

BAPYSHEV AKYLBEC MIRZABEKOVICH

**DEVELOPMENT OF A METHOD FOR GENERATING A GUARANTEED
FUEL RESERVE FOR CONTROLLING THE LAUNCH OF THE SPENT
STAGE OF LAUNCH VEHICLES**

ANNOTATION

Dissertations for the degree
Doctor of Philosophy (PhD) in the specialty
8D07111 - "Space engineering and technologies"

Relevance of the research topic. A hard landing of the spent stage of the launch vehicle in the designated fall areas leads to the collapse of the structure, the filling of the guaranteed fuel supply (kerosene, oxygen, heptyl, amyl), the occurrence of fires and, thus, requires large costs for the complete elimination of man-made consequences.

Currently adopted technologies for the creation and use of launch vehicles the life cycle of transport is gradually completed at the moment of separation of the stages of launch vehicles. This circumstance leads to the fact that the developer is not responsible for the environmental and emergency consequences that occurred after the completion of the rocket units. Consequently, launch vehicle developers are not interested in investing in the modernization of launch vehicles to extend the life cycle, since other enterprises that have nothing to do with the development of launch vehicles are engaged in eliminating the man-made consequences of launch vehicle launches at the Baikonur cosmodrome.

In addition, problems related to design, manufacture, assembly and operation, two problems arise in terms of the environmental impact of launches on the environment:

- the appearance of orbital stages with fuel residues in containers, which are potentially large-sized explosive space debris, in protected areas of near-Earth space;
- the presence of large areas of impact areas allocated for separating parts of the launch vehicle, namely, spent stages, head fairings, tail compartments.

The first problem has an international level and today specific requirements for organizational and design work to reduce the first problem, including the consequences of uncontrolled descent into the atmosphere, have been set for launch vehicle developers.

The second problem is primarily related to the presence of areas of impact of spent parts of launch vehicles on the territory of the country, in contrast to other countries operating launch vehicles that have areas of impact in the waters of the World Ocean.

Currently, in order to solve these problems, the Institute of Information and Computing Technologies carries out scientific and applied developments related to the environmental impact of rocket and space technology, which should be reflected in the created regulatory and technical documents that provide scientific and

organizational support for the environmental safety of rocket and space technology. Due to the current conditions, the research topic is definitely relevant.

General characteristics of the work. In the dissertation work, the implementation of processes for developing a guaranteed fuel reserve in the spent stage tanks of a launch vehicle and the development of an autonomous on-board launch system for the spent stage are considered.

The purpose of the dissertation is to study an innovative technology for creating launch vehicles based on a system for developing a guaranteed fuel reserve in the spent stage tanks of launch vehicles and to develop an autonomous on-board descent system. This study introduces certain changes in the design ideology and life cycle of launch vehicles, taking into account the actual technological process of preparing and launching space rockets and reducing the economic costs of restoring natural resources.

Research objectives that realize the goal of the dissertation:

- obtaining experimental dependences of changes in the evaporation rate of a model liquid in an experimental model installation with constant parameters of the supplied coolant and different angles of coolant input relative to the longitudinal axis of 0° and 30° ;
- conducting a comparative analysis of the results of mathematical modeling based on the 1st law of thermodynamics and Navier-Stokes equations;
- conducting a comparative analysis of the results of mathematical and physical modeling.

The object of research of the dissertation is spent stages of launch vehicles with guaranteed fuel reserves, an experimental stand.

Research methods. The following methods were used to solve the problems necessary to achieve the set goals: statistical analysis methods, experimental planning methods, numerical methods, and computer modeling methods.

The subject of the dissertation is experimental research on the development of a guaranteed fuel reserve in the spent stage tanks and technologies, schemes, composition and design solutions for an autonomous on-board descent system.

Scientific novelty. The proposed solutions consist in a new proposal for a combined method to reduce the man-made impact of the separated parts of launch vehicles by developing a guaranteed fuel reserve in the tanks and then using them for controlled descent of the spent stage using an autonomous on-board descent system, which significantly increases environmental safety in the fall areas of the spent stage of launch vehicles while maintaining high tactical and technical characteristics of existing LV.

Theoretical and practical significance. The theoretical significance of this dissertation is to develop an innovative technology for creating launch vehicles based on the method of generating fuel residues in tanks. The results can be widely applied in solving important applied problems related to controlling the movement of the spent stage of launch vehicles. The developed schemes and solutions make a direct contribution to the development of science and the field of information and space technologies in the country.

