Nonlinear Aircraft Model

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Overview

- Objective: Non-linear model for all icing conditions, clean, all-ice, wing-ice and tail-ice
- Motivation: Simulator

  Envelope Protection

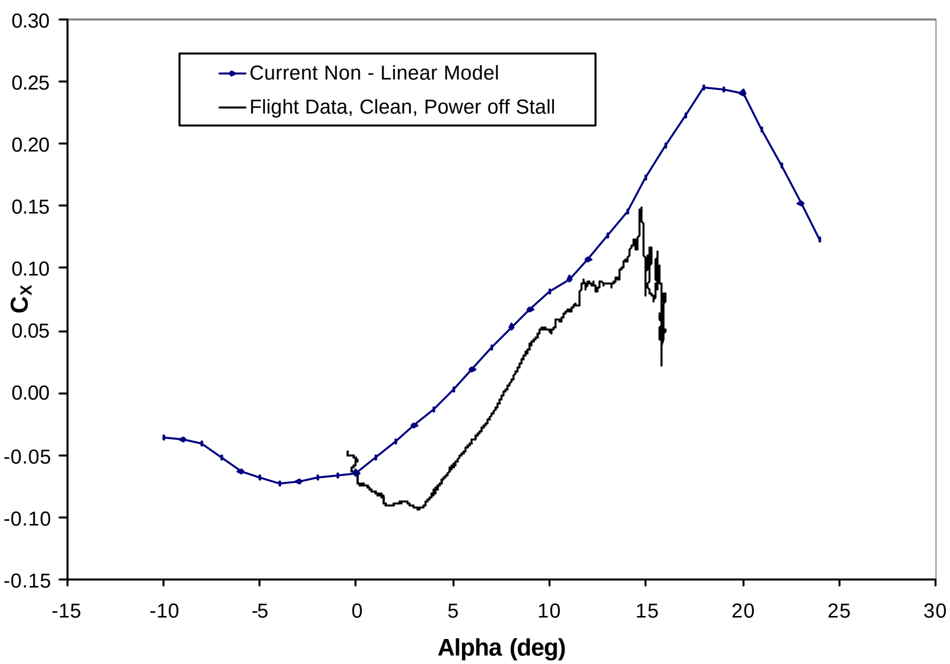
  FDC

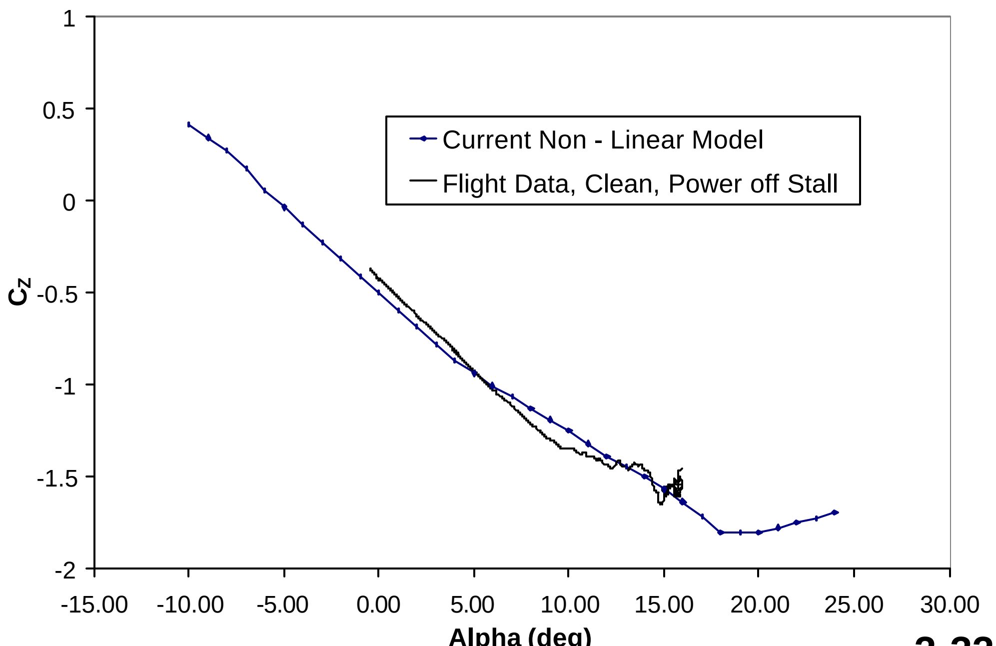
  Autopilot

  Characterization
- Approach: C_L, C_D, $C_M = f(\alpha, \delta_e, \eta)$

The Model

- Model based on B.A.R. rotary balance test results on the Twin Otter model
- Tests included the clean and a tail iced case of an estimated η_{ice} of 0.08
- Some values manually adjusted to provided a more realistic performance degradation based on Twin Otter flight data, $\Delta C_{L\alpha}$, $\Delta C_{M\alpha}$ etc





