AKTIV DE-ORBITING ONBOARD SYSTEM FROM LEO OF UPPER STAGES OF LAUNCHERS

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The active de-orbiting onboard system (ADOS) of upper separable parts (USP) stage of launchers from LEO into orbits of utilization with term of existence orbital lifetimes till 25 years is offered. ADOS it is based on use of power resources of not produced rests of liquid fuel onboard USP launchers with liquid propulsion module (LPM). Following systems enter in structure ADOS: the gas jet propulsion system consisting of a system of gasification, chambers of gas engines (GE), a control system. For gasification of the rests of liquid fuel the heat-carrier received in the autonomous gas generator is used. The gasification propellant components from each tank with temperature and the pressure determined by strength of the corresponding tank, move in chambers of the GE established on a top of a fuel compartment. After separation of a payload execute twist USP for preservation of its position in the space by activity of the GE. Ways of increase of a system effectiveness of gasification are offered by superposition on the entered heat-carrier of ultrasonic oscillations, and also introduction in gaseous fuel nanopowder of aluminum. The volume of adaptations of construction USP, connected with introduction ADOS does not exceed 5 % from weight of a dry construction.

1. General ideas of designing of ADOS

Development of the design solutions ensuring de-orbiting of USP of launchers and apogee boost motor (ABM) with LPM from orbits of the ascent into orbits of utilization is one of main directions of the international program on debris mitigation [1].

The technical problems connected to development the LPM with repeated actuation are well-known, therefore problems of de-orbiting USP are important and now. Problems of repeated actuation LPM in conditions of weightlessness are mainly connected to organization of flow of liquid propellant components in rocket engine, maintenance of absence of bubbles of gas, etc.

Other problems, for example, guidance of center of weights and around of center of weights, are decided much easier.

Below the design solutions based on realization of unused power resources of launchers remaining in tanks USP after cutoff LPM are offered.

As a rule, after cutoff the LPM in tanks there are unused rests of liquid fuel and oxidizer which values make up to 2-3 % from value of initial filling up. The essence of offered design solutions, consists of gasification of the rests of liquid fuel and oxidizer in each tank.

Further these gaseous components move in GE for improvement of the impulse translating USP for de-orbiting into orbit of utilization.

Carried out to estimations of power resources in not produced rests of liquid fuel and oxidizer on an example of USP show a capability of their transfer into an orbit with a lifetime lower than 25 years, that corresponds to recommendations [1,2].

The weight analysis of the carried out adaptations of construction of standard existing USP of the launcher has shown the comprehensible weight losses reaching up to 5 % dry weight of a design of construction of standard existing USP.

The further increase of efficiency of an offered gas jet propulsion system is planned on the fundamentals use of introduction of additional power sources, in particular, for process of gasification – ultrasound that will help to lower costs of fuel and oxidizer of obtaining of the heat-carrier, time for gasification of the rests of fuel and oxidizer, and for GE - introduction in fuel a nanopowder, for example, aluminum that will increase its thrust characteristics.

Practical realization of these proposals does not entail necessity of the solution of new technological problems since all necessary techniques of research of these processes can be developed on the basis of available theoretical and experimental researches in small enough terms.

The existing research and technological base of space-rocket branch as to the Russian Federation, Italy, France and other countries is capable to make necessary elements as for experimental improvement of such gas jet propulsion system, and its industrial production and operation.

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2. Definition of orbit parameters of utilization, value of a necessary impulse of transition and available power onboard an UPS

Value of a braking impulse for transfer UPS of the launcher with initial nearly circular orbits into elliptical orbit of utilization is determined proceeding from an altitude of a perigee of orbit of utilization at which aerodynamic braking with an orbit with a lifetime lower than 25 years. Definition of parameters of orbits of utilization represents an independent problem of the theory of flight of artificial satellites around of the Earth. In the offered article definition of power costs for transition to orbit of utilization for lifetime lower than in 25 years the program of NASA [2] was used.

