

液体のスロッシング効果を利用した 制振構造模型(SMD)の開発

2021/1/28

長谷川研究室

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背景と目的



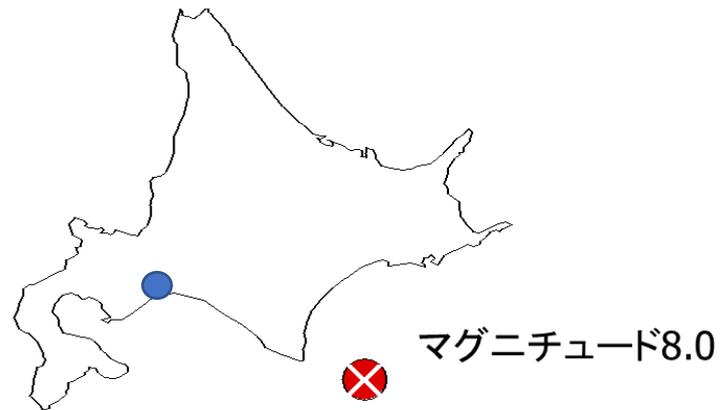
新横浜プリンスホテル



函館五稜郭タワー

メリット：メンテナンスと質量調節が容易

スロッシング現象について

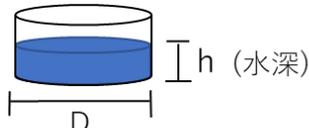


2003年十勝沖地震
2003年9月26日午前4時51分

設計プロセス

(a) スロッシング周期(T_s)の算定

円筒容器の T_s

$$T_s = 2\pi \sqrt{\frac{D}{3.6824 \text{ g} \cdot \tanh(3.6824h/D)}} \quad \dots (1)$$


D (直径)
 h (水深)

$$h/D = 1/4$$

T_s の近似式

$$T_s = 1.046\sqrt{D} \cong \sqrt{D} \quad \dots (2)$$

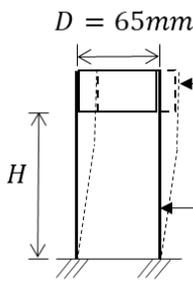
($\because \tanh(X) \cong 1.0$ for $x > 1$)

$D = 65\text{mm}$ の T_s

$$T_s = 0.27(\text{s})$$

(b) SMD模型柱材の設計

せん断型模型の諸元

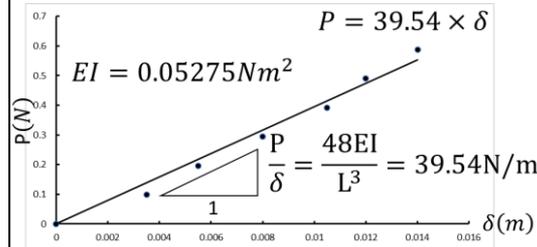
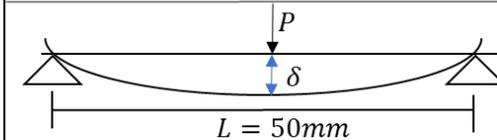


$D = 65\text{mm}$

液体容器
(プラスチックシャーレ)
 $m = 27 \text{ g / 段}$

板ばね
(鋼 $t = 0.5\text{mm}$)

板ばねの曲げ剛性 EI の算定



(c) SMD模型固有周期(T_m)の算定

せん断型モデルの T_m

$$T_m = 2\pi \sqrt{\frac{M}{K}} \quad \dots (3)$$

$$K = 2 \text{ 本} \times \frac{12EI}{H^3}$$

$$M = 3 \text{ 段} \times m$$

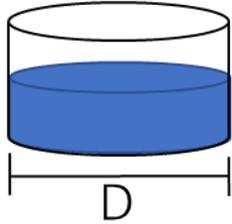
模型高さ H の逆算

$$H = \sqrt[3]{\frac{8EI}{m} \times \left(\frac{T_m}{2\pi}\right)^2} \quad \dots (4)$$

