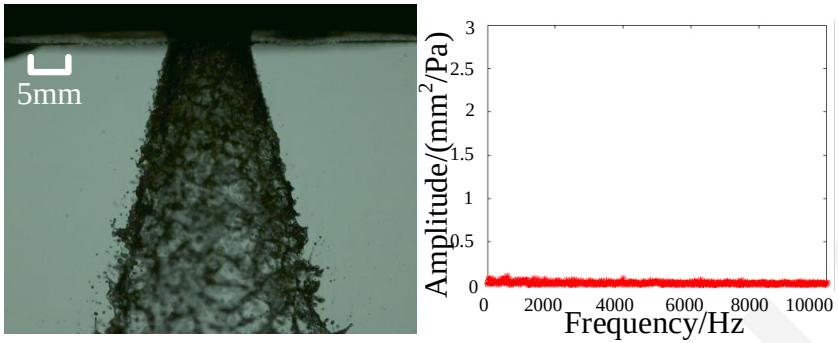
Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

Experimental and theoretical study on the break phenomenon of self-pulsation for liquid-centered swirl coaxial injectors

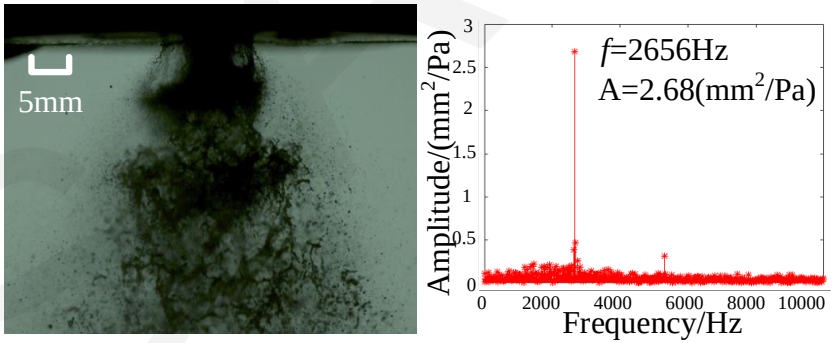
Peng-jin CAO, Xiao BAI, Qing-lian LI, Peng CHENG

Cite this as: Peng-jin CAO, Xiao BAI, Qing-lian LI, Peng CHENG, 2022. Experimental and theoretical study on the break phenomenon of self-pulsation for liquid-centered swirl coaxial injectors. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 23(2):140-155. https://doi.org/10.1631/jzus.A2100222

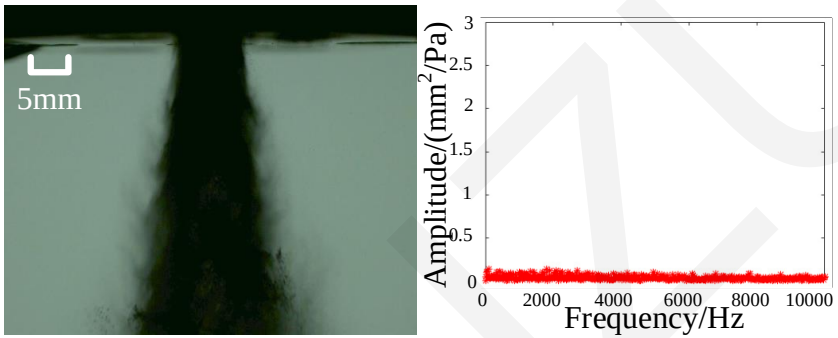
The break phenomenon of self-pulsation



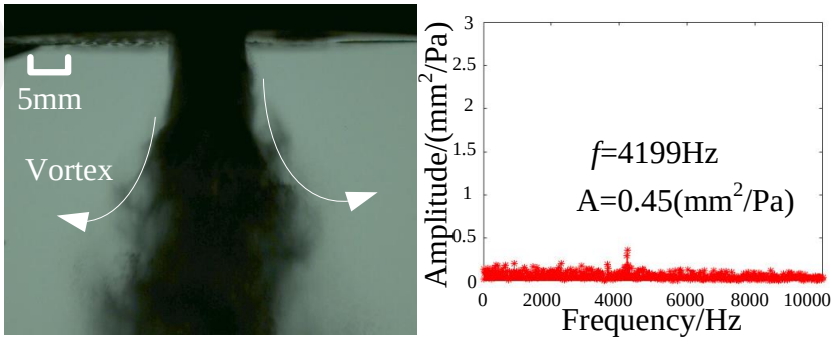
(a) Steady spray
J=1.05, Re_g=10085.95



(b) Self-pulsated spray
J=3.14, Re_g=22411.65



(c) Steady spray
J=8.90, Re_g=64123.49



(d) Self-pulsated spray
J=12.48, Re_g=89296.23

Fig. 1. The instantaneous spray images and frequency spectrum.

