Promotion and control of natural ventilation using Fluid Diode

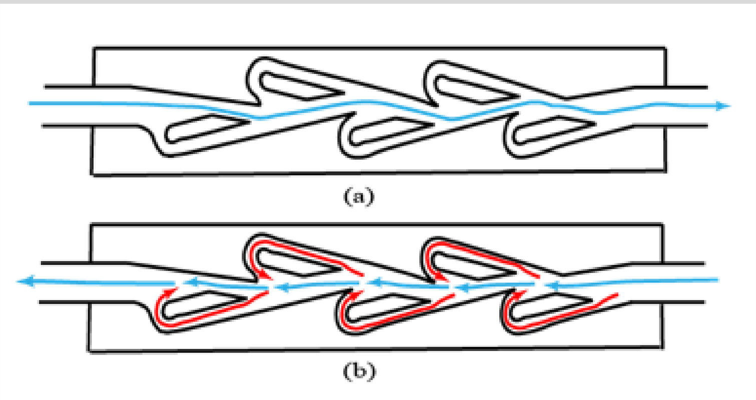
Part 1 Ventilation path control analysis and internal structure optimization using fluid diode plate

Research Background

- The introduction and use of efficient natural ventilation plays a major role in a building's energy conservation strategy
- Natural ventilation through simple openings may degrade air quality in adjacent rooms.
- To achieve efficient natural ventilation, it would be ideal to have openings that also control ventilation pathways.

Fluid Diode

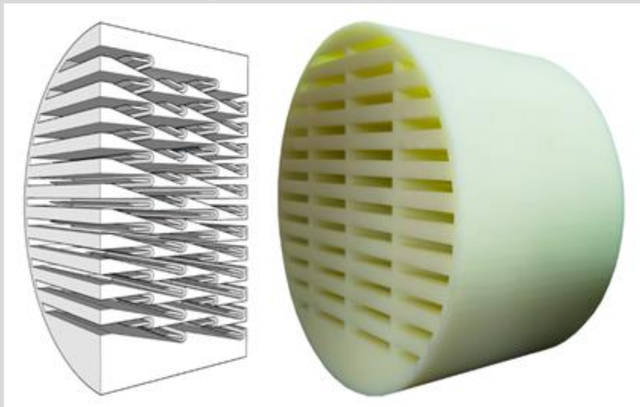
- Forward fluid flow resistance is lower than in the reverse direction Passive structure
- Typical - Tesla valve with no moving parts and varying flow resistance in the forward and reverse directions [1].



(a) Forward: Low resistance
(b) Reverse: High resistance

Previous Research

- Cao et al [2] optimized a fluid diode plate (FDP) based on the Tesla valve principle using CFD and wind tunnel experiments to determine its fundamental fluid resistance and reported its applicability to building ventilation systems.



FDP model

Airflow control analysis study of Fluid diode plate (FDP) applied to building windows

- The FDP optimized by Cao et al. was installed in a window of a real residential experimental building, and the effect of controlling its ventilation path was analyzed by CFD.

Analysis Method

- CFD analysis using Realizable k-ε model in RANS
- Characteristic 2 wind directions, bathroom with ventilation fan operating + case (i) closed window, (ii) open window, (iii) FDP
- (iii) In the FDP setup, a pressure jump corresponding to the forward and reverse pressure drop [2] of the FDP of Cao et al.

