Experimental study and analysis of shock train self-excited oscillation in an isolator with background waves

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Cite this as: Wen-xin Hou, Jun-tao Chang, Chen Kong, Wen Bao, Laurent Dala, 2020. Experimental study and analysis of shock train self-excited oscillation in an isolator with background waves. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 21(8):614-635. https://doi.org/10.1631/jzus.A2000042

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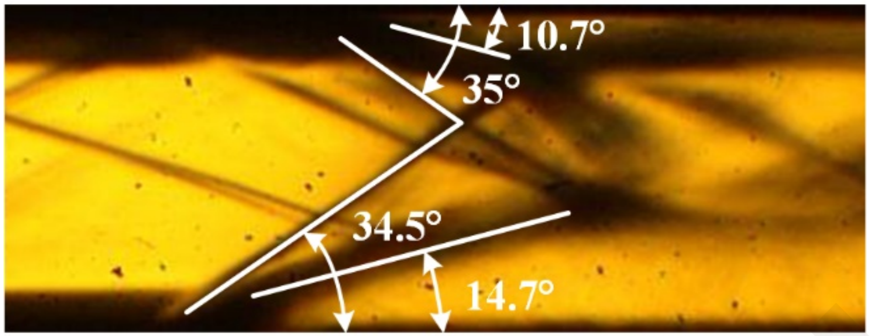
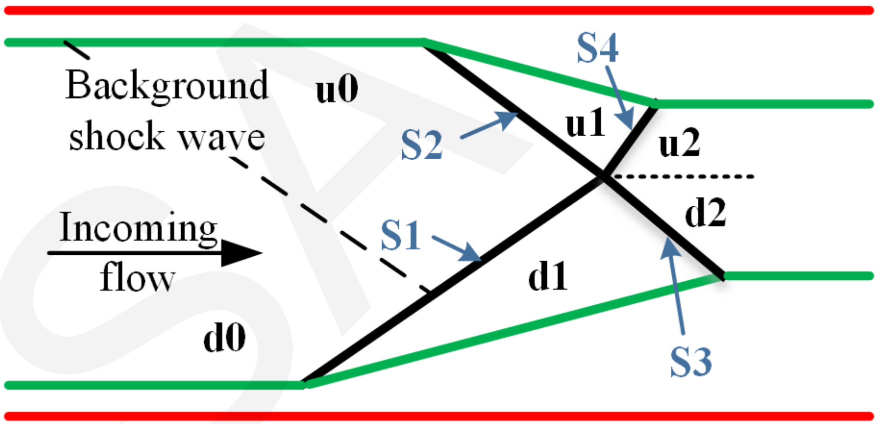
Effect of pressure discontinuity





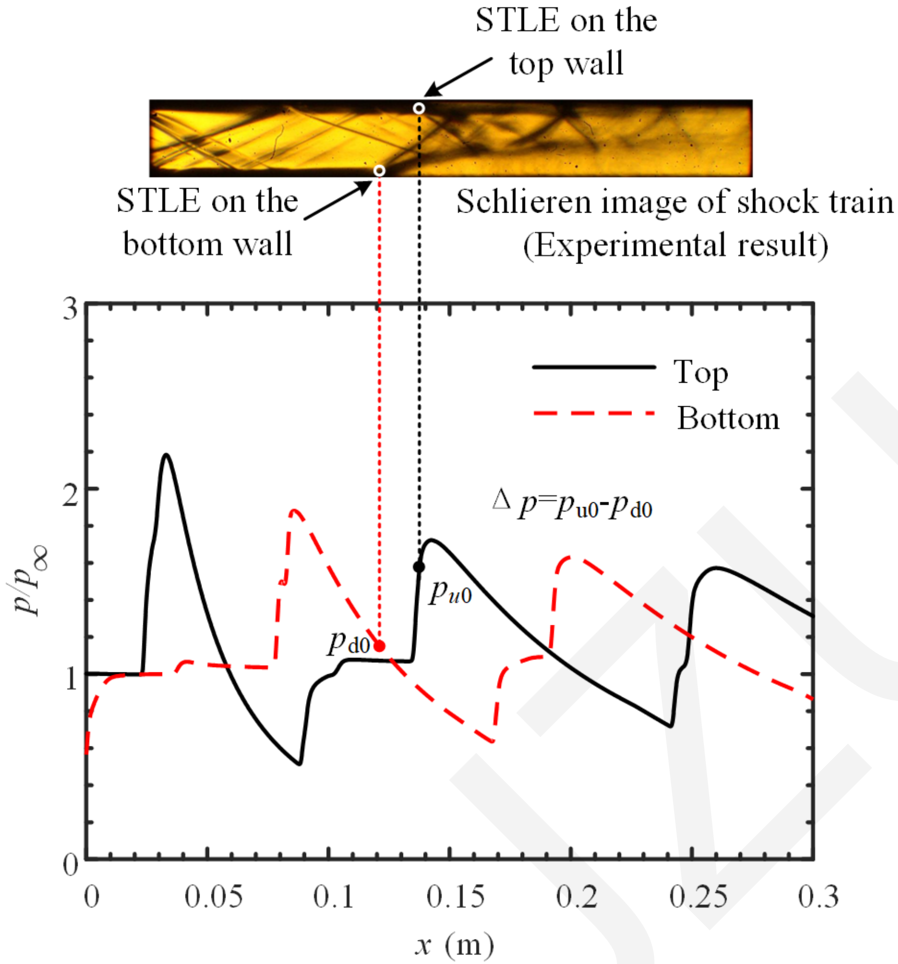
The flow in regions u2 and d2 should satisfy two conditions:

