# A uniform air flow distribution design strategy for use in tunnel transverse ventilation systems

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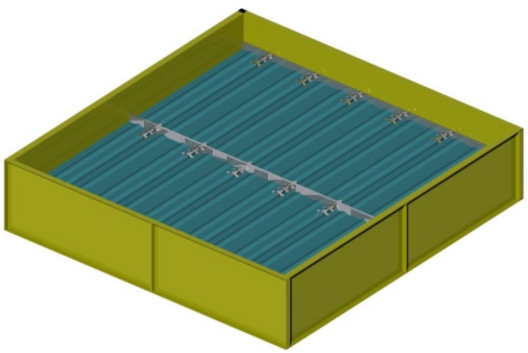
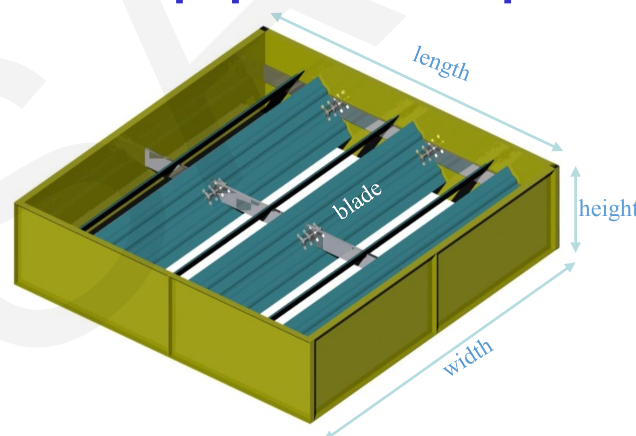
# Multi-blade opposed regulation damper

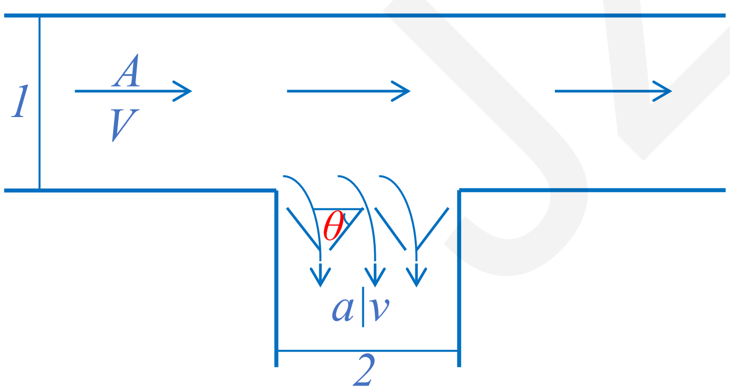
- Multi-blade opposed regulation dampers are specifically engineered for gas exhaust applications in which precise flow control equipment is required



