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A Development of Dynamic Wind Tunnel Testing Technique with a Magnetic Suspension and Balance System

-Measurements of Dynamic Stability Derivatives of a Non-axisymmetric Model-

Ryo Oshima, Manabu Yokoyama, Kei Komatsubara
(Institute of Fluid Science, Tohoku University)

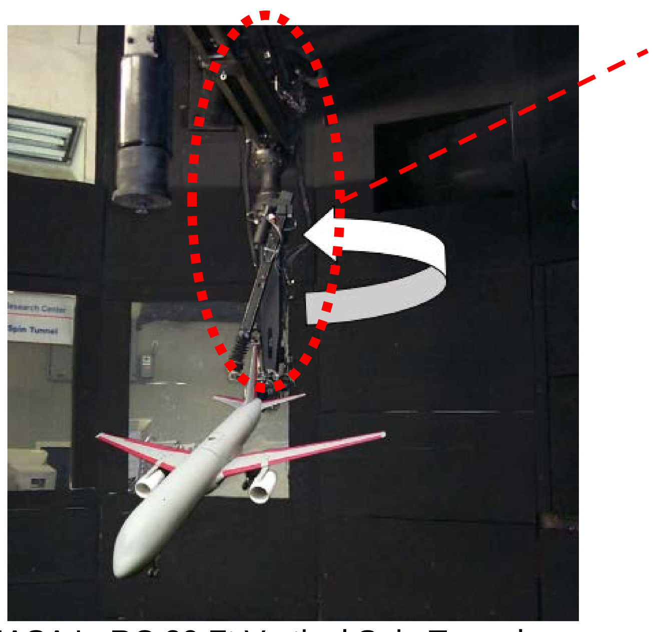
Background

- A development of high performance aircraft
  - Unsteady aerodynamic force
  - Dynamic stability derivatives

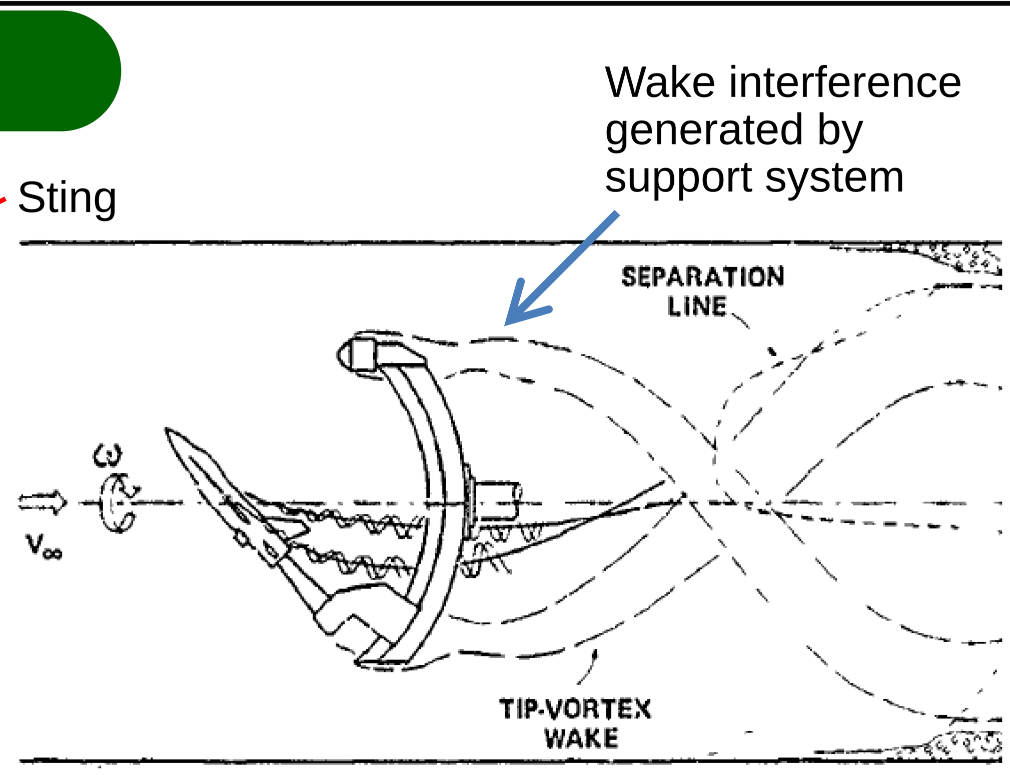
→ **Dynamic wind tunnel testing**

- Technical issue of dynamic wind tunnel testing
  - ✓ Support interference by moving the mechanical support system

