

بسم الله الرحمن الرحيم





شبكة المعلومات الجامعية التوثيق الالكتروني والميكروفيلم



جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار





بعض الوثائق الأصلية تالفة





بالرسالة صفحات
لم ترد بالأصل





Cairo University

**MODELLING AND SIMULATION FOR ENERGY EFFICIENCY
IMPROVEMENT IN COMMERCIAL BUILDINGS**

By

Ahmed Hamdi Salama

B.SC

A Thesis Submitted to the

Faculty of Engineering at Cairo University

In Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

In

MECHANICAL POWER ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

GIZA, EGYPT

2020

**MODELLING AND SIMULATION FOR ENERGY EFFICIENCY
IMPROVEMENT IN COMMERCIAL BUILDINGS**

By

Ahmed Hamdi Salama, BSc

A Thesis Submitted to the

Faculty of Engineering at Cairo University

In Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

In

MECHANICAL POWER ENGINEERING

Under the Supervision of

Prof. Dr. Essam E. Khalil

Professor, Mechanical Power Engineering Department

Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

GIZA, EGYPT

2020

MODELLING AND SIMULATION FOR ENERGY EFFICIENCY IMPROVEMENT IN COMMERCIAL BUILDINGS

By
Ahmed Hamdi Salama

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE
In
MECHANICAL POWER ENGINEERING

Approved by the Examining Committee:

Prof. Dr. Essam E. Khalil Hassan Khalil **Thesis Main Advisor**
Professor, Mechanical Power Engineering Department, Faculty of Engineering, Cairo University

Prof. Dr. Mahmoud Fouad **Internal Examiner**
Professor, Mechanical Power Engineering Department, Faculty of Engineering, Cairo University

Prof. Dr. Osama Ezzat Abd-Ellatif **External Examiner**
Professor, Mechanical Power Engineering Department, Faculty of Engineering at Shoubra, Benha University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

GIZA, EGYPT

2020

Engineer: Ahmed Hamdi Ahmed Mohamed Salama
Date of Birth: 11 / 01 / 1992
Nationality: Egyptian
E-mail: eng.ahmedhamdi@hotmail.com
Phone: 01277588818
Address: Al Saha St, Al Hawamdia, Giza
Registration Date: 1 / 10 / 2017
Awarding Date:/....../2020
Degree: Master of Science
Department: Mechanical Power Engineering
Supervisors: Prof. Dr. Essam E. Khalil Hassan Khalil



Examiners:

Prof. Dr. Essam E. Khalil	(Thesis main advisor)
Prof. Dr. Mahmoud Fouad	(Internal Examiner)
Prof. Dr. Osama Ezzat Abd-Ellatif	(External Examiner)

Title of Thesis:

MODELLING AND SIMULATION FOR ENERGY EFFICIENCY
IMPROVEMENT IN COMMERCIAL BUILDINGS

Key Words:

Energy Simulation; DesignBuilder; Energy Efficiency.

Summary:

In this thesis, a simulation investigation has been implemented for an office building existing in Cairo, Egypt. The building shape, location, orientation, systems and constructing materials have been modelled in DesignBuilder software, and then it has been simulated for a one year energy simulation. This energy simulation aims to study the energy effect of walls, having a different U-wall value which has been selected to be within the recommended range founded in the "Egyptian code for improving the energy efficiency in commercial buildings". These walls have different properties according to the constructing materials thicknesses. The results show the optimum state that can be selected for the user.

Disclaimer

I hereby declare that this thesis is my own original work and no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used, and have cited them in the references section.

Name:

Date:

Signature:

Dedication

To all my family members, my father, my mother, my wife, and my daughters Hana and Sama.

