Numerical Modeling of Viscoelastic Pipelines Vibrations Considering External Forces

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August 25, 2022

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Abstract. The vibration process of an extended section of a pipeline conveying medium are studied in the paper using the well-known classical models of laminar flow of an ideal incompressible fluid and the Bernoulli – Euler rod bending. A mathematical model of linear problems on transverse vibrations of a rectilinear viscoelastic pipeline with a medium moving inside it is derived. A computational algorithm has been developed to solve the problems of the dynamics of a viscoelastic pipe conveying fluid flow. To describe the stress-strain dependence, the Boltzmann-Volterra integral model is used. Based on the developed computational algorithm, a package of applied computer programs has been created that allows conducting numerical studies of dynamic strain of a pipeline conveying fluid flow, based on the Winkler base, considering the viscosity properties of the structure material and the pipe bases, axial forces, internal pressure, resistance forces and external forces. When modeling linear problems, a number of new dynamic effects were investigated: it was found that an account of viscoelastic properties of the material and the pipeline base leads to a decrease in amplitude and frequency of pipe vibrations; it was revealed that with an increase in the frequency of external loads, the amplitude and frequency of pipe vibrations increase. It is shown that an increase in external load parameter leads to an increase in vibration amplitude, and to a decrease in vibration frequency.

Keywords: mathematical modeling, computational algorithm, viscoelasticity, pipeline, vibrations, external forces.

1. Introduction

Pipelines are widespread elements of technology used in oil and gas industry, engineering structures, aircrafts and in other sectors of economy. A pipeline with a fluid flowing under pressure is a design element of many systems. They are used in nuclear facilities, in the aircraft industry, in oil and gas industry, in chemical production facilities, in water supply systems in residential buildings, and in a great number of other objects surrounding a person. In the event of high-pressure pipeline destruction, depressurization of a joint or pipe rupture at the point of attachment, the consequences of such accidents can lead to significant material losses and to fatalities and environmental disasters. In view of severe economic and environmental consequences of possible accidents, increased demands are placed on the strength of the structures being developed and on the piping systems that are part of them. In most cases, full-scale testing (up to destructive loads) of pipelines conveying fluids, is not always possible or difficult due to their high cost. Under these conditions, mathematical modeling of the dynamics of pipeline systems with fluid becomes especially relevant (Li Qian et al., 2020a, 2020b).

One of the main problems of pipeline transport systems is their susceptibility to corrosion due to pipe material contact with aggressive media. According to statistics, most accidents occurring in oil- and gas-conveying pipelines are the result of corrosion processes. In connection with this, there is an acute problem of finding alternative ways to modernize oil and gas pipeline systems, especially when transporting aggressive media. An obvious promising and modern direction is the introduction of pipes made of high-strength and corrosion-resistant composite materials.

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