Development of a Position Sensing Method for a Bluff Body at the IFS 0.1-m MSBS

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Introduction of MSBS

It is necessary to understand the relationship between a shape and an aerodynamic characteristic.
Introduction of MSBS

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Flow

Bluff Body  Streamlined Body

Automobile  Airplane  Re-entry Capsule
Introduction of MSBS

It is necessary to understand the relationship between a shape and an aerodynamic characteristic.

A bluff body has separated flow at the leading edge.

It has greater the pressure drag due to the larger wake.

In the conventional wind tunnel test, the model is fixed in the test section by Mechanical support device.

It causes the support interference to the flow field.

Conventional wind tunnel testing (http://www.aero.jaxa.jp)
Introduction of MSBS

Magnetic Suspension and Balance System (MSBS)

Magnetic Suspension and Balance System
(http://jaxamsbs.jaxa.jp)
Introduction of MSBS

- **Magnetic Suspension and Balance System (MSBS)**
  - Levitate the model by magnetic force and moment
  - Measure aerodynamic force from coil current
  - Coil current is determined by displacement of the model

  MSBS can evaluate aerodynamic force without support interference

- **TU-IFS 0.1-m MSBS**
  - Set up for High subsonic and Supersonic testing
    - Mach Number 0.5, 0.7, 1.7
    - Reduce the initial total pressure by settling chamber
  - Set up for Low speed wind tunnel testing
    - Velocity: \( U = 18 \sim 30 \) [m/sec]
    - Turbulent Intensity: 0.4 [%]
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Research achievements of the IFS 0.1-m MSBS

**High subsonic and Supersonic** For development of an aircraft flying at supersonic speed…

- 2014: We have constructed MSBS for supersonic wind tunnel
- 2017: Near field pressure measurement system
- 2018: Winged model testing at supersonic

**Low speed** For invention of new wind tunnel test technique…

- 2016: Dynamic wind tunnel test techniques
- 2018: New sensing method for bluff bodies
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Flow around a Small Fineness Ratio Bluff Body

- Flow separation at the leading edge of bluff body
- Complex wake structure
- Due to the limitations in the measurement range, testing of small fineness ratio bluff body were not performed in the IFS MSBS

Disk wake structure and coordinate system
(E. Berger 1990)
Background ~Cylinder~

Flow around a Small Fineness Ratio Bluff Body

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Fineness Ratio = $L/D$

Flow

$C_D$ vs. $L/D$

Drag of 3D axial circular cylinders
Optical System of the IFS 0.1-m MSBS

- CCD line sensor for model position measurement

Change of sensor output detects the model position
Conventional Position Measurement Method

Schematic of the IFS 0.1-m MSBS

- Challenges point of the current position sensing method
  
  ✓ Due to the distance between line sensors, there is the restriction on the model length that can be measured

  ✓ It is difficult to test the small fineness ratio bluff body
Objectives

Establish a new model position sensing method for a Small Fineness Ratio Bluff Body

Contents

✓ How to sensing model position
✓ Evaluation of new model position sensing method
How to Sensing the Model Position

1. Change arrangement of line sensor

   ![Diagram showing conventional and new arrangement of line sensor with and without markers.]

   - Conventional arrangement
   - New arrangement

2. Change marker on the model surface

   ![Diagram showing without and with line markers.]

   - Without marker
   - With 2 line marker
The model position information \((U, V, W, T, P)\) can be given as combinations of the boundaries of the model image.

- **4 line sensors** for detecting model position \((x, y, z, \theta, \psi)\)

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**Image of object**

- \(w_{\text{min},1}^-, w_{\text{max},1}^+, w_{\text{min},0}^-, w_{\text{max},0}^+, w_{\text{min},2}^-, w_{\text{max},2}^+, w_{\text{min},1}^-, w_{\text{max},1}^+, w_{\text{min},2}^-, w_{\text{max},2}^+\)

**Array of sensor elements**

- \(v_{\text{min},1}^-, v_{\text{max},1}^+, v_{\text{min},0}^-, v_{\text{max},0}^+, v_{\text{min},2}^-, v_{\text{max},2}^+, v_{\text{min},1}^-, v_{\text{max},1}^+, v_{\text{min},2}^-, v_{\text{max},2}^+\)

**Position sensing system on the 0.1-m MSBS**

- Lens and color filter (Blue)
- Small Fineness Ratio Cylinder Model
- LED
- Screen
How to Sensing the Model Position

- Position Information by Line Sensor

\[
U(x_{\text{pixel}}) = \frac{w_{\text{max},0}^+ + w_{\text{min},0}^- + w_{\text{min},0}^+ + w_{\text{max},0}^-}{4}
\]

\[
T(\theta_{\text{pixel}}) = \sum_{i=0}^{2} \frac{w_{\text{max},i}^+ + w_{\text{min},i}^- - w_{\text{max},i}^- - w_{\text{min},i}^+}{4}
\]
How to Sensing the Model Position

Position Information by Line Sensor

\[ V(\gamma_{\text{pixel}}) = \sum_{i=0}^{2} \frac{w_{\text{max},i}^+ - w_{\text{min},i}^- + w_{\text{max},i}^- - w_{\text{max},i}^-}{2} \]

✔ The model position \((y, z)\) is given by the size of the model image

The model position \((x, y, z, \theta, \psi)\) is obtained as displacement of the boundary of the model image \((U, V, W, T, P)\)
Evaluation of new model position sensing method

Test Section
Φ = 90 mm
L/D = 1.44
Cylinder Model

<table>
<thead>
<tr>
<th></th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>θ</th>
<th>ψ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum displacement [mm,deg]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.009</td>
<td>0.073</td>
<td>0.051</td>
<td>0.058</td>
<td>0.073</td>
</tr>
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</table>

At no wind situation, position variation is less than 0.1 [mm,deg]
Evaluation of new model position sensing method

Test Section
Φ = 90 mm

L/D = 1.44 Cylinder Model

Position data without wind flow

<table>
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<tr>
<th>Maximum displacement [mm,deg]</th>
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<tbody>
<tr>
<td>x</td>
</tr>
<tr>
<td>0.009</td>
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</table>

At no wind situation, position variation is less than 0.1 [mm,deg]
Conclusions

The position method of a small fineness ratio bluff body in the IFS 0.1 - m MSBS is developed

✓ In the proposed method, the model position \((y, z)\) is calculated from the size of the model image

✓ Position variation is less than 0.1 [mm,deg]

➢ Future work

✓ Evaluate the aerodynamic characteristic of a small fineness ratio bluff body by new model position sensing method
Thank you for your attention