65-Degree Delta Wing - Experiment and Code Validation Program Status

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Transonic CFD Peer Review
August 16-18, 1989
Overview

- Background
- Experimental program
  - Configuration definition
  - Test conditions
  - Model & testing status
- Calculations
  - Codes
  - Precursor estimates
- Summary
NASA—LANGLEY VORTEX LIFT RESEARCH

- Slender-body theory
  - Concept: Brown & Mcll.
    - 1947
  - 1955

- 3-D theory
  - S. Anal: FVS
    - 1966
  - Euler: NS
    - 1975
  - 1986

- Experiment
  - DM-1 (mod): 1947
  - Stab. & perf.: 1971
  - Dyn. stab.: 1970
  - Strakes: 1972
  - Vortex flap: 1979
  - M > 1: 1985
  - M ≈ 1: 1981
REYNOLDS NUMBER INFLUENCE ON LEADING EDGE FLOW

NASA Dryden/Langley flight exp.

\( \left( \frac{r_{le}}{c} \right) = 0.22\% \)

\( M = .6 \)
\( \alpha = 6^\circ \)

\( Rn_c = 20 \times 10^6 \)
\( Rn_c = 40 \times 10^6 \)
Geometric Features of NTF Delta Wing

$\Lambda_{le} = 65^\circ$, $c_r \approx 2.14\text{ft.}$, $b = 2.0\text{ft.}$

- Interchangeable leading edges
  - $[r_{le}/\bar{c}]_S = .05, .15, .30\%$
  - 8$\mu$ surface finish

- Sting
  - Symmetric
  - $d/b = 0.14$

- Flat plate center wing
  - $t/c_r = 0.034$
  - 8$\mu$ surface finish
  - Sharp trailing edge

- Pressures:
  - 183 orifices/configuration
  - $x/c_r = .2, .4, .6, .8, .95$
  - every 10% $x/c_r$ along l.e.
  - 0.010 inch diameter
Blunt Leading Edge Delta Wing Concept
1980

- Purpose- Determine the effects of Mach number, Reynolds number, and leading-edge radius on delta-wing flow separation.
  - Attached and separation-induced vortex flows
  - $0.2 \leq M_{\infty} \leq 1.2$
  - $1 \times 10^6 \leq R_{\infty} \leq 200 \times 10^6$
  - Independent Mach and Reynolds number control

- Capture salient flow features
  - Sharp and blunt leading-edge separation
  - Secondary vortex separation and transition
  - Vortex breakdown

- Simple geometry
  - Isolated delta wing
  - Fully analytic surfaces, continuous through $2^{nd}$ derivative
  - Representative of full-scale conditions

- Develop generic data base for code development
Instrumentation for NTF Delta Wing

- Wing Pressures:
  - 183 orifices/configuration
  - $x/c_r = .2, .4, .6, .8, .95$
  - every 10% $x/c_r$ along l.e.
  - 0.010 inch diameter

- Wing gauges
  - Internal bending/buffet gauge collocated with thermocouple
  - Upper and lower surfaces independently instrumented
  - Lateral center of pressure, vortex breakdown assessment
  - Thermal equilibrium

- Sting gauges
  - External bending gauges and thermocouples
  - Upper and lower surfaces instrumented
  - Located directly aft of wing trailing edge
  - Balance accuracy achieved $\Rightarrow C_N$ & $C_m$ data
65° NTF DELTA WING
Program Expansion for Code Validation
1986

- Need for additional data
  o LDV
  o Flow visualization

- Need for additional testing
  o Low Turbulence Pressure Tunnel
  o 8-foot Transonic Pressure Tunnel

- Second wing designed for LTPT
  o Identical geometry & instrumentation to NTF delta wing
  o Sized for adequate LV resolution with minimal wall interference
  o Result - 3/4 scale version

