Development of High-Subsonic Wind Tunnel Testing Technique Using a Magnetic Suspension and Balance System

-Capsule Model-

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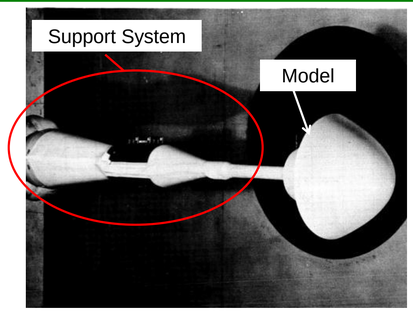
Background

Reentry Capsule

- Employments of a reentry capsule are considered
  - HAYABUSA , Mars exploration capsule and HTV return vehicle, etc.
- Dynamic wind tunnel test
  - Support interference by moving a mechanical support system

Dynamically unstable
from transonic to subsonic speed
→**Evaluate the dynamic characteristic**

Necessary to employ dynamic wind tunnel testing system without the support interference

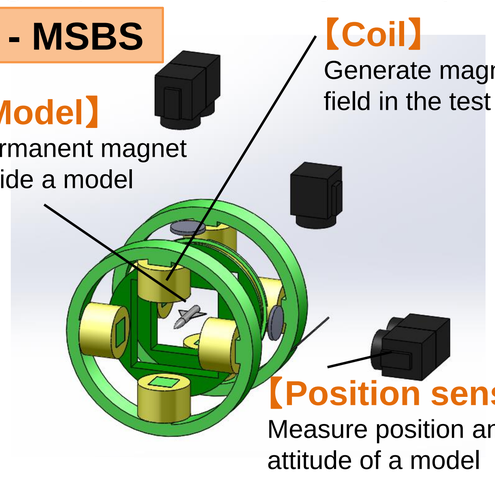


Dynamic wind tunnel test (reentry capsule)
(Cole D. Kazemba et al., 2012)

Magnetic Suspension and Balance System

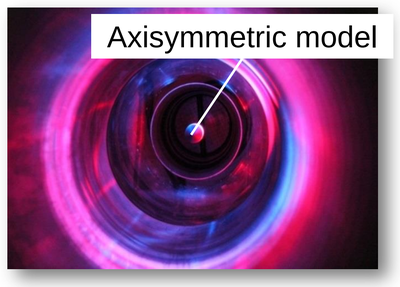
- Avoid support interference
- No motion restriction due to a mechanical support
- Suspension and balance system to evaluate aerodynamic forces by measuring coil currents
- Achieve to suspend a model at supersonic speed with a high speed control system (0.1 m - MSBS)

0.1 m - MSBS



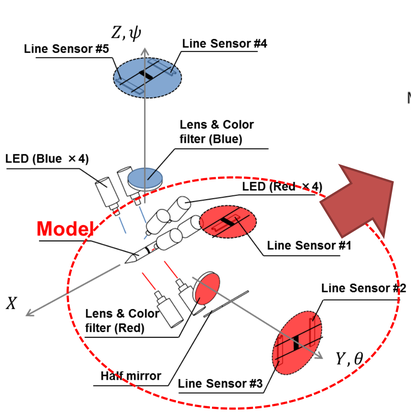
Motion equation (x- axis)

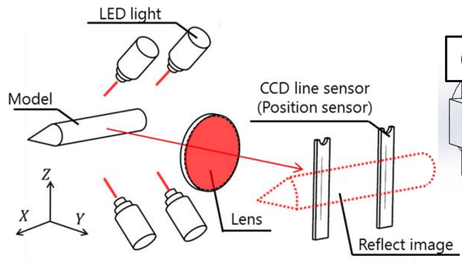
$$\frac{d(m\boldsymbol{v})}{dt} = \boldsymbol{F}_{mag,x} + \boldsymbol{F}_{aero,x}$$



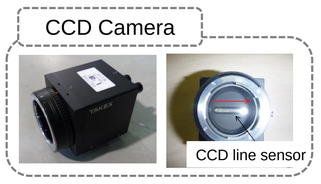
Optical Position Sensor System

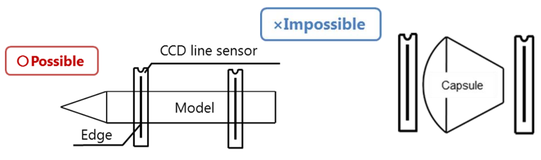
High speed and high accuracy by using 5 CCD line sensor cameras

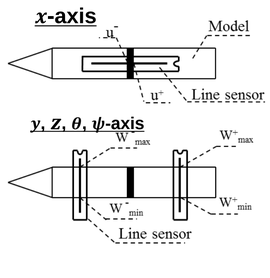




Cannot reduce distance between 2 CCD line sensors







$$\boldsymbol{x}_{count} = \frac{u^{\#1}_{max} + u^{\#1}_{min}}{2} - r\psi$$

Count number

$$\boldsymbol{y}, \boldsymbol{z}_{count} = -\frac{w^{\#4,2}_{max} + w^{\#4,2}_{min} + w^{\#5,3}_{max} + w^{\#5,3}_{min}}{4}$$

$$\boldsymbol{\theta}, \boldsymbol{\psi}_{count} = -\frac{w^{\#2,4}_{max} + w^{\#2,4}_{min} - w^{\#3,5}_{max} - w^{\#3,5}_{min}}{4u_0}$$

- Difficult to measure a low fineness ratio model (capsule model)

