Dimensioning and Economical Optimization of an Air Curtain Device

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Introduction

The usage of Air curtain units, installed on the large openings of industrial buildings is one of the most practical and effective preventive methods applied against the uncontrolled outdoor cold air flows through the open doorways.

The prevailing outdoor conditions and sometimes the indoor mechanical ventilation conditions do vary during the opening periods of the doorways of an industrial building. Consequently, the calculation of the rate of the penetrating outdoor cold air flows and their temperature, as well as the value of the pressure difference across the opening is a laborious task and should be approximated by the use of a dynamic calculation model. Also the dimensioning of an air curtain device is a matter of technical optimization which involves many effecting factors in the process (1) In order to facilitate and simplify the above mentioned task in different industrial building sites, a calculation model (DIECO) has been developed. It is also possible to determine the economy of an air curtain and its pay-back time by using this model. This calculation model is composed of several independent parts and the following is a brief description of them.

In this presentation of the method, the dimensioning of the air curtain is based on calculation of the pressure difference at floor level in order to achieve balance between the applying forces of the air jet. The leakage of the air curtain is estimated on the basis of the empirical results.

A Brief Description of the Calculation Model

The first part of the model is conceived in order to calculate the quantity of the infiltrating cold air flows through the openings. There are one main door way and four so called upper openings. The air flow through the main door opening is two-way flow, whilst in the upper openings it is one-way flow. All the openings could be located either on the windward side or on the lee side of the building. The calculation process can resume after the initial values have been set in. As a result of the calculation, the mass flow rates through the openings will be in balance and the corresponding total pressure difference across the door way at floor level will be determined. For each set of the initial values, the infiltration rates of the cold air flows through the main opening and the upper openings will be identified. Also, the distance of the neutral pressure level from the floor on the doorway opening as well as the static and the total pressure differences at floor level will be determined within the calculation process.

Dimensioning of Air Curtain

The most important task in dimensioning the air curtain is to determine the amount of pressure it shall overcome against the applying indoor and outdoor counter forces. This is done by applying the model. At first, a two-dimensional distribution table of temperature / wind, characterising the climatic conditions of the locality where the air curtain should be applied, has to be formed. Each time the pair of temperature and wind values have to be set in the input worksheet of the calculation model and the total pressure difference will be calculated. Once all the values have been calculated, it is possible to identify the value of the total pressure difference that can be applied in dimensioning the air curtain. The heat losses through the main opening are also calculated in the same manner and will be used in calculation of the pay-back time of the investment.

Optimizing the Width of the Nozzle and the Energy Economy in an Air Curtain

It can be assumed that the width of the nozzle has an optimum size, whenever the power of the fan is minimized. The power of a fan is the result of the multiplication of its volume airflow and its total pressure. When we minimize the power of the air curtain's fan, the energy consumption of the fan's motor is being minimized and the savings on energy consumption are being maximized as well. This is exactly the philosophy being applied in the optimization part of the model. Figure 1 shows the electrical energy consumed by a two-speed fan during a year in a building site located in Oulu in north of Finland, where the size of the door opening is 4 by 4 m. There is another opening of the same size on the opposite side of the hallway, which is open simultaneously. The door is open 275 h/a in average. The outer diameter of the duct work selected is d = 800 mm. In this example, first the width of the nozzle has been optimised through the optimisation part (45 mm) and the volume flow and pressure values of the two-speed fan has been calculated. Then, four other nozzle sizes have been selected and the volume flow and pressure values of the fans corresponding the size of each nozzle have been calculated for both full and 2/3 of speed.

