Experimental Investigation of Flexible Cantilevered Pipes Aspirating Water under VIV

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Summary. An innovative hydrodynamic campaign investigated three immersed flexible cantilevered aspirating pipes under VIV in a towing tank. Three experimental conditions have been considered: (i) aspirating flow; (ii) pure towing; (iii) combined aspirating and towing. Hopf bifurcations appeared in the aspirating case. Effects of supercritical internal flow on VIV were assessed and found small.

The experimental methodology and some results

The present extended abstract brings some experimental results concerning a hydrodynamic test campaign held at the Technological Research Institute (IPT) towing tank facility. The campaign showed 'weak' instabilities, of the Hopf bifurcation type, followed by fluttering of aspirating cantilevered flexible pipes, [1], [2], [3], and verified their small influence on VIV. Three flexible pipes, made of reinforced rubber hoses, with brass ballasts attached to the free end, were designed and built to respond, at the same towing speed, but each one at a distinct mode of vibration, the 1^{st}, 2^{nd} or 3^{rd} (Figure 1, above, left). The motions of the pipes were tracked down by an underwater optical system. The *ballasted-hose* concept and the desired natural mode of vibration were identified by the acronyms BH-k; $k = 1,2,3$. An in-house mathematical model [3] was specially derived and implemented to guide the design. Argand's like diagrams predicted instabilities for all modes at very small internal aspirating flow velocities, (example for the BH-2 model in Figure 1, above-right). Aspirating flows up to $2v_{crit}$ were assessed, isolated and combined with towing (up to the modal reduced velocity $U^*_{ny} = U/f_{ny}D \approx 14$; $n = 1,2,3$). Data analysis employed Galerkin's projection techniques in time domain, with modal functions obtained in the deformed configurations (also provided by the in-house model), followed by an innovative filtering procedure that uses the Empirical Mode Decomposition ([4], [5]), to remove very low frequency contents outside VIV's range (Figure 2, charts below). Such slow motions occurred in the streamwise direction, as consequence of drag fluctuations due to the model deflection and the emission of tip vortices structures.

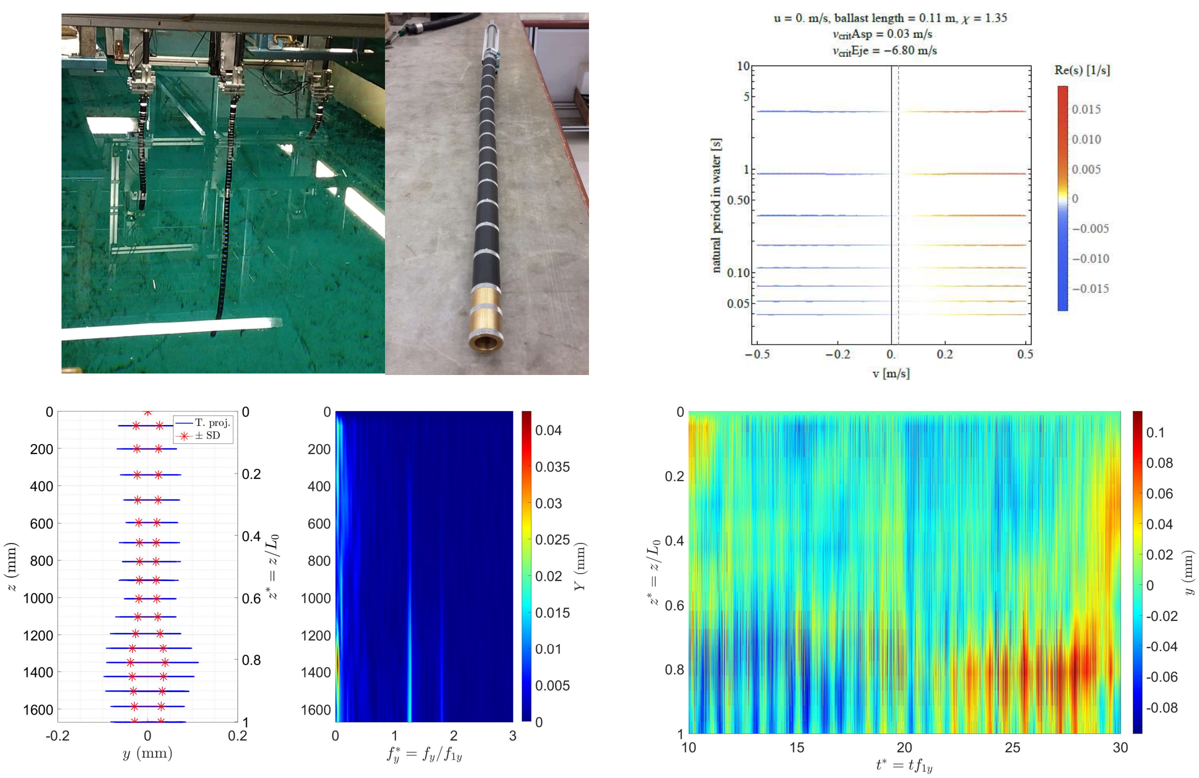

Figure 1: Above: left, ballasted-hose models; right, root-loci diagram, model BH-2. Below: aspirating case at $v = 2v_{crit}$.; left to right: spanwise trajectories projections, amplitude spectra and coordinate scalogram, in the crosswise direction w.r.t. towing.

