TraFi Liikenteen turvallisuusvirasto

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 →

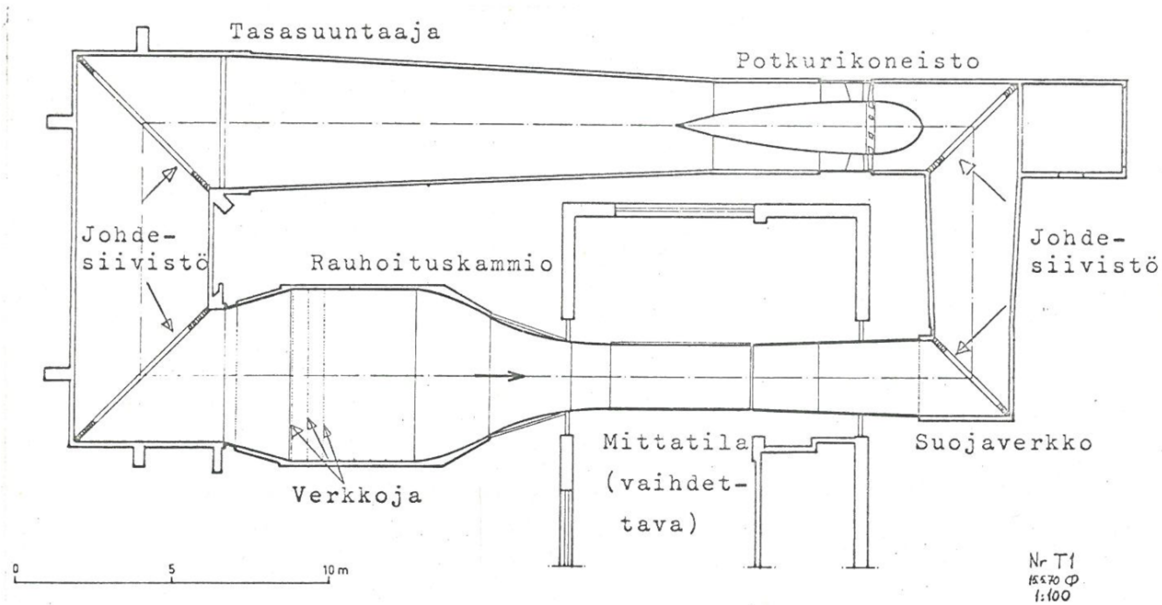
Objectives (cont'd)

- *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*

The Wind Tunnel

Aalto University Low Speed Wind Tunnel:

2m x 2m test section - max airspeed 60 m/s = 120 kt



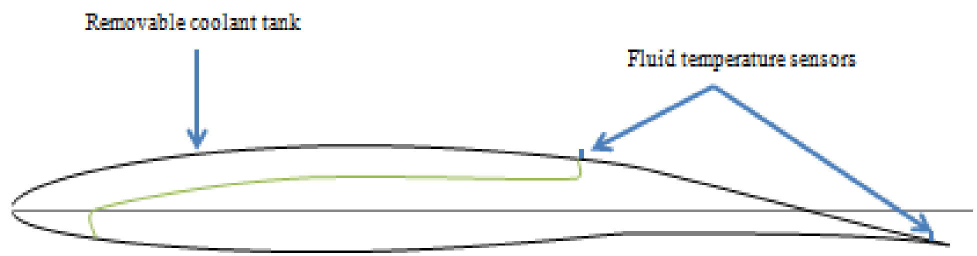
The Wind Tunnel Models

- *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*

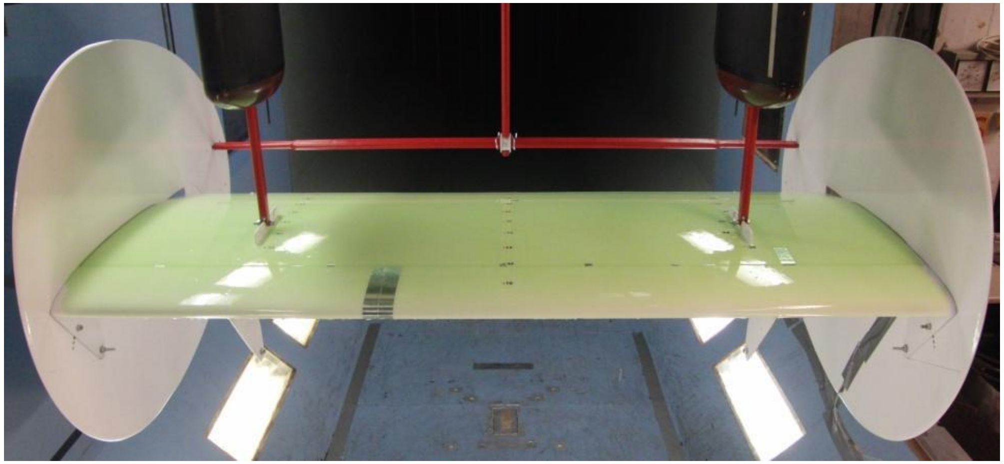
- *Rotation model: chord 0,65 m, three element DLR F15 - profile (representing a modern airliner wing), adjustable slats and flaps*
- *Force measurements, video recordings*