同調時($T_s = T_m$)の H 決定

$$H = 0.306\text{m} \rightarrow 30\text{cm}$$

スロッシング周期(T_s)の算定



h (水深) $T_s = 2\pi \sqrt{\frac{D}{3.6824 \text{ g} \cdot \tanh(3.6824h/D)}}$

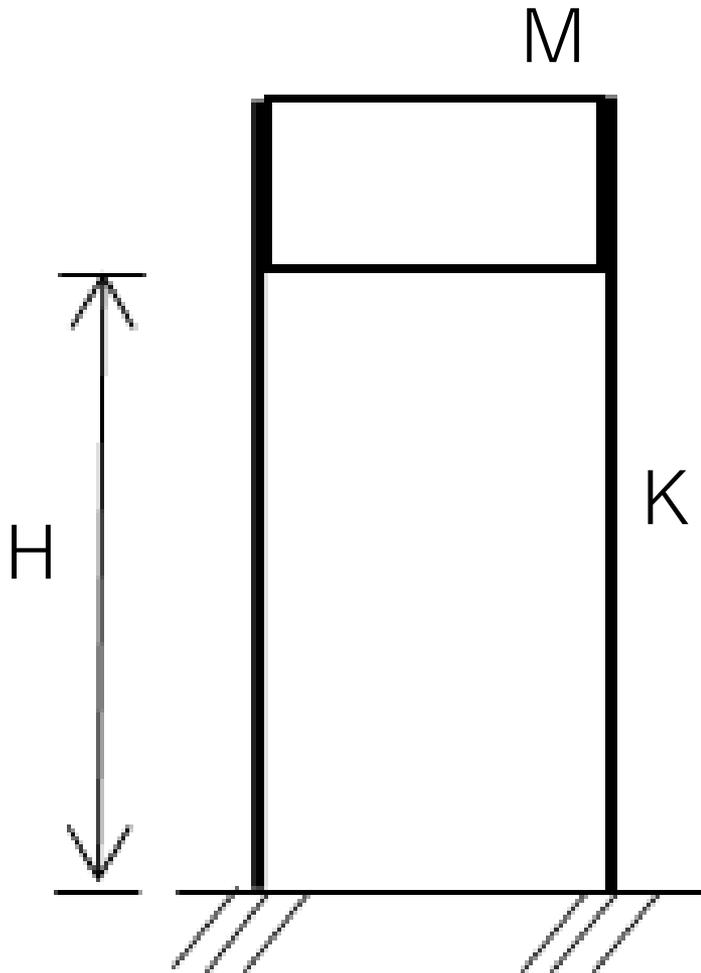
$h/D = 1/4$

$$T_s = 1.046\sqrt{D} \doteq \sqrt{D}$$

$$D = 65\text{mm} \text{ の } T_s$$

$$T_s = 0.27(\text{s})$$

同調時の建屋模型の決定



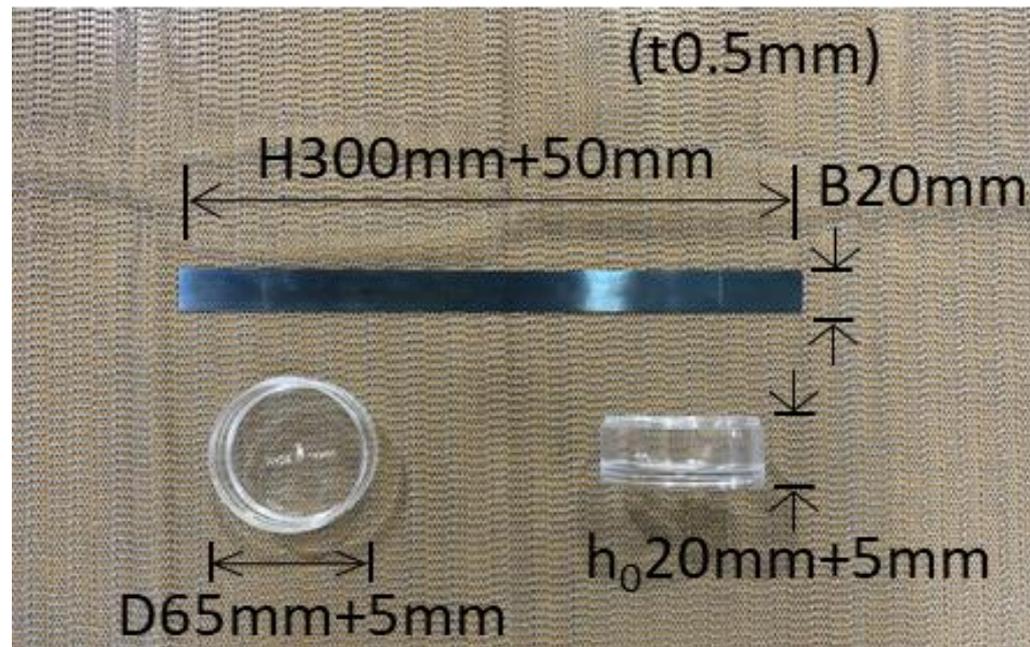
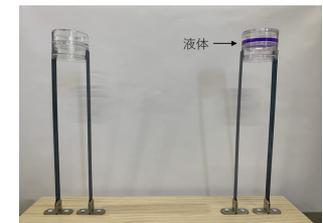
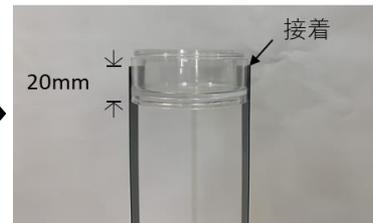
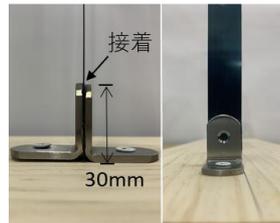
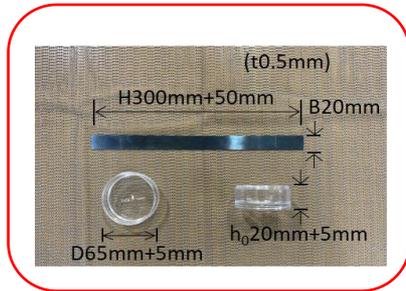
$$T_m = 2\pi \sqrt{\frac{M}{K}}$$

