1.0 Project title:

Effect of louvers opening configuration on building ventilation

1.1 The issue your project address

Electricity is still a requirement for all modern houses and a crucial input for all production operations. Due to the impacts of global warming and the security of the energy supply, appropriate energy regulations are therefore necessary to encourage efficient electricity usage in the residential sector in many countries. Given that the home sector accounts for nearly one-third of all global power consumption, attention should be paid to the characteristics of residential electricity use. (Chen, 2017). Furthermore, humans normally spend up to 80% of their time indoors, the air they breathe indoors must be at a great quality. According to the World Health Organization (WHO), contaminated air quality causes health problems in approximately 40% of building residents globally, and the National Institute of Health and Safety in the United States has publicly stated that 'Lack of Ventilation' is mainly accountable for 52% of the contamination found in indoor air ('WHO guidelines for air quality.', 1998). Enhancing the efficiency of a building ventilation system through natural ventilation can reduce the pollutants in indoor air, such as dust particles and biological contaminants.

2.0 Overview of the issue and your approach

Climate change is the most serious threat to both environment and humanity in the twenty-first centuries. According to temperature statistics, most places, including Malaysia, have observed warming trends in the previous 30 to 50 years (Rahman, 2009). Hence, natural ventilation in building is required to enhance building airflow and overcome the greenhouse effect.

Buildings consume about 40% of global energy, 25% of global water, 40% of global resources, and emit roughly 1/3 of global greenhouse gas (GHG) emissions, according to the United Nations Environment Programme (UNEP). (UNEP, 2021). When comparing natural ventilated and air-conditioned buildings, the carbon emitted and energy usage for air-conditioned buildings are 66% and 67% greater, respectively. As a result, the UNEP encourages the construction industry to combine new designs, technical innovation, and governmental policy to improve energy efficiency of a buildings (UNEP, 2021). Natural Ventilation has the potential and is a viable approach to attain thermal comfort without leading to climate change.

The objective of this study is to investigate the effect of various louvers opening configurations with different relative humidity on the velocity, pressure contours, and dimensionless flow rate (DFR).

The model utilised in this study is depicted in Figure 1. The general isolated reference model was based on the model by Kosutova (Kosutova *et al.*, 2019). The reference model is 150 mm × 150 mm × 150 mm (L × W × H). The reference model includes two louver openings, one on the windward facade and the other on the leeward facade. The dimensions of the opening are 70 mm × 40 mm (W × H). The louvers have a 10 mm gap between louvers, the slat angle of the louvers is 15°, while the thickness of the louver is 0.75 mm. The total thickness of the reference model is 10 mm and the wall porosity of the building is 12.5 %.

The computational domain of the study is based on the reference from literature (Kosutova *et al.*, 2019). To avoid any unwanted unintended streamwise gradients in approaching flow profile information, the flow domain was built with a 3H distance from the windward wall of the reference model to the inlet, 5H from edge to the reference model, 5H from the ceiling, and 15H from the leeward wall to the flow domain's outlet, where H has a value of 150 mm (0.15 m) which represents the height of the reference model, resulting in domain dimensions of 2850 × 1650 × 900 mm^3 (L × W × H). The computational domain and its dimensions are displayed in Figure 2. Figure 3 shows the 3D view of computational domain dimension.

The isolated building's meshing was done with ANSYS FLUENT 2021 R2. The reference model was surrounded by a domain called body of influence (BOI). To enclose the geometry, the first BOI, house BOI, was utilised. Windward BOI and leeward BOI were added to the windward and leeward louver openings, respectively, to properly compute the simulated flow through the louvers. Another BOI, called near BOI, was added, with a 150 mm offset from the model. Finally, a BOI titled far BOI was added to collect the entering flow and the flow movement outside the building. BOIs were used to assure that a fine mesh was formed around the reference model and other specified locations such as openings, resulting in a more accurate result. The 3D model was created with a cell count of 2,539,228 and a minimum orthogonal quality of 0.3 by adjusting the local and global sizing and putting the curvature sizing to the lowest value while keeping the normal angle at 10°. The mesh of the reference model is shown in the Figure 4.

The RNG k-ε turbulence model was used to execute 3D stable Reynolds-averaged Navier-Stokes (RANS) simulations. The SIMPLE method was also employed in this research. For the second order upwind discretization and pressure estimation, both the convection and viscous components of the numerical solution were used. Convergence was achieved as the scaled residuals recede downward towards 10^{-5}. The converged scaled residual is shown in Figure 5. Figure 6 depicts the medium grid, often known as Grid B with 2,539,228 cell numbers. This meshing has a final orthogonal quality of 0.3.

To examine the reference case (case 1), four single lines were conducted inside the reference model, x/D = 0.2, x/D = 0.4, x/D = 0.6, and x/D = 0.8, with x and D representing for variable length and building length, respectively. The average grid difference between the coarse and fine grids is 2.22%, as shown in Table 1. The average grid difference between medium and fine grids is 0.54%. Based on the comparison of two grids, medium grid had a far lower average than the coarse grid, which has a GCI of 0.54%. Since the GCI for the medium grid is less than 1, the medium grid is chosen to run the remaining simulations. Figure 7 shows the grid sensitivity analysis between coarse versus fine grid and medium versus fine grid. The FAC2 for an ideal set of data is 1. To summarize the findings, Table 2 (Grid B vs Kosutova RNG k-ε) and Table 3 (Kosutova Experiment) show the average FAC2 found for the middle-middle configuration of the reference model to be 0.8534 and 0.7284, respectively.

