Design of a Cogeneration Hybrid Propulsion System for Commuter Aircrafts With Thermal Recovery

TRANCOSSI, Michele <http://orcid.org/0000-0002-7286-5228>

Available from Sheffield Hallam University Research Archive (SHURA) at:
http://shura.shu.ac.uk/11202/

This document is the author deposited version. You are advised to consult the publisher's version if you wish to cite from it.

Published version


Copyright and re-use policy

See http://shura.shu.ac.uk/information.html
YES WE ACHEON!

Michele Trancossi
University of Modena and Reggio Emilia
Sheffield Hallam University

The present work has been performed as part of ACHEON Project | ACHEON Project - Aerial Coanda High Efficiency Orienting-jet Nozzle project, with ref. 309041 supported by European Union through the 7th Framework Programme (www.acheon.eu).
We have a dream...
Control of dynamic deflection of a jet without any part in movement:
- Fluidodynamic
- Electrostatic
- Propulsion;
- Distribution of chemicals
- Acclimatizing
- Deicing
- Technological Applications
- Etc.
Coanda effect: something exoteric...

**Bradshaw**

\[ \theta = f \cdot \sqrt{a \cdot b \cdot \frac{P_{\text{wall}} - P_{\infty}}{\rho \cdot u^2}} \]

**Newman**

\[ u_p = \frac{P_s - P_a}{P_0 - P_a} = -\left[ 2 \frac{b}{a} + \left( \frac{b}{a} \right)^2 \right] \]

**So and Mellor**

\[ \frac{u}{u_{pw}} = \left[ \frac{(P_t - P_r)}{(P_r - P_{sw})} + e^{-2ky} \right]^{1/2} \]

\[ u_{pw} = [2Pr - P_{sw}]^{0.5} \]

\[ \frac{\partial P}{\partial y} = k \rho u^2 \]

**Von Karman**

\[ \mu \frac{d^2u}{dy^2} = \frac{dp}{dx} \]
The fluid stream is subject to a difference of pressure that equilibrates the centrifugal force.

frictional effects that are depending on the velocity $u$

\[
\frac{\partial P_r}{\partial r} = \rho \cdot \omega^2 \cdot r = \rho \cdot \frac{u^2}{r} \\
\tau = \mu \cdot \frac{\partial u}{\partial r} = c_f \cdot \frac{\rho \cdot u^2}{2}
\]

\[
u(r) - u_{min} = \frac{R}{r} \cdot \Delta u_1 \rightarrow u(r) = \frac{R}{r} \cdot \Delta u_1 + u_{min,1}
\]
100% independent validation

very preliminary model presented by Unimore, from which the project starts, is acceptable


the last presented models works properly even if it needs to be implemented regarding better turbulence models and swirl.

## Computations

<table>
<thead>
<tr>
<th></th>
<th>60-60</th>
<th>58-62</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mass velocity [kg/m²s]</strong></td>
<td>60-60</td>
<td>58-62</td>
</tr>
<tr>
<td><strong>Fx [N]</strong></td>
<td>42.15</td>
<td>12.35</td>
</tr>
<tr>
<td><strong>Fy [N]</strong></td>
<td>0</td>
<td>41.92</td>
</tr>
<tr>
<td><strong>Thrust angle [º]</strong></td>
<td>0</td>
<td>73.35</td>
</tr>
<tr>
<td><strong>Efficiency [-]</strong></td>
<td>0.73</td>
<td>0.72</td>
</tr>
</tbody>
</table>
The turbulent kinetic energy shows that the control zone of jet is not just after the exit flow. What was the intuition before computation.

It is located little bit away from the exit.

High turbulence zone in z plane indicates the fact.
For the inlet velocity 10m/s, at the throat 30 m/s velocity is obtained.

Even slight velocity ratio for 1.5 (15ms⁻¹/10ms⁻¹) is able to deviate the jet either side.
And some experiments…
And some experiments…
And some experiments...
Can it work on airplanes?

• A wonderful work has produced by UoL
• It demonstrates that the nozzle increases the maneuverability of an airplane with surprising results.
Acheonizing an old fashioned plane...
### Boring Numbers

#### Empty weight
<table>
<thead>
<tr>
<th>Kg</th>
<th>4069</th>
</tr>
</thead>
</table>

#### Useful load
| Kg          | 662  |

#### Max takeoff weight
| Kg          | 3107 |

#### Max on board fuel

<table>
<thead>
<tr>
<th>Batteries (Boston Power Swing® 5300 Rechargeable Lithium-ion Cell)</th>
<th>Kg</th>
<th>Wh/kg</th>
<th>Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1050</td>
<td>207</td>
<td>4420</td>
</tr>
</tbody>
</table>

#### Fuel
| Kg          | 640  |

#### Propulsion

<table>
<thead>
<tr>
<th>Cogen</th>
<th>Rolls Royce Model 250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>kW</td>
</tr>
<tr>
<td>Mass</td>
<td>Kg</td>
</tr>
</tbody>
</table>

