MAE 210B – WQ 2018

Bluff-Body Turbulence Research Project Lit Study

Catalano, P a,\*, Meng Wang b, Gianluca Iaccarino b, Parviz Moin. Numerical simulation of the flow around a circular cylinder at high Reynolds numbers.

* Filename: catalano2003numerical
* Abstract:
  + results are compared with those obtained from steady and unsteady Reynolds-averaged Navier–Stokes (RANS)
  + LES solutions are shown to be considerably more accurate than the RANS results

Menter, F.R. and Egorov, Y. A Scale-Adaptive Simulation Model using Two-Equation Models. 2005.

* Filename: menter2005scaleadaptive
* Abstract
  + **Scale-Adaptive Simulation (SAS) concept**
  + von Karman length-scale allows SAS models to dynamically adjust to resolved structures in a URANS simulation
  + results in a LES-like behavior in unsteady regions of the flowfield
  + standard RANS capabilities in stable flow regions
  + allows the SST model to be operated in a SAS mode
* **Flow over cylinder**

Elkhoury, M. Assessment of turbulence models for the simulation of turbulent flows past bluff bodies.

* Filename: elkhoury2016assessment
* Abstract
  + Assessment of **novel one-equation turbulence model**
  + Compare to SA, SST-SAS
  + Unsteady, **3D flow over square cylinder**
  + Use case: comparable results to LES with fewer computational resources used

Liu, Yue, Xiaorong Guan \*, Cheng Xu. A production limiter study of SST-SAS turbulence model for bluff body flows.

* Filename: liu2017production
* Abstract
  + **production limiter** considering the efforts of strain rate tensor and rotation tensor is proposed for the Scale- Adaptive Simulation method (SAS).
  + two other limiters only considering strain or vorticity are also conducted for comparison

Murakami, S. COMPARISON OF VARIOUS TURBULENCE MODELS APPLIED TO A BLUFF BODY.

* Filename: murakami1993comparison
* Abstract:
  + shortcoming of the eddy viscosity modelling in the k-epsilon model is scrutinized in **comparison with the results of algebraic second-moment closure model** (ASM)
  + A new LES model with variable Smagorinsky constant is then presented.
  + **Flow around a cube, very old**

Robertson E., V. Choudhuryb, S. Bhushana,b,∗, D.K. Walters. Validation of OpenFOAM numerical methods and turbulence models for incompressible bluff body flows.

* Filename: robertson2017validation
* Abstract
  + verification and validation study was performed using the open source computational fluid dynamics solver OpenFOAM version 2.0.0 for incompressible bluff body fluid flows
  + flow over a backward facing step, a **sphere in the subcritical regime**, and delta wing with sharp leading edge

Rodriguez, I., RICARD BORELL2, ORIOL LEHMKUHL1,2, CARLOS D. PEREZ SEGARRA1 and ASSENSI OLIVA. Direct numerical simulation of the flow over a sphere at Re = 3700.

* Filename: rodriguez2011direct
* Abstract
  + **direct numerical simulation** of the flow over a **sphere** is performed
  + sub-critical regime at Re=3700
  + flow separates laminarly near the equator of the sphere and transition to turbulence occurs in the separated shear layer
  + a large number of turbulence statistics are computed and **compared with previous experimental and numerical data**

Rai, Man Mohan. TOWARDS DIRECT NUMERICAL SIMULATIONS OF TURBULENT WAKES.

* Filename: rai2008towards
* Abstract
  + three direct numerical simulations (DNS) of transitional/turbulent cylinder wakes are presented here.
  + A high-order accurate, upwind-biased, iterative-implicit, finite-difference scheme is used to solve these equations
  + **Example of very crude DNS**

Spalart, P. Detached-Eddy Simulation

* Filename: spalart2008detachededdy
* Abstract:
  + **Detached-eddy simulation (DES)** was first proposed in 1997 and first used in 1999
  + initial motivation of high– Reynolds number, massively separated flows, **better than RANS, LES**
  + Its principal weakness is its response to ambiguous grids, in which the wall-parallel grid spacing is of the order of the boundary-layer thickness
* Basiscs
  + Run simulations with **complete** geometry of complex, bluff bodies
    - Full-scale aircraft, cars
    - Flight Reynolds number
    - Good accuracy

Forsythe, James, Kyle D. Squires, Kenneth E. Wurtzler, Philippe R. Spalart. Detached-Eddy Simulation of the F-15E at High Alpha.

