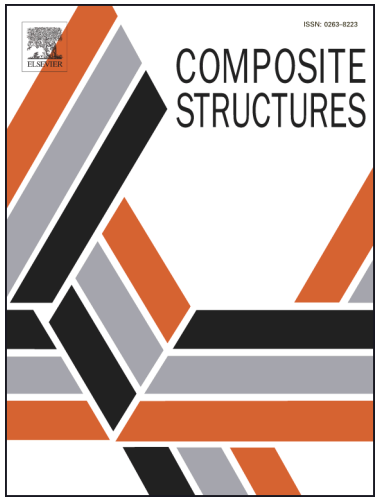


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# Dynamics of axially functionally graded cantilevered pipes conveying fluid

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## ABSTRACT

The linear dynamics of axially functionally graded (AFG) cantilevered pipes conveying fluid is studied, aiming at enhancing the dynamic stability of such fluid-interaction systems. Either the elastic modulus or the density of the AFG cantilevered pipe is assumed to be varied from the clamped to the free ends. The governing equation of the AFG pipe is derived first and then discretized by using the differential quadrature method (DQM). The effects of elastic modulus gradient and density gradient on the critical flow velocity for flutter instability are analyzed. It is found that, compared with uniform pipes, the decrease of density along the pipe length leads to a more stable system, while the opposite result may be obtained for the decrease of elastic modulus for small values of mass ratio. From the boundary curves of critical flow velocity versus density gradient and of critical flow velocity versus elastic modulus gradient, it is shown that the occurrence of Z-shape segments is possible when the mass ratio becomes large. Furthermore, the phenomenon of mode exchange has also been detected with increasing density gradient or elastic modulus gradient within a certain range of mass ratio.

*Keywords*: axially functionally graded materials; cantilevered pipe conveying fluid; flutter instability; mode exchange; critical flow velocity, DQM

## 1. Introduction

Since the time that the liquid and gas need to be transported from one place to another, the system of pipes conveying fluid has been playing an important role. Up to now, pipes conveying fluid have been widely used in both daily life and engineering, especially in the field of aerospace, oil exploitation, heat exchange and microfluidic devices [1-8].

In engineering practice, the most commonly used two types of boundary conditions of pipes conveying fluid are with both ends supported or clamped-free. In the past sixty years, indeed, the dynamical behavior of supported and cantilevered pipes was extensively studied in the field of fluid-structure interactions. In a famous review article by Paidoussis and Li [9], it was endeavoured to show that the system of pipes conveying fluid was

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