

# Micro-Newton scale variable thrust control technique and its noise problem for drag-free satellite platforms: a review

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# Core Issue

## High-precision detection

- ◆ space gravitational wave detection
- ◆ high-precision earth gravity field measurement
- ◆ reference frame drag effect measurement

requires



## Satellite platform



drag-free control

key challenge



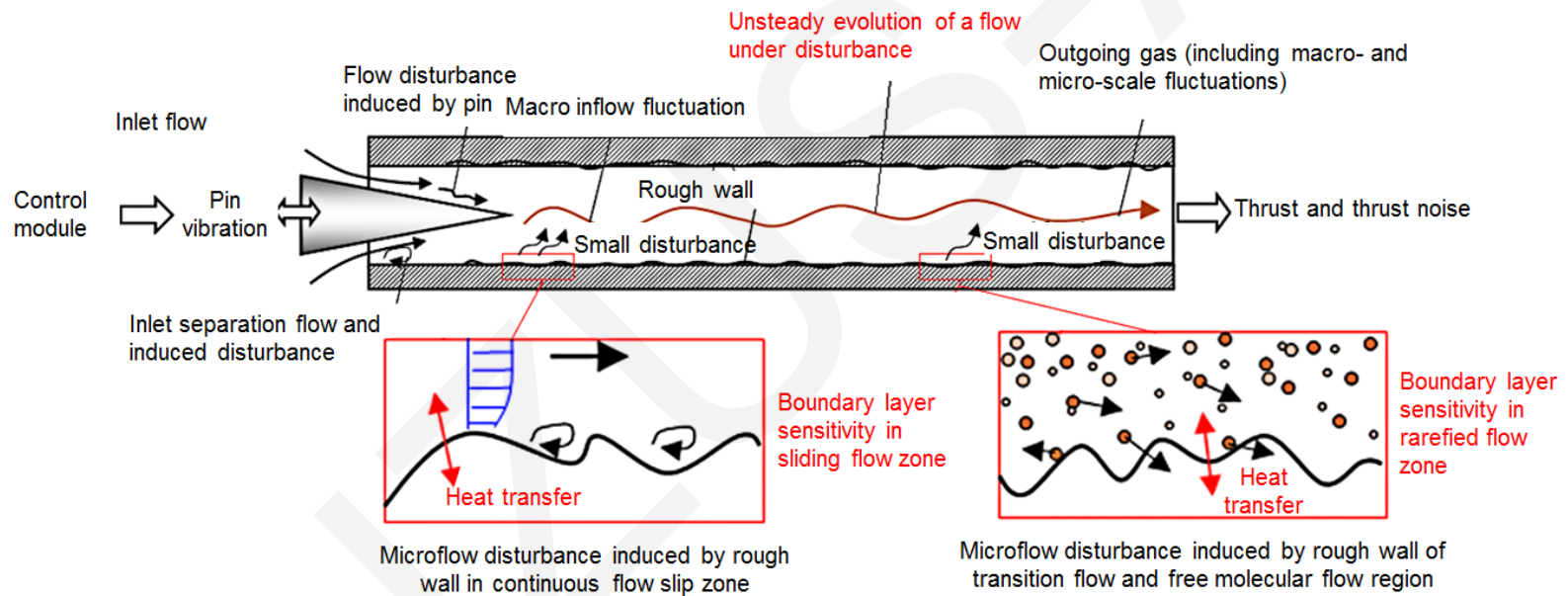
## key noise factors

## Thrust noise

- ◆ cross-basin flow problem
- ◆ control problem
- ◆ system instability and multiple-coupled problem

# Cross-basin Flow Problem

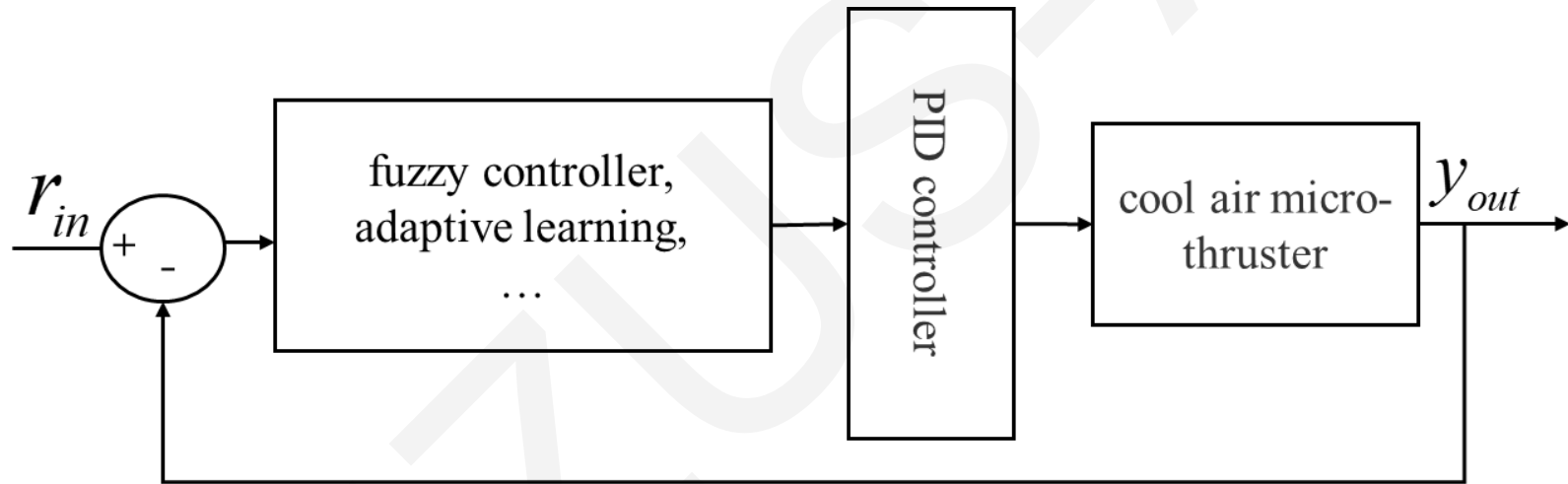
- The thrust noise will generate from the flow fluctuation's boundary layer sensitivity and flow stability problems.



