Icewing presentation

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Vastuullinen liikenne.
Yhteinen asia.
Background

Finnish Transport Safety Agency started granting safety related research from the beginning of 2012.

Aalto University’s application for aerodynamic research of deicing/anti-icing fluids was approved early 2012. The project was granted a second phase from beginning of 2013.

The first wind tunnel tests started 29. Feb 2012. The second phase has been completed during spring 2013.
Background

- Icewing Phase II includes allowance also for "networking" activities:
  ✓ To get contacts with the research community
  ✓ To discover on going activities in the field
  ✓ To get response and new views

- Presentations given at:
  ✓ AEA De-Icing/Anti-Icing WG meeting (13.3.2013 Brussels)
  ✓ SAE WG-12 meeting (9.-10.5.2013 New Orleans)
  ✓ AIAA Conference paper (26.6.2013 San Diego)
Rationale for the Project

• Present aerodynamic acceptance test standard SAE AS 5900 originates from 1990’s.

• SAE AS 5900 based on tests with Type II fluids of 1980’s.
• Concentrated in Boeing 737 geometry (test flights with B737)

• No major updates published.

• Very few aerodynamic tests published on Type IV fluids at all.
• NRC in Canada (funded by TC and FAA) the only facility actively publishing aerodynamic studies during recent years (especially related to HOT)
Rationale for the Project

Operative problems related to Type IV fluids

- Fluid residue problems in several different forms were encountered since mid 1990’s (applies to all thickened fluids)

- Some recent reported cases including Type IV fluid contribution:
  - 2010 an incident report of Finnair E-170: buffet and pitch limit indicator activation during an otherwise normal take-off. Possibly Type IV fluid contribution (OAT = -16 °C)
  - BAE ATP discontinued take-off at EFHK on 11.1.2010: (Within one year 7 similar cases. EASA presented a research plan to address this at SAE WG-12 9.5.2013)
Objectives

To study:

• *Type IV – fluid “flow off” behaviour on wing surface with different parameters*

• *Lift losses due to anti-ice treatment with Type IV-fluids during take off*

• *Possible premature fluid flow off during high speed taxi*

continuing →
Objectives (cont’d)

- Effect of two step de-icing treatment on fluid flow off and on lift loss during take off compared to one step treatment

- Effect of dilution of Type IV fluids on lift loss during take off

- Effect of real frost on lift loss during take off compared to Type IV and Type II treatment
**Aalto University Low Speed Wind Tunnel:**

2m x 2m test section - max airspeed 60 m/s = 120 kt
The Wind Tunnel Models

- **Fixed Model**: chord 1.8 m, profile NACA 63-210, with 5.5 deg folded trailing edge from 35% chord simulating the flap setting.
- **No force measurements** – video recording with a thickness calculation algorithm

- **Rotation model**: chord 0.65 m, three element DLR F15 - profile (representing a modern airliner wing), adjustable slats and flaps
- **Force measurements, video recordings**

- **Both models have coolant tanks to simulate the cold fuel in wing tanks**
Fixed Wing Model
Rotating Wing Model

Coolant tank
Fluids Applied in the Tests

- Fluid manufacturers reluctant

- One manufacturer delivered four different fluid types (T IV, T II, TI and AS 5900 reference fluid)

→ Coverage of different manufacturers inadequate

- Rheological properties determined for Type IV.
- Type II still to be tested
Rheological Properties of Type IV Fluid Applied

- Typical non-Newtonian behavior (shear thinning) of Type IV fluid:

![Graph showing the relationship between viscosity and rotational speed at a constant temperature of -10°C.](image)

- Viscosity variation with temperature – less typical:

  Test OAT mostly within the "plateau" area (0°C to -10°C)

  $n = \text{rotational speed Brookfield LV viscometer (spindle no LV2)}$

![Graph showing the relationship between viscosity and fluid temperature at different rotational speeds.](image)
Tests with the Fixed Model

Test arrangements:
1. Acceleration to 60 m/s + deceleration
   Acceleration simulates the take off run.

