

Computational fluid dynamics analysis on flow-induced vibration of a cryogenic poppet valve in consideration of cavitation effect

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Research background and simplified model

The valve plug will withstand **unbalanced pressure** during the switching process due to the complex **fluid-structure interaction (FSI)**, especially **with the occurrence of cavitation**, resulting in a convoluted generation and propagation of mechanical and fluid-dynamic vibrations.

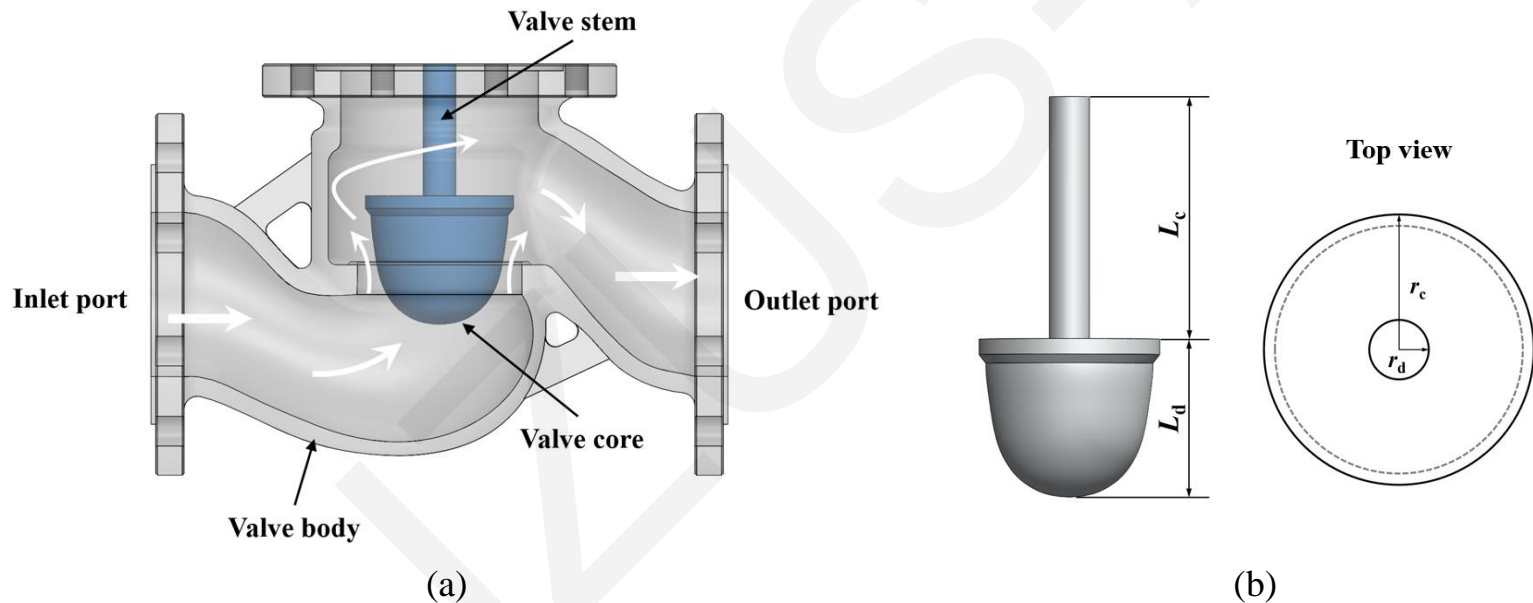


Fig. 1. The two-way cryogenic poppet-type control valve
(a) Overall structure; (b) The valve stem and valve disc

Dynamic characteristics of valve disc

Both the displacement and velocity of the valve disc vary periodically with time. The first impact time for cavitation flow is two cycles later than for the non-cavitation flow.

