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Squeal noise in hydraulic poppet valves

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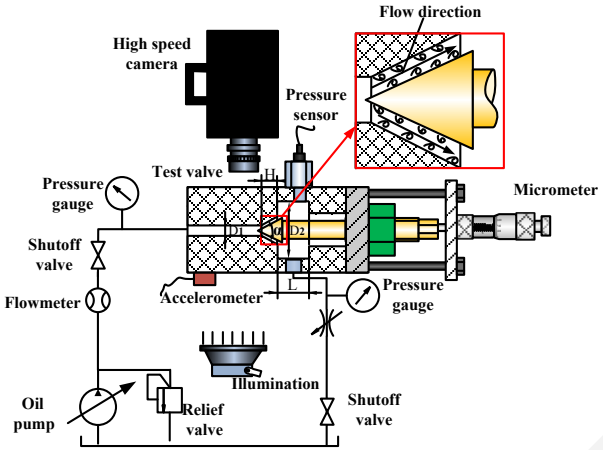
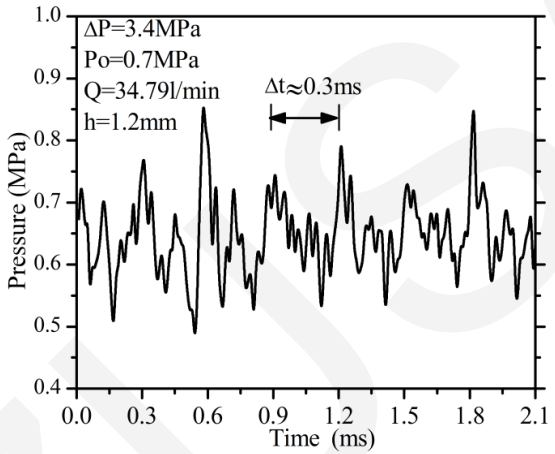
Mechanism of poppet valve squeal noise