$$H = \sqrt[3]{\frac{8EI}{m} \times \left(\frac{T_m}{2\pi}\right)^2}$$

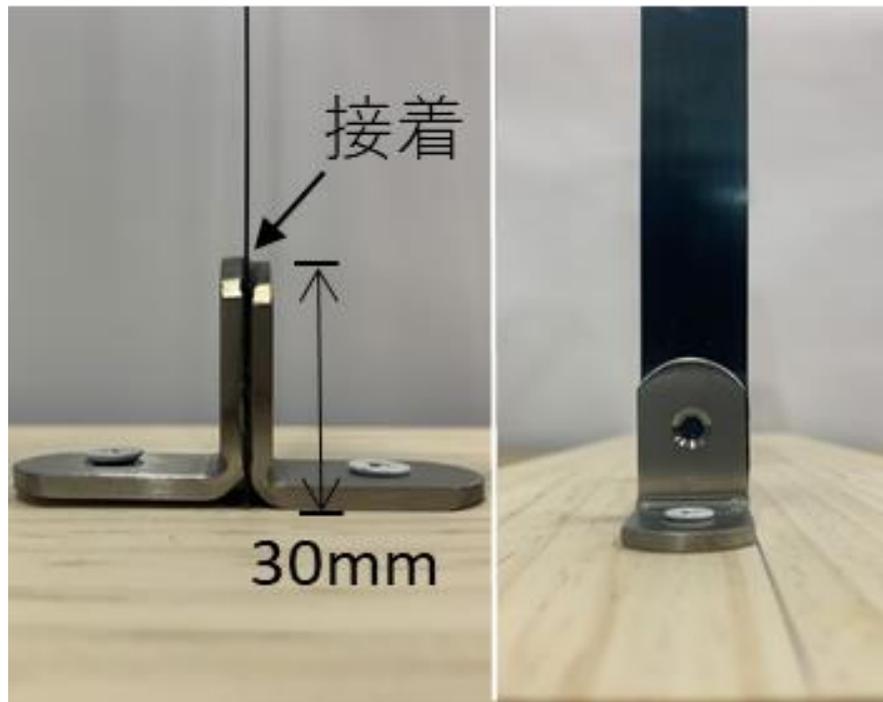
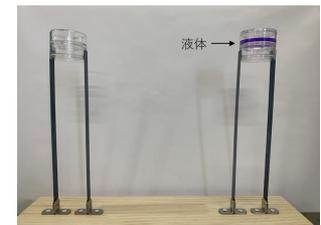
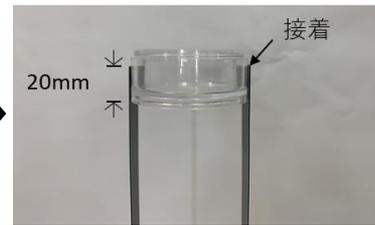
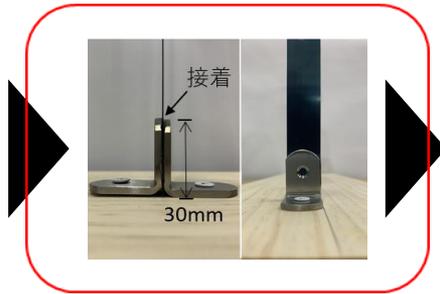
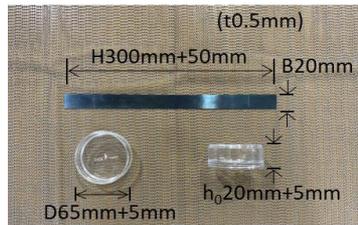
$$H = 0.306m \rightarrow 30cm$$