#### Motor
<table>
<thead>
<tr>
<th>Four Plettelberg Nova 150 mounted in two ACHEON Nozzle</th>
<th>Power</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kW</td>
<td>Kg</td>
</tr>
</tbody>
</table>

#### Performance

<table>
<thead>
<tr>
<th>Max speed</th>
<th>118.9 m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max cruising speed</td>
<td>109.4 m/s</td>
</tr>
<tr>
<td>Stall Speed</td>
<td>46.3 m/s</td>
</tr>
<tr>
<td>Stall Speed Carriage</td>
<td>25.1 m/s</td>
</tr>
<tr>
<td>Initial rate of climb</td>
<td>7.366 m/s</td>
</tr>
<tr>
<td>Service ceiling</td>
<td>8200 m</td>
</tr>
<tr>
<td>Long range cruising speed</td>
<td>54.4 m/s</td>
</tr>
<tr>
<td>Range with reserves at economical cruising speed</td>
<td>2000 km</td>
</tr>
</tbody>
</table>

#### Configuration

<table>
<thead>
<tr>
<th>Flight Condition:</th>
<th>Cesna 402 traditional</th>
<th>Cesna 402 ACEON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-Off</td>
<td>132012</td>
<td>44280 kJ</td>
</tr>
<tr>
<td>Second Take-Off Segment</td>
<td>504000</td>
<td></td>
</tr>
<tr>
<td>Enroute (30min)</td>
<td>1908000</td>
<td>636000 kJ</td>
</tr>
<tr>
<td>Approach Segment</td>
<td>267120</td>
<td>53000 kJ</td>
</tr>
<tr>
<td>Landing Segment</td>
<td>396036</td>
<td>13284 kJ</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>5207168</td>
<td>85664 kJ</td>
</tr>
<tr>
<td>Max on board energy</td>
<td>640</td>
<td></td>
</tr>
<tr>
<td>Reserve</td>
<td>-5207168</td>
<td>343916 kJ</td>
</tr>
</tbody>
</table>
And now... the best commuter ever built...

Dornier Do 28 D2 can take off from the garden behind my house...

ACHEON allows reducing of more than 50% the needs in terms of landing an takeoff space: from 170 m to less than 100.

Having some weight and payload

With RR series 250 turbofan cogeneration
...and let’s do it strange...
**whow... it can work!**

- **Assuming an angle of attack of 7.5°**
- **Take off**
  - angle of the fuselage and thrust 7.5°,
  - max thrust takeoff,
  - Vstall about 9 m/s
  - Vtakeoff = 10.65,
  - takeoff length about 12 m,
  - acceleration of 3 m/s.
- **Climbing**
  - angle of 20° about
  - speed about 14 m/s
  - angle of attack 7.5,
  - Thrust is oriented upward with an angle of 15°
- **Cruise**
  - min speed about 10-12 m/s
  - cruise speed of 25 m/s
- **Landing**
  - landing length less than 12 m.

---

<table>
<thead>
<tr>
<th>Component</th>
<th>Unit mass</th>
<th>Number</th>
<th>Total mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellers</td>
<td>37</td>
<td>4</td>
<td>148</td>
</tr>
<tr>
<td>Motors</td>
<td>72</td>
<td>3</td>
<td>216</td>
</tr>
<tr>
<td>Speed control</td>
<td>26</td>
<td>4</td>
<td>104</td>
</tr>
<tr>
<td>Servo</td>
<td>85</td>
<td>4</td>
<td>340</td>
</tr>
<tr>
<td>Receiver</td>
<td>50</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>Battery</td>
<td>786.2</td>
<td>2</td>
<td>1572.4</td>
</tr>
<tr>
<td>Cabling and accessories</td>
<td>200</td>
<td>1</td>
<td>200</td>
</tr>
</tbody>
</table>

**Total mass**: 2630.4

---

Less than 4 kg ➔ 5 to 45 m/s
About 4000 €
...and how can we improve it?
ACHEON balance...

- 600.000 Euro demonstrated that, even still embrional ACHEON works!
- We have demonstrated that ACHEON could fly... actually on subsonic airplanes
- it can be helped by thermal effects which needs further studies
- A large number of high quality papers produced
- Theoretical results reaches fully achieved TRL 2... even if they need further studies and further experimental validations to be exhaustive
- ... 2 patents... 1 connected patent.
- ... UOL, UBI, and VUB experimental results have started the road through TRL 3...
- We have encouraged new research direction on Coanda effect
- We have met other research groups working on Coanda Effect... they have also validated some results free of charge because of their scientific importance!
- ACHEON according to UNIMORE has been a success!
- What do you think about continuing it????
... and for tomorrow...
I think that ACHEON could work!

Thanks!

The present work has been performed as part of ACHEON Project | ACHEON Project - Aerial Coanda High Efficiency Orienting-jet Nozzle project, with ref. 309041 supported by European Union through the 7th Framework Programme (www.acheon.eu).