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

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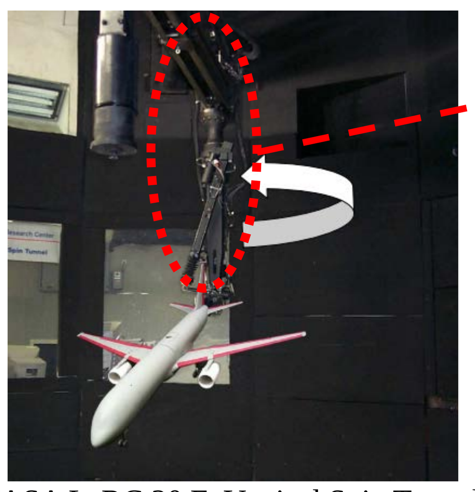
## Background

- Evaluation of dynamic aerodynamic force is required for aircraft which have high performance ⇒ Dynamic wind tunnel testing

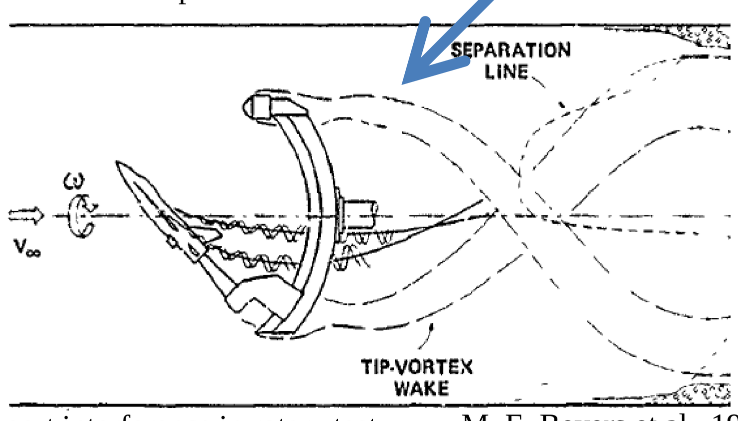
✓ CFD・・・
High accurate experimental results are required for validation

✓ EFD・・・
To measure under the dynamic flight condition is difficult because of support interference




NASA LaRC 20 Ft Vertical Spin Tunnel

Wake interference generated by support system




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

➢ Dynamic wind tunnel testing condition without support interference is required

## Objective

**A development of dynamic wind tunnel testing technique with MSBS**

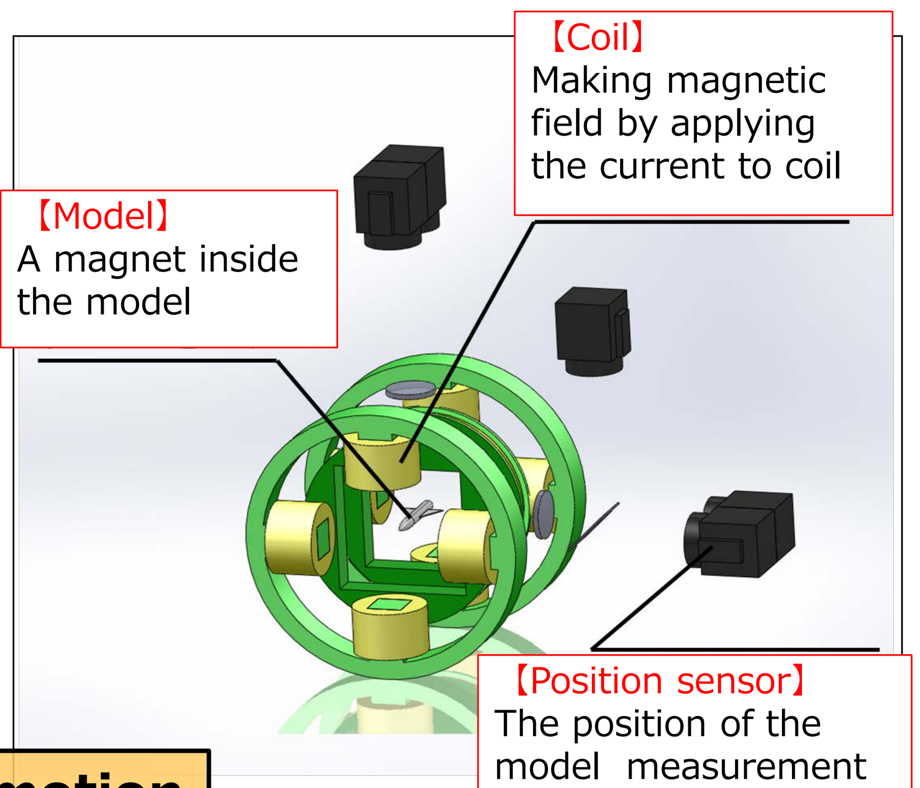
| Accuracy evaluations of forced oscillation and dynamic balance system | Conduct dynamic wind tunnel testing to evaluate the dynamic aerodynamic force and dynamic stability derivatives with winged model |
|---|---|
| Conducted | Future work |