- *Both models have coolant tanks to simulate the cold fuel in wing tanks*

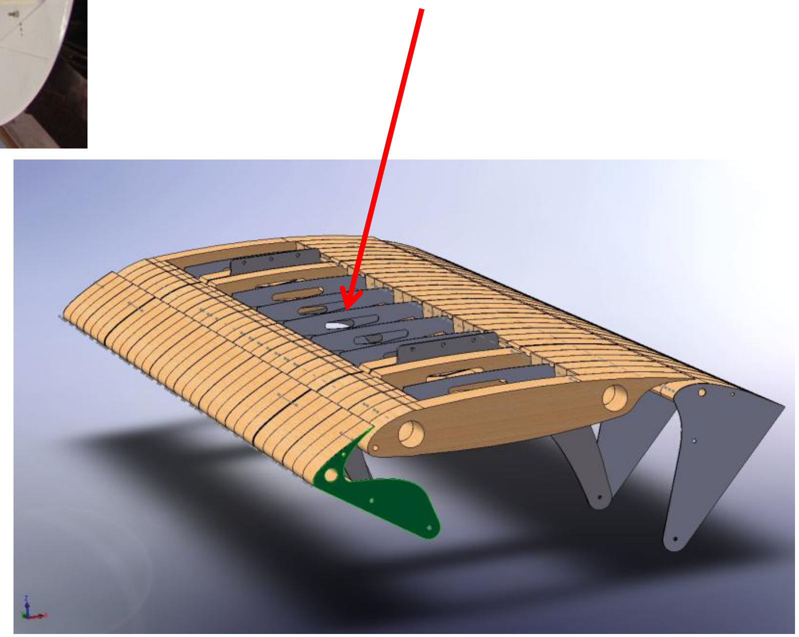
Fixed Wing Model



Rotating Wing Model



Coolant tank



Fluids Applied in the Tests

- *Fluid manufacturers reluctant*

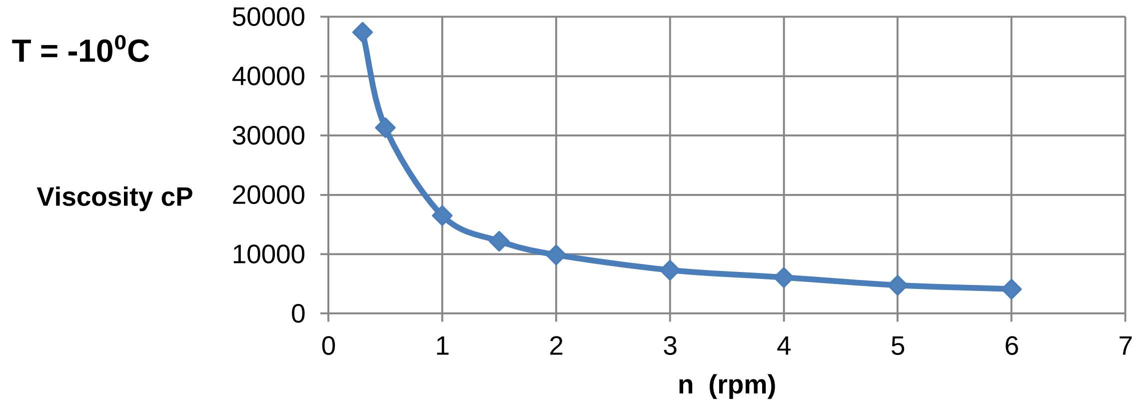
- *One manufacturer delivered four different fluid types (T IV, T II, TI and AS 5900 reference fluid)*

→ *Coverage of different manufacturers inadequate*

- *Rheological properties determined for Type IV.*
- *Type II still to be tested*

Rheological Properties of Type IV Fluid Applied

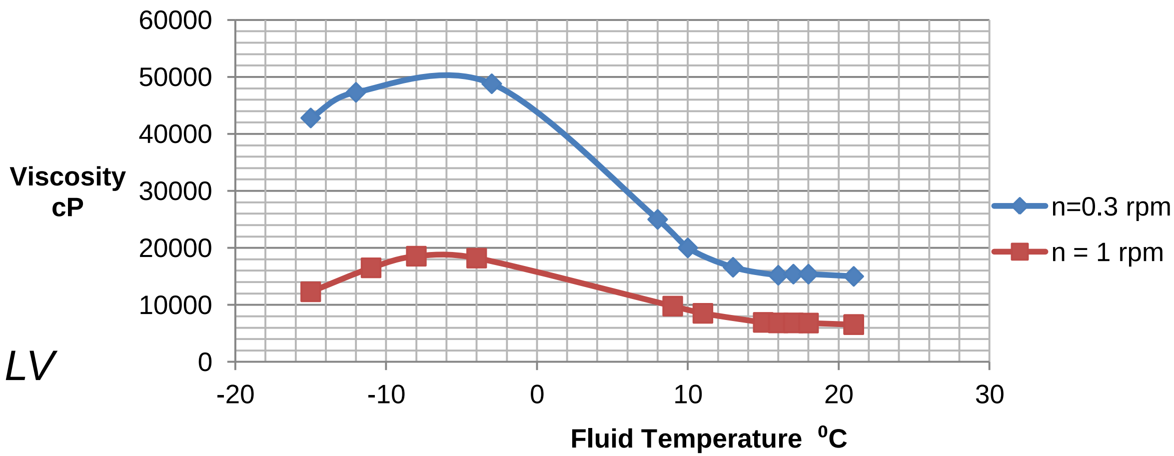
• *Typical non-Newtonian behavior (shear thinning) of Type IV fluid :*



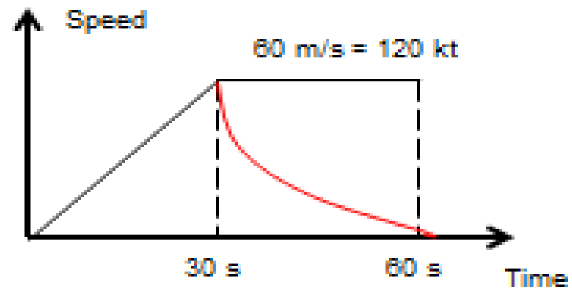
• *Viscosity variation with temperature – less typical:*

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

n = rotational speed Brookfield LV viscometer (spindle no LV2)



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

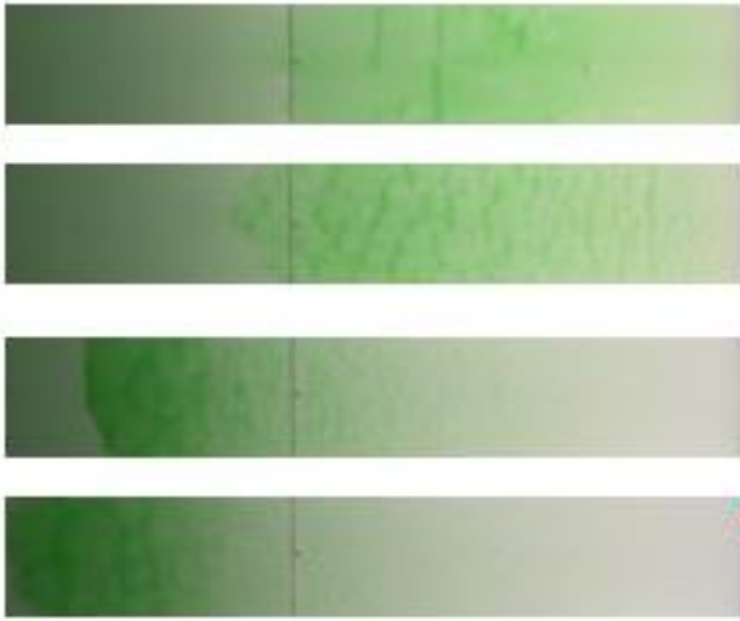
2. "Taxiing" tests: stepwise speed increments (5, 10, 15 m/s = 10, 20, 30 kt)

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

70 kt

NOTE: Speeds are not accurate !

