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Α.Π. :
Αθήνα,

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ΠΡΟΣΚΛΗΣΗ

Σας προσκαλούμε στην παρουσίαση της Διδακτορικής Διατριβής του Υ.Δ. **κ. MONFAREDI Morteza,** κατόχου BSc in Mechanical Engineering από το UNIVERSITY OF TABRIZ -IRAN και MSc in Mechanical Engineering Energy Conversion από το IRAN UNIVERSITY OF SCIENCE AND TECHNOLOGY, την οποία εκπόνησε στον Τομέα Ρευστών. Η παρουσίαση θα πραγματοποιηθεί την *Τετάρτη 8 Σεπτεμβρίου 2021* , ώρα 10:00π.μ. διαδικτυακά*. Ο τίτλος της Διδακτορικής Διατριβής είναι ο εξής :

«*The continuous Adjoint-based Aeroacoustic Shape Optimization by Coupling the Flowes – Williams and Hawkings Analogy with the URANS Equations* »

Ο Κοσμήτορας της Σχολής

Ν. Μαρμαράς
Καθηγητής Ε.Μ.Π

- Για οδηγίες για την πρόσβαση σας διαδικτυακά απεθυνθείτε στον Επιβλέποντα του Υ.Δ. Καθ. Κ. Γιαννάκογλου (kgianna@mail.ntua.gr)

The Continuous Adjoint-based Aeroacoustic Shape Optimization by Coupling the Ffowcs-Williams and Hawkings Analogy with the URANS Equations

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PhD Thesis Abstract

This doctoral thesis is concerned with the mathematical formulation, programming and verification of the continuous adjoint method to a hybrid noise prediction tool in order to perform aeroacoustic shape optimization with an affordable computational cost, even in industrial applications.

Aeroacoustic noise radiated by unsteady flows can be computed using a hybrid acoustic prediction tool, in which the near-field flow results from an unsteady CFD simulation while the acoustic propagation to far-field from the acoustic analogy. In this thesis, the GPU-enabled URANS solver PUMA (Parallel Unstructured Multi-row Adjoint), developed by the Parallel CFD & Optimization Unit of the NTUA, is used as the CFD tool. The compressible flow prediction variant of PUMA is extended with noise prediction capabilities based on the permeable surface Ffowcs Williams and Hawkings (FW-H) equation solver, in the frequency domain, resulting to a hybrid URANS/FW-H solver. At first, the implementation of the FW-H integral is verified through comparisons with the analytical solution of the sound field from a monopole source in uniform flow. The accuracy of the hybrid solver is additionally verified in different test cases by comparing results computed by the FW-H analogy with those of exclusively URANS runs.

The unsteady continuous adjoint solver of PUMA, previously developed for aerodynamic objective functions, is extended to deal with aeroacoustic shape optimization problems. The aeroacoustic objective function is defined in the frequency domain and stands for the total energy contained in the sound pressure spectrum. The method allows the computation of the sensitivity derivatives (SDs) of objective functions with respect to (w.r.t.) the shape controlling parameters (design variables) at a cost independent of their number, enabling the efficient use of Gradient-Based optimization methods.

The SDs are computed based on the so-called Field Integral (FI) adjoint formulation, resulting to the sum of surface and volume integrals in the final expression. Throughout the adjoint development, variations in the eddy viscosity and distance from the nearest wall due to shape changes are taken into account by differentiating the Spalart-Allmaras turbulence model and the Eikonal equation, i.e. a PDE computing distances from the walls, respectively. Use of a permeable FW-H surface located outside the grid displacement area, offers some simplicities regarding the mathematical development and includes the contribution of the acoustic analogy to the adjoint mean-flow and turbulence equations solely as source terms. The unsteady problems are treated in different ways depending on whether the period is constant or may change during the optimization. For the former, flow fields over a single period of the phenomenon are stored only; in contrast, the latter requires the flow fields over the whole solution time window, resulting to increased solution time and storage requirements.

A verification of the part of the code that differentiates the FW-H integral is performed by comparison of its results with closed-form derivatives' expressions. For cone of the constrained optimization problems, a method to handle equality constraints is developed based on a gradient projection with a new deferred correction scheme.

The developed aeroacoustic shape optimization tool is applied to a series of problems. Since a URANS based flow solution is performed, cases are selected from those with strong tonal behavior in their acoustic footprint. In all applications, a good agreement between predicted noise from the hybrid solver and pure URANS is achieved. For a number of pitching and plunging 2D airfoils at different flow conditions, adjoint-based computed SDs are verified w.r.t. those computed by finite differences. Aeroacoustic shape optimization is performed for these airfoils, achieving omni-directional noise reduction. Among them, a lift-constrained noise minimization is also performed which shows to be able to successfully retain the mean lift at its baseline level while still reducing noise. For a plunging airfoil in transonic flow, an evolutionary algorithm is also used to perform shape optimization for a multi-objective function (noise and lift) and results are compared with those of the adjoint-based optimization. Two cases with varying period during the optimization are considered, namely a 2D vortex shedding cylinder in laminar flow and the rod-airfoil benchmark. For the latter, aerodynamic and aeroacoustic results are extensively compared and validated w.r.t. available data in the literature. In addition, an early termination of the unsteady adjoint solution in the rod-airfoil case is shown to be able to considerably reduce the solution time and storage requirement while still computing acceptable SDs. In the same case, it is shown that the developed optimization tool supports objective functions defined in specific frequency ranges.

Regarding 3D applications, the flow around a sphere is solved and acoustic results are verified by comparison to URANS and then a shape optimization is performed. The industrial application of the developed software is conducted within the MADELEINE project funded by the European Union, by optimizing the geometry of an aero-engine intake. To save computational cost, periodic boundary conditions are used to reduce the solution domain size together with the use of a moving reference frame which leads to steady flow and adjoint runs. In order to assure a periodic adjoint solution, a continuous circumferential distribution of receivers at given radius and axial position is used for the computation of the objective function. The unsteady flow and adjoint fields required for computing the SDs are achieved by properly rotating the steady flow and adjoint fields.

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