Hierachical and component-wise 1D models for fluid-structure interaction problems

Alfonso Pagani, Erasmo Carrera
Dipartimento di Ingegneria Meccanica e Aerospaziale, Politecnico di Torino, Torino, Italy
E-mail:alfonso.pagani@polito.it, erasmo.carrera@polito.it

Keywords: fluid-structure interaction, flutter, gust response

Accurate predictive methods for Fluid-Structure Interaction (FSI) problems are of high interest in modern industry as well as in various research fields. In the recent decades, there have been significant advances in computational FSI research. In these researches, the attention has been mainly focused on the challenging problem of coupling the structure and fluid phenomena, which are commonly characterized by different scales and meshes (see for example [1]). However, the coupling techniques can be drastically simplified and the computational efforts reduced if 1D models are adopted.

In the present work, an advanced 1D formulation for accurate FSI analyses is proposed. In the first part, the structural formulation is developed by exploiting the Carrera Unified Formulation (CUF) [2], which allows one to hierarchically implement any-order beam model in an automatic manner. Particular attention is here focused on the component-wise CUF beam models, which have been recently adopted to analyse complex aircraft structures [3]. The refined CUF models are solved both numerically and analytically and, subsequently, adopted for flutter and gust response analyses by coupling with a doublet lattice panel method [4].

In the second part of the work, 1D CUF models are extended to the analysis of compressible, laminar, viscous flows and used to analyze flow fields in rigid pipes [5]. Finally, the fluid-mechanics models are coupled with 1D CUF structural theories for FSI analysis of flows into thin-walled deformable cylinders.

The results demonstrate the efficiency of the proposed advances 1D models, which are able to replicate 3D-like analyses with very low computational costs. These enhanced capabilities of the CUF/CUF FSI tool, along with the simplified modelling techniques that typically belong to 1D formulations, provide good confidence for future research in this direction.

References

[1] Hou, G., Wang, J. and Layton, A., Numerical methods for fluid-structure interaction - A review, *Communications in Computational Physics*, **Vol 12**, No 2, pp. 337-377 (2012).

[2] Carrera, E., Cinefra, M., Petrolo, M. and Zappino, E., *Finite Element Analysis of Structures through Unified Formulation*, John Wiley & Sons, UK (2014).

[3] Carrera, E., Pagani, A. and Petrolo, M., Component-wise method applied to vibration of wing structures, *Journal of Applied Mechanics*, **Vol 80**, art.no 041012 (2013).

[4] Pagani, A., Petrolo, M. and Carrera, E., Flutter analysis by refined 1D dynamic stiffness elements and doublet lattice method, *Advances in Aircraft and Spacecraft Science*, **Vol 1**, No 3, pp. 291-310 (2014).

[5] Pagani, A., *Component-wise models for static, dynamic and aeroelastic analyses of metallic and composite aerospace structures*, PhD Thesis, Politecnico di Torino (2015).