* Filename: forsythe2004detachededdy
* Abstract:
  + **Detached-eddy simulation (DES)** is used to predict the **massively separated flow around an F-15E at 65-deg** angle of attack
  + chord-based **Reynolds number of 13.6 × 106** and **Mach number of 0.3**
  + unstructured grids with the commercial solver Cobalt
  + DES predictions are assessed via **comparison to Boeing’s stability and control database** as well as to solutions of the Reynolds-averaged Navier–Stokes (RANS) equations
  + DES predictions of the lift, drag, and pitching moment, which were averaged over as many as 150 inertial timescales, **agree with the data more favorably** than the RANS results, **but both methods are within 10% of** the database
  + The **cost of DES was approximately seven times higher** than the steady RANS calculations on the same grid.

Cimarelli, Andrea \*, Adriano Leonforte, Diego Angeli. Direct numerical simulation of the flow around a rectangular cylinder at a moderately high Reynolds number.

* Filename: cimarelli2018direct
* Abstract
  + Direct Numerical Simulation (DNS) of the flow around a rectangular cylinder (elongated)
  + Reynolds number Re = 3000

Taylor, Z.J., a, E. Palombi a, R. Gurka a,b, G.A. Kopp. Features of the turbulent flow around symmetric elongated bluff bodies.

* Wind tunnel test of elongated bluff bodies

Hangan, H. Vickery, B.J. A wake model for two-dimensional (sharp-edged) bluff bodies.

* Filename: hangan1997wake
* Abstract
  + two-dimensional wake model for turbulence profiles is developed for (sharp-edged) bluff bodies based on similarity (self-preservation) and universality (different shapes)
  + **Empirical (experiment-based)** wake model

References from 2017

Ravindra G. Devi, Joseph Mathew, Peeush K. Bishnoi, Computations of turbulent near wakes of axisymmetric bodies

* Comparison of turbulence models over ellipsoid and sphere
  + K-epsilon, k-omega, Reynolds stress model
  + Before and after separation
  + Compare to experimental data
  + Previous studies have concerned LES and DNS
    - But RANS is an industry standard, it need its own studies
    - This paper provides that
* Solutions using CFX-5 finite volume solver
  + Grid made with unigraphics and ICEMCFD, unstructured
* Table 1 – compare global properties: drag coefficient, separation location, etc
* Turbulent intensity – Fig 4-6
  + No explanation of how calculated or which model used (probably RSM)

Catalanoa, Pietro, MengWangb, GianlucaIaccarinob, ParvizMoin, Numerical simulation of the flow around a circular cylinder at high Reynolds numbers

* Simulate flow around circular cylinder
  + Show LES is better than URANS
* Qualitative results
  + Compare wake contours
* Quantitative results
  + Compare mean flow velocities
  + Compare force coefficient time histories
* No turbulent parameter analysis

H.F. Lam\*, H.Y. Peng, Study of wake characteristics of a vertical axis wind turbine by two- and three-dimensional computational fluid dynamics simulations

* Filename: lam2016study
* Simulate flow past vertical axis wind turbine (entire structure, not just blades)
  + Transition SST (4-eqn) and DES
  + Validate with PIV data
* Previous work
  + Ferreria: PIV of real wind turbine
  + McLaren: 2-D Unsteady Reynolds Averaged Navier Stokes (URANS) with Shear Stress Transport (SST) turbulence closure on turbine blades
* Computational modeling
  + Mach < 0.3, use incompressible URANS
  + Use SST for resolving turbulent flow
    - Blends k-omega in close-wall with k-epsilon in far field
    - Transition SST: improved 4 eqn model
      * Accurately predict separated flow transition
  + Use Improved delayed DES (IDDES) to verify sensitivity to turb. Model
    - Based on SST, but also DES
  + SIMPLEC pressure-velocity coupling scheme
  + Sensitivity studies performed
    - 1st then 2nd order schemes
    - time step study
    - grid sensitivity study
    - Use wake stream velocity to check convergence – fig 6
    - Validate convergence by comparison to PIV
  + Wake profiles of SST and IDDES were identical
    - Not sensitive to turbulence model
    - Use SST for further analyses
* 3D SST Results
  + presented turbulence intensities are average of intensities in all 3 directions
  + Plot mean velocities and average turbulent intensities of 2D/3D cases
    - Plot profiles along different horizontal and vertical lines (HLs and VLs)
      * Note the orientation of the axes so that horizontal/vertical are intuitive
    - Horizontal line mean flow (fig 8, 9) and turb. Intensity (fig 10)
    - vertical line mean flow (fig 11, 12) and turb. Intensity (fig 13)