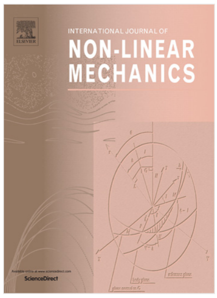
Accepted Manuscript



Reduced order modeling of a cantilevered pipe conveying fluid applying a modular methodology

Renato Maia Matarazzo Orsino, Celso Pupo Pesce

PII: S0020-7462(17)30533-4
DOI: https://doi.org/10.1016/j.ijnonlinmec.2018.04.003
Reference: NLM 2999

To appear in: *International Journal of Non-Linear Mechanics*

Received date : 26 July 2017
Revised date : 30 March 2018
Accepted date : 3 April 2018

Please cite this article as: R.M.M. Orsino, C.P. Pesce, Reduced order modeling of a cantilevered pipe conveying fluid applying a modular methodology, *International Journal of Non-Linear Mechanics* (2018), https://doi.org/10.1016/j.ijnonlinmec.2018.04.003

Reduced Order Modeling of a Cantilevered Pipe Conveying Fluid applying a Modular Methodology☆

Renato Maia Matarazzo Orsino[a,*], Celso Pupo Pesce[a]

[a] *Offshore Mechanics Laboratory, Mechanical Engineering Department, Escola Politécnica, University of São Paulo Av. Professor Lucio Martins Rodrigues, Tv. 4, n. 434, São Paulo - SP, 05508-020, Brazil*

Abstract

In this paper, a modular methodology, in which constraints associated to compatibility conditions can be included *a posteriori*, is applied for the derivation of a non-linear reduced order model of a cantilevered pipe conveying fluid, a classical problem in the area of Fluid-Structure Interaction (FSI). The dynamic response of this model is detailed in the neighborhood of the equilibrium state, by describing the dependency of the eigenvalues of its linearized form with respect to its parameters. For two scenarios, these responses are compared to benchmark results available in the literature. Also, two numerical simulations are proposed to compare how accurately the reduced order model can reproduce the results computed by a non-linear FEM model, previously proposed by the authors for this problem. The assessment of the numerical analyses indicates good agreement in the performed comparisons, which illustrates the good quality of the non-linear reduced order model proposed and suggests that the adopted modeling approach might be successfully applied for other problems in FSI.

Keywords: Modular Modeling, Fluid-Structure Interaction, Pipe Conveying Fluid, Udwadia-Kalaba Equation
2017 MSC: 00-01, 99-00

1. Introduction

This paper is part of a series of publications in which a novel approach for the modeling of Fluid-Structure Interaction systems is introduced and discussed. The new methodology allows to explore the modularities and symmetries within a given dynamic system, providing an algorithm in which all the effects due to kinematic constraints can be computed *a posteriori*, using adequate projection operators [1, 2].

Consider the benchmark problem of a pipe conveying fluid, initially studied by Benjamin [3, 4]. Along the years, several authors have been addressing this problem both theoretically and experimentally, see for instance [5–11], and an extensive literature review in this subject is presented in a comprehensive treatise by Païdoussis [12]. In a first approximation, the pipe can be considered as a homogeneous hollow solid cylinder that satisfies the Kirchhoff-Love beam model (small diameter when compared to the length), with an internal axial incompressible plug-flow (in which the boundary layer adjacent to the inner wall is neglected). It can be stated that the only source of non-linearities are the large displacements that the pipe is allowed to perform. Once the compatibility conditions are motion constraints, their effect in the dynamics of the system can be included *a posteriori*.

Orsino and Pesce [13, 14] already applied a recursive form of the modular approach for obtaining a FEM model for this system, by proposing a 4-level hierarchy of equations of motion (Figure 1) in which only the models at levels 2 and 3 satisfy both boundary and compatibility conditions. The simplicity brought to the modeling procedure due to the possibility of computing the non-linear effects *a posteriori* and the successful qualitative results obtained in numerical simulations, motivates further investigation on how this novel approach can be used to describe comprehensively the dynamic response of this system in the neighborhood of the equilibrium state. This can be done by linearizing the system and analyzing the dependency of its eigenvalues with respect to its parameters, which allows to identify the critical values of parameters for which transitions to instability are observed. The scope of this paper is twofold: (i) to propose a strategy to perform these analyses, based on the modular approach, and to compare the results so obtained with benchmark ones, available in the literature; (ii) to perform numerical simulations using the reduced order model for scenarios in which the non-linearities are significative, and to compare the results with the ones computed using the non-linear FEM model already derived.

Although following the same general discrete formulation presented in [13, 14] in which the compatibility condi-

☆This paper is an extended version of the work originally presented by the authors in the 9th European non-linear Dynamics Conference (ENOC 2017).

*Corresponding author
Email address: renato.orsino@gmail.com (Renato Maia Matarazzo Orsino)