Prediction of onset of density wave oscillation in single-heated and dual-heated systems using the MARS code

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INTRODUCE

Some previous studies reported the effect of the node size on the onset of density wave oscillation(DWO) W. Ambrosiniand2006, M. Colombo2012. This study considered the effects of the node size and time step on the onset of density wave oscillation(DWO) in single- or dual-heated-channel systems. The MARS code was used in this study. In addition, three different boundary-condition approaches were compared in terms of their adequacy in predicting DWO.

METHODS

We tested three different boundary-condition approaches to investigate the onset of DWO:

•Method1: The heat power is fixed. Water is injected from the bottom using a velocity inlet. Gradually reduce the flow rate and observe if the flow oscillates.

•Method2: The heat power is fixed. A pressure boundary is imposed on the inlet and outlet. Gradually reduce the pressure difference between the inlet and outlet and observe if the flow oscillates.

•Method3: Pressure boundaries are applied to the inlet and outlet, and the pressure drop is fixed. Gradually increase the heat power and observe if the flow oscillates.

We adopted the DWO determination method proposed by juhyung Lee 2021.

Then, the normalized mass flow rate is analyzed by the fast Fourier transform. If the frequency of the first peak is less than 1 Hz and the amplitude of the first peak is greater than 0.3, the flow is considered to be under density wave oscillation A flow example under DWO in the single-heatedchannel system is shown in Fig. 1