- **Condition 1:** $p_{u2} = p_{d2}$.
- **Condition 2:** $\varphi_{u2} = \varphi_{d2} \approx 0$,

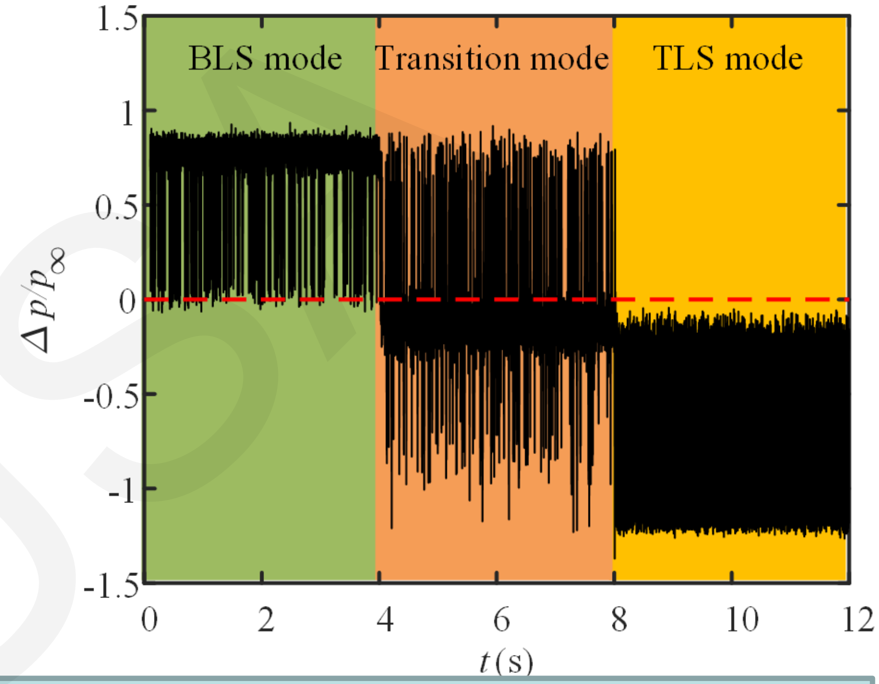
$$p_{u0} < p_{d0}. \quad \Rightarrow \quad \frac{p_{u2}}{p_{u0}} > \frac{p_{d2}}{p_{d0}}. \quad \Rightarrow \quad \delta_{\mathrm{u}} > \delta_{\mathrm{d}}$$

The large separation region will be formed on the wall with lower pressure.

