Improve of Commercial Kitchen Ventilation System Performance: Optimizing an Air Curtain of Kitchen Hood

B. Manshoor, I. Zaman, N. Azmi, and Amir KHALID

***Abstract*—**Commercial kitchen is a unique and complicated space. It is obvious that the main activity in the commercial kitchen is the cooking process. This activity generates heat and effluent that must be captured and exhausted from the space in order to control odor and thermal comfort. Kitchen hood is installed to remove smoke heat, spills and other contaminant. Existing kitchen hood does not fully support the absorption of smoke and heat. Therefore, an improvement of the kitchen hood was made to overcome this problem by adding an air curtain at the front of kitchen hood. This study was conducted to investigate the suitable velocity of air for the air curtain and also to determine the best angle of the air curtain in order to increase an efficiency of the kitchen hood. The air velocity for the air curtain was varies with 0.05m/s, 0.15m/s and 0.25m/s while the angle of air curtain flow was set to 250^{o}, 270^{o} and 290^{o}. In order to achieve the objectives, ANSYS FLUENT software (CFD) was used to carry out the simulation and analysis. From the simulation work, the minimum velocity of air flow tested which is 0.05 m/s is enough to control the heat for the size of kitchen simulated and the optimum angle of flow simulated is 270^{o}. Well implementation of an air curtain in the kitchen hood can improve an air quality in the commercial kitchen and also keep the kitchen space comfortable to the workers.

***Keywords*—**CFD, kitchen ventilation, makeup air.

I. Introduction

A COMMERCIAL kitchen is a complicated environment where multiple components of a ventilation system including hood exhaust, condition air supply, and makeup air system work together but not always in unison. It is obvious that the main activity in the commercial kitchen is the cooking process. This activity generates heat and effluent that must be captured and exhausted from the space in order to control odor and thermal comfort. It has been well recognized that a modern commercial kitchen is characterized by high heat loads and big temperatures which people work in affect the productivity. It was reported that at temperature increase of 12.22ºC above the comfort level in the space may contribute to a productivity loss as much as 30% [1]

The purpose of kitchen hoods is to remove the heat, smoke, and other contaminants. The thermal plume from appliances absorbs the contaminants that are released during the cooking process. Room air replaces the void created by the plume. If convective heat is not removed directly above the cooking equipment, impurities will spread throughout the kitchen, leaving discolored ceiling tiles and greasy countertops and floors. The kitchen supply air, whether mechanical or transfer or a combination of both, should be of an amount that creates a small negative pressure in the kitchen space. This will avoid odors and contaminated air escaping into surrounding areas [2-3].

II. Make-Up Air

Makeup air is introduced to facilitate efficient capture and contain in kitchen hoods. The six strategies includes: displacement ventilation/diffuser, air curtain diffuser, short-circuit supply, front face diffuser, perforated perimeter and backwall supply. One of the makeup air has investigated in this research is an air curtain [4].

A. Air curtain

Most of the hood manufactures recommend limiting the percentage of make-up air supplied through an air curtain less than 20% of the hood's exhaust flow. At such low air velocities, an air curtain may enhance capture and contain depending on design details. However, in the cases tested, the air curtain was the worst performing strategies at higher airflows [5].

B. Displacement diffuser

Supplying make-up air through displacement diffuser is an effective strategy for introducing replacement air. Unfortunately, displacement diffusers require floor or wall space that is usually at a premium in the commercial kitchen. A possible solution may be remote displacement diffusers (built into a corner) to help distribute the introduction of makeup air into the kitchen when transfer air is not viable.

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C. Short-circuit supply

Short-circuit supply is also one of the strategies make-up air. It was internal make-up hoods were developed as a strategy to reduce the amount of conditioned air required by an exhaust system. The laboratory testing demonstrated that when short circuit hoods are operated with excessive internal make-up air, they fail to capture and contain the cooking fluent, often spilling at the back of the hood.

