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Cavitation evolution and damage by liquid nitrogen in a globe valve

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Numerical Model and Validation

Physical Model and Grids:

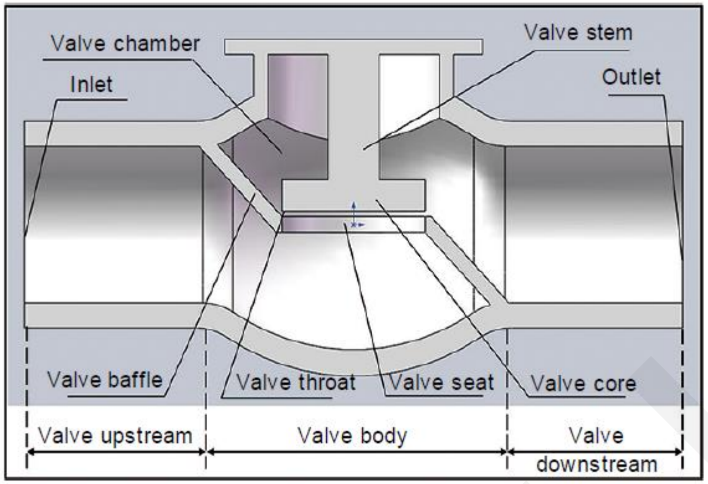

Fig. 1 Schematic structure of the cryogenic globe valve

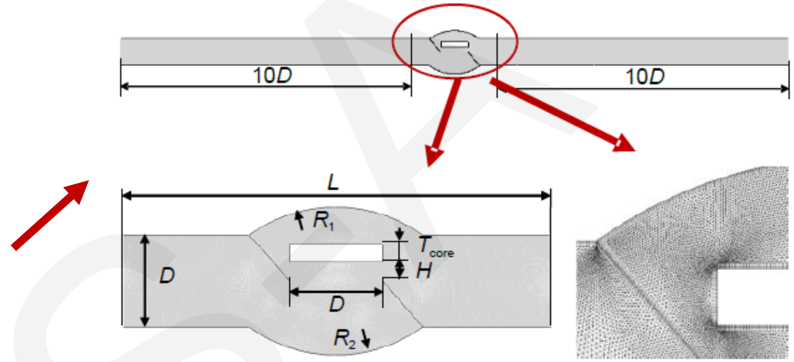

Fig. 2 Two-dimensional model of the cryogenic globe valve

Numerical Model:

- realizable k-ε model
- Mixture model
- Schnerr-Sauer cavitation model

Validation:

Table 2 Validation results for the numerical model of the hydrofoil compared to experimental results

Temperature (K)				Pressure (Pa)			
Position	Experiment (Hord, 1973)	Simulation	Deviation	Position	Experiment (Hord, 1973)	Simulation	Deviation
T1	81.13	80.95	−0.22%	P1	166200	155698	−6.32%
T2	81.53	81.68	0.18%	P2	169000	164310	−2.77%
T3	82.02	82.60	0.71%	P3	177100	177819	0.41%
T4	82.83	83.25	0.51%	P4	346600	368680	6.37%
T5	82.89	83.19	0.36%	P5	383800	369310	−3.78%

Results

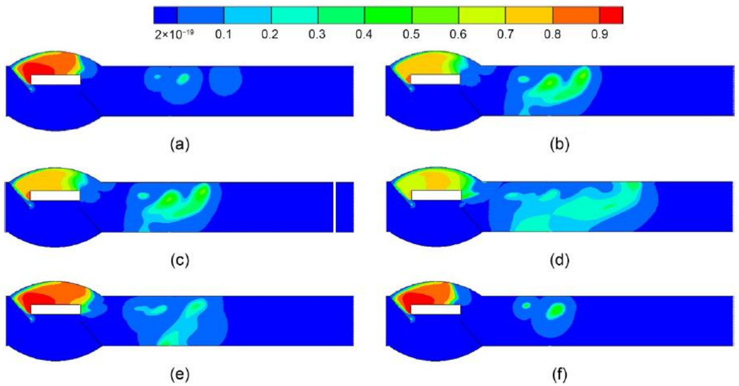

Fig. 6 Vapor volume fraction distributions in one period under 33% opening (1 stands for pure gas): (a) *t*; (b) *t*+32 ms; (c) *t*+43 ms; (d) *t*+70 ms; (e) *t*+118 ms; (f) *t*+133 ms