Squeal noise properties

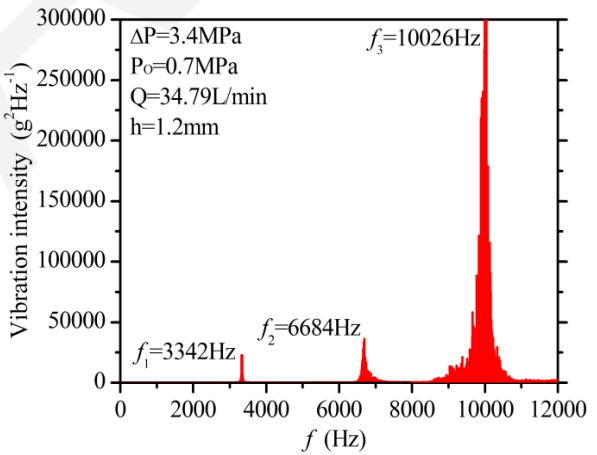
Test bench

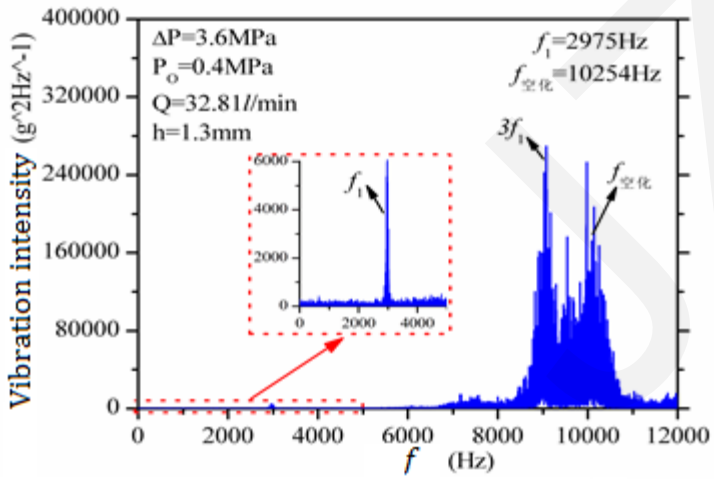


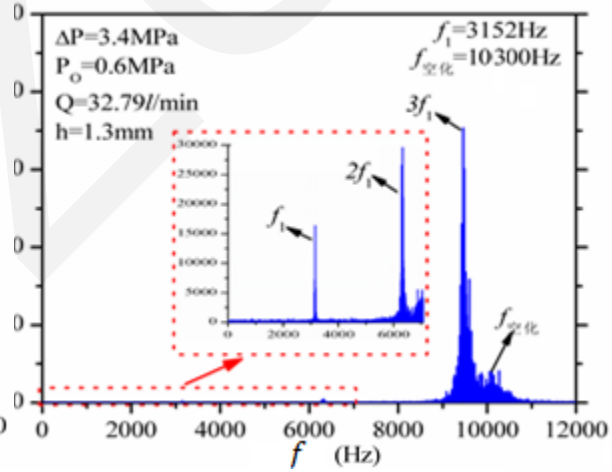
Pressure fluctuation

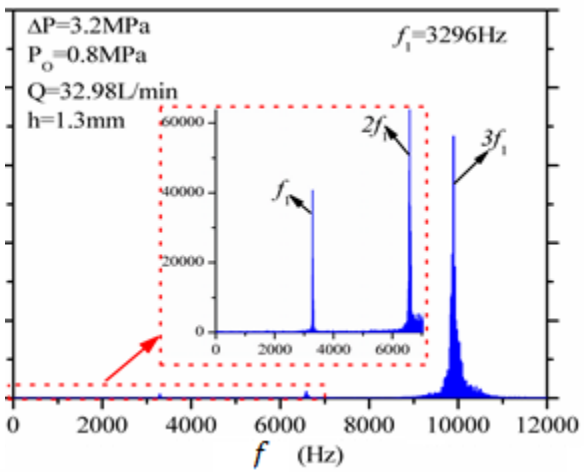


Corresponding spectrum





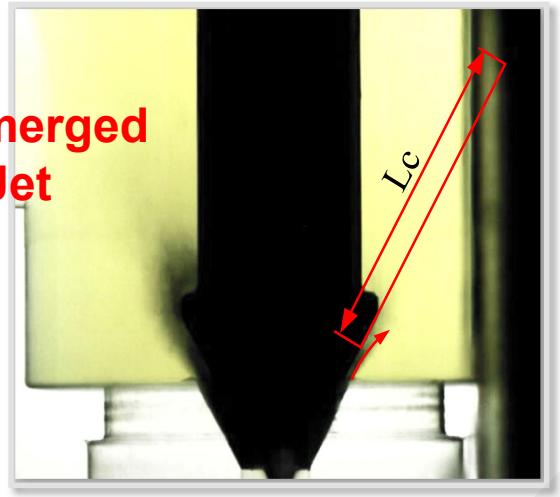


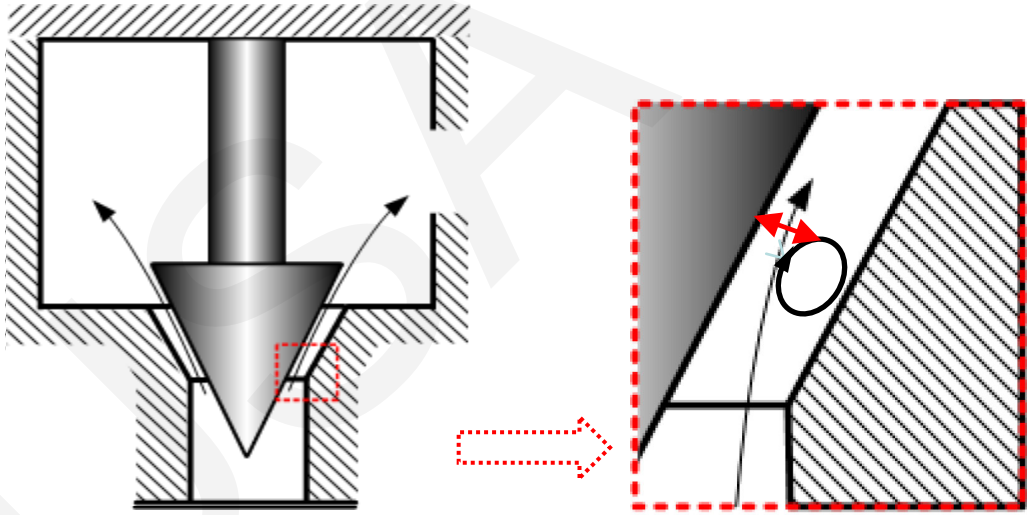