D. Front face supply

Supplying air through the front face of the hood is a configuration recommended by many hood manufacturers. In theory, air exits the front face unit horizontal into the kitchen space. However, a front face discharge with louvers or perforated face can perform poorly, if it's designed perforated face supply, which negative affected this hood's capture performance in same fashion as an air curtain or four-way diffuser.

E. Perforated perimeter

Perforated perimeter supplies are similar to a front face supply, but the air is directed downward. This may be advantageous under some condition, since the air is directed downward into the hood capture zone. One of the design of perforated perimeter known as four-way ceiling diffuser. Four-way ceiling diffuser located close to kitchen exhaust hood. Perforated plate ceiling diffusers can be used in the vicinity of the hood, and a greater number of ceiling diffuser reduces air velocities for given supply rate.

F. Backwall

Backwall plenums with larger discharge area may provide increase airflow rates as long as discharge velocities remain below maximum thresholds.

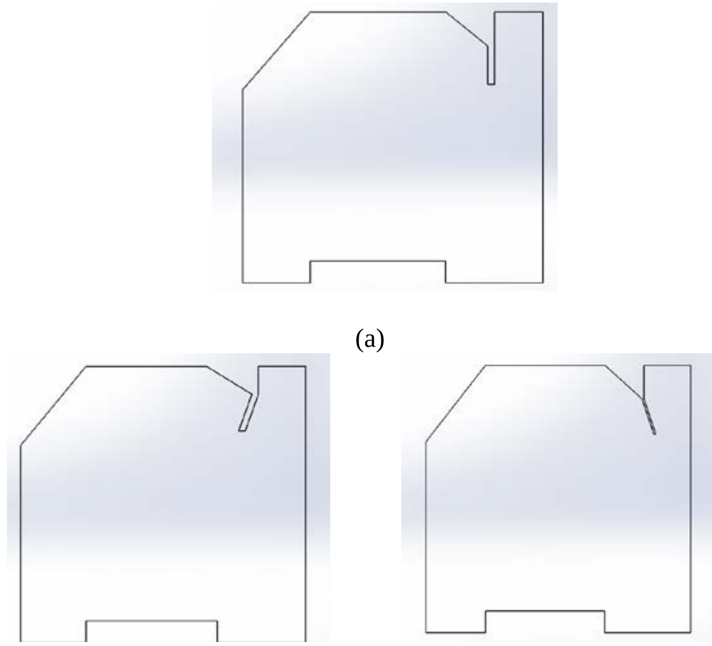
III. Research Objective

Air curtains are devices used to separate two spaces from each other. Usually, air curtains are composed by a fan or several fans which are blowing a stream of air toward the floor. Most of the time air curtains are installed inside the entrance, above the door. Air curtain also are widely used in: sealing entrances of cold rooms [6].

The two main kinds of air curtains are: heated air curtains and ambient air curtains (non heated air curtains). Ambient air curtain are using the inside air in a recirculation way. Cross draft and high air velocity due to improper introduction of air curtain can result in failure of the hood to capture and contain effluent from the appliances [7].

Thus, the objective of this research is to investigate on how the air curtain affects capture and containment (C&C) performance of commercial food service ventilation equipment. To realize the objective, the simulation word had been conducted to determine the optimum design of the air curtain in order to improve a commercial kitchen ventilation system performance.

Three models were used which is have a different angle of air flow, as showed in Fig. 1. For the air flow, three velocities were choose based on the most air flow used from available commercial air curtain in the market which are 0.05m/s, 0.15m/s and 0.25m/s.



(a)

(b) (c)

Fig. 1 Model of air curtain in difference angle (a) 270 degree (b)250 degree (c) 290 degree

IV. Simulation Work

The simulation work done by using commercial CFD software package ANSYS Fluent. An unstructured mesh was adopted for the spatial discretization of the domain, ensuring a better refinement in regions where higher gradients were expected. The turbulent at all boundaries condition has been set to 2% and back flow turbulent intensity at all boundaries has been set to 5%. The Semi-Implicit Method for Pressure Linked Equation (SIMPLE) method is used to reach a convergent solution set.