→ Dynamic wind tunnel testing condition without support interference is required



NASA LaRC 20 Ft Vertical Spin Tunnel



Support interference in rotary test M. E. Beyers et al., 1992

Magnetic Suspension and Balance System

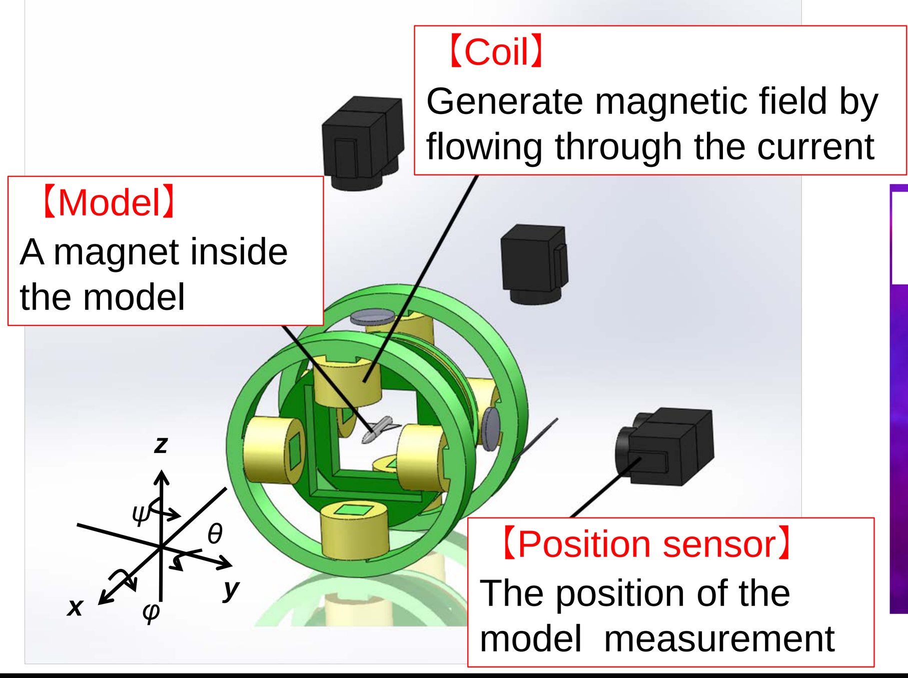
0.1m – MSBS at IFS

- No support interference
- Balance system to evaluate aerodynamic forces by measuring coil currents
- No motion limits by the mechanical support
- High speed control system (0.1m-MSBS)

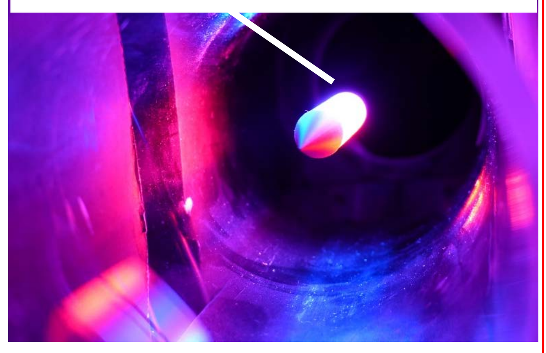
Equation of motion

$$\frac{d(m\boldsymbol{v})}{dt} = \boldsymbol{F}_{mag} + \boldsymbol{F}_{aero} + m\boldsymbol{g}$$

$$\frac{d(I\boldsymbol{\omega})}{dt} = \boldsymbol{N}_{mag} + \boldsymbol{N}_{aero}$$



Axisymmetric model



Unachieved technique

- ✓ **Support a non-axisymmetric model**
- ✓ **Accurate analysis method for dynamic test**

Objective

A development of dynamic wind tunnel testing technique for winged model with MSBS

Minimum Success

- Develop rolling moment control system in order to support non-axisymmetric model

