Nonlinear vibrations of a cylindrical pipe embedded in a fractional derivative medium

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Abstract. The model of a nonlinear cylindrical shell embedded into a fractional derivative Kelvin-Voigt medium has been utilized for studying the one-to-one and three-to-one internal resonances in cylindrical pipes conveying fluids by the fractional derivative expansion method.

Introduction

Pipes conveying fluid have important applications in many industrial fields, such as the oil extraction and transmission, offshore infrastructures, heat exchangers and civil engineering. Overview of mechanics of pipes conveying fluids is given in [1], including linear and nonlinear response of pipes made of elastic or viscoelastic materials. It is known that nonlinear vibrations could be accompanied by such a phenomenon as the internal resonance, resulting in strong coupling between the modes of vibrations involved, and hence in the energy exchange between the interacting modes. Internal resonances were studied in pipes as well [2]. In recent decades the fractional derivative models have been widely used for solving different dynamic problems of mechanics [3], among them in the dynamics of fluid-conveying pipes [4-9], in so doing a pipe, as a rule, is modelled as a Bernoulli-Euler or Timoshenko beam. However, the more realistic model of the pipe is a cylindrical shell containing fluid. Therefore, in the present paper, the model of the nonlinear cylindrical shell vibrating in a fractionally damped surrounding medium [10,11] has been generalized for the case of the conveying-fluid pipe embedded in a fractional derivative Kelvin-Voigt medium.

Results and discussion

The 1:1 and 1:3 internal resonances in cylindrical pipes conveying fluids have been studied by the fractional derivative expansion method [12]. The internal resonances belong to the resonances of the constructive type, despite of external resonances which could be eliminated by changing the frequency of external loads. Since all of internal resonances depend on the geometrical dimensions of the shell under consideration and its mechanical characteristics, that is why such resonances could not be ignored and eliminated for a particularly designed shell. The results of this study give useful information to avoid the internal resonance and control the resonant responses of the cylindrical pipes conveying fluid.

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