Pressure oscillation in the recess chamber

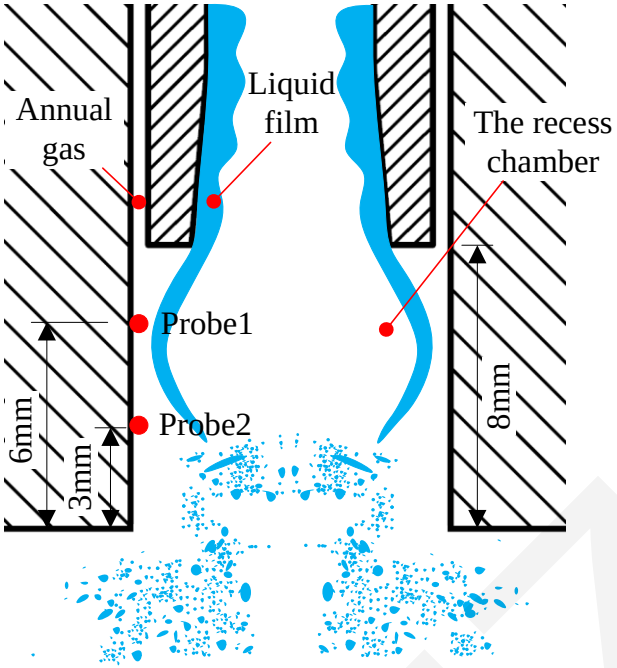


Fig. 2. The locations of monitoring points in the recess chamber.

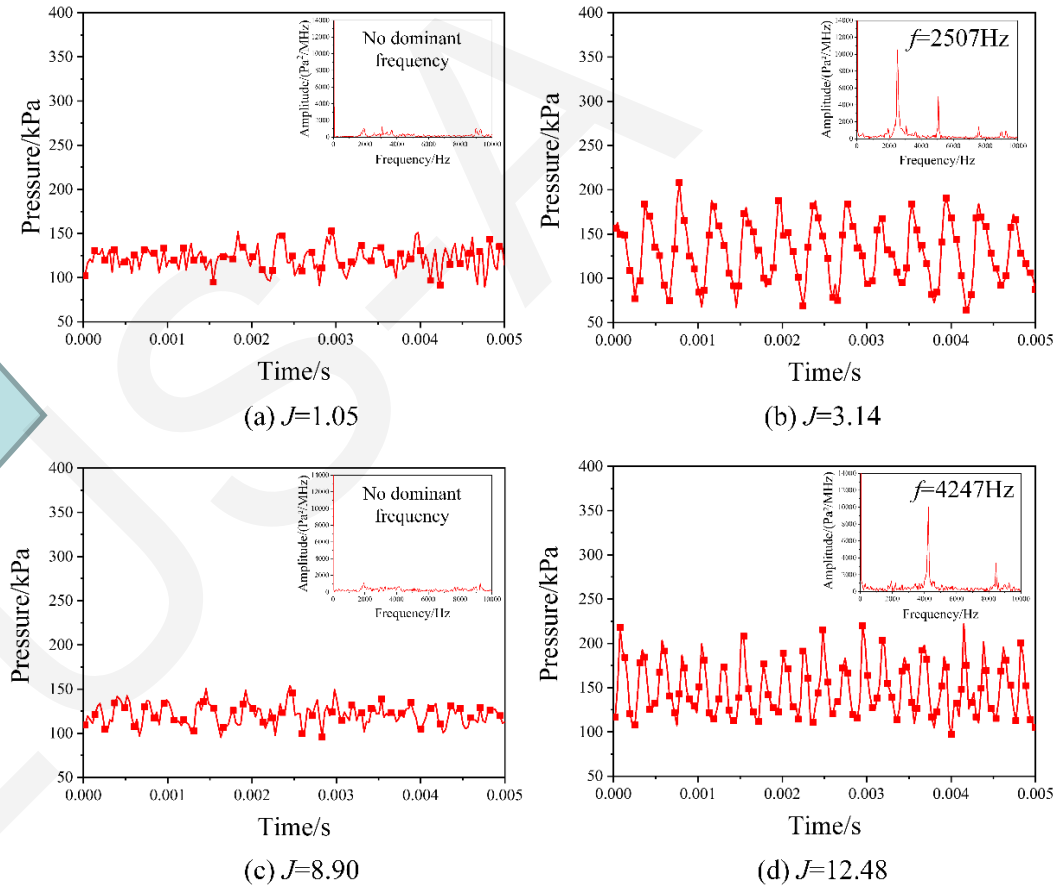
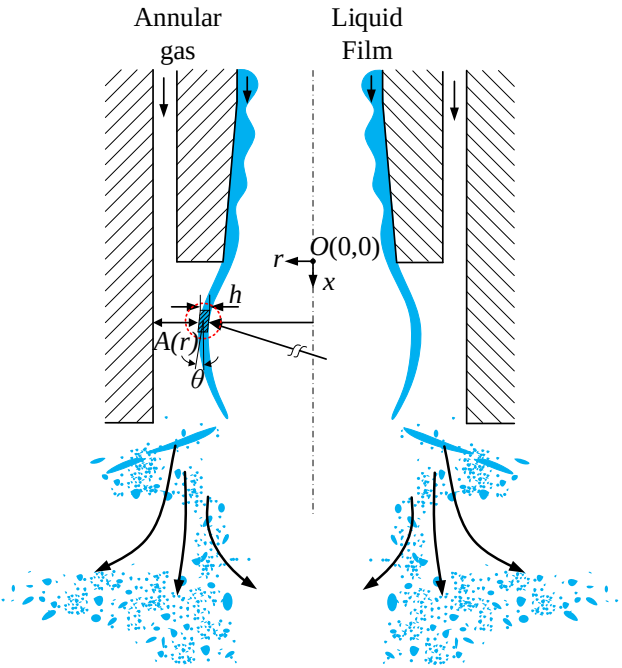
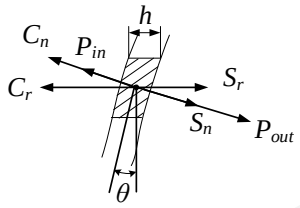


