UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FACULTY OF ELECTRICAL ENGINEERING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FINAL YEAR

PROJECT REPORT

BEKU 4894

DESIGN AND DEVELOPMENT OF AN AUTOMATED WINDOW CLIMBING ROBOT

AHMAD FAHIM BIN MUSTAFA

Bachelor of Mechatronics Engineering

2014/2015

"I hereby declare read through this report entitle "Design and Development of An Automated Window Climbing Robot" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering"

Signature : ……

Supervisor's Name : DR. MUHAMMAD FAHMI BIN MISKON

Date : ……

DESIGN AND DEVELOPMENT OF AN AUTOMATED WINDOW CLIMBING ROBOT

AHMAD FAHIM BIN MUSTAFA

A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronic Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014/2015

"I hereby declare read through this report entitle "Design and Development of An Automated Window Climbing Robot" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering"

Signature : ……

Name : AHMAD FAHIM BIN MUSTAFA

Date : ……

ACKNOWLEDGEMENT

All praises to ALLAH S.W.T. the Almighty God that has given me the strength, ideas and many other things upon this final year project. A very greet to our Prophet Muhammad S.A.W., his family and friends. Your blessing gives me an opportunity and some ideas to complete my final year project.

I would like to convey my thankfulness to my supervisor, DR. Muhammad Fahmi B. Miskon and my previous supervisor ENGR. Mohd Rusdy B. Yaacob for guidance throughout the progress of this project, for his nascent ideas, valuable guidance and continuous encouragement. This project report would not be possible completed without their guidance. I appreciate their countless hours spent in sharing their understanding, knowledge and experience throughout in this project.

At the end, I would like to express my great appreciation to my beloved parents and family who have been support me during my study in UTeM. Special thank also go to my friends for their cooperation and support during this project. Lastly, thanks to everyone who has contributed in completing this project.

ABSTRACT

Window cleaning is the most dangerous jobs when it comes to clean the skyscraper. There are many types of window cleaning technique that apply in this job. These techniques are dangerous if highly safety precaution do not take seriously and can lead to serious accident and death. Many reports regarding accidents that involving falling from skyscraper which results in serious injury and death to window cleaning workers. Until today, we are still using the same methods that are dangerous to the workers. To overcome this problem, an automated window climbing robot was designed and developed by using double acting pneumatic cylinder with suction mechanism in order to help the robot climb the window glass. When develop a window climbing robot, the major problem is gravitational force exerted toward the earth. As the solution, a window climbing robot is develop using the vacuum suction mechanism as the main holding mechanism with the helping of suction cups. The desired path for the robot which can hold and move on window glass surface. Performance of the robot in term of velocity of robot, the theoretical holding force of robot and vacuum suction pressure required are analyzed in this research. In FluidSim Software, the double acting pneumatic cylinder is simulate to find its theoretical velocity. In the experiment, the prototype is travel upward vertically follow the path. The distance travel by the prototype is taken by time to complete the path. The velocity of the prototype can be calculated. The mass of the robot is $0.466\ kg$ and the theoretical holding force of the prototype is $55.654\ N$ where the friction value is 0.5. The diameter required for the suction cups is $35\ mm$ and the minimum pressure required to hold the robot is $9.5\ bar$ and the empirical acceleration is $30\ m/s^2$. For the experiment, the velocity of cylinder is increase significantly with the increasing of pressure. The average velocity of prototype is $0.48\ m/s$ to complete $50\ cm$ path.

