# Parameters optimization of gas-water pulsed flow for cleaning plate heat exchanger

Hanqing Shi

Center for Strategic Studies, Chinese Academy of Engineering;

Department of Energy and Power Engineering, Tsinghua University.

**Abstract.** With the development of industry and the increase of energy consumption, plate heat exchangers have been widely used across various sectors due to their efficient heat exchange performance. Focusing on the application of gas-water pulse jet in plate heat exchanger cleaning, this paper focuses on the process parameter optimization of the gas-water mixer. The test results show that when the gas-water pulse jet flows into the plate heat exchanger, the airflow diffuses into a large number of small bubbles and bubble clusters, and forms a counterclockwise vortex under the outlet. As the ventilation time of the gas-water pulse jet increases, the initial pressure also rises. Longer gas stoppage times lead to higher internal pressures within the heat exchanger, resulting in improved cleaning effectiveness. The optimal operating frequency is 3 s of ventilation followed by 5 s of gas suspension.

**Keywords:** Plate heat exchanger; gas-water pulse; parameters optimization; cleaning parameters; gas-water pulse mixer.

## 1. Introduction

The cleaning and maintenance of plate heat exchangers are crucial for their effective operation [1,2,3]. Water jet cleaning is an efficient cleaning method with water as the main cleaning medium. The cleaning efficacy of cavitation jets largely derives from the micro-jet impact force generated by the collapse of cavitation bubbles. Pulse jet cleaning, which focuses on flow regulation and fluid energy concentration, generates high-energy jets with significant explosive power and impact force, making it effective at removing dirt and blockages [4]. The research results of Magnaudet J. [5], Wu H [6] and He Q [7] have demonstrated that gas-water two-phase flow has different pressure drop characteristics in various working environments. Water jet has the advantages of fast cleaning speed and relative environmental protection [8,9]. By combining the benefits of pulse jet cleaning and cavitation jet cleaning, this paper introduces a novel gas-liquid two-phase pulse jet cleaning method. Given its distinctive physical properties and cleaning effectiveness, this method shows substantial potential for application and further research. Overall, the cleaning efficiency of pulse jet cleaning varies with different operational conditions and process parameters.

This study investigates the gas water pulse cleaning technology for plate heat exchangers, specifically analyzing the effects of process parameters on the internal pressure and cleaning performance of the heat exchanger.

## 2. Method and experimental design

Gas-water pulse is to fill the compressed gas in the gas compressor into the water flow at a certain frequency. By using the compressibility of gas, the high-pressure gas in the water flow quickly contracts and expands, pushing the flow of water and increasing the speed of the water flow. At the same time, the high-frequency and high-pressure gas increases the turbulence of the water flow, improving the flushing effect on the heat exchanger plates and pipes. Because the shear force of the water flow on the wall is not easy to detect, the internal pressure data of the heat exchanger model is measured, and the pressure change is used to reflect the flushing intensity. Fig. 1 is the test flow chart of this test.