Fig. 3. The pressure time series and frequency spectrum in the recess chamber.

Theoretical analysis model for self-pulsation





C_n centrifugal force in n direction

C_r centrifugal force in r direction

S_n surface tension force in n direction

S_r surface tension force in r direction

P_{in} inner pressure

P_{out} outer pressure

Fig. 4. The force analysis of the liquid sheet element.

- **The liquid phase is incompressible and inviscid.**
- **The energy loss in the flow process is neglected.**

Conservation of mass:

$$\frac{d^2r}{dt^2} = \frac{p_{in} - p_{out}(r)}{\rho_l h(r)(\cos\theta)^2} + \frac{\omega(r)^2}{r} - \frac{2\sigma}{\rho_l h(r) r \cos\theta}$$

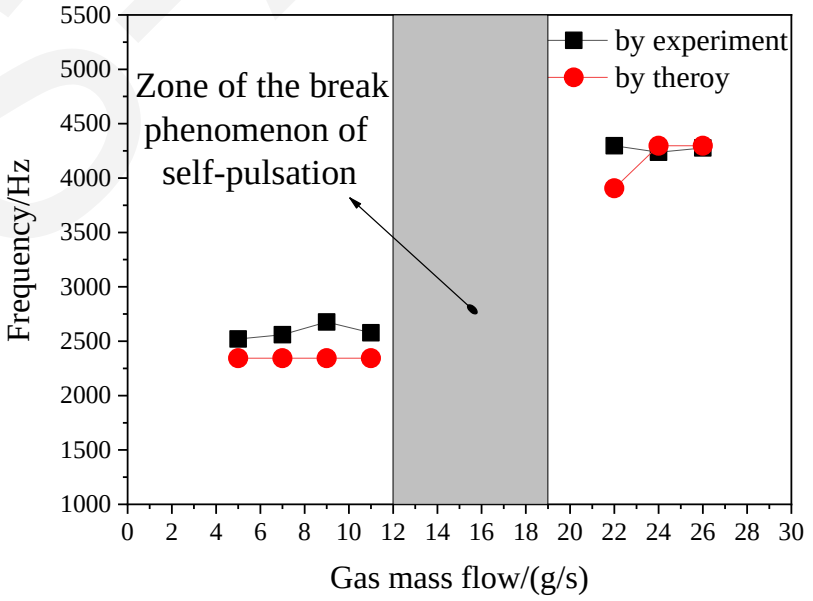


Fig. 5. The relationship between the experimental and theoretical self-pulsation frequencies.