blades closed




blades open

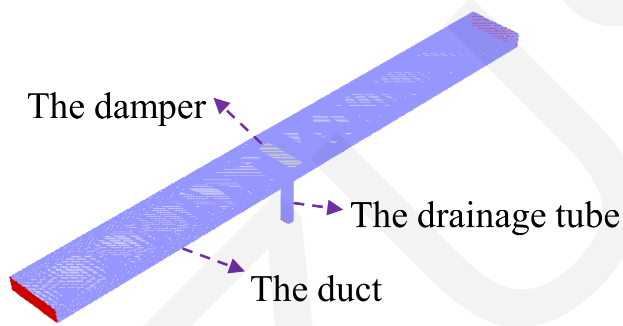


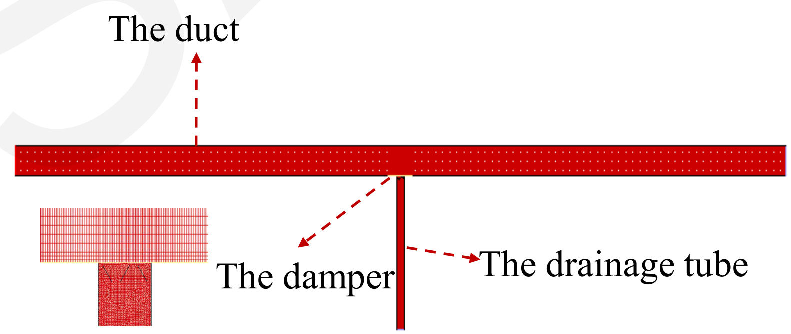

**Air volume adjustment is very convenient and flexible by changing the opening angle of the blades**

# Flow resistance of the damper

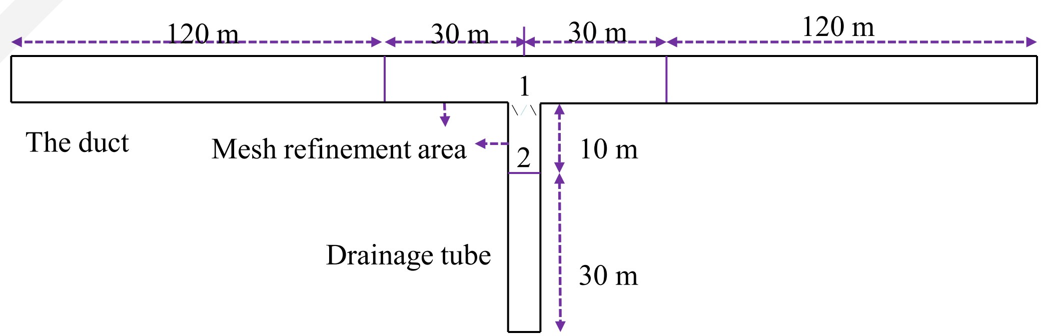
**Dimensional analysis** → **3D Numerical simulation** → **2D Numerical simulation**

