Numerical sizing of Active Flow Control concepts on the outer wing
NUMERICAL SIZING OF ACTIVE FLOW CONTROL CONCEPTS ON THE OUTER WING

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AFLoNext

**TS2**
**Active Flow Control on outer wing**
up to 21% fuel saving

Flow control technologies to enable more aggressive outer wing design for new aircraft configurations, thereby improving the performance and the loads situation in low and high speed conditions.

**TS1**
**Hybrid Laminar Flow Control on wing and fin**
up to 9% fuel saving

Hybrid Laminar Flow Control (HLFC) technology applied on fin and wing for friction drag reduction and thus performance increase in cruise conditions.

**TS3**
**Active Flow Control on wing / pylons**
Enables interaction of UBHR engines

Technologies for local flow separation control applied in wing/pylon junction to improve the performance and loads situation in take-off and landing conditions.

**TS4**
**Active Flow Control on wing trailing edges**
up to 1-2% fuel saving

Technologies to control the flow conditions on wing trailing edges: thereby improving the performance and loads situation in the whole operational domain.

**TS5**
**Noise reduction on flap and undercarriage**
Significant A/C noise reduction in approach

Technologies to mitigate airframe noise during landing generated on flap and undercarriage and through mutual interaction of both.

**TS6**
**Vibrations mitigation / control in undercarriage area**
Weight reduction of 100-200 kg on landing gear doors

Technologies to mitigate/control vibrations in the undercarriage area which are caused by highly unsteady or inhomogeneous inflow conditions in take-off and landing conditions.
Recall of Active Flow Control objectives

Global objectives:

- See how AFC can help in doing the compromise between low speed and cruise for an aggressive wing tip design.
- The aim is to increase the aerodynamic efficiency of the wing at Take-off by delaying potential flow separation in the outer wing region.
- The use of AFC should help in decreasing the associated drag and increasing L/D, thus leading to a steeper climb gradient in the second segment of climb (when the landing gear is retracted).
Baseline aerodynamic characterisation

Wing tip stall identification

\ Results on Medium and Real geometries
Baseline characterisation

Aerodynamic coefficients on simplified geometry and expected improvement with AFC

Flow topology

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AFC sizing and Workshare

Two identified AFC locations:
\ Separation line at the LE
\ Wing tip root region

Workshare

LE region:
_Between attachment line & separation line_

At the LE separation line:

Steady blowing + SJA
Steady blowing + PJA

Boundary conditions
Volume forcing

On the upper surface:
At 10% of chord

XRF1_JIG_BL_OW
CONF1+F. AoA=18°
instantaneous, with SJA, v6
U_{in,ref}=180m/s
M=0.2, Re=25e6

Transposition at aircraft level:

Steady blowing
Resolved slots

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Steady blowing versus Synthetic Jet

\(\text{AFC on the upper surface (10\% chord) with continuous blowing, Synthetic Jet (sinus or square):}\)

- **Steady blowing** \(M_{\text{jet}} = 0.8 \) (MF=1.3 kg/s)
- **Synthetic Jet**:
  - max \(M_{\text{jet}} = 0.8 \) or 0.5 ; 100 Hz
  - Pitch angle to surface = 30°

- **Baseline**

\[\text{lift coefficient } C_l \]
\[\text{drag coefficient } C_d \]

- **XRF1_JIG_HL_OW**: instantaneou, with SJA, \(v_6\)
  - \(U_{\text{jet, peak}} = 180 \text{ m/s}\)
  - \(M=0.2, Re=35e6\)

\[
\begin{align*}
\text{AoA} = 18° \\
\text{Ct. Blowing } dm/dt = 1.3 \text{ kg/s} \\
U_{\text{peak}} = 273 \text{ m/s} \\
20 \text{ Slits} \\
4\text{mm x 100mm} \\
\text{Baseline}\end{align*}
\]

\[
\begin{align*}
\text{AoA} = 18° \\
\text{SJA, } U_{\text{peak}} = 273 \text{ m/s} \\
20 \text{ Slits} \\
4\text{mm x 100mm} \\
\end{align*}
\]

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\begin{align*}
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20 \text{ Slits} \\
4\text{mm x 100mm} \\
\end{align*}
\]
Initial CFD studies with large slots

\[ \text{AFC on the upper surface (10\% chord) with continuous blowing, Synthetic Jet (sinus or square):} \]
\[ 4\text{mm wide slots} \]
Slots taking into account hardware constraints

\textbf{Limits due to the hardware technology}

- To get enough peak velocity, do not exceed 5 mm\(^2\) as slot area
- Typical slot size: 10 mm x 0.5 mm
- Spacing in span:
  - 1 mm Synthetic Jet
  - 3 mm Pulsed Jet
- Spacing between actuator rows:
  - 50 mm Synthetic Jet
  - 30 mm Pulsed Jet

\textbf{AFC on the upper surface:}

\textit{Mesh generated by ARA}

80 Slits
0.5 mm x 100 mm
Slots taking into account hardware constraints

AFC at the LE separation line with continuous blowing

- Steady blowing: M jet = 1
- Pitch angle to surface = 20°
Transposition at aircraft level

AFC at the LE separation line with steady blowing (200 m/s)

\[ \text{AoA} = 15^\circ \]
Slots taking into account hardware constraints

AFC at the LE separation line with continuous blowing (300m/s) and pulsed blowing (BAES type)

248 PJA at the LE

Cfx

AoA=18°

Baseline

Steady blowing

Pulsed blowing (f=50Hz)
Synthesis of AFC concepts

Evaluation based on % of improvement in L/D at wing tip stall AoA and $\alpha$ range

Steady blowing cases

Steady blowing cases

Steady blowing cases

Steady blowing cases

AoA range of improvement $> 5^\circ$
Synthesis of AFC concepts

Evaluation based on % of improvement in L/D at wing tip stall AoA and α range

Effect of Synthetic jet

Steady blowing

Synthetic Jet

V peak = 273m/s

V peak = 180m/s

AoA range of improvement ≈ 3°
Synthesis of AFC concepts

Evaluation based on % of improvement in L/D at wing tip stall AoA and α range

Effect of Pulsed jet

Pulsed blowing
Vp=300m/s 50Hz

Steady blowing

AoA range of improvement > 5°

Pulsed blowing
With Phase shift:
75% of Pulsed blowing efficiency

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Conclusions

The potential of AFC to delay flow separation in the outer wing region has been investigated in the AFlOnext project using CFD. The aim was to improve the L/D at Take-off.

As expected, the best AFC locations were found:
- Either close to the leading edge separation line to prevent vortices interaction
- Or at the wing tip root to strengthen the slat end vortex

Differences in flow mechanisms between steady blowing and Synthetic Jets have been underlined.

Taking into account sizing constraints coming from Hardware development within the AFlOnext project allowed showing the benefit of segmented thin slots, where longitudinal vortices help stabilising the flow.

On such a configuration Pulsed Jets were found as efficient as steady blowing for a blowing mass flow divided by a factor 2.

An overall synthesis was performed in order to extract general trends about best AFC location and actuation type. Updated requirements were also derived to specify the AFC hardware developed within the project.
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