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

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1. What is the IFS 0.1-m MSBS ?

✓ Introduction of the MSBS

✓ Research achievements of the IFS 0.1-m MSBS

2. Study on Bluff Body using MSBS

✓ Background

✓ Construction of sensor system for a small fineness ratio cylinder model

✓ Results

✓ Concluding Remarks

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Introduction of MSBS

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

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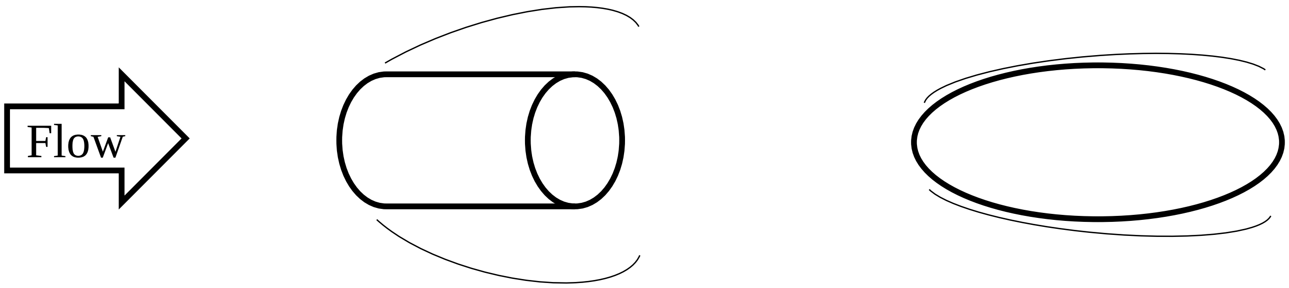
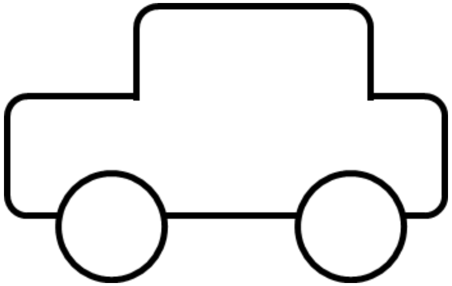


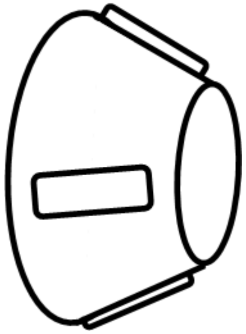
Bluff Body

Streamlined Body



Automobile

Airplane



Re-entry Capsule

Introduction of MSBS

It is necessary to understand
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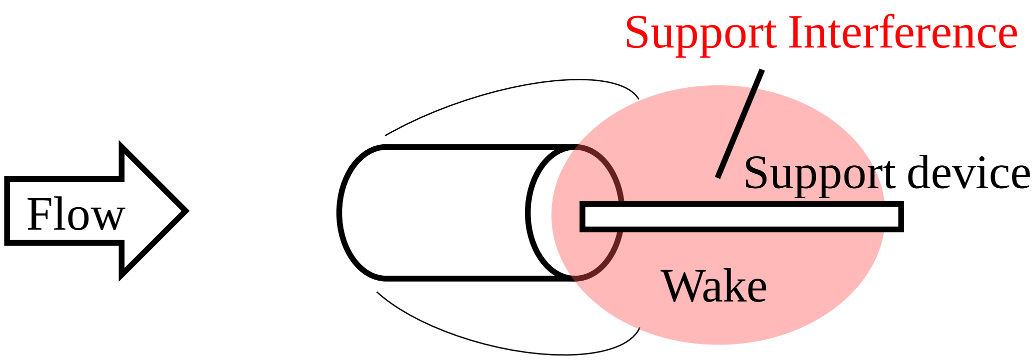
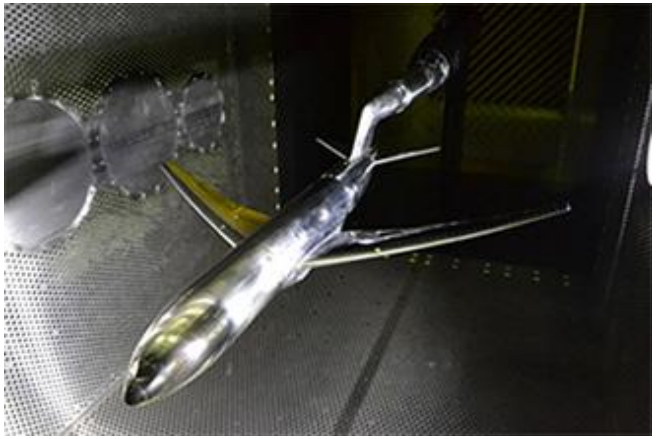


Bluff Body



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

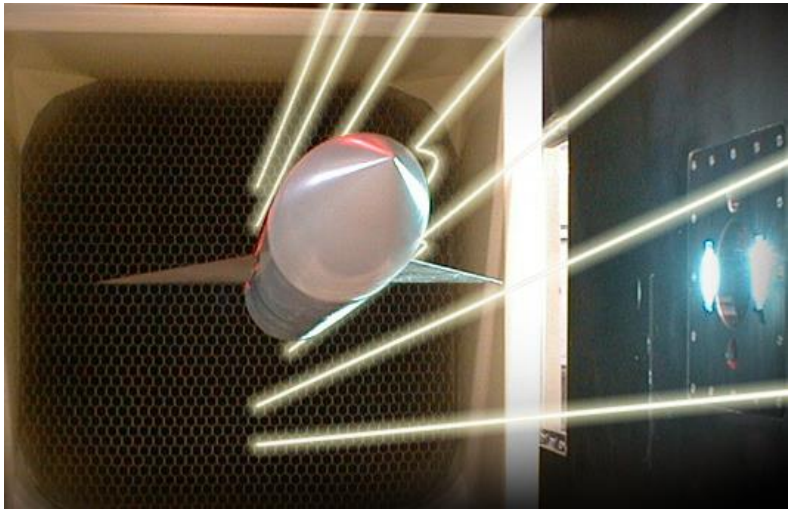
A bluff body has separated flow at the leading edge