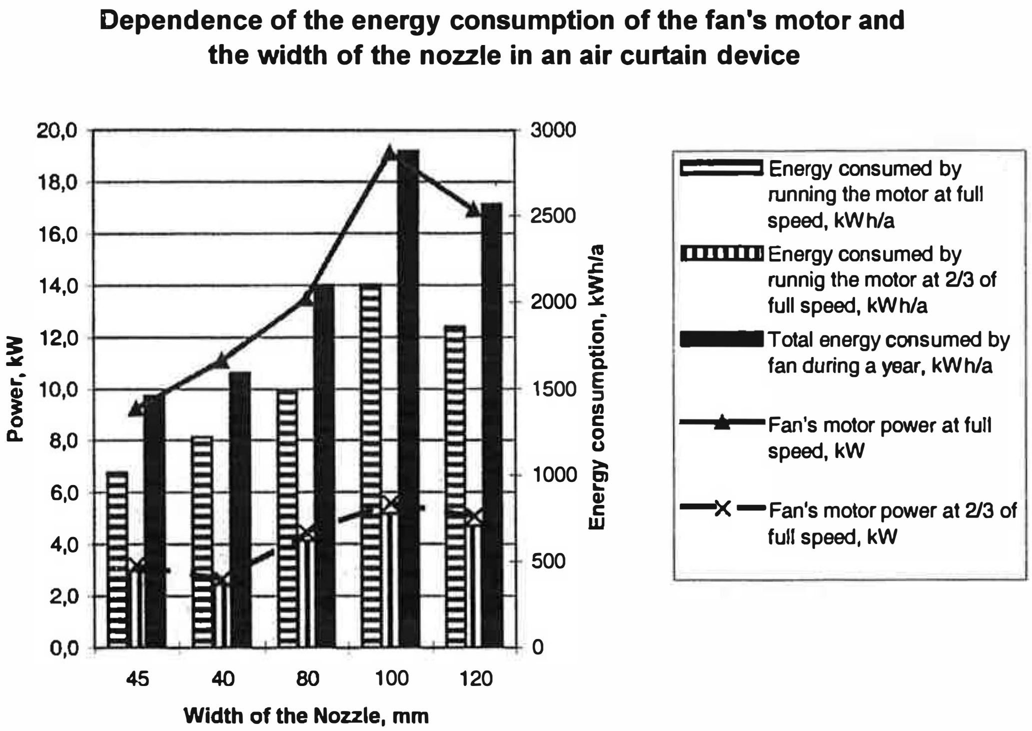

Figure 1. Energy consumption of the fan's motor during a year being compared in 5 different cases as opposed to the size of the air curtain's nozzle. The width of 45 mm is the one being obtained as the result of the optimization calculation in DIECO.

Figure 1 clearly demonstrates that the energy consumption of the fan's motor is higher with the bigger size of nozzle. Only when the width of the nozzle is as big as 120 mm the energy consumption of the fan's motor reduces compared with the previous sizes of the nozzle. However, the volume flow and the pressure to be developed by the fan become so high in this case that it is not possible to achieve those values by a fan of the same size as by the other selections. If the fan is one size bigger, the investment made on the fan is higher.

Discussion

The amount of energy consumed by running the air curtain's fan was calculated as a case study for the site being under construction in Oulu and it was equal to 1460 kWh/a as opposed to 86 486 kWh/a; corresponding to the amount of the saved energy by the reduce of the heat losses through the main opening due to the usage of the air curtain. It is obvious that the energy consumption of the fan is much smaller than the saved energy, but nevertheless it is an essential part of the calculation of the pay-back time of the investment. The wrong selection of the fan might result in higher investment on fan and ductwork of bigger size. The results achieved in this case justified the installation of the air curtain and the pay-back time was calculated to be roughly 3 years.

The calculation model has been proved to be a handy tool in predicting the infiltrated cold air flows through the building's openings, the total pressure difference across the opening at floor level, for dimensioning of the air curtain's different parts such as its nozzle and the fan as well as to estimate its energy economy . As a result of the calculation the size of the nozzle has been optimized and the energy consumption of the fan's motor has been reduced to a minimum by the right selection of the fan's size.

References

1. Valkeapää A., Hejazi-Hashemi S., Sirén K., Prevention of cold air flows in industrial buildings. Report B55, 1998, Helsinki University of Technology, HVAC-laboratory.