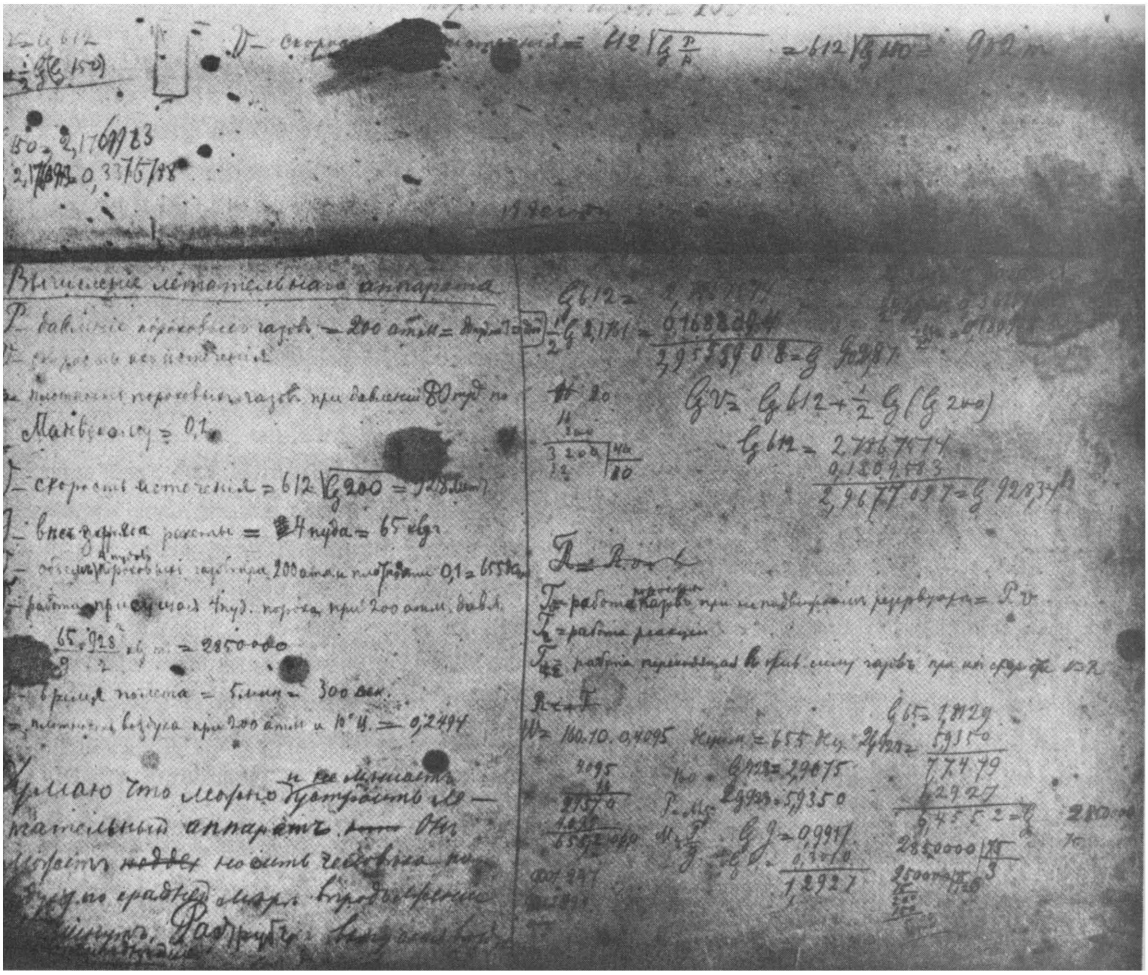


Fig. 1

150 and 200 atmospheres), and came to the following conclusion: "I suppose that we can and should build the aircraft. It would be able to carry a man in the air for five minutes at least. The funnel letting out the air with the most efficient speed will produce an economy of fuel and increase the time of flight."[3]

In 1882 Nezhdanovsky again returned to the possibility of producing jet propelled aircraft, discussing different variants of engines activated by the reaction of carbonic acid, water steam, and compressed air. He expressed the specific ideas of building a jet engine "after the principle of magazine or machine guns with two or three barrels with the same purpose of having the possibility of regulating the power and time

of the flight."[4] That same year he advanced the idea of building two types of heavier than air jet aircraft with and without wings. He also pointed out the possibility of using one of the engines which he had proposed, that operated on the reaction of compressed air, for the horizontal flight of lighter than air aircraft ("an air balloon shaped like a cigar").