$T_m = T_s$

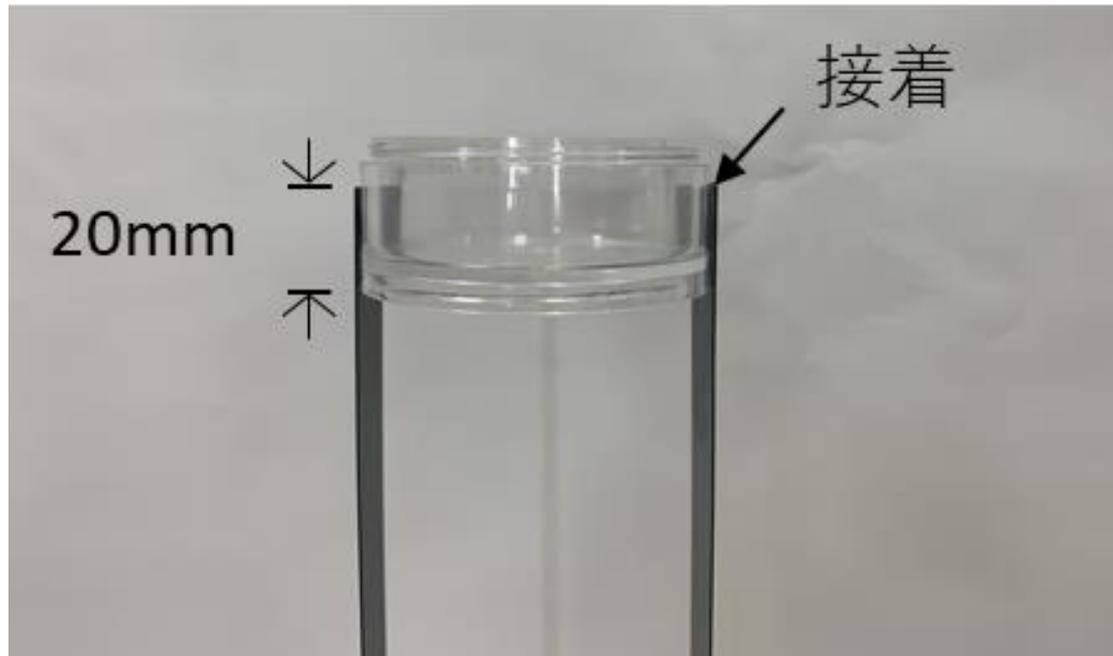
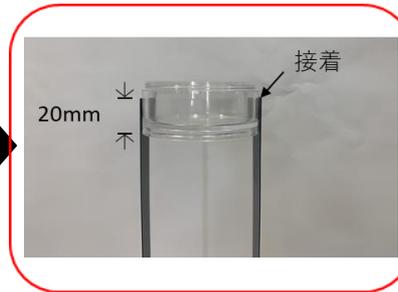
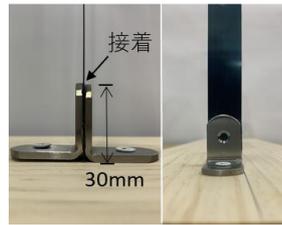
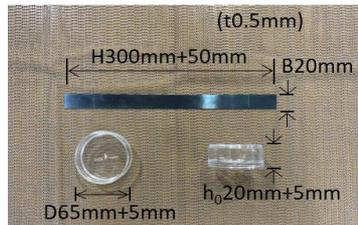
SMD模型の制作