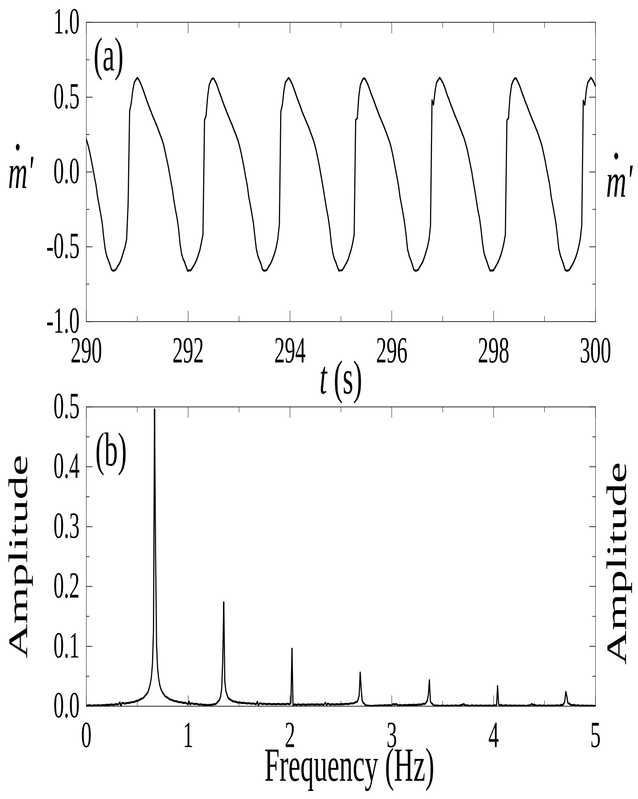


Fig. 1. Flow example under DWO: (a) Normalized mass flow rate and (b) FFT result

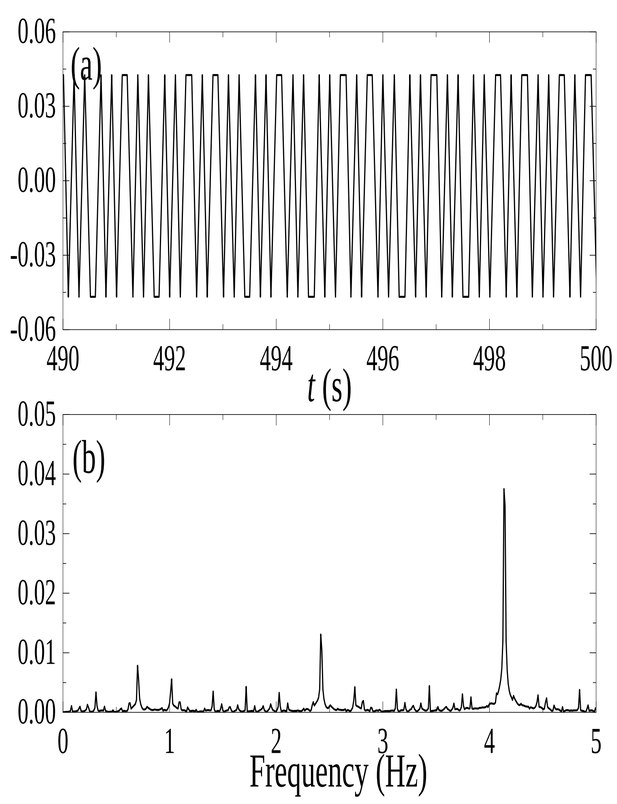
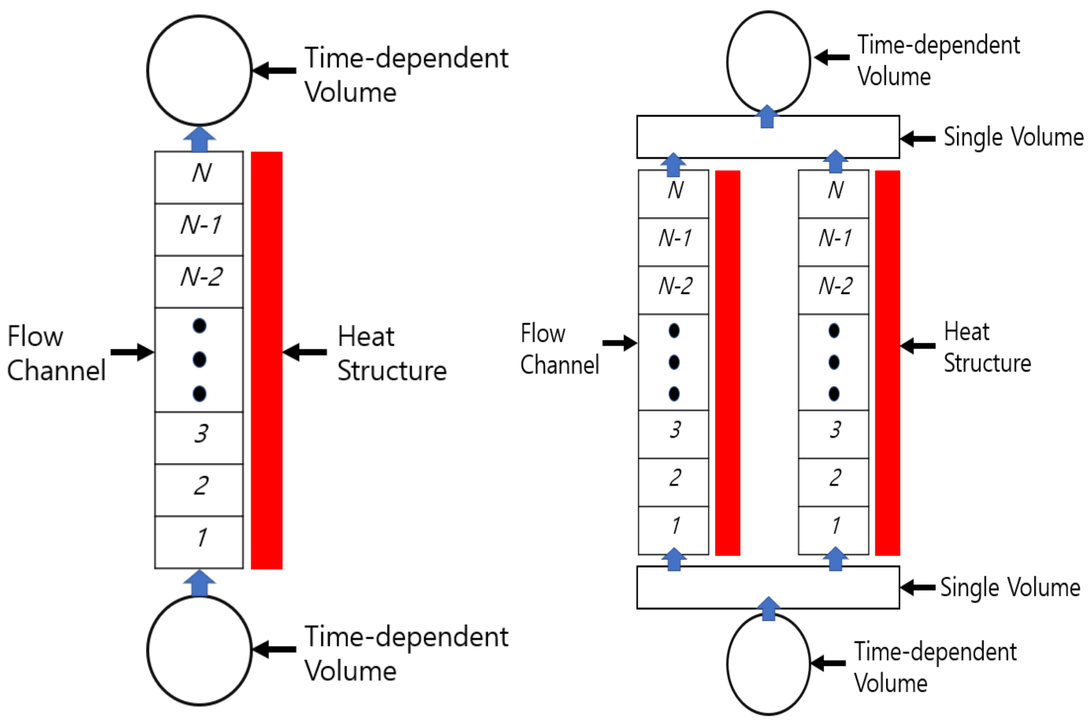


Fig. 2. Flow example under Error: (a) Normalized mass flow rate and (b) FFT result

SIMULATION CONDITION



Analysis conditions	
Node number	6,12,24,48,96
CFL	0.5, 0.1, 0.05
Δt	$\Delta t = \Delta x * CFL/u$

Analysis conditions	
Node number	5,20,40,80
CFL	0.5, 0.1, 0.05
Δt	$\Delta t = \Delta x * CFL/u$

SIMULATION RESULT

In single channel, Method 1 was found to adequately predict OFI when compared to experimental values. However, as shown in (Figure 2), the graph exhibited non-physical behavior with oscillations around the same point without intermediate stages. As the external pressure difference gradually decreases, the flow rate suddenly drops, creating a region where the OFI point cannot be detected. For this reason, Method 3 was deemed unsuitable, and the simulation was conducted using Method 2. In Dual channel the simulation was conducted using Method 1.

