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# Design and Optimization of Serve-Over in Concurrent Engineering Using CFD Modelling

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***Abstract— Computational fluid dynamic technique (CFD) today is play as a key role in design refrigerated cabinets. It is numerical tool that is widely used to simulate many processes in the food industry. CFD is considered as a viable technique to provide effective and efficient design solutions. This paper deals with the investigation of the flow in two types of cabinets In general The Refrigerated Cabinets energy consumption represents more than 50% of the overall energy consumed in Supermarket. A 2D and 3D investigation of the optimization of energy performance is conducted in this work. The flow simulation inside the cabinet will represent a guide line for the optimization and the reduction of the consumed energy. The actual concurrent engineering demands quick answers. The generated case study represents a step in the development of a standard method of design including real time CFD simulation.***

Keywords— Open Refrigerated Cabinets “ORC”, CFD, flow simulation, 2D and 3D design, temperature propagation, Fan

## I. Introduction

Refrigerated cabinets are used for refrigerating food protection at suitable storage temperature. It is in common usage and it an energy consumed appliance during stored the food. Energy used to refrigerated temperature is about half the total energy consumption in supermarket because of their negative interaction with ambient environment.

The ISO 23953-2:2005 and BS 6148 contain the needed requirements for the construction, characteristics and performance of the used refrigerated display cabinets. All the test condition and methods for checking that the requirements have been satisfied, as well as classification of the cabinets, their marking and the list of their characteristics to be declared by the manufacturer.

There are two types of refrigerated cabinets which are server-over display cabinets and refrigerated vertical display cabinet. The First type is used in small grocery stores and also used in every home for chilled and frozen foods cabinets. Mangeolles (1995) and Baleo (1995) were the first researchers who reviewed the design and performance of delicatessen cabinets, he classified designs under two separate types which it cool-top and convection the means of providing cooling to food within the cabinet was the main difference between the two types. Abas, (2006) studied the heat propagation in a vertical display cabinet. Abas used CFD modeling to investigate some of the design parameters include air curtain velocity, width, discharge angle and positioning of the air curtain outlet from the front edge of the top shelf and also the effect of using a Honeycomb on the flow path at the air curtain outlet (Abas et al, 2012).

Atkins, (1992) used (CFD) to investigated the effect of air curtain on the performance of energy and the temperature, the result showed that the removal of the air curtain leads to reduction the cold air inside the cabinets.

Chen, (2005) and Yuan used (CFD) to investigate the air flow they showed that the increase in air speed parallel to the cabinets had small effect in infiltration.

Faramizi, (1997) used (CFD) investigated how the cooling air effected the climate change. He founds that the vertical display cabinets is sensitive the humidity in ambient air which lead to increase the temperature inside the cabinets.

Rinil, (2005) reviewed the application of (CFD)in the spray drying. He concluded that the (CFD) can be useful tool for predicting temperature, velocity, gas flow and residence time and impact position.

## II. Mathematical model of the conjugate heat transfer

Continuity Equation:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (1)$$

Momentum Equations (Navier-Stokes):

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{dz}\right)=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)+X \qquad (2)$$

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{dz}\right)=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)+Y \qquad (3)$$

$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{dz}\right)=-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)+Z \qquad (4)$$

Energy Equation:

$$\rho c_p\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}+\frac{\partial T}{\partial t}\right)=-\left(\frac{\partial}{\partial x}(q_x)+\frac{\partial}{\partial y}(q_y)+\frac{\partial}{\partial z}(q_z)\right)+q''' \qquad (5)$$

The variations in the z direction in equations (1) to (5) were eliminated when conducting the 2D CFD modelling.

## III. Simulation of conjugate heat transfer inside serve-over

In order to conduct a flow simulation, several parameters have to be adjusted before the starting of the simulation. The result will present the simulation of two type of serve-over with design changes. The difference of design will justify the need of CDF in the optimization of the ODC behaviour.

### III.1 Setting Definition

The gas used for the cooling inside the serve-over is the natural air. The characteristic of the air is already defined by the software. In this study the flow type considered is the combined laminar and turbulent flow. In addition the humidity will be also counted equal to 62%.

Due to the lack of information regarding the different thermodynamic characteristics of the selected food in this condition will be affected by the temperature of its container. The container material will be the stainless-steel 321.

When thermal conduction in solids is enabled in an internal analysis, the Default outer wall thermal condition parameter permits to simulate thermal transactions amid the outer ideal walls and encircling environment wall. In this case the box is placed in an air-conditioned room that is the serve-over, alongside the air temperature of 277.2 K and warmth transfer across the beyond walls of the enclosure due to the convection in the room can considerably give to the enclosure cooling.

