University of Technology Sydney

Investigation into Two-Sided Windcatchers Used for Room Ventilation

By

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Certificate of Authorship / Originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in this thesis.

Amirreza Niktash

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Dedication

To my wife and my parents

Preface

Increased concern of environmental pollution has led to the use of renewable energy asan alternative source. Energy generating from fossil fuels in power plants has considerable disadvantages. Air pollution is one of the most important weak points in this kind of energy which makes many environmental organisations concerned. Expensiveness, scarceness and non- recyclability of fossil fuels energy sources are the other limitations of their application.

On the other hand, nuclear energy has its own risks and pollutions which makes its application unacceptable in many locations.

These days, the wide range of renewable energies applications have presented themselves as the alternative, popular and green sources of energy without the existing and usual limitations and disadvantages of fossil and nuclear energies.

Compatibility with nature and minimal impact on the environment, simple and reliable performance and sustainability are some of the advantages of these recyclable sources of energy.

Solar, wind, wave and hydroelectric power are all forms of renewable energy. All of these forms have a common origin; beside the fact that the earth provides a considerable and consistent supply and their use has little or no detrimental effect on the environment, they are all sourced from the sun. Other renewable sources besides the foregoing are biomass, geothermal energy and tidal energy. These sources do not directly depend on the sun.

The sun is directly responsible for solar energy (photovoltaic and thermal). The sun is also behind wind energy, since it causes the pressure differences that give rise to the winds and also wave energy. The sun contributes to the development of organic matter (biomass) and it is the main agent of the water cycles as well.

Innovative natural ventilation techniques such as the windcatcher and solar chimney have facilitated the effective use of natural ventilation in a wide range of buildings for increasing the ventilation rate. In addition to bringing energy savings, these environmentally friendly technologies also help create healthier interiors for occupants by preventing moisture development in the air and reducing pollutant concentrations effectively.

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C_1, C_2, C_μ, σ_k,and σ_ε: K-ε adjustable constants for turbulence flow, dimensionless

C_P : Pressure coefficient, dimensionless

C_S : Model constant, dimensionless

E_1 : Estimated fractional error, dimensionless

f_1: Fine grid solution, dimensionless

f_2: Coarse grid solution, dimensionless

h_1: Uniform discrete cell length of fine grid, [m]

h_2: Uniform discrete cell length of coarse grid, [m]

I : Turbulence intensity, dimensionless

k: Turbulent kinetic energy [m^2/s^2]

L: Characteristic length [m]

P: Surface pressure [KPa]

P_S : Static pressure[KPa]

r : Grid refinement ratio, dimensionless

$\bar{S}_{ij}$: Strain rate of the large scale or resolved field [S^{-1}]

U: Inlet stream velocity in X-direction [m/s]

u´, v´, w´: Turbulent fluctuation velocity components [m/s]

V_{ref}: Reference wind velocity [m/s]

ε: Dissipation rate of turbulent kinetic energy [m^2/S^3]

ρ: Density [kg/m^3]

μ: Dynamic viscosity [N.s/m^2]

μ_T^{SGS}:Sub-grid scale eddy viscosity [N.s/m^2]

ϑ_t^{SGS}: Sub-grid scale kinematic viscosity [m^2/s]

κ : Von Karman constant, dimensionless

ν_t: Kinematic viscosity [m^2/s]

τ_{ij}, τ_{kk}: Tangential stresses [N/m^2]

Δ : Grid filter width [m]

List of Acronyms

CFD: Computational Fluid Dynamics

DES: Detached-Eddy Simulation

DNS: Direct Numerical Simulation

FVM: Finite Volume Method

GEOM: Geometry

GUI: Graphical User Interface

LES: Large Eddy Simulation

MEMS: Micro-Elcectro-Mechanical

NURBS: Non-Uniform Rational Basis Spline

RANS: Reynolds Averaged Navier-Stokes

RNG: Re-Normalisation Group

SGS: Sub-Grid Scale

Abstract

A windcatcher is a structure for ventilation purposes fitted on the roof of a building to induce the stale inside air to the outdoors and supply the fresh outside air into the building.

The experimental studies of windcatcher systems for all cases are obviously costly or even impossible in practice. The assessment of the performance of windcatcher systems using Computational Fluid Dynamics (CFD) is very important for both their designs and improvements; CFD has become a reliable tool for flow analysis in buildings.

This thesis investigates the effects of some key factors on the performance of a two-sided windcatcher fitted on the roof of a typical room. A CFD software package developed by the ESI group is used for the quantitative and qualitative analysis of velocity magnitude, flow patterns, and ventilation flowrate. For all cases, RANS (Reynolds Averaged Navier-Stokes) CFD technique with the standard two-equation K-Ɛturbulence model is employed in steady state conditions for incompressible turbulent air flows. Based on the simulations and analysis, a model is selected. A LES (Large Eddy Simulation) CFD technique employing the Smagorinsky subgrid-scale (SGS) turbulence modelis used for evaluating the selected model in transient conditions. Results from RANS and LES are compared; and they show good agreement.

To verify the computational results, a laboratory scaled model from the selected computational model is constructed and these are compared with the experimental measurements; and fair agreement has been obtained.

All these investigations would lead to a significant development in evaluation and performance of two-sided windcatcher systems. This work has resulted in 8 research publications which are listed in Publications Section.