Effect of pressure discontinuity

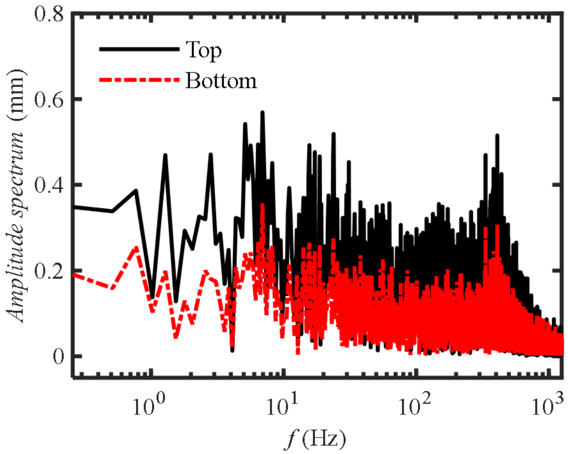


Wall pressure in unthrottled condition
(Numerical result)

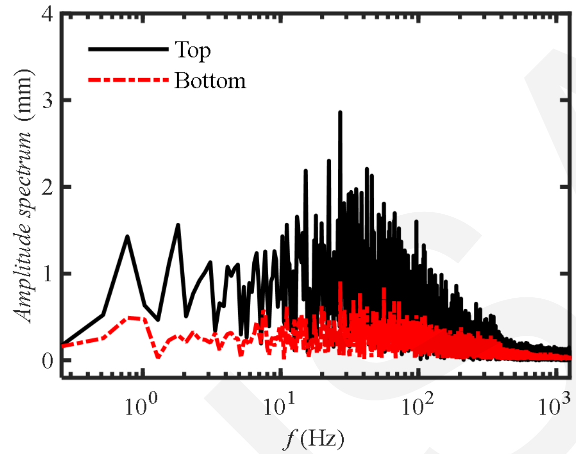


The mode of the shock train is related to the change of pressure at the position of the STLEs on both walls during the whole oscillation process.