Mechanism of poppet valve squeal noise

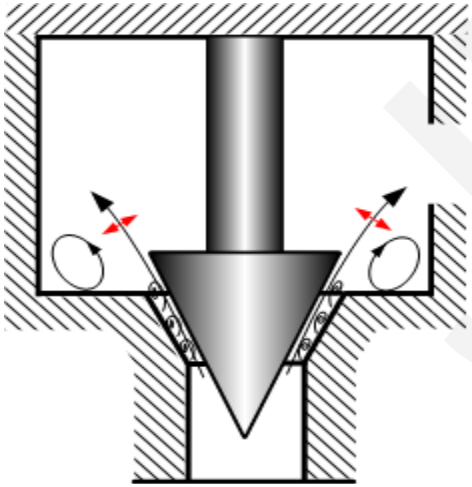
Noise excitation

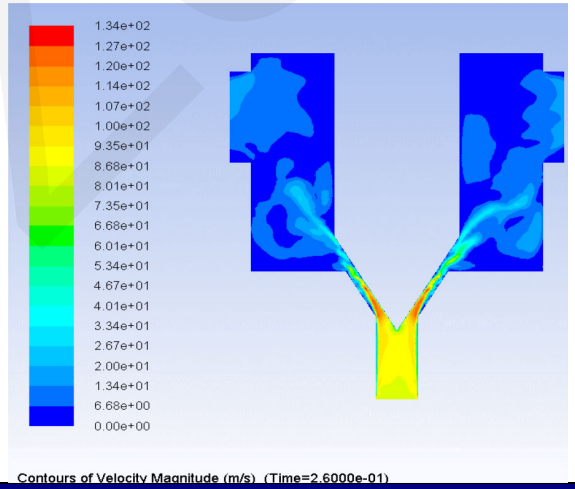
Submerged Jet

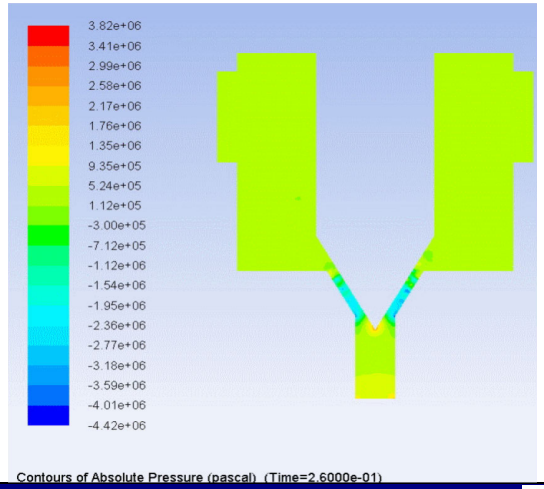




Shearing layer instability

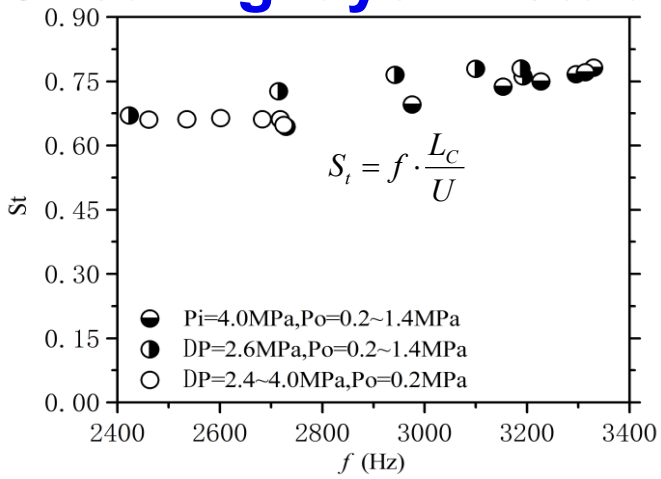




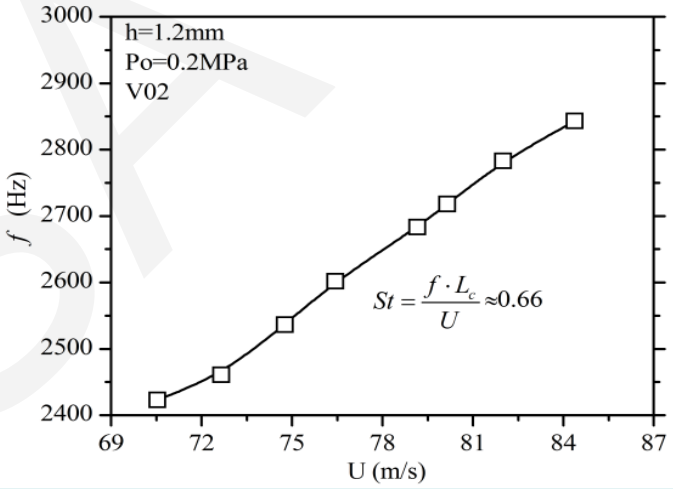