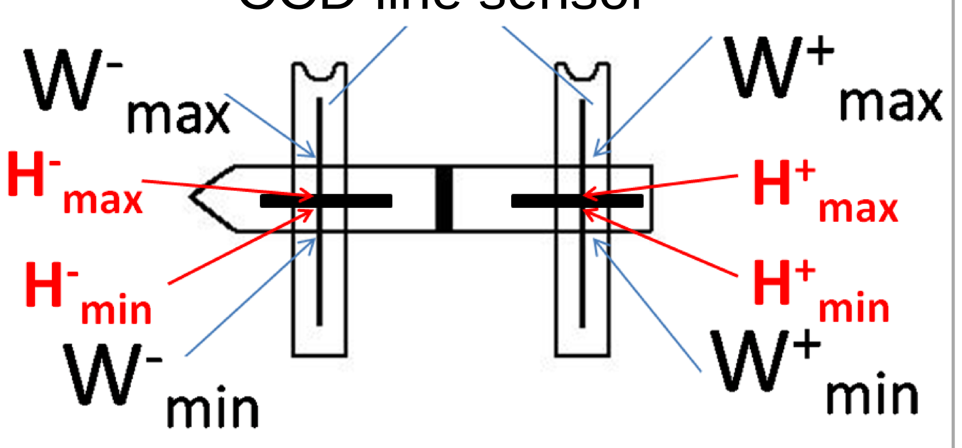
Full Success

- Dynamic stability derivatives measurement for winged model
- Comparison between the test results and DATCOM

Development of Rolling Moment Control System

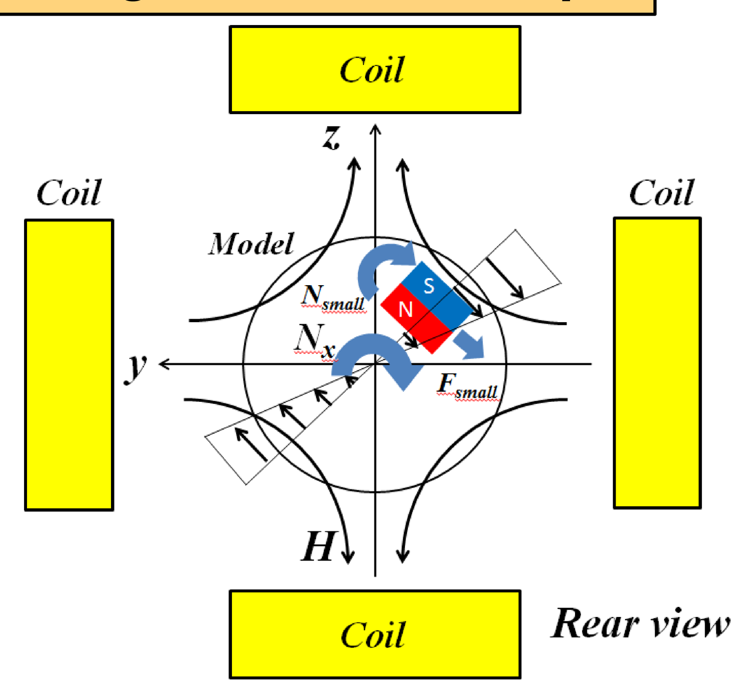
- Improvement of sensing system
- Measurement and adjustment of magnetic field for roll control

Improvement of Sensing System



$$\varphi = \{(W^+_{max} + W^+_{min} + W^-_{max} + W^-_{min}) - (H^+_{max} + H^+_{min} + H^-_{max} + H^-_{min})\}/4r$$

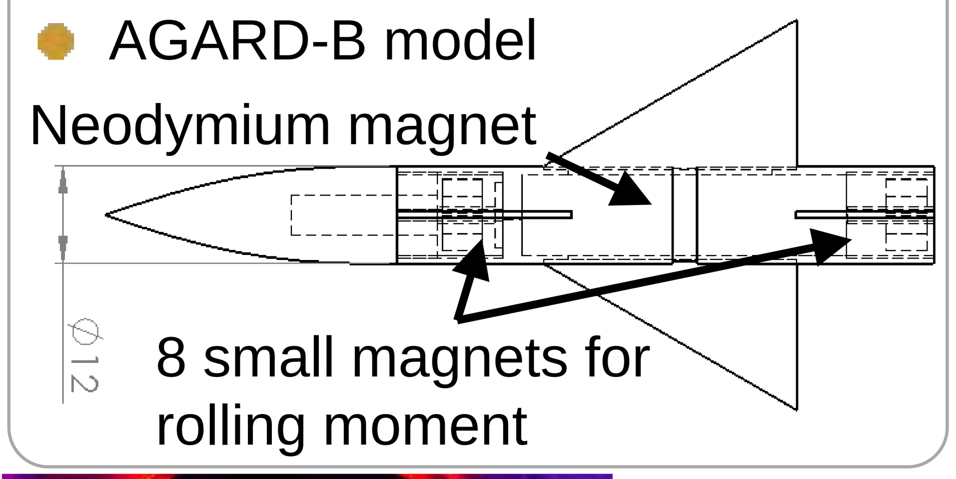
Rolling Moment Principle



- Additional small magnets are introduced
- Translational and rotative forces are acting on small magnets

