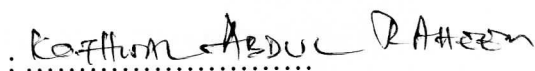


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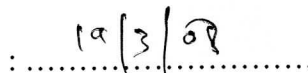
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Name of Supervisor

:  .....

Date

:  .....

ENCIK KOTHWAL ABDUL RAHEEM  
Pensyarah  
Fakulti Kejuruteraan Mekanikal  
Universiti Teknikal Malaysia Melaka  
1200, Ayer Keroh  
Melaka

**DESIGN OF PEM FUEL CELL POWERED LAWN MOWER**


**KOK HO KIET**

**THIS REPORT IS SUGGESTED AS  
A PART FROM THE REQUIREMENT OF BESTOWAL OF  
BACHELOR DEGREE OF MECHANICAL ENGINEERING  
(STRUCTURE & MATERIAL)**

**FACULTY OF MECHANICAL ENGINEERING  
UNIVERSITY OF TECHNICAL MALAYSIA MALACCA**

**MARCH 2008**

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## ABSTRACT

Mesin Pemotong mengandungi reka bentuk untuk menyokong pergerakan dalam atas lantai dengan bantuan roda. Motor elektrik yang membekalkan daya kilas untuk membolehkan pergerakan mesin pemotong untuk memotong permukaan yang dikehendaki, contohnya padang golf. Pembolehubahan dalaman kuasa bekalan membekalkan tenaga elektrik yang digunakan untuk memutar motor elektrik yang dipasang dalam mesin pemotong. Penukaran kedudukan boleh diubahsuai untuk memudahkan perubahan dengan mengurangkan geseran yang disebabkan oleh keberatan bekalan kuasa. Bekalan kuasa yang dibekalkan akan mampu menampung pergerakan mesin pemotong.

— **ABSTRACT**

The mower includes a frame which is supported for movement upon a plurality of ground engaging wheels and upon which are supported a modularly interchangeable power source and a plurality of reel lawn mowers. An electric motor provides driving torque to enable movement of the mower between and over golf course greens, for example or other surfaces to be mowed, electric motors provide driving torque for each of the reel lawn mowers. The interchangeable power source provides electrical energy for driving the electric motors, including the primary mover and the electrical motors for the reel type lawn mowers. The power source may be easily exchanged in the field for another, freshly charged power source. Exchange occurs using either a fixed change stand or a mobile change stand. The change stands are configured to facilitate exchange by reducing friction caused by the generally weighty power source. The power source is delivered to the fixed stand on towable trailers.

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## LIST OF SHORT FORM

PEM	=	Proton Exchange Membrane
US	=	United State
CPSC	=	Consumer Product Safety Commission
PEMFC	=	Proton Exchange Membrane Fuel Cell
SPEFC	=	Solid Polymer Electrolyte Fuel Cell
NEDC	=	New European Driving Cycle
CHP	=	Combine Heat & Power
PAFC	=	Product Acid Fuel Cell.
$v$	=	Velocity ( $\text{ms}^{-1}$ )
$w$	=	Angular Velocity ( $\text{rad/s}$ )
$T$	=	Torque ( $\text{Nm}$ )
$\alpha$	=	Angular Acceleration ( $\text{rad/s}^2$ )
$I$	=	Moment of Inertia ( $\text{kgm}^2$ )
$a_c$	=	Centripetal Acceleration ( $\text{m/s}^2$ )
$F_c$	=	Centripetal Force (N)
$L_D$	=	Design Life
$\sigma_T$	=	Tensile Stress ( $\text{N/m}^2$ )
$F_p$	=	Axial Load (N)
$A$	=	Area ( $\text{m}^2$ )
$D$	=	Diameter (m)
$\eta$	=	Load Factor of Safety
$K$	=	Torque Factor
$F_f$	=	Friction Force (N)
$F_n$	=	Normal Force (N)
$F_t$	=	Total Force (N)