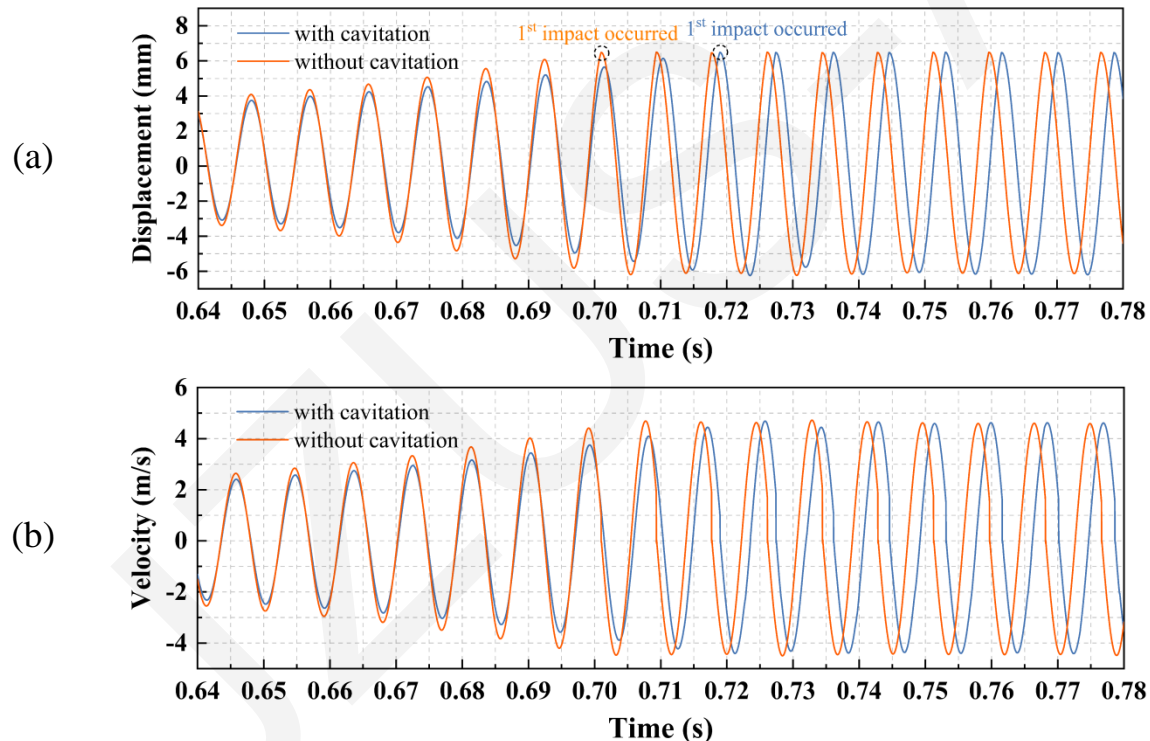


Fig. 2. Comparison of temporal evolutions of the valve disc movement with or without cavitation (a) Displacement; (b) Velocity

Cavitation flow field analysis

The cavitation **distribution and intensity** evolves periodically with the valve disc movement. At the moment of the impact, the pressure in the region behind the valve disc **greatly decreases** due to the inertia of the fluid, leading to **violent cavitation**.

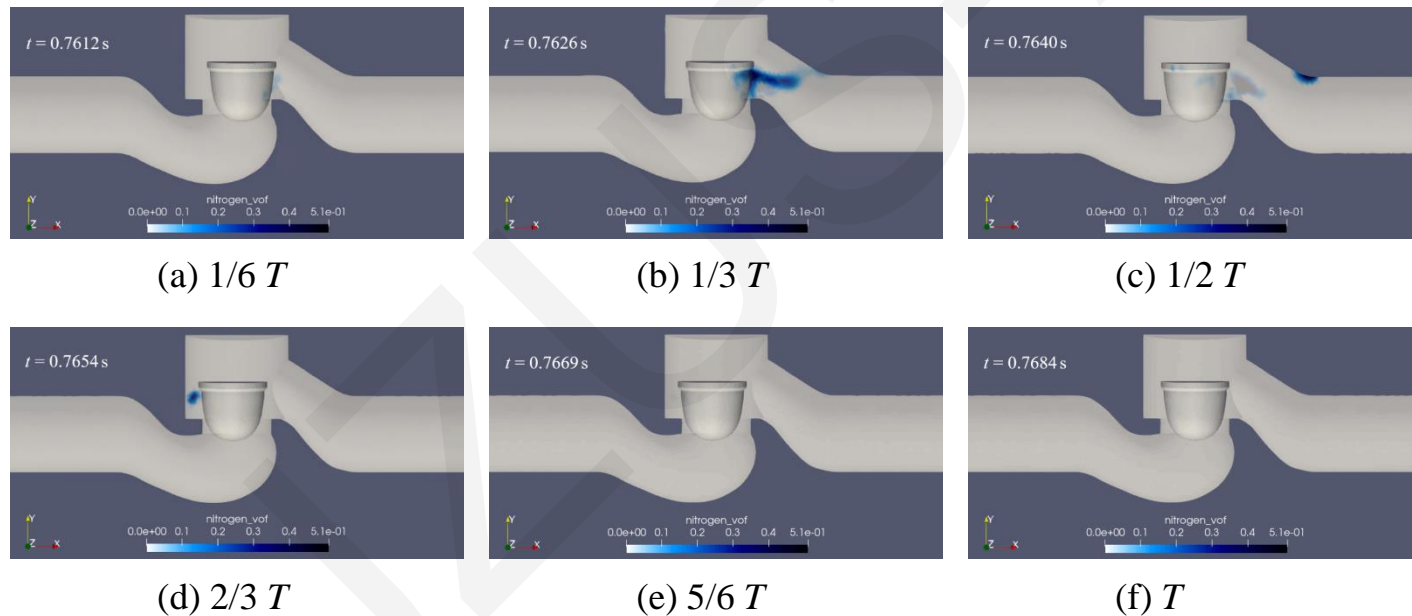


Fig. 3. Contours of the evolution of vapoious nitrogen volume fraction in a single period of vibration

Cavitation flow field analysis

With the valve disc moving far to the right, there is a sudden increment of velocity along with a **sudden decline of pressure** in the convergent-divergent section, and cavitation on the right side **intensifies gradually**.