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

Introduction of MSBS



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

Magnetic Suspension and Balance System (MSBS)

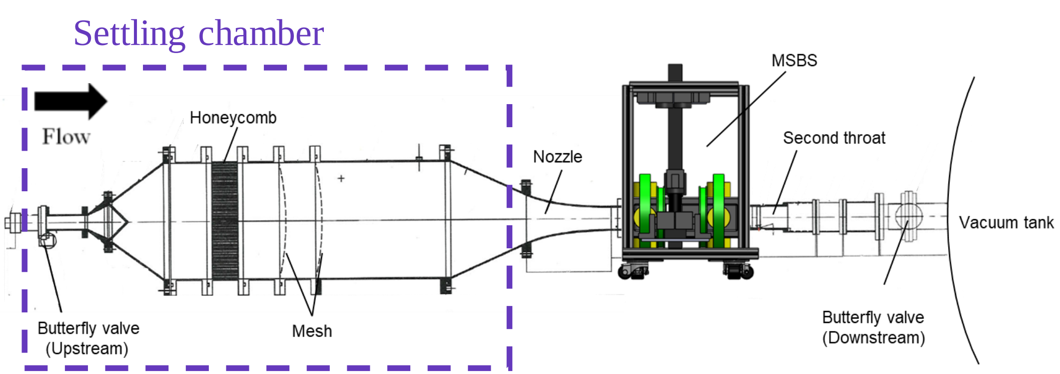
Introduction of MSBS

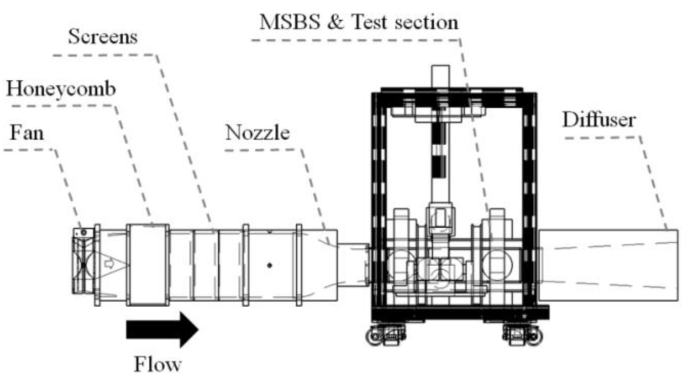
- Magnetic Suspension and Balance System (MSBS)
  - ✓ Levitate the model by magnetic force and moment
  - ✓ Measure aerodynamic force from coil current
  - ✓ Coil current is determined by displacement of the model

MSBS can evaluate aerodynamic force without support interference

Levitated model in the 0.1-m MSBS

- 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 ~ 30 [m/sec]
- ✓ Turbulent Intensity: 0.4 [%]

