ΕΘΝΙΚΟ
ΜΕΤΣΟΒΙΟ
ΠΟΛΥΤΕΧΝΕΙΟ
ΣΧΟΛΗ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

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ΚΟΣΜΗΤΟΡΑΣ

Προς τα Μέλη ΔΕΠ της
Σχολής Μηχ/γων
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ΠΡΟΣΚΛΗΣΗ

Σας προσκαλούμε στην παρουσίαση της Διδακτορικής Διατριβής του Υ.Δ. **κ. ΝΤΑΝΑΚΑ Γεωργίου** του Δημητρίου που εκπόνησε στον Τομέα Ρευστών , διπλωματούχος Μηχανολόγος Μηχανικός του ΕΜΠ, η οποία θα πραγματοποιηθεί την *Παρασκεύη 21 Δεκεμβρίου 2018*, ώρα ***10:00π.μ.*** στην Αίθουσα Τηλεκπαίδευσης (Πολυμέσων) στο Κτίριο της Βιβλιοθήκης του ΕΜΠ - Πολυτεχνειούπολη Ζωγράφου. Ο ελληνικός τίτλος της Διδακτορικής Διατριβής είναι ο εξής :

«Η ΧΡΟΝΙΚΑ ΜΗ-ΜΟΝΙΜΗ ΔΙΑΚΡΙΤΗ ΣΥΖΥΓΗΣ ΜΕΘΟΔΟΣ ΜΕ ΔΙΑΤΥΠΩΣΗ ΣΤΟ ΠΕΔΙΟ ΤΟΥ ΧΡΟΝΟΥ ΓΙΑ ΤΗ ΒΕΛΤΙΣΤΟΠΟΙΗΣΗ ΜΟΡΦΗΣ ΣΤΙΣ ΣΤΡΟΒΙΛΟΜΗΧΑΝΕΣ»

Και ο Αγγλικός ως εξής:

« UNSTEADY DISCRETE ADJOINT METHOD FORMULATED IN THE TIME-DOMAIN FOR SHAPE OPTIMIZATION IN TURBOMACHINERY»

Ο Κοσμήτορας της Σχολής

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Unsteady Discrete Adjoint Method Formulated in the Time-Domain for Shape Optimization in Turbomachinery

Η Χρονικά Μη-Μόνιμη Διακριτή Συζυγής Μέθοδος με Διατύπωση στο Πεδίο του Χρόνου για τη Βελτιστοποίηση Μορφής στις Στροβιλομηχανές

Georgios D. Ntanakas

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PhD Thesis Abstract

This PhD thesis deals with the mathematical formulation, solution, programming and validation of the unsteady discrete adjoint method, formulated in the time-domain, for the computation of first-order sensitivity derivatives for objective functions related to the aerodynamics of turbomachinery and their utilization in optimization algorithms. The cases that are tackled involve the constrained optimization of industrial, 3D, multi-row, turbomachinery configurations with transient and periodic flows.

The unsteady adjoint equations are formulated for an objective function in the form of a time-integral over a selected time-interval. The dual time-stepping technique is used to solve the unsteady adjoint equations along with an iterative

scheme, which is the adjoint to the 5-stage Runge-Kutta scheme used for the flow equations and which is derived "by-hand". The scheme is formulated so as to ensure same convergence rate as the Unsteady Reynolds-Averaged Navier-Stokes (URANS) solver. Algorithmic Differentiation (AD) is employed in the adjoint solver for the computation of selected differential terms. Its usage is restricted to low level operations and combined with hand-differentiation to ensure efficiency.

To enable communication between adjacent row-domains in the adjoint solver, the adjoint sliding interface is developed to replace the mixing interface technique used in steady state solvers. Its baseline is the sliding interface of the flow solver where grids of adjacent rows are generated so that there is a one-cell overlap. AD along with hand programming ensure that the implementation is consistent with the reverse flow of information in the adjoint solver.

The solver utilizes the SSD disk space instead of RAM to store and read-in, in a parallel manner, the per-time-step flow fields during the adjoint execution. Thus, RAM bottlenecks are avoided while run time is not significantly increased. The temporal coarsening technique is employed in the adjoint solver to decrease the run time and the required storage space when this exceeds the available storage capacity.

Adjoint-based derivatives are computed and used within the optimization workflow. If equality constraints are considered, the component of the objective function's gradient which is normal to the constraints' gradients is used along with the projected gradient descent method to update the design variables and, thus, the geometry. In unconstrained optimization problems, steepest descent is used.

The developed software is applied to the shape optimization of 3D, multi-row, turbomachinery cases for the first time in the literature. The application cases include one single row turbine case (transient operation), one stage turbine case (periodic flow study) and one 3-row compressor case (periodic flow study). The computed derivatives are validated against the derivatives computed via finite differences and, then, used in optimization setups with and without equality constraints.

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Key words: Computational Fluid Dynamics, Unsteady Discrete Adjoint Method, Sensitivity Derivatives, Shape Optimization, Transient Flow, Multi-row Turbomachinery

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