Force and Velocity Field Distribution on Drainage Pipes Excited by Two-Phase Flow

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Introduction

Vertical pipes conveying two-phase flow represent an unknown input of vibrational power with the ability of transmit power into attached passive structures and impart power to fluid environments perceived as audible noise.
Based in the knowledge that the vibration transmission should be expressed in terms of the active power [1], the force and velocity fields are sought as relevant quantities involved in the understanding of the physical problem.
In a companion paper [4] two methodologies, the circumferential and order decomposition, have been investigated in order to calculate the forces over the pipe-wall surface. In an experimental analysis both methods led to a close agreement. Although the order decomposition [3] offers a better assessment of the source allowing analyze the field variables along the interface as a series of single theoretical sources, with the zero and the first order governing the vibratory behavior of the pipe.
In the present paper, on route towards a proper structure-borne sound source characterization of drainage pipes exited by two-phase flow regime, the influence of the axial position and flow rate has been studied. Moreover, preliminary numerical results of the phase fraction and axial velocity within the pipe can be identified as a source mechanism related to flow-induced vibrations.

Experiment description

The experiment illustrated in Figure 1, represents the flushing of water discharges and consist basically in pumping water into an upper reservoir connected to a vertical pipe, such that promotes the generation of air slugs, vibrations and noise as consequences. The pipe used in the experiment corresponds to a standard PVC pipe of ~2 [m] length, 110 [mm] outer diameter and 3 [mm] wall thickness, which is connected to the water tank by means of a radial annular flange. Whilst the flow rate can be regulated by a variable frequency drive control.

Experimental results

Having the mobilities and the velocities of the source free along the circumferential contour, the back-calculated force field distribution and its respective orders can be obtained by measuring the velocity field over the pipe wall surface when exerted to a two-phase flow. Besides, the latter procedure can be repeated at different axial positions. In Figure 2, the influence of the axial position on the velocity distribution is presented. For all the

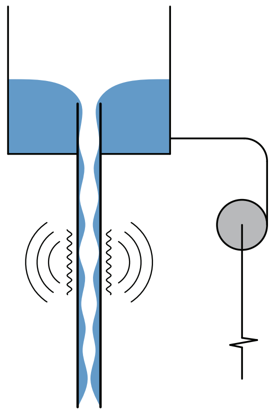

Figure 1: Schematic illustration of the test rig.

cases, axial locations were measured from the top of the pipe with not much dependence on the amplitude of the pipe wall response. Figure 3 summarizes the influence of the flow rate at a given axial position, where increasing the flow rate represents also an increase in the vibratory response until a limit when the air fraction can be considered negligible with respect to the fluid. The small variations between the velocity response at 2.0 and 2.5 [l/s] can be presumed to be related to the fact that the pipe can be seen as almost completely filled with water.

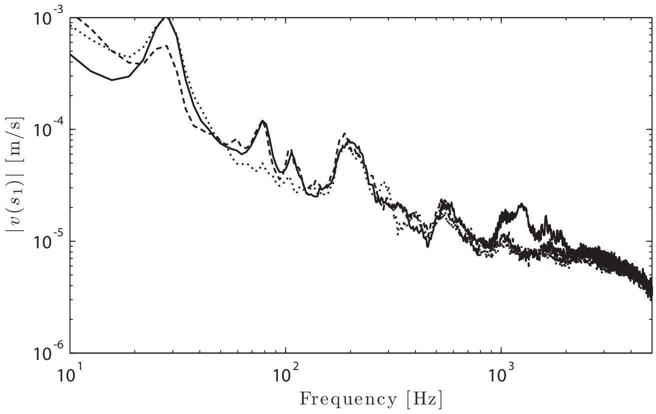

Figure 2: Velocity spectrum at s_1 and 2.0 [l/s]. ——, 0.11 L; ...., 0.36 L; – – –, 0.61 L.