Contents

Research achievements of the IFS 0.1-m MSBS

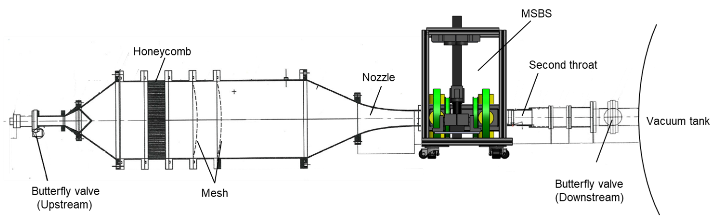
TOHOKU UNIVERSITY

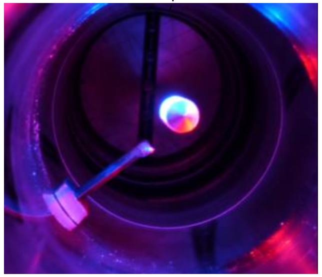
High subsonic and Supersonic

For development of an aircraft flying at supersonic speed…

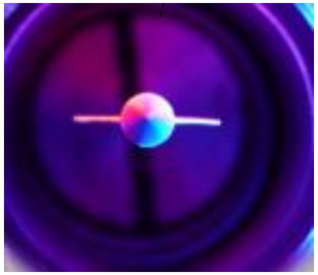
2014 2017 2018

We have constructed MSBS for supersonic wind tunnel





Near field pressure measurement system



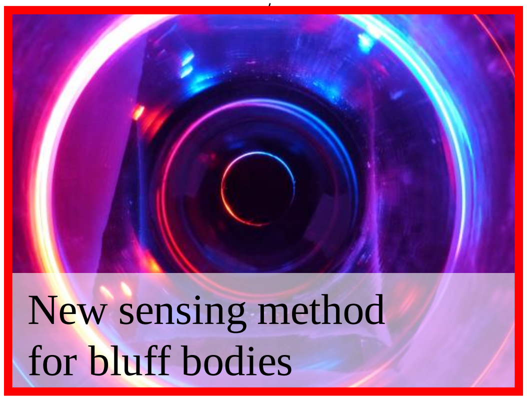
Winged model testing at supersonic

Low speed

For invention of new wind tunnel test technique…

2016 2018

Dynamic wind tunnel test techniques



New sensing method for bluff bodies

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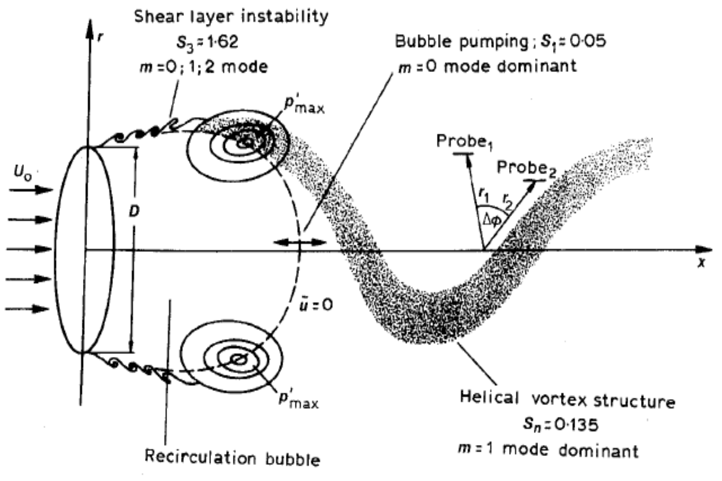
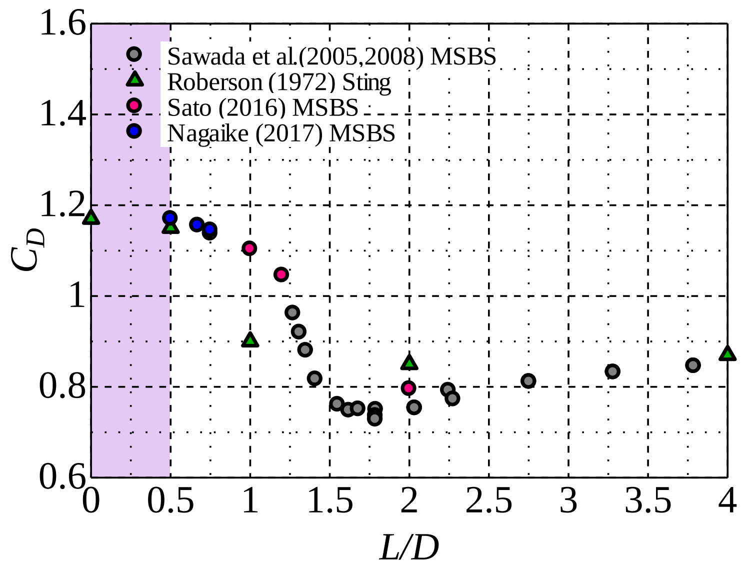
Background ~Cylinder~

- 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)



Drag of 3D axial circular cylinders

Background ~Cylinder~

- Flow around a Small Fineness Ratio Bluff Body
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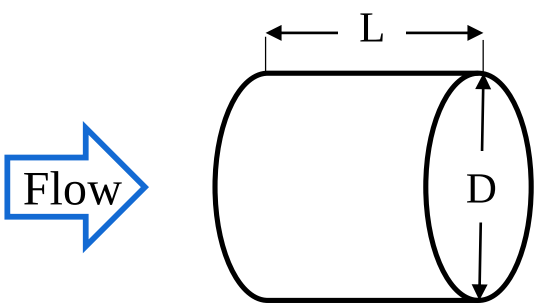
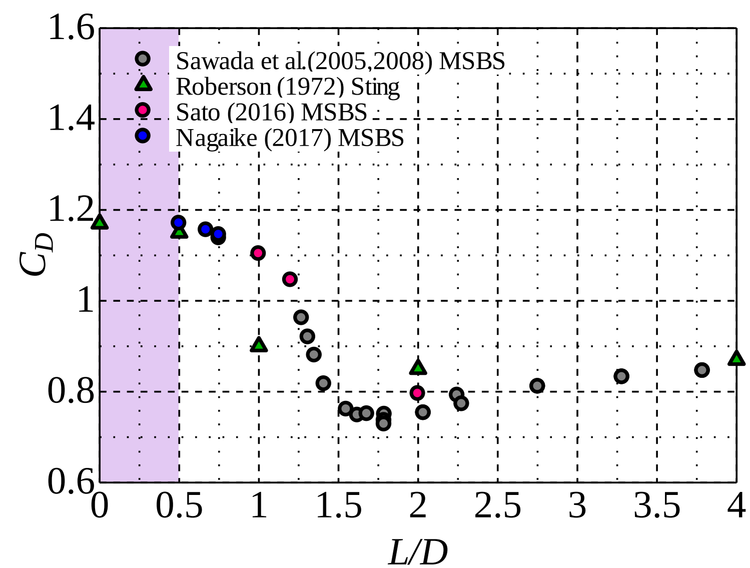
<u>Fineness Ratio = L/D</u>

