Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

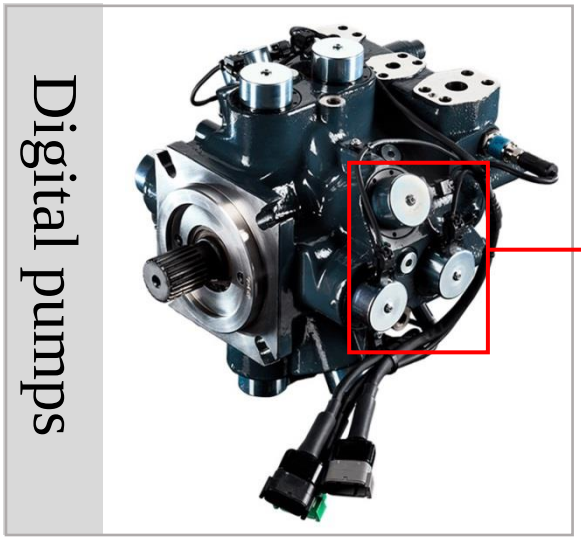
Geometrical transition properties of vortex cavitation and associated flow-choking characteristics in poppet valves

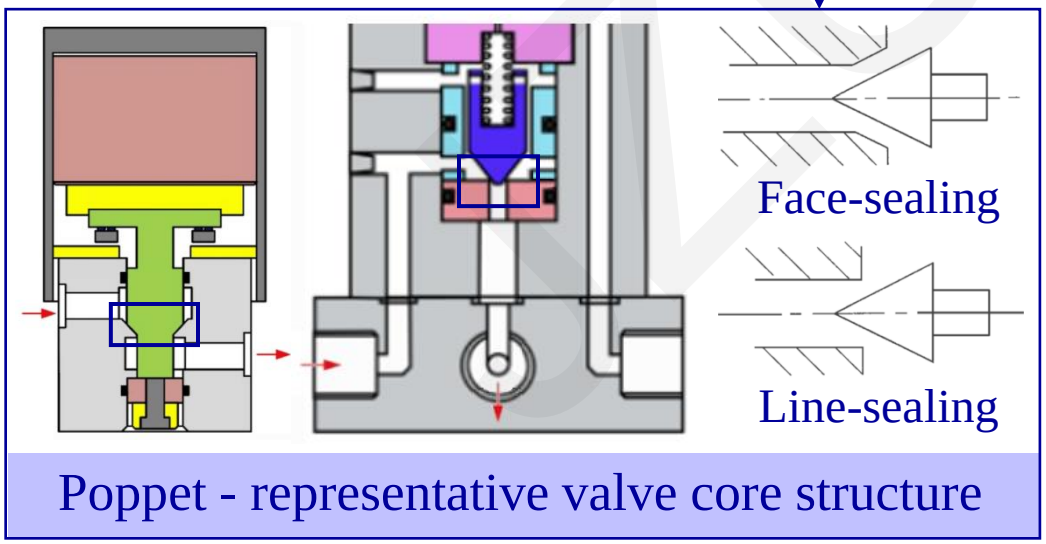
Liang LU, Zhongdong LIANG, Yuming LIU, Zhipeng WANG, Shohei Ryu

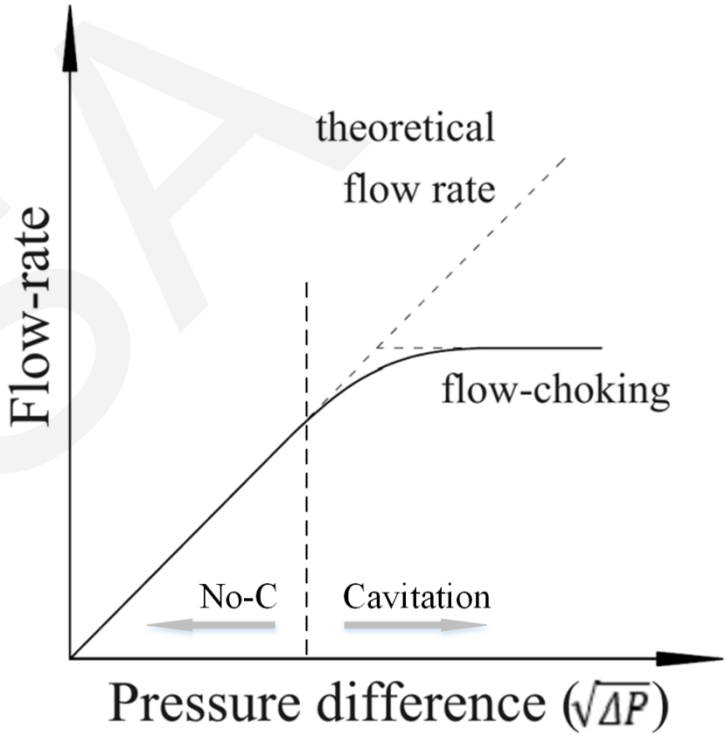
Key words:
Poppet valves, Vena contracta, Vortex flow, Vapor cavity, Flow-choking