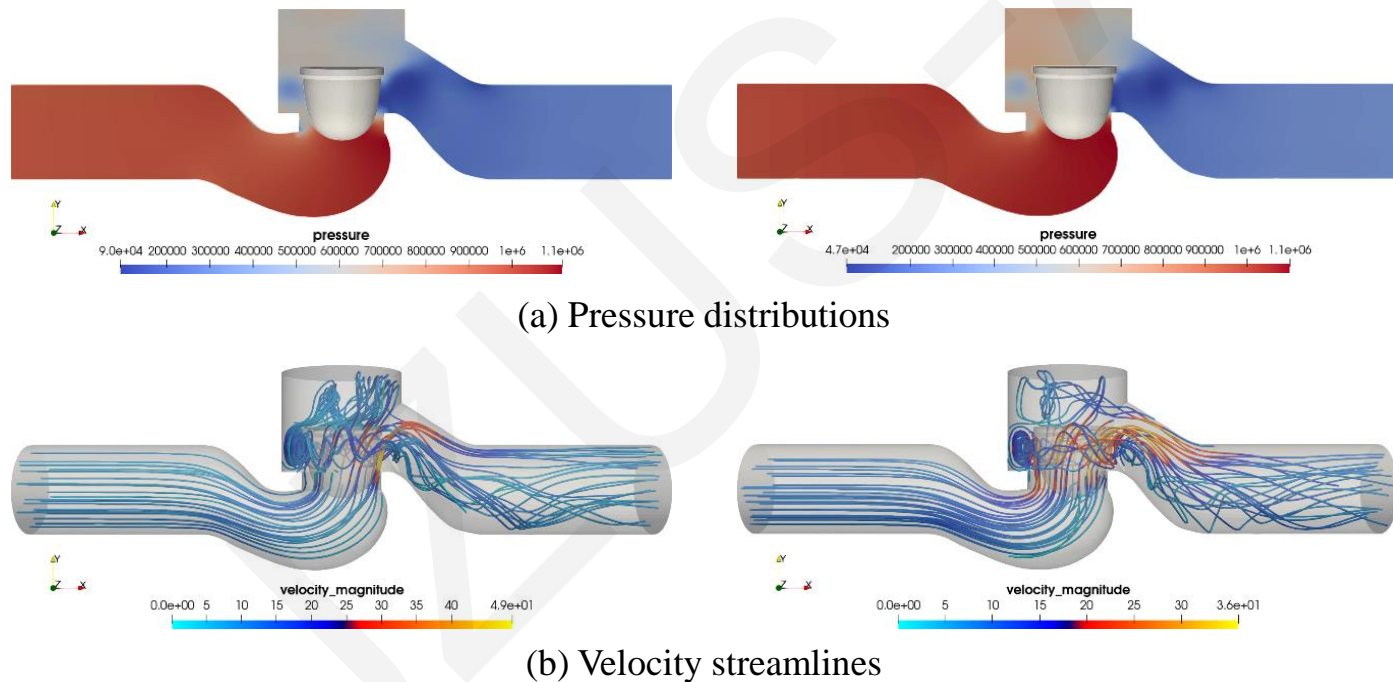


Fig. 4. Pressure distributions and velocity streamlines at different distances between valve disc and valve seat (left: 6.7 mm; right: 0.8 mm)

Parametric analysis and Conclusions

- With the **increase of the pressure difference**, the amplitude for pressure fluctuations as well as the average impact velocity increases, and the first impact time decreases.