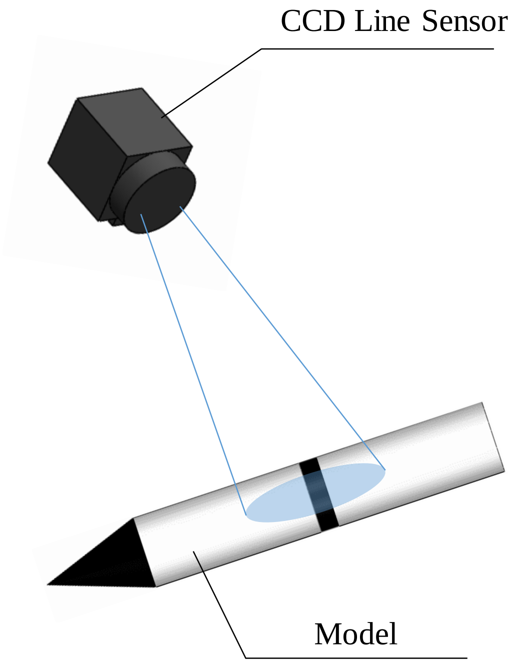


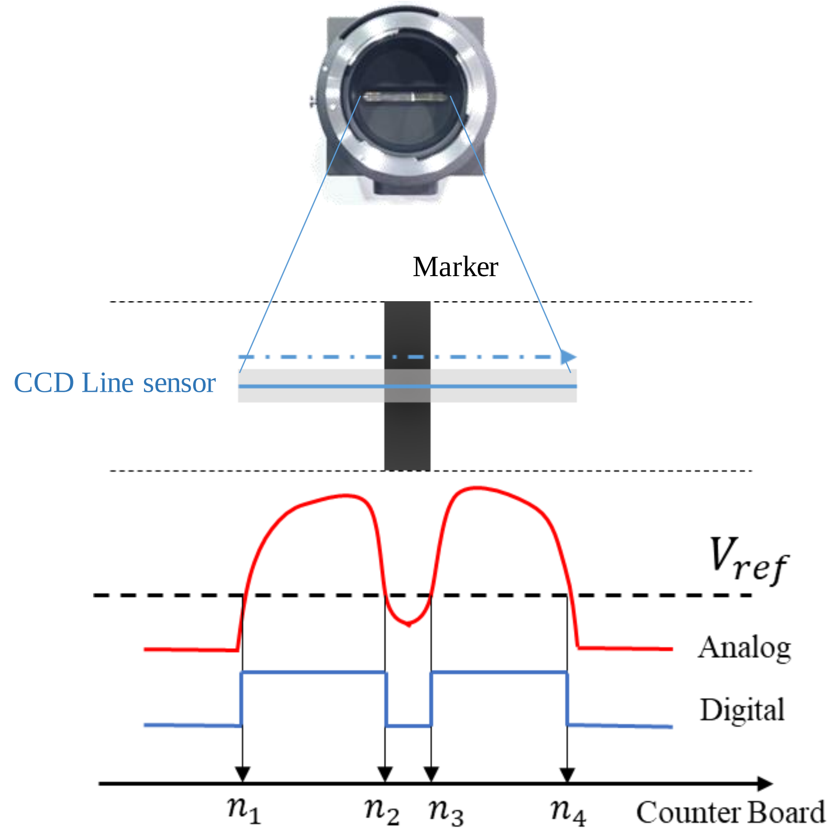


Drag of 3D axial circular cylinders

Optical System of the IFS 0.1-m MSBS

- CCD line sensor for model position measurement

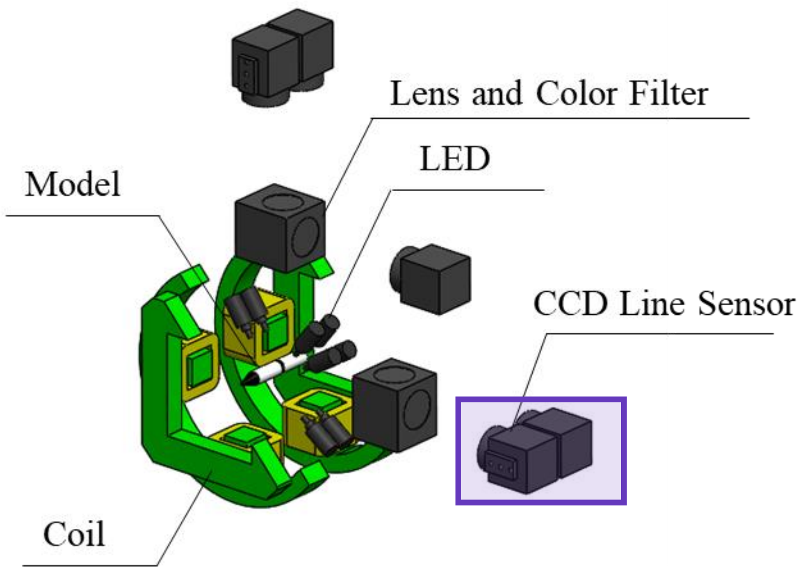




Line sensor signal process

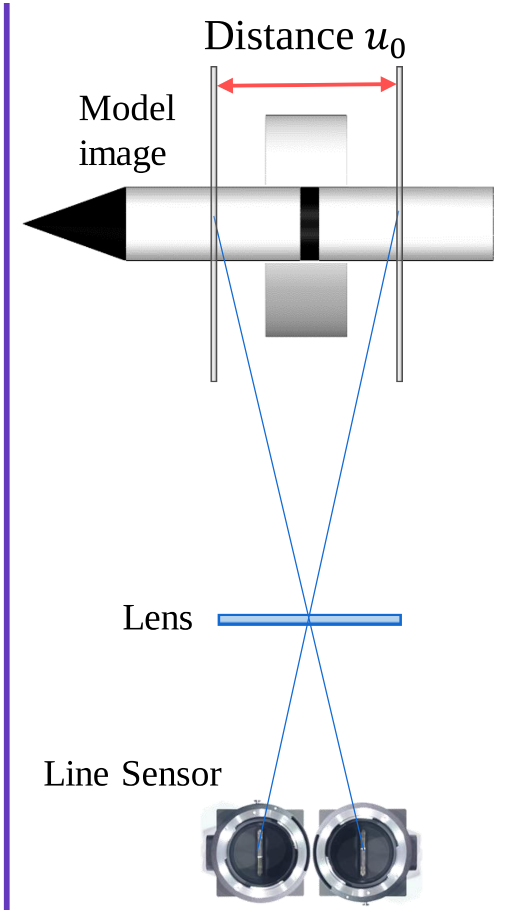
Change of sensor output detects the model position