Theoretical analysis model for self-pulsation

Liquid sheet trajectory → Pressure oscillation → The self-pulsation frequency

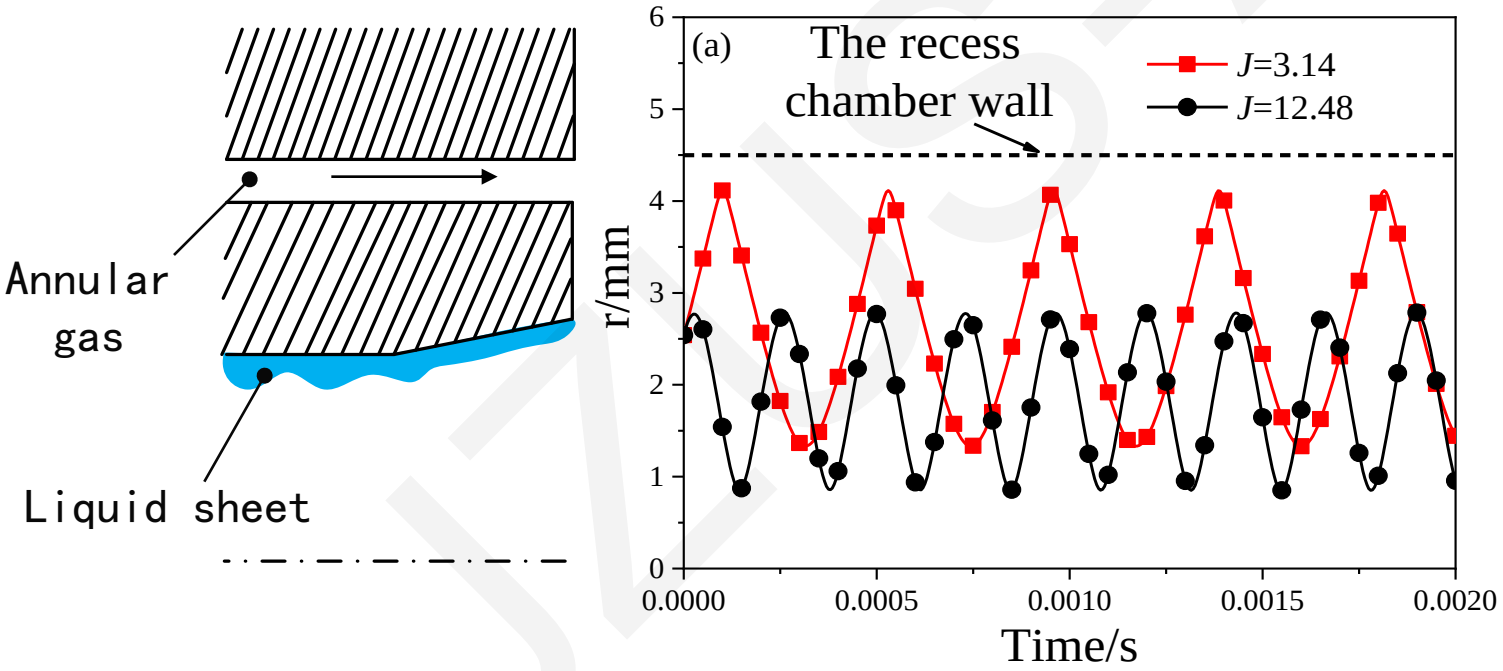


Fig. 6. The time series of the radial position of the liquid sheet element in the recess chamber (by the theoretical model).

Conclusions

- The self-pulsated spray is more symmetric before the break phenomenon, and the turbulence of the spray is greatly strengthened, leading to an asymmetric distribution of the spray after the break phenomenon.
- The flow dynamics in the recess chamber sequentially transform from a periodic expansion-dominated flow to a stable flow, and then develop to a periodic contraction -dominated flow during the break process of self-pulsation.
- The self-sustaining mechanism of self-pulsation changes from the periodic blockage of the conical liquid film before the break phenomenon to the periodic squeezing effect of the annular gas after the break phenomenon.