A REVIEW- ON DIFFERENT PROCESS PARAMETERS OF AIR CURTAIN

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Abstract: Air curtains are commonly used to shield stores from infiltrating cold outside air. For example air curtains are installed at the entrance of stores who leave their door open (for commercial reasons). The air curtain creates an aerodynamic sealing while the doorway is still open and free for passage. The customer is less withheld to enter the store and immediately feels the warm air jet when entering the store. Nowadays this technology is also being used for cold storage rooms. In these work different types of air curtain and there performance parameters were review and different parameter were identified on which the performance of air curtains depends.

Keywords: Air curtain, process parameters, optimization, infiltration, exfiltration

1. Introduction

Over the past decade, numerous high-rise buildings have been constructed in urban areas. Although high-rise buildings in cities could meet the demand of urban development, it would increase the difficulty level in emergency and evacuation planning especially in case of fire. It is well-known that smoke and toxic gases, such as carbon monoxide (CO), are the most fatal factor in fires, and more than 80% of people killed in building fires were killed by toxic smoke. Smoke and heat control systems are an essential part of fire protection in the fire safety design of buildings. In general, high-rise buildings provide fewer exits compared to their large residential capacity. For security reasons, elevators are generally forbidden in case of high-rise building fire. Therefore, stairwells are designed as the "safe zone" for fire evacuation in high-rise buildings. Unfortunately, most of stairwells in high-rise buildings fail to satisfy such "safe zone" requirement. For instance, the pressurization of stairwells is a commonly used smoke control system in buildings. However, large air supply volumes are required. Therefore, an air curtain could be a more efficient way of blocking smoke dispersion during fires. Moreover, compared to the traditional fire doors, another advantage of such virtual screens is the easy evacuation of people while still limiting smoke and heat transfer through the opening. Air infiltration is the uncontrolled outflow of outside air to buildings through the slots in the building envelope or through large openings such as doors.
It is estimated that on average, air infiltration is responsible for around 25% of the heating loads of modern buildings. For example, there is a lack of information on the appropriate jet properties in terms of discharge velocity, injection angle and slot width. Therefore, it is of great important to study the sealing effectiveness and the main parameters that affect the performance of air curtains for smoke blocking. With even more casings and casings than buildings, one of the main sources of air infiltrations that remain in commercial buildings are the entrance doors and infiltrations related to their frequent use.

2. Need of Air Curtains

Air infiltration (or air leakage) is often caused by the involuntary or inadvertent introduction of outside air into a building with the aid of the splits in the building wrap and / or entry doors. Infiltrations by door openings usually become very important when doors are frequently used, such as in restaurants, shops, supermarkets, offices and hospitals. It is reported by the US that they consumed 19% of the world's energy in 2011 and the construction sector (residential, commercial and government buildings) accounted for about 41% of primary energy consumption.
The four main end uses of the construction sector are environmental heating (37%), environmental cooling (10%), water heating (12%) and lighting (9%), which accounts for around 70% of the energy consumption site. For commercial buildings, air infiltration can reach up to 18% of total heat loss. A common energy code solution to reduce energy loss through the infiltration of air through open doors required a corridor instead of having only one door. Portals are not the ideal solution for building owners and developers, as they require a lot of space and are expensive to build (especially in tight and precious spaces, cost estimates are very high). In addition, the lobby doors are only effective to minimised air infiltration if both doors do not open simultaneously: a hypothesis that is generally not true on the high traffic doors of most commercial buildings.

3. Existing Research Work

In later past years, the usage of various Air Curtains has expanded the interest of engineers and researchers to simulate their issues & results with computational, experimental and numerical methods.

[1]. Long-Xing Yu et.al [2018] In this study, large-eddy simulations of air curtain flows had been performed by using Fire Dynamics Simulator (FDS) software for simulating momentum-driven planar jets. The effects of grid resolution, sub grid scale (SGS) eddy viscosity models and turbulent inflow boundary condition with synthetic eddy method (SEM) had been analysed. Computational results had been compared to experimental data obtained in the literature. Investigation of different set-ups of inlet boundary conditions, including the inlet duct length, velocity profile and method of generation of turbulence at the level of the inflow, revealed that the inlet boundary condition is the most influential factor governing the flow downstream. The mesh sensitivity study revealed that a grid resolution with 8 cells spanning across the width of the inlet is adequate for the flows considered.

