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Optimization of throttling windows to improve flow control of three-way control combiner valves

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Key words:

Three-way valve, Intersection flow, Throttling windows, Multi-objective optimization

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JZUS-A

1 Numerical model and validation

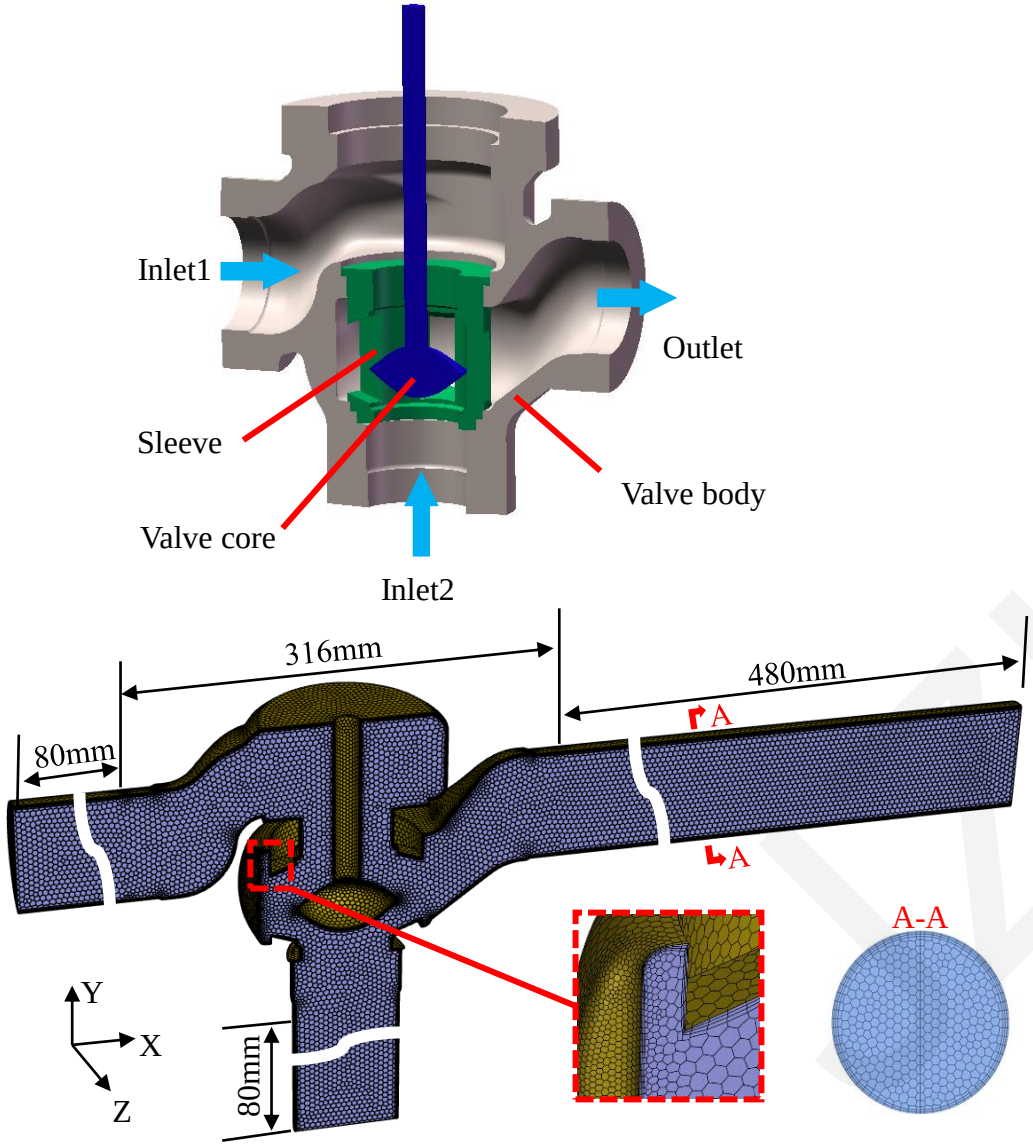
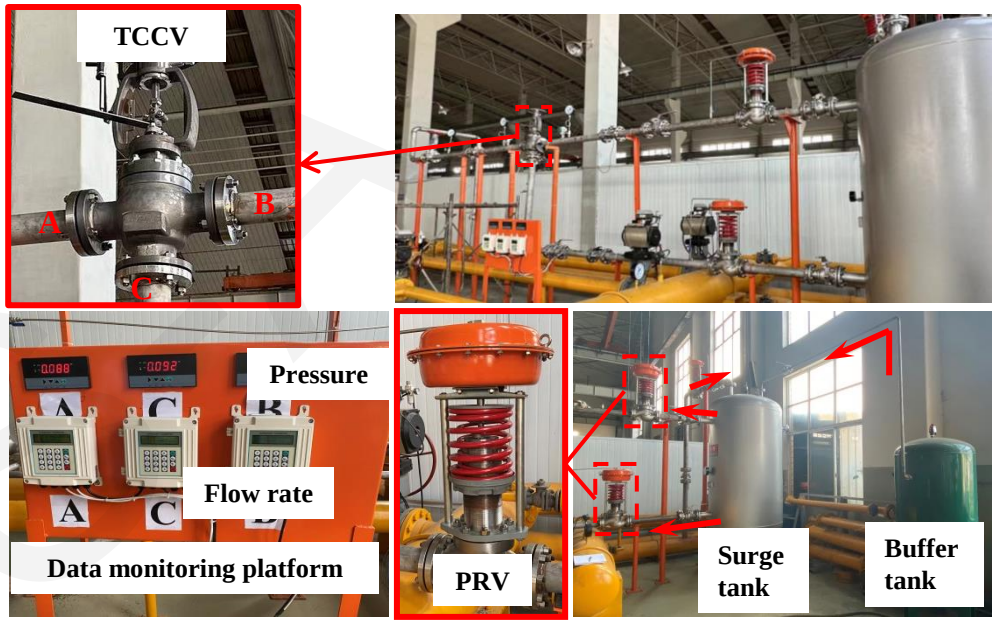