Mechanism of poppet valve squeal noise

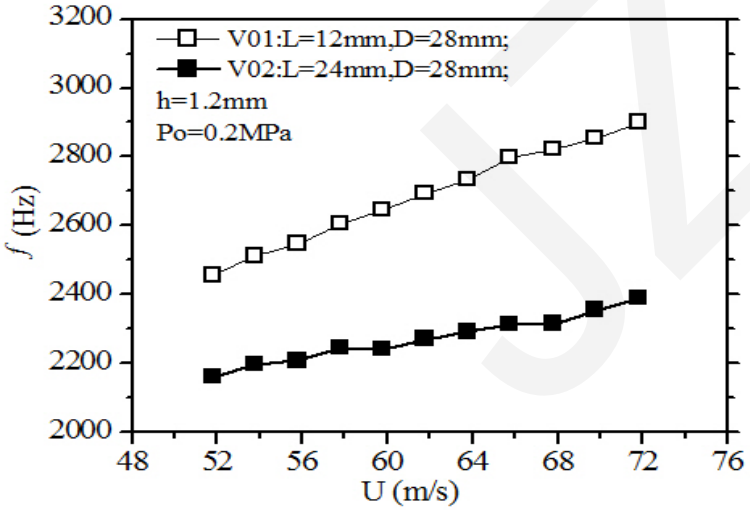
Shearing layer instability

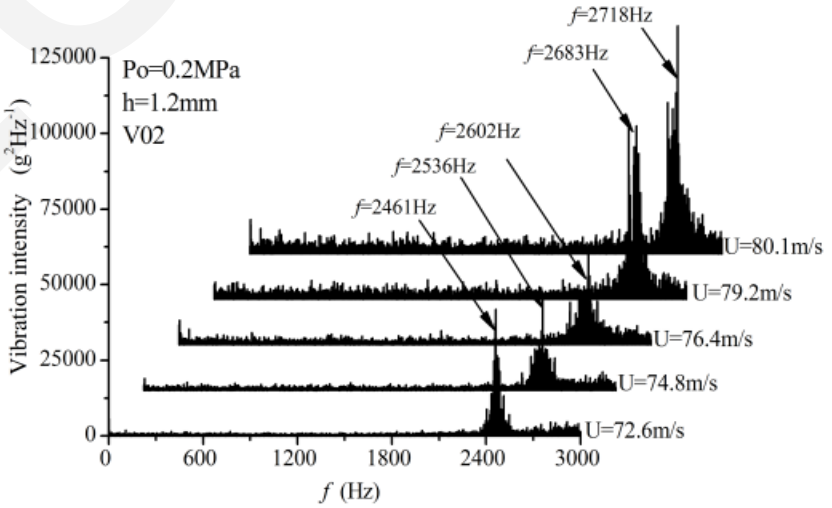


Strouhal number
St:0.5-2.5，shear layer instability



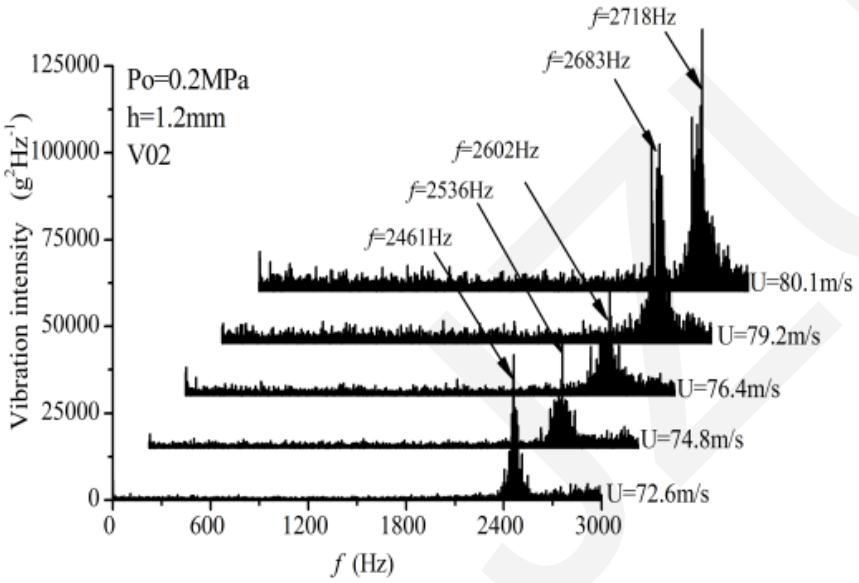
Fundamental frequency is high in small chamber valve

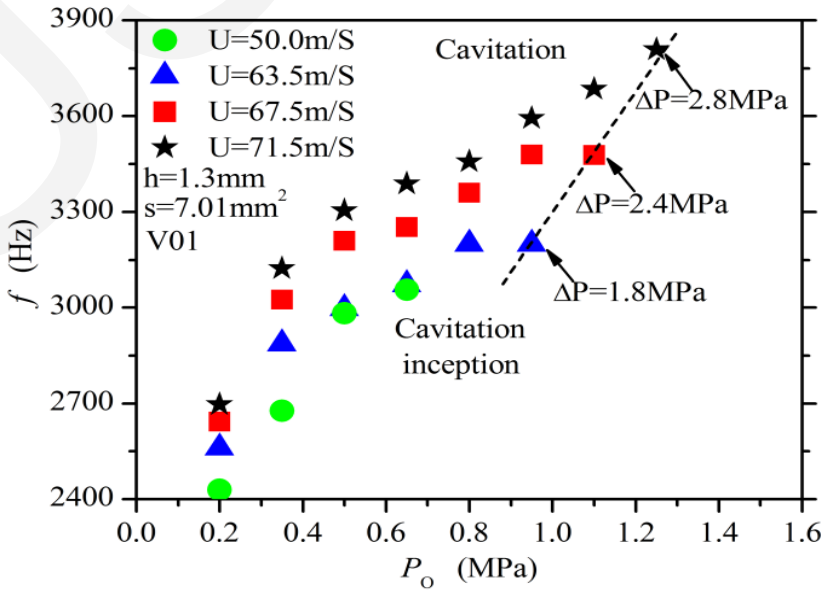




Mechanism of poppet valve squeal noise

Cavitation number increases with the increase of back pressure at constant flow velocity. The more the cavitation number is, the less the volume of vapor is . Less bubbles mixed in the oil fluid results into the increase of sonic speed, causing the increase of resonant frequency.

