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Flow-induced vibration characteristics of the U-type Coriolis mass flowmeter with liquid hydrogen

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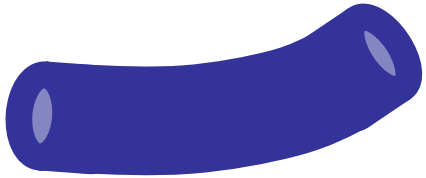
Establishment and validation of model



Curved tube

Establishment of model

$$\frac{\partial^4 v}{\partial s^4} - \frac{GJ}{EIa^2}\frac{\partial^2 v}{\partial s^2} - \frac{1+GJ/EI}{a}\frac{\partial^2 \Phi}{\partial s^2} + \frac{2M_f}{EI}U\frac{\partial^2 v}{\partial s \partial t} + \frac{M_f}{EI}U^2\frac{\partial^2 v}{\partial s^2} + \frac{M_t + M_f}{EI}\frac{\partial^2 v}{\partial t^2} = 0$$

$$\frac{\partial^2 \Phi}{\partial s^2} - \frac{EI}{a^2 GJ}\Phi + \frac{1}{a}\left(1 + \frac{EI}{GJ}\right)\frac{\partial^2 v}{\partial s^2} = 0$$

Validation of model

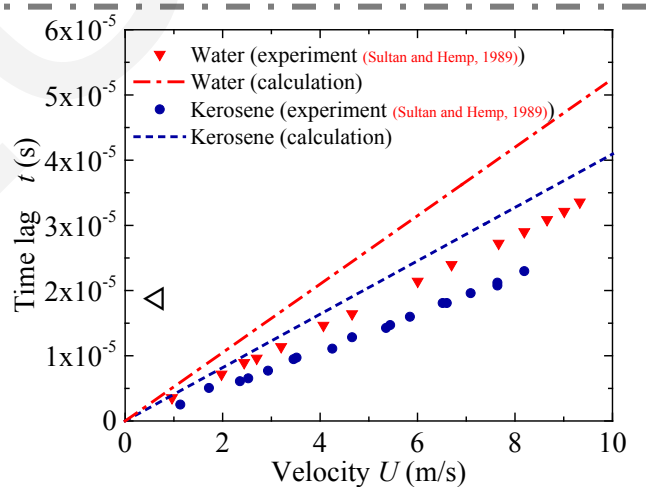
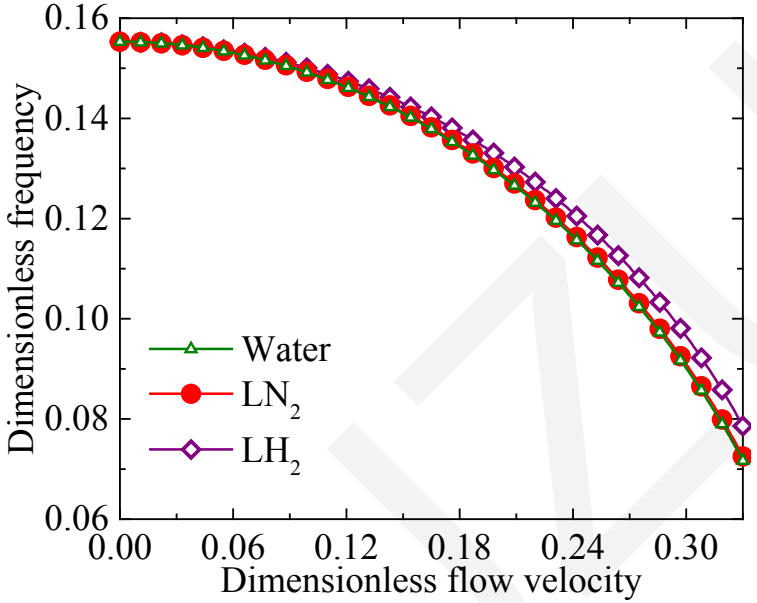


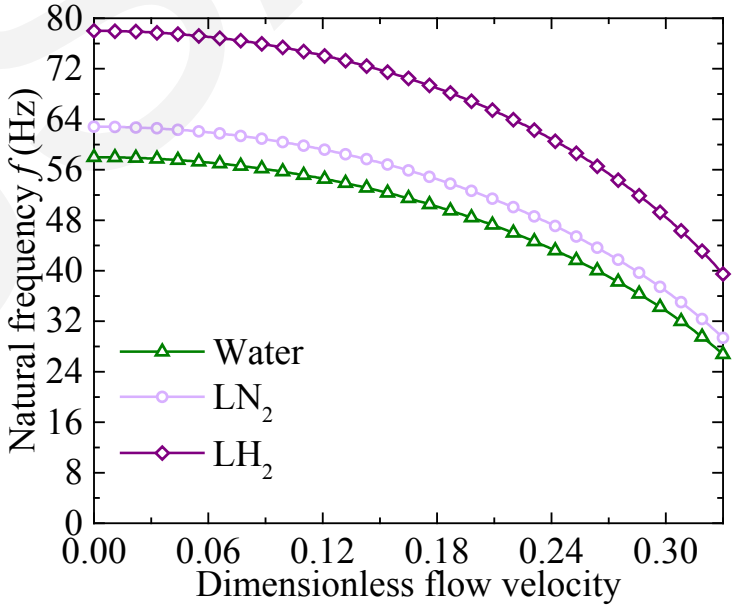
Fig. 1 Comparison of the theory with the experimental value

Effect of flow velocity

The natural frequency of the measuring tube will gradually decrease with the increase of the flow velocity. And for the measuring tube filled with different fluids, the relationship of the natural frequency of the tube with the fluid velocity is also different.



