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Differential equation-based wall distance computation for DES and RANS. (English)

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Summary: Surprisingly expensive to compute wall distances are still used in a range of key turbulence and peripheral physics models. Potentially economical, accuracy improving differential equation-based distance algorithms are considered. These involve elliptic Poisson and a hyperbolic-natured eikonal equation approaches. Numerical issues relating to non-orthogonal curvilinear grid solution of the latter are addressed. Eikonal extension to a Hamilton–Jacobi equation is discussed. Use of this extension to improve turbulence model accuracy and, along with the eikonal, enhance detached eddy simulation (DES) techniques is considered. Application of the distance approaches is studied for various geometries. These include a plane channel flow with a wire at the center, a wing–flap system, and a supersonic double-delta configuration. Although less accurate than the eikonal, Poisson method-based flow solutions are extremely close to those using a search procedure. For a moving grid case the Poisson method is found especially efficient. Results show that the eikonal equation can be solved on highly stretched, non-orthogonal, and curvilinear grids. A key accuracy aspect is that metrics must be upwinded in the propagating front direction. The Hamilton–Jacobi equation is found to have qualitative turbulence model improving properties.

MSC:

76F65 Direct numerical and large eddy simulation of turbulence
76M25 Other numerical methods (fluid mechanics) (MSC2010)

Full Text: DOI

References:

[1] B.S. Baldwin, H. Lomax, Thin Layer Approximation and Algebraic Model for Separated Turbulent Flows, AIAA Paper 78-257, 1978
[2] Chen, H.C.; Patel, V.C., Aiaa j., 26, 6, 641, (1988)
[3] B.S. Baldwin, T.J. Barth, A One-Equation Turbulence Transport Model for High Reynolds Number Wall-Bounded Flows, AIAA Paper 91-0610, 1991
[4] Spalart, P.R.; Allmaras, S.R., La rech. aerospatiale, 1, 5, (1994)
[5] Wolfshtein, M., Int. J. heat mass transfer, 12, 301, (1969)
[6] Secundov, N.; Strelets, M.K.H.; Travin, A.K., ASME J. fluids engrg., 123, 111, (2001)
[7] F.R. Menter, Zonal Two Equation \textit{k}−ω Turbulence Models for Aerodynamic Flows, AIAA Paper 93-2906, 1993
[8] D.B. Spalding, 10th International Heat Transfer Conference, Brighton, UK, 1994 (unpublished) · Zbl 0082.18703
[9] Kim, S.H.; Chung, M.K., Aiaa j., 39, 9, 1803, (2001)
[10] Tucker, P.G., ASME J. fluids engrg., 123, June, 372, (2001)
[11] Abid, R., Int. J. engrg. sci., 31, 6, 831, (1993)
[12] Iacovides, H.; Chew, J.W., Int. J. heat fluid flow, 14, 2, 146, (1993)
[13] M. Shur, P.R. Spalart, M. Strelets, A. Travin, in: Proceedings of the 4th International Symposium on Engineering Turbulence Modelling and Measurements, Ajaccio, Corsica, France, vol. 669, 1999
[14] Wigton, L.B., (), 1-15, Chapter 16; ISBN 981-02-3707-3
[15] Boger, D.A., Aiaa j., 39, 12, 2404, (2001)
[16] P.R. Spalart, Trends in Turbulence Treatments, AIAA Paper 2000-2306, 2000
[17] Fares, E.; Schroder, W., Int. J. numer. methods fluids, 39, 743, (2002)
[18] Mompean, G.; Gavrilakis, S.; Machiels, L.; Deville, M.O., Phys. fluids, 8, 7, 1856, (1996)
[19] Launder, B.E.; Reece, G.J.; Rodi, W., J. fluid mech., 68, Part 3, 537, (1975)
[20] Osher, S.; Sethain, J.A., J. comput. phys., 79, 12, (1988)
[21] Tucker, P.G., Int. J. numer. fluids, 33, 869, (2000)
[22] Tucker, P.G., Appl. math. model., 22, 293, (1998)

[23] Sethian, J.A., SIAM rev., 41, 2, 199, (1999)

[24] J.A. Sethian, personal communication, 2002

[25] M. Strelets, Detached Eddy Simulation of Massively Separated Flows, AIAA Paper 2001-0879, 2001

[26] Rumsey, L.; Sanetrix, M.D.; Biedron, R.T.; Melson, N.D.; Parlette, E.B., Comput. fluids, 25, 2, 217, (1996)

[27] P.G. Tucker, L. Davidson, Zonal \textit{k}-l-Based Large Eddy Simulations, AIAA Paper 2003-0082, 2003

[28] P.G. Tucker, Novel MILES computations for jet flows with noise, in: 3rd International Symposium on Turbulence and Shear Flow Phenomena, Sendai, Japan, June 25-27, 2003 (accepted)

[29] Tsai, Y.R., J. comput. phys., 178, 175, (2002)

[30] Tucker, P.G.; Pan, Z., Appl. math. model., 24, 591, (2000)

[31] Bartels, R.E., J. aircraft, 37, 3, 521, (2000)