Conventional Position Measurement Method



Schematic of the IFS 0.1-m MSBS

Optical System



Conventional line sensor arrangement

- 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

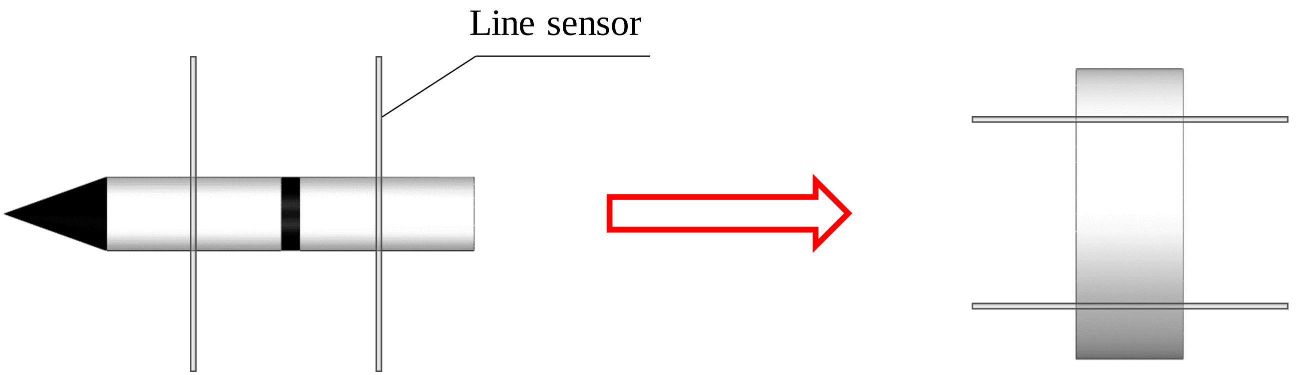
Objectives

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

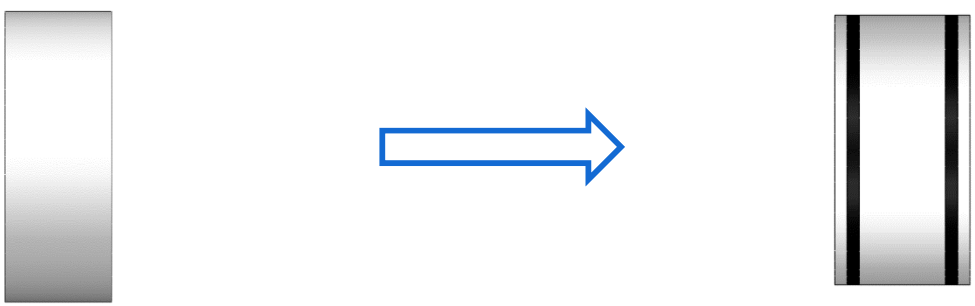
How to Sensing the Model Position

1. Change arrangement of line sensor



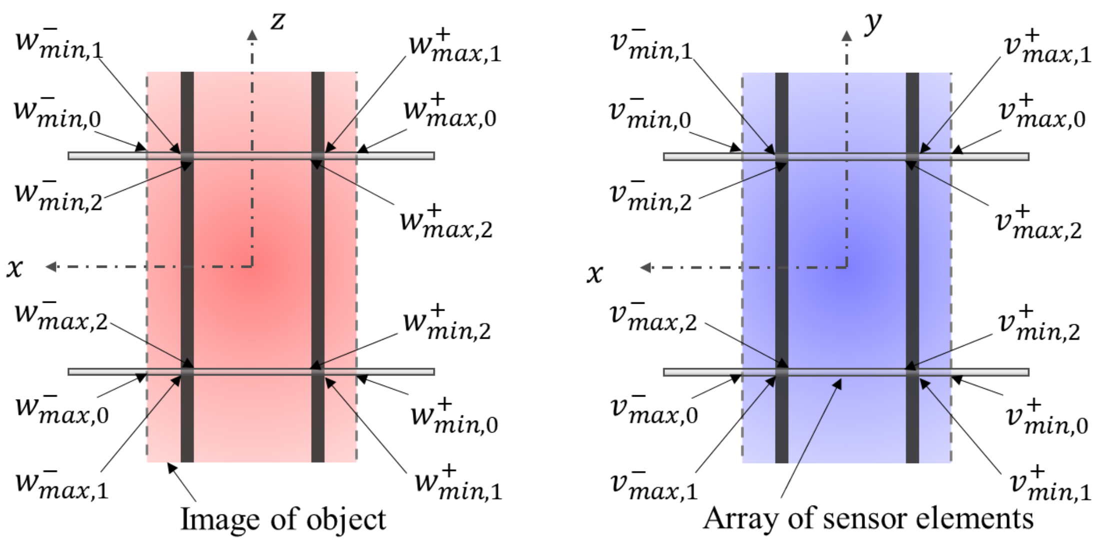
Conventional arrangement New arrangement

2. Change marker on the model surface

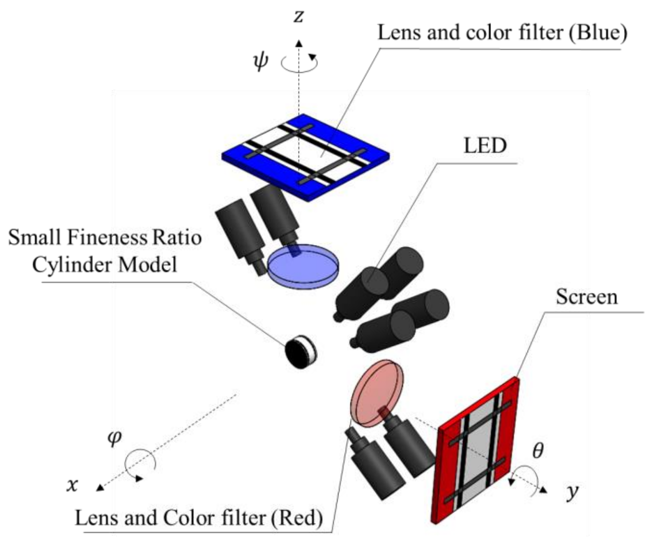


Without marker With 2 line marker

How to Sensing the Model Position



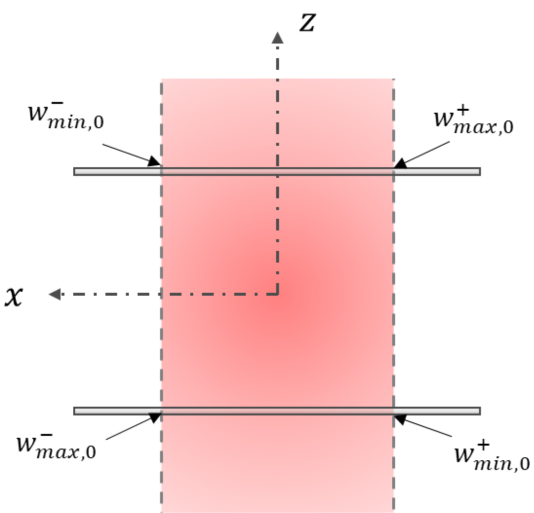
Object image and arrays of elements on a screen