In this case study two fans were selected. Fan is considered as an ideal device which it will create a flow with a certain volume (or mass) flow rate that depends on the difference amid the inlet and outlet pressures on the selected faces. In these projects it uses one of the pre-defined fans obtainable in the Engineering Database. Face coordinate arrangement is crafted automatically in the center of a planar face after you select this face as the face to apply the frontier condition or fan. The Z axis of this coordinate arrangement is normal to the face. The Face coordinate system t is crafted merely after one planar face is selected; in addition Fan is a type of flow boundary condition. In order to remove the behaviours of both Fans and Screws those elements were replaced by solid insulator material.

The heat source definition is considered as main step to conduct this study. In these cases the heat sources are usually considered as the new elements "food" introduced in the serve-over. The container of the food will be considered since the food and its container will be approximately in the same temperature.

In this case of study only one time of food will be considered but it is also easy to generate results in case of different types of food with different temperature are also introduced. The temperature considered is equal to the ambient temperature = 293.2 K.

The Table 1. gathers the different type of material allocated to the different parts used in this simulation.

Table 1. Material specification

| **Part** | **Material** |
|---|---|
| Outer Box "Serve-over" | Polystyrene |
| Food container | Stainless-steel 321 |
| Fan and Screw Lid | insulator |

### III.2 Results of first case of serve-over simulation

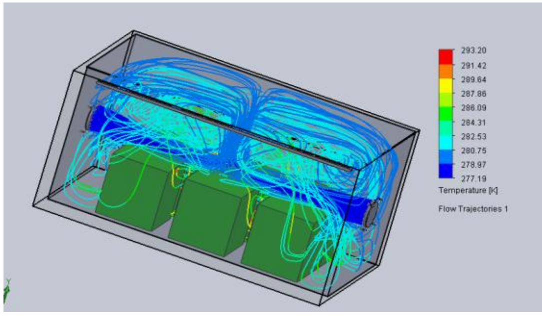

Figure 1. Temperature distribution

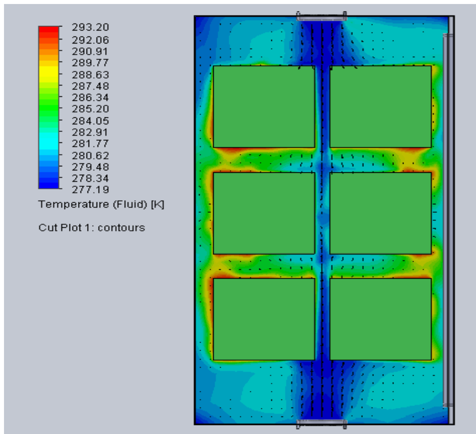


Figure 2. Temperature contours of crossed plan with Food container

Both Figure 1 and 2 show the behaviour of the temperature flow inside the ODC. Since both Fans are located in the middle of opposite faces and they are generating the same masse flow rate and the same temperature (277.2 K) the mid zone of the serve-over shows that the heat in that part is dissipated. The only places which present a residual heat are those which are no in direct contact with the flow.

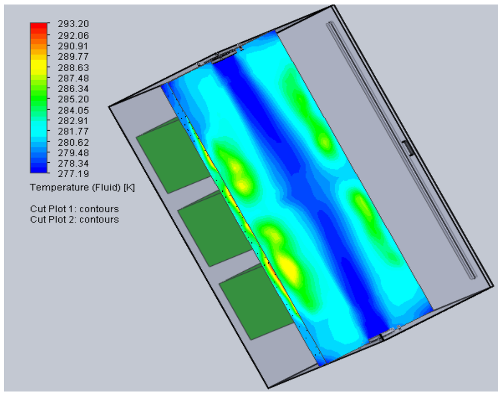


Figure 3. Temperature fluid contour of the upper part of the food container

Figure 3 shows that the upper parts of the food container require more time than the mid zone to reach the 277.2 K.

## IV. Results serve-over design change simulation

In this section some modifications were done on the design of the serve-over in order to remove or at least to reduce problems noted in the initial design.

In the left side of the serve-over, some additional plates were added to increase the fluid flow turbulence. The product (food container) will never be in direct contact of the downer inner face of the serve-over by adding pins.

Another type of change will be one the shape of the food container by adopting cylindrical shape instead of the prismatic.