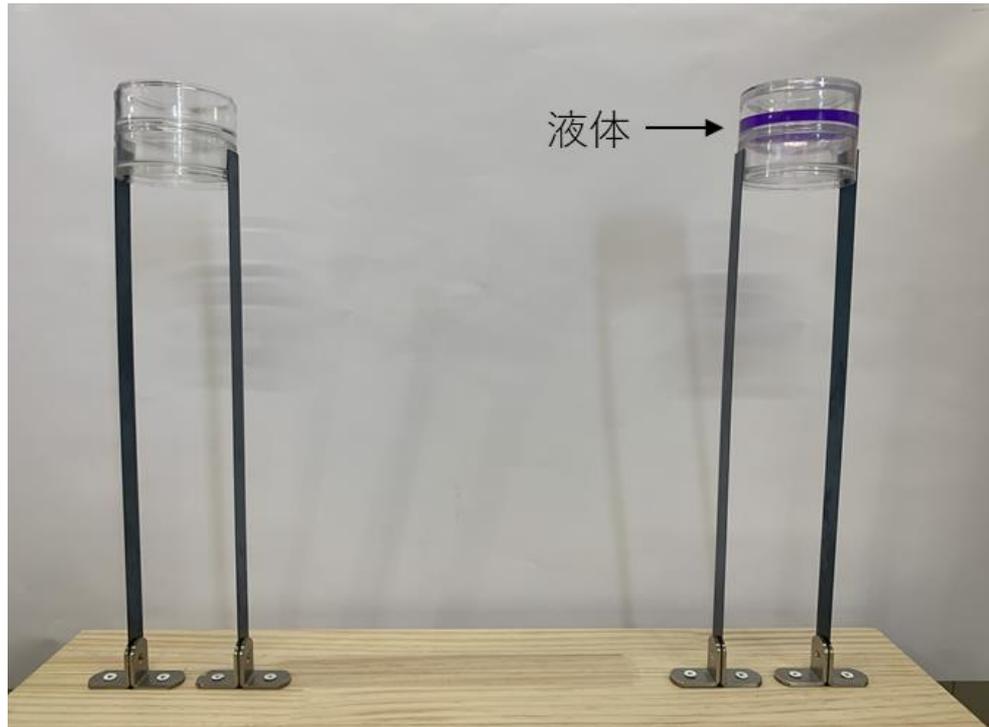
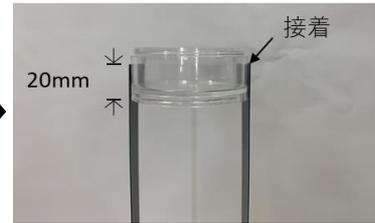
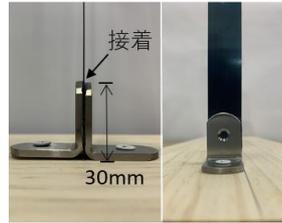
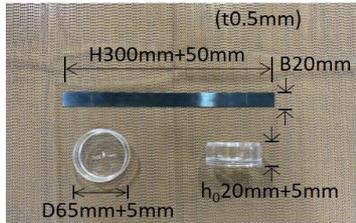
SMD模型の制作



