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Chapter 15

AN ANALYSIS OF YU. A. POBEDONOSTSEV'S SCIENTIFIC AND TECHNICAL ACTIVITY*

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Professor Y. A. Pobedonostsev, Doctor of Technical Sciences, corresponding member of the International Academy of Astronautics, is well known in broad circles of Soviet intelligentsia, and abroad, as the supervisor of the team at GIRD that created the first supersonic aerodynamic tunnel in the U.S.S.R., the solid-propellant ramjet engine, and, as the pioneer of a solid-propellant rocket engine, the man who made an invaluable contribution to the development and creation of reactive powder missiles—"Katyusha."

Y. A. Pobedonostsev was one of the pioneers of Soviet rocket engineering. Together with the staff of the RNII set up at the end of 1933, Y. A. Pobedonostsev took an active part in theoretical design and experimental work for reactive, solid-propellant powder missiles. The first fundamental investigations of the problems of RDTT interior ballistics were carried out by Y. A. Pobedonostsev.

While defining the physical nature of ballistic fuel burning in the rocket chamber, Y. A. Pobedonostsev calculated the range of usage of different laws of burning, showing the influence of the igniter on the amount of maximum pressure in the chamber. He ascertained that pressure depends not only on the relationship of geometric parameters of the chamber and the nozzle, but also on the speed of gas outflow along the rocket chamber.

Y. A. Pobedonostsev is one of the founders of RDTT interior ballistics. He hypothesized interior losses of gas pressure in the chamber of a reactive powder engine. On the grounds of this hypothesis, a half empiric method of defining the maximum pressure in the rocket chamber was created [1, p.62].

Using experimental data, Y. A. Pobedonostsev defined the diameter of the critical section of the nozzle in a formula. Defining the diameter of the critical section of the nozzle means preliminary calculation of engine parameters. This method proved correct only after a number of assumptions; the definition of dimensions of the nozzle reduces time and means of stand testing of the engine, and,

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if not entirely, considerably reduces the number of accidents occurring while testing rocket engines.

Y. A. Pobedonostsev paid much attention to the problem of development of rocket fuels and burning grain stability in RDTT. He discovered the " $\mathcal{H}$ " parameter – a quantity which is proportional to the gas speed along the solid propellant in a chamber. On the basis of his experiments, it was established that solid-propellant engines are characterized with anomalous burning at low pressures. As a result of these investigations, an experimental curve was plotted by which it became possible to define the lower boundary of allowable pressure in RDTT. Y. A. Pobedonostsev evolved the stability criterion of burning charges in RDTT – a geometric complex known as the " $\mathcal{H}$ " parameter.

The laws of interior ballistics discovered by Y. A. Pobedonostsev made it possible, for the first time, to calculate the amount of charge of solid fuel, determine the maximum pressure in the rocket chamber, and select the appropriate nozzle. Received dependences of pressure from the relationship $\rho = f[s/(6\kappa\rho)]$ were supplemented with dependences of the speed of gas outflow along the chamber, and the initial temperature of solid fuel. Experimental curves and formulae for the calculations of specific systems have been used up to now. As to the " $\mathcal{H}$ " parameter, it turned out to be viable, and, at present, it is one of the main factors determining the work of RDTT [1, p.63].

Y. A. Pobedonostsev also made his contribution to the ballistic projecting [range] of solid-propellant rockets. He proceeded from the assumption that the maximum range of a non-guided missile should be reached at the angle of 45° and, with sufficient precision, might be considered as the function of two arguments: maximum speed calculated with the help of Tsiolkovsky's formula:

$$V_{max} = J_1 g \ln\left(1 + \frac{\omega}{q}\right);$$

and, ballistic coefficient

$$C = \frac{i d^2}{q} \cdot 10^3$$

Here

d - is rocket gauge,
q - is passive weight,
ω - is weight of rocket charge,
i - is form factor.

For ballistic coefficient Y. A. Pobedonostsev transformed the expression to the form:

$$C = \frac{i d^2}{\omega} \cdot 10^3 \frac{\omega}{q} = K \frac{\omega}{q}$$

It allowed him to represent the maximum range of the missile by a family of curves.

$$X_{max} = f\left(\frac{\omega}{q}\right), \quad Heze \quad K = const$$

If reference values of charging density and coefficient

$$\alpha = \frac{q_{x}}{\omega}$$

are known for every combination, K and ω/q is sufficient for every given range X_{max}, then one might determine the main constructive parameters of the missile, and select the variant that has the least weight.

This solution made by Y. A. Pobedonostsev became the starting point for the development of other methods of determining ballistic projecting [6, 7].

Y. A. Pobedonostsev made considerable contributions to experimental ballistics of rockets. He created a supersonic aerodynamic tunnel (M 3,2). He continued to work with the problems of improvement of aerodynamics and flight stabilization of RS-82 and RS-132, and he carried out work on the improvement of precision and close grouping of shots with RS. Flight testing of reactive missiles from the U-15 planes brought good results [3, p.102]. By 1937-1938, theoretical and experimental work had been completed, and RS-82 and RS-132 began to be used in aviation. In the middle of 1939, in the RNII, new reactive missiles of 203 mm were developed, and RSM-13 was improved [4].

During World War II mighty reactive missiles of improved close grouping of shots, M-30 and M-31 UK, were created [2, 3, p.120].

In 1943, Y. A. Pobedonostsev began to deliver lectures on theory, calculations, and the projection of reactive power missiles; he also supervised course and diploma papers and published articles on different aspects of rocket engineering.

His lectures about man-made satellites and modern ballistic missiles were always listened to with great interest. Y. A. Pobedonostsev showed great erudition and knowledge of adjacent branches of science and astronautics.

REFERENCES

1. Erokhin B. T., Mazing G. Y., Proodnokov N. E., Y. A. Pobedonostsev's contribution to the development of the theory of a solid-propellant rocket engine. IIET AN USSR, p.46, Moscow, 1982, p.60.
2. The history of World War II (1941-1945), v.5, M., 1963, p.41.
3. Novikov V. N., Vernidub I. I. and others. The arms of victory. Izd. "Mashinostrienie," 1985, p303.
4. Pobedonostsev Y. A., Kuznetsov K. M. The first starts. Izd. "DOSAAF," Moscow, 1972, p.71.
5. Pobedonostsev Y. A. Modern problems of astronautics. Izd. "Znanie," 1957.
6. Shapiro Y. M., Mazing G. Y., Proodnokov N. E. The principles of projecting solid-propellant rockets. M., Voenizdat, 1968.
7. Pobedonostsev Y. A., Staniukovich K. P. Calculations of optimum ratio of compound rocket stages. Collection: "Some problems of mechanics," N 88, M., MVTU, 1958.