UDC 532:595

V.V. Gavrilenko, Doctor of Physics and Mathematics, Professor
(National Transport University, Ukraine)
O.S. Limarchenko, Doctor of Technical Sciences, Professor
(Kyiv National Taras Shevchenko University, Ukraine)
O.P. Kovalchuk
(National Transport University, Ukraine)

Multipurpose use of the pipeline-liquid system in the nonlinear range of perturbations

The pipelines on which the liquid is transported is an integral part of many transport and construction systems. Such systems surround us, both in the civil engineering sector, in transport systems and in transport infrastructure. Such systems are operated under high pressure conditions under vibration conditions. The pipelines are interacting with other components. Let's assume that the pipeline connects the fuel tank and the engine, the pipeline connects the turbine and the trunk line, which transports for example oil or gas.

The use of pipelines can be found in many areas of human life: pipelines are used in water supply, heating, technological cleaning, various constructions and structures, in automobiles, in mechanical engineering and mechanism, in power engineering, industry, aircraft engineering and space technologies. One of the most important tasks of science is the study of the behaviour of pipelines in transitional modes of fluid flow in the vicinity of critical velocities of the fluid. Particular attention is paid to the behaviour of the system when approaching the critical flow of velocities, when there is a loss of stability of the rectilinear form of the pipeline. This can lead to the destruction of the pipeline. Therefore, in view of the great value of such objects and the possible negative consequences in the event of pipeline destruction, the question arises about the development of effective methods for mathematical modelling of the pipeline system - the liquid in the linear and nonlinear ranges of system parameters changes. On the basis of the developed methods, it is necessary to conduct a study of passive and active quenching of unwanted oscillations that arise in the transitional modes of the system of the pipeline - the liquid during operation. The results showed that the mechanism of action of the Coriolis forces far exceeds the nonlinear mechanisms for promoting the redistribution of energy in a pipeline with a flowing fluid. Coriolis forces contribute to the excitation of higher forms of oscillation, which ultimately leads to the manifestation of a superharmonic in the resulting change in the parameters of the system fluctuations. For the case of different fixings of the pipeline, the expression of the Coriolis forces is decisive and leads to approximately the same effects. The presence of a free edge greatly enhances the manifestation of nonlinear mechanisms, which, moreover, manifest in conjunction with the action of the Coriolis forces.

The developed methods of mathematical modelling, to solve the problem of quenching of vibrations at this stage, are related to the study of passive and active quenching of unwanted oscillations that arise in pipeline-fluid systems during operation under transitional modes of motion.

Due to the choice of effective parameters and locations of damping devices, active damping of fluctuations of pipelines is possible. To provide an effective mode of operation of pipelines with liquid, to determine effective methods of damping oscillations, allows research of transient processes of pipeline dynamics. The results that can be obtained in the course of these studies can be applied in various fields: space and aviation industry, energy, transport industry, chemical and oil refining engineering.

A considered multicomponent system consists of an elastic tube which is under the influence of the high velocity flow of the fluid in it. Creation of a pipeline-fluid system model in the study of transients connected with significant mathematical difficulties. Classical linear theory does not provide results that are consistent with practice. It does not take into account the influence of nonlinear mechanisms, which significantly reduces the accuracy of modelling of real oscillations. When taking into account nonlinear members of the equations of motion, obtaining an exact analytical solution to the problem of pipeline dynamics is not possible even for the simplest cases of system movement. At the same time, the solution of the problem within the framework of nonlinear formulation by analytical methods is impossible so far, therefore, it is necessary to apply a numerical-analytical approach. The behaviour of this system is investigated on the basis of a nonlinear model whose construction is based on the Hamilton-Ostrogradsky variation principle. On the basis of the method, the motion of systems is presented in the form of decomposition in the form of oscillations. Such a problem is reduced to a discrete model: a finite-dimensional system of ordinary differential equations with respect to the amplitude parameters of the beam fluctuations on separate forms. The important point is that the input system for the case of a nonlinear model requires a mixed description of its component.

Numerical results have shown that the mechanism of these forces is much greater than the nonlinear mechanisms that facilitate the redistribution of energy in a pipeline with a liquid. For the case of various reinforcements of the pipeline, the manifestation of such forces is decisive and at the considered interval of time leads to approximately the same consequences; but the presence of a free edge greatly enhances the manifestation of nonlinear mechanisms. The developed model is sufficiently versatile and can be applied to study many application problems of pipeline dynamics in transitional modes of motion. Important results are an analysis of the influence and nature of various nonlinear mechanisms, the study of different fluid flow regimes, and the possibility of applying the flow law to damping oscillations.

References

1. Gavrilenko V.V., Lymarchenko O.S., Kovalchuk O.P., 2011. Model' nelinijnoi' dynamiky truboprovodu z shvydkisnoju techijeju ridyny pry riznyh sposobah zakriplennja [Model nonlinear dynamics of pipe with high–speed flow of fluid under different ways of fixing]. Proceedings of the National Transport

University.
Part 2. Kiev, NTU, Vol.24, 278-281.

2. Gavrilenko V.V., Lymarchenko O.S., Kovalchuk O.P., 2012. Harakter sylovoi' vzajemodii' truboprovodu z ruhomoju ridynoju pry shvydkisnomu ruhu ridyny [The character a forces interaction of pipe with movable fluid under high–speed flow of fluid]. Problems of the transport. Collection of scientific papers. Kiev, NTU, Vol.9, 249-252.
3. Vasylevskyy J.E., Lymarchenko O.S., Kovalchuk O.P., 2010. Mehanizm vtraty nelinijnoi' stijkosti truboprovodu pry shvydkisnij techii' ridyny [The mechanism of loss of nonlinear stability of pipe under high–speed flow of fluid] Municipal services of cities: Scientific and technical collection. Kyiv-Kharkiv Base, Vol.91, 49-56.
4. Kovalchuk O.P., 2015. Nelinijna dynamika truboprovodu z shvydkisnoju techijeju ridyny pry riznyh sposobah zakriplennja (Nonlinear dynamics of pipe with with high–speed flow of fluid under different ways of fixing) Proceedings of the National Transport University. Kiev, NTU, Vol.31, 242-245.
5. Babakov I.M., 1968. Teoryja kolebanyj [The theory of vibrations]. Moskow, Science, 560.
6. Bondar N.G., 1971. Nelinejnye avtonomnye zadachi mehaniki uprugih sistem [The nonlinear self-giving problems of the mechanics of inelastic systems]. Kiev, Budivelnik, 140.
7. Kilchevsky N.A., 1977. Kurs teoreticheskoj mehaniki [The course of the theoretical mechanics]. Moskow, Science, Vol.2, 544.
8. Mikhlin S.G., 1970. Variacionnye metody v matematicheskoj fizike [The variation methods in mathematical physics]. Moskow. Science, 512.