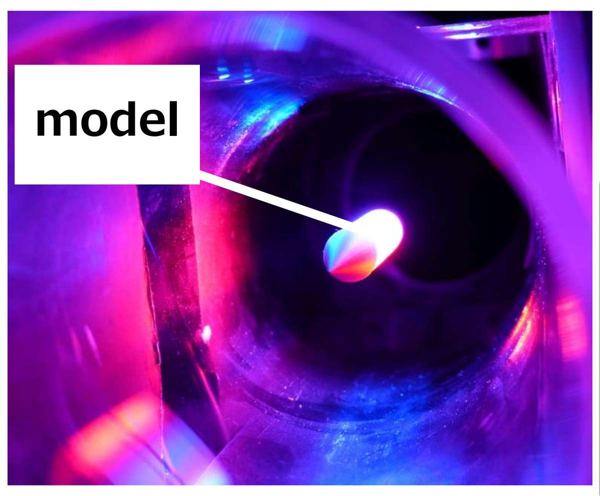
## Magnetic Suspension and Balance System

Support a model magnetically by the interaction between a magnet inside the model and magnetic fields generated by coils

### Characteristic

- No support interference
- Balance system to evaluate aerodynamic force by measuring coil current
- No motion limits by mechanical support




### Equation of motion

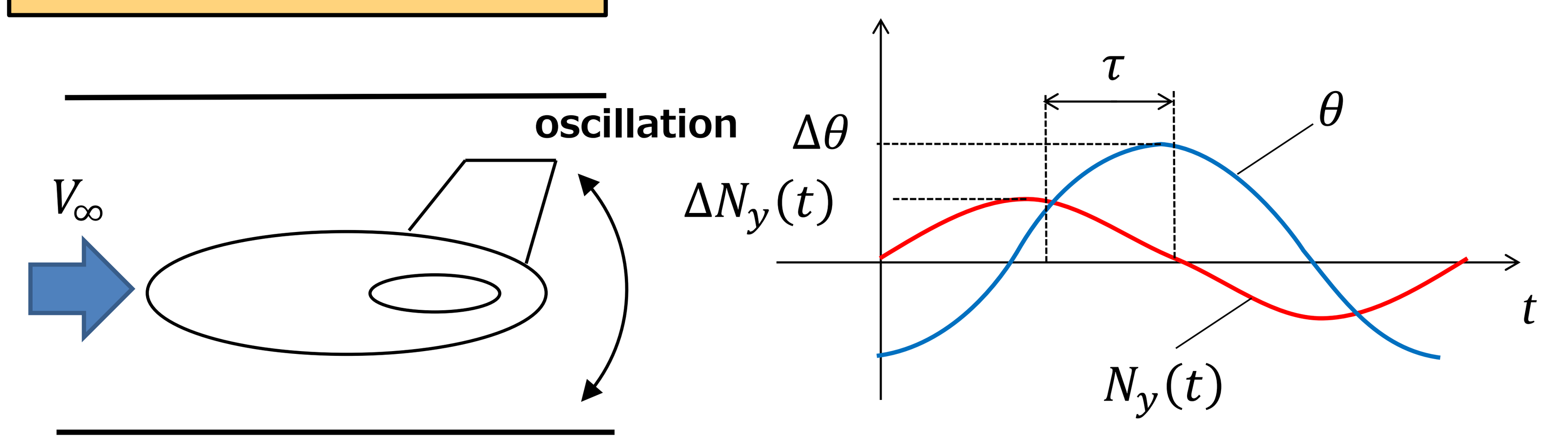
$$\frac{d(m\boldsymbol{v})}{dt} = \boldsymbol{F}_{mag} + \boldsymbol{F}_{aero} + m\boldsymbol{g}$$

