A concept of external aerodynamic elements in improving the performance of natural smoke ventilation in wind conditions

Wojciech Węgrzyński[1] **, Grzegorz Krajewski**[2] **and Grzegorz Kimbar**[3]

Building Research Institute (ITB), Fire Research Department
ul. Filtrowa 1, 00-611 Warszawa, Poland
[1] *e-mail: w.wegrzynski@itb.pl*
[2] *e-mail: g.krajewski@itb.pl*
[3] *e-mail: g.kimbar@itb.pl*

Abstract

This paper is a proposal of new device that may be used as a component of natural smoke ventilation systems – an external aerodynamic baffle used to limit the wind effect at the most adverse angle. Natural ventilation is not only affected by the external wind, but also dependant on the angle of wind attack. It has been proven, that at angles between 45° to 60° the performance of such device is the lowest. This is the reason why additional device is proposed – external baffle that could hypothetically increase the performance at chosen angles. The purpose of this paper is to explore this idea by numerical modelling of such external elements on a validated natural ventilator model, with use of ANSYS® Fluent® CFD model.

Keywords: fire, smoke, CFD, natural ventilation, NSHEVS

1. Introduction

Natural Smoke and Heat Exhaust Ventilators (NSHEV) system is the simplest, cheapest and highly effective device capable of the removal of smoke and other products of the fire from the building. The principle of the system operation is the buoyant force, caused by the difference of density between the ambient air and the hot smoke. This force causes smoke to move upwards and through the exhaust from the building. To date, the basis of many NSHEVs design is a methodology derived in the late 90s of last century[3], and its base are German code [2]. Other, more modern design guidelines [1,4] are extremely difficult to apply, which is proven by the amount of inquiry's coming to the Building Research Institute on this topic. More than that, incorrect application of these standards may result in many extra-curricular requirements, unnecessarily raising the cost of the investment.

2. Natural ventilators

The harmonized standard EN 12101-2 [1] defines the basic characteristics of NSHEV, among which the most influential on the design of whole system, is the discharge coefficient (C_v). This parameter can be explained as a mathematic description of the adverse impact of wind on the performance of the device, in laboratory conditions. Despite that this parameter is devoid of physical meaning, it has become the main design criterion by system designers around the world, which is reflected in aforementioned standards. Parameter directly used in the design – the aerodynamic free area, is derived by multiplying its total area by aerodynamic free area coefficient (discharge coefficient, C_v). This coefficient is found in aerodynamic tests carried for with and without wind (Fig. 1).

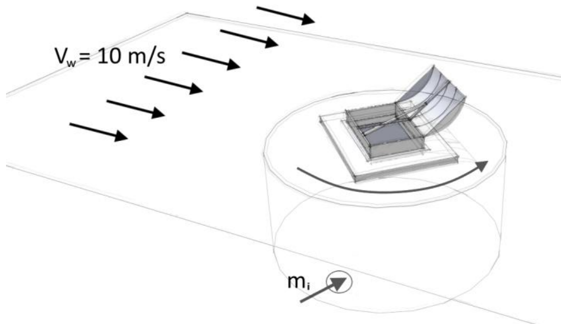

Figure 1: Test of aerodynamic free area (discharge coefficient) of natural ventilator in a wind tunnel

The ventilator performance is usually presented in a form of dimensionless discharge coefficient, calculated with the use of equation 1.

$$C_V = \frac{\dot{m}_{ing}}{A_{v,test}\sqrt{2\rho_{air}\Delta p_{\text{int}}}} \qquad (1)$$

where: m_{ing} - mass flow into the settling chamber, A_v – total area of the tested ventilator, ρ_{air} – ambient air density, Δp_{int} – pressure difference between settling chamber and the wind tunnel.

As presented above, the test method that is base of the design of the device, and further design of the system, in its basic concept introduced far-reaching restrictions and simplifications:

- only one arbitrarily chosen wind speed (10 m/s) and the extent of the pressure difference between the chamber and the wind tunnel, from 3 to 12 Pa;
- smoke ventilators are tested in ideal environment of wind tunnel, without further analysis of their performance in real buildings,
- important factors, such as the supply air, are not taken into account during the test.

3. New concept – external aerodynamic elements

To summarize the state of knowledge concerning the design of the device – NSHEV, it can be concluded that manufacturers are improving their products to ensure better results in aerodynamics test of free area, which does not necessarily translate into better performance of complete system. In opinion of the Authors, this situation can be improved, without altering the design of the devices themselves, thus without requirement of upgrading technical requirements for the devices and their costly CE marking. Proposed solution is to use independent, external aerodynamic elements, that would change the airflow near the ventilator, and greatly limiting adverse effect of the wind on the device, as shown on Fig. 2.

