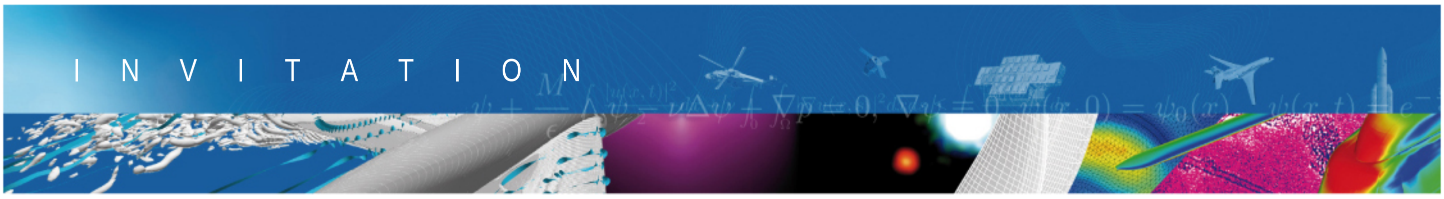

DEPARTEMENT MULTI-PHYSIQUE POUR L'ENERGETIQUE (DMPE)

Soutenance de thèse de Florian MONTEGHETTI

Mardi 16 octobre 2018 à 10 h 30 – Auditorium de l'ONERA/TOULOUSE

<u>Titre</u> : Analysis and Discretization of Time-Domain Impedance Boundary Conditions in Aeroacoustics

<u>Composition du jury</u> :

- Patrick JOLY, Directeur de Recherche à l'ENSTA / Paris
- Gwénaël GABARD, Senior Researcher à l'Université du Mans
- Bruno LOMBARD, Chargé de Recherche à Centrale Marseille
- Julien DIAZ, Junior Research Scientist à l'INRIA / Pau
- Jean-Pierre RAYMOND, Professeur des Universités à l'UPS / Toulouse
- Sjoerd RIENSTRA, Professeur à l'Université d'Eindhoven
- Denis MATIGNON, ERE et Directeur de thèse de l'ISAE / Toulouse
- Estelle PIOT, Ingénieur de Recherche et co-directrice de thèse de l'ONERA/DMPE / Toulouse

<u>Résumé</u> :

In computational aeroacoustics, time-domain impedance boundary conditions (TDIBCs) can be employed to model a locally reacting sound absorbing material. They enable to compute the effect of a material on the sound field after a homogenization distance and have proven effective in noise level predictions. The broad objective of this work is to study the physical, mathematical, and computational aspects of TDIBCs, starting from the physical literature.

The first part of this dissertation defines admissibility conditions for nonlinear TDIBCs under the impedance, admittance, and scattering formulations. It then shows that linear physical models, whose Laplace transforms are irrational, admit in the time domain a time-delayed oscillatory-diffusive representation and gives its physical interpretation. This analysis enables to derive the discrete TDIBC best suited to a particular physical model, by contrast with a one-size-fits-all approach, and suggests elementary ways of computing the poles and weights. The proposed time-local formulation consists in composing a set of ordinary differential equations with a transport equation.

The main contribution of the second part is the proof of the asymptotic stability of the multidimensional wave equation coupled with various classes of admissible TDIBCs, whose Laplace transforms are positive-real functions. The method of proof consists in formulating an abstract Cauchy problem on an extended state space using a realization of the impedance, be it finite or infinite-dimensional. The asymptotic stability of the corresponding strongly continuous semigroup of contractions is then obtained by verifying the sufficient spectral conditions of the Arendt-Batty-Lyubich-Vũ theorem.

The third and last part of the dissertation tackles the discretization of the linearized Euler equations with TDIBCs. It demonstrates the computational advantage of using the scattering operator over the impedance and admittance operators, even for nonlinear TDIBCs. This is achieved by a systematic semi-discrete energy analysis of the weak enforcement of a generic nonlinear TDIBC in a discontinuous Galerkin finite element method. In particular, the analysis highlights that the sole definition of a discrete model is not enough to fully define a TDIBC. To support the analysis, an elementary physical nonlinear scattering operator is derived and its computational properties are investigated in an impedance tube. Then, the derivation of time-delayed broadband TDIBCs from physical reflection coefficient models is carried out for single degree of freedom acoustical liners. A high-order discretization of the derived time-local formulation, which consists in composing a set of ordinary differential equations with a transport equation, is applied to two flow ducts.

Mots-clés : Time-domain impedance boundary condition, Acoustic boundary condition, Time-delay systems, Fractional kernels, Completely monotone kernels, Oscillatory-diffusive representation, Irrational transfer functions, Positive-real functions, Wave equation, Asymptotic stability, Memory damping, Discontinuous Galerkin, Linearized Euler equations, Duct aeroacoustics.