A coupled model for acoustic sensors with porous windscreens in laminar flow

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This talk focuses on the development of a high-fidelity coupled mathematical model for an acoustic particle-velocity sensor, the Microflown (de Bree, 2009). The sensor is known to be sensitive to airflow perturbations and is typically enclosed within a single or multi-layer porous windscreen to reduce the impact of wind-induced noise when used outdoors. To predict its acoustic response, a mathematical model is developed using a hierarchical approach (Bucalem and Bathe, 2011). The acoustic propagation within laminar flow is modeled using an Arbitrary Eulerian- Lagrangian (ALE) formulation, known as the Galbruns model (Maeder et al., 2020). Distinctly, the model describes perturbations atop an underlying flow offering a modular approach to flow and acoustic considerations. However, the porous media, generally modeled as a fluid-equivalent material has no equivalent model for sound propagation amidst flow. Consequently, a new macroscopic model is developed considering the motion of the fluid through the rigid solid frame of the porous material along with the acoustical perturbations, by extending a flow model with Galbruns-like approach, using again an ALE formulation. The underlying flow within the porous structure is modeled using the Darcy-Forcheimer model (Wood et al., 2020) and as such, the coupled model is aptly named the Darcy-Forcheimer-Galbrun model. We demonstrate the implementation of this model in a scattering problem formulated to measure the acoustic impact of flow and porous windscreen on the Microflown sensor. To ensure H1-coercivity of the formulation, the problem is regularized (Bonnet-Ben Dhia et al., 2010) and solved using the finite element method using standard linear piece-wise elements.

Keywords: Aeroacoustics, Coupled models, Microflown, Porous media

References

[1] H. E. de Bree: *The Microflown E-book*, Microflown Technologies, 2009. (Online: https://www.microflown.com/resources/e-books/e-book-the-microflown-e-book)

[2] M. L. Bucalem and K. J. Bathe: *The Mechanics of Solids and Structures - Hierarchical Modeling and the Finite Element Solution*, Springer Berlin Heidelberg, 2011. doi: doi:10.1007/978-3-540-26400-2.

[3] M. Maeder, G. Gabard, and S. Marburg: *90 years of Galbruns equation: an unusual formulation for aeroacoustics and hydroacoustics in terms of the La- grangian displacement*, Journal of Theoretical and Computational Acoustics, 28(04):2050017, 2020. doi: doi:10.1142/S2591728520500176.

[4] B. D. Wood, X. He, and S. V. Apte: *Modeling turbulent flows in porous media*, Annual Review of Fluid Mechanics, 52(1):171203, 2020. doi: doi:10.1146/annurev-fluid-010719-060317.

[5] A. S. Bonnet-Ben Dhia, J. F. Mercier, F. Millot, and S. Pernet: *A low-Mach number model for time-harmonic acoustics in arbitrary flows*, Journal of Computational and Applied Mathematics, 234(6):18681875, 2010. doi: doi:10.1016/j.cam.2009.08.038