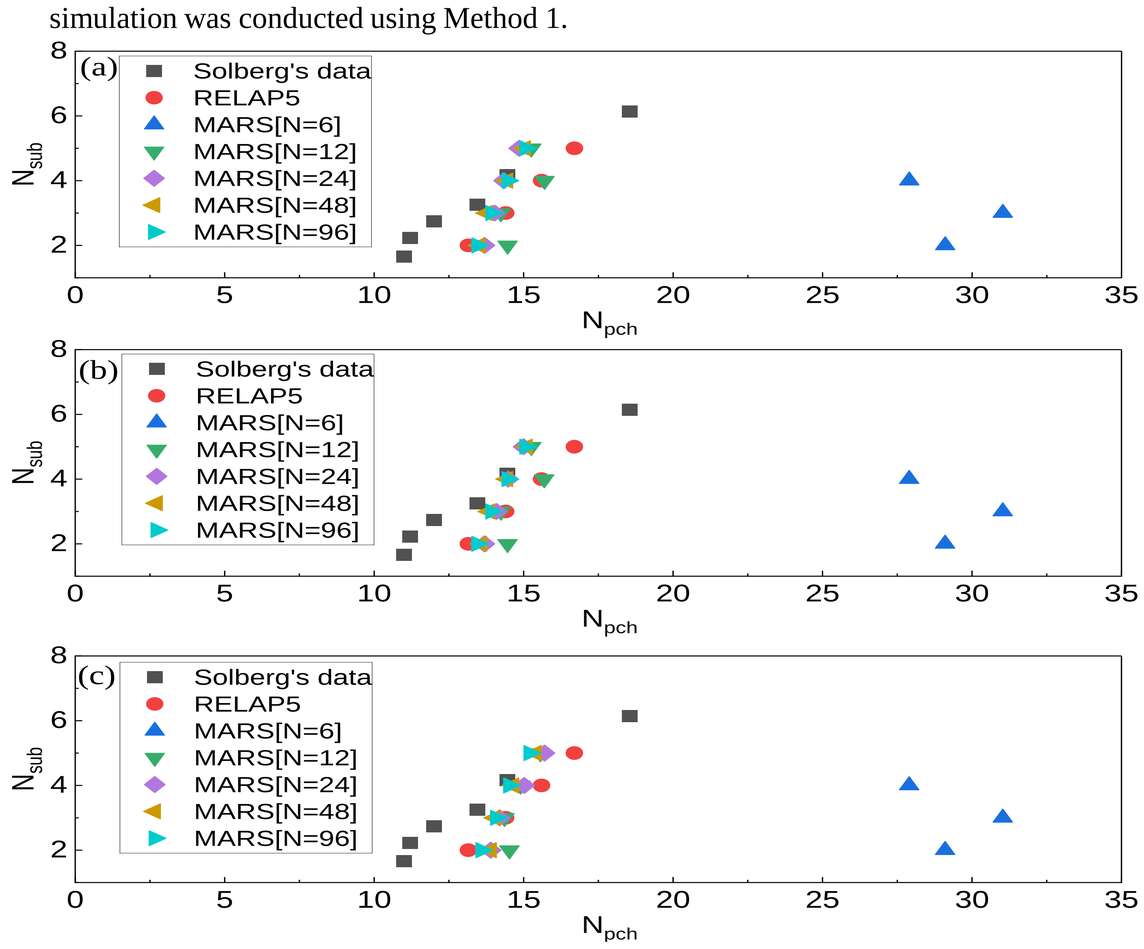


Fig. 3. (single channel) Effect of the number of nodes (N) on the onset of DWO for (a) CFL = 0.5 and (b) CFL = 0.1, (c) CFL = 0.05

