Broadband Trailing-Edge Noise
as a Canonical Benchmark Problem for Airframe Noise Predictions
Outcome of the BANC-III Workshop & Invitation for BANC-IV

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SHORT VERSION

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Introduction

Motivation behind BANC activity

Workshops on Benchmark Problems for Airframe Noise Computations (BANC)

- Objectives of the BANC workshops (since 2010) are
  - to provide a forum for a thorough assessment of simulation-based noise-prediction tools;
  - to identify current gaps in physical understanding, experimental databases, and prediction capability for the major sources of airframe noise;
  - to help determine best practices, and accelerate the development of benchmark quality datasets;
  - to promote future coordinated studies.

https://info.aiaa.org/tac/ASG/FDTC/ DG/BECAN_files/
Workshops on Benchmark Problems for Airframe Noise Computations (BANC)

- Workshop categories:
  1. Airfoil trailing edge noise (TEN)
  2. Unsteady wake interference between a pair of inline tandem cylinders
  3. Minimal 4-wheel landing gear
  4. Partially-dressed, cavity-closed nose landing gear
  5. The LAGOON Simplified Landing Gear configuration tested by Airbus and ONERA
  6. Slat Noise (DLR/ONERA Configuration)
  7. Slat Noise (modified NASA 30P30N Configuration)
  8. Acoustic Propagation Phase of Airframe Noise Prediction

new since BANC-II
Workshops on Benchmark Problems for Airframe Noise Computations (BANC)

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  8. Acoustic Propagation Phase of Airframe Noise Prediction

BANC-IV: 2–3 June 2016, i.e. directly following the 22nd AIAA/CEAS Aeroacoustics Conference in Lyon

http://www.aeroacoustics2016.com/
BANC-III-1 problem statement

Simulation matrix

Test cases (BANC-II-1 and III-1)

- Provide $c_p(x_1)$, $c_f(x_1)$, near-wake mean flow / turbulence profiles, surface pressure spectra $G_{pp}(f)$, FF noise $L_p(f_c)$ for CASES#1-5 ($Re = 1–1.5$ Mio.)

<table>
<thead>
<tr>
<th>Case#1</th>
<th>56 m/s 0°</th>
<th>NACA0012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case#2</td>
<td>55 m/s 4°</td>
<td></td>
</tr>
<tr>
<td>Case#3</td>
<td>53 m/s 6°</td>
<td></td>
</tr>
<tr>
<td>Case#4</td>
<td>38 m/s 0°</td>
<td></td>
</tr>
<tr>
<td>Case#5</td>
<td>60 m/s 4°</td>
<td>DU-96-180</td>
</tr>
</tbody>
</table>

CASE#1: single core test case for those who could not afford the full matrix

For the full problem statement with more specified definitions of:
- profile coordinates (sharp TE!)
- tripping devices (TBL-TE noise!)
- TBL transition locations
- ambient conditions, etc.
- data formatting instructions including templates

Please contact michaela.herr@dlr.de.
Overview on contributions

- **PoliTo:** Andrea Iob, wavePRO, Torino, & Renzo Arina, Politecnico di Torino, Italy & Paul Batten / S. Chakravarthy, Metacomp Technologies, USA (CA)
  - Hybrid RANS/LES (IDDES) coupled with Large-Eddy Stimulation

- **DLR:** Roland Ewert / Christof Rautmann, German Aerospace Center
  - CAA-code PIANO with RANS-based stochastic source model FRPM

- **IAG:** Dimitrios Bekiropoulos / Mohammad Kamruzzaman, University of Stuttgart, Germany

- **DTU:** Franck Bertagnolio, DTU Wind Energy, Technical University of Denmark
  - Simplified theoretical surface pressure prediction of “Blake-TNO”-type, combined with FF model (RANS input)
### Overview on contributions

<table>
<thead>
<tr>
<th>configuration/ participant</th>
<th>PoliTo</th>
<th>DLR</th>
<th>IAG</th>
<th>DTU</th>
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</thead>
<tbody>
<tr>
<td><strong>Case#1</strong> 56 m/s 0°</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td><strong>Case#2</strong> 55 m/s 4°</td>
<td>-</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td><strong>Case#3</strong> 53 m/s 6°</td>
<td>-</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<tr>
<td><strong>Case#4</strong> 38 m/s 0°</td>
<td>-</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td><strong>Case#5</strong> 60 m/s 4°</td>
<td>-</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>
Near-wake flow characteristics

Orientation of flow profiles position @ 100.38 % \( l_c \)
Near-wake flow characteristics CASE#1 SS

Overall comparisons
Aerodynamical data

PoliTo: CFD++ + SA (+ QCR terms)