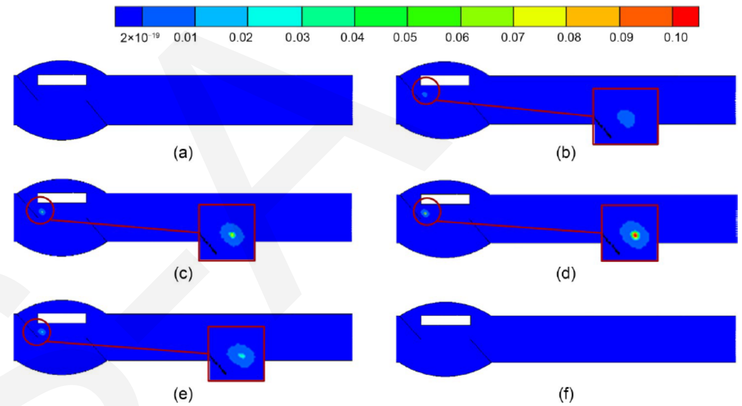

Fig. 8 Vapor volume fraction distributions in a period under 100% opening (1 stands for pure gas): (a) *t*; (b) *t*+1 ms; (c) *t*+2 ms; (d) *t*+5 ms; (e) *t*+6 ms; (f) *t*+7 ms

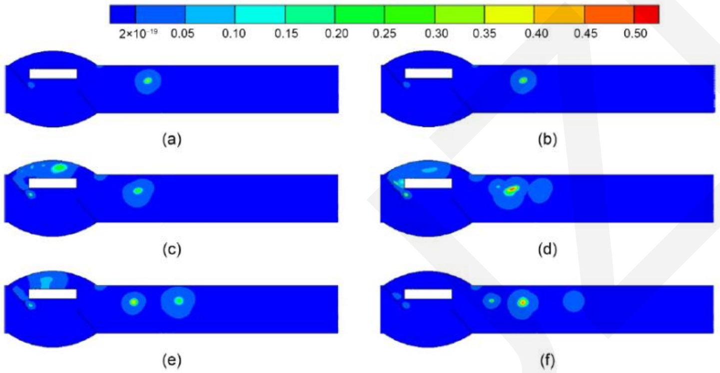

Fig. 7 Vapor volume fraction distributions in one period under 66% opening (1 stands for pure gas): (a) *t*; (b) *t*+7 ms; (c) *t*+16 ms; (d) *t*+20 ms; (e) *t*+28 ms; (f) *t*+31 ms