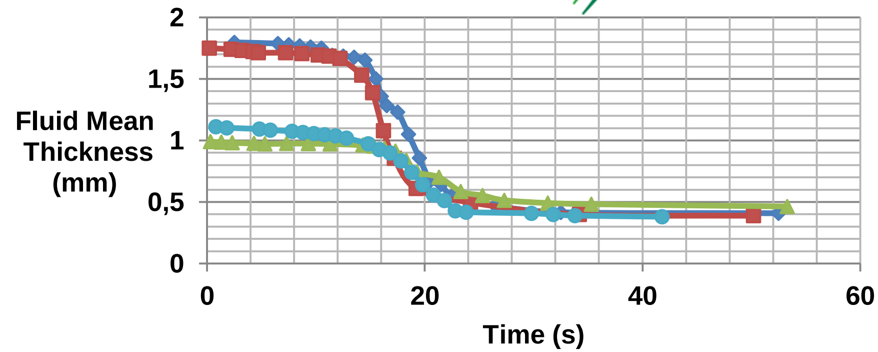
MD – 80 wing during T-O

50 kt

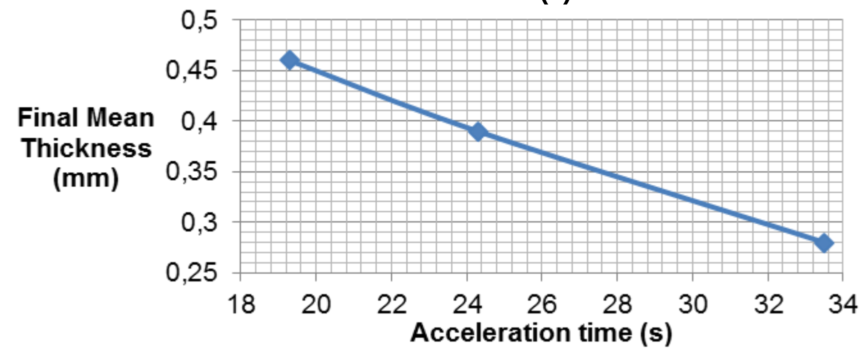
80 kt

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

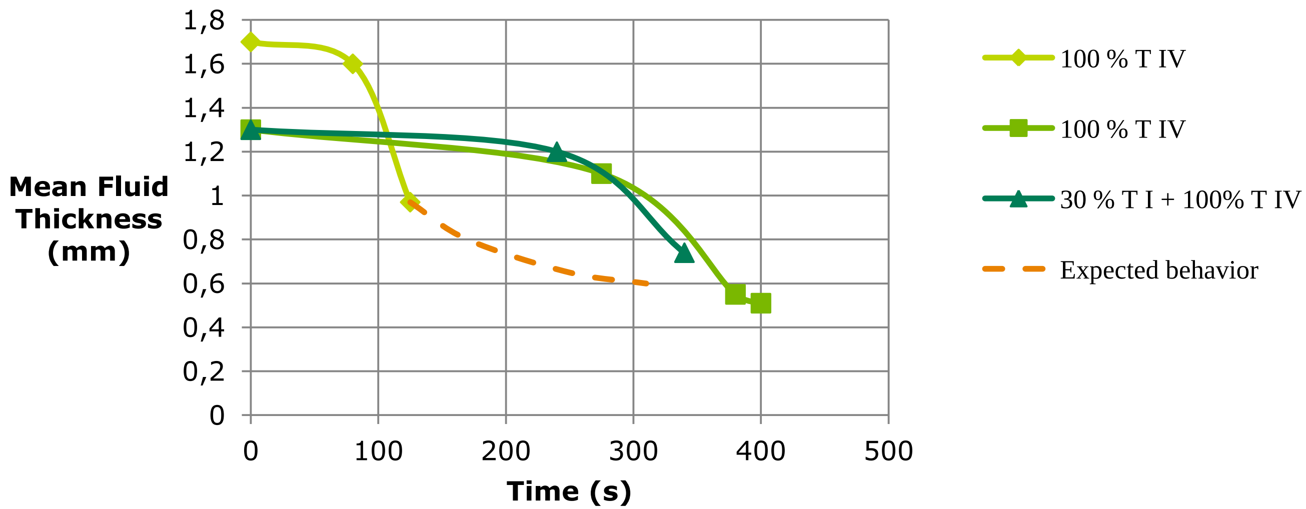


  Mean acceleration time at actual take offs during winter period 2003-4 among Finnair A321 fleet (63 freight flights) recorded to be 28 s (min 19 s)

- 2-step de-icing treatment compared to 1-step treatment:
  No measurable difference

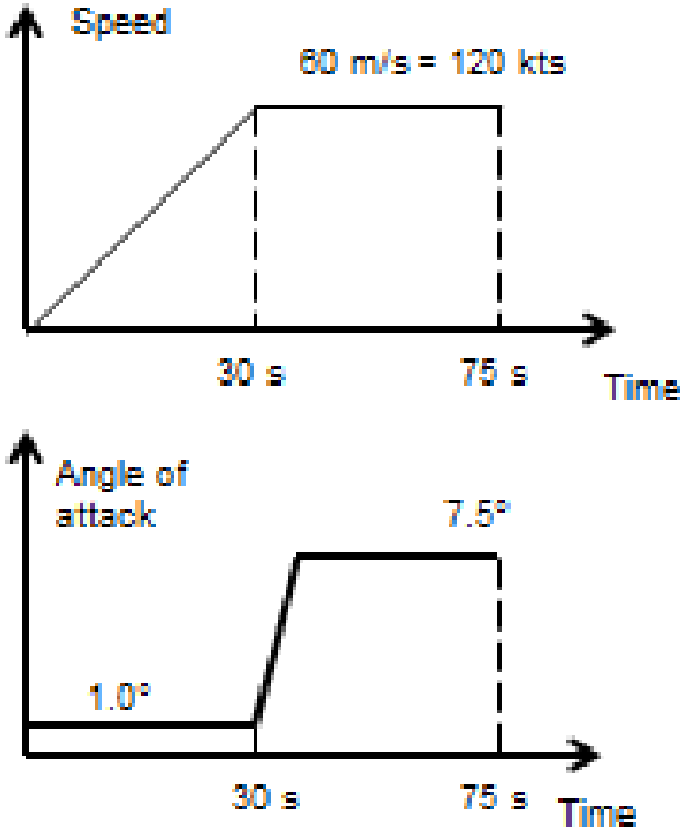
"Taxiing Tests":

- *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 → 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*

  → "acceptable" limit for lift coefficient loss = 5.24 % at the point when wing model reaches 7.5° angle in present study (though it doesn't correspond maximum C_L as in the previous reasoning !)