[2]. Viegas et.al [2018] this research work proposed an air curtain designed to guarantee an adequate separation between two areas, one clean and one contaminated. Vertical air curtains have often been used to separate two different climate zones in order to reduce heat transfer. The methodology of this survey included: (a) small scale tests on water models to ensure that the contamination did not cross the air curtain, and (b) an analytical development that integrates the main physical characteristics of the reaction aircraft. In the developed solution, the airflow had been removed from the contaminated compartment to reduce the airflow of the rejected curtain to the outside of the compartment.

[3]. Luo et.al [2017] this paper had described a research of smoke elimination and confinement with different kinds of air curtain at the stairwell entrance. A 1:12 small-scale model experiment was conducted and a complementary Fire Dynamics Simulator (FDS) simulation was performed on a full scale station Research showed one-stream being divided into double-stream was good to compart the smoke and the efficacy of opposite one-plane air curtain was better than the efficacy of one-plane air curtain when the both air curtain had the same the air supply volume. At the same time, the comprehensive efficacy of multi-stream and opposite vents was the best when interval of vents was set as double width of the vent.

[4]. Kim et.al [2017] In this study, a basic model of pressure chamber which is the core component of linear-jet type air curtain system is proposed and analysis of flow characteristics of pressure chamber depending on air flowrate was conducted through numerical analysis and experiment of basic model. It was concluded that Jet velocity at both ends of pressure chamber is slightly lower than the central part, and thus it's required to design the pressure chamber to make jet velocity becomes equal at all locations. The pressure was increased in relation of two-dimensional function in line with the increase in air flowrate. About 595 Pa pressure was formed near pressure chamber inlet in response to nozzle jet velocity of 30 m/s.

[5]. Zhang et.al [2016] In this research work, a series of computational fluid dynamics (CFD) simulations by using Fire Dynamics Simulator (FDS) software were carried out for a full scale corridor in high-rise building, in which different factors such as air curtain discharge velocity (ACDV), human evacuation and pressure difference were considered. The application of air curtains is introduced in high-rise buildings during fire was a effective approach to confine fire-induced smoke transportation. The results showed that with the ACDV increasing, the smoke flowing resistance of air curtain is greater. This indicates that an air curtain with greater ACDV would be more beneficial to the smoke confinement in high-rise building fires.

[6]. Goubran et.al [2016] this study was focused on investigating the effectiveness of different entrance doors in reducing air infiltration in buildings. This paper had presented the results from a preliminary effort in our recent studies: the experimental validation of the numerical modelling of air infiltration through single doors (double swing) using computational fluid dynamics (CFD). It was concluded that vestibules doors are effective in reducing air infiltration. Currently vestibules are required as an energy saving measure for most commercial buildings. A reduced scale experimental chamber was built and the experimental setup was modelled in CFD. The volumetric airflow rates to the chamber were controlled and the resulting pressure differences across the door were measured and compared to the CFD results as well as existing sources in the literature.

[7]. Xing Yu et.al [2016] In this work, Computational Fluid Dynamics (CFD) simulation results, obtained with Fire Dynamics Simulator (FDS 6.0.1), are presented in order to analyse the performance of an air curtain in blocking fire-induced smoke in a tunnel configuration. The key objective is the determination of the effectiveness of a vertical air curtain in blocking the fire-induced smoke spreading downstream of the air curtain, as function of the momentum of the air curtain. The results are presented in non-dimensional form, in terms of a 'momentum ratio' R. This is the ratio of the vertically downward air curtain momentum to the horizontal smoke layer momentum at the position of the air curtain. For small values of R, the sealing effectiveness E increases as the momentum ratio R increases.

[8]. Linden et.al [2016] through this paper, they had investigated the effects of an opposing buoyancy force on the performance of an air curtain in the doorway which separates a warm indoor environment from the cold exterior. Such an opposing buoyancy force arises for example if a downwards blowing air curtain is heated. We conducted small-scale experiments using water, salt and sugar solutions as the working fluids. The effectiveness curve of a downwards blowing air curtain as a function of the deflection modulus was measured for situations in which the initial density of the air curtain was less than both the indoor and the outdoor fluid density, which corresponds to the case of a heated curtain. It was found that the effectiveness of the air curtain starts to decrease if it is heated beyond a critical temperature. We also discuss the question whether it is more energy efficient to use a heated air curtain or an air curtain operating at room temperature.

