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MATHEMATICAL SIMULATION OF HARD EXCITATION OF CAVITATION SELF-OSCILLATIONS IN A LIQUID-PROPELLANT ROCKET ENGINE FEED SYSTEM

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Hard self-oscillation excitation differs from soft excitation in that self-oscillations are set up only if the initial departure of an oscillating system from equilibrium is strong enough. Experimental studies of cavitation oscillations in hydraulic systems with cavitating pumps of liquid-propellant rocket engines (LPREs) include works that describe hard excitation of cavitation oscillations. By now, hard excitation regimes have not been explained theoretically, to let alone their mathematical simulation.

This paper presents a mathematical model of hard excitation of cavitation oscillations in a LPRE feed system, which comprises a mathematical model of cavitation self-oscillations in a LPRE feed system that accounts for pump choking and an external disturbance model. A mechanism of hard excitation of cavitation oscillations in a LPRE feed system is proposed. It is well known that hard excitation of cavitation self-oscillations may take place in cases where the pump feed system is near the boundary of the cavitation self-oscillation region. In this case, the self-oscillation amplitudes are small, and they are limited only by one nonlinearity (cavity volume vs. pump inlet pressure and flow relationship). Under excitation of sufficient intensity, the pump inlet pressure and flow find themselves in the choking characteristic; this may be responsible for choking and developed cavitation self-oscillations, which remain of interrupted type and do not go into the initial small-amplitude oscillations even after excitation removal. A mathematical simulation of hard excitation of cavitation self-oscillations was conducted to determine the parameters of cavitation self-oscillations in a bench feed system of a test pump. The simulation results show that without an external disturbance the pump system exhibits small-amplitude self-oscillations. On an external disturbance, developed (interrupted) cavitation oscillations are set up in the system, which is in agreement with experimental data. The proposed mathematical model of hard excitation of cavitation self-oscillations in a LPRE feed system allows one to simulate a case observed in an experiment in which it was possible to eliminate cavitation self-oscillations by an external disturbance.

Keywords: liquid-propellant rocket engine, inducer-equipped centrifugal pump, cavitation, cavitation self-oscillations, hydrodynamic model, choking, hard excitation.

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