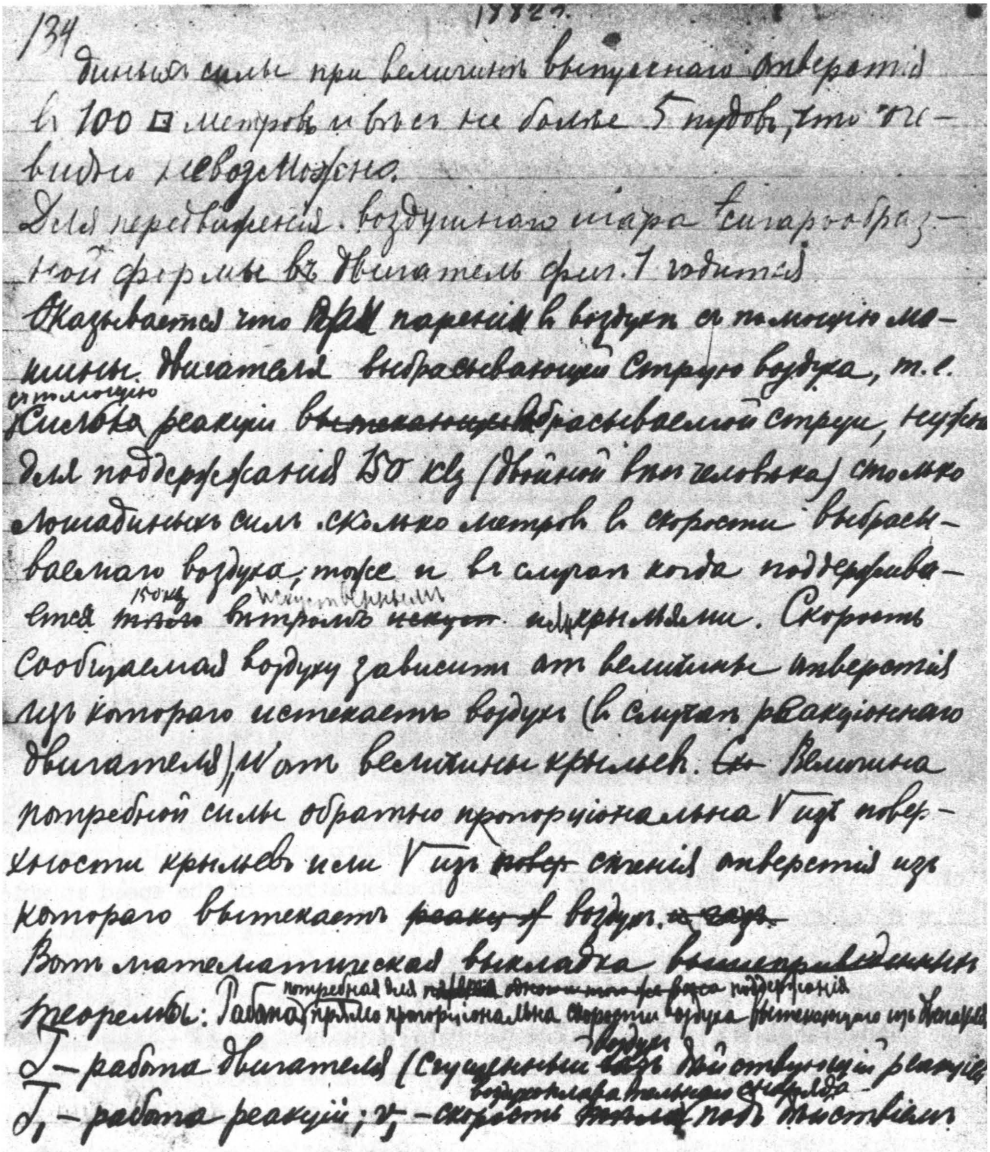
At the same time Nezhdanovsky attempted to calculate the work needed to carry out jet flying. One of the first tasks he set was determining the work necessary to counterbalance the gravitational force on the aircraft. As a result of his calculations, (Figures 2 and 3), Nezhdanovsky arrived at the conclusion that the work needed to support a body is directly proportional to the speed of the air flowing from the engine, and inversely proportional to the square root of the wing surface or to the square root of the section of the opening from which reaction gas exhausts.[5]

Nezhdanovsky advanced that theory in 1882. One should bear in mind that in this case Nezhdanovsky meant the air to be taken from the ambient atmosphere, as can be seen from his further notes. Therefore, he sought here to determine the work needed to balance the aircraft weight using the flow of ambient air compressed in a vessel and projected with a speed W in the direction of the gravitational force.