Tests with Rotating Model

Parameters:

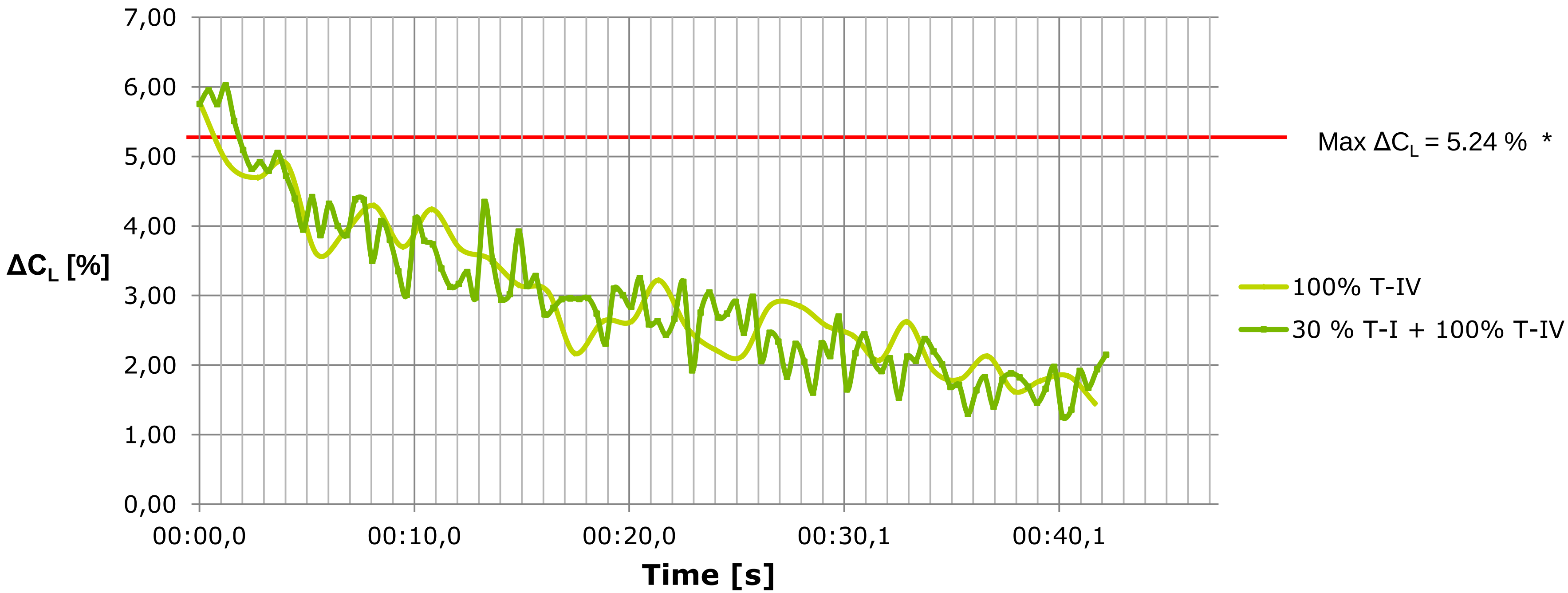
- *One - step treatment compared to two-step one*
- *Different types of fluids: 100% IV, 75% IV, 100% II*
- *Acceleration time*
- *Actual frost*