ABSTRAK

Pembersihan tingkap adalah satu pekerjaan yang merbahaya apabila ia melibatkan pembersihan bangunan pencakar langit. Terdapat pelbagai jenis teknik pencuci tingkap yang diaplikasi di dalam perkerjaan ini. Teknik ini berbahaya jika langkah keselamatan tidak di ambil serius dan boleh membawa kepada kemalangan dan kematian. Banyak laporan mengenai kemalangan yang melibatkan pekerjaan ini dimana ia membawa kepada kecederaan serius dan kehilangan nyawa terhadap pekerja pembersih tingkap. Sehingga sekarang, mereka masih menggunakan kaedah yang berbahaya kepada pekerja. Untuk mengatasi masalah ini, robot memanjat tingkap direka bentuk dan dibangunkan dengan menggunakan satu silinder pneumatik bertindak berganda dan mekanisma penyedutan. Apabila membangunkan robot pemananjat tingkap ini, masalah utama dihadapi ialah tekanan graviti oleh dikenakan terhadap robot. Sebagai penyelesaian, satu robot memanjat tingkap dibangunkan dengan menggunakan mekanisma vakum penyedutan sebagai mekanisma pengangan utama dengan bantuan penyedut. Jalan yang digunakan oleh robot akan di reka dan dibangunkan. Prestasi robot dari segi halaju robot, daya pegangan teori robot dan sedutan vakum tekanan yang diperlukan dianalisis dalam kajian ini. Dalam Perisian FluidSim, silinder pneumatik bertindak berganda adalah simulasi untuk mencari halaju tujahan rodnya. Dalam eksperimen, prototaip berjalan menaik menegak mengikuti jalan yang disetkan. Jarak yang di lalui oleh prototaip diambil dengan masa yang diperlukan untuk melengkapkan jalan tersebut. Jisim robot adalah $0.466\ kg$ dan daya pegangan teori prototaip adalah $55.654\ N$ di mana nilai geseran ialah 0.5. Diameter cawan sedutan adalah $35\ mm$ dan tekanan minimum yang diperlukan untuk memegang robot adalah $9.5\ bar$ dan pecutan empirikal bagi pneumatik adalah $30\ m/s^2$. Untuk percubaan, halaju silinder adalah peningkatan ketara dengan peningkatan tekanan. Halaju purata prototaip adalah $0.48\ m/s$ untuk melengkapkan $50\ cm$ perjalanan.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

WCR	Window Climbing Robot
AC	Alternating Current
DC	Direct Current

CHAPTER 1

INTRODUCTION

1.0 Overview

In this chapter, there are sub-sections which will explain more details about the research background, motivation, problem statement, objectives, and scope of research. Those explanations will provide overall understanding for audience regarding the project that researcher design and develop. Furthermore, this research may be useful in the future after few modification and improvement.

1.1 Research Background

Nowadays, a major problem of the skyscrapers is cleaning at the outside of the building. There are some methods to clean the outside of the skyscrapers such as using Bosun's chair. The Bosun's chair are moving upward and downward in order to complete the cleaning task. In this method, the man power is used to complete the task. For example, Figure 1.1 and Figure 1.2 shows how the Bosun's chair is used to transport the worker to complete their task.

Figure 1.1: Workers complete their task using Bosun's chair

Figure 1.2: Worker cleaning the window using Bosun's chair

Besides Bosun's chair, there is another method that is very popular in this cleaning sector such as using platform. The platform is using cable that attach from the roof of the

skyscrapers. The platforms are carrying the workers and their cleaning equipment to complete their cleaning task. This method is applied as shown as figure 1.3.

Figure 1.3: Cleaning workers are using platform to complete their task

Another popular method for cleaning window glass is using crane. The crane is using to transport the workers to the particular window glass at the ground. In this method, there is limitation on the height of the building because the crane is control on the ground as figure 1.4.

Figure 1.4: Workers using crane for their job

1.2 Motivation

By year 2014, there are many tall building have been built as the increscent of population. Most tall building can be seen in Hong Kong, Dubai, Taiwan and even Malaysia. Tall building usually comes up with some problem where a worker needs to risk their life for cleaning the building's window. Media reported many accidents happen to window cleaning workers and some of them faced death or disable for the rest their life. In January, 5 2008, Alcides Moreno, 37, fell almost 500 ft. from the roof of a Manhattan skyscraper [1]. BBC News reported in April 22 1998, two window cleaners were killed when the cradle they were working in plunged 100 ft. to the ground [2].