The practical significance of this dissertation is that: a) reducing the anthropogenic impact of launches of all LV in the fall areas of the Republic of Kazakhstan and neighboring states, respectively; b) preventing fires in the fall areas; c) increasing the life expectancy of the population in the fall areas of separating spent stages of launch vehicles (in 7 regions: Karaganda, Ulytau, Kostanay, Akmola, Pavlodar, Kyzylorda and East Kazakhstan regions).

Scientific provisions submitted for defense:

- methodology for developing a guaranteed fuel reserve in the tanks of the spent first stage of launch vehicles;
- selection of design parameters for improving the launch vehicle;
- methodology of experimental studies on the extraction of unprocessed fuel residues in the tanks of the spent first stage of launch vehicles.

The reliability and validity of scientific statements, conclusions and results of the dissertation is confirmed by the correct formulation of the problem and the use of well-known mathematical methods, methods of fluid mechanics and experimental research methods.

Connection of the dissertation work with other research works. This dissertation work was carried out under the grant scientific project of the Ministry of Education and Science of the Republic of Kazakhstan 2018-202-2020 years "Theoretical and experimental research of innovative technology for creating a launch vehicle with improved environmental characteristics on the example of promising launch vehicles launched from the Baikonur cosmodrome" (project ID: AP05131162).

Testing the work. The main results and conclusions of the dissertation work were reported and discussed at scientific events:

1. IV International scientific and practical conference "Informatics and Applied Mathematics", dedicated to the 70th anniversary of Prof. Biyarova T.N., Vuitsik V.Ch. and the 60th anniversary of Prof. Amirgaliyeva E.N., Almaty, 2019;
2. III International Scientific Conference " The Latest Mechanical Science and Technologies " (MSTU-2019), Omsk, Russia, (April 23-24) 2019;
3. International Scientific Conference "Modern Problems of Informatics and Computing Technologies", Almaty, 2020;
4. XI International Scientific and Technical Conference "Energy, Infocommunication Technologies and Higher Education", dedicated to the 45th anniversary of the Gumarbek Daukeyev Almaty University of Energy and Communications. - Almaty, 2020;
5. 3rd International Conference on Electrical, Communication and Computer Engineering (ICECCE), Kuala Lumpur, 2021.

Publications. On the topic of the dissertation, the author has published more than 12 works, including 6 publications in scientific publications recommended by the Committee for Quality Assurance in Science and Higher Education of the Republic of Kazakhstan for publishing the main results of scientific activities; 1 publication in scientific journals included in the Scopus database; 5 publications in the works of domestic researchers and international scientific conferences abroad.

Dissertation structure and scope. The dissertation contains a title page, content, introduction, five chapters, conclusion, list of sources and appendices used. The total volume of the dissertation is 93 pages.

The main content of the work. This paper is presented in the following order.

The introduction discusses the relevance of the chosen topic of the dissertation, the purpose, object, subject and objectives of the research. The results of these studies, their scientific novelty and practical significance are described.

The first section is devoted to the current state of the problem of the impact of fuel residues in launch vehicle tanks on the environment. At the end of the chapter, we present a solution to this problem, the so-called fuel leftover generation and development of an autonomous on-board descent system.

The second section presents the development of a method for generating a guaranteed fuel reserve. This chapter offers possible options for vaporizing the model liquid and installing an autonomous on-board descent system on the spent stages of launch vehicles.

In the third section, the methodology for selecting structural and layout parameters for the modernization of launch vehicles was considered. This chapter summarizes the composition of the autonomous on-board descent system.

The fourth section presents physical and mathematical modeling. The program and methodology of physical modeling are considered, mathematical modeling is carried out in the ANSYS Fluent software product.

In the fifth section, a comparative analysis of physical and mathematical modeling is carried out.

Personal contribution of the author. The main results of the research carried out in the dissertation work were obtained by the author independently. In the dissertation, the applicant justified the composition of the autonomous on-board descent system. In the articles, the applicant justified the design and layout parameters of an autonomous on-board launch system for improving launch vehicles. In this paper, the applicant conducted theoretical and experimental studies of the evaporation process of a model liquid in a closed tank under the convective action of a heat carrier.