Available reserves of characteristic velocity on board UPS are determined under the formula of the Ziolkovsky:

$$V_{расп} = P_{уд.}g_0 \ln\frac{m_0}{m_{kkc}} \qquad (1)$$

where $P_{уд}$, , - a specific thrust,

$m_0 = m_{ккс} + m_{топл}$,

$m_{ккс} = m^{оч}_{ккс} + m_{ADOS}$,- dry mass of construction UPS after separation of a payload, including mass of an ADOS

$m_{ADOS} = m_{сг} + m_{су}$, - mass of ADOS,

$m_{сг}$ - mass of a construction of a system of gasification in which structure gasliquidsystem, deliveries of the heat-carrier elements enter in fuel tanks, reserves of the compressed gas, capacities for fuel of the gas generator,

$m_{су}$,– mass of control system ADOS in which structure enter the measuring equipment, DFCC, drives (the chamber of the GE), a system of a power supply,

$m_{топл} = m^{т}_{оч} + m^{т}_{ADOS}$,

$m^{т}_{оч}$ - the propellants remaining at the end of the mission, either un-burnable or performance reserve in tanks UPS, fillings up of lines of a LPM etc. that makes up to 3 % from initial propellant loading,

$m^{т}_{ADOS}$, - propellant budgets for obtaining the heat-carrier system of gasification.

In connection with that propellant budgets $m^{т}_{ADOS}$ participate in gasification of fuel in tanks, as gas move in the chamber of GE, they are summarized to mass second propellant consumption, and received as additional power onboard for realization of an impulse of transition from orbit as its payload into orbit of utilization.

The carried out estimations of orbit parameters of utilization show, for example, for nearly circular orbits an altitude of 950-1000 *km* value of a perigee of orbit of utilization H_π makes near 680 - 700 *km*, and values of a required braking impulse [2] from 65 up to 75 *м/s*.

3. The scheme of activity of an ADOS

After separation of a payload from an UPS and its maintenance on the set distance

$$S_{зад} = V_{от} t_{ув}, \qquad (2)$$

where – $V_{от}$ speed of separation of a payload,

$t_{ув}$- time of withdrawal from UPS, implements start of a system of gasification and, accordingly, $\tau_{пр}$ start GE after a while implements.

Value $S_{зад}$, or $t_{ув}$ at known speed of separation $V_{от}$, is determined by the minimal distance of a maintenance of a payload from UPS on which the plume GE does not affect instrumentation of a payload.

Time of a warm-up and gasification of the propellants remaining at the end of the mission, either un-burnable or performance reserve in tanks UPS up to achievement of the set pressure for activity GE, but not exceeding permissible intratank pressure from conditions of strength of propellants tanks, is determined by parameters of activity of gas generators.

Thus, the satisfaction of a condition of time balance between time of withdrawal and time of a warm-up and gasification of the propellants remaining at the end of the mission, either un-burnable or performance reserve in tanks is necessary:

$$\tau_{пр} \geq t_{ув} = \frac{S_{зад}}{V_{от}} \qquad (3)$$

The gas jet propulsion system includes a system of gasification of the propellants remaining at the end of the mission, either un-burnable or performance reserve in tanks etc, the chamber GE.

On fig.1 the scheme of a construction of a propellant compartment with arrangement of elements ADOS is adduced.

Realization of process of gasification results in necessity of presence of the autonomous gas generator 8 with own system of maintenance of submission of the heat-carrier 11, 12, 13, 14 and propellant budgets 6, 7, necessary for gasification of the staying liquid propellant components.

At supply of hot gas-generator gas from the autonomous gas generator 8 in tanks 1,2 there is an intensive process of heating and evaporation, in tanks pressure increases and at achievement of as much as possible permissible tanks corresponding to strength, break of membranes 19, 20 implements. After break of membranes in the pipelines connecting tanks O and F with chambers GE 22, pairs components go in chambers 22 where enter reaction.

Maintenance of synchronism of processes of gasification in tanks O and F (simultaneous break of membranes, temperatures of components and pressure) options of activity 9,10, 15,16 autonomous gas generators 8.