Based on the number of simulation cases, the simulation is divided into two batches. The first batch focused on the effect of various opening positions with louvers on natural cross ventilation in the building. The second batch would investigate the impact various opening positions with louvers in the building, with the inclusion of the temperature and relative humidity setting.

The influence of various opening configurations with louvers on natural cross ventilation is explored in this research. As a result, in batch 1, various aperture configurations with louvers will be examined in order to see how natural cross ventilation airflow is influenced when both louvers in windward and leeward sides and various opening configurations are integrated. Table 4 shows the simulation cases in Batch 1.

In Batch 2, this research examines the effect of various opening configurations with louvers on natural cross ventilation with different temperature and relative humidity setting. The various opening configurations and various relative humidity are presented in the Table 5.

The essence of the solution:

The DFR is shown in Figure 8 for all opening configurations and multiple relative humidity percentage including no relative humidity, 80% relative humidity, 60% relative humidity, 40% relative humidity, and 20% relative humidity. It can be demonstrated that the relative humidity has a minimal impact on the DFR in any configuration of openings, indicating that it will not have a major impact on the building's flow rate. The top-top opening configuration has the greatest DFR, following by top-bottom, middle-middle, bottom-top and bottom-bottom opening configurations. These findings are in agreement with recent research, which indicates that the top-top opening configurations resulted in higher flow rate throughout the building (Kosutova *et al.*, 2019; Moey *et al.*, 2021). Lastly, Tominaga and Blocken (Tominaga and Blocken, 2016) reach the conclusion that the internal airflow resistance is greater when the inlet and outlets opening locations are at different elevations and that the inlet opening position affects the pressure difference that produces cross ventilation flow.

Tables 6 to 10 illustrate the indoor airflow pattern and pressure distribution for all twenty-five cases with varying opening configurations and relative humidity levels. The contours agree well with Bernoulli's equation, which asserts that fluid velocity is inversely proportional to fluid pressure. As observed in the contours, the largest pressure happened on the windward wall of above 1Pa to maximum range due to the effect of air colliding with the windward wall, while the lowest pressure occurred on the leeward wall side of the simulation model of -0.01 Pa to -1.74 Pa.

The varying pressure values obtained indicate that changing the position of apertures can have a considerable impact on both the opening pressure and the indoor pressure. The pressure differential between the inlet and outlet openings is the driving force behind wind-induced ventilation, with the greater the pressure difference, the greater the air velocity. When each opening configuration is compared, the bottom-bottom opening design has the lowest opening pressure at the inlet aperture. Bottom-bottom opening arrangements, on the other hand, have the smallest pressure difference between the windward and leeward openings. As a result, among all opening configurations, the velocity at the middle-middle opening louver opening configurations has the maximum velocity at the intake apertures.

Furthermore, Tables 6 to 10 reveal a tendency in which the 20% relative humidity simulation model has a little greater pressure of 0.02 Pa than the 80% relative humidity simulation model, which has a 0.02 Pa lower pressure on every opening configuration. From the table 4.7 to 4.11 above, it clearly shows that the top-bottom opening configuration gets the greatest pressure differences while the bottom-bottom opening configuration gets the lowest pressure differences. The pressure will be higher in windward wall indicates the re-orange region while the leeward wall will be the least pressure indicates the green region. The addition of relative humidity does not have any major changes on the contours prove that the relative humidity will not have any effect on the velocity and the pressure parameters.

6.0 Project description:

The aim of this study is to investigate the effects of louver opening configuration and relative humidity for natural ventilation of an isolated building. This study contains four different relative humidity settings (20%, 40%, 60% and 80%) with five different opening configurations windward and leeward walls. A middle-middle louver opening configuration was first studied to validate the result with (Kosutova *et al.*, 2019). Each louver opening configuration was simulated using Computational Fluid Dynamics (CFD) with RNG k-epsilon turbulence model with enhanced wall treatment. Grid sensitivity analysis and model validation was conducted using previous study to ensure accuracy on findings. From initial analysis, comparison shows good agreement as the results are similar. From the simulation cases, increasing relative humidity for various louver opening configuration does affects the overall temperature distribution in each wall. From the results, the dimensionless flow rate (DFR) in Top-Top Louver opening configuration shows the greatest DFR. This statement have an agreement with recent researches which indicates the Top-Top louver opening configurations has an highest flow rate throughout the building. Furthermore, according to the velocity contour, the top-top and top-bottom opening configurations have a greater air exchange rate at the top of the building, while the bottom-bottom and bottom-top opening configurations have a higher air exchange rate at the bottom of the building. Therefore, this study concludes that opening position with louver plays an important role on the internal airflow and DFR in building natural ventilation.

The stakeholders in your project: SEGi University, Faculty of Engineering, Built Environment and Information Technology

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