UNIVERSITI PUTRA MALAYSIA

# DEVELOPMENT OF A PULSED LAUNCHER SYSTEM

MOHD REZAL MOHAMED

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# DEVELOPMENT OF A PULSED LAUNCHER SYSTEM

**By**

**MOHD REZAL MOHAMED**

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**DEVELOPMENT OF A PULSED LAUNCHER SYSTEM**

By

**MOHD REZAL MOHAMED**

**November 2007**

**Chairman : Syed Javaid Iqbal, PhD**

**Faculty : Engineering**

Launcher is a device used to launch a projectile. Launcher requires energy to operate and it could be air pressure, compress spring, chemical or electromagnetic energy. Normal launcher applies an explosive to launch a projectile like rocket and bullet. It produces a loud sound, smoke and fire when the explosion occurred. This will shorten the lifetime of barrel and launch pad when the explosion erodes it. Thus to overcome this problem, a launcher is design to launch a projectile without producing a loud sound, explosion and fire. A pulsed launcher system is design using single coil with complete switching circuit, projectile, control circuit, and capacitor bank. The purpose in designing this launcher is to launch a projectile and obtaining the highest projectile speed of designed launcher with correct value of capacitor bank and projectile position. Experiments and simulations are done to identify the relationship between voltage, capacitance, and projectile initial position. Results are obtained by collecting data and tabulated in graphs. Based on the results it found that the coil current increase when the voltage and capacitance of the capacitor bank is increases and vice versa. The projectile speed is decreasing when the projectile initial position is more than half of the coil length. The position of the projectile with a correct value of capacitor bank is obtained for the designed launcher to operate with highest projectile speed. In this research, a 16 mH coil give a highest projectile speed of 23.07 $ms^{-1}$ (horizontal motion) and 11.62 $ms^{-1}$ (vertical motion) when the coil is supply with 680.2 V, 286 uF capacitor bank at 1 cm projectile initial position inside the coil. The energy conversion from electric energy to kinetic energy is low, 10.05 % for horizontal motion and 2.55 % for vertical motion. The launcher requires more energy to launch the projectile at vertical motion to overcome the gravitational force.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

**PEMBINAAN SEBUAH SISTEM PELANCAR DENYUT**

Oleh

**MOHD REZAL MOHAMED**

**November 2007**

**Pengerusi : Syed Javaid Iqbal, PhD**

**Fakulti : Kejuruteraan**

Pelancar adalah alat yang digunakan untuk melancarkan peluncur. Pelancar memerlukan tenaga untuk beroperasi dan ia mungkin dari tekanan udara, pegas mampat, tenaga kimia atau elektromagnet. Pelancar biasanya menggunakan bahan letupan untuk melancarkan peluncur seperti roket dan peluru. Ia akan menghasilkan bunyi yang kuat, asap dan api apabila letupan berlaku. Ini akan memendekkan jangka hayat tiub tong dan alas pelancar apabila letupan menghakisnya. Oleh itu untuk mengatasi masalah ini, satu pelancar direka untuk melancarkan peluncur tanpa menghasilkan bunyi yang kuat, letupan dan api. Sistem pelancar denyut dihasilkan menggunakan satu gegelung dilengkapi dengan litar pensuisan, peluncur, litar kawalan, dan bank kapasitor. Tujuan pelancar ini dihasilkan adalah untuk melancarkan peluncur dan mendapatkan kelajuan tertinggi peluncur bagi pelancar yang dihasilkan pada nilai bank kapasitor dan posisi peluncur yang betul. Ujikaji dan simulasi telah dijalankan untuk mengenalpasti hubungkait antara voltan, kapasitan, dan kedudukan permulaan peluncur. Keputusan diperolehi dengan mengumpulkan data dan menjadualkannya didalam graf. Berdasarkan kepada keputusan, didapati arus gegelung akan meningkat apabila voltan dan kapasitan bank kapasitor meningkat dan sebaliknya. Kelajuan peluncur akan berkurangan apabila kedudukan awal peluncur lebih daripada separuh daripada panjang gegelung. Kedudukan peluncur dengan nilai bank kapasitor yang tepat telah diperolehi supaya pelancar yang dihasilkan beroperasi dengan kelajuan peluncur yang tertinggi. Didalam penyelidikan ini, gegelung 16 mH menghasilkan kelajuan tertinggi peluncur 23.07 $ms^{-1}$ (gerakan mendatar) dan 11.62 $ms^{-1}$ (gerakan menegak) apabila gegelung dibekalkan dengan 680.2 V, 286 uF bank kapasitor pada kedudukan awal peluncur 1 cm didalam gegelung. Perubahan tenaga daripada tenaga elektrik kepada tenaga kinetik adalah rendah, 10.07 % untuk gerakan mendatar dan 2.55 % untuk gerakan menegak. Pelancar memerlukan tenaga yang banyak untuk melancarkan peluncur pada gerakan menegak bagi mengatasi daya tarikan graviti.