Mission control of center of mass and around of center of mass on a segment activity ADOS in a considered case implements on the basis of twist UPS around of a centerline at once after separation of a payload due to powder engines of twist 23. It is supposed, that orientations of a centerline of UPS practically coincides vector of orbital speed. The is provided with selection of parameters of a mode and installation of a control system is in the long term planned on the basis of modern navigation methods and control. Is in the long term planned to use instead of powder rocket of twist 23 controlled chambers GE, established in one-sedate controlled drives. In this case the expediency of twist UPS its stabilization in the space disappears.

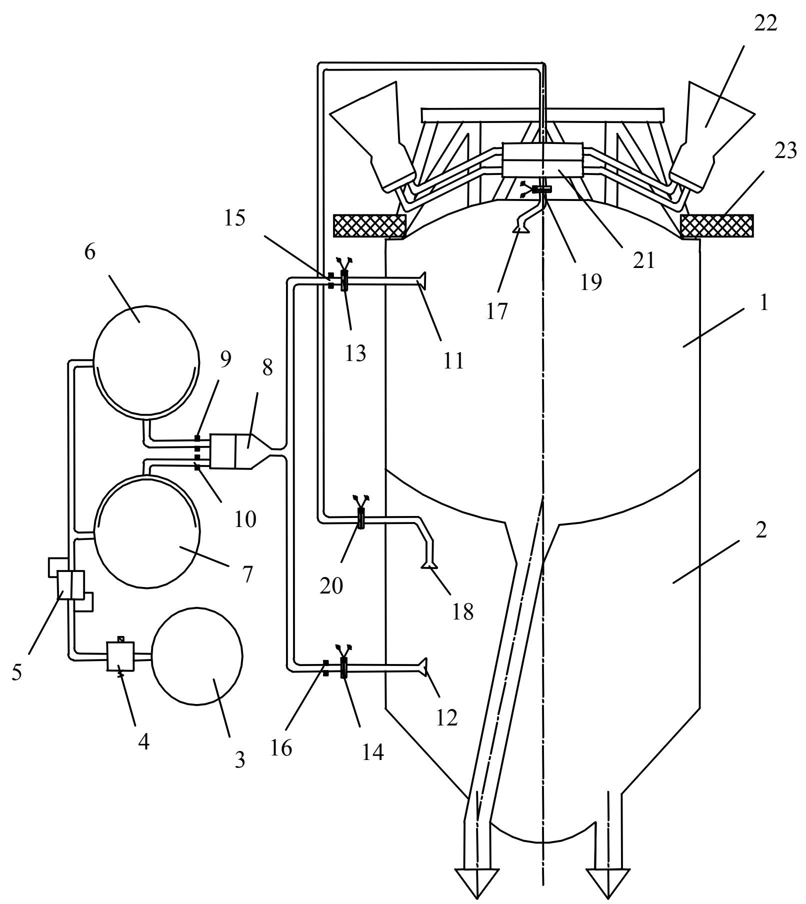


Fig. 1. Schема of a propellant compartment with accommodation of elements ADOS

1, 2 – oxidizer & fuel tanks, accordingly; 3 - sphere - bottle with neutral gas; 4 - the electro pneumatic valve; 5 - the reduction gearbox; 6,7 - expulsive tanks with an oxidizer and fuel; 8 - the gas generator; 9,10, 15,16 - account spacers; 11,12 - the pipe connection of input; 13,14,19,20 - membranes; 17,18 - pipelines of supply; 21 - a gas collector; 22 – chambers GE; 23 - powder rocket of twist.