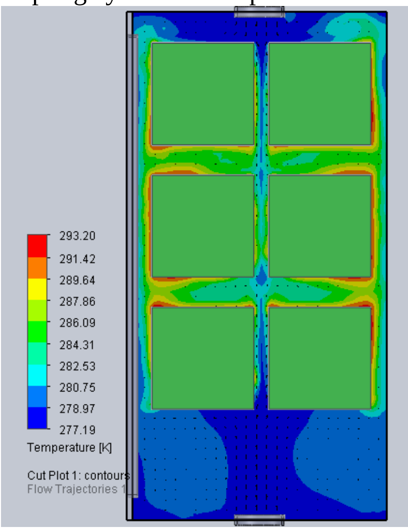


Figure 4. 2D Temperature contours of crossed plan with Food container -serve-over design change-

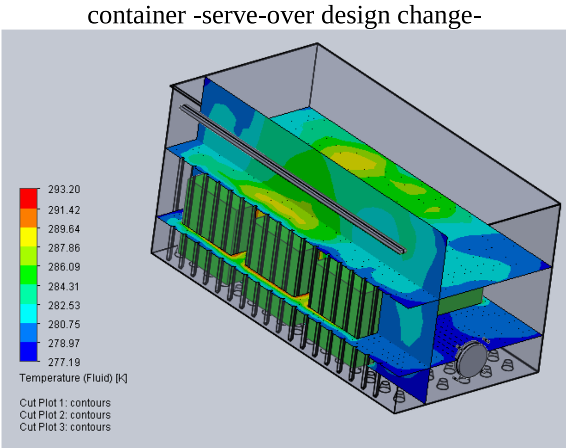


Figure 5. 3D Temperature contours of crossed plan with Food container serve-over design change

According to the Figure 2 & 3, it is possible to note that the fluid temperature (cool air) is occupying more space than in the initial design. The adding of pins to the dower face and plate the left side of the serve-over contribute to the increase of the cooled area. The direct consequence of this improvement will be by the reduction of the temperature of the food container.

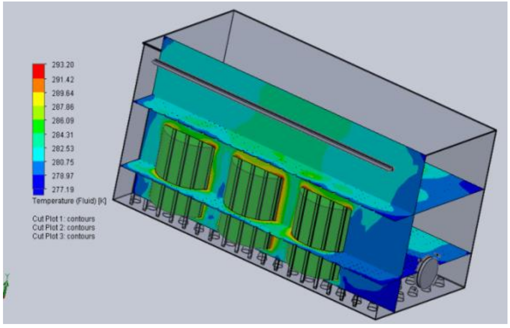

Figure 6. 2D Temperature contours of crossed plan with Food container –Food Container design change-

The modification made in the shape of the food container shows that the circular form presents a better way to dissipate the heat. (figure 6 and 7)

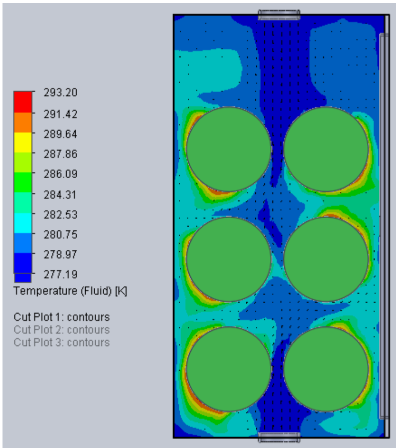


Figure 7. 3D Temperature contours of crossed plan with Food container design change

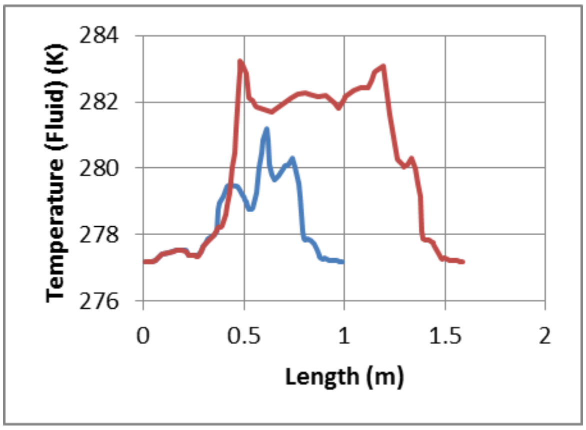


Figure 8. Variation of the temperature distribution

The curves presented in Figure 8 shows that the temperature depends widely on the path the flow.

## V. Conclusion

During this work, several study were followed, especially Abas, (2006). The different cases studies simulated in this work showed as that not only the design of the display cabinet is playing role in the optimization of the used energy. The food container geometry contributes on the heat exchange and dissipation.

According to the result found in Figure 7 and 8, it will be useful to enlarge the inlets of the cool air (Fans).

## VI. Acknowledgement

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