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TITLE: Oscillating 65 Deg. Delta Wing, Numerical

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TITLE: Verification and Validation Data for Computational Unsteady Aerodynamics [Donnees de verification et de valadation pour l’aerodynamique instationnaire numerique]

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ADP010704 thru ADP010735

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INTRODUCTION

This data set consists of steady and unsteady numerical solutions of a sharp-edged cropped delta wing with a leading edge sweep of 65° undergoing a pitching oscillation. The geometry of the wing corresponds with the geometry of the wind tunnel model described in the previous data set (chapter 17E), the difference being the absence of the fuselage in the numerical model. The presence of the fuselage on the upper surface flow is believed to have an effect at small angles of attack only on the forward region of the wing and to have an effect on the location of vortex breakdown at large angles of attack.

The pitching oscillation has an amplitude of $3^\circ$, the mean angle of attack is $9^\circ$. The position of the oscillation axis and the reduced frequency have been set to match one of the reduced frequencies of the aforementioned experiment, while the Mach number has been increased from the experiment's Mach number 0.12 to 0.4 to reduce computational time.

The data set includes field solutions from Euler as well as from Reynolds averaged Navier-Stokes (RANS) calculations for four equidistant instants within one oscillation cycle and for the corresponding static solution ($\alpha = 9^\circ$). Comparison of the Euler and RANS solutions shows the well known differences in strength and spanwise location of the primary vortex-induced suction peak due to the absence of a secondary vortex in the Euler solution. The agreement with the experimental results is very good.

LIST OF SYMBOLS AND DEFINITIONS

- $C_p$: static pressure coefficient, $C_p = (p-p_\infty)/q_\infty$
- LE: leading edge
- $M_\infty$: freestream Mach number
- RANS: Reynolds averaged Navier-Stokes
- $Re_\infty$: Reynolds number
- TE: trailing edge
- $T_\infty$: freestream temperature
- $U_\infty$: freestream velocity
- $b = 2s$: wing span
- $c_1$: root chord
- $f_o$: model oscillation frequency
- $q_\infty$: dynamic pressure
- $\alpha$: angle of attack, degrees
- $\alpha_0$: mean angle of attack, degrees
- $\Delta\alpha$: oscillation amplitude
- $\beta$: angle of sideslip
- $\omega^*$: reduced frequency, $\omega^* = 2\pi f_o c/U_\infty$

FORMULARY

1. General description of model
   1.1 Designation: VFE WB1 · SLE
   1.2 Type: cropped delta wing
   1.3 Derivation: NLR 65°-wing
   1.4 Additional remarks: none
   1.5 References: 1

2. Model geometry
   2.1 Planform: cropped delta wing, see Fig. 1
   2.2 Aspect ratio: 1.378
   2.3 Leading edge sweep: 65°
   2.4 Trailing edge sweep: 0°
   2.5 Taper ratio: 0.15
   2.6 Twist: 0°
   2.7 Root chord: 1.0
2.8 Semi span of model 0.3964
2.9 Area of planform 0.4558
2.10 Definition of profiles symmetrical with sharp leading edge; 5% rel. thickness; arc segment from LE to x/c = 0.4; airfoil NACA 64A005 from x/c = 0.4 to x/c = 0.75; straight line with 3° inclination from x/c = 0.75 to TE, see Fig. 4
2.11 Lofting procedure between reference sections N/A
2.12 Form of wing-body junction N/A, no fuselage
2.13 Form of wing tip rounded, see Fig. 2
2.14 Control surface details N/A
2.15 Grid type structured grid
2.16 Grid size Euler grid: 96 * 32 * 80 cells
RANS grid: 192 * 80 * 128 cells
2.17 Additional remarks Euler grid identical with WEAG-TA 15 CE III "Fine Grid"
2.18 References on model geometry 1

3 CFD code used
3.1 Euler code DASA code, using modified Jameson type scheme (dual timestepping)
3.2 RANS code FLOWer Version 112.1 using modified Jameson type scheme (dual timestepping)
3.3 Turbulence model Baldwin-Lomax with Degani-Schiff modification, no fixed transition
3.4 Computational time Euler: 6-8 hours per oscillation cycle
RANS: 60 hours per oscillation cycle on a SGI Power Challenge, 1 processor used
3.5 Additional remarks unsteady calculation started with steady solution (α = 9°), unsteady solution converged after 2 - 3 model oscillation cycles
3.6 References on CFD code 2