Non-axisymmetric Model

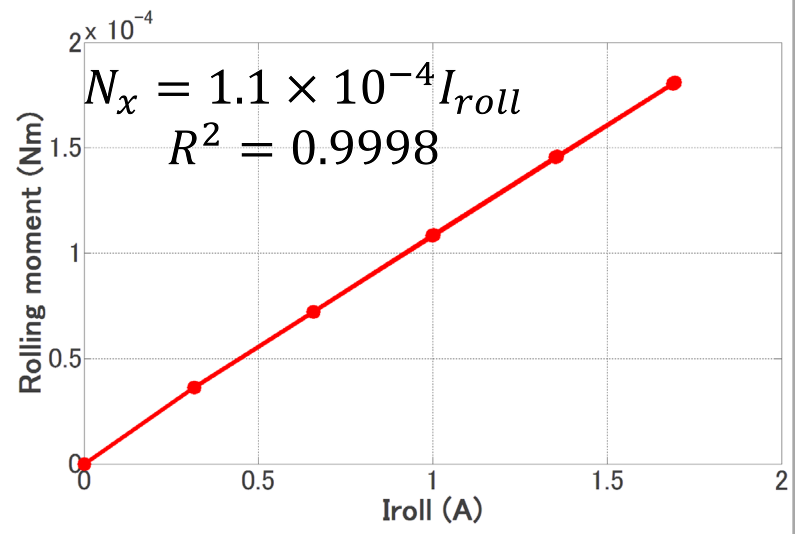
- AGARD-B model



Winged model

Winged model can be suspended !!

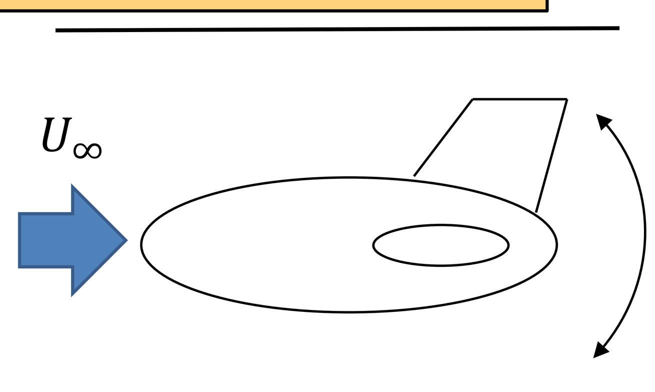
Rolling Moment Evaluation



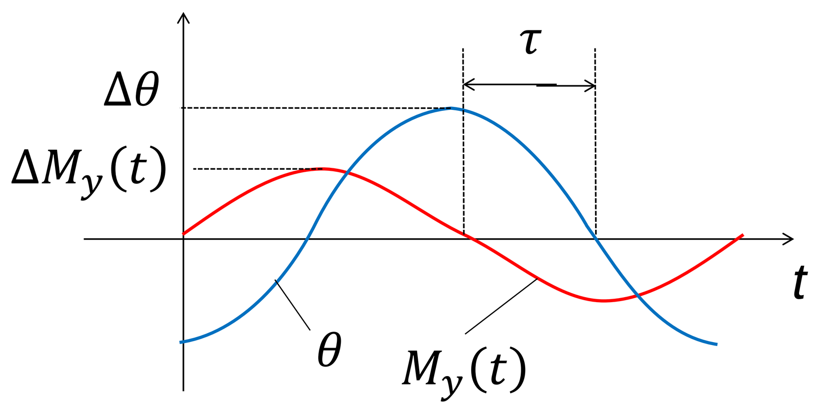
- Rolling moment is proportional to coil current
- Possible to evaluate rolling moment acting on the model

Dynamic Stability Derivatives Measurement

Forced Oscillation



Pitching oscillation



- **Measurements of amplitude and phase difference**

Dynamic Stability Derivatives Evaluation

Inertia moment / Damping derivatives / Restitutive derivatives

$$J_Y\ddot{\theta} + (C_Y^{flow} + C_Y^{calm})\dot{\theta} + (K_Y^{flow} + K_Y^{calm})\theta = M_Y^{flow} \quad \text{(Wind-on)}$$