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

◆ Feedback control system
✓ PI control
✓ Double phase advancer

## Evaluation technique for dynamic aerodynamic force

### Forced oscillation




**Pitching motion**: Angle of attack changes with pitch angle

- Measurements of amplitude and phase difference are required

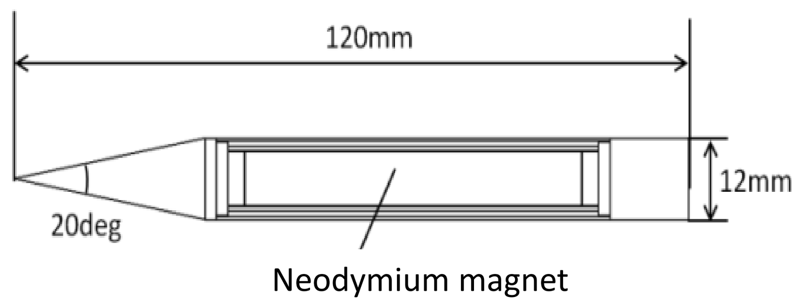
### Evaluation for aerodynamic force

$$\begin{cases} \dfrac{d(I\boldsymbol{\omega})}{dt} = \boldsymbol{N}_{mag} & \text{(Wind-off)} \\ \dfrac{d(I\boldsymbol{\omega})}{dt} = \boldsymbol{N'}_{mag} + \boldsymbol{N}_{aero} & \text{(Wind-on)} \end{cases} \Rightarrow \boldsymbol{N}_{aero} = \boldsymbol{N}_{mag} - \boldsymbol{N'}_{mag}$$

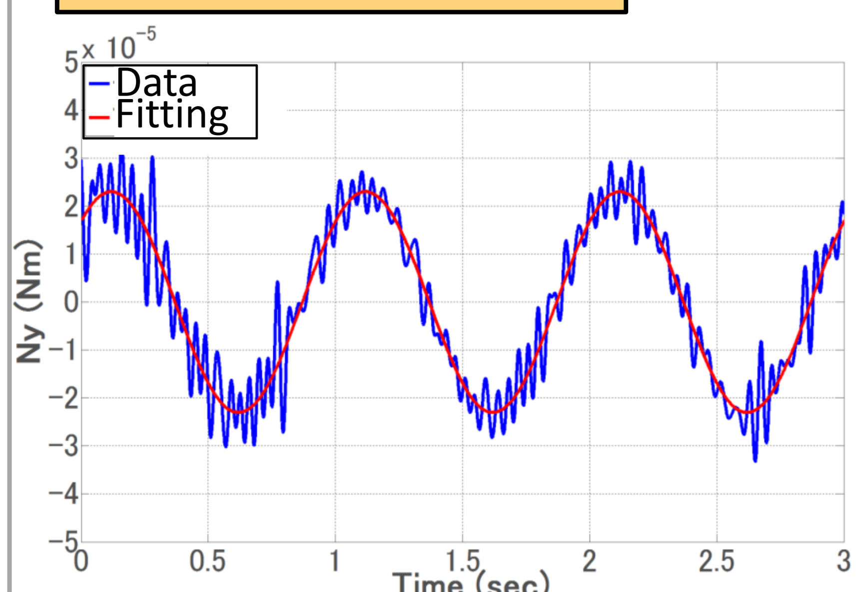
- Oscillate the model as same waveform at both wind-off and wind-on ⇒ Confirm the performance of oscillation
- Measure the amplitude and phase difference of aerodynamic force ⇒ Confirm the performance of dynamic balance system

