Energy and Buildings 108 (2015) 413–419

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Evaluation of reversed airflow in a ventilation system with multiple fans

Amalie Gunner*, Alireza Afshari, Niels Christian Bergsøe

Aalborg University, Danish Building Research Institute, A.C. Meyers Vænge 15, 2450 Copenhagen SV, Denmark

ARTICLE INFO

Article history:
Received 7 July 2015
Received in revised form
13 September 2015
Accepted 14 September 2015
Available online 15 September 2015

Keywords:
Reversed airflow
Manifold
Supply
Ventilation
Pressure drop
Fan
Energy

ABSTRACT

Mechanical ventilation systems have a significant influence on the energy demand of buildings. The Government's aim is to reduce the energy demand for mechanical ventilation by 2020. Therefore, energy efficient mechanical ventilation systems are required.

Using dampers to balance the ventilation system, the centralised fan must provide sufficient static pressure to overcome the maximum pressure drop in the system. This means that there will be excess pressure in parts of the duct system. Using decentralised fans instead of dampers, the excess pressure can be eliminated as each fan provides the pressure needed for that particular part of the duct system.

In duct systems in conventional supply ventilation systems, there is a positive static pressure compared with the pressure inside the building. Using decentralised fans, parts of the duct system will have a negative pressure and room air may enter the duct system and spread to other parts of the building.

In this paper, the possibility of reversed airflow was investigated. An evaluation of reversed airflow was implemented both theoretically and experimentally. With the objective of simulating a malfunctioning, one integrated fan did not operate during the investigations while the others did.

When a manifold was used to distribute the pressure, the reversed airflow was eliminated. This was due to the positive pressure in the manifold that was maintained by the main fan. When the ventilation system was a regular supply duct system with a main fan and a main duct with branches, then there was a possibility of reversed airflow if a fan malfunctioned.

1. Introduction

In order to lower the electric energy used for mechanical ventilation, it is essential to develop ventilation systems with low energy consumption. In order to achieve low energy consumption in relation to a low pressure drop, it is necessary to design and install a ventilation system properly. Correct dimensioning and design of ventilation systems can reduce the energy demand of fans and result in lower operational costs [1–3].

Variable-air-volume (VAV) air handling systems save energy by reducing fan power during partial load conditions. However, most VAV systems do not make use of the full savings potential because the main fan is dimensioned to maintain a constant pressure in the supply duct. This duct pressure is set so that it is high enough to obtain sufficient air supply to the zones served at full-load conditions. Many building systems operate at less than full load most of the time due to varying weather conditions and because most air handling systems are designed with more capacity than needed. As a result, duct pressure–and therefore energy consumption – is almost always higher than required when this constant-pressure strategy is employed [4].

In three previous publications, the method and applicability of a novel mechanical ventilation system were tested [5–7]. For this novel design, the ventilation system with dampers was converted into a new system with fans instead of dampers. When the dampers were replaced with fans, the overpressure across the dampers was eliminated.

In Fig. 1, a simple illustration of the dimensioning method is shown. The diagram to the left shows a ventilation system with a fan and dampers in the branches. Equal airflow in all branches is assumed. The fan has to be dimensioned according to the total airflow and the maximum pressure – which in this example corresponds to branch D.

The diagram to the right shows a ventilation system with a main fan and decentralised fans in the branches. Again, equal airflow in all branches is assumed. The main fan has to be dimensioned for the total flow as well as the branch with the least pressure – in this example branch A [7].

* Corresponding author.
E-mail address: amg@sbi.aau.dk (A. Gunner).

http://dx.doi.org/10.1016/j.enbuild.2015.09.031
0378-7788/

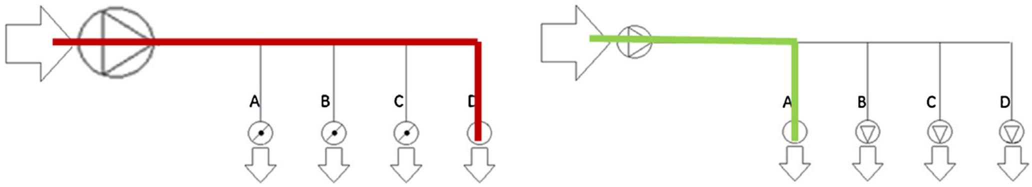

Fig. 1. Simple illustration of the dimensioning method.

Fig. 2 shows the system characteristic for the two different ventilation systems. It can be seen that there is a potential for energy saving when using fans to balance the air in a ventilation system [8].