Acknowledgment

In the beginning of anything, we ask our God to support us and provide us with faith that when I would like to do something to make things around me better and asking him to support me, and to drive me toward things that enhance everyone's life. Thanks God for creating me in a good health and mentality that helped me to be in the situation I am in. I hope that I could use all the resources that our God have provided me with through my life. In the second place I would like to thank my parents for everything that they have provided me with, I believe that they are one of the greatest blessings that God has provided me with. My mother that words cannot describe the efforts she was exerting to raise, teach, and take care of me. My father who was guiding, supporting, and providing me with not only anything he has and thinks could help me. He was making my studying time as a priority for any family plans, caring about my progress not only through my Master's degree but through my whole life. His caring was inspiring me to go on when I am depressed, pushing me through when I am not motivated enough. He was providing me with his wise opinions, that his wisdom came from a wide range of different experiences, experiences which I believe they were obtained by reading daily newspapers and books, studies at faculty of law which enabled him to have different interpretations for one situation, and to look at things from different points of view, and a life experience which gained by going through a lot of a major and minor things through his life. I would like to thank my wife. She is a doctor, and she has a little baby to take care of "my lovely daughter". Although she was so busy and so stressed, she didn't forget that I am going through my Master's degree. Special thanks to Prof. Dr. Essam E. Khalil Who was so helpful, kind, and very modest in dealing with anyone. There is nothing better than dealing with a modest person who simplify and facilitate anything from his side. Eventually, thanks God for all blessings that I have, what I know and realize, and what I don't.

LIST OF CONTENTS

LIST OF TABLES	vi
LIST OF FIGURES	vii
NOMENCLATURE	ix
ABSTRACT	x
CHAPTER 1: INTRODUCTION	1
1.1 General	1
1.2. Simulation	3
1.2.1. Building energy simulation	3
1.2.2. Energy simulation benefits	3
1.3. Simulation needed information	3
1.4. Simulation procedure	5
1.5. Energy simulation factors	5
1.5.1 Geometrical aspects	5
1.5.1.1 Thermal zoning	5
1.5.1.2 Aspect Ratio	6
1.5.2 Energy use intensity	6
1.5.3. Simulation run time	7
1.5.4. Zone occupancy	7
1.6. Air gap effect	8
CHAPTER 2: LITERATURE REVIEW	10
2.1 World energy consumption	10
2.2 Building energy consumption	12
2.3 Modelling and approaches	14
2.4 Energy simulation examples	16
CHAPTER 3: GOVERNING EQUATIONS and SIMULATION	23
3.1 Introduction	23
3.2 Continuity Equation	23
3.3 Momentum Equation	23
3.4 Energy Equation	23
3.5 Complementary Equation	23
3.6 Zone Loads	24
3.6.1 Internal loads	24
3.6.1.1 General lighting	24
3.6.1.2 People	24
3.6.1.3 Equipment	24
3.6.1.4 Solar radiation	24
3.6.1.5 Conduction through walls	25
3.7 solution algorithm	26
3.8.1 conduction transfer function	26
3.8.2 Finite difference algorithm	27

3.8.2.1 Crank-Nicholson scheme	27
3.8.2.2 Fully implicit scheme	27
3.9 Convergence criteria	27
CHAPTER 4: ENERGY MODEL	28
4.1 Introduction	28
4.2 Room data	31
4.2.1 Windows Data	31
4.2.2 Roof data	31
4.2.3 Walls data	31
4.2.4. Outside conditions	32
4.2.5 Inside conditions	32
CHAPTER 5: RESULTS AND DISCUSSIONS	34
5.1 Walls simulation	34
5.2.1 Case1: Wall, Mass, R-0.0 (0.00), U-0.480 (2.73)	34
5.2.2 Case2: Wall, Mass, R-1.0 (0.18), U-0.367 (2.08)	36
5.2.3 Case3: Wall, Mass, R-2.0 (0.35), U-0.269 (1.53)	38
5.2.4 Case4: Wall, Mass, R-11.0 (1.94), U-0.168 (0.95)	40
5.2.5 Case5: Wall, Mass, R-10.0 (1.76), U-0.102 (0.58)	42
5.2.6 Case6: Wall, Mass, R-45.0 (7.92), U-0.021 (0.12)	44
5.3 CFD Results	48
5.3.1 External CFD results	48
5.3.2 Internal CFD results	51
5.4 Discussion	57
5.4.1 Energy discussion	57
5.4.2 CFD discussion	60
CHAPTER 6: CONCLUDING REMARKS and FUTURE WORK	61
6.1 Conclusions	61
6.2 Future Work	61
References	62

LIST OF TABLES

Table 1.1	Monthly Design Dry Bulb for Cairo according to ASHRAE fundamentals 2017	3
Table 2.1	Preliminary cost analysis of an office building	17
Table 4.1	Different walls with different U-wall value	31
Table 4.2	Cairo location data	32
Table 4.3	General office occupancy schedule assumption	32
Table 4.4	General Office equipment schedule assumption	33
Table 4.5	General Office general lighting schedule assumption	33