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

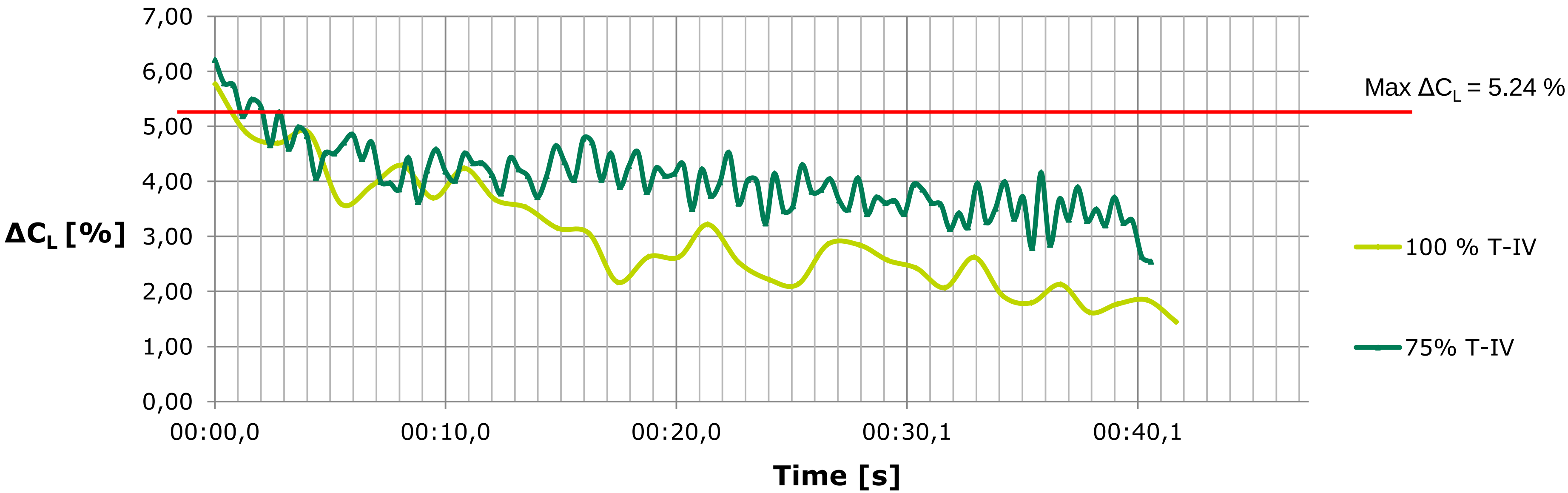


Note: Time = 0 at the point when AoA reaches the max value of 7.5°

* Δ C_L considered as maximum in acceptance standard basis

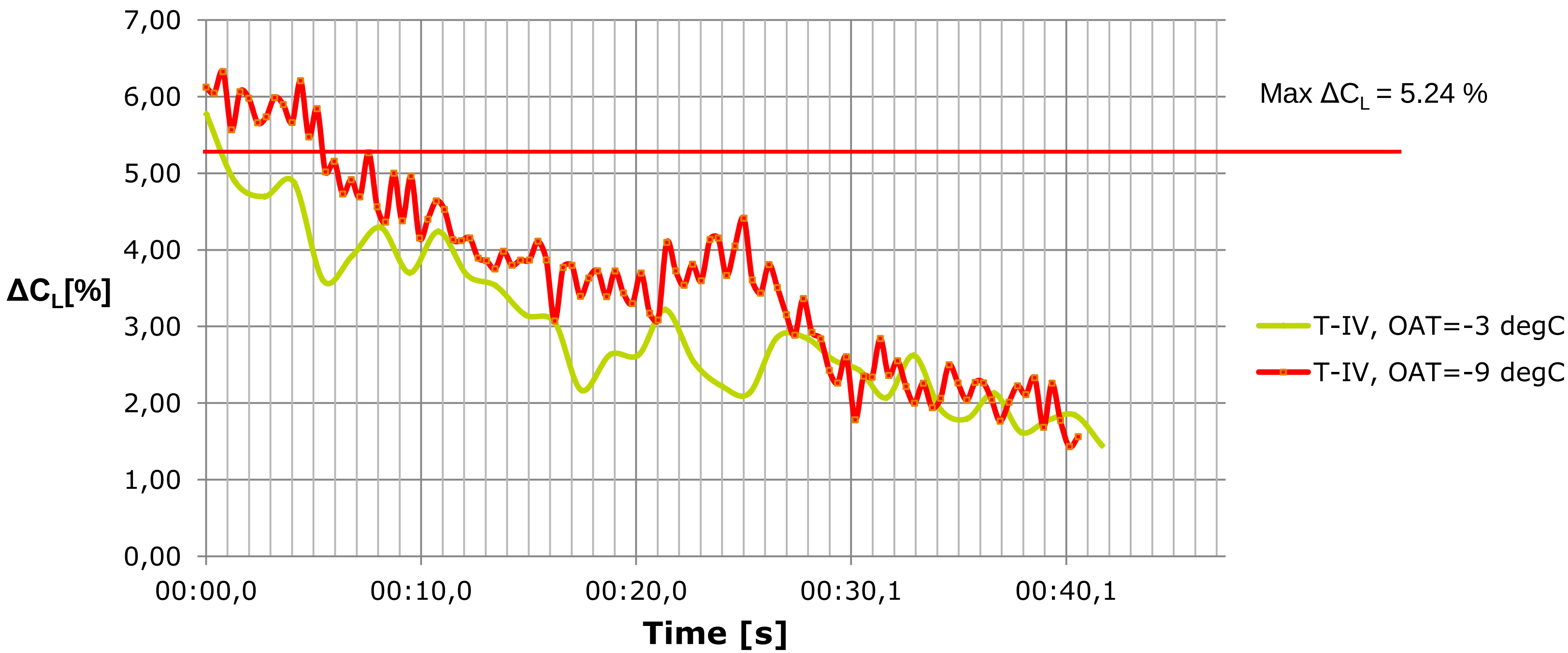
Preliminary Results for Rotating Model

Effect of diluting the anti-ice fluid with water



Preliminary Results for Rotating Model

Effect of temperature (OAT) on Type IV fluid



Preliminary Results for Rotating Model

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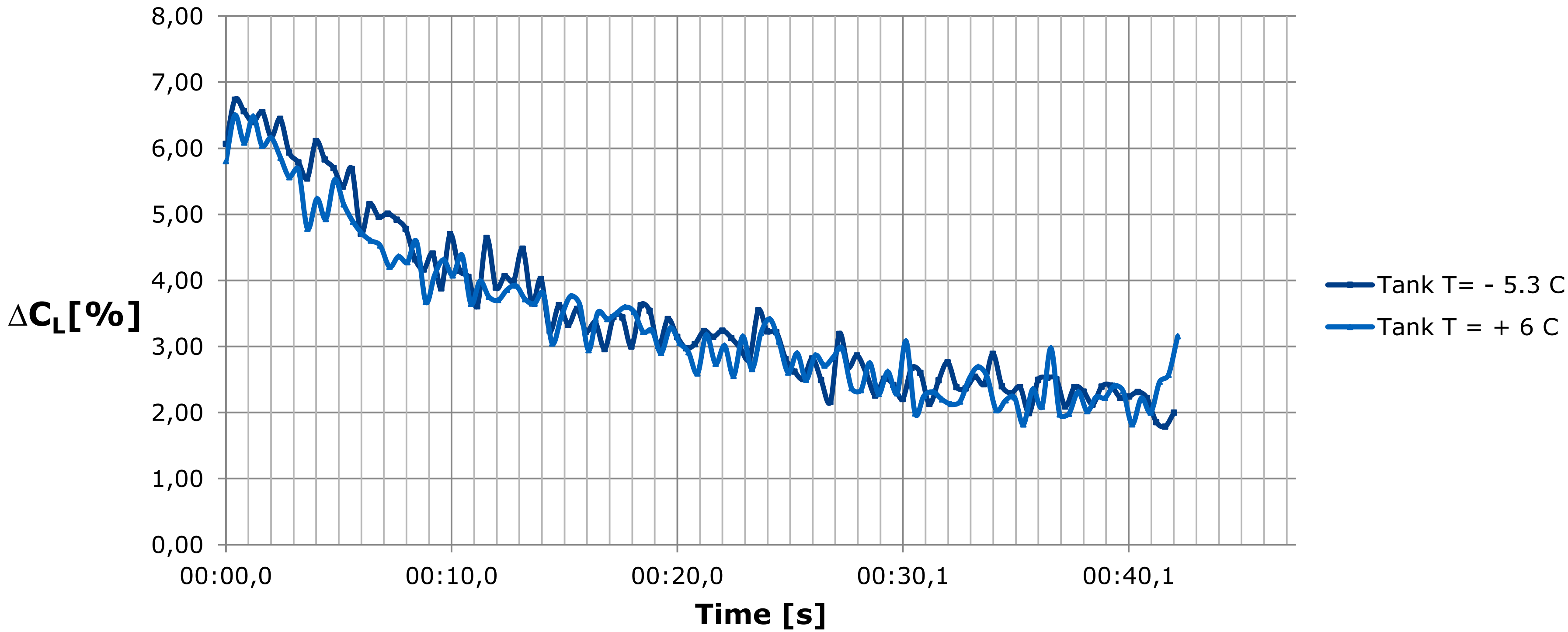
Effect of coolant tank temperature on Type IV fluid (OAT = 0°C)