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I certify that an Examination Committee has met on 2nd November 2007 to conduct the final examination of Mohd Rezal Bin Mohamed on his Master of Science thesis entitled "Development of a Pulsed Launcher System" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the student be awarded the relevant degree. Members of the Examination Committee were as follows:

**Sudhanshu Shekhar Jamuar, PhD**
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

**Senan Mahmod Abdullah, PhD**
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

**Samsul Bahari Mohd. Nor, PhD**
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

**Kaharudin Dimyati, PhD**
Associate Professor
Faculty of Engineering
Universiti Malaya
(External Examiner)

**HASANAH MOHD GHAZALI, PhD**
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date : 29 January 2008

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

**Syed Javaid Iqbal, PhD**
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

**Norhisam Misron, PhD**
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

**Jasronita Jasni, MSc**
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

______________________
**AINI IDERIS, PhD**
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date : 21 February 2008

## DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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**MOHD REZAL BIN MOHAMED**

Date:

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AC | Alternating Current |
| AWG | American Wire Gauge |
| DC | Direct Current |
| DPDT | Double Pole Double Throw |
| emf | Electro Magnetic Force |
| ESR | Equivalent Series Resistance |
| FEMM | Finite Element Magnetic Method |
| GI | Galvanized Iron |
| IC | Integrated Circuit |
| IGBT | Insulated Gate Bipolar Transistor |
| IR | Infrared |
| LED | Light Emitting Diode |
| MOSFET | Metal Oxide Semiconductor Field Effect Transistor |
| PCB | Printed Circuit Board |
| RMS | Root Mean Square |
| SCR | Silicon Controlled Rectifier |
| SWG | Standard Wire Gauge |
| TTL | Transistor-Transistor Logic |

# CHAPTER 1

# INTRODUCTION

## 1.1 Project Overview

Launcher is a device used to launch a projectile. Launcher requires energy to operate and it could be air pressure, compress spring, chemical or electromagnetic energy. The electromagnetic launcher converts energy from electrical to mechanical through the action of magnetic field.

The title of thesis is “Development of a Pulsed Launcher System” requires studying and developing launcher characteristics that enable a projectile to move along the tube. The tube is placed inside the coil that can be energized. The projectile is moved by induced force. There is no electrical contact between the projectile and the coil.

A pulse power supply is needed to energize the coil. A capacitor bank produces the pulse supply for the coil. Parallel and serial combinations of electrolyte capacitors are required for optimizing coil efficiency. Coil energy conversion efficiency is the percentage ratio between energy converted to move the projectile with energy stored in the capacitor bank. A charging control circuit is designed to control the capacitor bank charging time. Discharging the capacitor bank creates a large current through the coil for a short period. This current-pulse energized the coil that acts as an electromagnet to attract the projectile inside the coil for that moment.

An arcing will be produced when an inductive load is connected to the capacitor bank. A solid-state device is used as a switching device to reduce the arching and power loss. A distance sensor is used to detect the projectile movement and sent the data to the oscilloscope. The oscilloscope will record the travel time when the projectile travel along the sensor. The projectile speed is obtained by dividing the travel length with the travel time of the projectile. This projectile speed data is used to determine the launcher efficiency. A coil current is measured with different value of capacitor bank using current sensor. The coil current data is used to measure the peak time and the peak value for calculating the correct current-pulse timing in the coil. The projectile moves with maximum speed at correct timing.