IAG-LWT 2-point correlation measurements

IAG: FLOWer + SST (+ anisotropy model)
DTU: EllipSys2D + SST

Traveling probe
Waiting probe
Overall comparisons
Aerodynamical data

Near-wake flow characteristics CASE#1 SS

PoliTo: CFD++ + SA (+ QCR terms)
DLR: TAU + SST (4 : 2 : 1)
IAG: FLOWer + SST (+ anisotropy model)
DTU: EllipSys2D + SST

\[
\begin{align*}
\langle u_1^2 \rangle &= 2/3 k_T \\
\langle u_2^2 \rangle : \langle u_3^2 \rangle : \langle u_3^2 \rangle &= 4 : 2 : 3 \\
\langle u_2^2 \rangle &= 0.45 k_T
\end{align*}
\]
Overall comparisons

TEN farfield noise data

elliptic mirror @ DLR AWB

NASA BPM database

1/3-octave band spectra

b = 1 m
r = 1 m

θ = 90° chord-normal view direction for noise prediction
Overall comparisons

Farfield noise data

1/3-octave band FF noise spectra $L_{p(1/3)}(f_c)$ CASE#1

- PoliTo: IDDES-LEST/FWH
- DLR: PIANO-FRPM
- IAG: Rnoise (‘Blake-TNO’ / Brooks & Hodgson)
- DTU: (‘Blake-TNO’ / Brooks & Hodgson)

**Chart 12**

<table>
<thead>
<tr>
<th>$f_c$, kHz</th>
<th>$L_{p(1/3)}$, dB</th>
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**CASE#1, PoliTo**

**CASE#1, DLR**

**CASE#1, IAG**

**CASE#1, DTU**

**CASE#5, DLR**

**CASE#5, IAG**

**CASE#5, DTU**
Overall comparisons
Pressure data

FF pressure data (all cases) sorted to identify common trends, supplemented by surface pressure data;

are relative effects captured by the predictions?

Position @ 99 % \( l_c \)
PSDs (measurement data normalized to \( \Delta f = 1 \text{ Hz} \))

- SS
- PS
Effect of flow velocity on $L_{p(1/3)}(f_c)$ and $G_{pp}(f)$: CASE#1 vs. #4

Overall comparisons
Pressure data
Overall comparisons

Effect of a-o-a on $L_{p(1/3)}(f_c)$: CASES#1 to #3

Pressure data

- measurement data:
  - individual datasets
  - averaged comparison spectra

- CASE#1
- CASE#2
- CASE#3

- CASE#1, DLR
- CASE#2, DLR
- CASE#3, DLR

- CASE#1, DTU
- CASE#2, DTU
- CASE#3, DTU

- grey: measurement data
- DLR simulation
- DTU simulation
- IAG simulation

$\alpha$
Effect of airfoil geometry on $L_{p(1/3)}(f_c)$: CASE#2 vs. CASE#5

Overall comparisons
Pressure data

Measurement data:
- Dashed line: individual datasets
- Solid line: averaged comparison spectra

CASE#2
CASE#5

Measurement data:
- Grey: measurement data
- Dotted line: DLR simulation
- Dashed line: DTU simulation
- Solid line: IAG simulation
The outcome of the BANC-III workshop category 1 has been summarized.

Results display a high scientific quality level; FF TEN predictions are within or very close to the provided data scatter band, TEN maxima are principally well-predicted; but:

- General trends (a-o-a, velocity scaling) are not always correctly predicted.
- Code-specific advantages/disadvantages are observable, indicating that a methodology which comprehensively predicts all of the requested nearfield & FF quantities is not available to date.

The category 1 workshop problem remains a challenging simulation task due to its high requirements on resolving/modeling of TBL source quantities.

We still faced a comparatively low number of participants, these were mainly developers of faster approaches dedicated for use in an industrial context (design-to-noise), BANC-III-1 results will hopefully activate multiplied follow-on activity by anyone interested to join the community.
We hope to motivate a more representative spectrum of the TEN community to participate at BANC-IV-1 in 2016.

BANC-IV-1 will supplement the existing CASES#1–5 by additional datasets:

- **0.6-m chord NACA64-618** data provided by DTU Wind Energy; $c_p(x_1)$, flow profiles, $L_{p(1/3)}(f_c)$, $G_{pp}(f)$, spanwise correlation of $G_{pp}$; $Re = 1.43$ Mio.

<table>
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<tr>
<th>Case#6</th>
<th>45.03 m/s -0.88°</th>
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<tr>
<td>Case#7</td>
<td>44.98 m/s 4.62°</td>
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The by now established BANC category 1 data base is open for use to anyone interested and will be maintained according to your feedback.

The BANC-IV-1 updated problem statement will be soon available; if you wish to be included in the distribution list please contact:

**michaela.herr@dlr.de**

See you at BANC-IV 2–3 June 2016 in Lyon?

Thank you for your attention!