Numerical model

A numerical CFD model has been implemented using the open source package OpenFOAM® and the multiphase flow solver `interFoam` for 2 incompressible, isothermal immiscible fluids. The problem considers the transient filling of water in a tank that then flows into a finite ver-

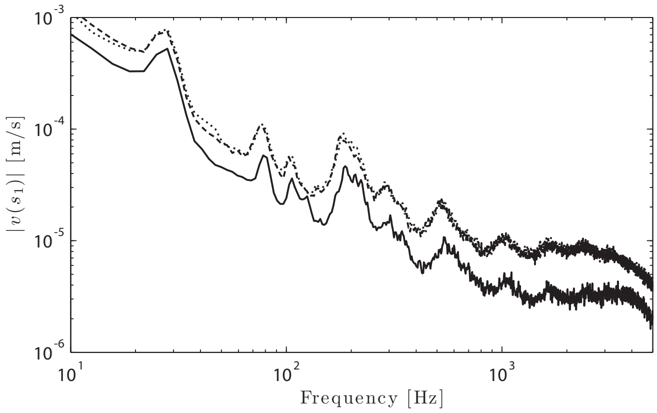

Figure 3: Velocity spectrum at s_1 and $0.55\,L$. ——, 1.4 $[l/s]$; ...., 2.0 $[l/s]$; − − −, 2.5 $[l/s]$.

tical pipe and generates two-pase flow. For simplicity a 2D axisymmetric model has been considered, where the domain is formed by a wedge-like geometry. Initially, the whole system is set to be filled with air except by a region in the water tank, condition given by the `setFieldsDict` dictionary and the `setFields` utility. The geometry and mesh were generated by running the `blockMesh` utility, defining 6 boundary patches for the water inlet, pipe outlet, walls, symmetry line, wedge surfaces and atmosphere. Figure 4 (a) shows the phase fraction distribution at a given time step for the region where the pipe is connected to the water reservoir. The phase fraction values can be found in a range between 0 and 1, corresponding to the gas and liquid phase respectively. It is worth to point out the presence of several air slugs conveying downstream. Figure 4 (b), presents the axial velocity contour (negatives values in the flow direction) for the same model region previously described. The higher values can be found in the area where the air portion is about to be closed by water. Figure 5 present more clear the relationship between the phase fraction and the axial velocity as a evidence which can be recognized as a source mechanism which drives the pipe.

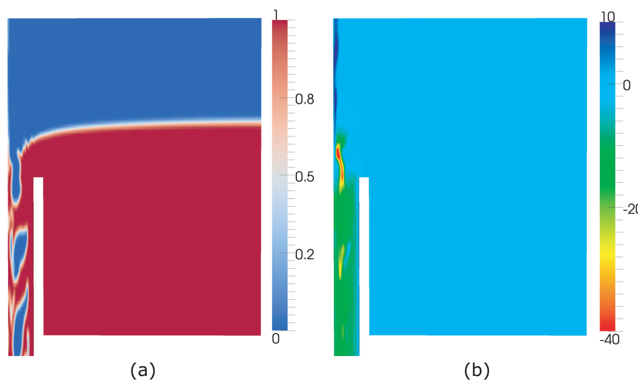

Figure 4: Numerical results from CFD at $t = 1.8\,[s]$. (a) Phase fraction [ ]; (b) Axial velocity [m/s].

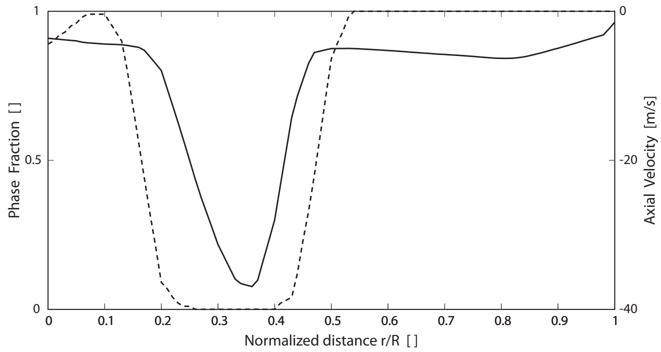

Figure 5: Velocity and phase variation along the radial direction at $L = 0$, $t = 1.8\,[s]$. ——, Axial velocity; − − −, Phase fraction.

Concluding remarks

Drainage pipes conveying two-phase flow can be considered as active structures. The coupling between the fluid fluctuations within the pipe and the pipe walls can be attributed as an input of vibrational power which can either transmit power into attached structures or radiate noise. Experiments demonstrate that the flow rate has a major influence in the response measured on the pipe wall surface irrespective of its axial position and it is limited when the water fraction starts to be dominant with respect to air. The results from the numerical simulations suggest that the generation of air slugs constitutes a source mechanism producing sudden changes in velocity which need to be studied more in detail for further flow characterization.

Acknowledgments

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