SMD模型の制作

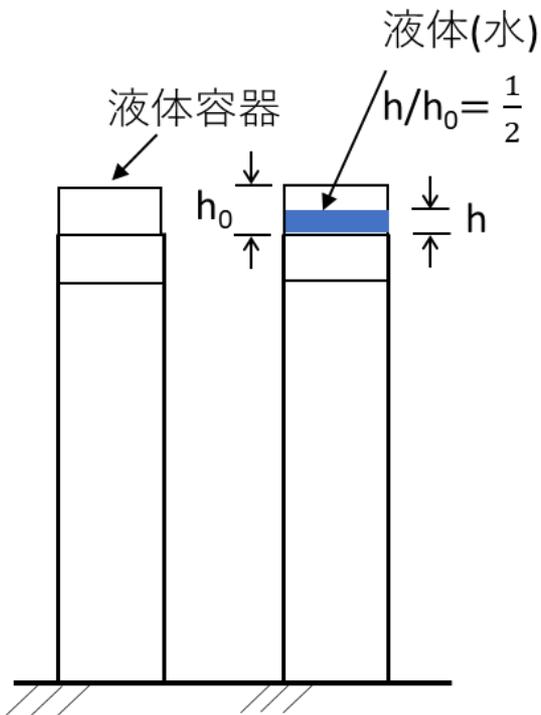


SMD模型の制作

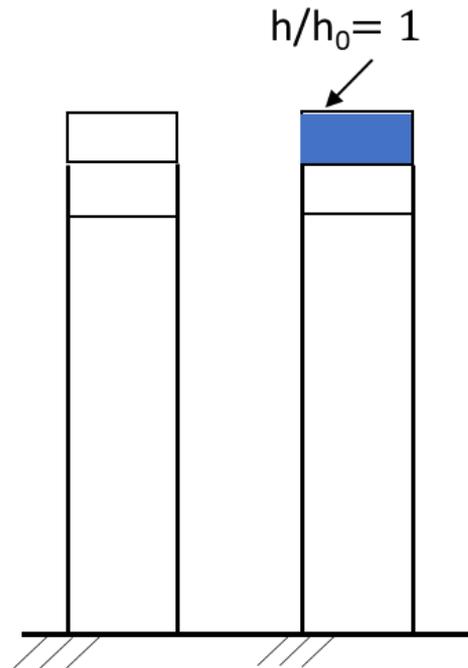


自由振動実験

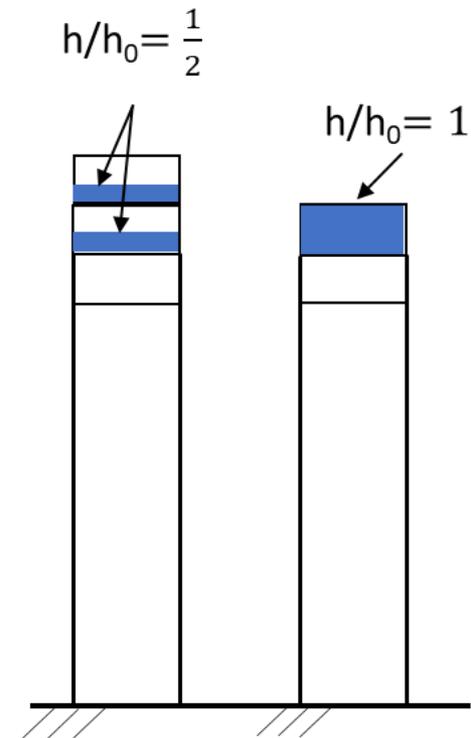
(a) $h/h_0=1/2$ の実験