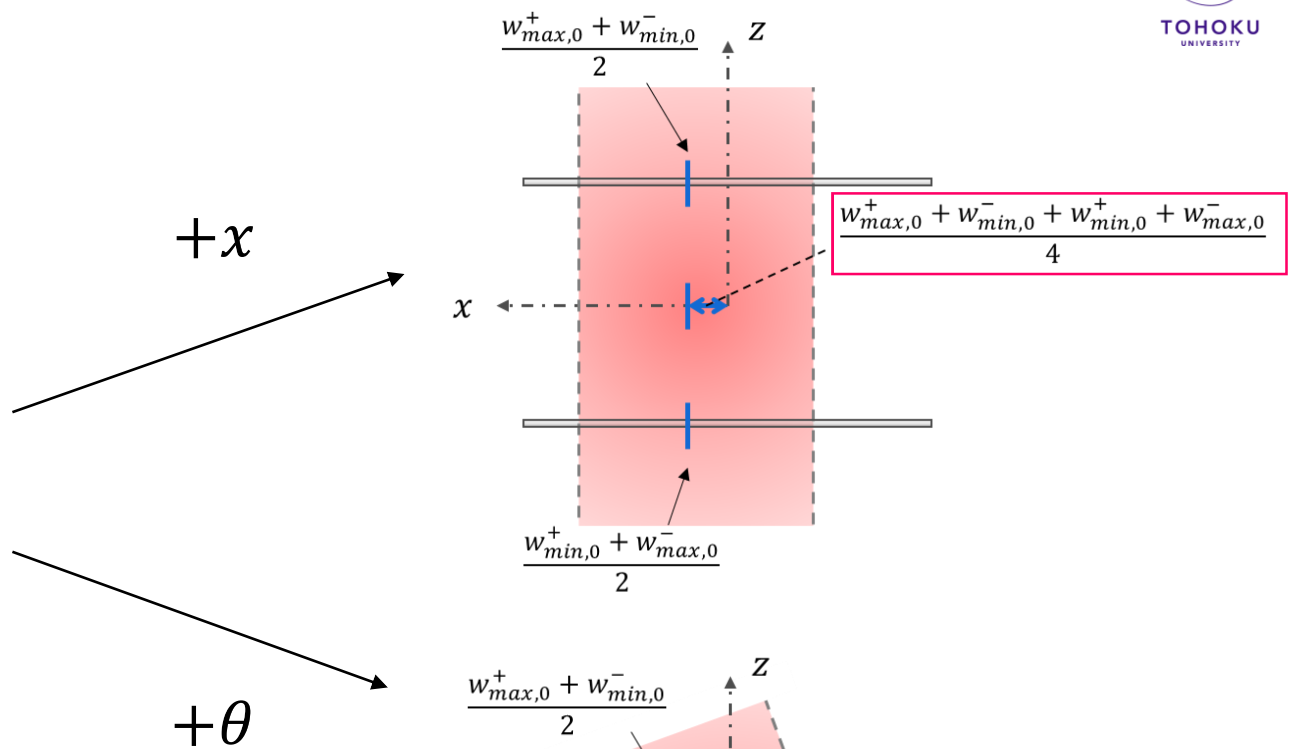
Position sensing system on the 0.1-m MSBS

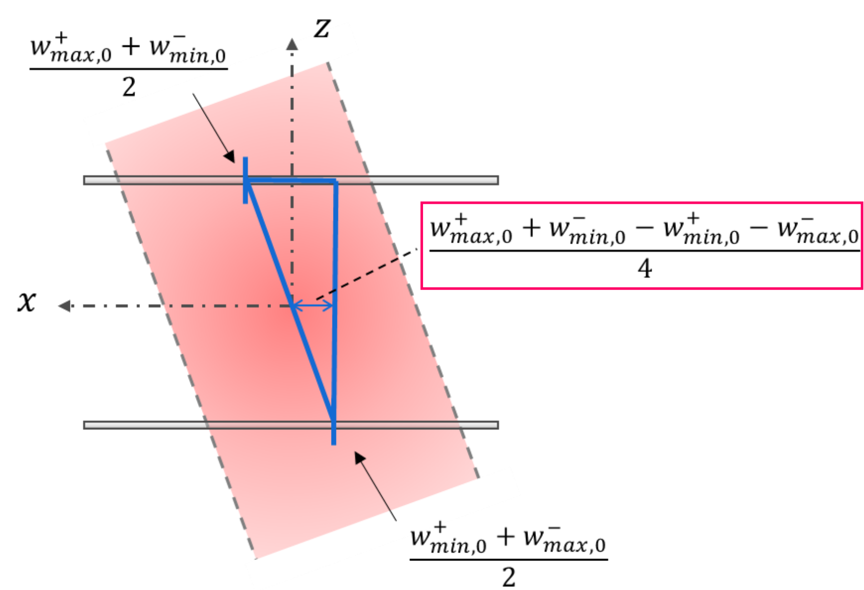
- ✓ The model position information (U, V, W, T, P) can be given as combinations of the boundaries of the model image
- ✓ <u>4 line sensors</u> for detecting model position (x, y, z, θ, ψ)

