CHAM

Pioneering CFD Software for Education & Industry

External Flow and Natural Ventilation Modelling of An Apartment

PHOENICS Case Study - HVAC

Introduction

This report describes how PHOENICS environmental flow solver FLAIR-EFS can be used to model both external flow and natural ventilation of a building. FLAIR-EFS is specifically designed to model flows dependant on wind, terrain and built environments.

In this particular the flow is driven by wind which affects the flow around a group of buildings, one of which has an apartment located on the top floor. This problem serves as a demonstration of the capabilities of FLAIR-EFS for a type of application defined by CHAM agents, Shanghai Feiyi, and used for training purposes.

Figure 1 Domain (left) and building of interest (right)

CFD Model and Setup

Figure 1 shows several buildings at the centre of the domain. The central building contains an apartment on the top floor which will be the subject of study. The apartment has several open windows which allow air to flow through the building.

There are two locations where there are assumed to be groups of people (red boxes) and one location where there is a refrigerator (yellow box), all of which act as sources of heat. The windows and people are specified using domain material blockages. The people are a source of heat and humidity.

A hybrid differencing scheme is used to solve for pressure, momentum, temperature and relative humidity. The heat intensity/apparent temperature is calculated using the formula

$$HI\ (AT) = T_a + 0.33e - 0.7w.s - 4$$

where

T_a = Dry bulb temperature (C)

e = Water vapour pressure (hPa)

$w.s$ = Wind speed (m/s)

The vapour pressure, *e*, is calculated from the temperature, T_a, and relative humidity, *r.h*, using the equation

$$e = \frac{r.h}{100} \times 6.105 \exp\left(\frac{17.27T_a}{237.7 + T_a}\right)$$

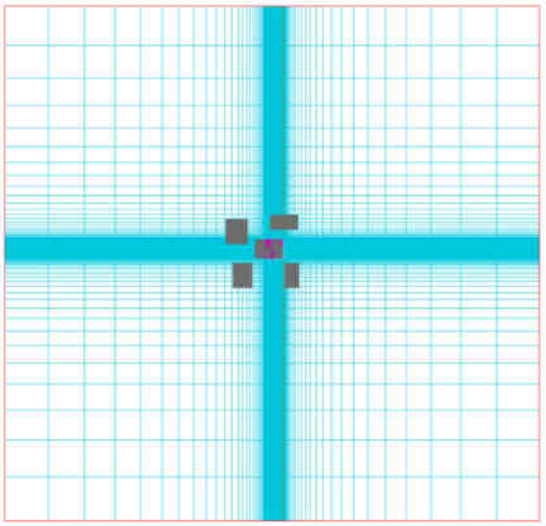
where
$r.h$ = Relative Humidity (%)

Specifications

- Domain : 363*m* x 353*m* x 128*m*
- Wind speed: 5*m/s*, Wind direction: N
- Relative Humidity: 70%
- Ceiling heat source: 415W/m^2
- People heat source: 500*W,* People humidity source: 4×10^{-5}*kg/s*
- Refrigerator heat source: *500W*

Mesh

Figure 2 shows the mesh used for the full domain and also for the "region of interest", which spans the apartment. The domain is discretised with a 112 x 110 x 88 grid which is refined towards the region of interest, which has a uniform 55 x 55 x 325 Cartesian grid. This gives a uniform grid in this region with cells of size 0.21*m* x 0.24*m* x 0.12*m*.



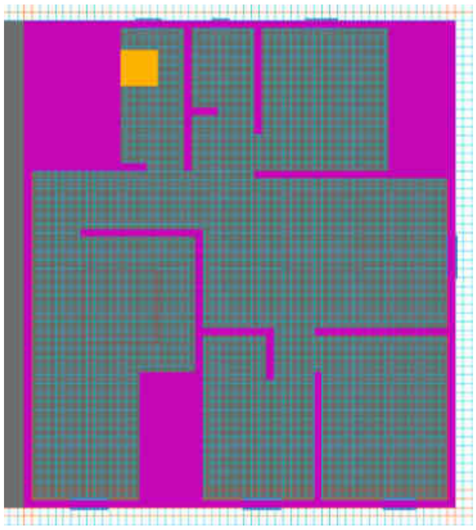


Figure 2 Mesh for full domain (left) and for region of interest (right)

Results

Error! Reference source not found. shows how the air flows around the building and enters the apartment through the north windows and exits through the east and south windows at a height of 1.5*m* above the floor of the apartment.

Figure 3 Velocity contours and vectors at height 1.5m above the apartment floor

Figure 4 shows vectors inside the apartment, coloured by velocity.

Again, we see that the flow enters the apartment through the north windows and exits at the east and south windows highlighting several regions of re-circulating air.

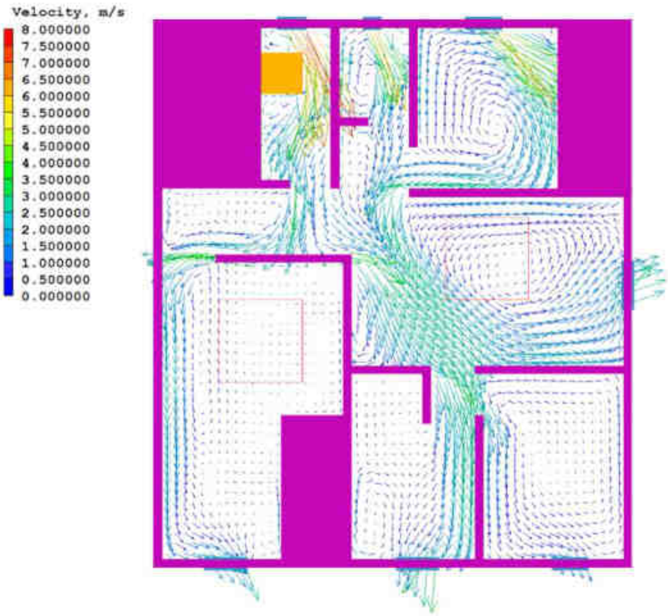


Figure 3 Vectors coloured by velocity at 1.5m above the apartment floor

Figure 4 shows the temperature distribution at 1.5*m* above floor level inside the apartment. The warmer areas are where there is a combination of proximity to heat source and lack of flow movement. When warmer air inside the apartment is recirculated, we see higher temperature areas.