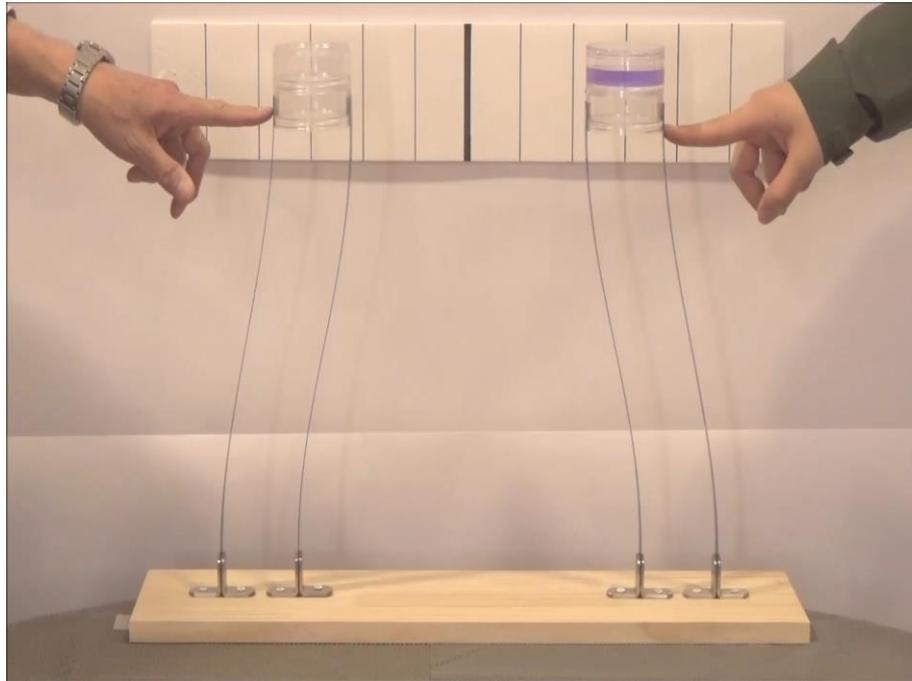
(b) $h/h_0=1$ の実験



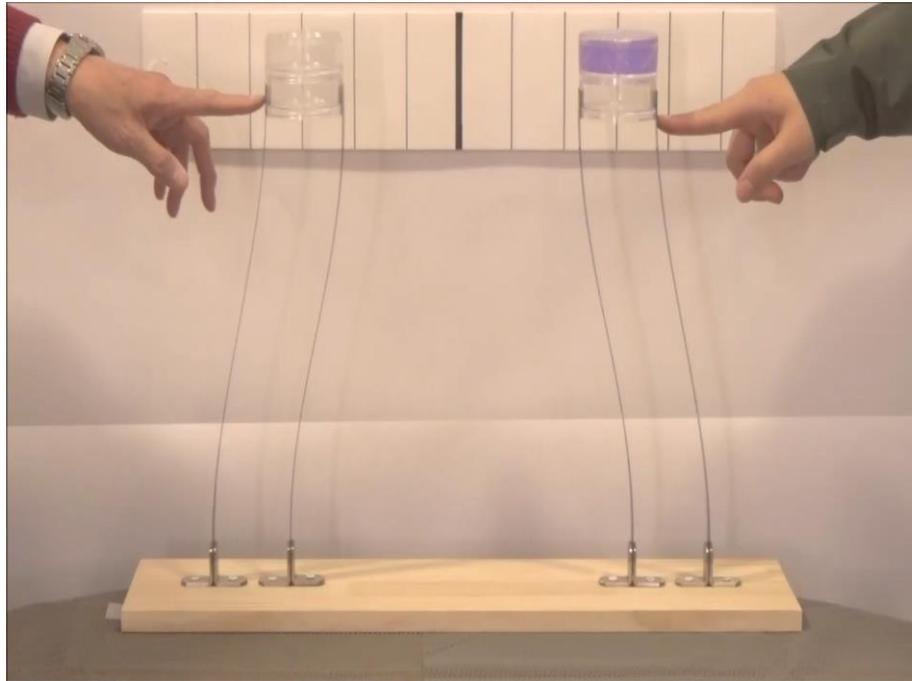
(c) $h/h_0=1/2$ (2段容器)の実験



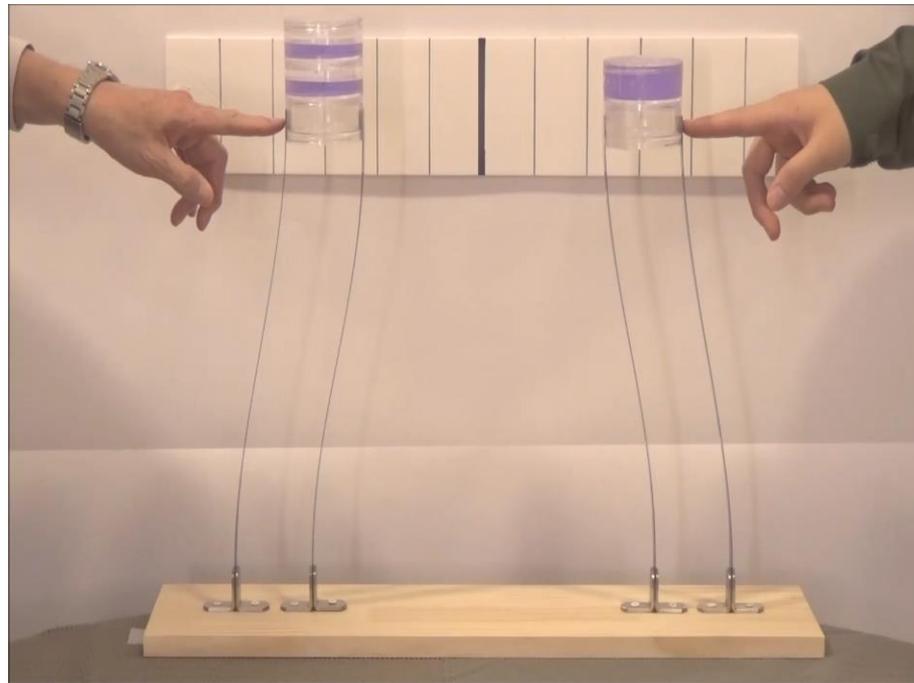