The accuracy of using computational fluid dynamics as a tool for the prediction of flow features depend on the choice of the turbulence model. The standard k-ε model is the most common turbulence model and it is routinely used for indoor environment analysis [9]. In the Fluent menu 'operating condition', gravity is selected and is set to -9.81m²/s.

For the boundary conditions, the temperature at the heat source was set as a combustion temperature with the temperature of 1273 K. The temperature at the inlet was set at room temperature, 297 K and the outflow temperature set as external environment, which are 300 K. Fig. 2 showed the 2D model of the kitchen that used for the simulation work.

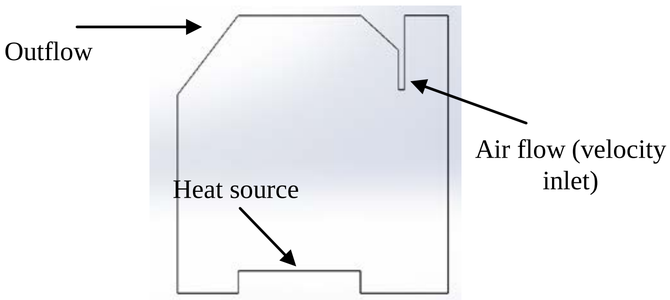
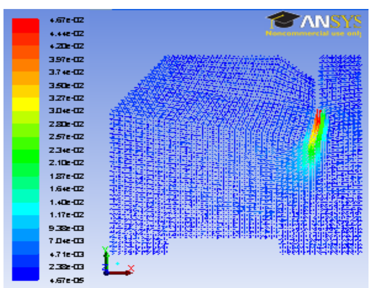


Fig. 2 Model of kitchen use for simulation work

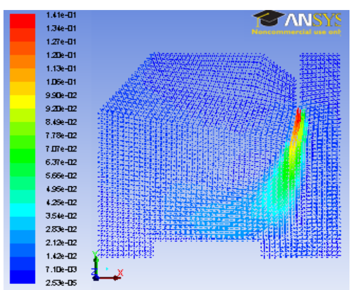
V. Result and Discussion

A. Effect of velocity

Fig. 3 showed the velocity vector distribution for the three cases of simulation.



(a)



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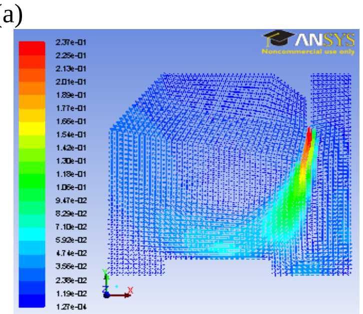


(c)

Fig. 3 Velocity vector (a) 0.05 m/s (b) 0.15 m/s (c) 0.25 m/s

From the figure, the air flow with the velocity of 0.05 m/s is the best flow for this study compare to another two flows. It is because the high flow (0.15 m/s and 0.25 m/s) was high enough to disturb the heat source where it can give an effect to the cooking conditions.

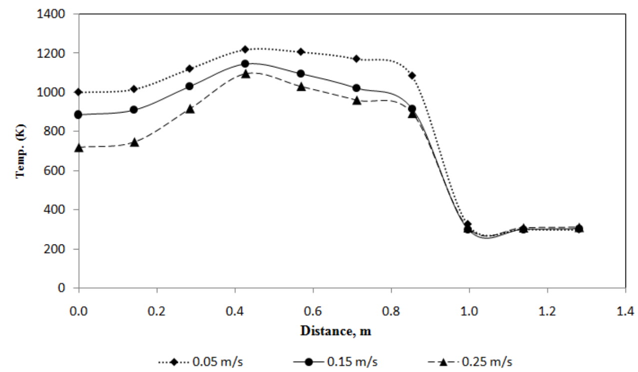
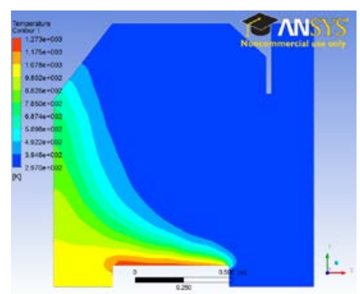