Model Formulation

- Extrapolate/Interpolate
- Review of icing severity model

$$C_{A,iced} = \left(1 + K_{CA} h\right) C_{A,clean}$$

Linear Model

- C_A : Stability and control derivative of interest
- η : Icing severity factor
- K_{CA}: Scaling factor for a particular S&C derivative

- For the iced nonlinear model the same basic idea was adopted
- However, changes in the forces and moments were modeled as functions of icing

Nonlinear Model

- C_A : Force or moment coefficient of interest
- η : Icing severity factor
- K_{CA}: Scaling factor for a particular force or moment coefficient

Model Formulation (cont'd)

ΔC_A values from B.A.R. data curve fit as a function of angle of attack and elevator deflection

$$K_{CA} C_{A,clean} = -\frac{\Delta C_A}{h_{ref}}$$

Where η_{ref} is the η value for the B.A.R. data

The non-linear model provides $K_{CA}C_{A,clean}$ as a function of α and δe for lift, drag, pitching moment

Lift Formulation

Loss in lift due to icing was modeled as a function of the icing severity of the wing

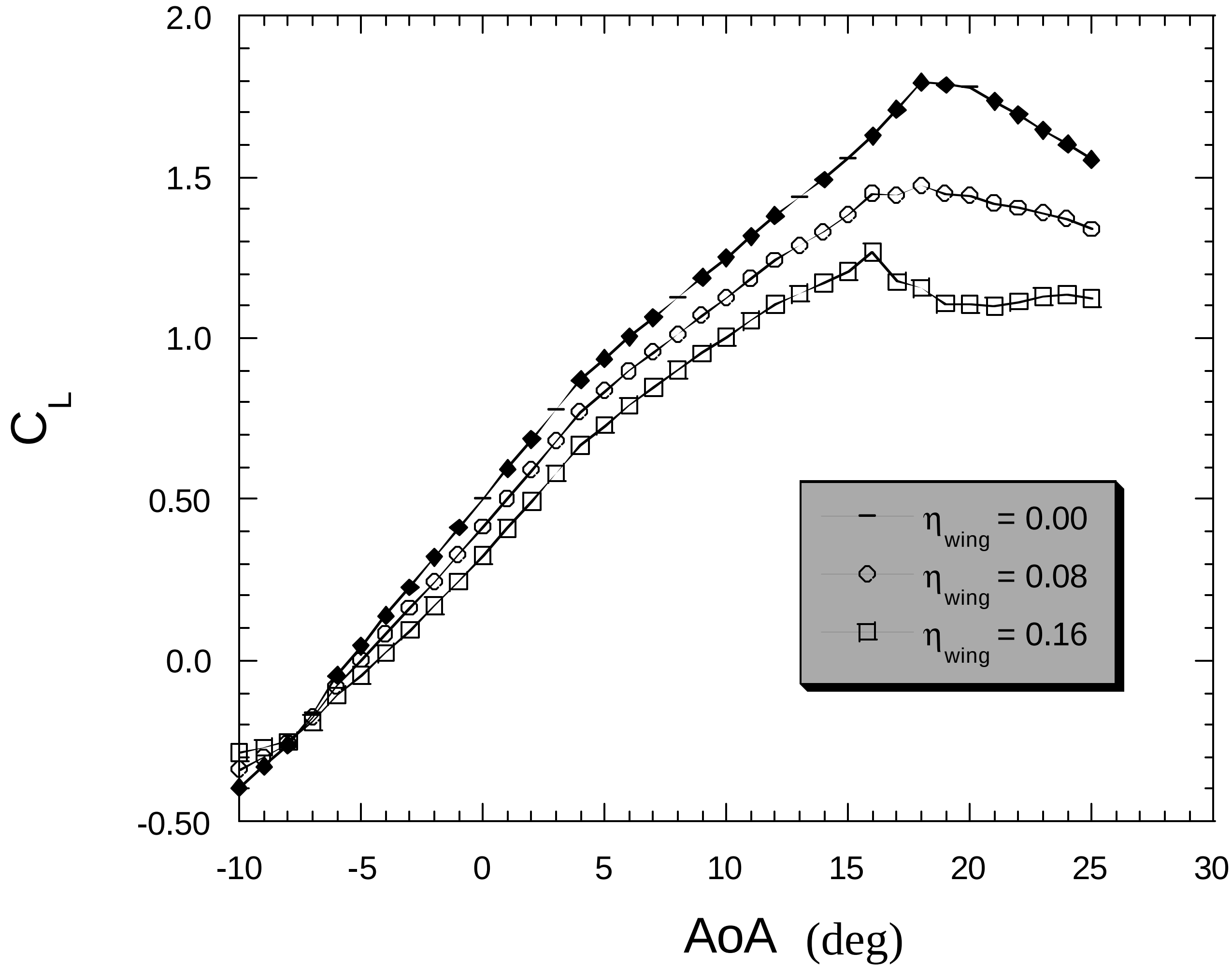
The effect of tail-plane ice on lift was neglected