Vapor volume distributions under openings of 33%, 66% and 100%

Results

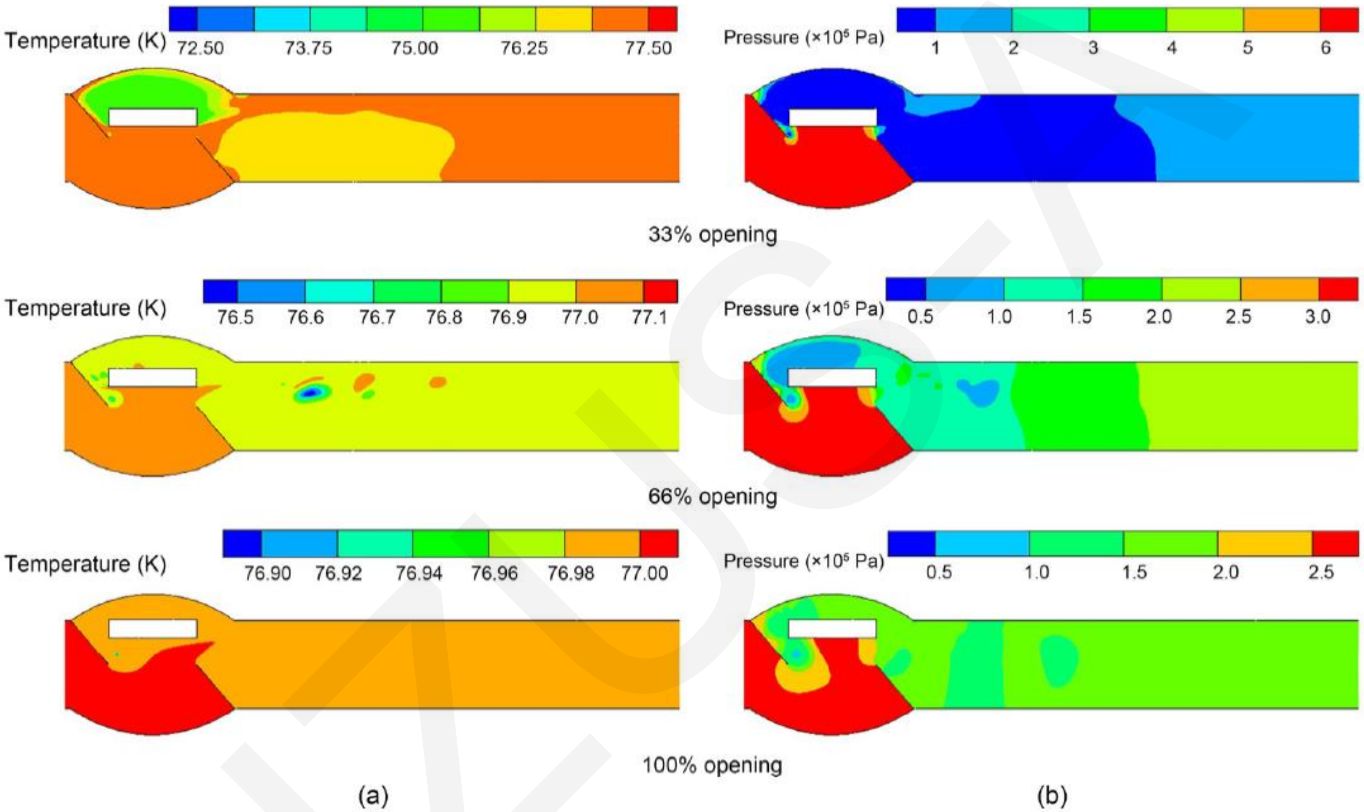

Fig. 9 Temperature distributions (a) and pressure distributions (b) at the maximum vapor volume fraction under each opening

Temperature and pressure distributions under openings of 33%, 66% and 100%

Results

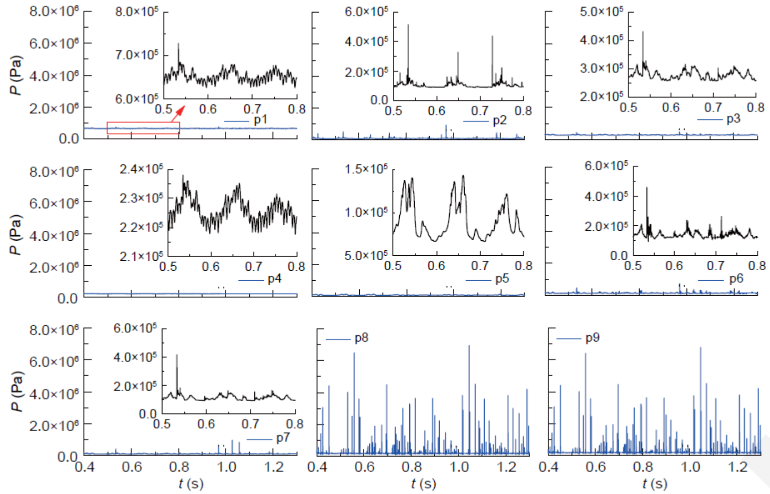

Fig. 12 Pressures of monitoring points under 33% opening. References to color refer to the online version of this figure