## Performance of oscillation and balance system

### Axisymmetric model




### Evaluation method

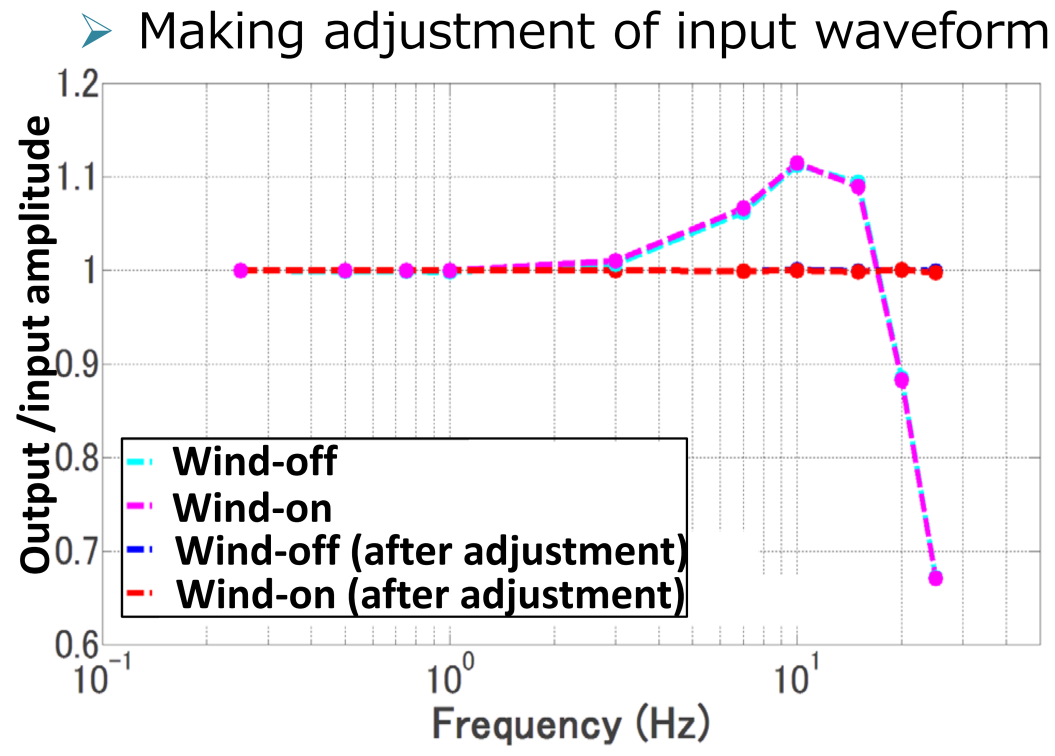



- Conducted fitting process by the method of least squares after filtering process

