Aliabadi, S. K.; **Tezduyar, T. E.**

Parallel fluid dynamics computations in aerospace applications. (English) Zbl 0862.76033

Int. J. Numer. Methods Fluids 21, No. 10, 783-805 (1995).

Summary: Massively parallel finite element computations of the compressible Euler and Navier-Stokes equations using parallel supercomputers are presented. The finite element formulations are based on the conservation variables, and the streamline-upwind/Petrov-Galerkin stabilization method is used to prevent potential numerical oscillations due to dominant advection terms. These computations are based on both implicit and explicit methods, and their parallel implementation assumes that the mesh is unstructured. The implicit computations are based on iterative strategies. Large-scale three-dimensional problems are solved using a matrix-free iteration technique which reduces the memory requirements significantly. The flow problems we consider typically come from aerospace applications, including those in three-dimensional and those involving moving boundaries interactig with boundary layers and shocks. Problems with fixed boundaries are solved using a semidiscrete formulation, and the ones involving moving boundaries are solved using the deformable-spatial-domain/stabilized-space-time formulation.

MSC:

76M10 Finite element methods applied to problems in fluid mechanics

76N10 Existence, uniqueness, and regularity theory for compressible fluids and gas dynamics

65Y05 Parallel numerical computation

Keywords:

Euler equations; Navier-Stokes equations; streamline-upwind/Petrov-Galerkin stabilization method; matrix-free iteration technique; moving boundaries; boundary layers; shocks; semidiscrete formulation; deformable-spatial-domain/stabilized-space-time formulation

Full Text: DOI

References:

[1] and , 'A multi-dimensional upwind scheme with no crosswind diffusion', in (ed.) Finite Element Methods for Convection Dominated Flows, AMD Vol. 34, ASME, New York, 1979, pp. 19-35.

[2] Brooks, Comput. Methods Appl. Mech. Eng. 32 pp 199– (1982)

[3] and , 'Finite element formulations for convection dominated flows with particular emphasis on the compressible Euler equations', AIAA Paper 83-0125, 1983.

[4] Hughes, Comput. Methods Appl. Mech. Eng. 54 pp 223– (1986)

[5] Hughes, Comput. Methods Appl. Mech. Eng. 58 pp 305– (1986)

[6] Hughes, Comput. Methods Appl. Mech. Eng. 58 pp 329– (1986)

[7] and , 'Finite element computation of compressible flows with the SUPG formulation', in and (eds.), Advances in Finite Element Analysis in Fluid Dynamics, FED Vol. 123, ASME, New York, 1991, pp. 21-27.

[8] Le Beau, Comput. Methods Appl. Mech. Eng. 104 pp 27– (1993)

[9] Aliabadi, Comput. Mech. 11 pp 300– (1993)

[10] and , 'Massively parallel compressible flow computations in aerospace applications', Pre-conf. Proc. Second Japan-US Symp. on Finite Element Methods in Large-Scale Computational Fluid Dynamics, Tokyo, 1994.

[11] , , and , 'Massively parallel finite element computation of three-dimensional flow problems', Proc. 6th Jn. Numerical Fluid Dynamics Symp., Tokyo, 1992, pp. 15-24.

[12] Tezduyar, IEEE Comput. 26 pp 27– (1993) · Zbl 05090697 · doi:10.1109/2.237441

[13] Hirt, J. Comput. Phys. 14 pp 227– (1974)

[14] Hughes, Comput. Methods Appl. Mech. Eng. 29 pp 329– (1981)

[15] Ramaswamy, Int. j. numer. methods fluids 7 pp 1053– (1987)

[16] Huerta, Comput. Methods Appl. Mech. Eng. 69 pp 277– (1988)

[17] Tezduyar, Comput. Methods Appl. Mech. Eng. 94 pp 339– (1992)

[18] Tezduyar, Comput. Methods Appl. Mech. Eng. 94 pp 353– (1992)

[19] Aliabadi, Comput. Methods Appl. Mech. Eng. 107 pp 209– (1993)

[20] 'A finite element method for computational fluid dynamics', Ph.D. Thesis, Department of Civil Engineering, Stanford University, 1985.

[21] and , 'Development of time-accurate finite element techniques for first-order hyperbolic systems with particular emphasis on the compressible Euler equations', NASA-Ames University Consortium Interchange, Rep. NCA2-OR745-104, 1982.

[22] 'Finite element analysis of the compressible Euler and Navier-Stokes equations', Ph.D. Thesis, Department of Mechanical Engineering, Stanford University, 1988.

[23] The Finite Element Method, Linear Static and Dynamic Finite Element Analysis, Prentice-Hall, Engelwood Cliffs, NJ, 1987.

[24] 'Stabilized finite element methods for incompressible flows with emphasis on moving boundaries and interfaces', Ph.D. Thesis, Department of Aerospace Engineering, University of Minnesota, 1992.

[25] Saad, SIAM J. Sci. Stat. Comput. 7 pp 856– (1986)

[26] Saad, SIAM J. Sci. Comput. 14 pp 461– (1993)

[27] Turbulence et Couche Limite, Cepadues Editions, 1990.

[28] , , and , 'The design and implementation of parallel unstructured Euler solver using software primitives', AIAA Paper 92-0562, 1992.

[29] and , 'An efficient communication strategy for finite element methods on the connection machine CM-5', Comput. Methods Appl. Mech. Eng., in press.

[30] Sakamotto, J. Fluids Eng. 112 pp 386– (1990)

[31] Magarvey, Phys. Fluids 4 pp 800– (1961)

[32] Möller, Phys. Z. 35 pp 57– (1938)

[33] 'An investigation of the unsteady flow pattern in the wake of cylinder and spheres using a hot wire probe', Tech. Rep. WT-21, Division of Engineering, Brown University, 1957.

[34] Kim, Phys. Fluids 31 pp 3260– (1961)

[35] Boundary-Layer Theory, 7th edn., McGraw-Hill, New York, 1979.