[9]. Viegas et.al [2016] in this paper both the analytical model and the saltwater experiments were presented. In this investigation, it was proposed to use downward air curtains to stop the flow of smoke, which will not affect visibility in escape routes. The methodology which was followed had included: (i) the development of an analytical model that correlates the relevant characteristics of a jet with the characteristics of the environment in which the fire develops, (ii) experiments on small scale ladder with salt water modelling to evaluate the convective parameters that control the smoke retention of the curtain, (iii) CFD simulations to evaluate the performance of a large-scale air curtain near a source of fire and (iv) fire experiments with a large-scale test sample. Test results confirmed that downward air curtains can prevent smoke flow through openings and show good agreement with the theoretical model to predict the minimum escape rate from the fire compartment.

[10]. Liangzhu et.al [2015] In this research work, they had investigated the impact of the entry of buildings with air curtains on the use of energy from buildings for the reference building of medium-sized offices of federal government. Computational fluid dynamics simulations were performed to characterize the air barrier infiltration characteristics. A common energy code solution to reduce the energy loss of air filtration through the building entrance required a lobby in climate zones 3 through 8. However, a corridor is expensive and requires more construction space. In comparison, the air curtain is less expensive and is designed to prevent air infiltration into the open air, while allowing unimpeded pedestrian access.

[11]. Zhou Dan et.al [2015] In this work, a dynamic grid technique was adopted to research the law of smoke flow diffusion inside the tunnel when the bottom of a metro train was on fire and to compare the effect of longitudinal ventilation modes on the smoke motion when the burning train stopped. It was found that research on the distribution of smoke in tunnels is significant for the fire emergency rescue after an operating metro train catches fire. Research results showed that the slipstream curves around the train obtained by numerical simulation were consistent with experimental data. When the train decelerates, the smoke flow first extends to the tail of the train. With the decrease of the train’s speed, the smoke flow had diffused to the head of the train. After the train stops, the slipstream around the train formed in the process of train operation played a leading role in the smoke diffusion in the tunnel.

[12]. Wang et.al [2014] this study had developed an approach to determine the infiltration and the exfiltration characteristics of building entrance equipped with an air curtain. A detailed parametric study for different ambient temperatures, pressure differences across the air curtain and different door usage frequencies was conducted by using computational fluid dynamics simulations. Air curtains have been widely used as a barrier against infiltrations and associated energy losses through building entrances while still permitting an unobstructed pedestrian entryway. However, the evaluation of the energy performance of an air curtain often needs to quantify the infiltration rates under variable ambient conditions and door usage patterns. The calculated air infiltration rates were then correlated to the pressure differences across the air curtain. The numerical approach was first verified by comparing the obtained correlations for the building entrance without the air curtain to the published data in the literature.

[13]. Frank et.al [2014] in this study, they had investigated the performance of an air curtain in the doorway of a ventilated building both theoretically and experimentally. The vertical leakage distribution in the building envelope was modelled by means of a small top window that was located above the door. The presence of this additional displacement ventilation pathway raised the position of the neutral level above the mid-height of the doorway, i.e. $h_b=2 < h_N$. The main controlling parameter was the deflection modulus Dm, which is the ratio between the momentum flux of the air curtain and the transverse forces due to the displacement ventilation. For a relatively warm interior, we find that, for small values of Dm, the air curtain is drawn inside the space by the ventilation flow. For large values of Dm, the flow through the doorway is controlled by the air curtain.

[14]. Cowlard et.al [2013] this work had focused to highlight the critical elements of a fire safety strategy for tall buildings and thus attempt to highlight some specific global performance objectives. A survey of tall building fire investigations is conducted in order to assess the effectiveness of current designs in meeting these objectives, and the current state-of-the-art of fire safety design guidance for tall structures is also analysed on these terms. In the realm of tall buildings the most notable failures in history, those of the WTC towers, widely accepted as fire induced failures, have not to any significant extent affected the way they are designed with respect to fire safety. This is clearly reflected in the surge in numbers of Tall Buildings being constructed since 2001. The combination of the magnitude and time-scale of the WTC investigation coupled with the absence of meaningful guidance resulting from it strongly hints at the out dated ness of current fire engineering practice as a discipline in the context of such advanced infrastructure.