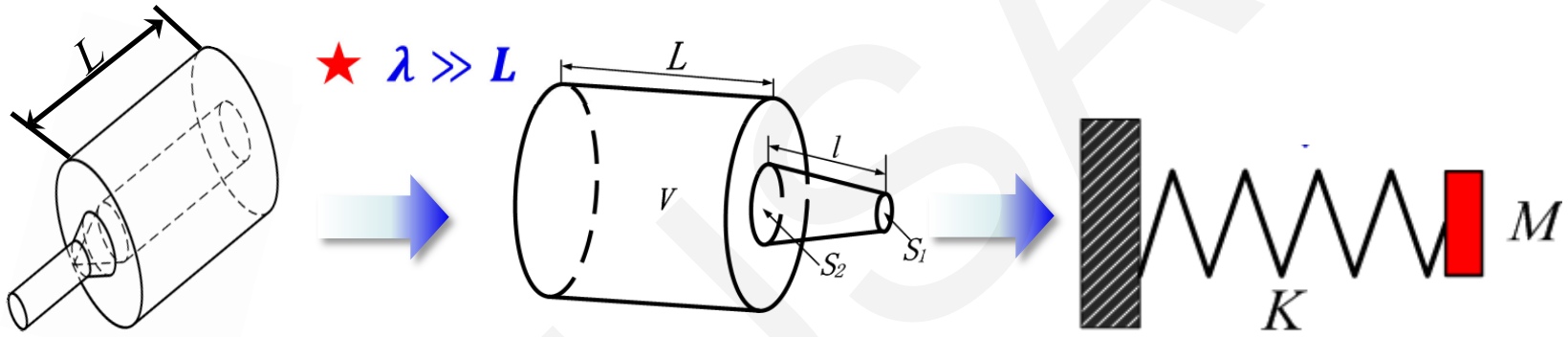




Mechanism of poppet valve squeal noise

Resonance frequency of the Helmholtz resonator

Lumped parameter model:



Resonance frequency：

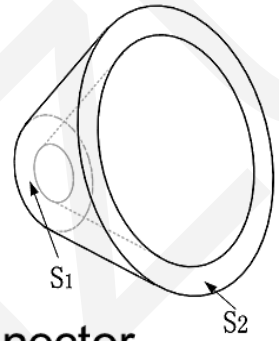
$$f_{res} = \frac{C}{2\pi}\sqrt{\frac{S}{l \cdot V}}$$