Preliminary *Results for Rotating Model*

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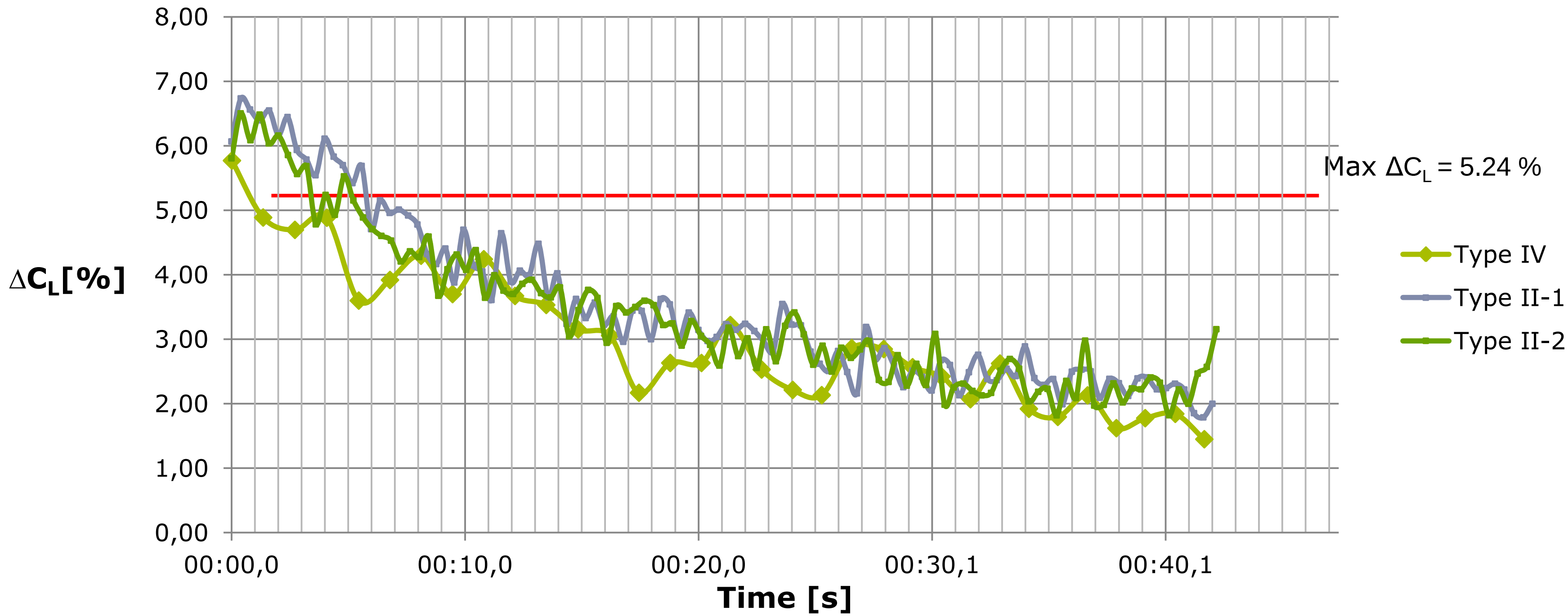
Comparison of Type II and IV fluids



<u>Preliminary</u> Results for Rotating Model

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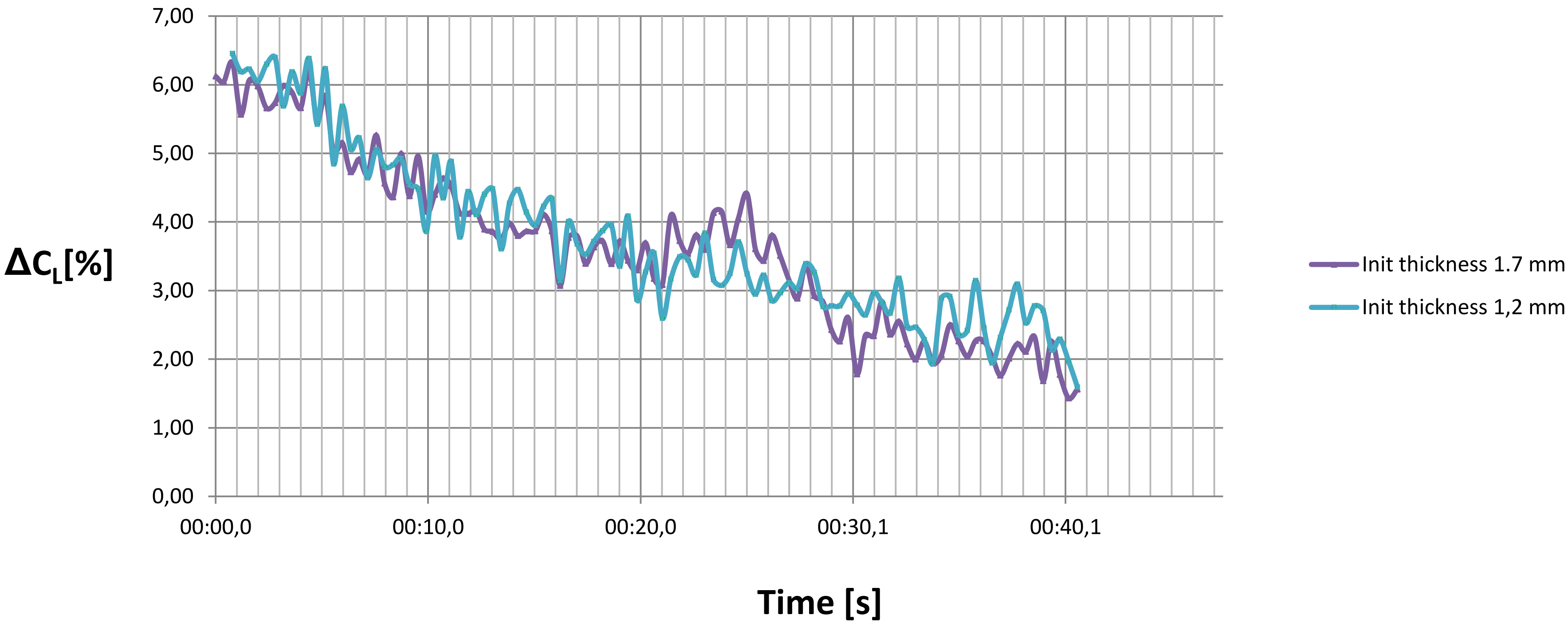
<u>*Effect of fluid initial thickness on Type II fluid*</u>