- Either wing testable in 8-foot TPT

- Wings could be tested in Unitary
  o $1.5 \leq M_\infty \leq 4.5$
FVS SOLUTION GEOMETRY FOR 65° DELTA WING IN LTPT

Vortex-flow Model

H/B = 2.5
L/H = 1.5
b/B = 0.444, 0.500, 0.667 (NTF)

α = 15°
b/B = 0.500
Planned Experimental Program - 1987

$0^\circ \leq \alpha \leq 30^\circ$

- National Transonic Facility
  - Static surface pressures
  - Forces, moments, buffet
  - Vortex-core condensation

- Low Turbulence Pressure Tunnel
  - Static surface pressures
  - Flow visualization
  - 2-D LDV

- 8-foot Transonic Pressure Tunnel
  - Static surface pressures
  - Flow visualization
  - 3-D LDV
Model and Testing Status

- NTF delta wing
  - 1980 - Initiated
  - 1984 - Model delivered & accepted
  - 1985 - Pressure tubing problem identified & resolved
  - 1986 - Model ready for final gauging

- 3/4 scale delta wing
  - 1987 - Initiated
  - 1989 - Model delivered & accepted but not yet gauged

- No testing of delta wing in NTF
  - Numerous test entry postponements (tunnel controlled by separate Branch)
  - Down time for facility modification & improvement
  - Accident (delta-wing prepared as next entry)
Status of Other Facilities

• 8-foot TPT
  ○ 1981 - 1988 - Dedicated to LFC experiment
  ○ Spring '89 - Authority transferred to AAD/TrAB
  ○ Summer '89 - Returned to configuration aerodynamics status
  ○ No lv system

• LTPT
  ○ Spring '89 - Authority transferred to FldMD
  ○ 3D lv system on site but not yet operational
Revised Experimental Program
1989

- Shift emphasis to 8'TPT
  - Primary aerodynamic assessments
  - $r_{le}, C_p$, forces & moments, buffet, flow visualization
  - Expand testing to utilize tunnel envelope
    - $0.2 \leq M_\infty \leq 1.2$, $0.5 \times 10^6 \leq R_e \leq 6 \times 10^6$
    - Test either (both?) model(s)

- LTPT - await completion of LV system

- Remain prepared for NTF test

- NASA testing will benefit from AFWAL/European data base
  - $65^\circ$ cropped delta wing
Computational Methods for Flow Assessment

- Linear theory
  - Suction analogy

- Nonlinear methods with modeled vortices
  - Linear potential with modeled vortex sheets
  - Full potential with embedded vorticity

- Navier-Stokes methods
  - FMC1 (incompressible, tvd-like, implicit hybrid GS-af)
  - CFL3D (compressible, upwind, implicit 3f-af)
  - TLNS3D (compressible, central, explicit Runge-Kutta)
Precursor Computations - CFL3D
1987

- Objectives
  - Assess aerodynamic sensitivities ($r_{le}, R_e, \alpha, etc.$)
  - Quantify aerodynamic features (vortices, shocks, separation)
  - Obtain estimates of pressures, forces, and moments prior to testing

- Preliminary conditions
  - Moderate leading-edge radius
  - Laminar flow
  - $M_\infty = 0.4, \quad R_e = 0.67 \times 10^6, \quad \alpha = 4^\circ, 8^\circ, 12^\circ$

- Additional conditions planned
PARTICLE TRACES

65 deg NTF Delta Wing
Upwind Scheme

0.100 MACH
4.00 DEG ALPHA
1.00x10^6 Re
1.0 TIME
64x64x50 GRID
Summary

- Comprehensive blunt leading-edge separation program reviewed
  - Compressible attached & separated delta-wing flows
  - Shock, vortex, & shock-vortex structures
  - Multiple facilities, models, theories, and codes

- Experiment
  - Two models ready
  - Test entry in NTF uncertain
  - Focus on 8-foot tests
  - LTPT, UPWT tests still possible

- Theory
  - Hierarchy of methods available now
  - Computations will continue