In the previous publications, the focus was on the possibility of saving energy by using decentralised fans instead of dampers. It was found that there was a potential for saving energy by using fans for balancing the airflow. The saving potential is dependent on the pressure in the system and the efficiency of the fans. In conventional mechanical ventilation systems, a centralised fan pressurises the duct system and decentralised balancing dampers control the airflows by introducing flow resistances into the duct system. It was found that the energy demand could be reduced by up to 40%.

This article focuses on reversed airflow in the distribution system. If reversed airflow occurs, then air might be transferred from one branch to another. This may cause polluted air to be transferred from one room to another.

In this article, reversed airflow in two mechanical ventilation systems with multiple fans is investigated by means of calculations and validated by full-scale experiments in a laboratory environment.

2. Reversed airflow

In a traditional ventilation system with dampers, see Fig. 1 to the left, reversed airflow is not possible. When the fan operates, it creates a positive pressure in the supply duct system which ensures that a reversed airflow does not occur. In a ventilation system with multiple fans, reversed airflow can occur if any of the fans malfunctions.

The objective of this study was to investigate whether reversed airflow occurred in a ventilation system with multiple fans when a fan stopped operating. If one of the fans in the duct system stopped operating, then the pressure downstream of the fan might be negative. This can result in polluted air from the ventilated space being transferred into the branch and further on to other branches and rooms.

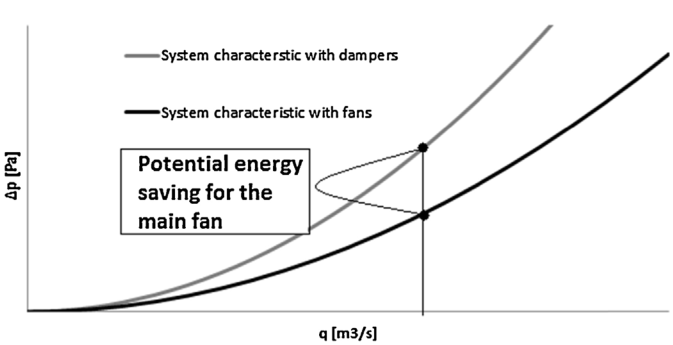

Fig. 2. System characteristic for a ventilation system with dampers (grey) and a ventilation system with fans (black). The black dots show the operating points for the two systems with the same supply airflow.

3. Method

The theoretical analysis of the ventilation system was carried out in the Pressure Flow Simulation programme (PFS) [9]. The experimental analysis was carried out in a laboratory environment with an average temperature of 20 °C and a relative humidity of 45%.

The possibility of reversed airflow was demonstrated by calculations and experimental analysis of two ventilation systems, see Fig. 3. One of the systems was a supply duct system with a main duct and four branches, while the other system was a supply duct system with a manifold and seven branches. In each branch except for the branch with the least pressure, a fan was placed to balance the airflow. The static pressure and the airflow were calculated and measured, when one fan at a time was switched off. The fan was deliberately switched off in order to simulate a malfunction.

In the supply duct system without manifold, the four ducts were of equal length. The system had an inlet diameter of 160 mm and four branches with a diameter of 125 mm. In each branch, the nominal airflow was set to 25 l/s. The fans were axial fans of the brand ebm-papst type 5214 NH (127 × 127 × 38 mm).

In the manifold system the seven branches were of different lengths, so that there was unequal pressure distribution in the branches. In each branch, the nominal airflow was set to 10 l/s. The system had an inlet diameter of 315 mm and seven outlets each with a diameter of 100 mm. The applied fans were axial fans of the same brand ebmpapst. The fan type fixed to the first two inlets was 8412 N (80 × 80 × 25 mm), the fan type fixed to the third and fourth inlets was 3412 NHH (92 × 92 × 25 mm) and the fan type fixed to the last two inlets was 5214 NH (127 × 127 × 38 mm).

The main fan for both distribution systems was a centrifugal fan with backward curved blades from ebm-papst with a diameter of 190 mm.

3.1. Measurement device accuracy

Static pressure and air velocities were measured by means of a hand-held Testo measurement instrument 645. According to the manufacturer, the accuracy of the Testo device is ±0.03 m/s for the air velocity and ±0.5% for the pressure.

Measurement points were placed at a distance of minimum of five times the hydraulic diameter downstream of an obstacle [10]. The measurement points are shown as red dots in Fig. 3. All measurements were made at 1-s intervals and calculated for an average of 3 min. At all measurement points, the velocity measurements were made at three levels. The measurement method had an accuracy of ±3%.

4. Results

4.1. Theoretical analysis of the system

4.1.1. Supply duct system with multiple fans

In a duct system with a main duct and branches, reversed airflow may occur if a fan malfunctions. In Table 2, the theoretical pressure and airflow are presented. The table presents the results from a