Fig. 1 Geometry and mesh of the TCCV



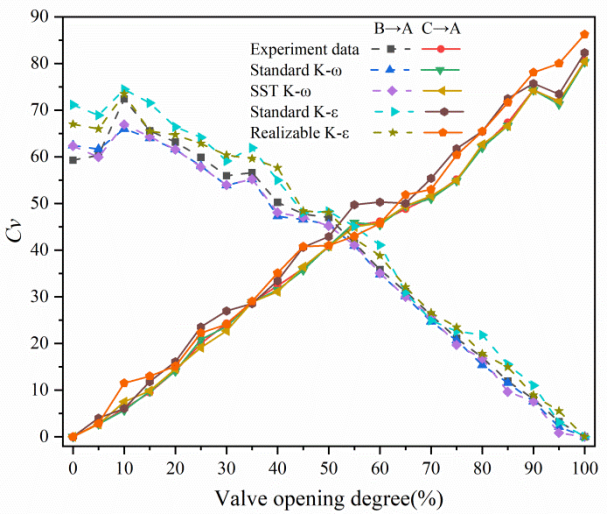


Fig. 2 Experiment and validation

2 Intersecting flow calculation method

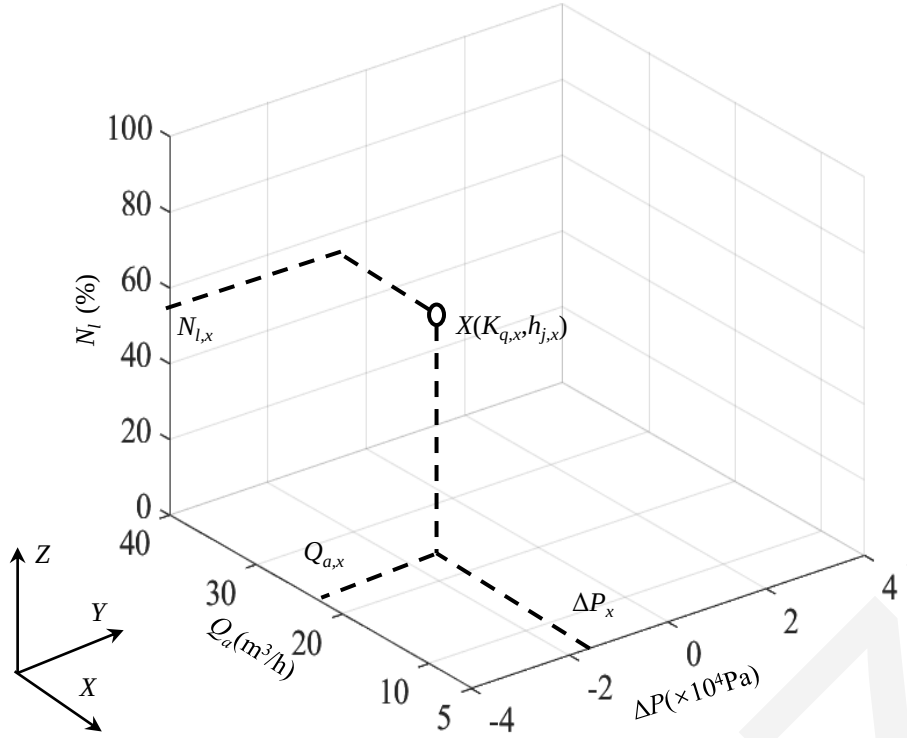


Fig. 3 Schematic diagram of intersecting flow calculation method

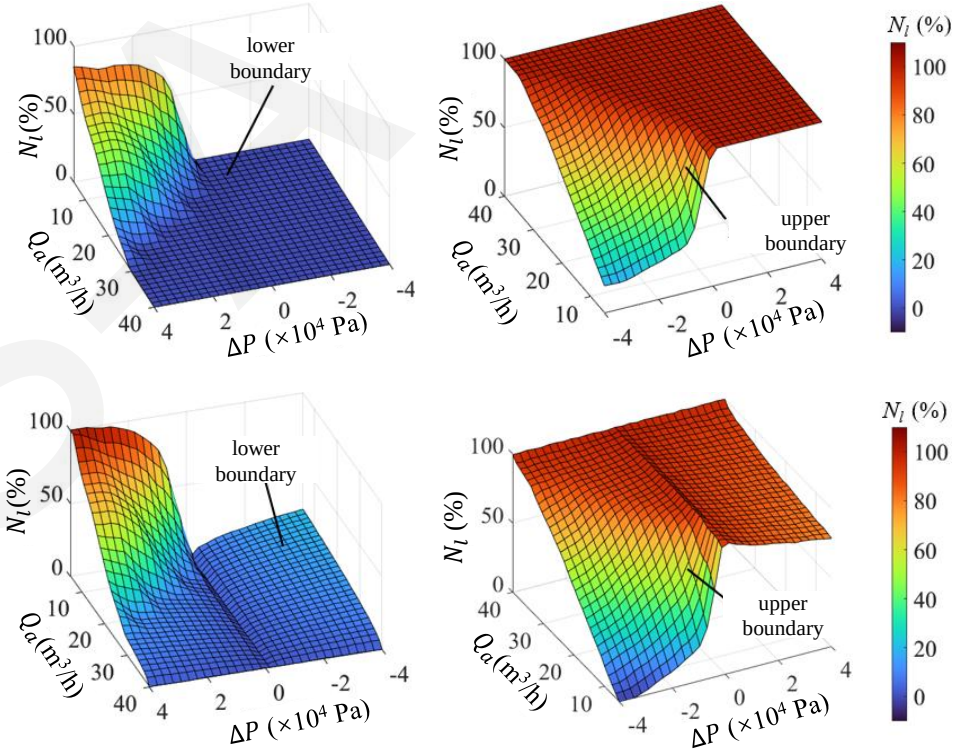


Fig. 4 Effective boundary and controllable boundary

- A calculation method for flow rate under various operating conditions has been developed based on the principle of intersecting flow.
- The concepts of effective and controllable domains are proposed to describe performance.

