CR1 - RANS of the Common Research Model (6th AIAA Drag prediction workshop)

Marshall Galbraith, MIT, USA
galbramc@mit.edu

Joseph Derlaga, NASA Langeley, USA
joseph.m.derlaga@nasa.gov

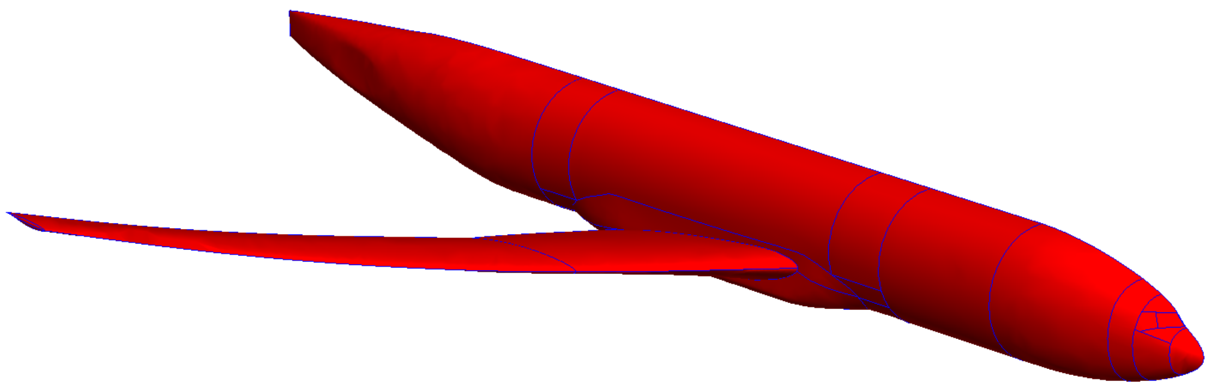
[source:https://aiaa-dpw.larc.nasa.gov/Workshop5/workshop5.html]

Primary Goal

The common research model (CRM) was extensively studied with state-of-the-art CFD codes in the sixth drag prediction workshop (DPW-6). The objective of this test case is to obtain mesh-converged lift, drag and moment coefficient values on the CRM wing-body configuration at cruise conditions. This test case is primarily intended to assess hp-adaptation schemes, but fixed grid results are also welcome. A series of curved finite element methods are provided, and a large number of grids on the DPW-6 website available with various grid topologies.

Required Verification Case

Participants should verify their codes using the VR4 RANS Joukowski verification test case. The verification should be performed on the provided fixed grids. Any hp-adaption schemes should also show adaptive results computed with the Joukowski airfoil geometry. Make sure that both the airfoil geometry and farfield boundary are maintained in the adaptation process. Please only include additional slides with drag error vs. h results computed with adapted grids during the verification portion of the talk.



CRM Wing Body (WB) configuration with 2.75° aeroelastic deflection

Geometry and meshes

Participants should use the version 09 CRM Wing Body configuration with a 2.75° aeroelastic deflection.

The farfield boundary should be located more than 100*b/2, were the full span is b=2,313.50 inch. Hence, participants with a rectangular farfield are encouraged to define the box with the coordinates (-115675, 0, -115675) and (115675, 115675, 115675).

Of primary interest for this test case are solutions based on hp-adaptation. However, a number of fixed grids are also available for participants to use. The DPW-6 webiste has grids linear grids suitable for both structured and unstructured finite volume/finite difference codes. In addition, Steve Karman at Pointwise has graciously provided a set of curved finite element tetrahedral meshes. For sake of comparison, participant should run a grid series of calculations on the provided fixed grids. Adaptive grid calculation should use a sequence of grids that achieve converged solutions in non-dimensional lift, drag, and moment coefficients.

Additional results on meshes generated by the participants can be provided as well. In that case, the meshes should be made available in a common format (GMSH, CGNS) to interested other participants. Please contact Marshall Galbraith if you have additional meshes you would like to share with the community.

Flow and boundary conditions

Similar to the 4th DPW-6 test case, the CRM is considered under transonic cruise conditions. The flow is assumed to be steady-state and fully turbulent. Unlike the 4^{th} DPW test case with a fixed C_L, computations are to be performed with a fixed angle of attack of 2.75° with the corresponding aeroelastic deformed geometry.

Specifically the flow conditions and reference quantities are:

- Steady-state RANS (fully turbulent flow, no transition)
- Mach = 0.85
- α = 2.75°
- Re = 5×10^6 based on reference chord c_{ref} = 275.80 inch
- Prandtl number Pr=0.72
- Turbulent Prandtl number Pr_t = 0.9
- Dynamic viscosity based on Sutherland's law with a reference temperature of 100°F
- Free air farfield boundaries, no modeling of support structures or wind tunnel walls
- neg-SA freestream v_t/v = 3.
- Moment reference center at x_{ref} = 1325.90 inch, z_{ref} = 177.95 inch
- Reference area (half model) for coefficient computations: A_{ref} = 297360 $(\text{inch})^2$

Participants are urged to use the "negative-SA" turbulence model outlined in this paper: http://www.iccfd.org/iccfd7/assets/pdf/papers/ICCFD7-1902_paper.pdf. As this workshop is focused on numerical errors rather than modeling errors, reducing variation in the results based on turbulence modeling differences will simplify comparison of the results.

Note that the standard SA model and negative-SA model are equivalent when the SA working variable is positive. While the negative-SA model is more numerically robust, solutions with the standard SA model are also welcome.

Results from other turbulence models are also welcome.

We also strongly recommend the use of test cases from the NASA Turbulence Modeling Resource (http://turbmodels.larc.nasa.gov/) web site to verify correct implementation of the turbulence model.

Data Submission

1. Plot the drag coefficient error vs. work units to evaluate efficiency, and drag coefficient error vs. length scale $h=1/\sqrt[3]{DOF}$ to assess the numerical order of accuracy.

2. The raw data should be provided in three columns, $1/\sqrt[3]{DOF}$, lift coefficient, drag coefficient, moment coefficient, and work units. The data should be separated by different p values. An example format is provided below:

P = 0

h ($1/\sqrt[3]{DOF}$)	CL	CD	CM	Work Units (optional)
xxx	xxx	xxx	xxx	xxx
xxx	xxx	xxx	xxx	xxx

P = 1

h ($1/\sqrt[3]{DOF}$)	CL	CD	CM	Work Units (optional)
xxx	xxx	xxx	xxx	xxx
xxx	xxx	xxx	xxx	xxx

Common Inconsistencies

The following is a list of common inconsistencies that can lead to computing a different "truth" drag coefficient value.

1. Using a different Prandtl number than 0.72 or turbulent Prandtl number of $Pr_t = 0.9$.
2. Using constant viscosity instead of Sutherland's law.
3. Using the wrong reference temperature other than 100°F
4. Using isothermal wall rather than adiabatic wall.
5. Using the wrong CAD geometry that is not the wing-body with 2.75° aeroelastic deflection.
6. Using something different from a freestream value of $v_t/v = 3$.

References

Geometry reference for the CRM:

- J.C. Vassberg, M.A. DeHaan, S.M. Rivers and R.A. Wahls, "*Development of a Common Research Model for Applied CFD Validation Studies*", AIAA Paper 2008-6919, AIAA Applied Aerodynamics Conference, Honolulu, HI, August, 2008

For further information, please refer to the DPW-6 web site and the references cited therein.