УДК 629.764

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AN EXTREMELY SMALL AUTOPHAGE ROCKET FOR ORBITING A PICO SATELLITE

A new experiment is the main object of the paper. The experiment continues the series of the tests which are carried-out to clarify the engineering feasibility of an inertial autophage rocket. A distinguish feature of the new test set is a reverse-feed gasification chamber. The successful firing of it is a step towards inertial-pulse engine, the core part of a very small, simple and cheap pocket launch vehicle for pico and femto satellites.

Key words: *pocket autophage pulse-inertial launch vehicle, reverse-feed gasification chamber.*

What are the ways to decrease the cost of putting payloads into orbit radically?

According to expert estimations the cost of orbiting payloads into a low Earth orbit must be $10^1...10^2$ times lesser than the present-day values to trigger the utilization of the near-Earth space and planets [1]. While the present state of humankind technology suffices to begin the colonization, the launch vehicle state-of-the-art brakes it and – even more – leads to the deceleration of the world's launching activity and reducing space industry. What are the ways to make the access to space cheaper? Considering a huge amount of proposed projects it is possible to decide that an answer is absent now. Reusable launchers need unacceptably expensive reparation between their flights (like Space Shuttle). Economically sound airbreathing space planes must be equipped with rocket engines suitable to be reused for $10^2... 10^3$ times [2] (like Skylon). New structure materials (like lithium or carbon composites), propellants (like liquid methane) or propulsions (like hybrid) cannot change the situation radically. Are the other ways for now? We don't know them for manned missions and big payloads, however, for the emerging market of pico and femto satellites it is possible to propose a methods of decreasing the launching cost by means of the use of autophage pico launchers, very small rockets with an initial mass of several tens kilograms and manufacturing cost of several thousand US dollars.

The idea of the pulse-inertial autophage launch vehicle

According to our estimations the development of a launch vehicle with an initial mass lesser than 1...1.5 tons is impossible theoretically if the conventional design and technology are used. Such a rocket associates with 3-4 stages and several million or more dollars for a payload with a weight of 10...30 kg. It would be scarcely suitable to meet the pico and femto satellite market requirement in a global mass scale. Is it possible to change the conventional design to make launch vehicles smaller and cheaper? Taking into account that the mass of a launch vehicle tank structure is a half of the launch vehicle initial dry mass and the cost of the launch vehicle engines is more than the half of the vehicle total cost, let us look for a design having no propellant tank structure and equipped with light and simple engine. From the point of view an autophage rocket proposed in 1960 [3] looks interesting. An improvement of the idea with a pulse engine and a gasification chamber gives a pulsed-inertial autophage rocket presented in fig. 1.

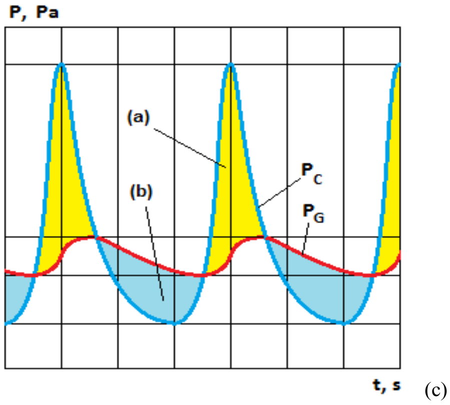
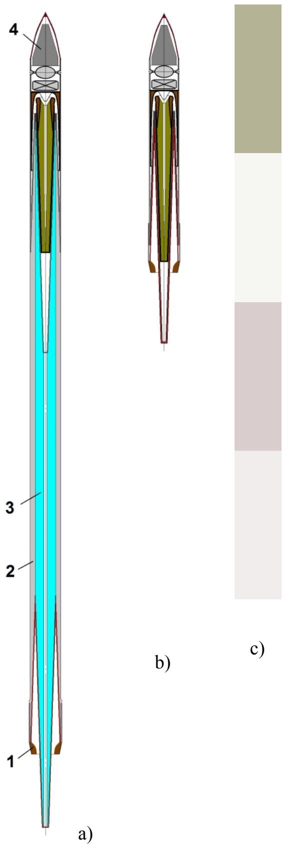


Fig. 1. The idea of a pulse-inertial autophage rocket: a) – a portion of propellant burns in a combustion chamber; b) – the next portion of propellant fills the combustion chamber; c) – P_C and P_G vs time; 1 – combustion chamber; 2 – valves; 3 – hot wall; 4 – gasification chamber; 5 – fuel; 6 – oxidizer

The work of the rocket is similar to a well-known airbreathing pulse engine. Let us consider the work as a recurrent sequence of discrete processes. When a portion of propellant burns a combustion chamber pressure P_C closes injection valves and presses the hot wall of a gasification chamber to the rocket case of easily gasified matter, fig. 1 a). The gasification chamber is designed like considered in [4] one. A part of the case contacting to the hot wall gasifies and fills the gasification chamber so the gasification chamber pressure P_G rises. When the burnt portion of propellant flows out the combustion chamber pressure P_C falls, P_G opens the valves and a new portion of propellant takes place in the combustion chamber, fig. 1 b). At the time a flow of the combustion products causes a thrust which prevents throwing the rocket case out from the gasification chamber. Then the processes repeat. In the both cases the inertia of the rocket case is cooperate with P_C and the thrust.

