UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

PARAMETER STUDY OF HOPPING MECHANISM FOR ONE LEGGED CRANK-TYPE HOPPING ROBOT

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PARAMETER STUDY OF HOPPING MECHANISM FOR ONE LEGGED CRANK TYPE HOPPING ROBOT

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DECLARATION

"I declare that this thesis entitled "Parameter study of hopping mechanism for crank type hopping robot" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of other degree.

Signature : ……………………………………………….....

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Date : ……………..

APPROVAL

I hereby declare that I have read this thesis and my opinion this thesis is sufficient in term of scope and quality award for Master of Science of Electrical Engineering.

Signature :…………………………………………………………

Supervisor name :…………………………………………………………

Date :…………………………………………………………

DEDICATION

Specially dedicated to my family

ABSTRACT

Hopping is a desirable locomotion for a mobile robot particularly to move in unstructured environment. One of the common mechanisms for realizing the hopping locomotion is by using crank type mechanism. However the behaviour of the crank mechanism in terms of hopping performance is unknown. It is hypothesized that hopping performance of crank type hopping robot is influenced by three mechanical parameters which are crank length, spring coefficient and mass of robot. Thus the objectives of the research is to model the behaviour of crank type hopping robot particularly in terms of the effects of mechanical parameters (i.e. spring coefficient, mass and crank length) of the hopping robot towards its hopping performance, to design and simulate one legged hopping robot using Matlab software and finally to validate the simulation with experiments. The simulation and experimentation works were done by setting one of the mechanical parameters as constant value while the other two parameters were set as variable parameters. The step was repeated by changing each of the mechanical parameters as a constant while the other two are variables and vice versa. For experimentation purposes, a one legged hopping robot was developed. In the experiment, the hopping height was measured by using a calibrated Infrared Ranging (IR) sensor. The result shows that the equation of behaviour for the crank type hopping robot performance is true for a certain region as long as the upward force (stored energy in spring) can counter the downward force (force from mass).

ABSTRAK

Lompatan adalah satu cara pergerakan bagi robot untuk bergerak pada permukaan yang tidak rata. Salah satu mekanisma bagi pergerakan melompat adalah jenis engkol. Walau bagaimanapun, prestasi mekanisma tersebut dari segi tinggi lompatan adalah tidak diketahui. Hipotesis mengatakan kebolehan melompat bagi robot jenis engkol dipengaruhi oleh tiga pemboleh ubah mekanikal iaitu panjang engkol, kekenyalan spring serta berat robot tersebut. Oleh sebab itu, objektif kajian ini adalah untuk memodelkan prestasi robot jenis engkol terutama dari segi pemboleh ubah mekanikal, simulasi pergerakan robot melompat menggunakan perisian 'Matlab'serta mengesahkan simulasi tersebut dengan eksperimen. Kerja-kerja berkaitan simulasi dan eksperimen telah dilakukan dengan menetapkan salah satu pemboleh ubah sebagai pemboleh ubah tidak bersandar sementara dua lagi nilai pemboleh ubah ditetapkan sebagai malar. Langkah-langkah tersebut diulang dengan menukar setiap parameter tersebut menjadi pemboleh ubah tidak bersandar dan sebaliknya. Tinggi lompatan robot bagi eksperimen diukur dengan menggunakan sensor Infra merah. Hasil kajian menunjukkan bahawa persamaan matematik bagi prestasi robot melompat jenis engkol adalah diterima sebagai betul selagi nilai daya yang tersimpan di dalam spring boleh melawan daya yang dikenakan oleh berat robot.

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LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AD	Analogue to Digital
CAD	Computer Aided Design
CPG	Central Pattern Generator
DC	Direct Current
DOF	Degree of Freedom
IR	Infrared Ranging
NLM	Nonlinear Model Predictive Control
PD	Proportional Derivative
PID	Partial Integral Derivative
PWR	Pulse Width Modulation
RMSE	Root Mean Squared Error

LIST OF PUBLICATIONS

Rahim, N. H. A., Kassim, A. M., Miskon, M. F., & Azahar, A. H. (2011). Effectiveness of central pattern generator model on developed one legged hopping robot. *2011 IEEE Student Conference on Research and Development* (pp. 85-88).

Rahim, N. H. A., Kassim, A. M., Miskon, M. F., & Azahar, A. H. (2013). Optimization of one legged hopping robot hardware parameters via solidworks. *2013 IEEE International Conference On Advances in Mechanical Engineering* (pp. 544-549).

