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► **To cite this version:**

Jose Antunes, Philippe Piteau, Xavier Delaune, Romain Lagrange. Spectral Extrapolation of Frequency-Dependent Fluidelastic Coupling Coefficients from Causality Enforcing. 26th International Conference on Structural Mechanics in Reactor Technology (SMiRT 26), Jul 2022, BERLIN, Germany. cea-04488803

**HAL Id: cea-04488803**

**<https://cea.hal.science/cea-04488803>**

Submitted on 4 Mar 2024

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## Spectral Extrapolation of Frequency-Dependent Fluidelastic Coupling Coefficients from Causality Enforcing

Jose Antunes<sup>1</sup>, Philippe Piteau<sup>2</sup>, Xavier Delaune<sup>2</sup>, and Romain Lagrange<sup>2</sup>

### Introduction

Frequency-dependent coupling forces are common in many systems of practical interest, in particular flow/structure interactions. The importance of fluidelastic forces in flow-excited vibrations should not be under-estimated, in view of their damaging potential. Typically, fluidelastic coupling coefficients are experimentally obtained from vibration experiments, within a limited experimental frequency range, see Piteau et al. (2019). For performing nonlinear time-domain computations, conversion of limited fluidelastic data from the frequency-domain to the time-domain is mandatory, and non-causality will be artificially introduced if one simply assumes that data is nil outside the measured frequency range. Here, a new method is proposed for the frequency interpolation and extrapolation of experimental fluidelastic data, by enforcing the causality of reconstructed flow-coupling forces. The method is tested and illustrated using as reference data simulated fluidelastic coefficients based on the Granger-Paidoussis model, in the context of heat-exchanger tube bundle vibrations, although the problem addressed embraces a much wider range of applications.

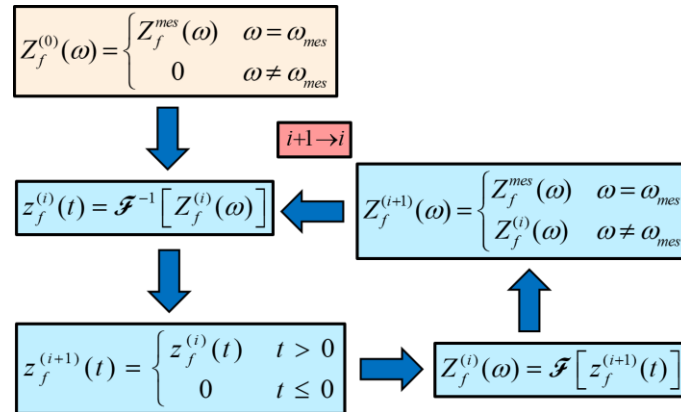


Figure 1. Scheme of the proposed causal data reconstruction technique.

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## Data interpolation/extrapolation method

Given the flow-coupling force  $F_f(\omega) = Z_f(\omega)X_s(\omega)$ , the proposed reconstruction technique for the flow dynamical coefficient  $Z_f(\omega) = -\omega^2 m_f(\omega) + i\omega c_f(\omega) + k_f(\omega)$  is nonlinear and iterates alternatively between the frequency and time-domains. The experimentally available data is enforced on  $Z_f(\omega)$ , in the frequency-domain, while causality is enforced on  $z_f(t)$ , in the time-domain, at each iteration. Further conditions, such as the regularity of  $Z_f(\omega)$  and  $z_f(t)$  can be conveniently enforced within the proposed iterative scheme.

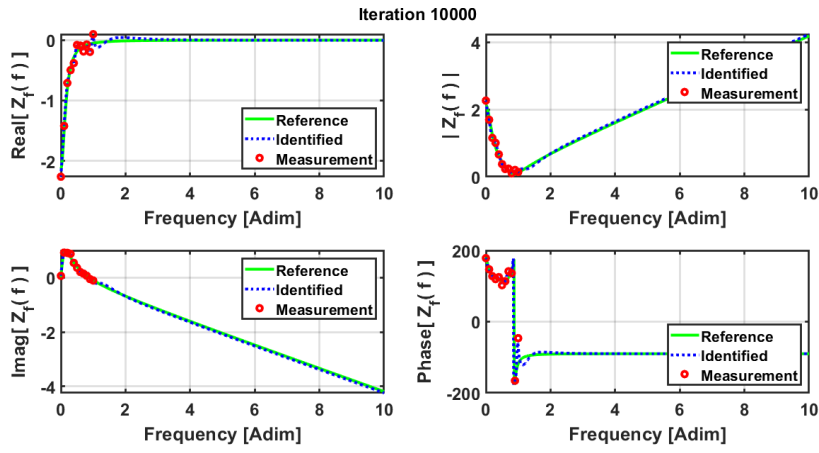


Figure 2. Reference function from the Granger-Paidoussis fluidelastic model, simulated noisy band-limited experimental data and the frequency-extrapolated result.

## Results

As shown in Figure 2, the method is tested and illustrated using as reference data simulated fluidelastic coefficients based on the Granger-Paidoussis (1996) model. As expected, the frequency-extended data produced fulfills the frequency-domain Kramers-Kronig causality relations, while the reconstructed results range from moderate to very satisfactory. Although unable to recover dynamical features of the flow-coupling forces totally absent from the measured frequency range, the proposed approach has the significant advantage of being model-independent and leads to augmented data that is both regular and physically consistent.

## References

- Piteau, P., Delaune, X., Borsoi, L., and Antunes, J. (2019) "Experimental identification of the fluid-elastic coupling forces on a flexible tube within a rigid square bundle subjected to single-phase cross-flow", *Journal of Fluids and Structures*, 86, 156-169.
- Granger, S., and Paidoussis, P. (1996) "An improvement to the quasi-steady model with application to cross-flow-induced vibration of tube arrays", *Journal of Fluid Mechanics*, 320, 163-184.