Average Temperature: 20.3 ˚*C*

Figure 4 Contours of Temperature inside the apartment building

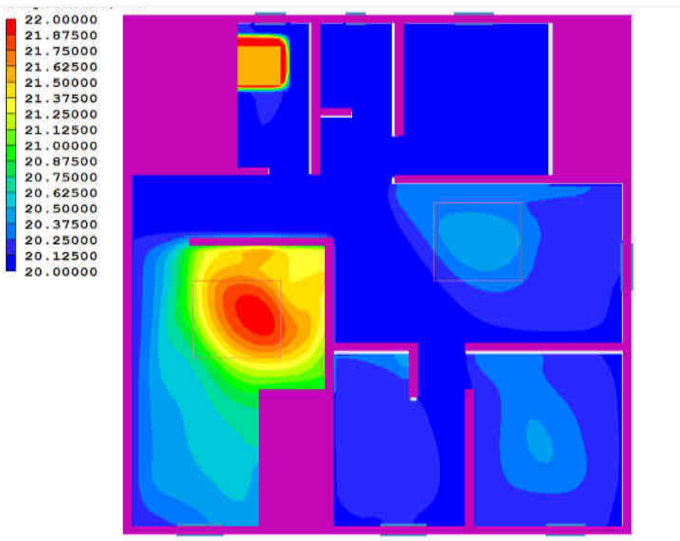


Figure 5 shows the contours of heat intensity at height 1.5*m* above the floor level inside the apartment. We can see that it differs from Figure 4 as the velocity of the flow lowers the heat intensity. The warm region around the refrigerator is no longer as pronounced due to velocity. The average heat intensity is higher due to the relative humidity.

Average heat intensity: 20.8 ˚*C*

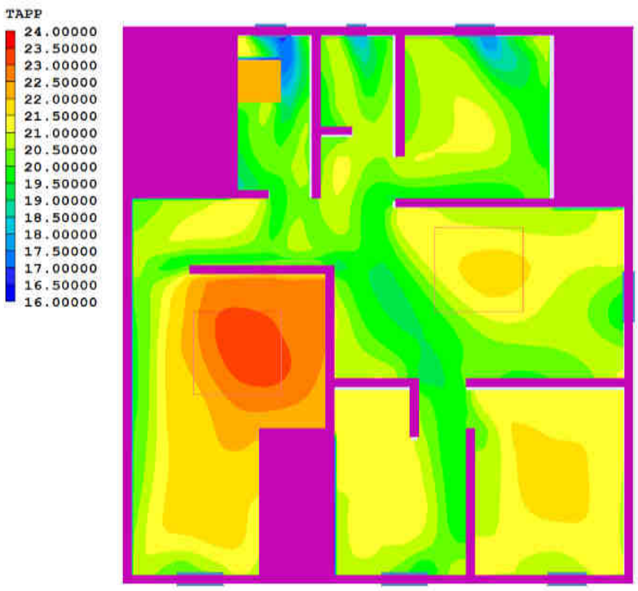


Figure 5 Contours of heat intensity inside the apartment building

Figure 7 shows the distribution of pressure on the East facing wall of the building of interest. There are lower pressures at the edges of the building where the velocity accelerates around the corners.

Average pressure: -6.31 *Pa*

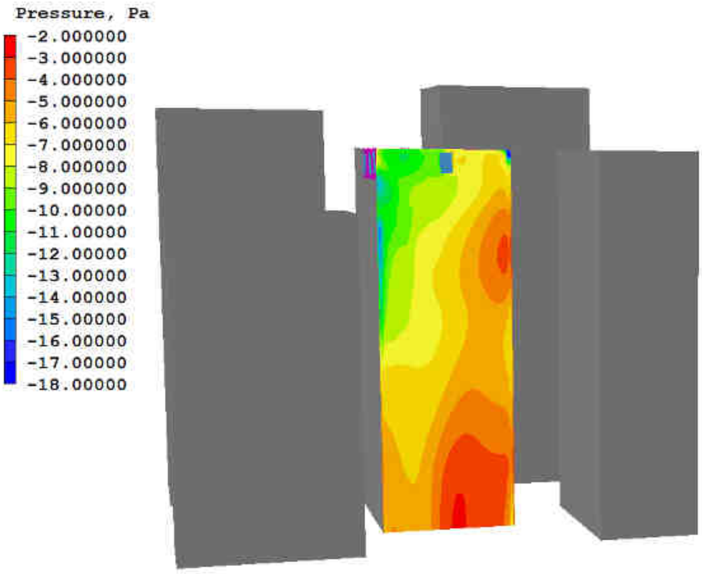


Figure 6 Pressure contours on the East surface of the building of interest

Observations

The purpose of this example was to show how the low-cost FLAIR-EFS sub-set of CHAM's PHOENICS-FLAIR software can be used to simulate natural ventilation in an apartment in conjunction with the external wind. The FLAIR-EFS "region of interest" is used to concentrate the mesh within the apartment.

Examples of velocity-vector plots and contour plots of temperature, heat intensity and pressure are presented.