$$\xi = f(\frac{v}{V}, \theta)$$

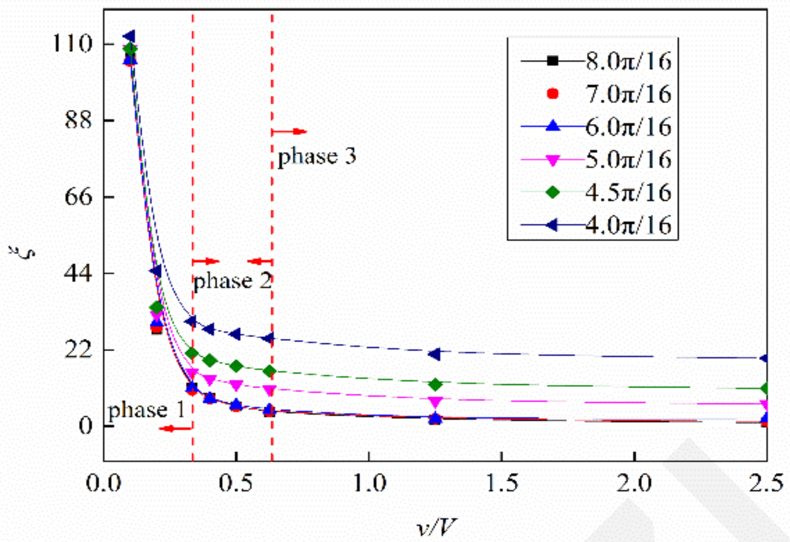


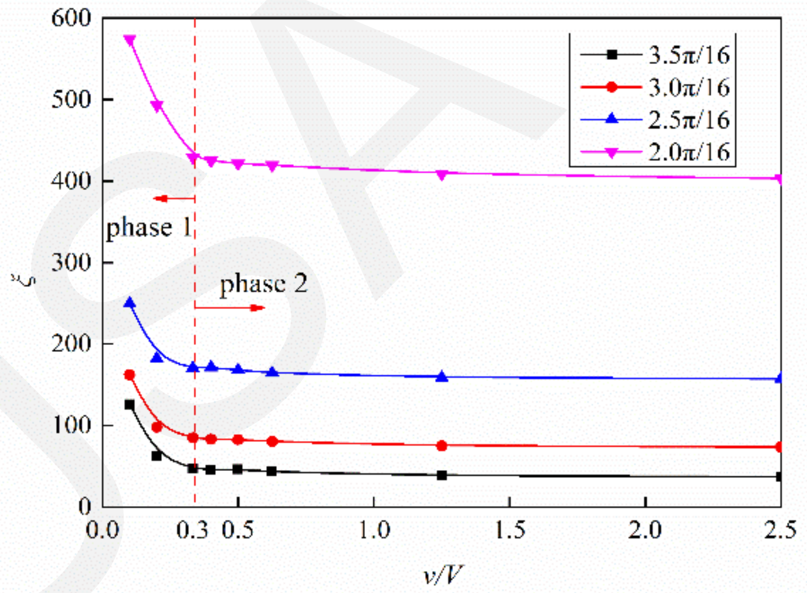




**ξ can be characterized as a function of velocity ratio (v/V) and opening angle (θ)**



# Flow resistance of the damper




**Local resistance coefficient curves for for big opening angles**

**Local resistance coefficient curves for small opening angles**

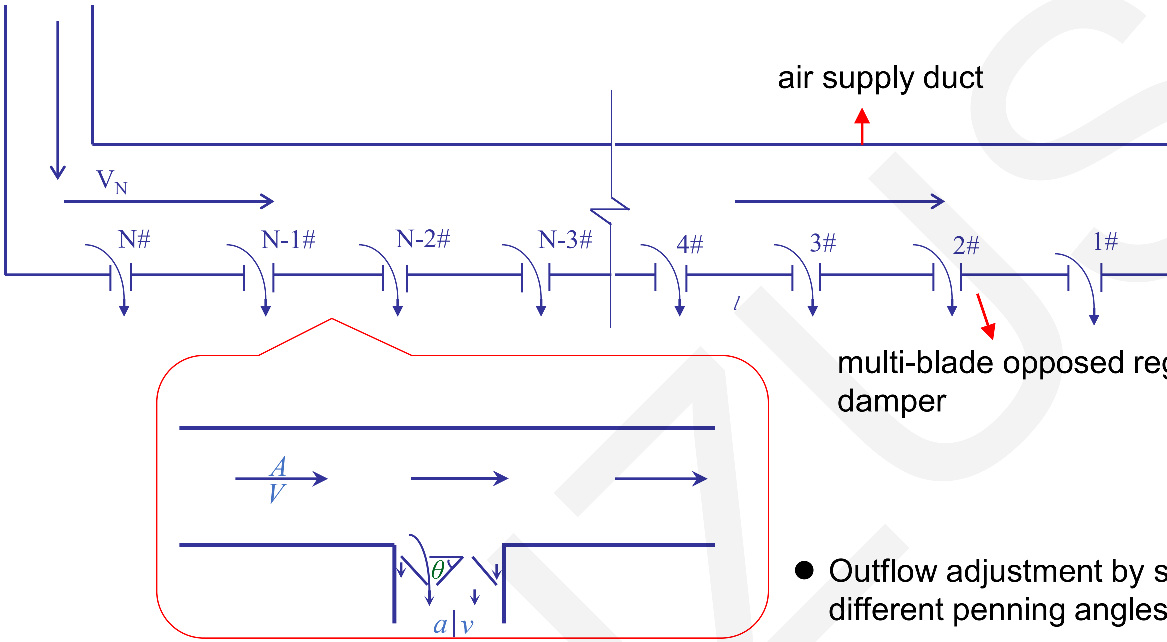
Both 2D and 3D CFD simulation methods were carried out to figure out the resistance coefficients under different opening angle and velocity ratio conditions

# Design strategy for uniform air flow distribution

- **In tunnel transverse ventilation systems, fixed amount of fresh air flows into the duct from the entrance and uniformly flows out of the duct through dampers.**

$$P_x = P_0 + \left(\frac{\lambda x}{3d} - 1\right)\frac{\rho V_x^2}{2}$$

**Static pressure prediction from air flow in the duct**




- Outflow adjustment by setting different penning angles.

$$P_n = P_e + \xi_n \frac{\rho}{2} v^2 + \frac{\rho}{2} v^2 - \frac{\rho}{2}\left(\frac{nV_N}{N}\right)^2$$

**Static pressure neede to banlance the resistence**

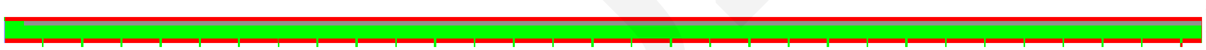
A uniform air flow distribution design strategy by changing the blade opening angle was finally obtained

# Design case

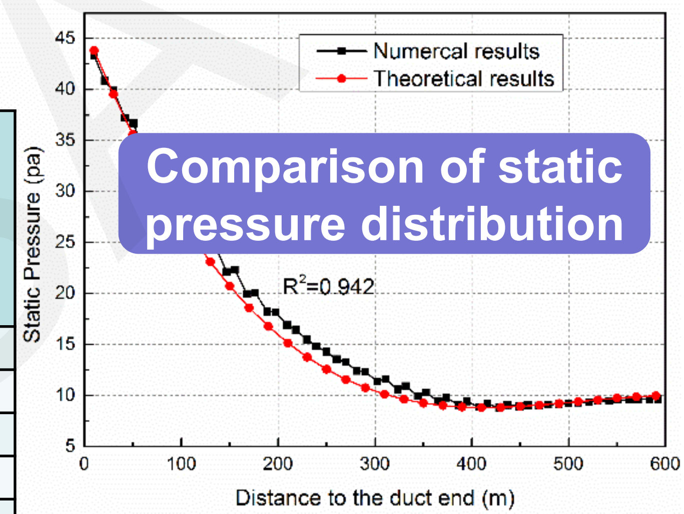
- **A 600 m air supply duct was taken as a design case.**

