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On the Vibrational Analysis of Cantilevered Fluid Conveying Micro-Beams Rested on Various Elastic Foundations

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ABSTRACT: In this research, using modified couple stress theory, dynamic stability of a cantilevered fluid conveying beam embedded in several types of surrounded elastic media has been studied. The governing equation for lateral vibrations of the micro-tube conveying fluid is derived using the extended Hamilton's principle. The numerical results are obtained by employing the extended Galerkin's method. For the sake of validation, the acquired results for simple cases are compared and outcomes indicate a very good agreement with those of previous studies available in the literature. The stability diagrams of different configurations with different flow velocities are studied and the effects of various factors such as material length scale, external diameter and different elastic properties on the stability of the system are considered. Results indicate that elastic surrounding media may enlarge the stability regions significantly at larger values of mass ratio parameter while decrease it for smaller values of mass ratio parameter. Furthermore, using elastic media mathematically defined by series functions provides the capability to simulate almost any real time operational environment the micro-tube embedded in and results in an optimal stability state of the micro-structure carrying fluid flow.

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introduction

1- Introduction

The field of Fluid-Structure Interactions (FSI), especially pipes carrying fluid flows, is extensively investigated by numerous researchers. Due to their application in various fields of engineering especially in chemical plant piping systems, municipal water supply, heat exchangers, risers and marine structures, production pipelines, boiling water reactors, hydropower systems, pump discharge lines and etc., their dynamics is widely studied.

The most important issue concerning the dynamical behavior of micro/nanofluid conveying systems is their instability caused by internal fluid flow movement and has been used to be an attractive field of study to researchers. Extending the stability region of micro/nanotubes is a crucial requirement that should be considered in designing such systems. Undoubtedly, fluid conveying structures embedded in different elastic environments are much more anticipated to result in wider thresholds of stability.

Recently, the application of micro/nanostructures in high-tech fields has been considered as a novel rich dynamical problem in the field of mechanics of vibrational systems. Applications include information technology, semiconductors, fluid storage, transport and biosensors, electromechanical devices, actuators and biology, among others. Recent developments have accompanied to design and manufacture smaller micro/nano tubes which have made researchers to promote theoretical models enabling them to mathematically model such systems with satisfying precision, considering the micro/nano structure small effects. Recent research outcomes revealed that materials exhibit strong size-dependent characteristics in micron and nano sizes.

The objective of the current paper is to investigate the effect of different types of variable, partial and series elastic as well as Pasternak media on the dynamical behavior of cantilevered micro-tubes in order to clarify the effect of such simulated environments on the stability thresholds. Various essential diagrams such as stability maps showing the effect of material length scale, external diameter and different types of elastic foundations are plotted and their influence on stability borders have comprehensively studied and analyzed. It will be portrayed that both the material length scale coefficient and various forms of elastic and Pasternak foundations have a significant effect on the stability of the system under consideration and considering their role on dynamical behavior and response of the structure is inevitable.

2- Methodology

In this section the so called extended Galerkin procedure is applied to discretize the partial differential equation of oscillatory motion of the micro-tube. The proper weighting functions η have been chosen so that they satisfy the specified essential boundary conditions. The transverse normalized displacement η is approximated as the following series [1, 2].

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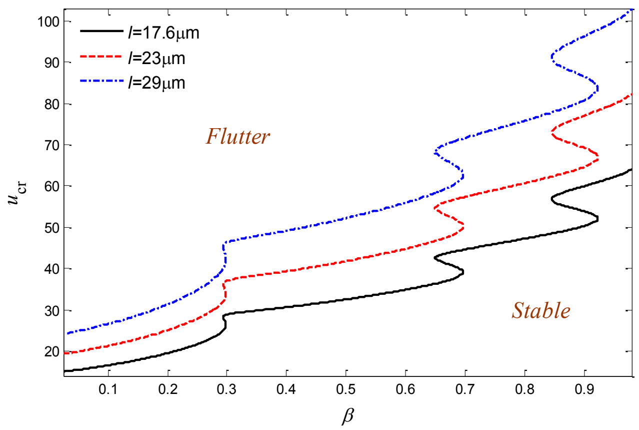