As conclusion, this project was undertaken to design a window cleaning robot that can replace the window cleaner's job. This robot is using simple pneumatic system and double acting cylinder as the main actuator of the robot with the helping suction cups to hold on window glass surface.

1.3 Problem Statement

There are several types of design of the robot that are need to analyze based on their performance in holding mechanism and locomotion mechanism. The design are mobile robot, walking robot and the rigging robot. Each of the design have their own performance in holding mechanism and locomotion mechanism based on mass of the robot, velocity of the robot moving on the window surface and the complexity of the holding mechanism.

Firstly, the most problem that occurred in developing a wall climbing robot is difficult for the robot to overcome the gravitational force exerted towards the earth. The key problem with this explanation is the mass of the robot. The mass of the robot will affect the gravitational force. When the mass of the robot increase, the gravitational force exerted on the robot also increase. So, a lightweight robot is suggest to overcome this problem. The window climbing robot design must have at least two separately part, first window cleaner and second is control system.

Secondly, the velocity of the robot is one of the major problem in designing the robot. Each of the design have their own performance on the velocity. For the mobile robot, the velocity is good but it have complex mechanism. For the walking robot, the velocity is fair, not as good as mobile robot and it have fair complex mechanism. For the rigging type robot, the velocity of the robot is fair but the robot is not handy and easy to operate because it have different mechanism to hanging the robot on the window surface.

Another problem happen is the robot tends to fall down when about to move if the suction and locomotion mechanism is not well synchronized. A suitable pneumatic system is design to hold the robot on the window surface. Number of suction cups also must take in account because it will increase the mass of robot.

Evidence suggests that holding and locomotion mechanism are among the most important factors for designing and develop a prototype of window climbing robot. For holding mechanism a vacuum suction with minimum number of suction cups needed and for the locomotion, it suggested a double acting pneumatic cylinder use as the main actuator of this robot.

1.4 Objectives

Based on the problem statement stated above, the objectives of this project are:

i) To design window climbing robot using double acting pneumatic cylinder with the vacuum suction mechanism.
ii) To design and develop the desired path for the prototype which can hold and move on window glass surface.
iii) To analyze performance of the robot in term of velocity of prototype, the theoretical holding force of robot and vacuum suction pressure required.

1.5 Scope of Research

The scope of this project is focused on design mechanical part of the robot. In the mechanical part, researcher concentrated on two elements such as suction mechanism and locomotion mechanism. Researcher also focus on analyze the different pressure in the suction cups and method to control the vacuum suction. This prototype is analyze by simulation and lab experiment are conducted to test this prototype. The simulation is using Festo FluidSim software, and the experiment is to find the velocity of the prototype by different pressure supply from the compressor by take a constant distance and time to complete the distance. The distance is $50\ cm$ and time taken the prototype will be recorded. This prototype will move in vertical straight line only on the window glass surface.

CHAPTER 2

PROJECT BACKGROUND AND LITERATURE REVIEW

2.0 Overview

This chapter consists of fundamental theories based on the characteristic of window climbing robot that are mention in chapter 1. Besides that, comparison between design, locomotion mechanism and holding mechanism of the robot based on the previous research are in the literature review.

2.1 Project Background

This subsection is the project background of this project. There are 3 part of fundamental theories that is major problem and must be take into account when develop the prototype of window climbing robot.

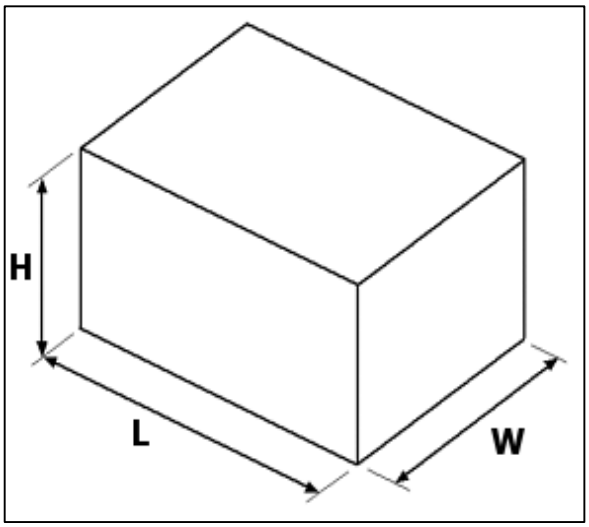
2.1.1 Mass of the prototype

The mass of the prototype can be calculated based on the equation (2.1). The mass of prototype must include all the component on the prototype.