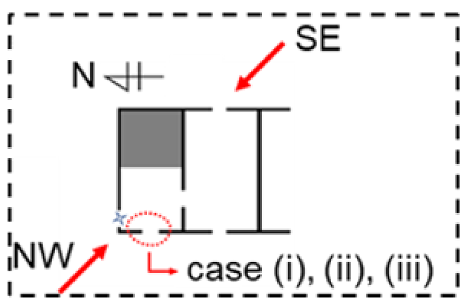
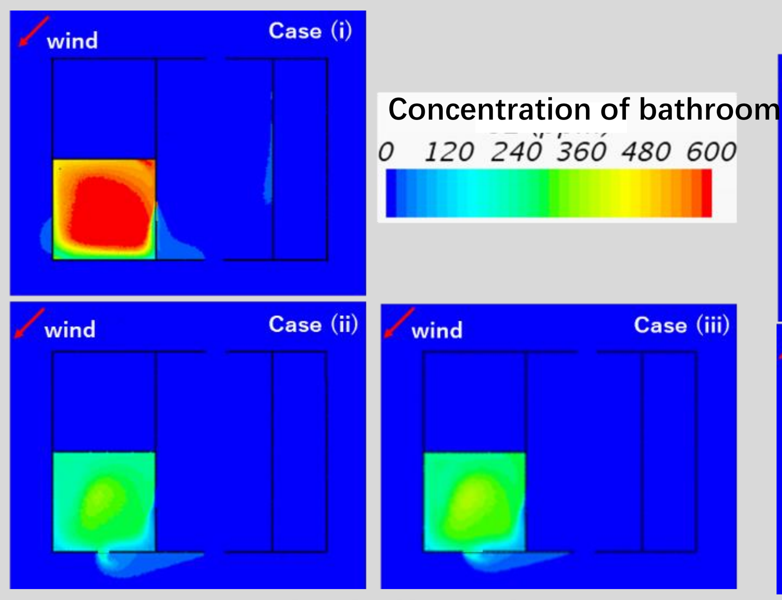


Table 1. Case setting

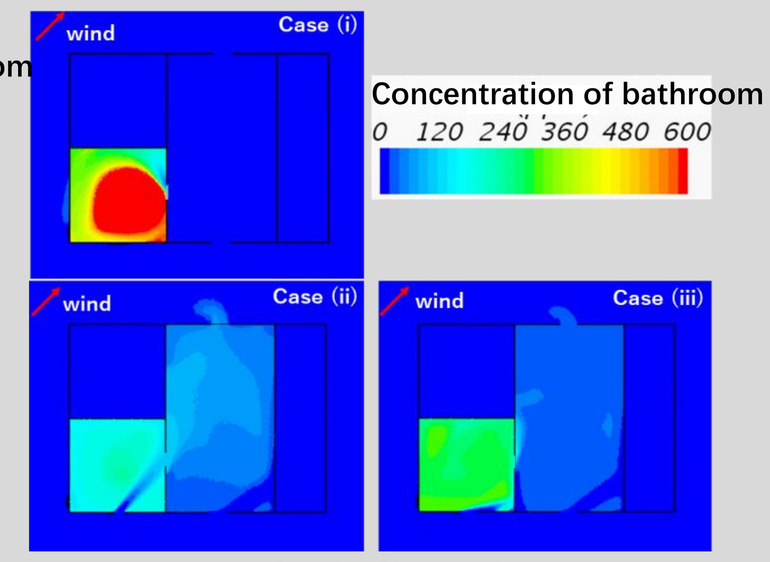
Case	Multipurpose room	Bathroom	
(i)	2 windows	fan	a closed window
(ii)	2 windows	fan	an opening window
(iii)	2 windows	fan	an FDW

Analysis Results

- FDP has basic ventilation path control performance as a bathroom window.
- The NW wind direction concentration distribution shows that there is room to improve the FDP.



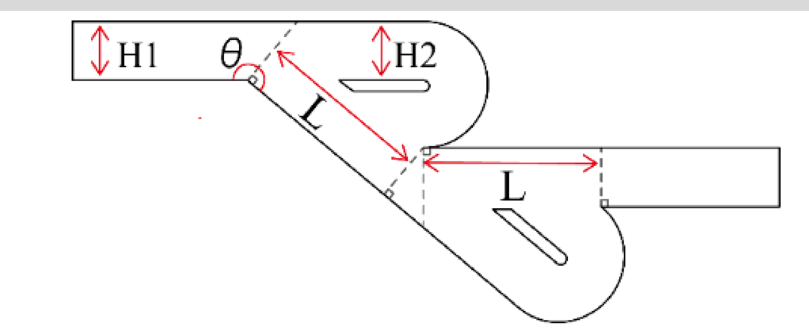
SE wind direction



NW wind direction

FDP performance improvement (analysis method)

- Create various internal structures by changing parameters (parametric design)
- CFD analysis of the created internal structure to find the optimal shape



Parameters set (H1,H2,Θ,L)