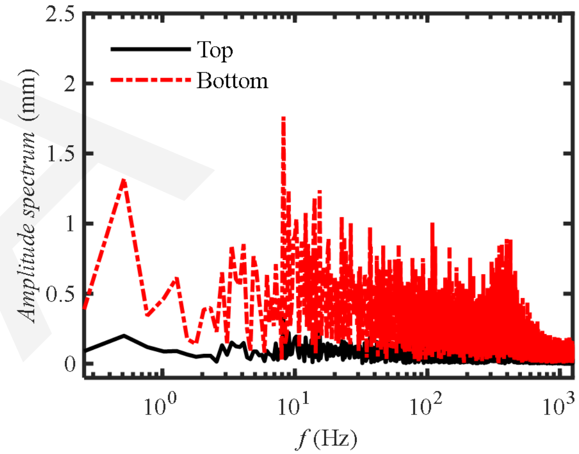
Effect of wall pressure gradient



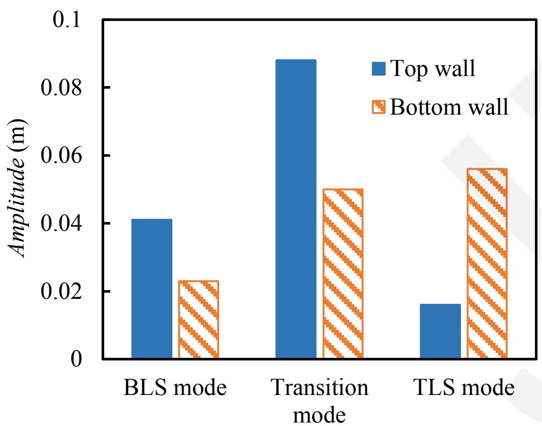
BLS mode



Transition mode



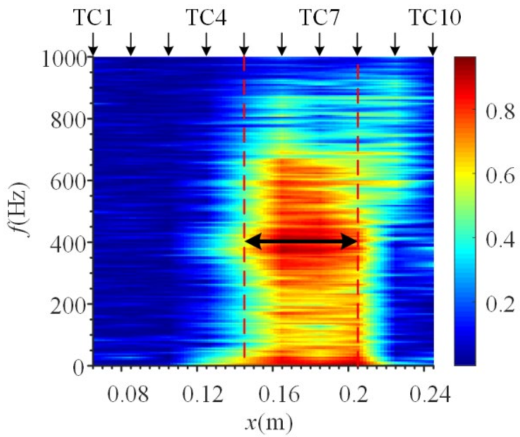
TLS mode



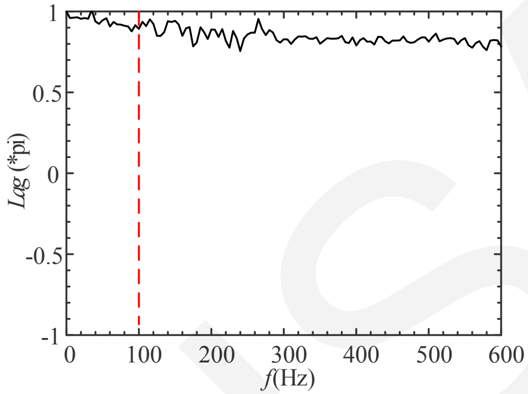
Oscillation mode	Wall pressure gradient with respect to x	
	Top wall	Bottom wall
BLS mode	negative	positive
Transition mode	negative	positive
TLS mode	positive	negative

When located in a negative pressure gradient region, the oscillation of the leading edge strengthened; when located in a positive pressure gradient region, the oscillation weakened.

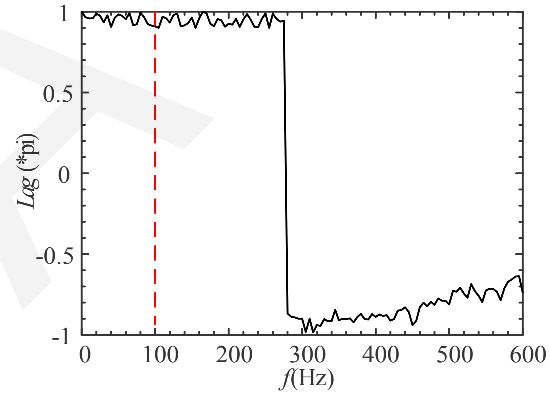
Source of perturbation



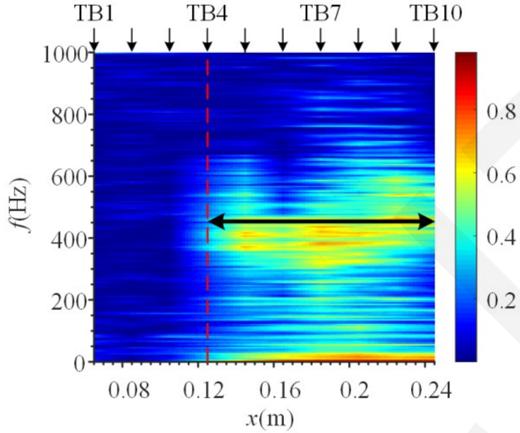
Contour of pressure coherence on top wall



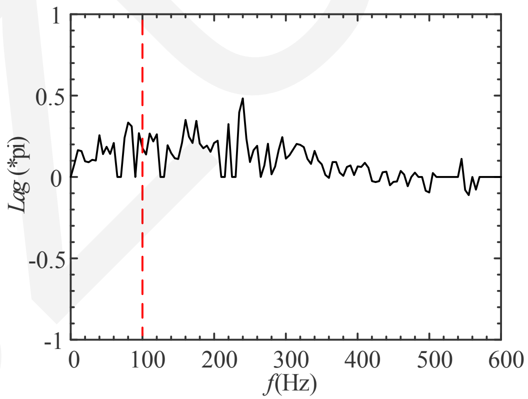
Phase lag between pressures at TC7 and TC5



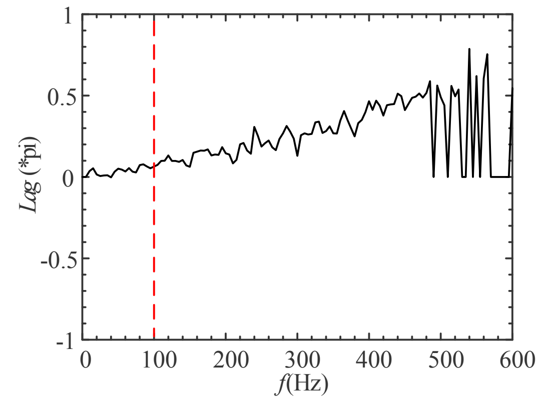
Phase lag between pressures at TC7 and TC8



