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SOLUTION OF CURRENT PROBLEMS IN THE DYNAMICS OF HYDROMECHANICAL AND VIBRATION PROTECTION SYSTEMS

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This paper overviews the main results of the solution of current problems in the dynamics of liquid-propellant rocket engines (LPREs), liquid-propellant launch vehicle (LV) pogo stability, the dynamics if vibration protection systems, blade machine gas-dynamics, and the dynamics of hydraulic systems with cavitating restrictors. These results are as follows. Coupled longitudinal and longitudinal bending oscillations of the feed lines and the liquid in hydraulic systems with cavitating LPRE pumps were simulated mathematically. The start of a sustainer LPRE with generator gas afterburning was simulated mathematically. The effect of damping the oscillations of individual dynamic links of the liquid-propellant LV body on the LV pogo stability and longitudinal oscillation amplitude was studied numerically. A technique was developed for the theoretical prediction of dynamic loads on liquid-propellant LV upper stages and spacecraft during the orbital injection. The pogo stability of new liquid-propellant space rockets of tandem and pack configuration was predicted theoretically at the draft design stage. A new pneumatic system was proposed for the Sich-2 spacecraft to protect it against longitudinal vibration loads during the orbital injection. A vibration protection system was designed to protect operators of vehicles of different purposes from impact and alternating loads. Up-to-date methods were developed for aerodynamic shape refinement of aircraft gas-turbine engine compressor blade channels. Unsteady liquid flow in a hydraulic system with a cavitating plate orifice was simulated numerically. Topical problems of solids grinding in a liquid medium were solved on the basis of the development and making of an experimental cavitation pulse plant for the production of fine-dispersed media and investigations into the hydrodynamics of new industrial devices with cavitating components.

Keywords: *liquid-propellant rocket propulsion system, liquid-propellant rocket engine, dynamics, stability, vibration protection system, blade machine gas-dynamics, mathematical simulation.*

1. *Pylypenko V. V., Zadontsev V. A., Dovgotko N. I., Grigoriev Yu. E., Manko I. K., Pylypenko O.V.* Liquid-propellant rocket propulsion system dynamics and liquid-propellant launch vehicle pogo stability (*in Russian*). Teh. Meh. 2001. No. 2. Pp.11–37.
2. *Dolgopolov S. I.* Semiempirical technique for determining coefficient of liquid inertia resistance due to inverse flows at inlet of centrifugal inclined Archimedean screw pump (*in Russian*). Teh. Meh. 2014. No. 2. Pp. 36–42.
3. *Dolgopolov S. I.* Characterization of cavitation self-oscillations in a hydraulic system in the case of coupled longitudinal oscillations of the pipeline structure and the liquid (*in Russian*). Teh. Meh. 2014. No. 3. Pp. 79–86
4. *Dolgopolov S. I.* Effects of nonlinear characteristics of bellows on parameters of cavitation self-oscillation under combined longitudinal oscillation of line structure and fluid (*in Russian*). Teh. Meh. 2015. No. 3. Pp. 30–38.
5. *Pylypenko O. V., Prokopchuk A. A., Dolgopolov S. I., Khoryak N. V., Nikolaev A. D., Pisarenko V. Yu., Kovalenko V. N.* Mathematical simulation and stability analysis of low-frequency processes in a liquid-propellant sustainer engine with generator gas afterburning (*in Russian*). Vestnik Dvigatelestroeniya. 2017. No. 2. Pp. 34–42.
6. *Pylypenko O. V., Prokopchuk A. A., Dolgopolov S. I., Pisarenko V. Yu., Kovalenko V. N., Nikolaev A. D., Khoryak, N. V.* Peculiarities of mathematical modeling of low-frequency dynamics of the staged liquid rocket sustainer engines at its startup (*in Russian).* Kosm. Nauka Tehnol. 2017. V. 23, No. 5. Pp. 3–12.
7. *Khoriak N. V., Dolhopolov S. I.* Features of mathematical simulation of gas path dynamics in the problem of the stability of low-frequency processes in liquid-propellant rocket engines (*in Russian*). Teh. Meh. 2017. No. 3. Pp. 30–44.
8. *Nikolaev A. D., Bashliy I. D.* Determination of parameters of propellant oscillation in tanks of space stages of launch vehicles before restarting the cruise engine with low filling (*in Russian*). Teh. Meh. 2013. No. 3. Pp. 10–20.
9. *Nikolayev O. D., Bashliy I. D., Sviridenko N. F. , Khoriak N. V.* Determination of the parameters of motion of the gas–liquid interface in the fuel tanks of launch vehicle space stages in passive portions of the flight (*in Russian*). Teh. Meh. 2017. No. 4. Pp. 26–40.
10. *Kolesnikov K. S.* Pogo Oscillations of a Liquid-Propellant Rocket (*in Russian*). Moscow: Mashinostroyeniye, 1971. 260 pp.
11. *Natanzon M. S.* Pogo Self-Oscillations of a Liquid-Propellant Rocket. Moscow: Mashinostroyeniye, 1977. 208 pp.