3 Optimization of throttling windows

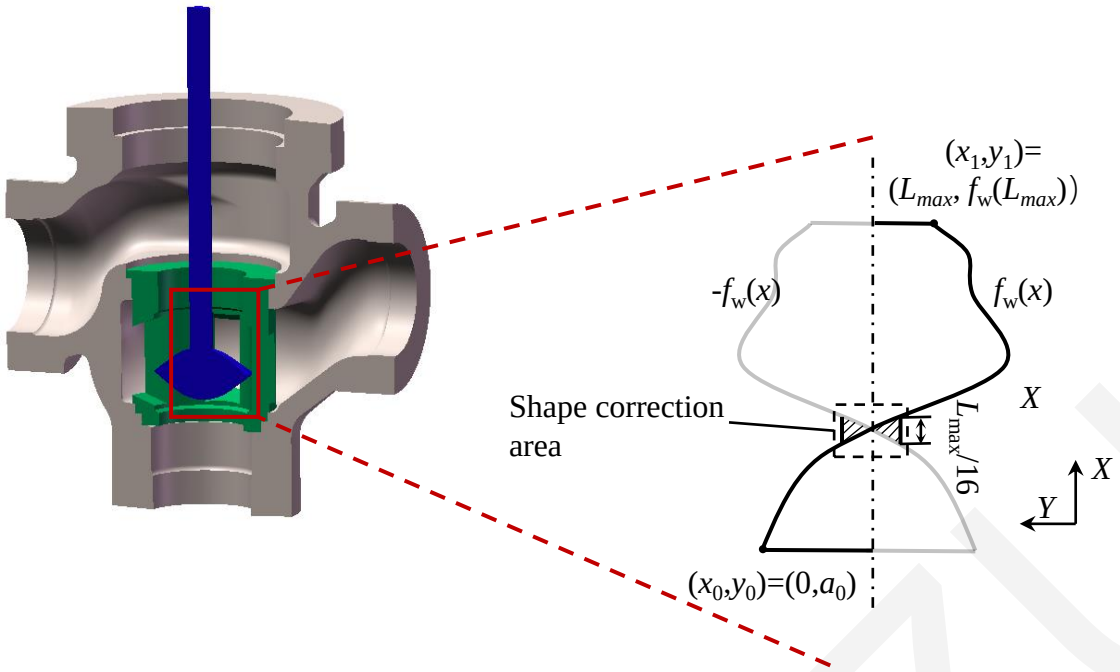


Fig. 5 Parametric design method for throttling window

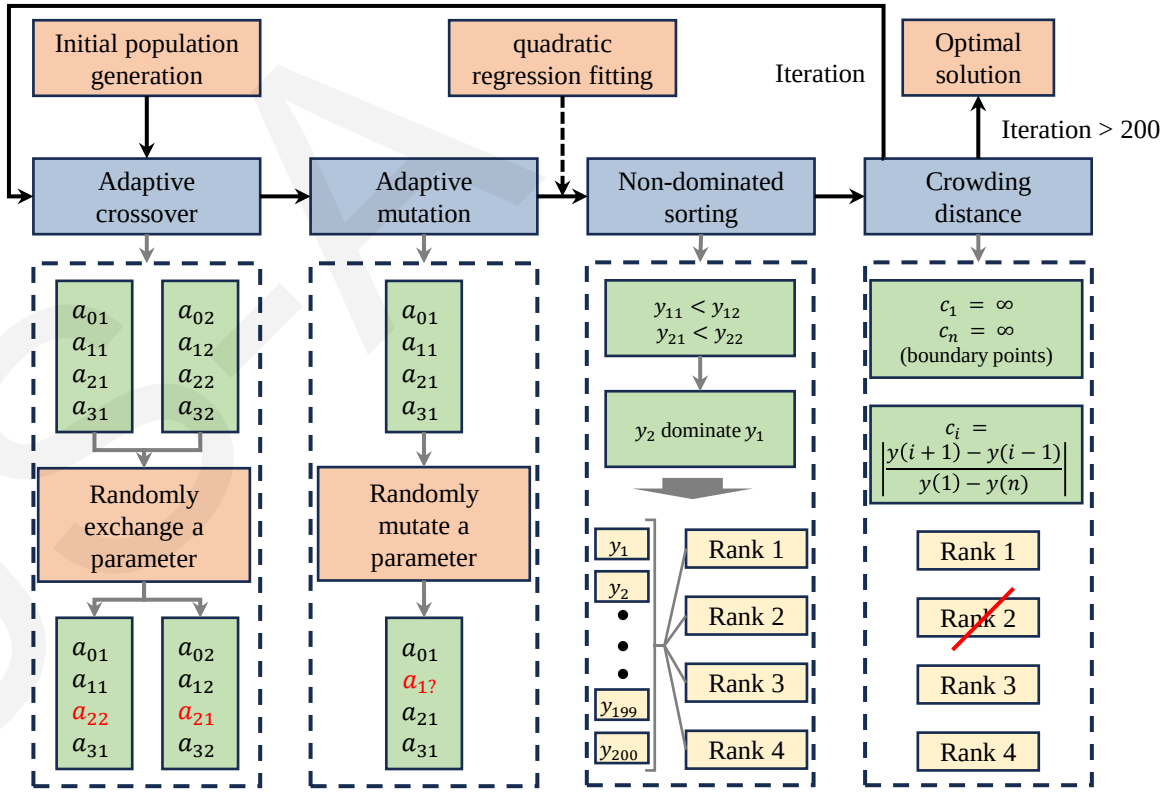


Fig. 6 Block diagram of optimization

- A parametric design method for the throttling windows is proposed, establishing relationships between shape parameters and performance indexes.
- The adaptive non-dominated sorting genetic algorithm is used to optimize the shape parameters of the throttling windows.