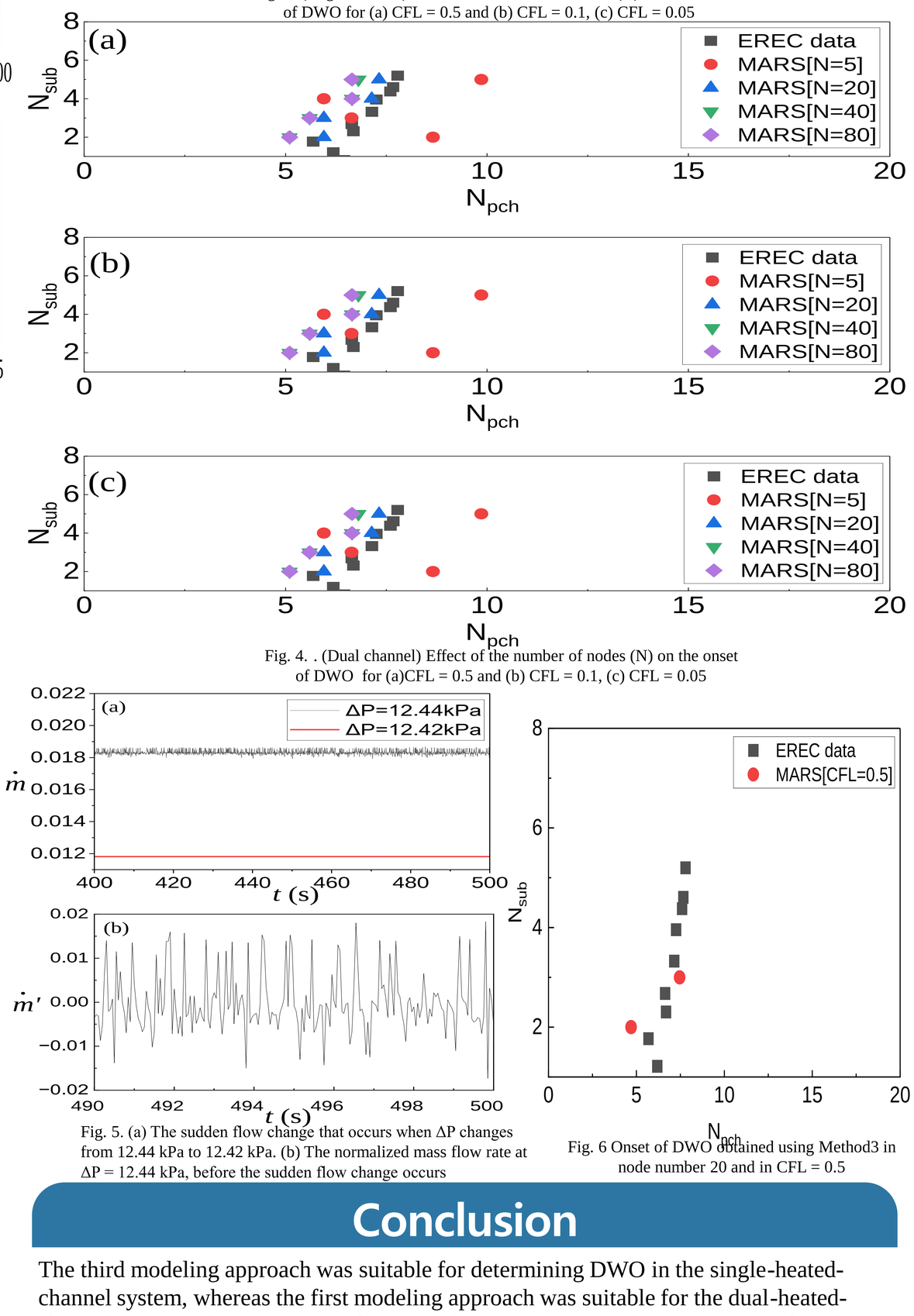


Fig. 4. . (Dual channel) Effect of the number of nodes (N) on the onset of DWO for (a)CFL = 0.5 and (b) CFL = 0.1, (c) CFL = 0.05

Fig. 5. (a) The sudden flow change that occurs when ΔP changes from 12.44 kPa to 12.42 kPa. (b) The normalized mass flow rate at ΔP = 12.44 kPa, before the sudden flow change occurs

Fig. 6 Onset of DWO obtained using Method3 in node number 20 and in CFL = 0.5

Conclusion

The third modeling approach was suitable for determining DWO in the single-heated-channel system, whereas the first modeling approach was suitable for the dual-heated-channel system. The effects of node size and time step appeared insignificant unless the number of nodes was small.