Cite this as: Liang LU, Zhongdong LIANG, Yuming LIU, Zhipeng WANG, Shohei RYU, 2024. Geometrical transition properties of vortex cavitation and associated flow-choking characteristics in poppet valves. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 25(6):455-469. https://doi.org/10.1631/jzus.A2300114

Background







Cavitation at the valve notch frequently leads to **flow-choking** phenomena, which results in poor valve performance.

Methods

Experimental approach

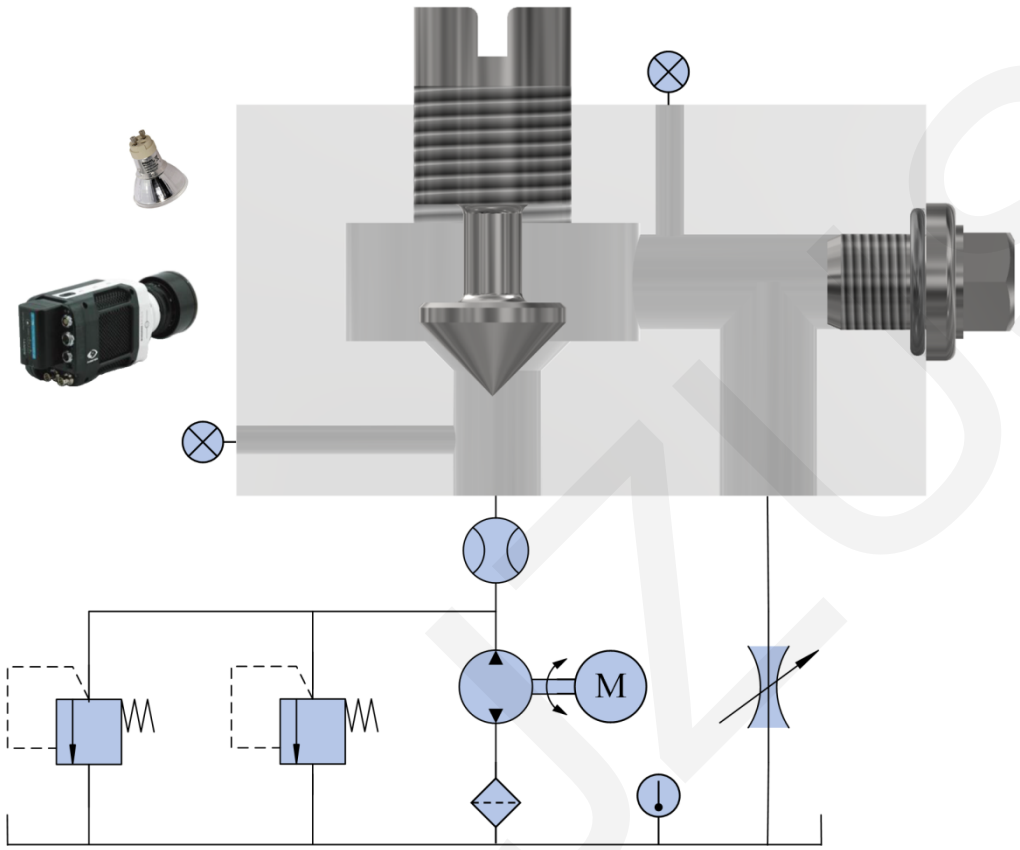


Fig. 1 Schematic of visualization experiment system

Numerical approach

- Rotationally symmetric geometry
- Large Eddy Simulation
- Mixture multiphase model
- Schnerr-Sauer cavitation model