How to Sensing the Model Position



Model image on x-z screen



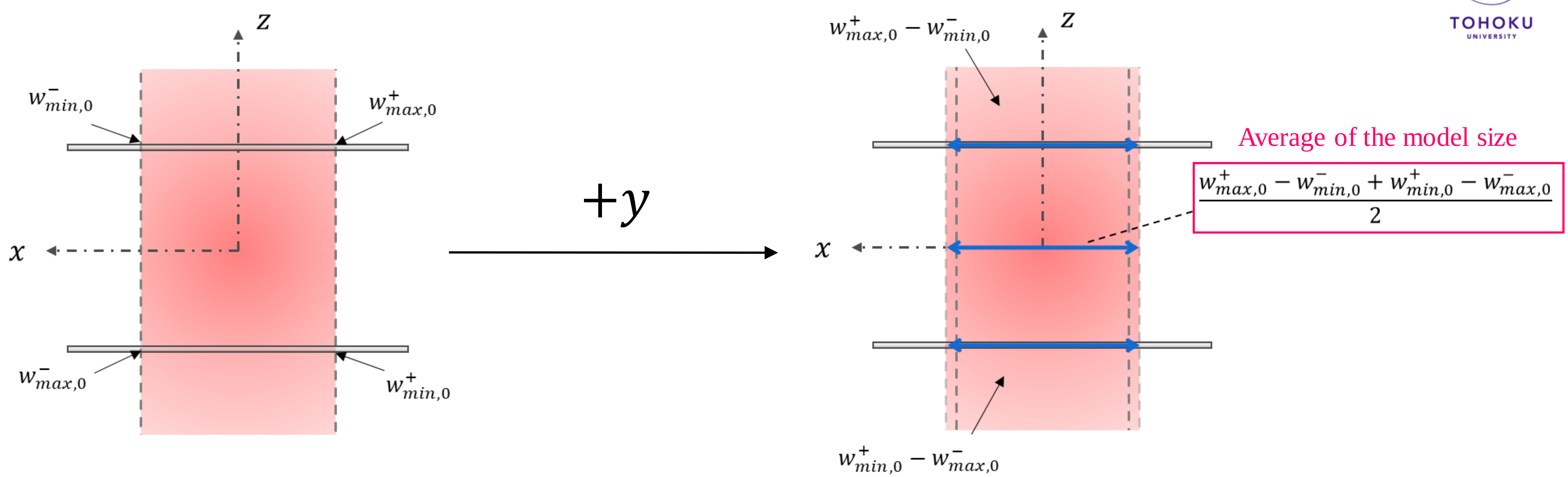


- Position Information by Line Sensor

$$U(x_{pixel}) = \frac{w^+_{max,0} + w^-_{min,0} + w^+_{min,0} + w^-_{max,0}}{4}$$

$$T(\theta_{pixel}) = \sum_{i=0}^{2} \frac{w^+_{max,i} + w^-_{min,i} - w^+_{min,i} - w^-_{max,i}}{4}$$

How to Sensing the Model Position



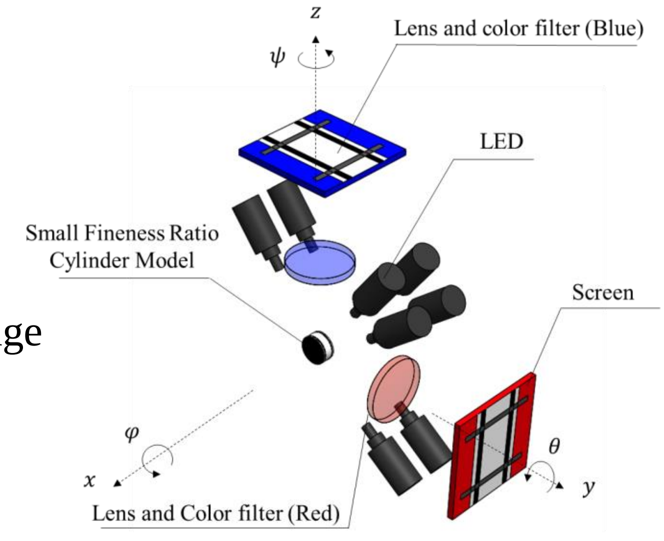
Model image on x-z screen

- Position Information by Line Sensor

$$V(y_{pixel}) = \sum_{i=0}^{2} \frac{w^+_{max,i} - w^-_{min,i} + w^+_{min,i} - w^-_{max,i}}{2}$$

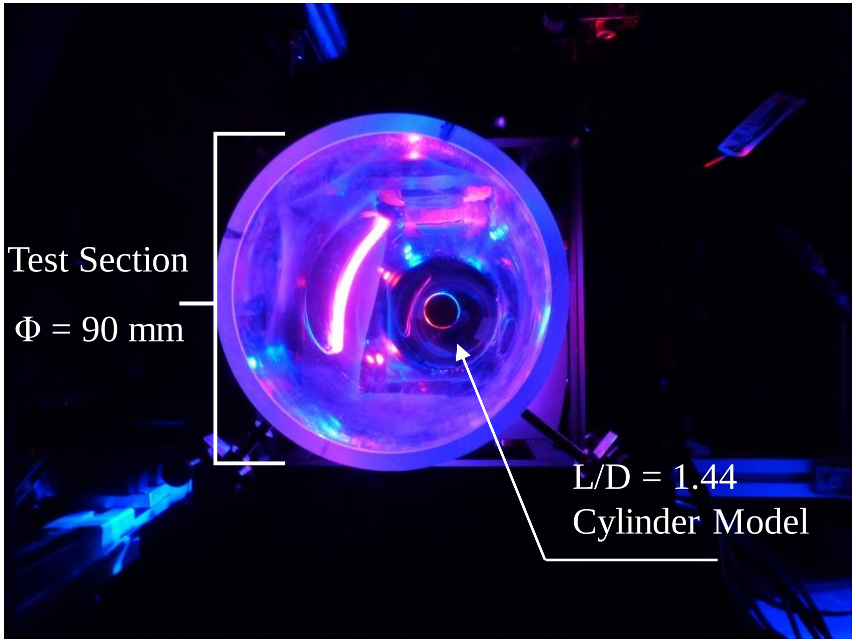
✓ The model position (y, z) is given by the size of the model image