(a)の実験ケース



(b)の実験ケース



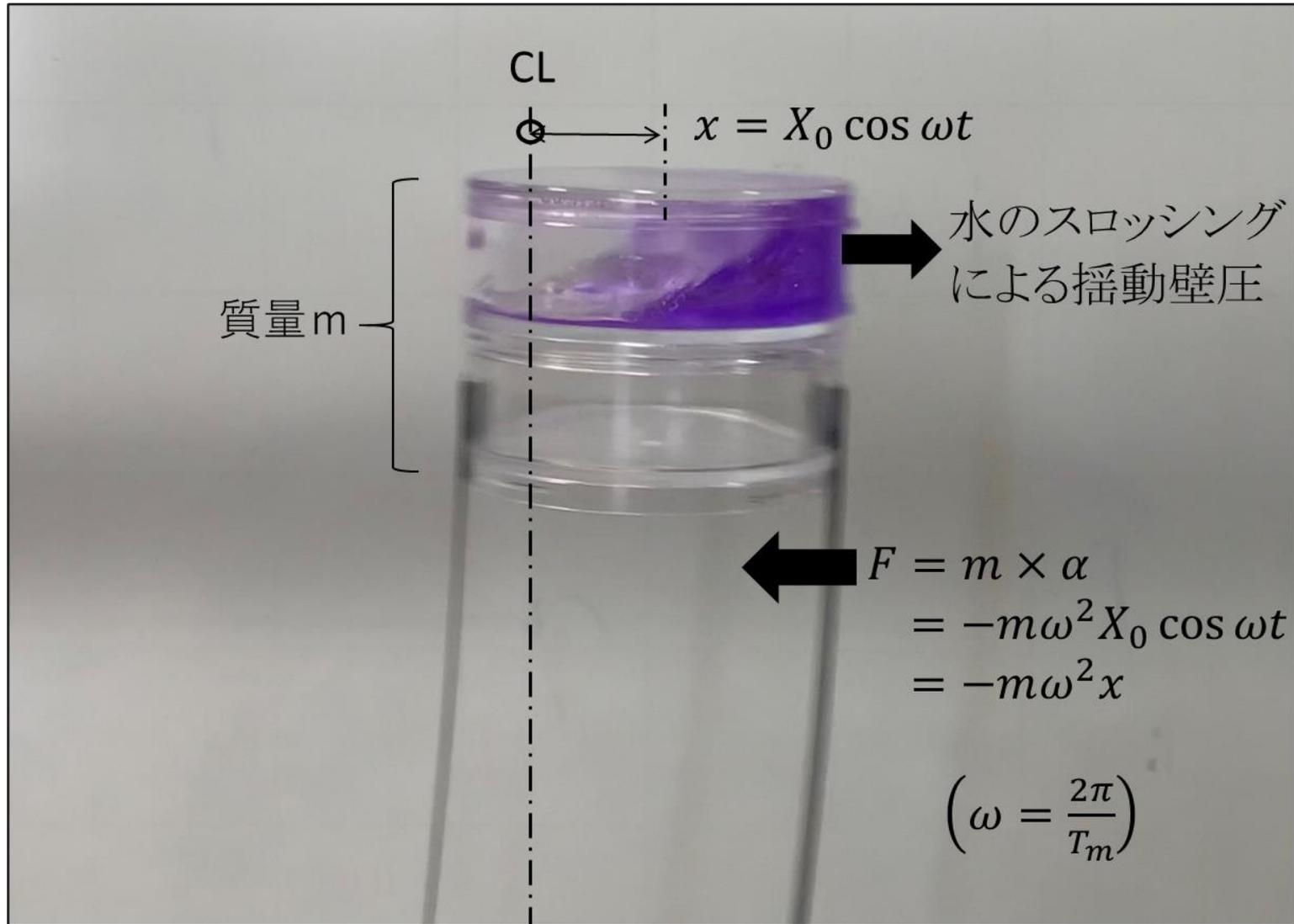
(c)の実験ケース



制振効果のメカニズム



制振効果のメカニズム



まとめ

- ①設計・制作してSMD模型開発を行った
- ②自由振動実験による制振効果の確認
- ③学習教材としての活用

