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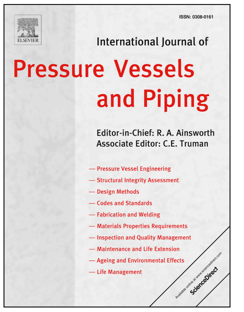

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Numerical Investigation of Dynamic Response of a Pipeline-Riser System caused by Severe Slugging Flow

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Abstract: Internal two-phase Flow Induced Vibration (FIV) is significantly important to secure the reliability and integrity of the piping systems in processing/engineering systems. To predict the dynamic behavior of a pipeline-riser system caused by Severe Slugging (SS), a fluid-structure interaction model was developed involving SS transient model and theories of plane frame structure. In numerical solutions, Euler's method was used to solve the equations of SS model, and Galerkin's method was adopted to discretize the dynamic equations in space, and Newmark method was employed for time-domain integration of the discretized equations. Variable time-steps were employed for higher computational efficiency and accuracy in the integration process. The verification experiments were performed to study the characteristics of SS and piping vibrations. The results show that the model predictions are in agreement with the experiment data basically. Detailed analysis of the simulation results reveals that the dynamic response of the pipeline-riser system is closely related to the periodic characteristics of SS. The elastic foundation can suppress the vibration amplitude and the internal force of the declined pipe, while the bending moment can be transferred to the riser, which can induce the intense bending vibration of the riser. The shearing force and bending moment of the declined pipe on the elastic foundation vary in large range when the slug heads and tails are passing through. The results indicated vulnerable spots and components of a pipeline-riser system when SS appear, which are significant to the safety and health of piping systems.

Key words: Severe slugging; Pipeline-riser system; Two-phase FIV; Fluid-structure interaction; Structural dynamics; Numerical simulation

1. Introduction

The dynamic behavior of pipes conveying fluid is of considerable importance in many engineering fields, and oscillations have been observed in nuclear reactor system components, various elements of high-performance launch vehicles, missiles and oil pipelines, etc [1].

The problem of dynamics of pipes conveying flowing fluid has received considerable attention in the last several decades. According to a historical research by Païdoussis and Issid [2], the first publication on this subject was made by Bourrieres (1939). Bourrieres derived the equation of motion and examined theoretically and experimentally the dynamic instability of a cantilevered pipe conveying fluid. Housner [3] and Niordson [4] were the first to study the dynamics of pipes supported at ends, obtained the correct linear equations of motion in different ways and reached the correct conclusions regarding stability. The equations of motion can also be derived by using the equilibrium method [2,5,6]. Since then numbers of dynamical theory and methods of analysis and applications were developed on this subject [7–9].

Almost all of these studies are in view of pipes conveying the single-phase flow, and few publications on the dynamics of pipes conveying gas-liquid 2-phase flow can be found. However, cases of two phase flow induced piping vibration frequently occur. Hara [10] investigated the vibration of the horizontal pipe theoretically, and compared the result with the experimental data. He discovered a significant relation between piping system natural frequency and