Phenomenological multimode models for flexible pipelines transporting slug flows and undergoing vortex-induced vibrations

Victoria Kurushina[1], Narakorn Srinil[1], Juan Padrino[1], David Swailes[2]
[1] *School of Engineering, Newcastle University, UK*
[2] *School of Mathematics, Statistics and Physics, Newcastle University, UK*

Abstract. Pulsations of internal slug liquid-gas flows coupled with the effect of external flow vortex-induced vibration (VIV) are modelled and investigated for a long-span horizontal flexible pipeline. Depending on the slug unit frequency, length and velocity, the pipeline dynamics undergoing VIV are described using a Galerkin multimodal reduction approach based on the assumed natural modes of a pinned-pinned Euler beam. The Coriolis and centrifugal forces from the internal flow, and the nonlinear lift and drag forces from the uniform external flow are accounted for. Resonant phenomena in a wide range of the internal/external fluid-structure parameters are investigated, highlighting the multi-frequency and multi-mode responses.

Background and Preliminary Results

Inspired by a recent progress of Ma and Srinil (2020) in applying a steady-state slug flow model, the present study aims to investigate various slug flow patterns affecting the dynamics of a horizontal flexible pipeline immersed in the uniform flow leading to vortex-induced vibration (VIV). The travelling slugs can be presented as a sequence of moving masses, extending the original model previously proposed in Hara (1973). The steady slug flow pattern is incorporated into the Coriolis and centrifugal forces with the fluctuating mass function with a constant velocity. Phenomenological wake oscillator suggested in Facchinetti et al. (2004) is applied to simulate the fluctuations of drag and lift forces acting on a flexible structure. The present analysis outcomes would be relevant to offshore subsea engineering applications where marine riser and pipelines are subject to external current flows, while transporting hydrocarbon liquid-gas flows.

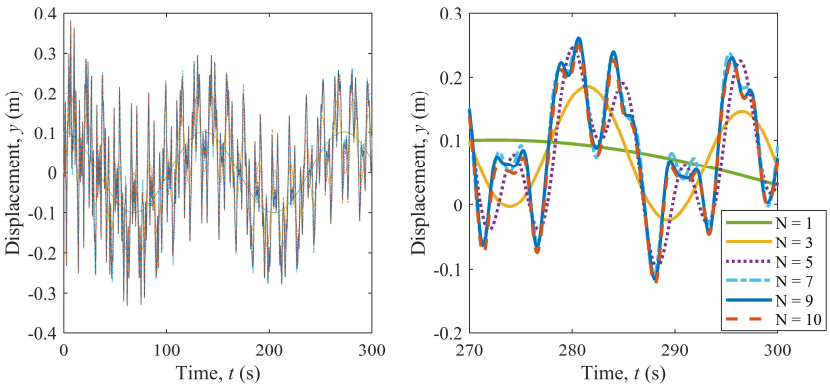

Figure 1: Time histories of displacement amplitudes of the horizontal flexible pipeline subjected to slug flow induced vibration at the pipe middle span, showing a convergence of the assumed number of modes N=10.

Capabilities of the phenomenological moving mass and wake oscillator models with a Galerkin multimode discretization are the key contributions of the present study which can be further extended to a curved vertical riser with various inclinations and curvatures. By considering a horizontal flexible pipeline transporting slug flows as an example, Figure 1 presents time histories of pipe dynamic displacements versus the number of assumed multimode (N) in the Galerkin modal reduction. Results suggest the solution convergence requiring a high number of modes and the intermittent dynamics under pulsation, amplitude and frequency modulations.

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