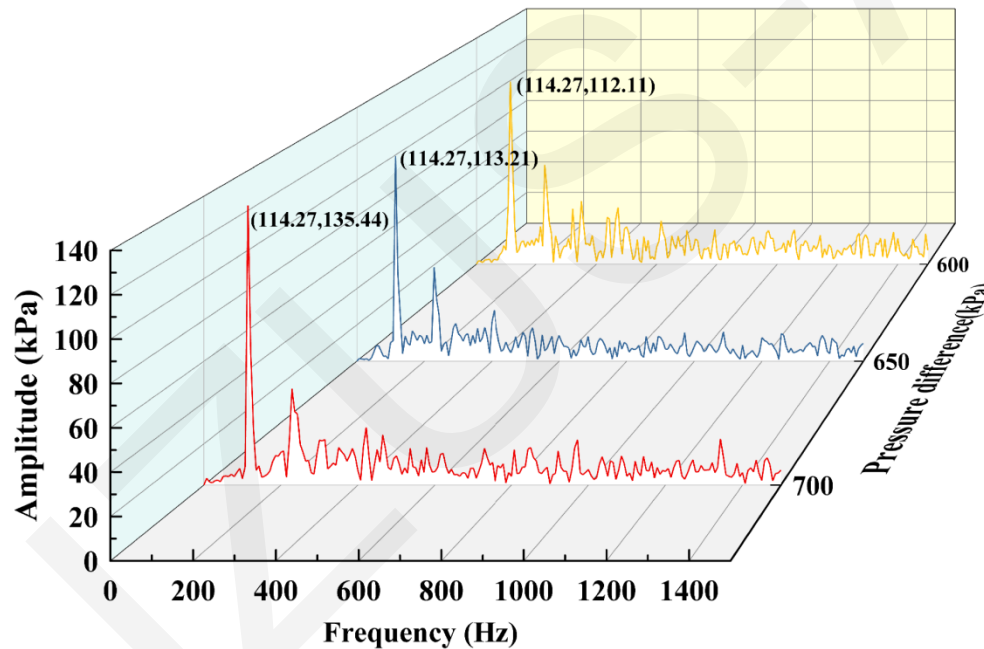


Fig. 5. Comparison of the frequency spectrum (FFT) of pressure variations for monitored point under different pressure difference conditions

Parametric analysis and Conclusions

- With the increase of **valve opening**, both the dominant frequency and the maximum displacements of the valve disc decrease, and the amplitude of pressure fluctuations also decreases.

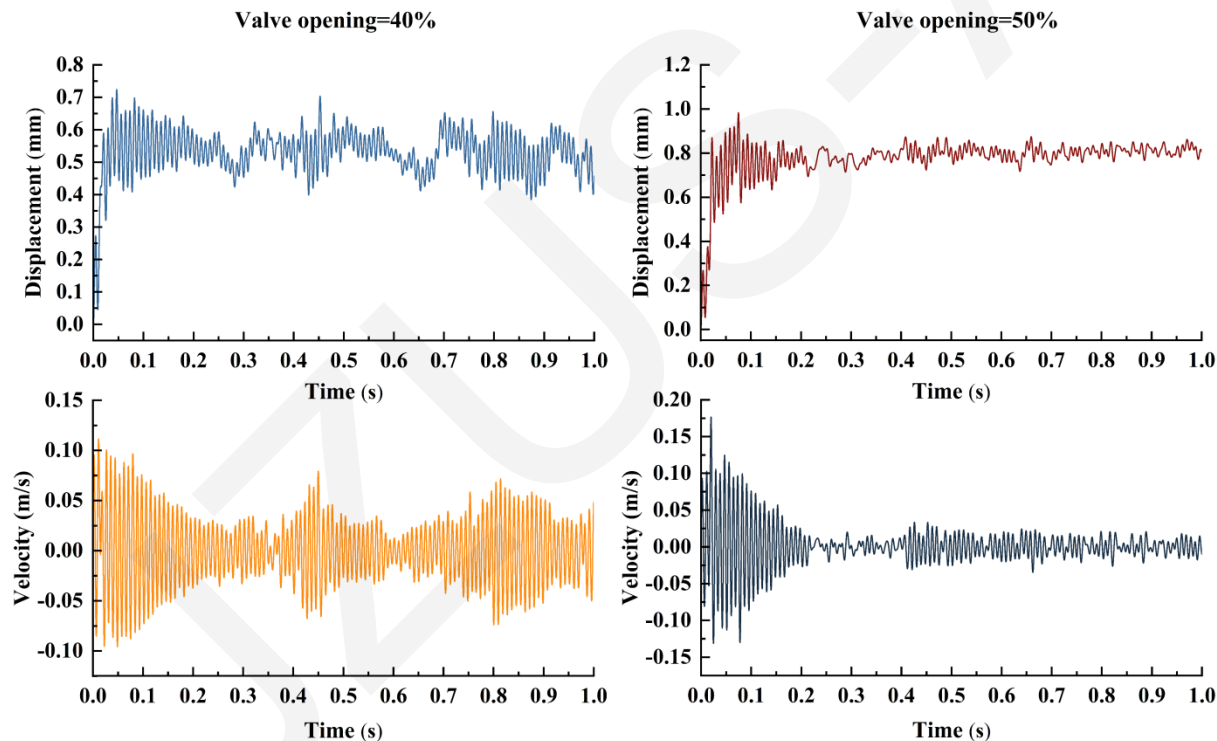


Fig. 6. Temporal evolutions of valve disc displacements and velocities for valve opening of 40% and 50% for LN₂ flow ($P_{in} = 1000$ kPa)