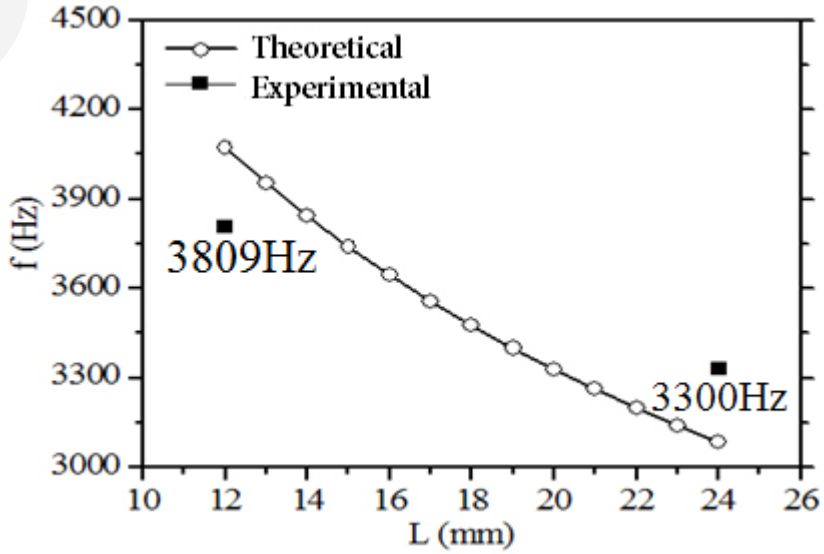
C：sonic speed

l: Length of tapered connnector

S：mean section area，where $S = \sqrt{S_1 S_2}$

V：Chamber volume





Mechanism of poppet valve squeal noise

Effects of back pressure on the frequency

1.Multi-phase flow & acoustic frequency

Acoustic frequency：

$$f = \frac{C}{2\pi}\sqrt{\frac{S}{lV}}$$

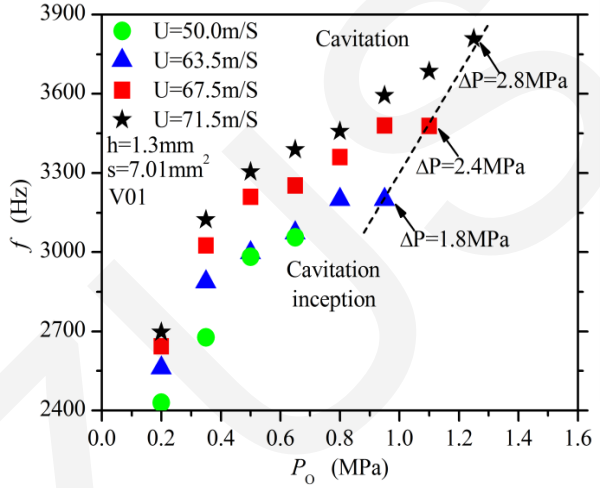
C：sonic speed

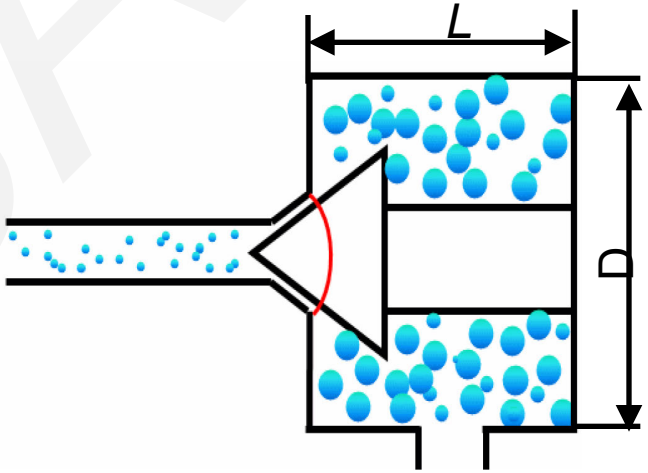
l: Length of tapered connnec

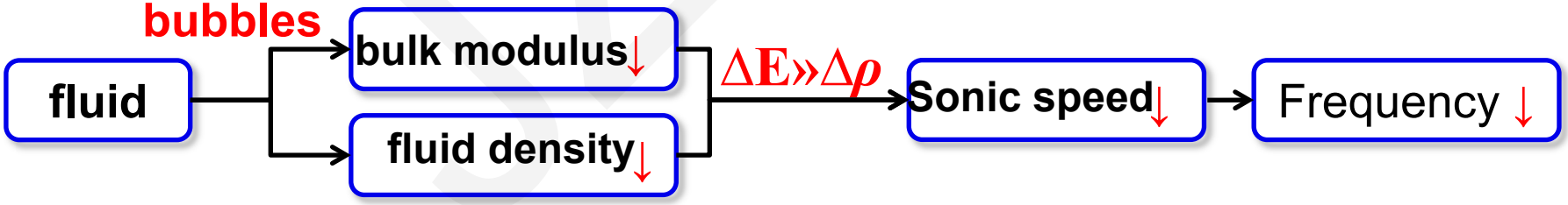
S：mean section area，where

V：**Chamber volume**

Sonic speed：$C = \sqrt{\frac{E}{\rho}}$



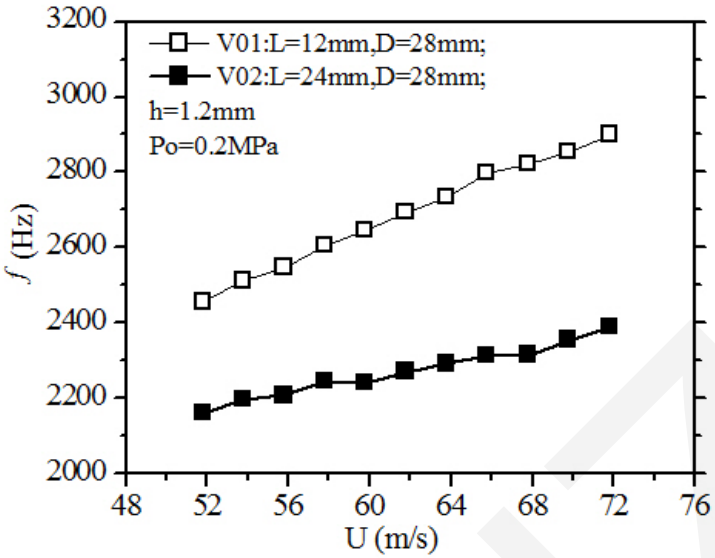




Mechanism of poppet valve squeal noise

Effects of back pressure on the frequency

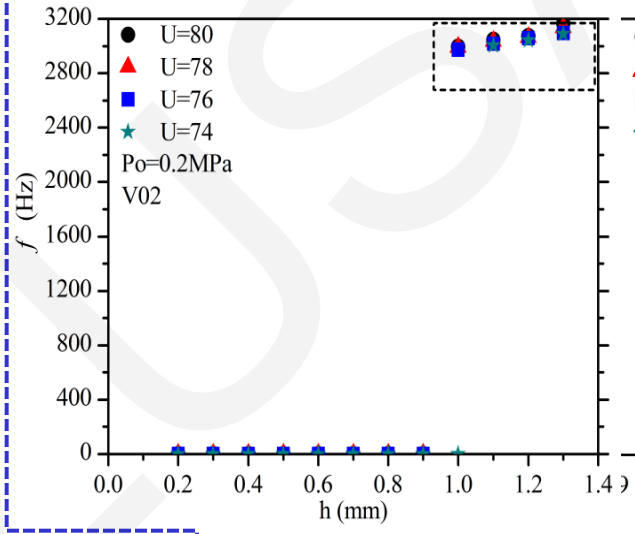