[15]. Na Luo et.al [2013] In this work, a modified Opposite Double-Jet Air Curtain (ODAC) is introduced in order to confine smoke movement and to exhaust smoke during a high-rise building fire. Here, a study including an experiment and a numerical simulation, was performed to determine the efficacy of a modified ODAC. The experiment was conducted on a 1:12 scale model of a high-rise building. A complementary Fire Dynamics Simulator (FDS) simulation was conducted on a full scale building. The influences of the air curtain discharge velocity and heat release rates (HRRs) were examined. The results of this study show that given the same supply air volume and HRR, the carbon monoxide (CO) concentration with the ODAC is clearly lower than the levels found with a traditional air curtain in a high rise building fire.

[16]. Zhang et.al [2012] In this research, a series of experiments were conducted to study the inclination impact on the CO concentration and smoke movement pattern in a tunnel model of inclination angles varying from -10º to 10º to the horizontal and with n-Heptane pool fires in three pans of various sizes. The study of the tunnel’s inclination effect on the fire in an inclined tunnel is of vital importance to the evacuation of people during a conflagration in a tunnel. When a fire emergency happens in an inclined tunnel, the inclination affects, the temperature, the visibility, the thickness of carbon monoxide (CO), and the movement of the smoke. In this paper, the inclination effect is studied in terms of the CO concentration and the smoke movement pattern in an inclined tunnel fire.

[17]. Vittori et.al [2012] In this study a numerical study of cellular confinement during a fire in tunnels by using air curtains was presented. A single cell confinement arrangement was tested by varying the relevant jet discharge velocity and width, observing its resistance to be crossed by smoke and heat, via CFD simulations, in steady state conditions. For the proposed 2-D domain, the length of the confinement cell has no influence on confining the smoke and heat propagation. The most effective air barriers are those operated at higher discharge Reynolds numbers. However, the most important parameter turns out to be the curtain width.

The jet potential core is related to this parameter. A wider jet nozzle leads to a longer potential core and a more efficient air curtain even in case of jet deflection.

[18]. Goncalves et.al [2012] this work had presented a numerical and experimental study on the performance of air curtains in the aerodynamic sealing of the access doors of the refrigerated spaces. In refrigerated industrial spaces, such as retail stores, where sometimes doors must remain open for long periods, infiltration loads can account for more than half of the total cooling load. The use of air curtains can significantly reduce the infiltration of air through the doors and, at the same time, allows the free access of people and equipment. For this proposal, a 3D numerical model was developed with the aim of simulating the non-isothermal turbulent air flow generated by the air curtain from the moment the door was opened. The computational domain represents a laboratory scale model consisting of two similar communicating rooms connected by an entrance on which the air curtain is installed. One of these rooms represents a refrigerated room and the other, the external environment.

[19]. Krajewski et.al [2011] The objective of this document was to exploit the application of CFD in the calculation, optimization and design of air barriers used to separate smoke-free areas in case of fire. The properly designed air curtain produces a pressure drop that prevents transverse flow through the opening. Most air curtains have been tested on small models that are difficult to extrapolate. The intention of this document was to present the CFD possibilities when designing air curtains used in fire safety engineering. Using CFD methods, we can analyse all the parameters necessary to verify if an air curtain has been designed correctly. According to the simulations carried out, it is essential to state that the air curtains can be used as a division of the smoke-free areas in case of fire.

[20]. Rivera et.al [2011] in this research work, the influence of flow instabilities on the efficiency of a twin-jet air curtain formed by a cold stream parallel to a hot stream was studied. Two cases were considered: the Reynolds number and mean flow velocity of both streams were set to 1000 and 3 m/s, respectively. The results obtained from 3D LES simulations were compared with experimental data and earlier LES numerical results using the FDS code. Energy spectra exhibit decay laws with −5/3 and −3 slopes. Instabilities with a characteristic Strouhal number of about 0.4 were detected. Kelvin–Helmoltz type instabilities play a more significant role than the Gortler type instabilities present at the wall for applications of plane impinging jets to ambience separation.

4. Conclusion

It is found that the performance of air curtain depends on different process parameters of air curtain. The performance of air curtains depends on the velocity of air curtain jet at which it is coming from the air curtain. The performance of air curtains also depends on the angle of air jet at which it is coming from the air curtain. The performance of air curtain is measure on the basis of air jet stable at different pressure difference that is restricting the intrinsic and extrinsic flow of air. Intrinsic flow means flow of outside unconditional air to inside conditional environment; it is cause due to increase in outside pressure as compared to inside pressure. Extrinsic means the flow of inside condition air in moving outside, it is mainly caused due to higher pressure inside the system as compared to outside environmental pressure.

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