

SOLID PROPELLANT ROCKET ENGINES

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1. Introduction

Solid propellant rocket engines (SPRE) are called the direct reaction engines, in which chemical energy of the solid propellant being placed in the combustion chamber is transformed at first to thermal energy, and then to kinetic energy of the combustion products thrown away with high velocity in the environment. The momentum of combustion products discharging through the nozzle is equal to the impulse of reactive force being created by the engine.

2. Historical information

First of rockets known to us were rockets with primitive powder rocket engines used in China near 5000 years ago for pleasure and military aims (so-called "fiery arrows", Figure 1).

The first rocket propellant was black smoky powder (potassium saltpetre with charcoal mixture). In Russia, powder rockets appeared in the beginning of XVII century. In 1680, Tsar Peter I founded "rocket institution" in Moscow for firework rockets making. In 1717 lighting signal rockets existed for 200 years without changes. In the beginning of XIX century, Englishman Kongrev improved the "fiery arrows" having been borrowed from Hindus. He replaced bamboo tube by metallic one and the stub - by incendiary, demolition or splintery projectiles. The port of Bulong in 1806 and Copenhagen in 1807 were burnt down by the English navy with the help of these rockets at the time of Napoleon war. Forty thousand rockets had been launched on the

city and Denmark capitulated (so-called "one-day war").



Figure 1. "Fiery arrows": 1- bamboo; 2- black smoky powder; 3- wooden pole for the stabilization; 4- stub

First Russian fighting rockets were created by general A.D. Zasiadko. The "Rocket Institution", in which handicraft mass production of Zasiadko design rockets was made, had been created in 1826 near Petersburg. Rockets had 2...4 inches caliber and the shooting distance near 3 km. Zasiadko rocket engine was a steel cartridge-case, in which black smoky powder was pressed with central conic channel whose length was equal $3/4$ the load length.

Zasiadko rockets are characterized by:

- cheapness (It is cheaper than an artillery projectiles of the same caliber);
- design simplicity and fast production;
- demoralizing action on an opponent (whistle, fiery jet).

In the middle of XIX century, general K.I. Konstantinov's works led out Russian rocket technology of that time on the first place in the world. He invented the automatic press with the distant-reading control and pressure adjustment for the powder pressing into the body, as well as the machine-tool for the channel drilling in the load. He replaced the spherical fighting head by the conic one, improved the stabilizer, and so on. Russian rockets' distance was 4...5 km with thirty meters dispersion to 60-th of XIX century.

In 1887, powder rockets were struck off the Russian army armament list in connection of the threaded artillery eminent successes on the one hand, and in connection of loads from black smoky powder essential disadvantages: the composition non-uniformity, cracks appearing during the storage which caused gaps on launchers and the distance dispersion.

It was necessary to develop a new monolithic solid propellant burning in parallel layers from the surface and use a simple and safe technology for loading.

Russian engineer-chemist A.I. Tikhomirov, being the founder of rocket projectiles on the unsmoky powder elaboration in the USSR, studied the problem of powder rocket projectiles creation since 1897.

In 1921, the gas dynamics laboratory (GDL) was established in Leningrad. It was the first Soviet research and experimental - organization for the elaboration of rocket projectiles on the unsmoky powder. In 1927...1933, powder boosters for light and

heavy airplanes (U-1, TB-1 and others) and powder rocket projectiles of various purposes, in particular, for airplanes armament were developed. A.I. Tikhomirov, V.A. Artemiev, B.S. Petropavlovsky, G.E. Langemak, and others, took part in these systems elaboration.

In 1933, the Rocket research institute (RRI) had been established, where rockets with SPRE final works were executed. RS-82, RS-132 rockets (figures meant the caliber) were intended for airplanes armament. The first fighting application of these rockets dated from August 1939, when they were successfully used in battles with Japanese in the Halkhin-Gol lake region.

In 1938...1941, I.I. Gvay, V.V. Galkovsky, A .P. Popov and others, created many load launcher mounted on lorry in RRI, which caused the rocket weapon efficiency to be raised considerably.

The first rocket volley for German occupants was made in 14 July, 1941 near Orsha city by captain I.A. Flerov battery. Special guards' mortar units were created later on, which main weapons were fighting cars BM8-48, BM-13-SN, BM31-12. This weapon was known as "Katusha" among the people.

The ballistic powder of "N" mark - nitrocellulose in nitroglycerine solid solution with some additions was used in these rockets. Loads were many tablets made by stamping or shnek-pressing methods.

In 1941, SPRE with many channels loading from double-glycole [2], double-base powder was created in Germany. Also, other projectiles (field, anti-aircraft) including faust-cartridge (reactive cartridge) were created on the basis of this powder. In the USA and England successes were more modest in this period (anti-aircraft rockets, anti-tank rockets "Bazuka", airplane boosters).

Double-base powders of that time had the essential problem that it could only be made by means of stamping or pump-pressing methods. It limited SPRE dimensions to eight hundred millimeters diameter. It hindered intense large-scale SPRE development. Besides, ballistic solid propellants had low energetic characteristics ($T_c \sim 2\ 300\ \text{K}$; $I_{sp} \sim 2\ 200\ \text{m}\cdot\text{s}^{-1}$).

In 50-th years of XX century, the new class of solid rocket propellants was created. It was mixed solid rocket propellants being the mechanical mixture of non-organic oxidizer with organic fuel-binding with light metals (aluminum mostly) additions. These propellants enable to make loads by means of the direct filling in the combustion chamber, that is, limitations for the engine dimensions fall off. These propellants have also more high energetic characteristics ($T_c \sim 3100\ \text{K}$; $I_{sp} \sim 2500\ \text{m}\cdot\text{s}^{-1}$).

SPRE of 6.6 m diameter was elaborated in USA.

In 1969, 96.8 per cents (1000 "Minuteman" rockets and 656 "Polaris" rockets) of ballistic rockets consisted in US army armament were supplied with SPRE and only 3.2 per cents ("Atlas", "Titan") - with liquid rocket engines.

All emergency recovery systems are supplied with only SPRE. At present, SPRE occupies the key position in all technique regions, where rocket engines are used.

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Biographical Sketches

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