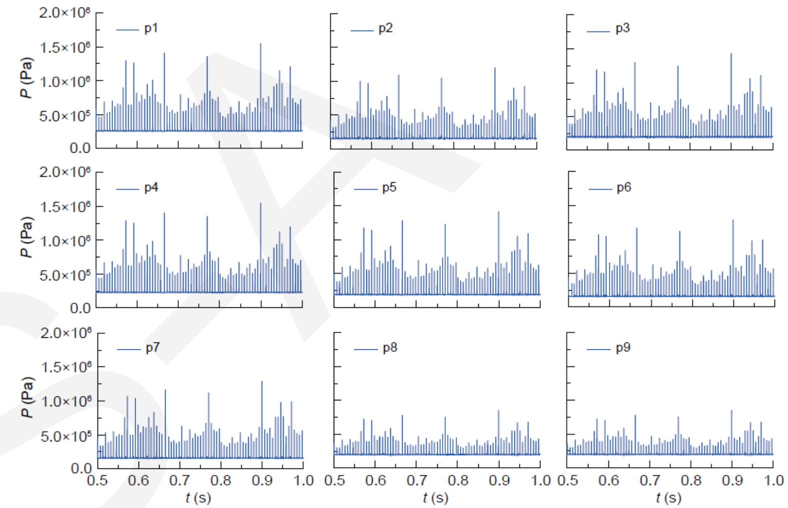

Fig. 15 Pressures of monitoring points p1–p9 under 100% opening

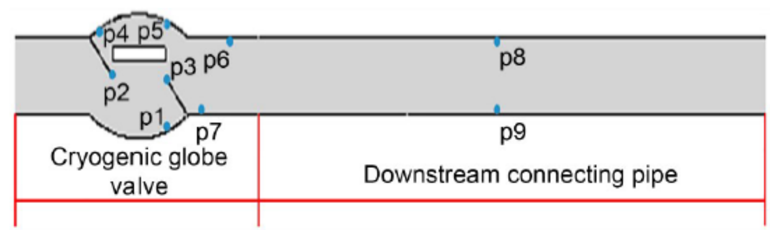

Fig. 11 Monitoring points along the wall surface of cryogenic globe valve and downstream pipe