$$m = L \times W \times H \times \rho \tag{2.1}$$

Where

m : $Mass\ of\ the\ prototype$



L : $Length\ (cm)$

W : $Width\ (cm)$

H : $Height\ (cm)$

ρ : $Density\ (g/cm^3)$

Figure 2.1: Dimension of the prototype

2.1.2 Theoretical Holding Forces

The holding force of the suction cups surges relatively with the difference between the environmental weight and the weight inside the cup. This implies the holding force is corresponding to the weight distinction and the suction space. Greater the contrast between climatic weight and weight in the suction cup, the more the possessions force. The force can contrast contingent upon a change of the weight distinction and region limits.

In this part, the suction cup will attach to the window glass and moving vertically. The holding force acting on the suction cup is calculated by using the equation (2.2). This lifting force is used to lift up the robot from bottom.

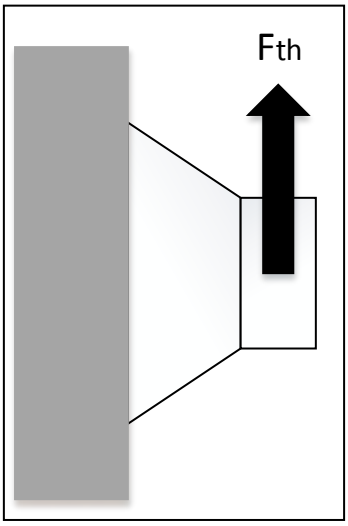


Figure 2.2: Lifting force on the suction cup

$$F_{th} = \frac{m}{\mu} \times (g + a) \times s \qquad (2.2)$$

Where

F_{th} : $Theoritical\ holding\ force$ (N)

m : $Mass(kg)$

g : $Acceleration\ due\ to\ gravity$ (9.81 m/s^2)

a : $Acceleration\ of\ system$ (30m/s^2) $consider\ the\ emergency\ of\ situation$

μ : $Coefficient\ of\ friction$

s : $Safety\ factor$ ($vertical$: 1.5)

2.1.3 Suction Cup Diameter

Suction cups are utilized to hold and move robot on the window surface. The climatic weight presses the suction cup against the window surface when the air weight is greater than the weight between the suction cup and the window surface. This weight fluctuation is come to by connecting the suction cup to a compressor, which discharges the air from the space between the cups and the window surface. In the event that the suction cup is in association with the surface of the window, outside air can't enter it from the sides and a vacuum is created.

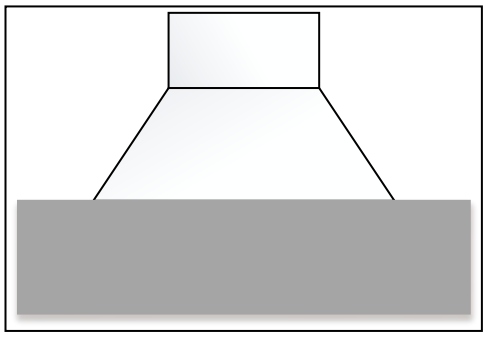


Figure 2.3: Suction cup

The diameter of suction cup is based on the theoretical holding force of the prototype. The theoretical holding force of the prototype is stated in equation (2.2). The shape of the suction cup is selected based on the surface of the window glass. As known the window glass surface is flat, smooth and undulating surface, so the type of suction cups selected is standard type. The diameter of suction cup is based on table 2.1.