12. *Pilipenko V. V.* Providing the LPRE – Rocket Structure Dynamic Compatibility. 29th Joint Propulsion Conference and Exhibit: Report (Monterey, June 28-30, 1993). Monterey,1993. AIAA 93-2422.
13. *Pilipenko V. V., Zadontsev V. A., Natanzon M. S.* Hydrosystem Cavitation Self-Oscillations and Dynamics (*in Russian*). Moscow: Mashinostroyeniye, 1977. 352 pp.
14. *Pilipenko V. V.* Cavitation Self-Oscillations (*in Russian*). Kiev: Naukova Dumka, 1989. 316 pp.
15. *Khoryak N. V.* Effects of energy dissipation of liquid propellant oscillation in tanks and structural damping a liquid launch vehicle on its longitudinal stability (*in Russian*). Teh. Meh. 2013. No. 3. Pp. 21–33.
16. *Khoryak N. V., Nikolaev A. D., Dolgopolov S. I.* Effect of in-tank liquid propellant oscillation damping on the amplitudes of liquid-propellant rocket pogo oscillations (*in Russian*). Aviatsionnaya Tekhnika i Tekhnologiya. 2014. No. 7/114. Pp. 34–40.
17. *Nikolaev A. D., Khoryak N. V., Serenko V. A., Klimenko D. V., Khodorenko V. F., Bashliy I. D.* Considering dissipative forces for mathematical modeling longitudinal vibrations of liquid launch vehicle body (*in Russian*). Teh. Meh. 2016. No. 2. Pp. 16–31.
18. *Naumenko N. Ye., Sobolevskaya M. B., Sirota S. A., Nikolaev A. D., Bashliy I. D.* Nonlinear oscillation of free surface of a liquid into horizontally located cylindrical tank. Teh. Meh. 2015. No. 4. Pp. 92–102.
19. *Khoryak N. V.* Characterization of a dynamic damper of liquid-propellant rocket body pogo oscillations (*in Russian*). Teh. Meh. 2014. No. 3. Pp. 58–70.
20. *Khoryak N. V., Nikolaev A. D., Dolgopolov S. I.* Theoretical estimation of the efficiency of dynamic damper of liquid-propellant rocket pogo oscillations (*in Russian*). Aviatsionnaya Tekhnika i Tekhnologiya. 2015. No. 9/126. Pp. 26–31.
21. *Bashliy I. D., Nikolaev A. D.* Mathematical modelling 3D oscillation of shell structures with a fluid using modern tools for computer designing and analyzing (*in Russian*). Teh. Meh. 2013. No. 2. Pp. 18–25.
22. *Bashliy I. D.* Determination of stressed-strained conditions for structure of space stage of liquid launch vehicle under longitudinal oscillation (*in Russian*). Teh. Meh. 2014. No. 1. Pp. 26–36.
23. *Nikolaev A. D., Khoryak N. B., Bashliy I. D., Pirog V. A., Khodorenko V. F.* Mathematical modelling 3D oscillation of liquid launch vehicle upper stage with cruise gimbal-mounted engine (*in Russian*). Teh. Meh. 2014. No. 2. Pp. 24–35.
24. *Melashich S. V.* Intelligent expert system for aerodynamic designing and optimization of compressor blade rows for gas-turbine engines (*in Russian*). Teh. Meh. 2013. No. 2. Pp. 72–79.
25. *Rublevsky E. Yu., Plakushchy D. A., Pismenny V. I., Kvasha Yu. A.* Numerical study of a two-stage fan (*in Russian*). Vestnik Dvigatelestroyeniya. 2013. No. 2. Pp. 169–176.
26. *Melashich S. V., Bolotova N. V.* Parametric description of vane form of compressor row blades of aircraft gas turbine engines (*in Russian*). Teh. Meh. 2013. No. 3. Pp. 42–49.
27. *Melashich S. V.* Applications of artificial neuron networks for solution of an inverse problem of gas dynamics of compressor cascades (*in Russian*). Teh. Meh. 2014. No. 1. Pp. 46–51.
28. *Melashich S. V., Kvasha Yu. A.* Numerical simulation of transonic flow in an axial-flow compressor rotor (*in Russian*). Teh. Meh. 2014. No. 3. Pp. 15–22.
29. *Melashich S. V.* Solution of inverse problems of gas dynamics of flat compressor cascades based on numerical simulation of turbulent flows (*in Russian*). Teh. Meh. 2015. No. 1. Pp. 65–72.
30. *Melashich S. V.* Utility of stochastic methods in solution of problems of aerodynamic optimization of gas-turbine engine compressor cascade shape (*in Russian*). Teh. Meh. 2015. No. 3. Pp.. 39–45.
31. *Melashich S. V.* Computations of stressed-strained state of compressor rim blade using OpenFOAM numerical simulation platform (*in Russian*). Teh. Meh. 2017. No. 2. Pp. 51–60.
32 *Kvasha Yu. A., Zinevich N. A.* Aerodynamic optimization of spatial form of impeller blade of supersonic compressor stage (*in Russian*). Teh. Meh. 2016. No. 2. Pp.35–42.
33. *Kvasha Yu. A., Zinevych N. A.* Aerodynamic optimization of the shape of supersonic compressor stage guide blades (*in Russian*). Teh. Meh. 2017. No. 4. Pp. 18–25.
34. *Bolotova N. V., Kvasha Yu. A.* Numerical simulation of cavitation self-excited oscillation through hydraulic system behind plate orifice (*in Russian*). Teh. Meh. 2013. No. 1. Pp. 61–67.
35. *Pylypenko O. V.* Development of burners for high-performance combustion of coal-water fuel (*in Russian*). Teh. Meh. 2015. No. 4. Pp.. 23–33.

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