(a). Variation of the dimensionless natural frequency with the dimensionless flow velocity

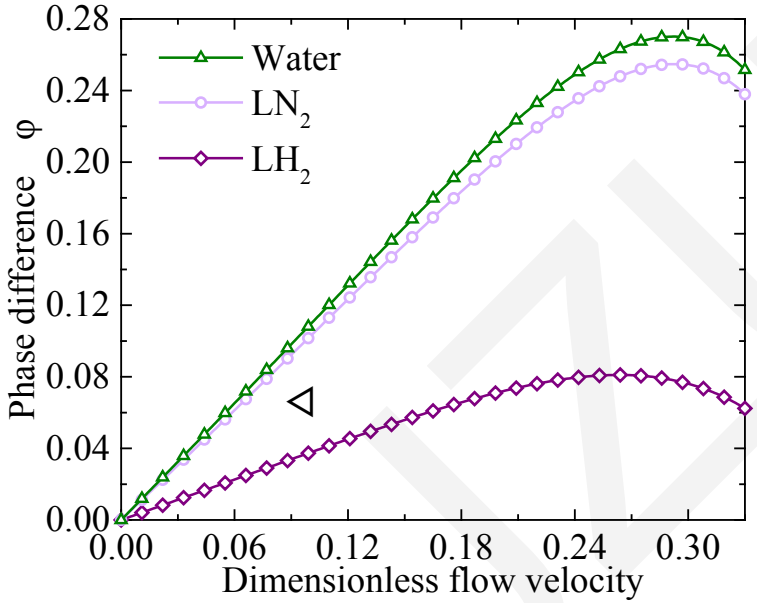


(b). Variation of excitation frequency with the dimensionless flow velocity

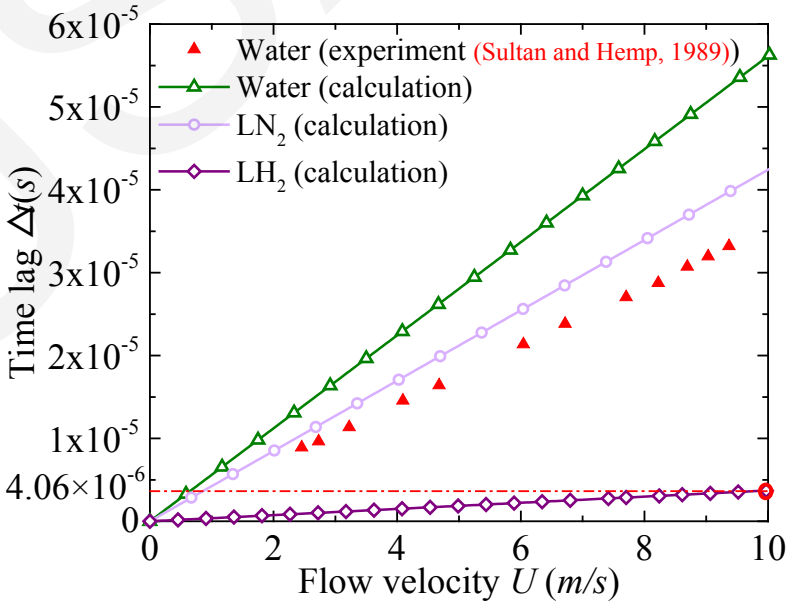
Fig. 2 Effect of flow velocity on the measuring tube frequency

Effect of flow velocity

In a certain flow velocity range, the time lag and the phase difference is linear with the flow velocity, and the relationship corresponding to different fluids will also be different. The time lag corresponding to LH_2 is an order of magnitude smaller than the water and LN_2.