Nezhdanovsky differed from most inventors who tried to solve the problem of jet flight before him. He was little concerned with the design of the aircraft, devoting most of his attention to the problem of creating a jet engine and finding the best fuel for it. "I suppose," he wrote in some of his working papers, "it is sufficient to design and draw the engine in accordance with the above-mentioned conditions; the construction of the aircraft itself can be left to other technicians. Nevertheless, I put down the ideas referring to the construction of the aircraft."[6]

And really, in Nezhdanovsky's papers, we find many original ideas of essential significance and undoubted historical interest. Already in 1882-1884 he had proposed jet nozzles (Figure 4), through which the working fluid (steam or gas) passed, carrying with it a great mass of ambient air. According to Nezhdanovsky this would increase the reactive effect.[7] Further, Nezhdanovsky dealt with calculations of the speed at which combustion products flow, thought of such problems as fuel feeding into the combustion chamber by means of pumps, and the use of one of the fuel components for cooling the walls of the combustion chamber.

Nezhdanovsky also devoted much thought in his investigations to the energy problems of jet engines. In his search for the most suitable source of energy, he discussed nitroglycerine, gun powder gases, compressed air, water steam, carbonic acid, and different explosive mixtures. Nezhdanovsky also proposed to use as an energy source an explosive mixture consisting of two liquids, fuel and oxidizer, which deserves special attention. In his manuscript of 1882-1884 (see Figure 5), he wrote: "On the basis of



134 1882 г.

движущей силы при величине выпускного отверстия в 100 □ метров и вес не более 5 пудов, что очевидно невозможно.

Для передвижения воздушного шара сигарообразной формы в двигатель фиг. 1 годится

Оказывается что ~~для~~ парение в воздухе с помощью машины двигателя выбрасывающей струю воздуха, т. е. отталкивающую силою реакции ~~вытекающих~~ выбрасываемой струи, нужно для поддерживания 150 kg (двойной вес человека) столько лошадиных сил, сколько метров в скорости выбрасываемого воздуха; тоже и в случае когда поддерживается 150 kg ~~того~~ [illegible] искусственными крыльями. Скорость сообщаемая воздуху зависит от величины отверстия из которого истекает воздух (в случае реакционного двигателя) и от величины крыльев. Величина потребной силы обратно пропорциональна √ из поверхности крыльев или √ из ~~повер~~ сечения отверстия из которого вытекает ~~реакц~~ воздух. ~~[illegible]~~

Вот математическая выкладка ~~вышеприведенной~~ теоремы: Работа потребная для [illegible] пропорциональна скорости воздуха вытекающего из [illegible]

T — работа двигателя (сущ[illegible] воздух [illegible] реакцию)