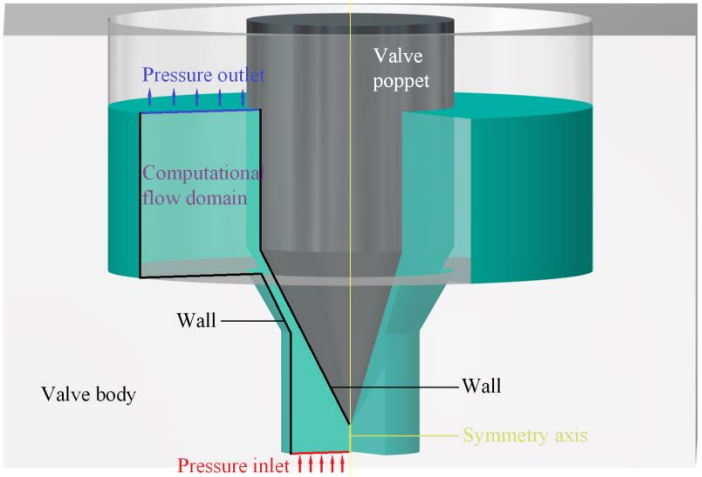


Fig. 2 Simplified computational flow domain

Results

Face-sealing - Thick-wall-orifice flow - Large-scale fixed vapor cavity
Line-sealing - Thin-wall-orifice flow - Discrete vapor cavities
Cavitation surge occurs in all cases, and the surge periodicity of fixed cavitation is more pronounced due to the constricted cavitation region.

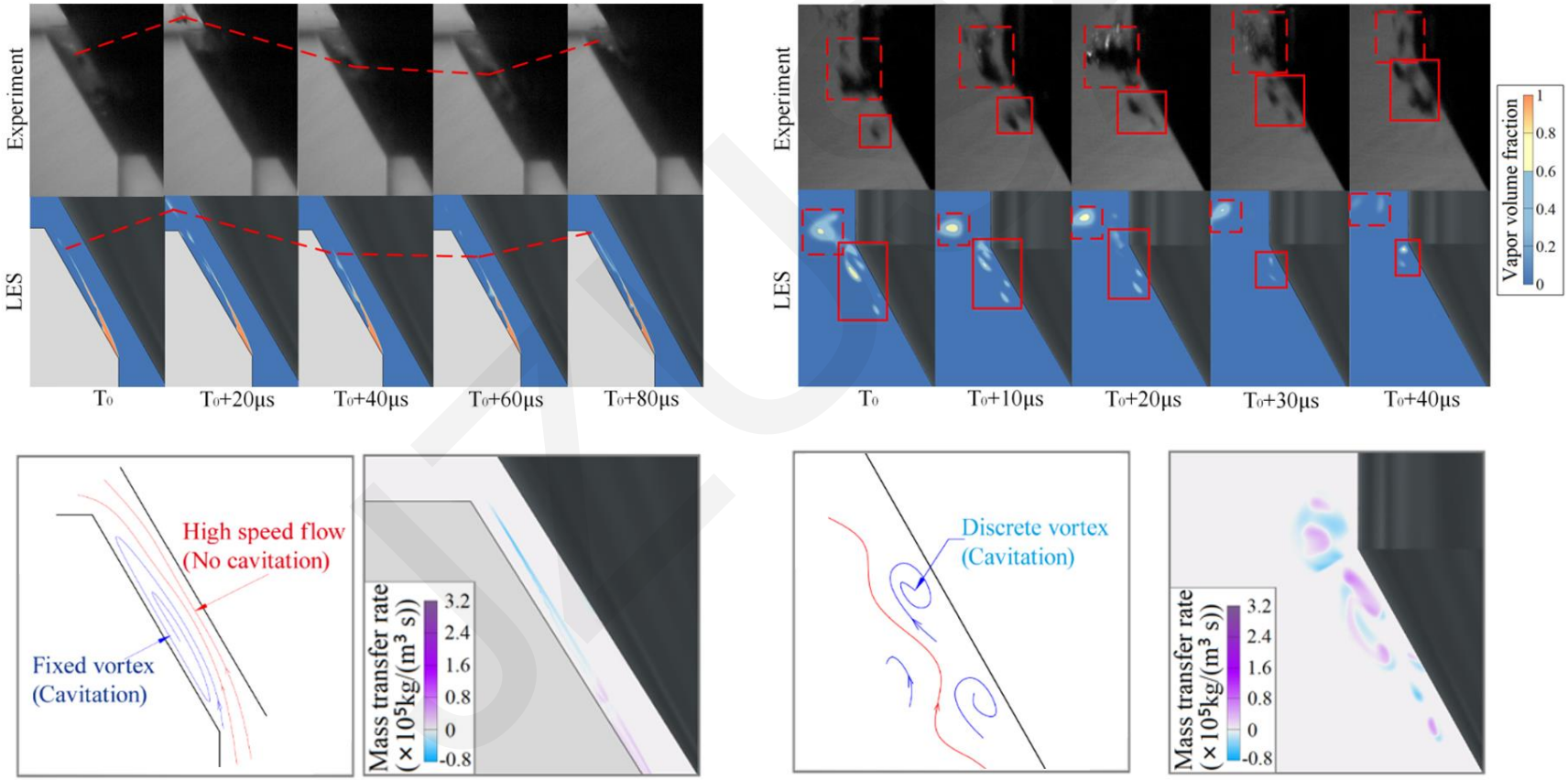


Fig. 3 Cavitation in two different geometries

Results

In structures similar to a thick-walled orifice, flow-choking is more severe.

