Tezduyar, T.; **Osawa, Y.**

Fluid-structure interactions of a parachute crossing the fair wake of an aircraft. (English)

Zbl 1113.76407
Comput. Methods Appl. Mech. Eng. 191, No. 6-7, 717-726 (2001).

Summary: In this paper we describe a computational technique for simulation of the fluid-structure interactions of a parachute crossing the far wake of an aircraft. This technique relies on using the long-wake flow data already computed, in our case, with the Multi-Domain Method (MDM) we developed earlier. The fluid-structure interaction computations are carried out over a domain enclosing the parachute and moving with the payload. This domain functions as one of the subdomains of the MDM designed specifically for the parachute fluid-structure interactions considered here. The boundary conditions for this subdomain are extracted from the long-wake flow data, at locations corresponding to the positions of those boundaries in the subdomain over which the wake flow data were computed. The Navier-Stokes equations of incompressible flows, governing the fluid dynamics, are solved with the Deforming-Spatial-Domain/Stabilized Space-Time (DSD/SST) formulation, which can handle changes in the spatial domain occupied by the fluid. This formulation is coupled to the finite element formulation used for solving the membrane equations governing the structural mechanics of the parachute canopy and the equations governing the mechanics of the suspension lines. The numerical example included demonstrates how the technique described here, functioning as a component of the MDM, enables us to simulate the fluid-structure interactions of a parachute crossing an aircraft wake.

MSC:

76M10 Finite element methods applied to problems in fluid mechanics
76D25 Wakes and jets
74F10 Fluid-solid interactions (including aero- and hydro-elasticity, porosity, etc.)

Full Text: DOI

References:

[1] Tezduyar, T.E.; Osawa, Y., Methods for parallel computation of complex flow problems, Parallel computing, 25, 2039-2066, (1999)

[2] Osawa, Y.; Kalro, V.; Tezduyar, T.E., Multi-domain parallel computation of wake flows, Computer methods in applied mechanics and engineering, 174, 371-391, (1999) · Zbl 0963.76049

[3] Osawa, Y.; Tezduyar, T.E., A multi-domain method for 3D computation of wake flow behind a circular cylinder, Computational fluid dynamics journal, 8, 296-308, (1999)

[4] Osawa, Y.; Tezduyar, T.E., 3D simulation and visualization of unsteady wake flow behind a cylinder, Journal of visualization, 2, 127-134, (1999)

[5] T.E. Tezduyar, Y. Osawa, The multi-domain method for computation of the aerodynamics of a parachute crossing the far wake of an aircraft, Computer Methods in Applied Mechanics and Engineering 191 (2001) 705-716, this issue · Zbl 1113.76406

[6] Tezduyar, T.E., Stabilized finite element formulations for incompressible flow computations, Advances in applied mechanics, 28, 1-44, (1991) · Zbl 0747.76069

[7] Tezduyar, T.E.; Behr, M.; Liou, J., A new strategy for finite element computations involving moving boundaries and interfaces – the deforming-spatial-domain/space – time procedure: I. the concept and the preliminary tests, Computer methods in applied mechanics and engineering, 94, 339-351, (1992) · Zbl 0745.76044

[8] Tezduyar, T.E.; Behr, M.; Mittal, S.; Liou, J., A new strategy for finite element computations involving moving boundaries and interfaces – the deforming-spatial-domain/space – time procedure: II. computation of free-surface flows, two-liquid flows, and flows with drifting cylinders, Computer methods in applied mechanics and engineering, 94, 353-371, (1992) · Zbl 0745.76045

[9] Hughes, T.J.R.; Hulbert, G.M., Space – time finite element methods for elastodynamics: formulations and error estimates, Computer methods in applied mechanics and engineering, 66, 339-363, (1988) · Zbl 0616.73063

[10] Hughes, T.J.R.; Franca, L.P.; Hulbert, G.M., A new finite element formulation for computational fluid dynamics: VIII. the Galerkin/least-squares method for advective – diffusive equations, Computer methods in applied mechanics and engineering, 73, 173-189, (1989) · Zbl 0697.76100

[11] Hansbo, P.; Szepessy, A., A velocity – pressure streamline diffusion finite element method for the incompressible navier – stokes equations, Computer methods in applied mechanics and engineering, 84, 175-192, (1990) · Zbl 0716.76048

[12] T.J.R. Hughes, A.N. Brooks, A multi-dimensional upwind scheme with no crosswind diffusion, in: T.J.R. Hughes (Ed.), Finite Element Methods for Convection Dominated Flows, AMD, vol. 34, ASME, New York, 1979, pp. 19-35

[13] Brooks, A.N.; Hughes, T.J.R., Streamline upwind/petrov – galerkin formulations for convection dominated flows with particular emphasis on the incompressible navier – stokes equations, Computer methods in applied mechanics and engineering, 32, 199-259, (1982) · Zbl 0497.76041

[14] T.E. Tezduyar, M. Behr, S. Mittal, A.A. Johnson, Computation of unsteady incompressible flows with the finite element methods – space – time formulations, iterative strategies and massively parallel implementations, in: P. Smolinski, W.K. Liu, G. Hulbert, K. Tamma (Eds.), New Methods in Transient Analysis, AMD, vol. 143, ASME, New York, 1992, pp. 7-24

[15] Stein, K.; Benny, R.; Kalro, V.; Tezduyar, T.E.; Leonard, J.; Accorsi, M., Parachute fluid – structure interactions: 3-D computation, Computer methods in applied mechanics and engineering, 190, 373-386, (2000) · Zbl 0973.76055

[16] Kalro, V.; Tezduyar, T., A parallel 3D computational method for fluid – structure interactions in parachute systems, Computer methods in applied mechanics and engineering, 190, 321-332, (2000) · Zbl 0993.76044

[17] Saad, Y.; Schultz, M., GMRES: a generalized minimal residual algorithm for solving nonsymmetric linear systems, SIAM journal of scientific and statistical computing, 7, 856-869, (1986) · Zbl 0599.65018

[18] Bathe, K.J., Finite element procedures, (1996), Prentice-Hall Englewood Cliffs, NJ · Zbl 0511.73065

[19] A. Lo, Nonlinear dynamic analysis of cable and membrane structure, Ph.D. Thesis, Department of Civil Engineering, Oregon State University, 1982

[20] Behr, M.; Tezduyar, T.E., Finite element solution strategies for large-scale flow simulations, Computer methods in applied mechanics and engineering, 112, 3-24, (1994) · Zbl 0846.76041