4 Result of optimization

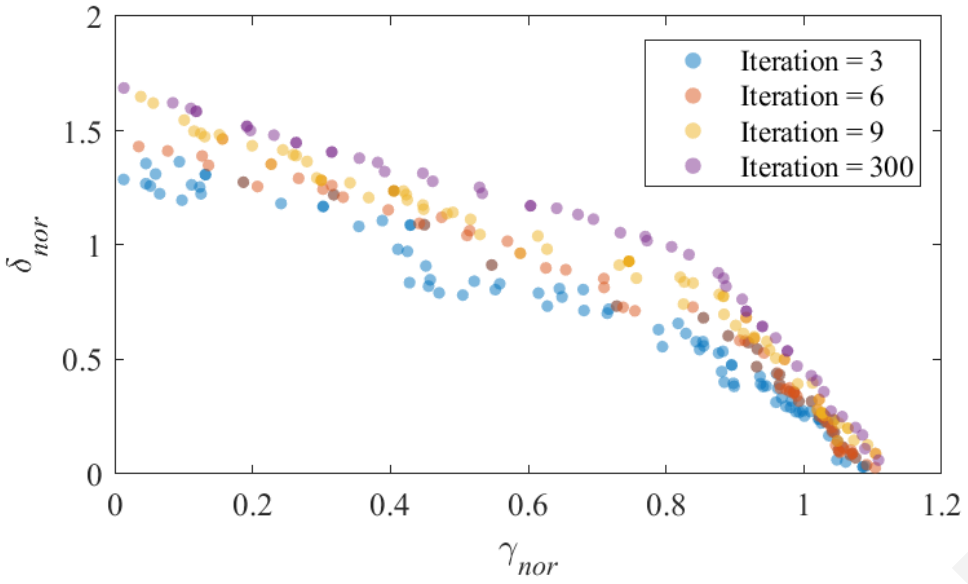


Fig. 7 Pareto front of ANSGA-Ⅱ

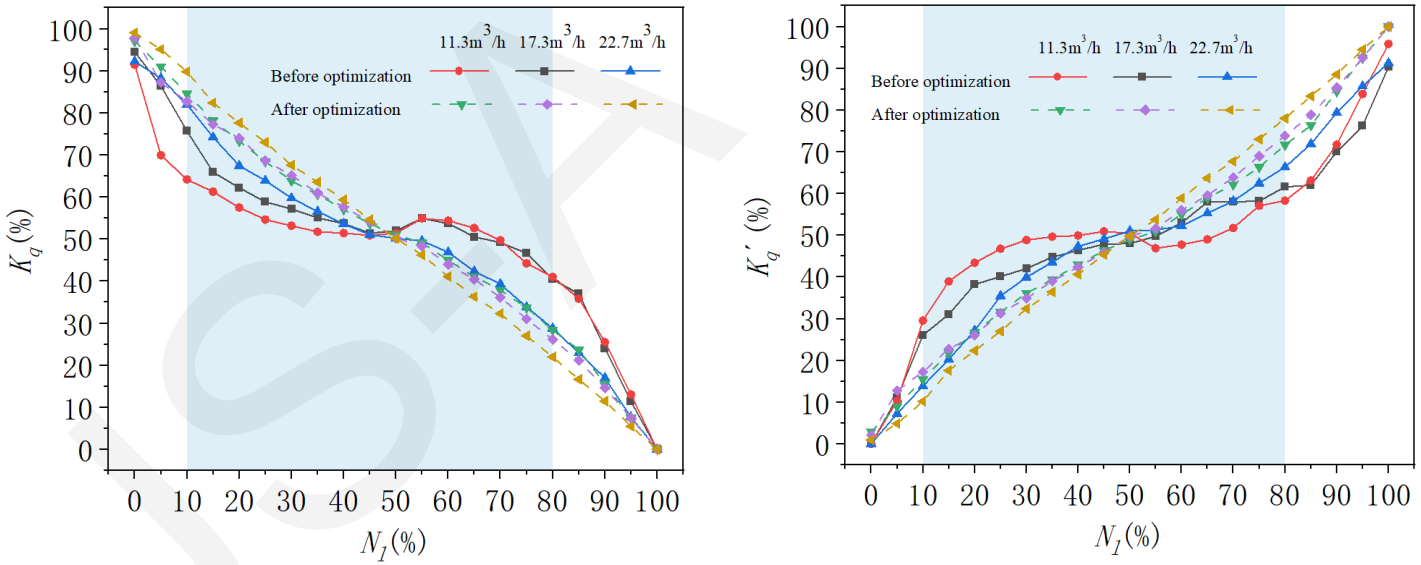


Fig. 8 Relative flow rate of the TCCV before and after optimization

- In the Pareto front, multiple fitness functions are balanced to obtain the optimal solution in the design space.
- After optimization, the problems of a limited adjustable operating range and excessive flow resistance under some operating conditions have been partially solved.

5 Conclusions

- The flow rate distribution analysis shows that the flow rates through the left and right throttling windows vary linearly with the degree of valve opening, while the middle throttling windows maintain relatively constant flow rate ratios. This information is crucial for calculating the equivalent contraction ratio and assessing the valve's control performance and flow resistance.

- The backflow phenomenon can be divided into four stages, from no backflow to significant backflow. Defining operational boundaries ensures that the valve operates safely and effectively, maintaining the desired boric acid concentration at the outlet without backflow. The analysis of the flow field revealed that the left throttling window is the first to experience backflow. Therefore, ensuring no backflow in the left throttling window is vital for the effectiveness of the TCCV.

- The optimization of the shape of throttling windows using ANSGA-II resulted in a 31.0% increase in the adjustable operating range and an 18.3% reduction in the maximum local resistance, improving the comprehensive performance of the TCCV.

Related work: Jun Qi, Lu-kun Zhou, Kan Sheng, Shi-jie LIN, Tian-zuo Qu, Jin-yuan Qian, Qi-shu Fang. 2024. Intersection Flow Mechanism of Three-way Control Combiner Valve. In 2024 4th International Conference on Energy, Power and Electrical Engineering (EPEE) (pp. 116-120). IEEE.