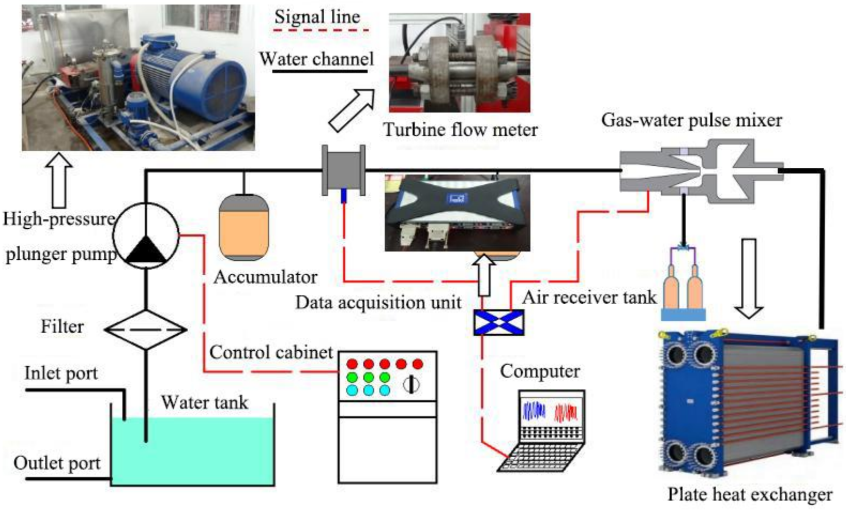


Fig. 1 Test flow chart

The working parameters were optimized by adjusting key variables such as pulse frequency, gas pressure, and water flow. In the test, the system was connected according to Fig. 1, and the pump and gas compressor were activated with initial pressures set to 0.1 MPa. Data acquisition software was used to collect results, and the PLC control program was started to run a 120-second pulse input. A pulse frequency test was conducted by fixing gas and water pressure at 0.1 MPa and varying the ventilation cycle between 1–8 s, completing 64 test sets. For the water pressure test, pump flow ranged from 3 to 5.5 $m^3/h$ in 0.5 $m^3/h$ increments, with water inlet pressure adjusted from 0.1 to 0.4 MPa while keeping the pulse frequency at 3s on/3s off. In the gas pressure test, liquid pressure was fixed at 0.1 MPa, pulse frequency remained 3s on and 3s off, and gas output pressure was varied from 0.1 to 0.5 MPa. To further compare the cleaning performance of gas-water pulses at different frequencies on plate heat exchangers, TPU plastic particles were applied to a plate to simulate marine fouling. The cleaning effectiveness was evaluated by measuring changes in the particle-covered area before and after cleaning, as illustrated in the Fig. 2.


(a) Effect before flow channel cleaning (b) Effect after flow channel cleaning

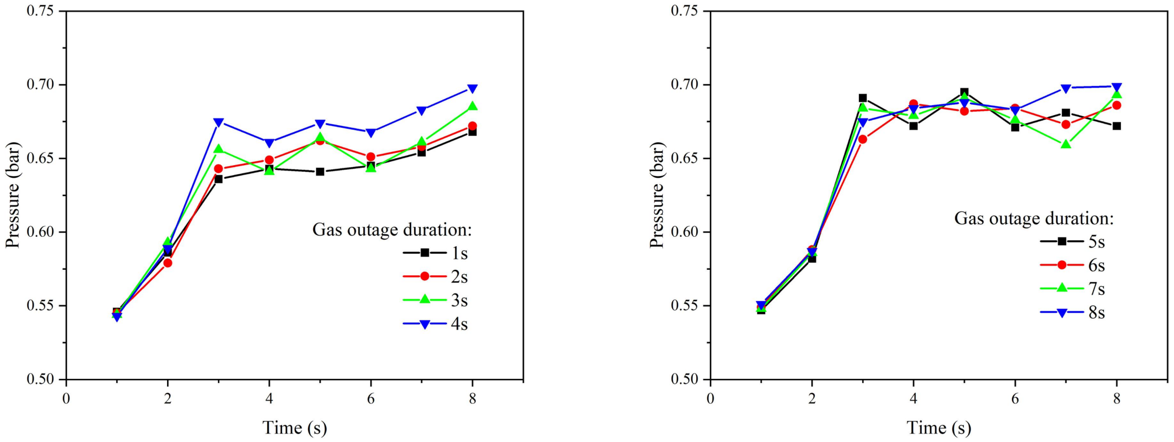
Fig. 2 Comparison of effects before and after flow channel cleaning

## 3. Results and discussion

### 3.1 Pulse frequency variation test

An experimental study was conducted to investigate the effect of pulse frequency on the flow field pressure within a plate heat exchanger, with a particular focus on the impact of ventilation time and gas-off time. The goal was to identify the optimal pulse frequency for achieving the best flushing effect and improving work efficiency.