(a). Change of phase difference with the dimensionless flow velocity

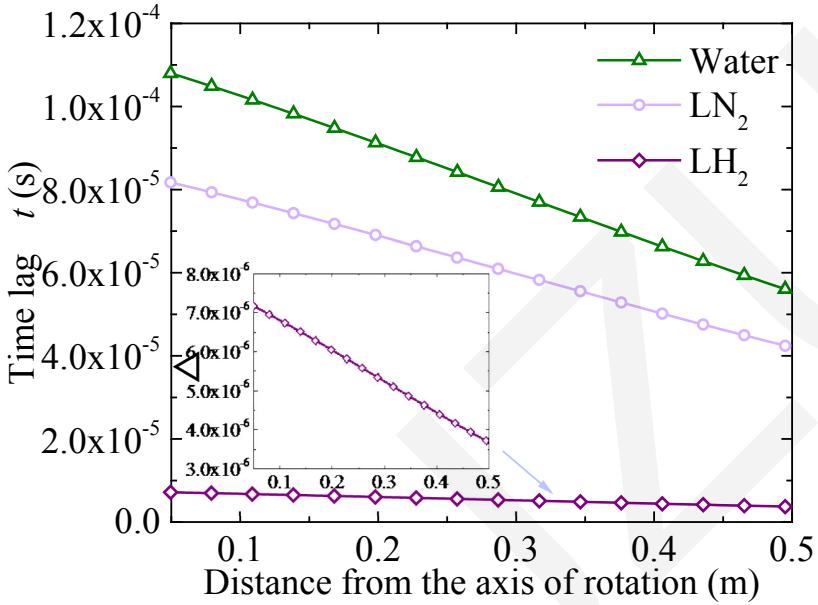


(b). Change of time-lag with the fluid flow velocity

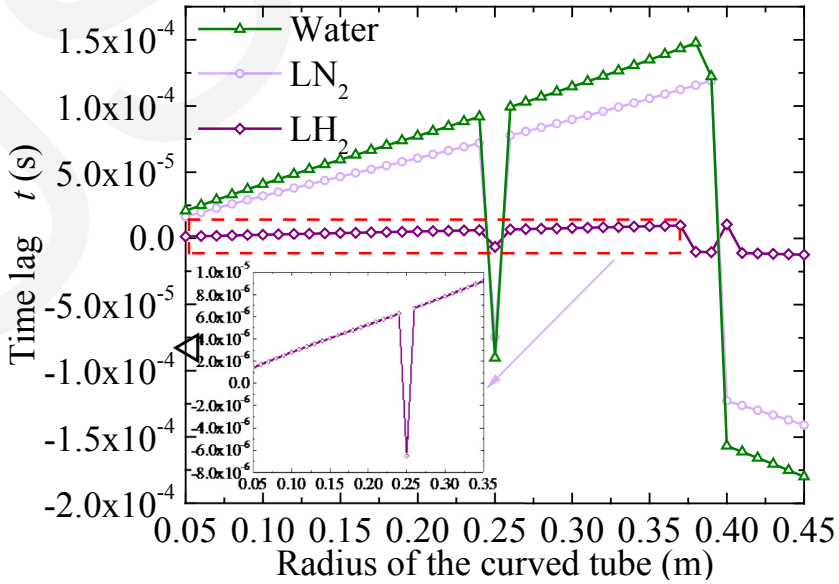
Fig. 3 The change of phase difference and time lag with flow velocity

Effect of flow velocity

The detector position and the geometric parameters of the measuring tube can significantly affect the time lag. The time lag decreases as the detector is far away from the axis and increases as the curved tube radius increases.



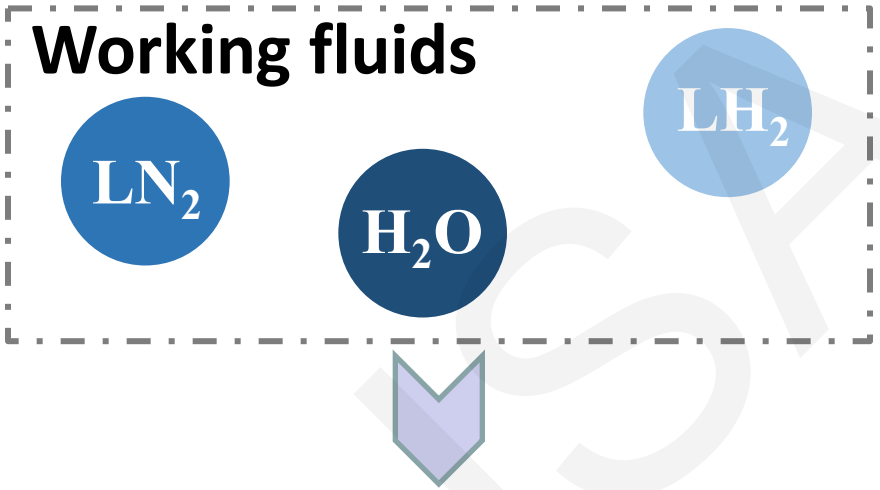
(a). Variation of time lag with the position of the detector from the axis



(b). Time lag changes with the radius of the curved tube

Fig. 4 Effect of detector position and geometric parameters on the time lag

Conclusions



- ✓ The time lag of LH_2 is one order of magnitude smaller than that of water and LN_2.
- ✓ Errors will be generated if the mass flow rate of LH_2 is measured with CMF calibrated with water and LN_2.
- ✓ The time lag decreases as the sensor moves away from the axis of rotation of the CMF.
- ✓ When the length of the straight pipe is constant, the time lag will gradually increase as the radius of the curved pipe increases.