Fig. 4 Temperature distribution at 2 m from the floor measured from the wall

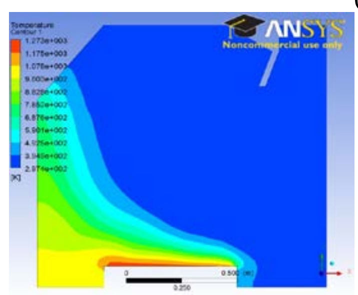
In the Fig. 4, the temperature distribution was plotted at 2 m from the floor and the distance in the graph are the distance from the wall (*x = 0*) to the place that assumed as a working place. Here we assume the people will work at around 1 m to 1.3 m from the wall. From the graph, it was showed that the minimum air flow (0.05 m/s) is enough to give a comfort level that similar to the high flow at the working place. Therefore, the rest of the result will only discuss an effect of this flow.

B. Effect of air flow angle

As mentioned, there are three angles was studied here. Fig. 5 showed the contour of temperature distribution for the three angles tested.



(a)



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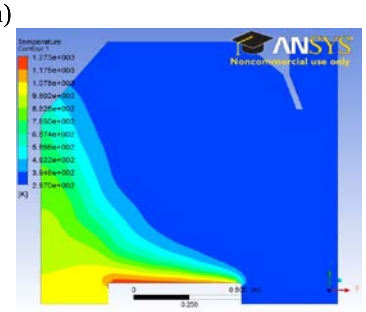

(c)

Fig. 5 Temperature distribution for different angle of air flow

From the figure, it showed that the temperature distribution is almost same for the three angle of the air flow. Its means that for this case, the angle of air flow did not give any effect to the temperature distribution in the kitchen area simulated.

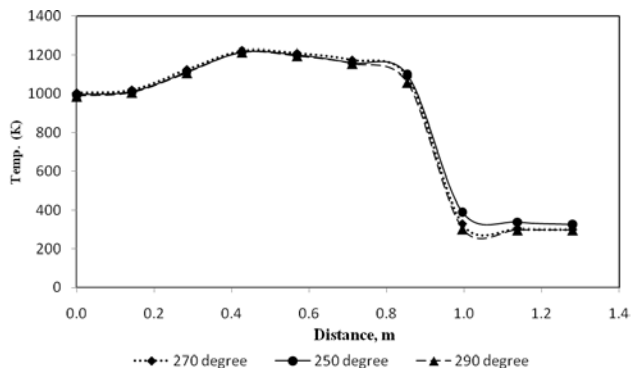

Fig. 6 Temperature distribution at 2 m from wall at different angle of air flow

In the Fig 6, the temperature distribution was comparing when the different angle applied at the air flow of 0.05 m/s. From the result, it showed that the temperature from the wall towards the working area (at 1 m from the wall) almost did not change. The temperature at the working area slightly change but with only a small value. All the temperature at the working area is still in acceptable range with around 295 K to 300 K.

VI. Conclusion

Comfort is very important in working space for improving efficiency of worker. The make-up air strategy is one of the methods to improve an air ventilation quality in the commercial kitchen, hence increase a comfortable satisfaction in the working space. Proper selection of the make-up air will help for improving the air quality in the commercial kitchen area. In this project, air curtain was studied in term of air flow velocity and also a suitable angle of the air flow. This study are important to determine an optimize air flow and angle for the air curtain. From the commercial kitchen hood simulated here, the suitable air flow is the lowest flow tested. In term of flow angle, three angles tested and it showed that the angle did not give any significant to the air ventilation. As a conclusion, air ventilation in the commercial kitchen can be improved by using air curtain with a minimum flow rate. However, another study need to be conduct in order to fulfill the comfort requirement in the kitchen space such as particular matter, other gasses, odor etc.

Acknowledgment

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