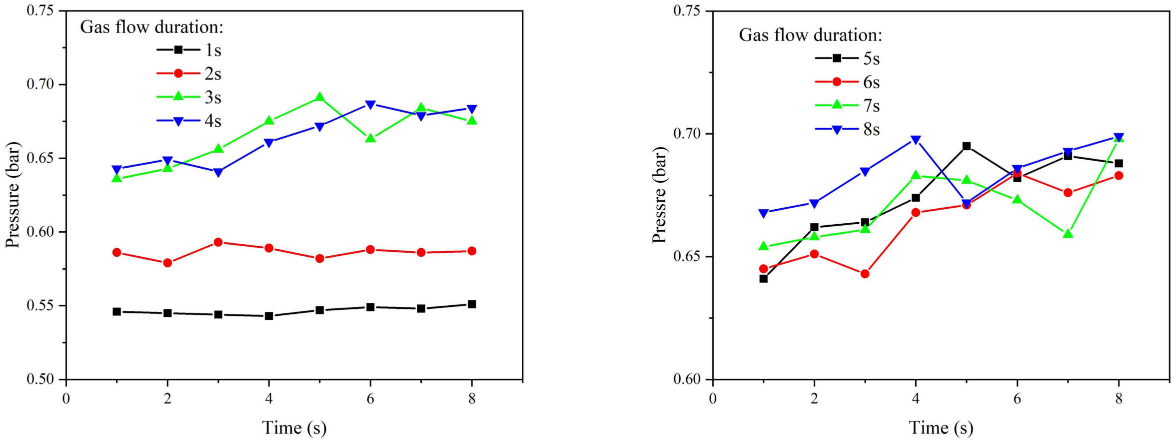
By varying the ventilation time while keeping the gas-off time constant, the pressure change inside the heat exchanger was recorded, as shown in Fig. 3. As illustrated, when the gas-off time is 1 second, increasing the ventilation time causes the internal pressure of the plate heat exchanger to rise. The pressure increases more sharply from 1 to 3s, then rises more gradually from 3 to 8s, reaching its maximum at 8s. In Fig. 3(b), the overall pressure trend shows a gradual increase, with a slight drop at 6s. From 1 to 3 s, the pressure rises more sharply, while from 3 to 8s, the change becomes less pronounced. This minor rise may be attributed to the increasing imbalance between the supply and consumption rates of the gas, which may lead to a decrease in gas supply pressure. Additionally, the potential loss of pressure could be due to imperfect gas sealing within the heat exchanger, causing the gas-water pulse jet to become more chaotic.



(a) Gas outage duration: 1-4s (b) Gas outage duration: 5-8s

Fig. 3 Effect of gas outage duration on pressure

The pressure changes with varying gas stop times and constant ventilation times are presented in Fig. 4. As shown in Fig. 4(a), when the ventilation time is 1 second, the internal pressure of the heat exchanger fluctuates between 0.54 bar and 0.55 bar, with a minimal variation. However, at a ventilation time of 2s, the pressure increases to a range between 0.57 bar and 0.6 bar, indicating an increase in the chaotic intensity of the flow field. Similar trends are observed in Fig. 4 (b). As the ventilation time increases, the initial pressure also increases. Between 3 and 8s of ventilation, an increase in gas stop time further raises the pressure inside the heat exchanger. These findings suggest that the gas supply capacity significantly influences the effectiveness of gas-water pulse cleaning. Longer gas stop times stabilize the output pressure of the gas supply system, resulting in higher pressure within the heat exchanger and improved cleaning performance.



(a) Gas flow duration: 1-4s (b) Gas flow duration: 5-8s

Fig. 4 Effect of gas flow duration on pressure

### 3.2 Water flow variation test

To investigate the relationship between water flow and water pressure, the water pressure was monitored within the range of 3 m3/h-5.5 m3/h. Fig. 5 illustrates the correlation between pump flow and outlet pressure, revealing a linear relationship between water flow and pressure. After performing linear regression, a correlation coefficient of 0.9846 was obtained. Fig. 6 demonstrates the change in internal pressure of the heat exchanger under varying water pressures. With a constant gas output pressure of 0.1 MPa and a pulse cycle of 3 s of gas flow and 3 s of gas stop, the water pressure was adjusted sequentially from 0.1 MPa in 0.1 MPa increments. Once the system pressure stabilized, the average of three peak values was recorded. The results indicate that the internal pressure of the heat exchanger increases with water pressure, exhibiting a linear relationship with a correlation coefficient of 0.9804.