2.Chamber length & frequency

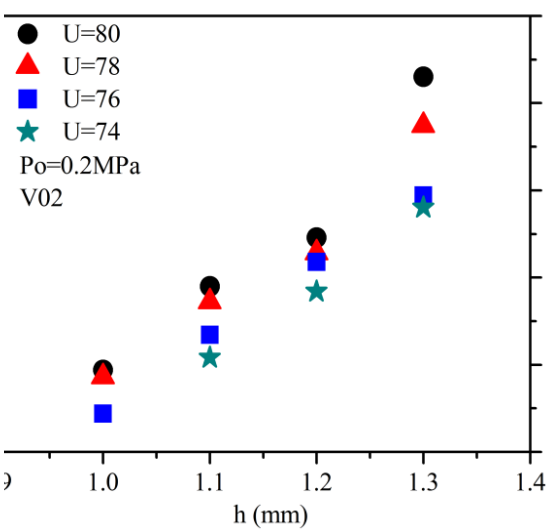


Length L ↑ → Volume ↑

Volume ↑ → Frequency ↓

3.Openings & acoustic frequency





Poppet lift ↑ → Section ↑

Section ↑ → Frequency ↑

Conclusions

1. The suddenly expanded volume of the poppet valve chamber at the exit of the narrow metering orifice forms a Helmholtz resonator actually, the resonance is apt to occur if the external excitation frequency overlaps with that of resonator

2. Any factor which affects the acoustic resonant frequency of cavity influences the fundamental frequency of squeal noise as well. And it can be suppressed effectively by removing the frequency overlaps between the resonant frequency and the exciting frequency induced by shear layer instability