In order to propose such standardized elements, it is necessary to perform large program of numerical and aerodynamic studies on their performance, which is one of the key tasks of this project. Since this is a completely new development, no knowledge is available on the performance of such external elements. As a reference, existing solutions – mounting deflectors directly on ventilators [5], provides up to 10% performance gain, which translates to a minor qualitative improvement, Fig. 3. It is possible, that an external element may provide better protection against a wind, and in some cases also cause an underpressure at the proximity of natural ventilator, that would additionally increase its performance.

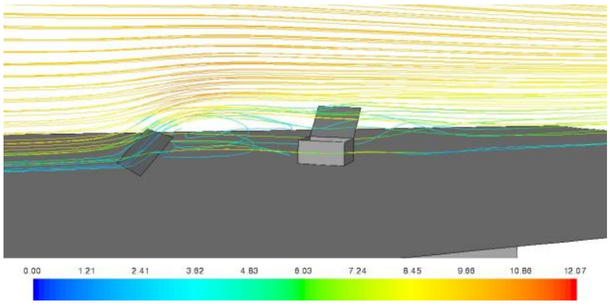

Figure. 2: The use of additional aerodynamic element influencing air flow in proximity of smoke damper exposed to wind. Pathline colour describes the velocity of air (0-10 m/s), own research with use of ANSYS Fluent v 13.0.0

4. Conclusions

CFD method can be successfully used in evaluation of performance of the NSHEVs, located on the roof of a building. The same method can be also used to evaluate if addition of external aerodynamic elements, will improve the system performance in adverse wind conditions.

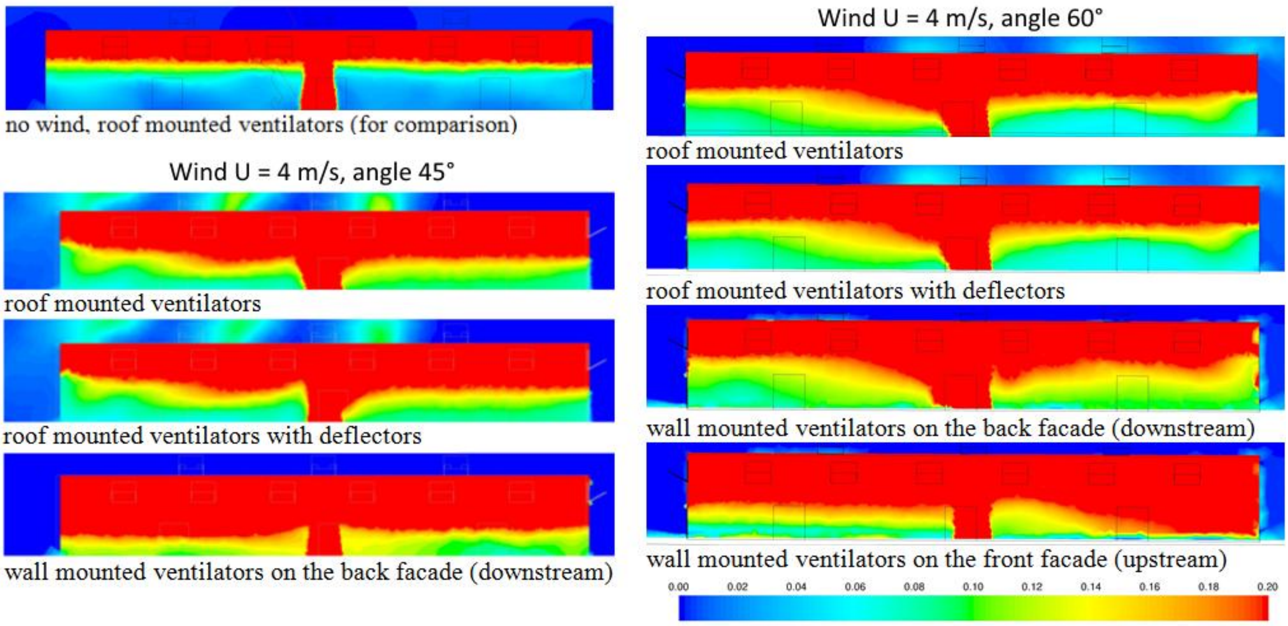

Figure 3: Comparison of mass smoke density plots for various natural ventilation solutions, at different wind angle and velocities [5]

References

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