Fluid-structure interaction and homogenization: from spatial averaging to continuous wavelet transform

S. Mokhtari[*,a], G. Ricciardi[a], V. Faucher[b], P. Argoul[c] and L. Adelaide[c]

[a] CEA CADARACHE, DEN/DTN/STCP/LTHC
13115 Saint-Paul-Lez-Durance, France
e-mail: samy.mokhtari@cea.fr

[b] CEA CADARACHE, DEN/DTN

[c] IFSTTAR, MAST/EMGCU
14-18 Boulevard Newton, 77455 Marne-la-Vallée Cedex, France

ABSTRACT

In fluid-structure interaction (FSI), a local approach, where the two media are modeled and computed separately, is generally implemented. In such simulations, the treatment of the interface represents a key issue [1]. In specific applications, where the solid medium presents a discontinuous but periodic design, a global approach is preferred, inspired by porous media, multiphase flows or homogenization techniques. It relies on a spatial averaging of the fluid and structure balance equations [2]. The main advantages of such a global approach, compared to the local one, stand in the vanishing interfaces, and in the possible use of coarser meshes. A similar spatial filtering process is also used in Large Eddy Simulation (LES) for turbulence modeling, by means of a convolution product between a filter kernel (e.g. a box or gaussian function) and the balance equations. However, the general assumption of commutativity between the convolution product and spatial derivatives does not stand in the case of bounded flows. Furthermore, such filtering techniques present another major drawback: the loss of microscopic information, and the resulting need of a closure model for the filtered equations. In the FSI context, this closure represents the force applied by the fluid on the micro-structure. In an inviscid compressible flow, this force is entirely driven by the pressure on the interface, which corresponds to unresolved scales in a filtered (homogenized) problem.

In order to homogenize the fluid and solid media, while by-passing the limitations previously outlined for classical filtering techniques (i.e. boundary conditions, loss of information and closure), the authors put forward a new formalism, based on the continuous wavelet transform (CWT). Once applied to the balance equations, the CWT allows to define a closure link between resolved and unresolved scales, without relying on any model or correlation. Indeed, the CWT allows to reconstruct a signal at the microscopic scale from its wavelet coefficients (i.e. the resolved scales). Considering, as a case study, an inviscid compressible flow interacting with pressurized water reactors (PWR) fuel assemblies, it is thus possible to recover the microscopic pressure, and consequently the force applied by the fluid on the micro-structure. To confront this wavelet-based modeling, first numerical tests are led on a 2D academic case study, for which a reference solution is computed with EUROPLEXUS software. These preliminary simulations show promising results on the CWT ability to reconstruct the pressure at the microscopic scale, with a limited number of wavelet coefficients.

REFERENCES

[1] Faucher, V., Crouzet, F. and Debaud, F. Mechanical consequences of LOCA in PWR : full scale coupled 1D/3D simulations with fluid-structure interaction. *Nuclear Engineering and Design*, (2014) **270**:359-378.

[2] Ricciardi, G., Bellizi, S., Collard, B. and Cochelin, B. Row of fuel assemblies analysis under seismic loading: modelling and experimental validation. *Nuclear Engineering and Design*, (2009) **239**:2692–2704.