Preliminary Results for Rotating Model

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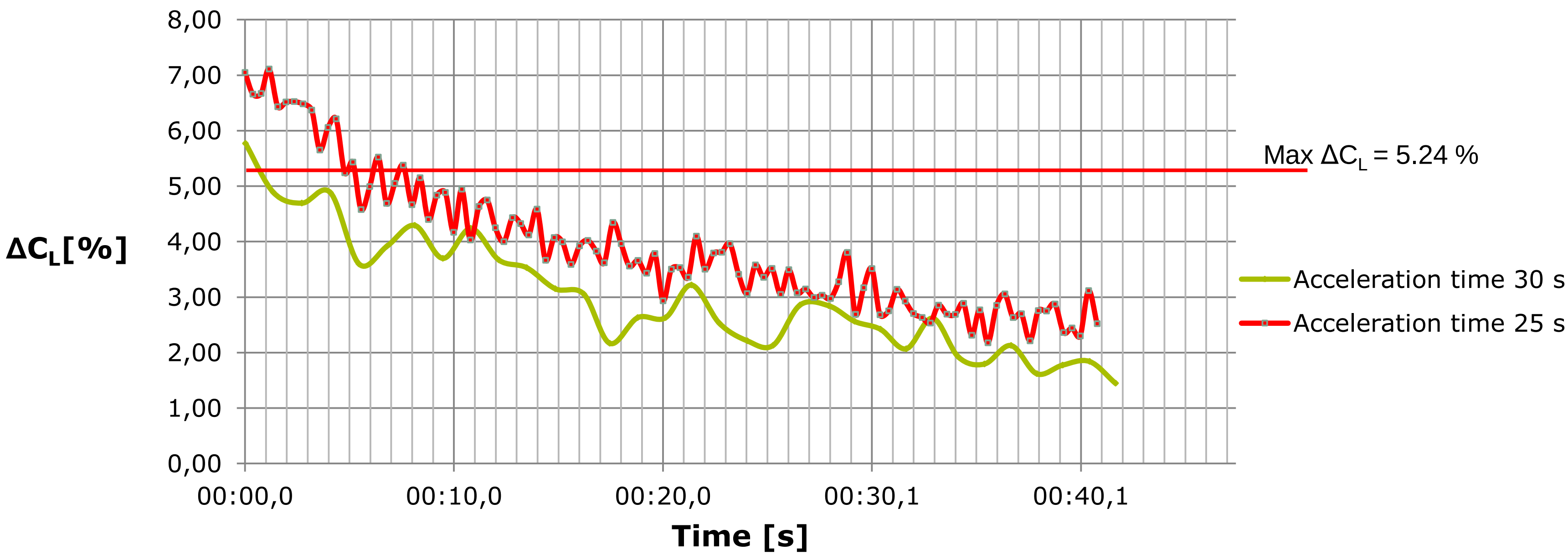
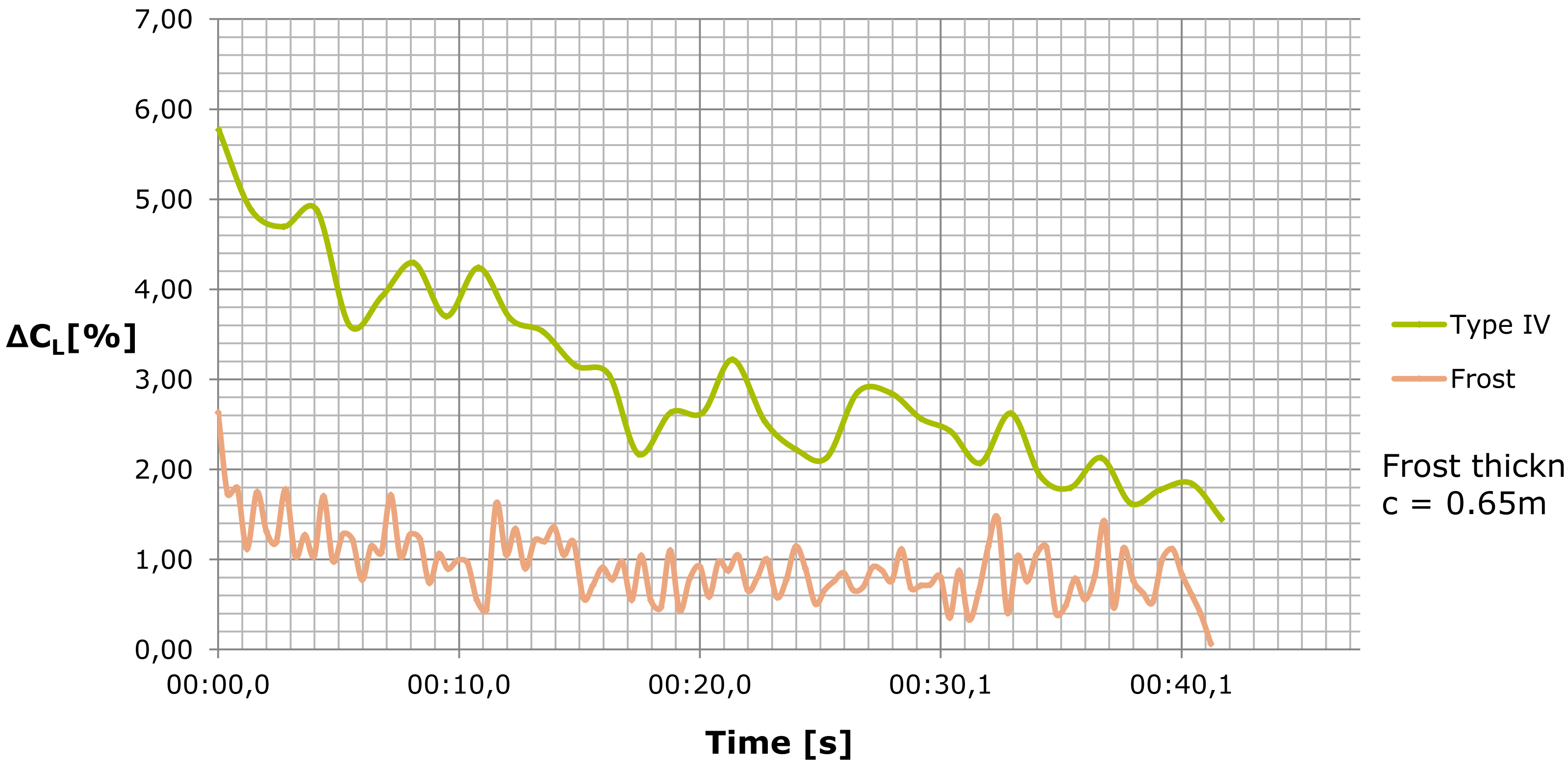
Effect of acceleration time