**Opening angle design list**

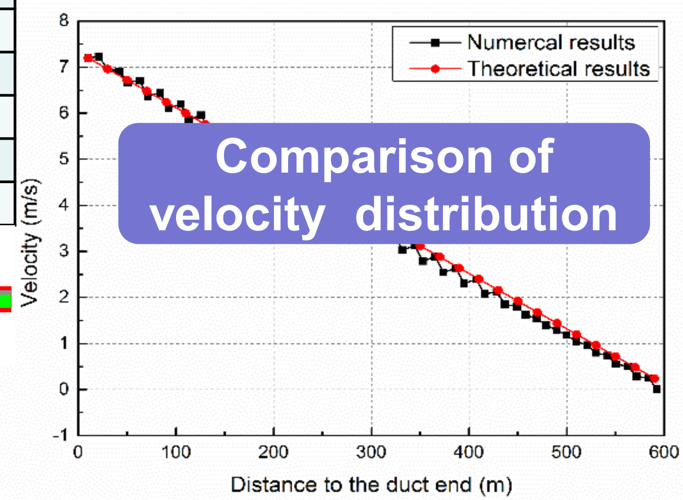
| NO | Distance to the duct end（m） | Velocity（m/s） | Static pressure（Pa） | Local resistance coefficient | Velocity ratio | Opening angle θ | Applied dampers |
|---|---|---|---|---|---|---|---|
| 2# | 30.0 | 0.48 | 9.87 | 24.69 | 1.67 | 3.83×π/16 | 1~3# |
| 5# | 90.0 | 1.20 | 9.40 | 25.51 | 0.67 | 3.96 ×π/16 | 4~6# |
| 8# | 150 | 1.92 | 8.93 | 27.87 | 0.42 | 3.98 ×π/16 | 7~9# |
| 11# | 210 | 2.64 | 8.87 | 32.77 | 0.30 | 3.95 ×π/16 | 10~12# |
| 14# | 270 | 3.36 | 9.62 | 41.25 | 0.24 | 3.87 ×π/16 | 13~15# |
| 17# | 330 | 4.08 | 11.58 | 54.32 | 0.20 | 3.72 ×π/16 | 16~18# |
| 20# | 390 | 4.80 | 15.15 | 73.00 | 0.17 | 3.48 ×π/16 | 19~21# |
| 23# | 450 | 5.52 | 20.73 | 98.32 | 0.14 | 3.22 ×π/16 | 22~24# |
| 26# | 510 | 6.24 | 28.72 | 131.29 | 0.13 | 3.01 ×π/16 | 25~27# |
| 29# | 570 | 6.96 | 39.52 | 172.94 | 0.11 | 2.80×π/16 | 29~30# |



**Numerical simulation model**



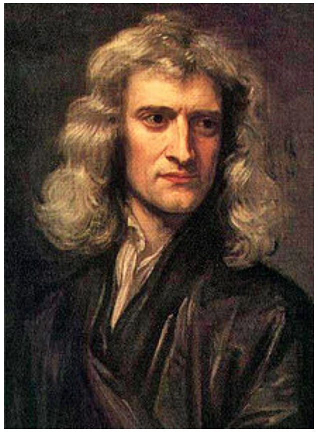

**Comparison of static pressure distribution**




**Comparison of velocity distribution**

# Conclusions

- Uniform air flow distribution is especially needed to dilute the vehicle exhaust gases, or the vehicle emissions to acceptable concentrations in tunnel transverse ventilation systems.
- Multi-blade diverter dampers are engineered specifically for gas exhaust applications and it can be directly installed on the air supply duct.
- The air flow volume adjustment is very convenient and flexible with the damper by just setting different blade opening angles.
- The the local resistance coefficient ξ arisen when air flow out of the duct through the damper were investigated.



With the simulation results, theoretical analysis based on Bernoulli equation was implemented to establish the relationship between the local resistance coefficient and the opening angle. And finally the uniform air flow distribution design strategy corresponding with the opening angle adjustment was obtained, in addition, a sufficient consistency between the theoretical and numerical calculation results in a design case verified the reliability of the strategy.