4 Model motion
4.1 Mode of applied motion sinusoidal pitching motion about axis parallel to model Y-axis.
Axis location: x/c = 0.5625, axis located below wing plane, z/c = 0.042
4.2 Range of amplitude Act = 3°, 6°
4.3 Range of frequency ω* = 2πfc/Um = 0.56
4.4 Additional remarks none

5 Boundary conditions
5.1 Mach number 0.4
5.2 Total pressure atmospheric
5.3 Temperature T = 300 K
5.4 Range of model incidence αinc = 9°
5.5 Definition of model incidence model incidence defined relative to the wing plane
5.6 Position of transition, if free N/A
5.7 Additional remarks distance of far field ±3c in x direction, 6s in y direction, ±3c in z direction

6 Data presentation
6.1 Test cases for which data could be made available
α = 9°, Δα = 3° and Δα = 6°. Re = 3.1·10³, ω* = 0.56, Ma = 0.4, Euler and RANS solutions
6.2 Test cases for which data are included in this document
α = 9°, Δα = 3°, Re = 3.1·10³, ω* = 0.56, Ma = 0.4, Euler and RANS solutions
6.3 Variables included x, y, z, u/Um, v/Um, w/Um, Cp, total pressure loss, enthalpy
6.4 Data available as field solution for $\alpha = 9^\circ$ static case, $\alpha = 9^\circ$ dynamic case (upstroke), $\alpha = 12^\circ$ dynamic case, $\alpha = 9^\circ$ dynamic case (downstroke), $\alpha = 6^\circ$ dynamic case, see Fig. 3.

6.5 Steady forces and moments
6.6 Unsteady forces and moments
6.7 Other forms in which data could be made available
6.8 References on data presentation
6.9 Additional remarks

data of RANS solution available for every other grid point in each direction. Data for Euler and RANS solutions formatted as TECPL** input file.

7 Comments on data
7.1 Accuracy
7.2 Other relevant calculations on same model
7.3 Relevant calculations on other models of nominally the same airfoil

2nd order in time, 2nd order spatial (Euler and RANS)
one, but unsteady Euler calculations on the presented grid for the cases $\alpha = 9^\circ \pm 6^\circ$ and $\alpha = 21^\circ \pm 6^\circ$ are part of the CE IV of WEAG TA-15

no, but comparison of RANS results with experimental data of same dynamic parameters from chapter 17EI is shown in Fig. 5.

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List of references

FORMAT OF DATA SET
As mentioned in section 6.9, the data set is submitted as a series of TECPL** input files. The files are ASCII files, their size has been reduced with the UNIX command compress. The contents of the files can be deduced from their names, all files containing Euler solutions start with the letters eu, whereas all files containing Navier-Stokes solutions start with the letters ns. The numbers following those letters indicate the angle of attack. Finally, the letters ... up indicate upstroke movement (ca increasing) of the model, the letters -dn indicate downstroke movement and the letters -st indicate a steady solution.

As an example, the first lines of an arbitrary data file are printed below. Three columns have been omitted.

Since the data are written as ASCII files, they can be read by any other program using the Fortran 77 code fragment below. In the data files each row of data corresponds to a data point and each column corresponds to a variable. The order of the variables is specified in one of the first rows, starting with the tecplot-specific keyword VARIABLES. The dimensions in i-, j- and k-direction are specified in the line starting with the keyword ZONE.

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do 1, imax
  do 1, var = 1, numvar
    read *, array(var, i, j, k)
  end do
  end do
end do

FIGURES

Figure 1: Geometry of the delta wing, RANS grid, every other gridline shown

Figure 2: Geometry of wingtip at x/c_i = 0.9, Euler grid
Figure 3: Available steady and unsteady solutions

Figure 4: Definition of airfoil

Figure 5: Comparison of results from RANS calculation with experimental data ($\alpha = 9^\circ$, $\Delta \alpha = 3^\circ$, $\omega^* = 0.56$)