Fig. 1. Flutter instability boundaries for three distinct values of ℓ in terms of dimensionless mass ratio $\beta; D = 10\mu m, K_G = K_W = 0$

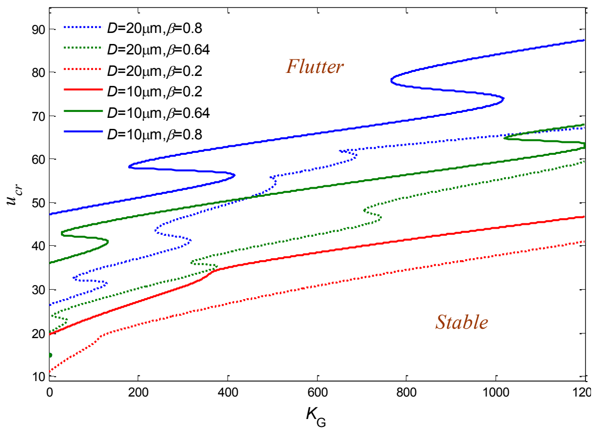

Fig. 2. Flutter instability boundaries for three distinct values of ℓ in terms of dimensionless mass ratio $\beta; D = 10\mu m, K_G = K_W = 0$

$$\eta(\xi,\tau)=\sum_{r=0}^{n}\varphi_r(\xi)q_r(\tau) \tag{1}$$

respectively. Finally, the discretized form of the equation of motion can be acquired to be:

$$[M]\{\ddot{q}(\tau)\}+[C]\{\dot{q}(\tau)\}+[K]\{q(\tau)\}=0 \tag{2}$$

Following the procedure presented in the eigenvalues and the corresponding eigenvectors of the above mentioned micro-tube system can be obtained by solving the eigenvalue problem. Recalling that , the real part of ω being associated with frequency of oscillations while the imaginary part is associated with the decaying rate of amplitude.

3- Results and Discussion

Enhancing the material length scale parameter by choosing appropriate materials is a certain scenario of enlarging the stability region of the system [3, 4].

Embedding the system in a variable type of elastic media can either stabilize or destabilize the fluid-conveying cantilevered micro-tube with respect to the equivalent system without foundations, depending severely on β values.

Determination of the operational conditions of the structure especially the true range of dimensionless mass ratio parameter enables one to enhance the stability regions of the micro-tube significantly by considering the appropriate form of the elastic foundations such as variable, partial, series or Pasternak

4- Conclusion

The more the value of γ is, the more dissipative the system will be, however, the system will later undergo flutter instability.

Varying k0 for variable elastic foundations, affirms that as the parameter γ increases, the instability-restabilization-instability sequence occurs in a more limited range. Hence, one can deduce that flutter velocity and frequency sets are smaller in smaller values of γ

In case of partly supported elastic foundations, depending on the operational values of , one can choose the location of the foundation such that to enlarge the stability region. Moreover, shortening the foundation which is highly dependent on , would result in a more stable condition. Hence, by determining the real time operational values of , one can select not only the appropriate length of the partial elastic foundation, but also, its true position to significantly enlarge the stability area.

By considering series foundations of various polynomial orders, simulation of virtually any operational environment for the micro-tubes conveying fluid flow is feasible. Furthermore, for the sake of comparison, assuming the rigidity surface to be a constant, one can define series foundations to optimally promote the system stability.

In general, one can conclude that the influence of Pasternak foundations on the enlargement of stability regions is much more prominent than elastic foundations. Considering a Pasternak foundation for low values of leads to a gradual enhancement of the critical values of flow velocities. However, for moderate and higher values of this parameter, the critical flow velocities do not monotonously increase with increasing and a clearer feature of S-shaped segments is observed indicating an enhancement in the number of transference of instability modes.

Determination of the operational conditions of the structure especially the true range of dimensionless mass ratio parameter enables one to enhance the stability regions of the micro-tube significantly by considering the appropriate form of the elastic foundations such as variable, partial, series or Pasternak.

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