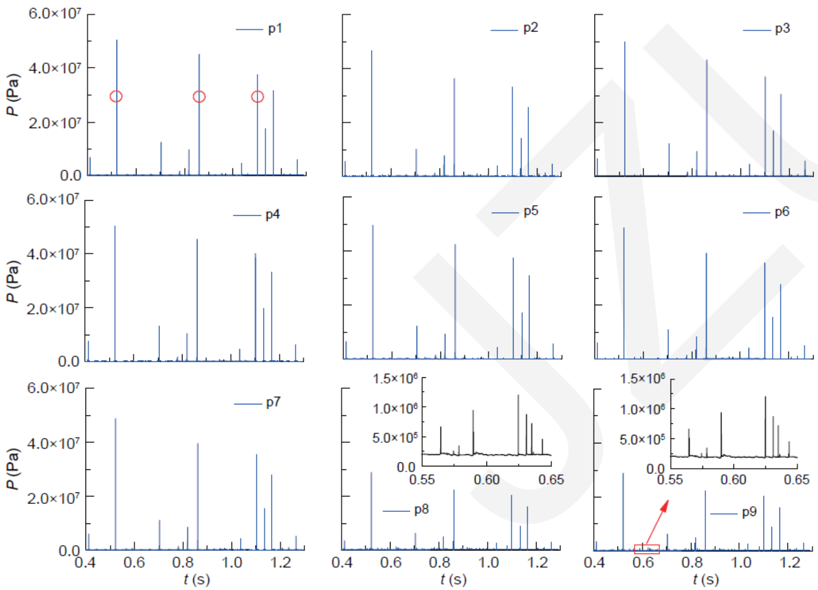

Fig. 13 Monitoring points' pressures under 66% opening

Pressure of monitoring points under openings of 33%, 66% and 100%

Results

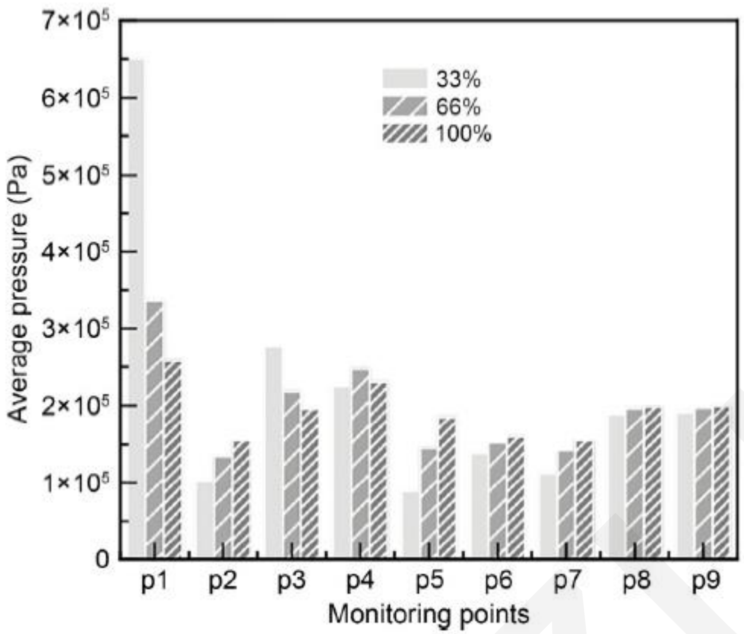

Fig. 17 Average pressures of monitoring points under various openings

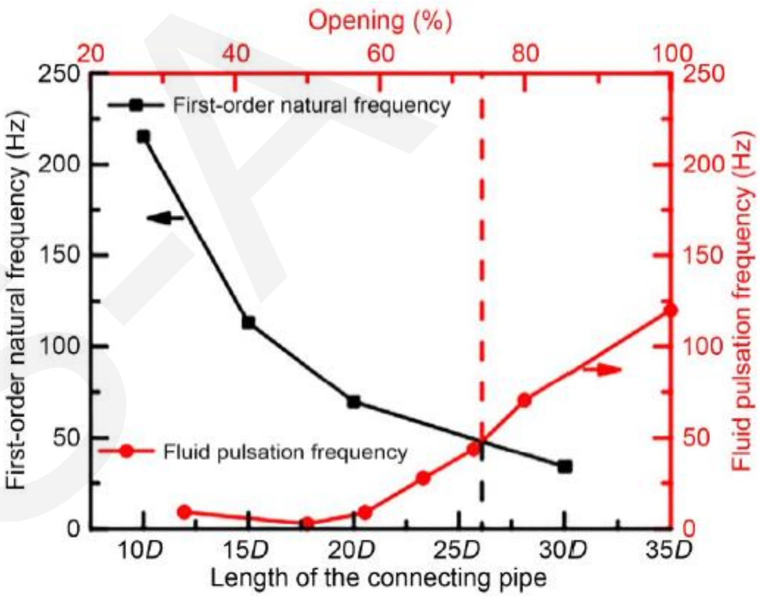

Fig. 20 First-order natural frequency of the valve system with different lengths of connecting pipes and fluid pulsation frequency under different openings

Average pressures of monitoring points under various openings (left)
Frequency analysis of valve system and fluid pulsation frequency (right)

Conclusions

- With the increase of the opening, the cavitation period and vapor volume fraction decrease significantly, and the cavitation location changes from the large area at the valve chamber and downstream pipe to the left baffle.
- The maximum pressure pulse appears under the middle opening of 66% with the maximum value reaching 50 MPa, about an order of magnitude larger than those of the 33% and 100% openings.
- The values of the natural frequency and the fluid pulsation frequency are equal with a connecting pipe length of 26D and a valve opening of 74%. This critical point can be used to guide the design of the connecting pipe length to avoid resonance.