100 % Type IV Fluid



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 → 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 -

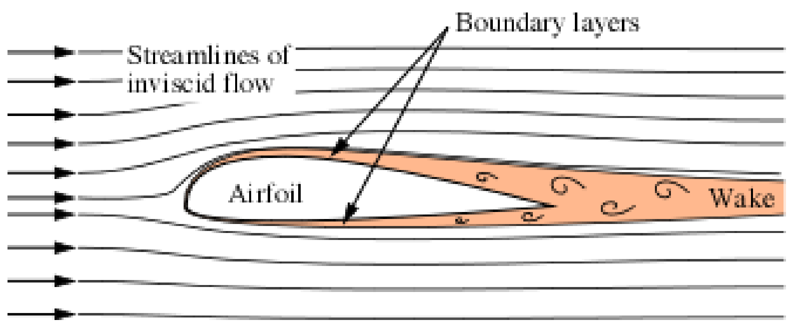
Reasoning behind FPET-test

Correlation chain

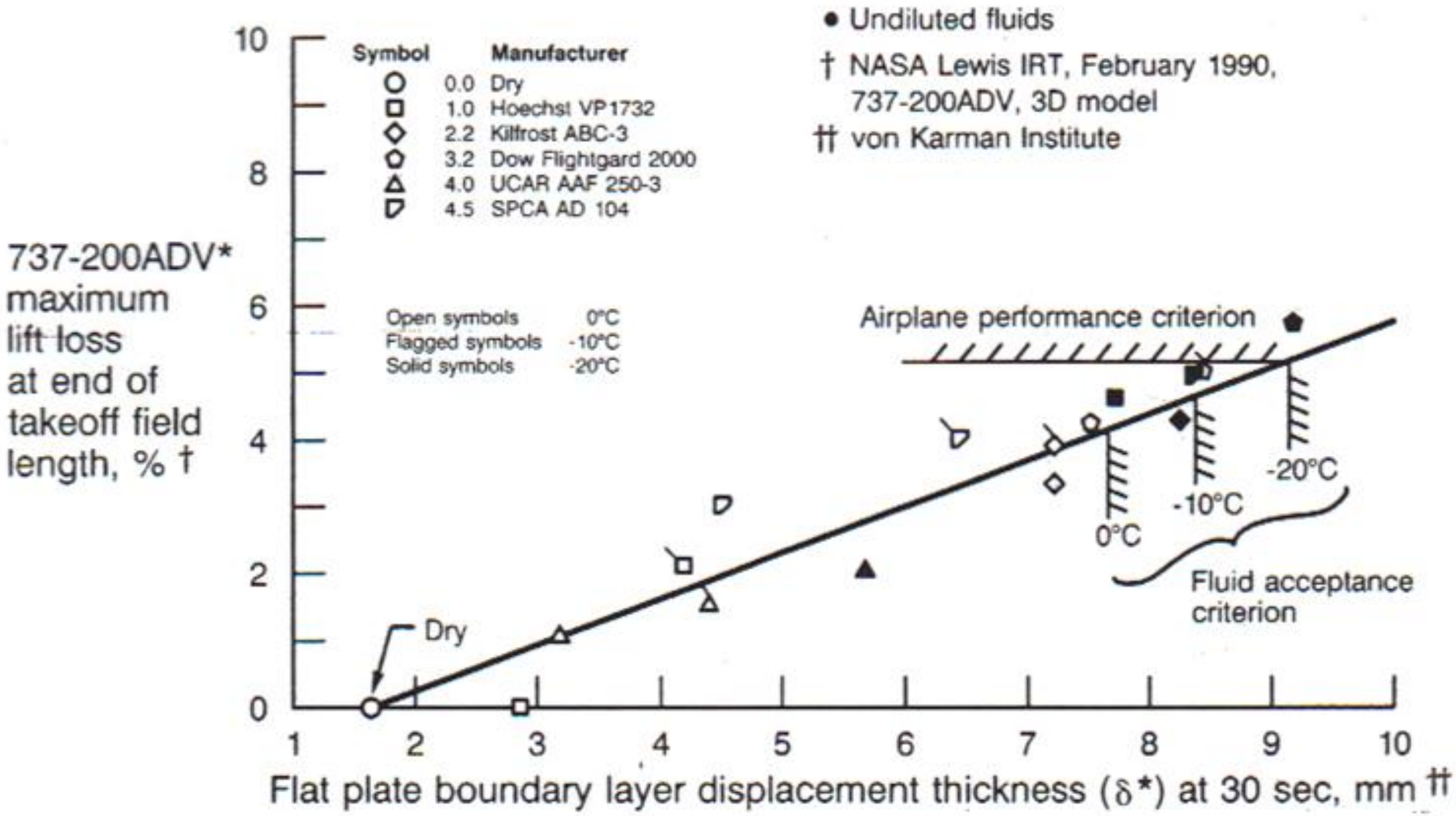
- *Flight test (B737) lift loss*
- *3 D wind tunnel test lift loss*
- *2D wind tunnel test lift loss*
- *2D wind tunnel wing model BLDT at trailing edge at α = 8°*
- *BLDT on a flat plate*

*BLDT = Boundary Layer Displacement Thickness = δ**

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



Correlation between lift loss and FPET BLDT



Flat Plate Elimination Test (FPET) arrangement

(back to main text)