T_1 — работа реакции; v_1 — скорость [illegible] под действием

Fig. 2

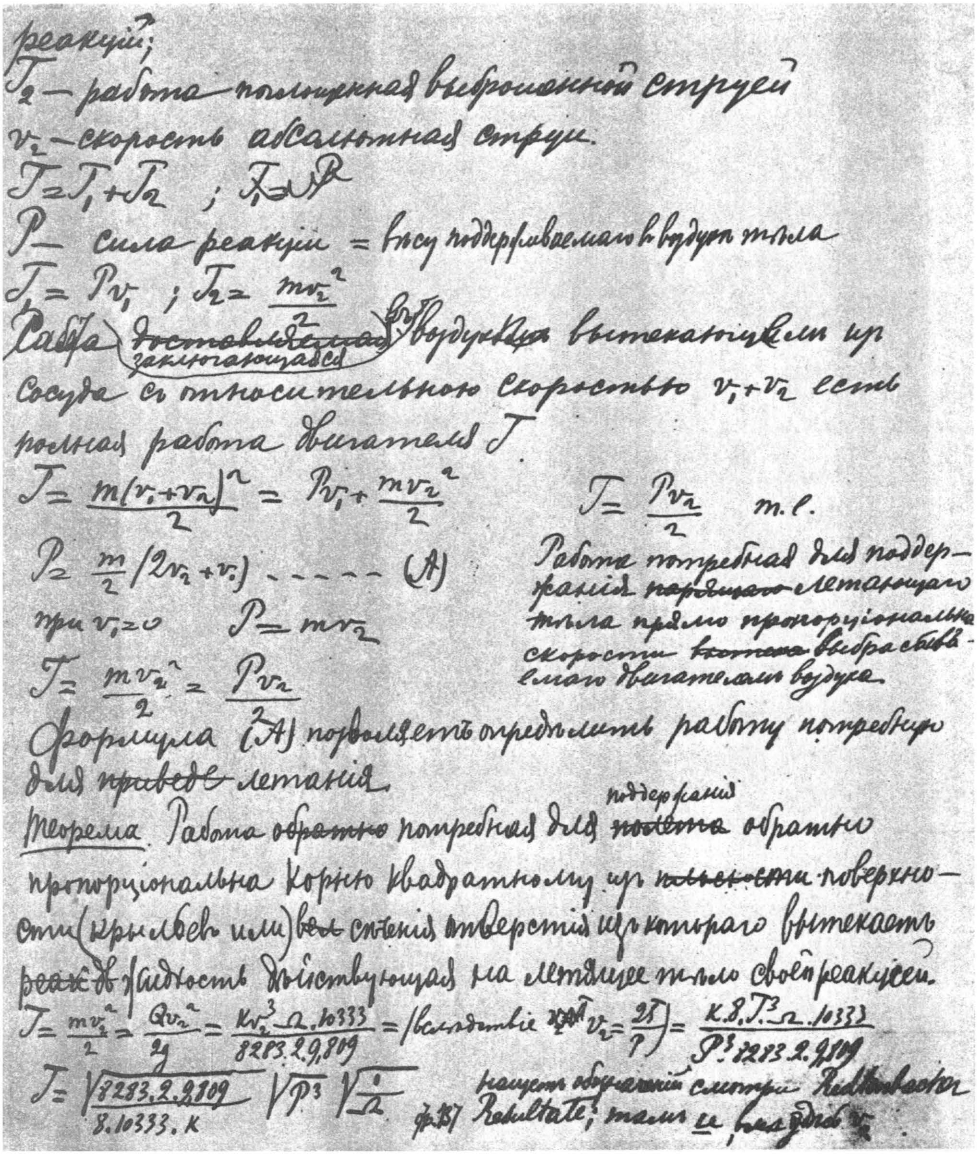

реакции;
T_2 — работа полезная выброшенной струей
v_2 — скорость абсолютная струи.
$T = T_1 + T_2$; $T_1 = \lambda P$
P — сила реакции = весу поддерживаемого в воздухе тела
$T_1 = Pv_1$; $T_2 = \frac{mv_2^2}{2}$
Работа ~~доставляемая~~ заключающаяся в воздухе вытекающем из сосуда с относительною скоростью $v_1 + v_2$ есть полная работа двигателя T.
$T = \frac{m(v_1+v_2)^2}{2} = Pv_1 + \frac{mv_2^2}{2}$
$P = \frac{m}{2}(2v_2 + v_1)$ - - - - - (A)
при $v_1 = 0$ $P = mv_2$
$T = \frac{mv_2^2}{2} = \frac{Pv_2}{2}$
$T = \frac{Pv_2}{2}$ т. е. Работа потребная для поддержания ~~парящего~~ летающего тела прямо пропорциональна скорости ~~потока~~ выбрасываемого двигателем воздуха.
Формула (A) позволяет определить работу потребную для ~~правед~~ летания.
Теорема. Работа ~~обратно~~ потребная для ~~полета~~ поддержания обратно пропорциональна корню квадратному из ~~площади~~ поверхности (крыльев или) ~~всех~~ сечения отверстия из которого вытекает ~~реак~~ жидкость действующая на летящее тело своей реакцией.
$T = \frac{mv_2^2}{2} = \frac{Qv_2^2}{2g} = \frac{Kv_2^3 \Omega .10333}{8283.2.9,809} =$ (вследствие $v_2 = \frac{2T}{P}$) $= \frac{K.8.T^3 \Omega .10333}{P^3 .8283.2.9,809}$
$T = \sqrt{\frac{8283.2.9,809}{8.10333.K}} \sqrt{P^3} \sqrt{\frac{1}{\Omega}}$
наиболее обыкновенный смотри Redtenbacher стр. 137 Resultate; там Ω, вместо v_2.

Fig. 3