TABLE OF CONTENTS

PAGE

CHAPTER 1

INTRODUCTION

This chapter presents the introduction to hopping robot and motivations of the research followed by the problem statement and research objectives. Besides that, scope and contribution of research is discussed in detail. In the final part of this chapter, thesis organization is explained.

1.1 Hopping robot

This section covers why hopping robot has been extensively studied when compared to wheel robots in recent years. In addition, earlier development in hopping robotic research area in terms of history and field of study are also discussed.

Most of the wheeled type robots' efficiency depends on environmental qualities(Siegwart & Nourbakhsh, 2004) and normally only suitable to flat ground. Opposite to the prepared surface, real environment is much more unpredictable thus ordinary wheeled type locomotion robots are not quite effective and not adaptable in real environment application. When realizing the weakness, a few researcher starts to study on hopping robot due to the capability to move on unprepared and uneven surface including places that never been reached before.

Research on legged robot was started by Raibert (1986). The research was about simple control algorithm while focusing on physical characteristic and actuator. After that, the research area has developed to different field of study. Berkemeier & Fearing (1998) has done research on sliding and hopping gaits for an under actuated robot with only one actuator despite of other hopping robot in that era which commonly has at least two actuator. In the same year, Farley *et al.*, (1998) have done research on mechanism of leg stiffness adjustment for hopping on surfaces of different stiffness.

After that, the research area have been widened to study of impact force reduction for hopping robot (Y. Sato *et al.,* 2005), force control in one legged hopping robot while landing (Krishnan *et al.*, 2009) and landing motion of articulated hopping robot (Sung & Youm, 2007). Besides that, Rutschmann (2012) has done research to control foothold placement, torso angle and leg angle of a one legged hopping robot.

1.2 Motivation

As explained in the previous section, further study in hopping robot area increases the chances of exploration in area which is beyond human reach. However, there are some limitations in hopping robot design that may influence the hopping performance.

In hopping robot area, pneumatic and hydraulics actuators become most favourable actuator due to its ability to produce sufficient power to the system. However, use of both actuators may have a few disadvantages such as maintenance of the hydraulic components is complex and require cost(Li et al. 2013)

To solve the problem, some researcher starts to design hopping robots with electrical motors. At first, hopping robot with electrical motor design seems to be the best solution but the use of electrical motor also has a disadvantage. Electrical motor normally cannot produce sufficient power especially sudden impact from stall position which is important for high speed locomotion.

These two disadvantages has become main motivation to the research to design a small size of hopping robot with sufficient power.

1.3 Problem statement

The relationship between spring coefficients, mass of robot and crank length towards hopping height are not known yet. In addition, the optimum parameter to determine the maximum achievable hopping height is unknown. A model which resembles the true system of one legged hopping robot is needed so that the number experiment to determine the maximum hopping height can be decreased. It is hypothesized that hopping height has linear relation towards all of the mechanical parameters. However, there are a few conditions which the relation cannot be defined. It is hypothesized that each mechanical parameter value has certain range of linear relation while other value outside the range may cause different hopping performance.

1.4 Aim and objectives

The aim of the research is to study the fundamental of hopping mechanism for crank type hopping robot. Specifically, the objectives are:

1. To develop a model of one legged crank type hopping robot.
2. To model the behaviour of crank type hopping robot particularly in terms of the effects of mechanical parameters (spring coefficient, mass and crank length) of the hopping robot towards its hopping performance.
3. To validate the model of the crank type hopping robot behaviour using simulations and experiments.

1.5 Scope of research

Mechanical parameters which control the performance of the one legged hopping robot is the main part of the research. Other aspects taken into account are listed below:

1. Simulation of one legged hopping robot using Matlab software.
2. Experiment of one legged hopping robot.
3. Design and setting up a prototype of one legged hopping robot.
4. To determine optimum mechanical parameters of the one legged hopping robot prototype in terms of maximum achievable hopping height.

1.6 Contribution of research

In this thesis, a new model that describes the behaviour of the crank type hopping mechanism for legged hopping robot is developed. Besides that, mechanical parameters that influence hopping height performance also identified and validated by simulation and experimentation.

1.7 Thesis organisation

This thesis consists of five chapters starting with introductions in chapter 1 followed by chapter 2 which discusses previous research on hopping robot. Chapter 3 explains the development of one legged hopping robot including the experimental setup. Performances of one legged hopping robot are shown in chapter 4 before further discussion and evaluation. Finally, chapter 5 concludes the thesis and recommendation for future task.