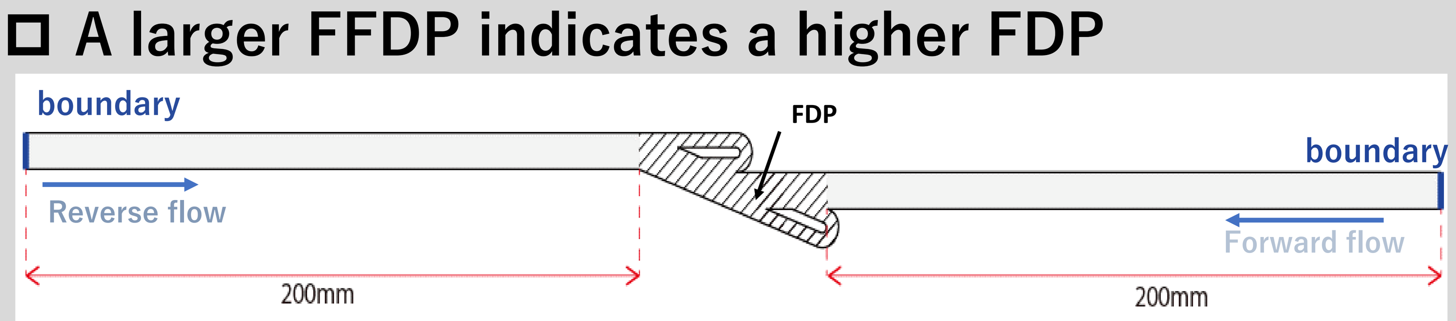
Parameter	L				H2				Θ				H2,Θ			
H1[mm]	5				5				5				5			
H2[mm]	2				1.75	2	2.25	2.5	2				2.22	3.58	4.9	6.14
H3[mm]	1.4	3.1	4.9	6.6	1.932	1	0.932	0.4	1.432	4.17	6.812	9.2767	1	1	1	1
θ [rad]	10/9π				10/9π				10/9π	7/6π	11/9π	23/18π	10/9π	7/6π	11/9π	23/18π
L[mm]	15	20	25	30	15				15				15			

Case of internal structure created

FDP (evaluation index)

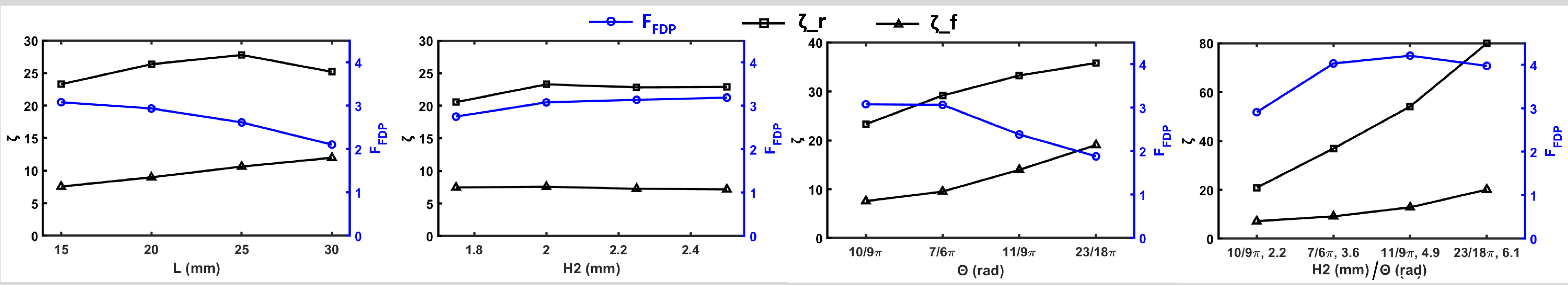
- $F_{FDP} = ζ\_r / ζ\_f$

  ζ_r : Pressure drop difference when wind flows (revers)
  ζ_f : Pressure drop difference when wind flows (forward)
  the pressure loss difference ζ indicates the pressure difference between the inflow and outflow boundaries
- A larger FFDP indicates a higher FDP



FDP performance improvement (analysis results)

- Under the present analytical conditions, the smaller L and θ and the larger H2, the larger the pressure drop ratio.
- Under the present analysis conditions, the pressure loss ratio was maximum when H2/θ =1.28 (mm/rad).



Change L　Change H2　Change Θ　Change H2 & Θ

1) N. Tesla, Valvular conduit. (1920). US Patent 1,329,559
2) Z. Cao et al., Novel fluid diode plate for use within ventilation system based on tesla structure, Build. Environ. 185 (2020)

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