UNIVERSITI TEKNOLOGI MARA

INFLUENCE OF COMPUTATIONAL PARAMETERS ON TURBULENCE FLOW STRUCTURE CHARACTERISTIC IN TWO DIMENSIONAL IDEALIZED URBAN STREET CANYON FOR LARGE-EDDY SIMULATION

NORHARYATI BTE SALEH

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Civil Engineering)

College of Engineering

June 2022

ABSTRACT

The use of Computational Fluid Dynamics (CFD) as a research tool has been utilized in many ways to predict the turbulent flow nature in an urban environment such as a street canyon. A review of past relevant studies on the atmospheric process in large or long street canyons indicates an arbitrary selection mainly for two parameters, namely computational domain and grid resolution that have significant influences on the accuracy and reliability of the predicted flow field, particularly for turbulence flow phenomena. However, most of the studies were merely done at the early stage of simulation and most sensitivity tests on those parameters have been done separately in previous studies while the rigorous study on the correlation among the grid resolution size and computational domain size is still limited. This study performs a series of large eddy simulations (LES) to investigate the turbulent flow fields within and above a two-dimensional idealized street canyon with a unity aspect ratio (ratio of street width, *W* to building height, *H*). The effect and correlation of domain size and grid resolution on turbulent flow statistics (mean, fluctuation and energy momentum components) are evaluated through the implementation of comparison for three different domain sizes (*2H* x *H* x *6H*: small (streamwise (*x*), spanwise (*y*), and vertical (*z*) directions), *6H* x *H* x *6H*: medium and *10H* x *H* x *6H*: large) with three different sizes of grid resolution (*H/8*: coarse, *H/16*: medium, and *H/32*: fine). The domains are designed to vary in streamwise lengths with fixed spanwise length and vertical height. Comparison with the available wind tunnel study shows a good agreement for mean velocity profiles for all cases. The results signify that the mean velocity component is relatively independent of the domain size and grid resolution. The contribution of the grid resolution parameter is found to be more significant on the turbulence characteristic performance for this particular study, rather than the computational domain size parameter effect. On average, the variation magnitude different among the grid resolution cases is measured 40 percent, 22.4 percent, and 39.6 higher than the domain size cases for velocity, standard deviation, and Reynold shear stress component near the roof level, respectively. By considering less computational power demand, the study suggested that the mean velocity flow field inside a street canyon can be well predicted even using the small domain with medium and fine grid resolution rather than the large street canyon. However, the use of a small or medium domain is not recommended for the turbulence flow analysis, since the data prediction is prominent for the inconsistency and discrepancy. The finding on the correlation and contribution of computational domain size and the grid resolution size in this current study is found to be reliable for saving numerical resources without compromising numerical accuracy. Nevertheless, these results are expected to provide additional information relevant to uncertainty estimation upon execution of computational fluid dynamics (CFD) simulation, particularly in the LES simulation model.

ACKNOWLEDGEMENT

With the Graciousness and Mercifulness of ALLAH S.W.T, I would like to thank to my main supervisors, Associate Prof. Dr. Mohd Hisbany Mohd Hashim for all their guidance and advice with this PhD. I would also like to thank Dr. Mohd Faizal Mohamad and Prof. Dr. Azmi Ibrahim as well as the team member from the Wind Engineering and Building Physics Center (WEBPC) for their technical support and priceless help on my study. Their immense knowledge and plentiful experience have encouraged me in all the time of my academic research and daily life.

This thesis is dedicated to the memory of my beloved mother, Jah Ibrahim, who passed away before I started my doctoral journey as well as my supported father, Saleh Hj. Mohmad, who I had promised to make his proud by the achievement of this monumental academic goal. My humble effort I dedicated to my sweet and loving husband, Mohd Nazmir Hj. Mohamad Jahro for his great patient and remains willing to engage with the struggle of 'turbulent' life in allowing and providing me the space and time to make me able to get such success and complete the thesis. InsyaAllah, may our life flow be more 'steady' after this with our 'little one'. I also appreciate all the support I received from the rest of my family.

Lastly, I would like to thank the School of Civil Engineering, the Universiti Teknologi MARA and the Kementerian Pendidikan Tinggi Malaysia for the scholarship support that allowed me to conduct this thesis. I thank you with all of me. ALLAH IS THE GREATEST.

TABLE OF CONTENTS