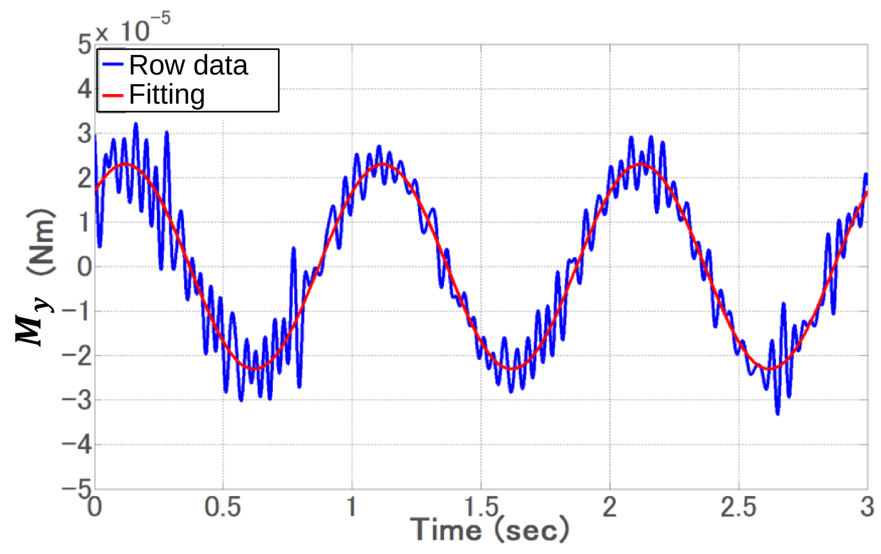
(Apparent value: C_Y^{calm}, K_Y^{calm})

$$J_Y\ddot{\theta} + C_Y^{calm}\dot{\theta} + K_Y^{calm}\theta = M_Y^{calm} \quad \text{(Wind-off)}$$

Subtract wind-off from wind-on →

$$C_{m_q} + C_{m_{\dot{\alpha}}} = -\frac{2U_\infty}{Q_\infty S c^2} C_Y^{flow}$$

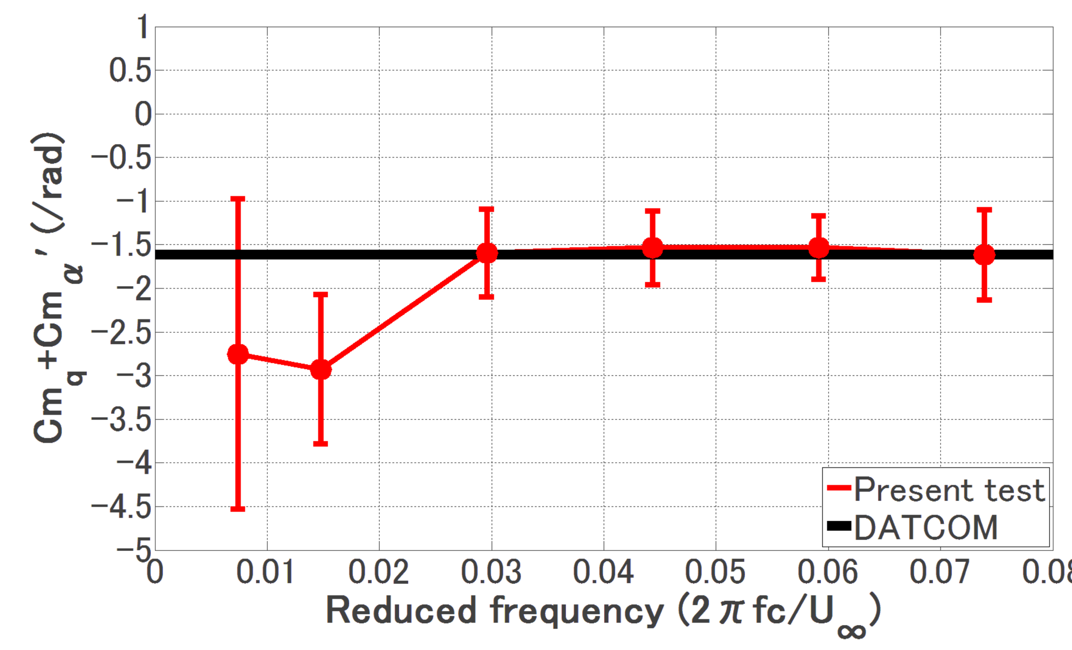
Analysis Method



- Conduct fitting process by the method of least squares

$$y = A\sin(2\pi f t + \tau)$$

Experimental Results



- The experimental results are agree with DATCOM
- Low accuracy at low frequency ranges

★Dynamic stability derivatives can be evaluated without support interference by using MSBS
★The other stability derivatives measurement will be conducted and validated