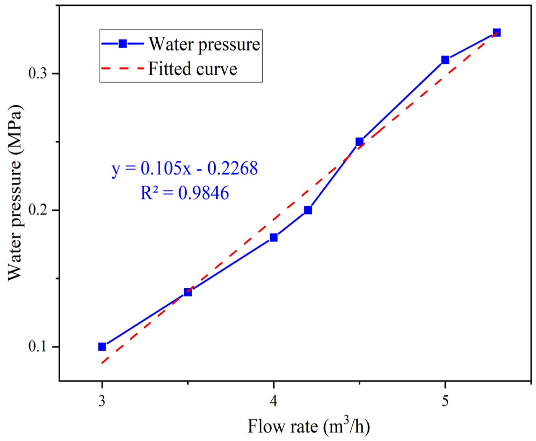


Fig. 5 Relationship between water flow and water pressure

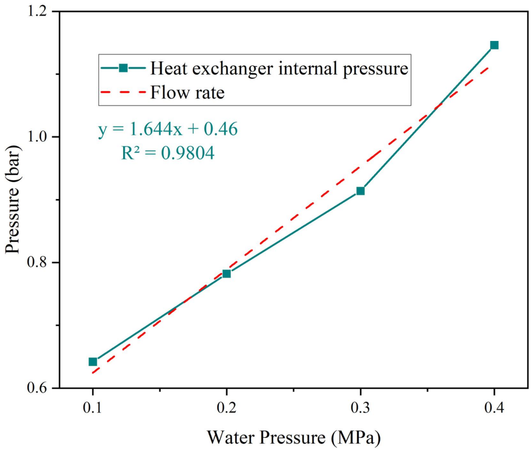


Fig. 6 Changes in internal pressure of heat exchanger under different water pressures

### 3.3 Gas pressure variation test

Fig. 7 shows the change in internal pressure of the heat exchanger under varying gas pressures. With the water pressure fixed at 0.1 MPa, the pulse cycle remained 3 s of ventilation followed by 3 s of gas stop. The gas pressure was incrementally adjusted from 0.1 MPa, and once the system pressure stabilized, the average of three peak values was recorded. The internal pressure of the heat exchanger was found to increase with increasing gas pressure, showing a linear relationship with a correlation coefficient of 0.995.

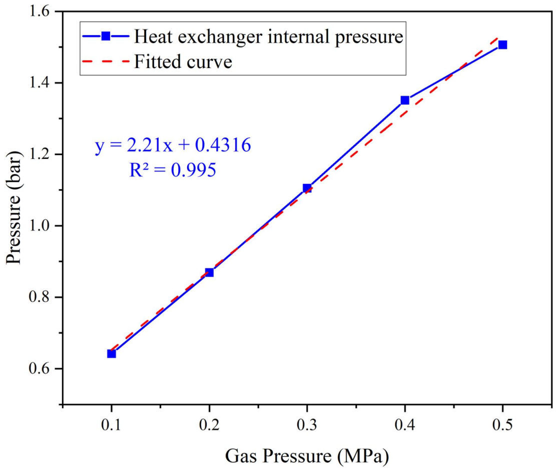


Fig. 7 Changes in internal pressure of heat exchanger under different gas pressures