Contour of pressure coherence on bottom wall

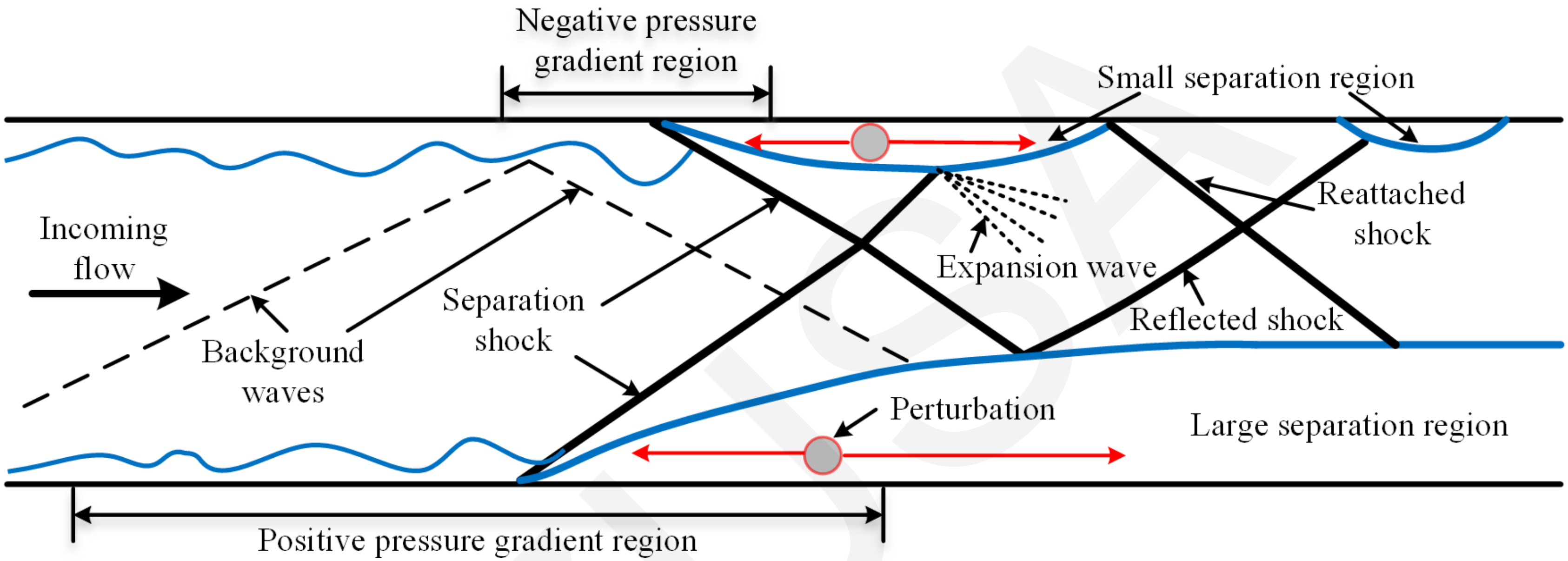


Phase lag between pressures at TB6 and TB4



Phase lag between pressures at TB6 and TB8

Schematic of self-excited oscillation



- ◆ Background waves cause pressure discontinuity and wall pressure gradient.
- ◆ The pressure at the position of the STLE on the bottom wall is lower. A large separation region is formed on the bottom wall.
- ◆ A perturbation is generated in the separation region and propagates upstream and downstream, causing movement of the STLE.
- ◆ The oscillation range of the STLE is related to the wall pressure gradient.
- ◆ The mode of the shock train self-excited oscillation is related to the pressure change in the oscillation range of the STLE on both walls

Conclusions

- The pressure discontinuity induced by background waves causes the asymmetry of the shock train structure. During shock train self-excited oscillation, the oscillation mode depends on the magnitude of the change of pressure in the oscillation range of the shock train leading edges on the top and bottom walls.
- The wall pressure gradient induced by background waves affects the oscillation range and oscillation intensity of the shock train leading edge. The influence of the wall pressure gradient on the shock train leading edge is independent of the oscillation mode of the shock train.
- The separation region induced by the leading shock is the source of perturbation that caused self-excited oscillation, regardless of the oscillation mode of the shock train.