A version of the pulsed-inertial autophage launch vehicle conceptual design is presented in fig. 2. The rocket tubular case of polymeric fuel contains solid oxidizer. A conical shell at the end of the case is a spike engine of the rocket. Gasiform propellant is fed into the engine through channels in the shell [5 and 6]. The engine moves along the rocket case by means of its own thrust. The first stage equals about 95 percent of the launch vehicle initial mass and reaches a speed of about 6 km/s. So the jettisoned first stage engine burns in the atmosphere. By the way there are no pollutions and impact areas on the Earth surface. The most important feature of the design is a possibility to make a launcher extremely light and small about 30...50 kg initial mass and 1...1.5 m initial length for a 70...100 gramme payload, due to unusually small structure mass fraction, about 5...6 percent, of its initial mass.



a)

b)

c)

Fig. 2. The conceptual design of a portable pulse-inertial autophage launch vehicle: a) – initial configuration; b) – final configuration; c) – second stage separation; 1 – first stage conical shell spike engine; 2 – fuel; 3 – oxidizer, 4 – payload with attached second stage engine

An experimental investigation of a reverse-feed gasification chamber

To check the engineering feasibility of the inertial-pulse engine a series of experiments are carried-out. At the previous stages of the series a single-unit gasification chamber for solid fuel and oxidizer was developed and successfully tested [5, 6, 7, 8, and 9]. A new experiment was designed and implemented at Dnipropetrovs'k National University in late 2014. The idea of the experiment is illustrated with fig. 3 [10]. A pneumatic pusher feeds a gasification chamber with the propellant rod consisted of a solid fuel envelope and an oxidizer core. Contacting the gasification chamber hot wall, a part of the rod transforms into gases. The gasiform propellant components pass through the channels formed with grooves on the gasification chamber and a cover into a combustion chamber at the area of its head. There the gases mix and burn. The flows of hot combustion products heating the gasification chamber from its root to nose are reverse to the gas flows inside the gasification chamber channels, which gives the name of the chamber. The experimental plant and its main parts are presented in fig. 4.

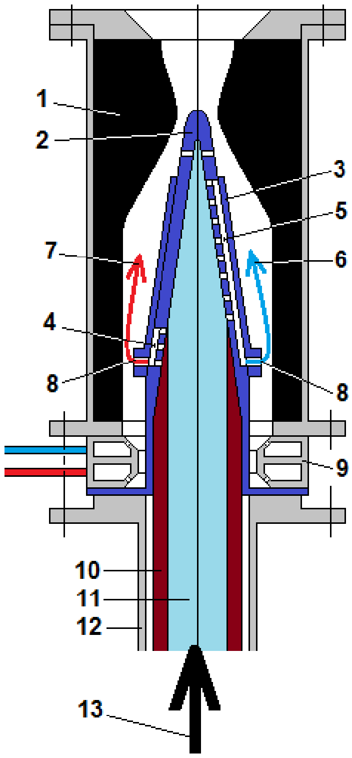


Fig. 3. The schematic of the reverse-feed engine experimental model: 1 – combustion chamber; 2 – gasification chamber; 3 – cover; 4 – fuel channels; 5 – oxidizer channels; 6 – gasified oxidizer flow; 7 – gasified fuel flow; 8 – oxidizer and fuel injection holes; 9 – injection head of auxiliary propellant; 10 – pipe of polymeric fuel; 11 – solid oxidizer; 12 – guide pipe; 13 – pneumatic pusher

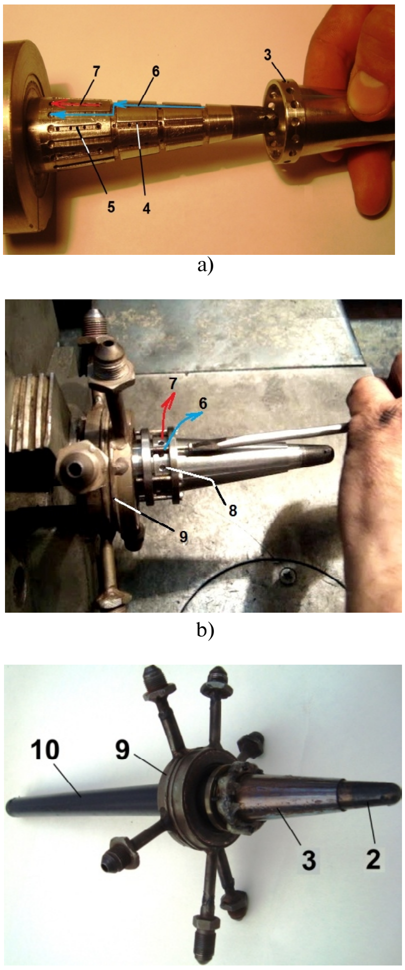


Fig. 4. The new parts of the experimental plant (the numbers correspond to fig. 3): a) – the gasification chamber with the cover taken away; b) – the gasification chamber with the cover mounted; c) – propellant charge