**Fig. 1 Mechanism of cross-basin flow fluctuation and thrust noise in a micro nozzle**

# Control Problem

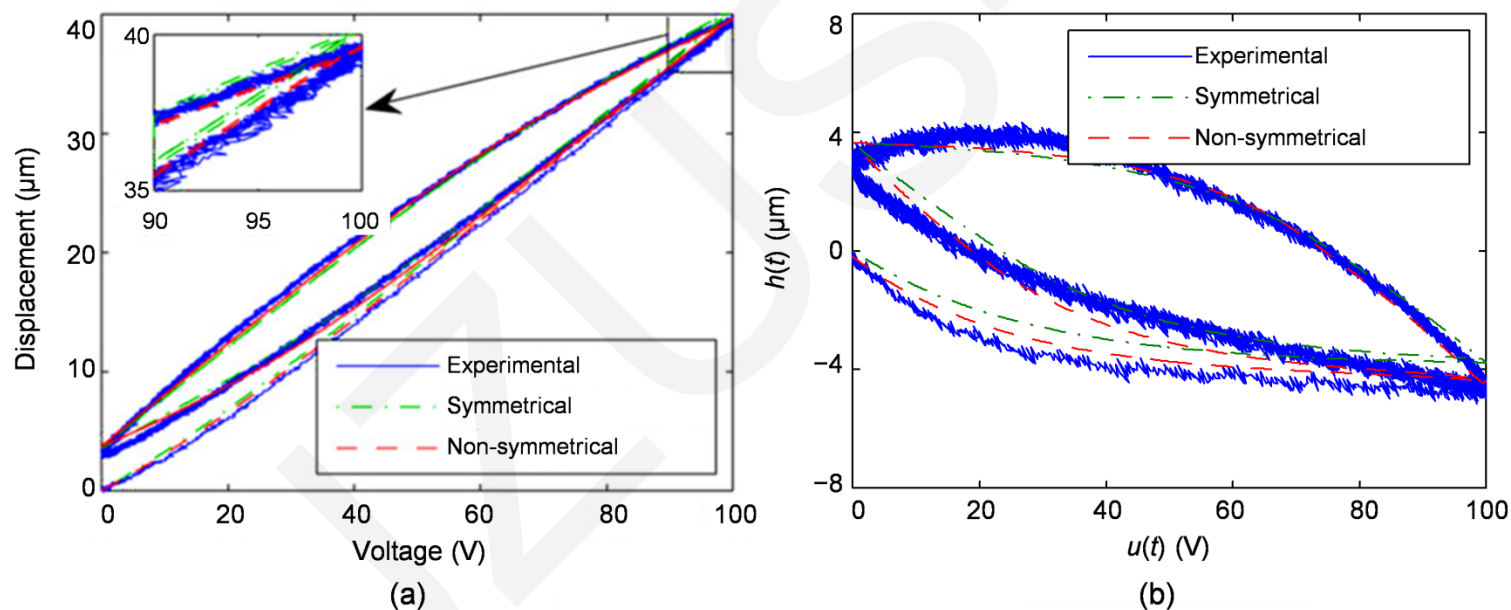
- The commonly used PID solution falls short of the target for drag-free control



**Fig. 2 Example of control methods in MVTC: (a) block diagram of variable universe fuzzy PID controller, where  $r_{in}$  is the input of system and  $y_{out}$  is the output of system.**

# System Instability and Multiple-coupled Problem

■ In real engineering, the three items: the drive actuator, measurement feedback, and the cross-basin flow environment, are coupled together.



**Fig. 3 Hysteresis simulation and linearization of piezoelectric ceramic actuators based on Bouc-Wen hysteresis operators: (a) hysteretic curves; (b) hysteresis component. Reprinted from (Zhu and Wang, 2012), Copyright 2012, with permission from Elsevier**

# Conclusions

- Based on existing research, there is still a lack of in-depth consideration of ‘complex cross-basin flow,’ ‘space working environments,’ ‘thrust noise mechanism,’ and ‘active suppressing methods,’ which could bring a further improvement of the noise problem in the future.



## Drag-free Control