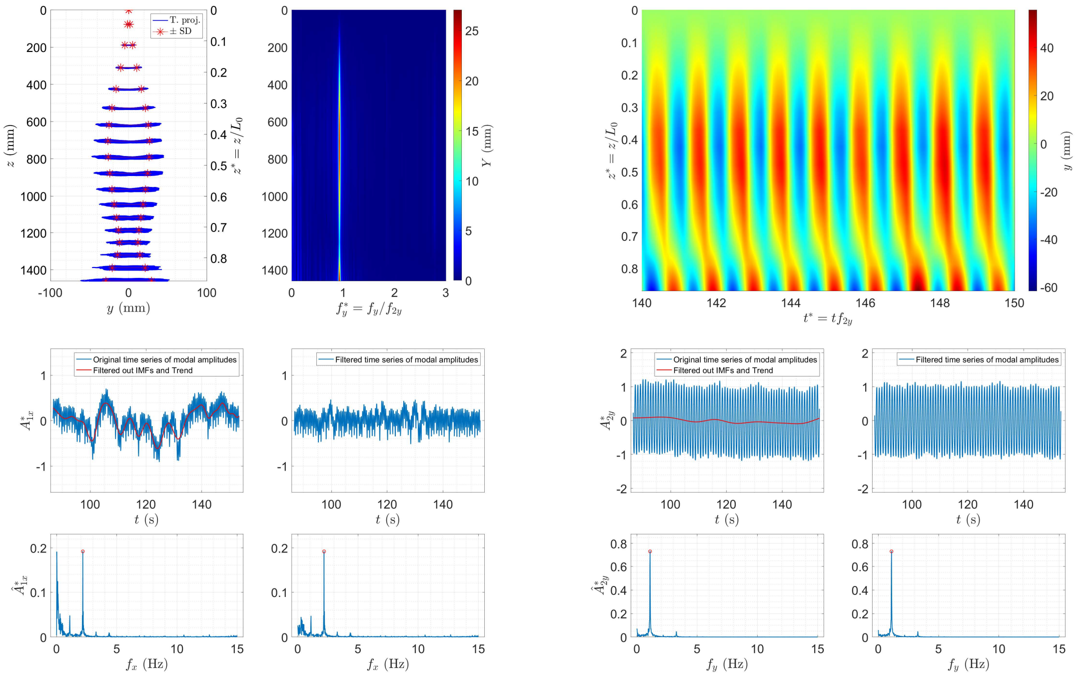

Figure 2: Model BH-2. Above, left to right: spanwise trajectories projections, amplitude spectra and coordinate scalogram, in crosswise direction. Below. EMD filtering of modal amplitude time series of the 1^{st} and the 2^{nd} mode shapes in streamwise (left) and crosswise (right) directions. Towing at modal reduced velocity $U_{2y}^* = 8.37$ ($U = 0.33$ m/s).

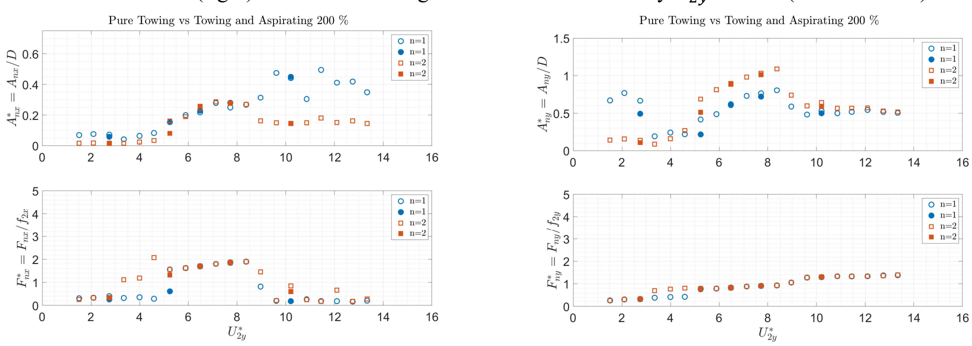

Figure 3: Model BH-2. Dimensionless modal amplitudes A_{nx}^* and A_{ny}^* and dimensionless dominant oscillation frequencies F_{nx}^* and F_{ny}^* of the n^{th} vibration mode contributions, as function of modal reduced velocity U_{2y}^*, in streamwise (left) and crosswise (right) directions. Empty markers: towing only. Filled markers: towing and aspirating at $v = 2v_{crit}$.

In pure aspirating conditions, at $v = 2v_{crit}$, a 1^{st} natural mode instability is depicted in the spanwise amplitude spectra at $f_y^* \approx 1.25$ and in the scalogram, coordinate shifting between positive and negative values along time (Figure 1, below, left and right, respectively). An expected behavior showed up in the pure towing case, the 2^{nd} natural mode shape dominating the dynamics (Figure 2, above). An example of the EMD filtering procedure is presented in Figure 2 (below). VIV is practically not altered by the aspirating flow, even at $v = 2v_{crit}$ (Figure 3). Aside a small decrease in amplitudes and in the respective dominant frequency values, no significant differences in modal responses were observed, compared to the pure towing case. Moreover, the aspirating flow mitigated the low frequency content in the streamwise oscillation, possibly by changing the tip vortex field structure. A more detailed analysis shall be presented in the full paper.

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