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

### Performance of oscillation

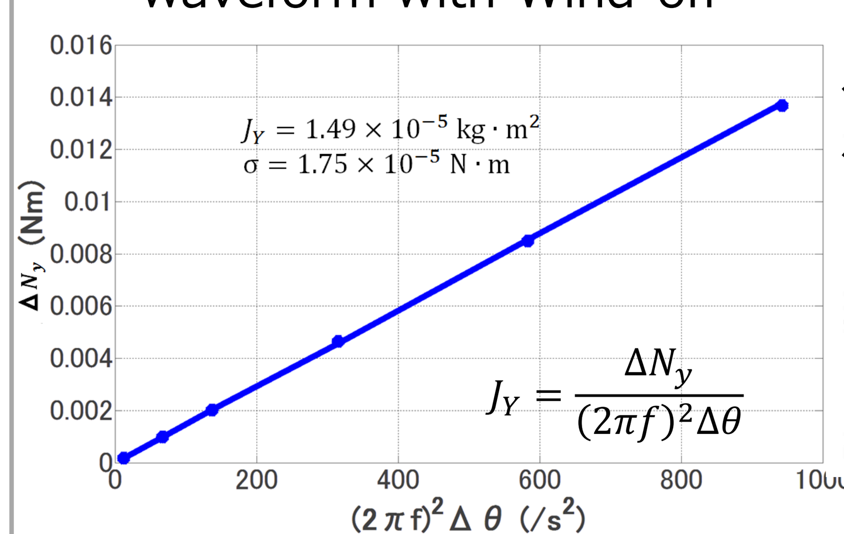
- Evaluation of the amplitude characteristic with wind-on (flow velocity is 11 m/s) and wind-off
  - ➢ Making adjustment of input waveform

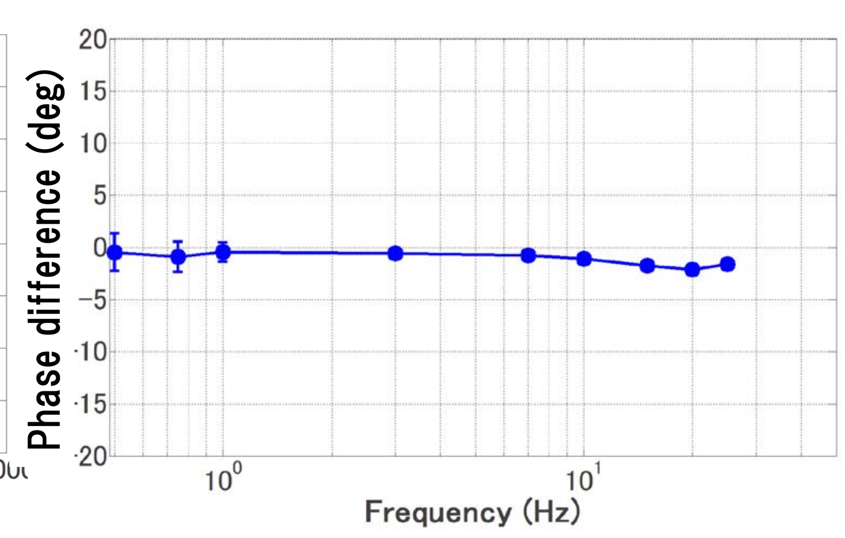



- Succeeded in keeping the oscillation under an uncertainty of 0.2 %
- Standard deviation between Wind-off and Wind-on ⇒ 0.015 degree

### Performance of balance system

- Measurement the oscillation waveform and pithing moment waveform with Wind-off




- Standard deviation of difference between regression line and pitching moment ⇒ $\sigma = 1.75 \times 10^{-5}$ Nm
  - ➢ Small error by electrical noise in the case of high frequency oscillation
- 95 % confidence interval ⇒ $9.0 \times 10^{-5}$ Nm (Maximum)
  - ➢ The criterion to evaluate the accuracy of oscillation, balance system and analysis
- Phase difference with an uncertainty of 2 degree

★A good performance for pitch oscillation and dynamic balance system
★The dynamic balance system might have the ability of dynamic wind tunnel testing

## Future work

➢ Construction of control system for a winged model
➢ Confirm the balance system performance of multi-degree of freedom oscillation

⇒ Evaluation of dynamic aerodynamic forces and dynamic stability derivatives