$$C_{L,iced} = C_{L,clean} + \Delta C_L$$

$$C_{L,iced} = C_{L,clean} + K_{C_L} \eta_{wing} * C_{L,clean}$$

Lift Model

Smart Icing Systems Review, September 30, 2002



Drag Formulation

The drag rise was also modeled as a function of the icing condition of the wing

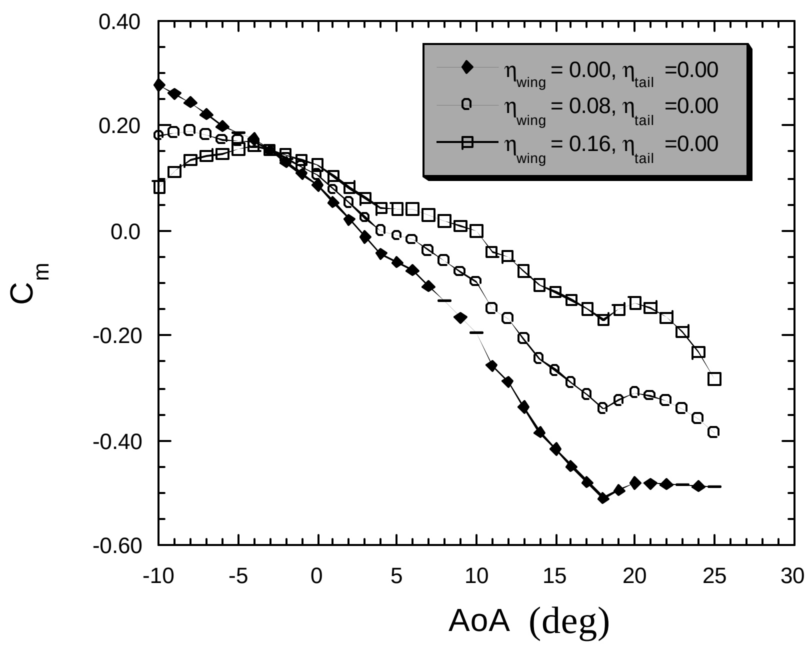
$$C_{D,iced} = C_{D,clean} + \Delta C_D$$

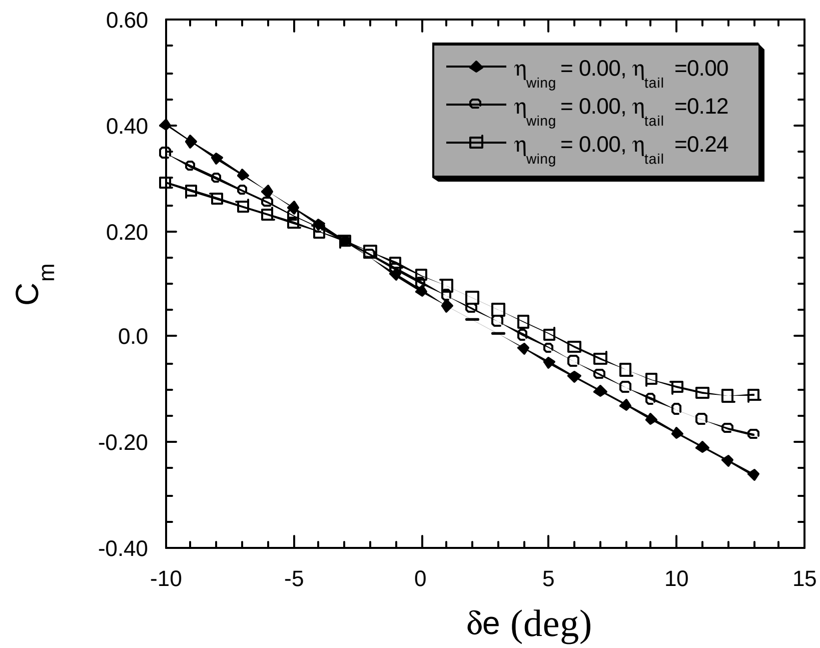
$$C_{D,iced} = C_{D,clean} + K_{C_D} \eta_{wing} * C_{D,clean}$$

Pitching Moment Model

The pitching moment was modeled as a function of both the wing and tail ice

$$C_{m,iced} = C_{m,clean} + K_{Cm,a} h_{wing} * C_{m,clean} + K_{Cm,\partial e} h_{tail} * C_{m,clean}$$





Work in Progress

- ΔC_l (rolling moment) due to differential in the lift generated by left and right wing
- Use different η values on left and right wing to simulate asymmetric icing
- Calculate rolling moment due to different ΔC_L values on each wing