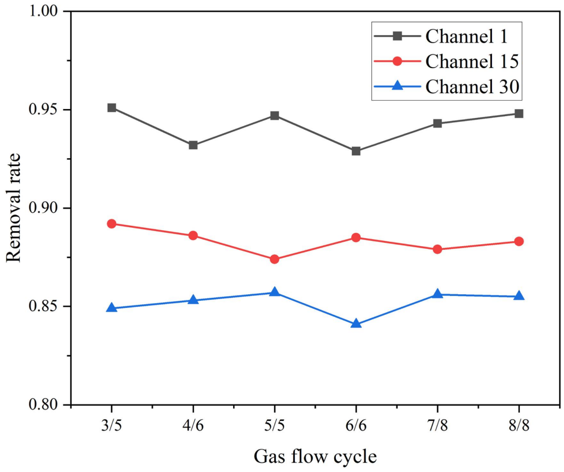


Fig. 8 Removal rate under different gas flow cycles

### 3.4 Analysis of cleaning effects at different frequencies

Pulse frequency plays a crucial role in gas-water pulse cleaning technology. In this study, six pulse frequency combinations were tested under a ventilation pressure of 0.2 MPa and a total cleaning time of 10 minutes. Based on the pulse frequency variation analysis, the selected frequencies included 3s on/5s off (3/5), 4s/6s (4/6), 5s/5s (5/5), 6s/6s (6/6), 7s/8s (7/8), and 8s/8s (8/8). As shown in Fig. 8, channel 1 achieved the best cleaning effect with a removal rate of about 93%–95%. In general, cleaning performance was better in channels closer to the pulse jet inlet due to greater gas expansion and upward flow, which led to reduced bubble activity in more distant channels. Channels 1 and 15 showed the best results at a 3/5 frequency, while channel 30 performed best at 5/5. Overall, the optimal frequency was determined to be 3s on and 5s off.

## 4. Conclusion

To enhance the cleaning efficiency and effectiveness of plate heat exchangers, this paper analyzes the flow dynamics within the heat exchanger and conducts an optimization test of the gas-water pulse cleaning parameters, focusing primarily on pulse frequency, water flow rate, and gas pressure. The main findings are as follows:

(1) When the gas-water pulse jet flows into the plate heat exchanger, the airflow diffuses into a large number of small bubbles and bubble groups, forming a counterclockwise vortex below the outlet.

(2) As the ventilation time of the gas-water pulse jet increases, the initial pressure also rises. From 1s to 3s, the pressure within the heat exchanger increases more significantly, while from 3s to 8s, the pressure increase is less obvious. Longer gas outage times lead to higher internal pressures, resulting in better cleaning effectiveness.

(3) The water flow rate and pressure in the test system exhibit a linear relationship, with a correlation coefficient of 0.9846. When other conditions are held constant, the internal pressure of the heat exchanger increases with rising gas pressure.

(4) The changes in pulse frequency were tested and the results show that modifying the pulse frequency significantly enhances the cleaning effectiveness of the heat exchanger. The optimal operating frequency is 3s of ventilation and 5s of gas suspension.

## References

[1] Xu H, Qin X, Meng W, et al. Experimental performance analysis of plate-fin and printed circuit heat exchangers in cyclopentane-based organic Rankine cycle under various operating conditions[J]. Applied Thermal Engineering, 2025, 278: 127436.

[2] Ye H, Wang J. Conjugate heat transfer simulation and additional thermal resistance analysis in pillow plate heat exchangers[J]. Chemical Engineering and Processing - Process Intensification, 2025, 216: 110407.

[3] Yu Y, Li Y, Liu Y, et al. Failure analysis of perforation in aluminum alloy plate-fin heat exchanger for electric multiple units transformer[J]. Engineering Failure Analysis, 2025, 179: 109788.

[4] Xu G, Du Y, Han H, et al. Experimental and numerical investigation of the frictional performance of the single-phase flow through a dimple plate heat exchanger[J]. International Journal of Thermal Sciences, 2025, 217: 110081.

[5] Magnaudet J., Eames I. The motion of high-reynolds-number bubbles in inhomogeneous flows[J]. Annual Review of Fluid Mechanics, 2000, 32: 659 - 708.

[6] Wu H, Zhou F, Wu Y. Intelligent identification system of flow regime of oil-gas-water multiphase flow[J]. International Journal of Multiphase Flow, 2001.

[7] He Q, Kasagi N. Numerical Investigation on Flow Pattern and Pressure Drop Characteristics of Slug Flow in a Micro Tube[C]//ASME 2008 6th International Conference on Nanochannels, Microchannels, and Minichannels. 2008Darmstadt, Germany: ASMEDC, 2008.

[8] Liu Y, Gao M, Zhang H, et al. A novel cleaning technology: Study on the cleaning performance control of self-excited oscillating pulsed SC-CO2 jet[J]. Journal of Environmental Chemical Engineering, 2025, 13(2): 116070.

[9] Lu H-H, Lin C-P, Le T-C, et al. Novel wet electrostatic precipitator using pulse-air-jet-assisted water flow (PJWF) for online dust cake removal[J]. Separation and Purification Technology, 2025, 367: 132863.