

BIFUNCTIONAL THRUST-VECTOR CONTROL SYSTEM OF LAUNCH VEHICLE SPACE STAGE ENGINE

The results of the development and research of a bifunctional thrust-vector control system of the liquid rocket cruise engine for advanced upper stages of the Cyclon-4M type launch vehicle are reported to extend the capabilities of thrust-vector control in several times and functional system capabilities in retaining high static, dynamic and overall-mass characteristics of actuator devices for the flight control system of a flight vehicle, to improve the stability of conditions of the flight stabilization and an operational reliability and to decrease power consumption for the flight vehicle trajectory control. The system is based on a simultaneous use of mechanic (gimbal engine swinging) and gas dynamic (a solid plug-type spoiler in supersonic flow for propellant injection) systems. Dynamic qualities and the flight control of the launch vehicle stage are compared under autonomous conditions and in combination with the above-mentioned mechanical and gas dynamical systems of the thrust-vector control. Rational operational conditions for every type of the thrust-vector control system are determined in their simultaneous operation. Physical bases for creating controlled forces and the results of calculations of static and dynamic (controlled) characteristics of every system are presented. The emphasis is on the development of a new gas dynamic system that operates under relay conditions at the flight stabilization and under analogue conditions in control of the stage flight trajectory. Some new solutions for the system of nozzle liquid injection are given.

Keywords: liquid rocket engine, thrust-vector control system, gas dynamic forces in nozzle, engine chamber swinging, system resistance, flight control.

1. Sixtieth Experience in Rocket manufacturing and Cosmonautics (*in Russian*) / Edited by A. V. Degtyarev. – Dnepropetrovsk: Art-Press, 2014. – 540 p.
2. Kovalenko T. A. Space stages as a control object (*in Russian*) / T. A. Kovalenko, Yu. D. Sheptun // Proceedings of Scientific Conference on Information Technology for Control of Complex Systems. – Dnepropetrovsk: Publishing House “Svidter A. L.”, 2011. – p. 210. – 213.
3. Dynamic Design of Rockets. Problems of Rocket Dynamics and their Space Stages: Book (*in Russian*) / I. M. Igdalov, L. D. Kuchma, N. V. Polyakov, Yu. D. Sheptun. Edited by S. N. Konyukhov. – Dnepropetrovsk: Publishing House of the Dnepropetrovsk National University, 2010. – 254 p.
4. Rocket as a Control Object (*in Russian*) / I. M. Igdalov, L. D. Kuchma, N. V. Polyakov, Yu. D. Sheptun / Edited by S. N. Konyukhov. – Dnepropetrovsk: Art-Press, 2004. – 544 p.
5. Kovalenko N. D. Rocket Engine as an Actuator of Rocket Control Flight System (*in Russian*) / N. D. Kovalenko. – Dnepropetrovsk: ITM, NASU&NSAU, 2003. – 412 p.
6. Special features of development work of thrust-vector control system for liquid rocket altitude engines (*in Russian*) / N. D. Kovalenko, G. A. Strelnikov, Yu. D. Sheptun, G. N. Kovalenko, A. D. Ignatyev // Vestnik DNU. Raketno-Kosmicheskaya Tekhnika. – 2008. – No 14.1. – P. 49 - 63
7. Comparison of controls of launch vehicle space stage (*in Russian*) / T. A. Kovalenko, N. D. Kovalenko, Yu. D. Sheptun // Vestnik DNU. Raketno-Kosmicheskaya Tekhnika. – 2011. – Vol. 1, No 14. – P. 64- 71.
8. Gas dynamic systems of thrust-vector control for liquid rocket engines as actuators of flight control system of upper rocket stages (*in Russian*) / N. D. Kovalenko, G. A. Strelnikov, G. N. Kovalenko, T. A. Kovalenko, Ye. L. Tokareva, A. D. Ignatyev, N. P. Sirotkina // Tekhnicheskaya mekhanika. – 2013. – No 4. – P. 70 – 83.
9. Patent for Invention 103528 Ukraine, IPC F02K 9/00. Technique of Thrust-Vector Control of Liquid Rocket Engine and Liquid Rocket Engine for it (*in Ukrainian*) / Kovalenko M. D., Sheptun Yu. D., Strelnykov G. O., Kovalenko T. O., Surotkina N. P.; applicant and patentee ITM, NASU&NSAU. – a 2011 14384; filed 05.12. 2011; published 25. 10. 2013, Bul. No 20. – 11 p.
10. Patent for Invention 105214 Ukraine, IPC F02K 9/56, F02K 9/82. Technique of Thrust-Vector Control of Liquid Rocket Engine and Liquid Rocket Engine for it (*in Ukrainian*) / Kovalenko M. D., Sheptun Yu. D., Kovalenko T. O., Surotkina N. P.; applicant and patentee ITM, NASU&NSAU. – a 2011 12467; filed 24.10.2011; published 25. 04. 2014, Bul. No 8. – 10 p.
11. Patent for Invention 105214 Ukraine, IPC F02K 9/00. Technique of Thrust-Vector Control of Liquid Rocket Engine with Turbo-Pump Unit for Supplying Propellant Components in Combustion Chamber and Liquid Rocket Engine for it (*in Ukrainian*) / Kovalenko M. D., Strelnykov G. O., Sheptun Yu. D., Kovalenko G. M., Kovalenko T. O., Surotkina N. P.; applicant and patentee ITM, NASU&NSAU. – a 2013 06211; filed 20.05.2013; published 05.08.2014– 11 p.
12. Application a 2013 08511 Ukraine, IPC F02K 9/00. Technique of Thrust-Vector Control of Liquid Rocket Engine and Liquid Rocket Engine for it (*in Ukrainian*) / Kovalenko M. D., Strelnykov G. O., Sheptun Yu. D., Kovalenko G. M., Kovalenko T. O., Surotkina N. P.; applicant and patentee ITM, NASU&NSAU. –filed 08.07.2013. - 9 p.
13. Application for Invention Ukraine, IPC F02K 9/00. Liquid Rocket Engine with Turbo-Pump System of propellant supply in Combustion Chamber and System of Gas Dynamic Thrust-Vector Control (*in Ukrainian*) / Kovalenko T. O., Kovalenko G. M., Kovalenko G. M., Surotkina N. P.; applicant and patentee ITM, NASU&NSAU. – No 57/ 683 -02 of 23.09. 2014. – 8 p.