## 1.2 Problem Statement

Normal launcher used an explosive to launch the projectile like rocket and bullet. The high energy produces by the chemical reaction in the explosive material able to move the projectile with a high speed. There are disadvantages of using this method and one of the problems is, it produces a loud sound when explosion occurred. A smoke and fire also come out. The lifetime of the barrel and launch pad is short and need to be replaced when the explosion erode it. Thus, a non-explosive launcher is required to overcome this problem. The proposed launcher should be able to move the projectile without producing loud sound, explosion and fire. In this launcher almost no heat is produced.

## 1.3 Objectives

The objectives of this project are:

1. To design and develop a Pulsed Launcher System.
2. To identify relationship between voltages of capacitor bank, capacitance of capacitor bank and projectile position with a certain fixed coil dimension and parameters.
3. To get an optimized value of voltage and capacitance of capacitor bank and projectile position with a certain fixed coil dimension and parameters.

## 1.4 Thesis Outline

This thesis is divided into five chapters and each chapter is described separately. The thesis introduction is describes in Chapter 1. The basic content of the thesis is described in this chapter including the thesis objectives. Chapter 2 of the thesis is about the literature review of the previous research and basic knowledge of the components and hardware used in the design. The research methodology is explained in Chapter 3 with overall design method used in this design is also described detail including the control circuit, switching circuit, capacitor bank, and the coil. Experimental results of launcher are discussed in Chapter 4. During the experiment, a lot of data is collected which is plotted and then analyzed. Result of these data and analysis is discussed in Chapter 4 while conclusion and suggestion for future work in Chapter 5.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Linear launcher is like a conventional motor in which the projectile moves in the linear direction rather that in the rotation [1-5]. This kind of launcher may have a set of solenoids, which are placed along the moving object. This looks like a tubular launcher, which primarily consists of simply row of coaxial coils.

## 2.2 Preview of Previous Research

A physical model for a single stage reluctance accelerator is developed from basic principles and cast in variation (Langrangian) form [6]. A mathematical model for reluctance launcher is formulated by considering the three armature state inside the coil for single stage reluctance accelerator. Experiments and simulations are done to compared the results and identify the armature speed using different armature material. A 25 g mild steel armature have a velocity of 18.9 $ms^{-1}$ when the single stage reluctance accelerator is connected to 104 V, 40000 uF capacitor bank using a power transistor switch. The energy conversion from electric energy to kinetic energy is low, approximately 9 %.

The reluctance accelerator [6] is upgraded by model it using finite-element solver [7]. In this system equations it describe the time domain finite element model of a reluctance accelerator to reduce the computation time and give a result approximate to reality which is better than model used in previous reluctance accelerator. The eddy current effect is included in the model whereas the previous research not.

An analysis of five stage pulsed linear induction launcher has been studied. A developed formulation for the electromagnetic analysis of system with conductors in relative motion has been applied to the pulsed linear induction launcher [8]. The skin effect, the thermal and mechanical stresses and the possible rise of transversal motion instabilities have been taken into account. The application of the formulation to the axisymmetric configuration is straightforward and results in an increased computation speed of one order of magnitude. A 68.2 g aluminium armature has a final speed of 226 $ms^{-1}$ when the launcher is supplied with 10, 12, 15, 18, and 20 kV of 125 uF capacitor banks for each stage.

A triggered vacuum switches, TVS is used for designing a three stage reconnection electromagnetic launcher [9]. It has advantages over the spark gaps. It has smaller volume, no need maintenance, no auxiliary gas system, and less electromagnetic interference. The launcher have a 10 % energy conversion when it is supplied with 4500 V, 1.44 mF capacitor bank which give a highest speed of 41 $ms^{-1}$ for 160 g aluminium projectile.

All the previous research used a big capacitor in their design. A solid state device is used as a switching component to connect the capacitor bank with the coil except paper [9] used a vacuum switches. The launcher energy conversion is low, less than 10 % and projectile speed is depend on the value of voltage and capacitance of capacitor bank, material and weight of projectile, and stage, whether single coil or multiple coils. It seems that previous research does not study on the projectile initial position inside the coil. Although they succeed to launch the projectile at desired