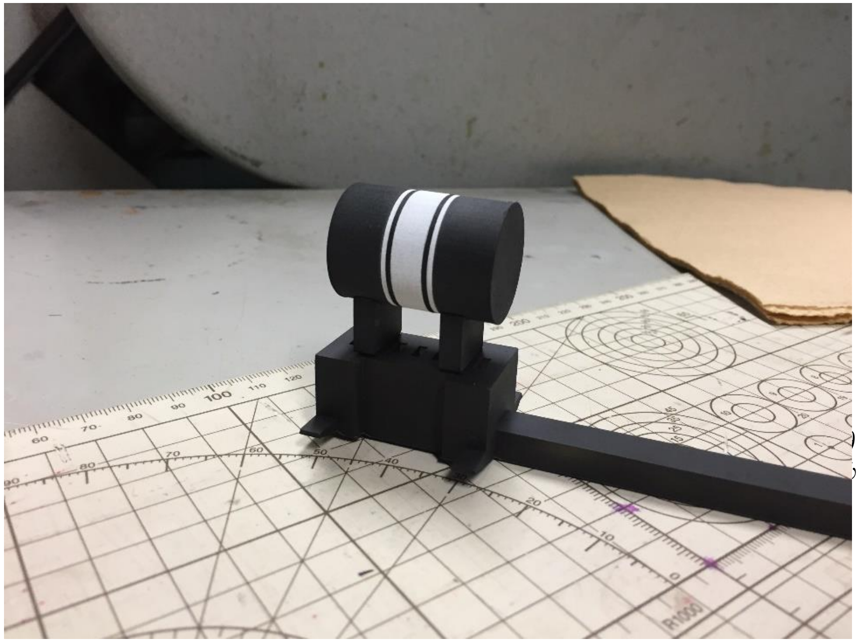
The model position (x, y, z, θ, ψ) is obtained as displacement of the boundary of the model image (U, V, W, T, P)



Position sensing system on the 0.1-m MSBS

Evaluation of new model position sensing method

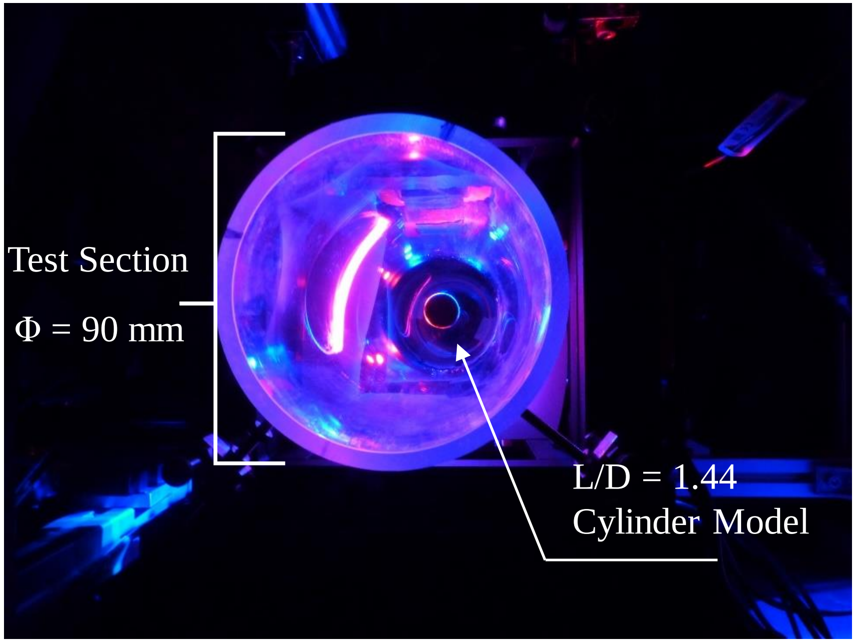


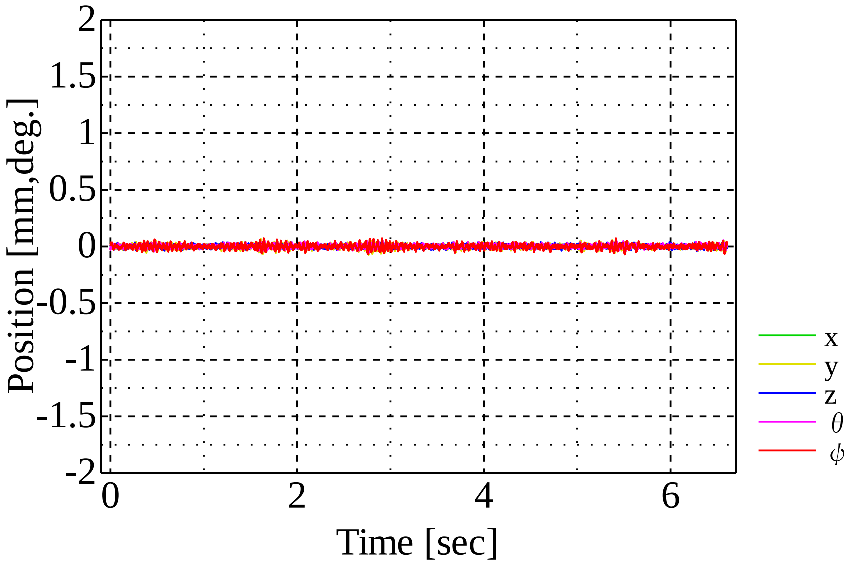


Maximum displacement [mm,deg]				
x	y	z	θ	ψ
0.009	0.073	0.051	0.058	0.073

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

Evaluation of new model position sensing method





Position data without wind flow

Maximum displacement [mm,deg]				
x	y	z	θ	ψ
0.009	0.073	0.051	0.058	0.073

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