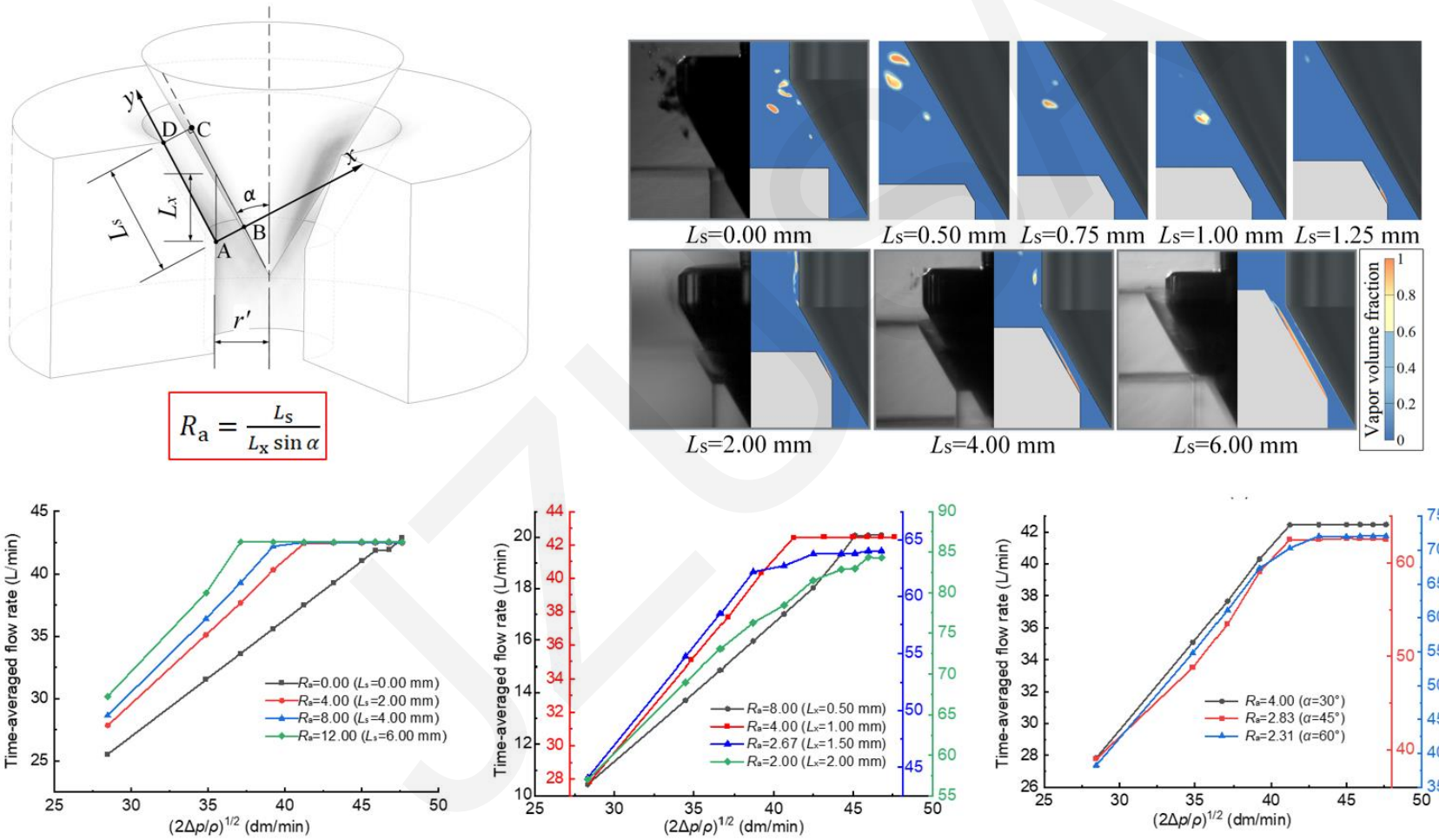


Fig. 4 Cavitation and flow-rate characteristics in different structures

Conclusions

- Cavitation at the notch of the poppet valve is induced by localized vortices. The distribution of vapor cavities is associated with the local low pressure caused by vortices.
- The properties of the vapor-cavity geometry and the vena contracta at the valve notch are determined by notch structure. The pressure condition only affects the number or scale of vapor cavities.
- The equivalent length-to-diameter ratio (R_a), determined by the valve opening, sealing length, and throttling angle, can serve as an indicator of flow-choking. For structures with larger R_a, the internal vena contracta dominates, producing large-scale vapor cavity, and leading to significant flow-choking.
- The R_a threshold is estimated to be approximately 2.