The results of the new experiment

We have reached: (1) a successful work of the reverse-feed gasification chamber with no burn-through of its cover, (2) the gasification and combustion of a 210 mm polyethylene-ammonium nitrate propellant rod for 143 s with a shortening rate of about 1.4 mm/s supporting with auxiliary propane-oxygen propellant, fig. 5, (3) self-sustaining combustion of the propellant rod with about the same shortening rate when propane (not oxygen) is turned-off.

Several improvements of the experimental engine will follow the test in the next step. Polyethylene fuel tube will be changed for stronger polypropylene and the tube wall will be made thinner to approach to stoichiometric fuel-to-oxidizer ratio. Finally each injection hole of the gasification chamber cover will be equipped with a clapper valve to get a pulse mode.

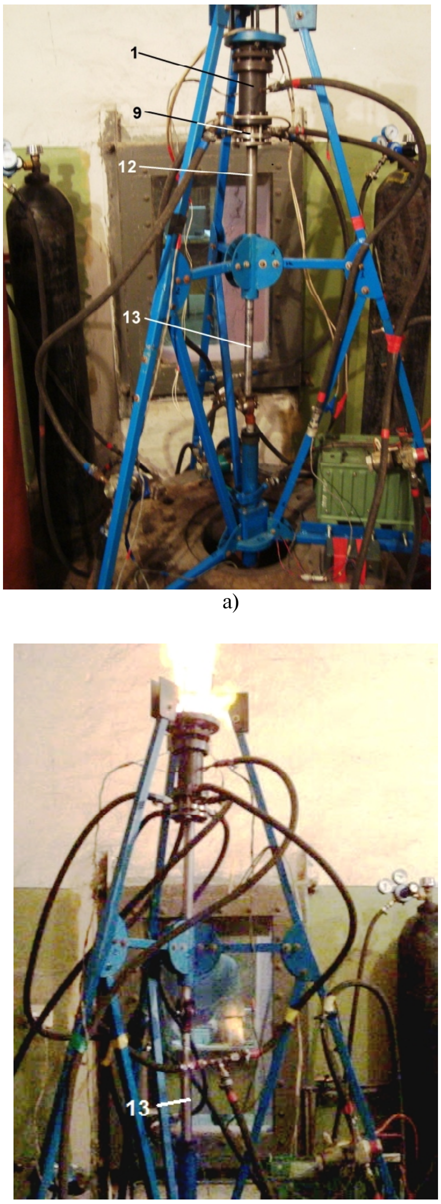


Fig. 5. The transformation of the experimental set during the firing (the numbers correspond to fig. 3): a) – the initial configuration, the pusher is in the bottom position; b) the final configuration, the pusher is put into the guide pipe in the top position

A mobile phone in orbit

In a case of successful development a small launcher like presented in fig. 2 can be used to orbit a small payload with a weight of a mobile phone for scientific and educational purposes or for mass personal use. Except this, small teams of alpinists, hunters, sailors, travellers, anti-terrorist troops and so on can be equipped with such a portable launcher for safe emergency communication in a case when other means are failed or impossible.

Acknowledgements

The fire testing described above was carried-out in the framework of the Scientific and Research Work No 4-284-13 funded by the Ukrainian Government. The main part of this article was presented at 12th Reinventing Space Conference, London, the UK, 18-20 November 2014, paper No BIS-RS-2014-31.

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Поступила в редакцию 17.04.2015

Ємець В.В., Дронь М.М., Ємець Т.В. Гранично мала автофажна ракета-носій пікосупутників

Стаття містить опис нового досліду, що продовжує експериментальну розробку інерційної автофажної ракети. Особливістю нового експерименту є використання газифікаційної камери з реверсною подачею палива, успішне вогньове випробування якої є ще одним кроком у напрямку створення інерційно-пульсового двигуна для нової малої і дешевої портативної ракети-носія піко- і фемтосупутників.

Ключові слова: *портативна автофажна пульсово-інерційна ракета-носій, газифікаційна камера з реверсною подачею палива.*

Емец В.В., Дронь М.М., Емец Т.В. Предельно малая автофажная ракета-носитель пикоспутников

Статья посвящена описанию нового исследования, которое продолжает экспериментальную разработку инерционной автофажной ракеты. Особенность нового эксперимента состоит в использовании газификационной камеры с реверсной подачей топлива, успешное огневое испытание которой является очередным шагом на пути создания инерционного-пульсирующего двигателя для новой малой и дешёвой портативной ракеты-носителя пико- и фемтоспутников.

Ключевые слова: *портативная автофажная пульсирующая-инерционная ракета-носитель, газификационная камера с реверсной подачей топлива.*