4. The analysis of processes warmly - and mass transfer at gasification of the rests of liquid propellant components in tanks

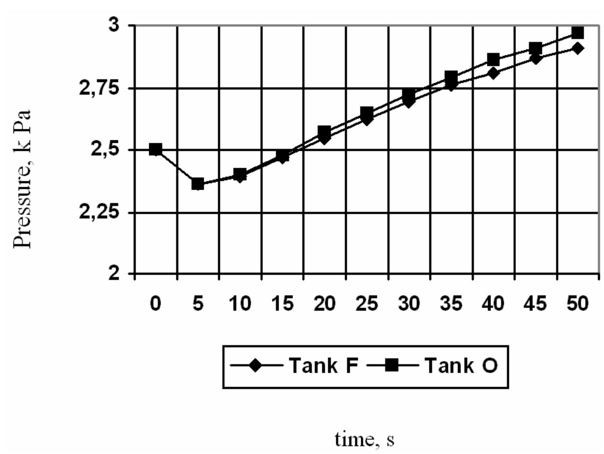
Absence of g-load after stages staging results in absence of a mirror of propellant components in tanks, to random mass distribution of the liquid rests of fuel in a volume of tanks O& F.

It results in some problems by selection of boundary conditions of a liquid in tanks at realization of numerical modeling process warmly – mass transfer.

Difference of a considered problem from known consists that in these activities the closed capacity in a field of mass forces with presence in it of a mirror of liquid fuel was traditionally considered. In a considered case boundary conditions as uniform distribution of the rests of a liquid on internal surfaces of a propellant tank are adopted.

Parameters of a system of gasification (temperature, pressure, second arrival of generator gas) for maintenance of gasification of the rests of liquid propellant and creation of necessary upstream pressure in the engine in view of conditions of heat exchange between walls of tanks, ablation gasificated propellant we shall determine from the analysis of a system of the equations adduced in [3]. It is necessary to emphasize, that value of a heat flow to configuration items of a propellants tanks take advantage of relation in a broad band of the numbers Re, received in activity [4].

On fig.2 results of calculations of activity of a system of gasification for tanks O& F pair AA-27И + NDMH on an example of a separable part 2-nd stages of the launcher "Kosmos - 3M" with realization of the required braking impulse ΔV determined pursuant to are adduced [2].



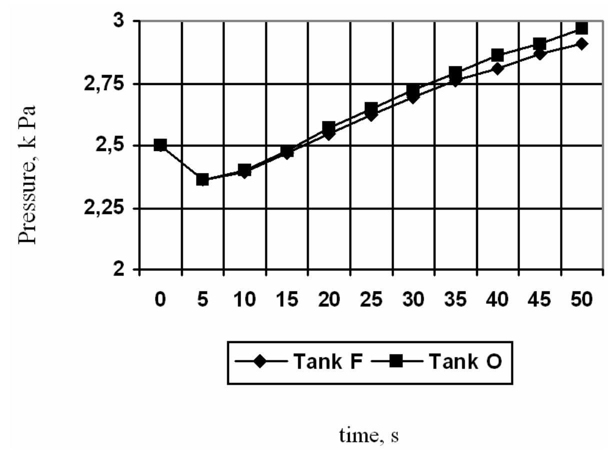


Fig.2

5. An estimation of volumes of adaptation of a design of a separable part of a final stage for realization of its utilization from orbit

In table №1 the structure of elements ADOS and their rough mass is adduced. As the prototype for an estimation of mass of a system it is used USP the second stage of the launcher "Kosmos - 3M".

	Elements of system ADOS	Rough mass, kg	The note
1	The gas generator with the supply system of propellant components, configuration items and automatics	16,9	Standard elements
2	Propellant budgets	67,5	AA+NDMH, take part in realization of an impulse of transfer of a stage into orbit of utilization
3	Pipelines of submission gasificated propellant components in GE	7,2	Standard elements
4	Four-chamber GE	2,2	New development
5	Powders engine for twist USP around of a centerline	5,0	Standard elements
6	Total	31,3	Corresponds up to 3 % from "dry" mass of the second stage of the launcher "Kosmos-3M"

Tab 1. Structure of elements ADOS

From tab. №1 follows, that is not required new development, except for four-chamber GE, having analogues and prototypes. In branch there is a significant experience of development of similar engines. All elements are made in a nominal complete set by the domestic industry, fulfilled.

Volumes of ground and flight improvement do not exceed conventional volumes at improvement of modernized products of space-rocket engineering at presence of prototypes

6. References

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