   To gain better resolution in results the constant speed phase of 30 s (as per AS 5900) was not adopted

2. “Taxiing” tests: stepwise speed increments (5, 10, 15 m/s = 10, 20, 30 kt)

Measurements:
- Fluid thickness values calculated from video frame RGB-values (in house Matlab-software)
- Elcometer fluid film thickness gauge measurements on wing surface before and after test
- Comparison between applied and off-scraped fluid volumes
Fluid Flow Off Mechanism

Wind tunnel model

30 kt
50 kt
80 kt

MD - 80 wing during T-O

NOTE: Speeds are not accurate!
Effect of Parameter Variations

- **Initial fluid mean thickness** (1 – 2 mm)
  Behaviour as reported for Type II fluids in earlier publications

- **Acceleration time** (19 – 33 s)
  Strong dependence – in contrast to some of earlier studies

  Mean acceleration time at actual take offs during winter period 2003-4 among Finnair A321 fleet (63 freight flights) recorded to be 28 s (min 19 s)

- **2-step de-icing treatment compared to 1-step treatment:**
  No measurable difference
“Taxiing Tests”:

- No published experimental studies before present one
- Results alarming considering the premature fluid flow off before takeoff

Mean fluid thickness variation with taxi time at speed of 14-15 m/s (28-30 kt)
Tests With Rotating Model

Test Arrangements:

- Acceleration to 60 m/s \rightarrow rotation @ 3°/s to 7.5° for about 40 s

- Configuration selected to correspond realistic pressure distribution on wing during take-off

- Anti-ice fluid was applied before the take-off configuration was adjusted to simulate the sequence of events in reality

- "Taxiing" tests conducted as with fixed model
Assessment of Rotating Model Results

- SAE AS 5900 test criteria is based on correlation between thickening of BLDT (=Boundary Layer Displacement Thickness) on flat plate and degradation of wing lift coefficient at lift off.

- Reasoning behind AS 5900 BLDT limit values:
  Clean wing margin of $V_2$ to stall speed (1g) is 13 % ($V_2 = 1.13V_s$)
  De/anti-iced wing margin may be reduced to 10 % ($V_2 = 1.1V_s$)
  This reduction means in terms of lift coefficient a 5.24 % reduction.

- Acceptance test considers conditions at the point of rotation
  \[ \text{“acceptable” limit for lift coefficient loss = 5.24 \% at the point when wing model reaches 7.5° angle in present study} \text{ (though it doesn’t correspond maximum } C_L \text{ as in the previous reasoning !)} \]
Tests with Rotating Model

Parameters:
- One-step treatment compared to two-step one
- Different types of fluids: 100% IV, 75% IV, 100% II
- Acceleration time
- Actual frost

Measurements:
- Force measurements to determine the lift loss compared to clean wing
- Video recording for qualitative analysis
Preliminary Results for Rotating Model

Comparison between 1- and 2-step treatment

Note: Time = 0 at the point when AoA reaches the max value of 7.5°

* $\Delta C_L$ considered as maximum in acceptance standard basis
Preliminary Results for Rotating Model

Effect of diluting the anti-ice fluid with water

Max $\Delta C_L = 5.24\%$

$\Delta C_L \,[\%]$ vs Time [s]
Preliminary Results for Rotating Model

Effect of temperature (OAT) on Type IV fluid

Max $\Delta C_L = 5.24\%$

$\Delta C_L[%]$ vs Time [s]
Preliminary Results for Rotating Model

Effect of coolant tank temperature on Type IV fluid (OAT = 0°C)
Comparison of Type II and IV fluids

Max $\Delta C_L = 5.24\%$
Effect of fluid initial thickness on Type II fluid
Effect of acceleration time

100 % Type IV Fluid

Max $\Delta C_L = 5.24\%$
Preliminary Results for Rotating Model

Frost and Type IV fluid (average frost thickness around 0.07 mm)

Frost thickness = 0.05 – 0.1 mm
$c = 0.65m \rightarrow k/c = 0.0001$
Future Plans

Possible future issues of interest

- Detrimental effects of thickened fluids on unpowered flight controls of low rotation speed aircrafts (ref. BAE ATP incidents)
- The effect of composite skin of future airliner wings on anti-ice fluid behaviour
- Further high speed taxi tests (with a real aircraft ?)
- Other ??

- Coordination with SAE, AEA and EASA
- END -
**Reasoning behind FPET-test**

- Flight test (B737) lift loss
- 3D wind tunnel test lift loss
- 2D wind tunnel test lift loss
- 2D wind tunnel wing model BLDT at trailing edge at $\alpha = 8^\circ$
- BLDT on a flat plate

\[ \delta^* = \int_0^\infty \left( 1 - \frac{u(y)}{u_0} \right) dy \]

**BLDT = Boundary Layer Displacement Thickness = $\delta^*$**
Correlation between lift loss and FPET BLDT
Flat Plate Elimination Test (FPET) arrangement

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