Position sensor applicable to a capsule model is required

Objective

Development of Wind Tunnel Test Technique for a Reentry Capsule Using a MSBS

Minimum Success

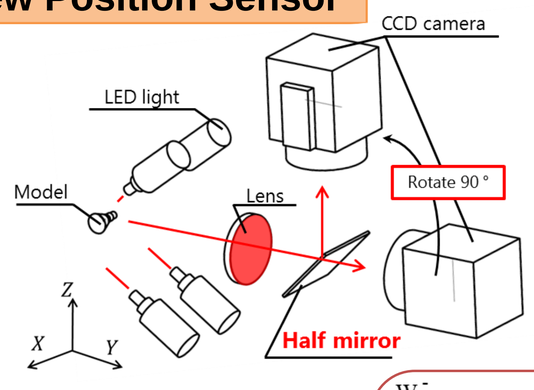
- Develop a new position sensor applicable to a capsule model

Full Success

- Suspend a capsule model magnetically in High-subsonic speed

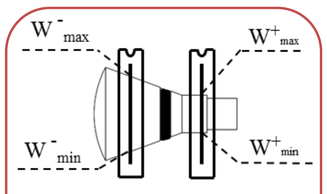
Development of a New Position Sensor

New Position Sensor



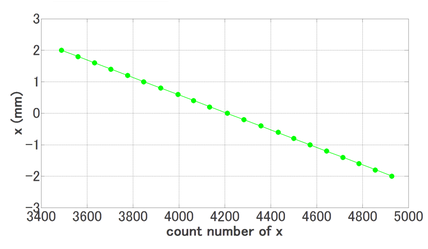
✓ Add a half mirror
✓ Allocate two cameras independently

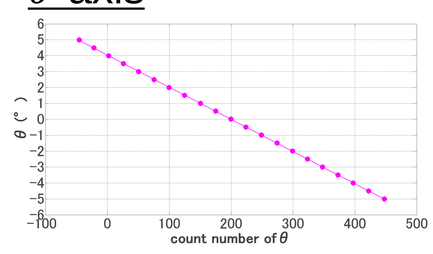
Axisymmetric model (Supersonic)
Capsule model



Capsule model can be detected!

Sensor Calibration





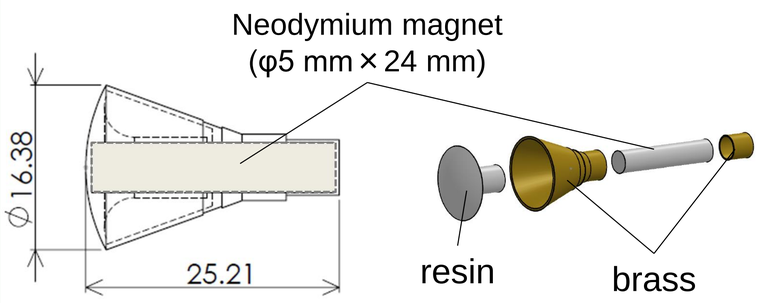
- Count number is proportional to displacement of the model
  (Count number is the boundary value between the model edge and line sensor)

Direction	Calibration Range
x, y, z [mm]	±2
θ, ψ [°]	±5

Low fineness ratio model such as a capsule model can be measured

High-Subsonic Wind Tunnel Test

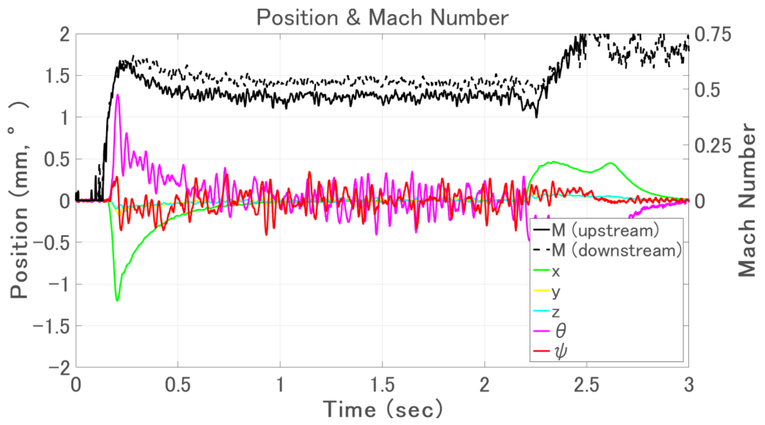
Capsule Model (Mercury-type)



- 1/100 scale model used in project mercury
- Adopt brass as model's material in order to increase inertia moment

The capsule model can be suspended!!

Model Position and Mach Number



- The flow of Mach 0.5 can be created with high-subsonic wind tunnel
- The model displacement can be suppressed within calibration range by reducing total pressure

Force Calibration (Future Work)

Equation of magnetic force

$$\boldsymbol{F}_{mag,x} = M_0 h_{x,x} I_{drag}$$

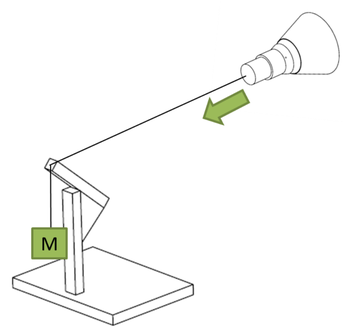
magnet moment of the magnet; magnetic field derivative per unit current; drag coil current

Unknown value

$$\boldsymbol{F}_{load} = M_0 h_{x,x} I_{drag}$$

Known weight; Evaluated by MSBS

$$M_0 h_{x,x} = \frac{F_{load}}{I_{drag}}$$



- Determine the relation between weight and coil current by using known weight

◆The capsule model can be suspended magnetically in Mach 0.5 by using MSBS
◆Drag coefficient will be evaluated by conducting force calibration