Wake vortex alleviation by oscillating flap setting: An experimental study

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Goal

Premature decay of a wake vortex system by triggering long-wavelength instabilities (Crow) using configurative methods at lift device (OFS - Oscillating Flap Setting)
Overview

- description of F13 model
- measurement devices and test setup
- test configurations
- results
  - effects from the towing tank tests
  - comparison of configurations
- summary, outlook
The experimental DLR-F13 model

- Wortmann profile FX63-137B-PT (modified at Princeton University)
  -> Low-Reynolds-number profile
- Main wing: $b_w = 0.3$ m, $A_{R_w} = 6.0$, $\alpha_w = 10.0^\circ$
- Horizontal tail plane: $b_{HTP} = 0.12$ m, $A_{R_{HTP}} = 3.43$, $\alpha_{HTP} = -6.0^\circ$
- Flap moving frequency: 0.8 Hz and 1.0 Hz (taken from formerly obtained experimental data)
- Tracking velocity: 2 m/s (to ensure $Re \approx 100 000$)
The experimental F13 model
The water towing tank Göttingen (WSG)

- length: 18 m
- cross section: 1,1 x 1,1 m
- trailing velocity: 1.0...5.0 m/s
- launching: 1977
The stereo-PIV-measurement device

- time resolution: 10 Hz
- camera traversing unit: downward motion of vortex system can be followed
- programable start of measurement: The modulation range varies correspondently to the decrease of flow velocity
## Test configurations

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Inboard flap (°)</th>
<th>Midboard flap (°)</th>
<th>Outboard flap (°)</th>
<th>Frequency (Hz)</th>
<th>$v_\infty$ (m/s)</th>
<th>HTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0 / 0</td>
<td>0 / 0</td>
<td>0 / 0</td>
<td>--</td>
<td>2</td>
<td>yes/no</td>
</tr>
<tr>
<td>01</td>
<td>0 / -20</td>
<td>0 / 10</td>
<td>0 / 10</td>
<td>0.8</td>
<td>2</td>
<td>yes</td>
</tr>
<tr>
<td>02</td>
<td>0 / -20</td>
<td>0 / 10</td>
<td>0 / 10</td>
<td>1.0</td>
<td>2</td>
<td>yes</td>
</tr>
<tr>
<td>03</td>
<td>0 / -20</td>
<td>0 / 10</td>
<td>0 / 10</td>
<td>0.8</td>
<td>2</td>
<td>no</td>
</tr>
<tr>
<td>04</td>
<td>0 / -10</td>
<td>0 / -10</td>
<td>0 / 20</td>
<td>0.8</td>
<td>2</td>
<td>yes</td>
</tr>
<tr>
<td>05</td>
<td>0 / -10</td>
<td>0 / -10</td>
<td>0 / 20</td>
<td>0.8</td>
<td>2</td>
<td>no</td>
</tr>
</tbody>
</table>
Test configurations

configuration 01 - 03

configuration 04 - 05
Result of experiment

configuration 00
$v_{\text{down}} = 30 \text{ mm/s}$

$0 / 0 / 0 / -- \text{ Hz with HTP}$
Result of experiment

configuration 00
$v_{\text{down}} = 30 \text{ mm/s}$

$0 / 0 / 0 / -- \text{ Hz without HTP}$
Result of experiment

configuration 01

$v_{\text{down}} = 30 \text{ mm/s}$

-20 / 10 / 10  0.8 Hz with HTP
Result of experiment

configuration 02
$v_{\text{down}} = 30$ mm/s

-20 / 10 / 10 1.0 Hz with HTP
Result of experiment

configuration 03

$v_{\text{down}} = 25 \text{ mm/s}$

-20 / 10 / 10 0.8 Hz without HTP
Result of experiment

configuration 04
$v_{\text{down}} = 30 \text{ mm/s}$

-10 / -10 / 20  0.8 Hz with HTP
Result of experiment

configuration 05
\(v_{\text{down}} = 20 \text{ mm/s}\)

-10 / -10 / 20  0.8 Hz without HTP
Comparison of experimental results

configuration 00

0 / 0 / 0

with HTP

--- Hz

configuration 01

-20 / 10 / 10

with HTP

0,8 Hz
Comparison of experimental results

configuration 00

0 / 0 / 0
with HTP
--- Hz

configuration 04

-10 / -10 / 20
with HTP
0,8 Hz
Comparison of experimental results

configuration 00

0 / 0 / 0
without HTP
--- Hz

configuration 03

-20 / 10 / 10
without HTP
0,8 Hz
Comparison of experimental results

configuration 00

0 / 0 / 0
without HTP
--- Hz

configuration 05

-10 / -10 / 20
without HTP
0,8 Hz
Comparison of experimental results

configuration 01
-20 / 10 / 10
with HTP 0,8 Hz

configuration 03
-20 / 10 / 10
without HTP 0,8 Hz
Comparison of experimental results

configuration 04
-10 / -10 / 20
with HTP
0,8 Hz

configuration 05
-10 / -10 / 20
without HTP
0,8 Hz
Comparison of experimental results

configuration 01
-20 / 10 / 10 with HTP 0,8 Hz

configuration 04
-10 / -10 / 20 with HTP 0,8 Hz
Comparison of experimental results

configuration 01
-20 / 10 / 10
with HTP
0,8 Hz

configuration 02
-20 / 10 / 10
with HTP
1,0 Hz
Summary and outlook

- Perturbation of 2- or a 4-vortex-system depends on triggering frequency and on deflection configuration of wing devices
- Experimental studies are showing an evident effect concerning triggering of vortex instabilities
- All tests are very well reproducible
- The strong outboard loading configurations seem to be the more promising way to achieve earlier vortex decay
- The existance of additional HTP vortices has a marginal influence on vortices which are shed from flap devices
- Development of ring-shaped structures which are typical for Crow instabilities occurs primaly in farfield -> experimental studies require a larger water towing tank or wind tunnel
- Flow visualization with video equipment was not possible due to the required space of PIV measurement system
Thank you!