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## CHAPTER 1

### INTRODUCTION

#### 1.0 Introduction

Projek Sarjana Muda (PSM) is compulsory finished up by an undergraduate student with a Bachelor holder in Mechanical Engineering field. To complete this project, a title is regarding the design and development of fuel cell powered lawn mower. An opening ideal of lawn mower will be discussed in this subtitle and the details will be discussed thoroughly in Chapter 2. A lawn mower is a device which one or more revolving blades are used to cut grass or other plants to a certain length. Lawn mower employing a blade that rotates about a vertical axis are known as rotary mower, while those employing a blade assembly that rotate about a horizontal axis are known as cylinder or reel mower. Nowadays, with the rapid development in this high technology era, many different designs have been made, with a particular purpose is suited respectively. For example, the smallest types, pushed by a human, are suitable for small residential lawn and gardens. For the larger lawn, it is suitable to use a ride-on mower. Meanwhile, for the multi-gang mower pulled behind a tractor, are design for the large expanses of grass such as golf courses and municipal parks. The principle of a lawn mower and the specification will be discussed in the following chapter. In order to design a fuel cell powered lawn mower, the specification of fuel cell must be took understanding. A fuel cell is an electrochemical energy conversion device. It produces electricity from external supplied of fuel and oxidant. Many combination of fuel and oxidant are possible. The hydrogen cells uses hydrogen as fuel and oxygen as oxidant. The details on fuel cell will discuss in the following chapter in details.



## 1.1 Problem Statement

To completing a design on lawn mower, there are many problems to be take consideration. Nowadays, so many types with different specification of lawn mower are designed for the uses respectively. The initial thing to be considered is how large the lawn for the designing of a lawn mower. In addition, the principle of a lawn mower and PEM (Proton Exchange Membrane) fuel cells should be took understanding. For instance, how the revolving blade can be make, how fast of the cutting speed of the blades for a lawn mower and where it is suitable to use the lawn mower that designed. Once the problems are clearly stated, the process of designing a new lawn mower will be held smoothly.

## 1.2 Objective

The objectives of this project are:

- Design of fuel cell powered lawn mower.
- To Analysis Structural of Lawn Mower

## 1.3 Scope of project

This project is regarding the design based on the concept that adapted to unstructured environment. The scopes include:

- To study the principle of a lawn mower.
- To design a new lawn mower
- To draw out a lawn mower using CAD software
- To analysis lawn mower part using Finite Element Analysis method
- To present at the end of this report.

## 1.4 Thesis outline

Thesis outline is a summary of every chapter is described to introduce about the chapter. Chapter 1 introduced about the project title which is lawn mower, problem encountered, and contents of the thesis and the objective and scope of project. Chapter 2 covers the literature review for lawn mower and PEM fuel cell. In this chapter, all of the specification and the principles will review in details. Next chapter is Chapter 3, it will describe the project implementation from collection data and information until the design is verified. Chapter 4 describes the mechanical design of the lawn mower. Chapter 5 includes the analysis of the lawn mower part. Chapter 6 detailed the discussion of the mechanical design after the analysis. Last is the conclusion and recommendation to conclude all and give suggestion for development in future.

## 1.5 Summary

This chapter has simply introduced the project title to be completed. In order to complete a perfect design, problem statement must take consideration. When the problem is verify, the objective and scope of project will focus on the problem statement and then redesign a new lawn mower. In order to make the report tidily, a thesis outline is added to smooth the work.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.0 Introduction To lawn Mower

A lawn mower, alternately spelled lawnmower, is a device which by means of one or more revolving blades is used to cut grass or other plants to an even length. Lawnmowers employing a blade that rotates about a vertical axis are known as rotary mowers, while those employing a blade assembly that rotates about a horizontal axis are known as cylinder or reel mowers. Many different designs have been made, each suited to a particular purpose. The smallest types, pushed by a human, are suitable for small residential lawns and gardens, while larger, self-contained, ride-on mowers are suitable for large lawns, and the largest, multi-speed mowers pulled behind a tractor, are designed for large expanses of grass such as golf courses and municipal parks.

##### 2.0.1 History of Lawnmower

The first Lawn mower was invented by English engineer Edwin Beard Budding in 1827. Budding's mower was designed primarily to cut the lawn on sports grounds and expansive gardens as a superior alternative to the scythe. His patent of 25 October 1830 described "a new combination and application of machinery for the purpose of cropping or shearing the vegetable surfaces of lawns, grass-plats and

pleasure grounds." The patent went on to state, "country gentlemen may find in using my machine themselves an amusing, useful and healthy exercise." It took ten more years and further innovations to create a machine that could be worked by donkey or horse power, and sixty years before a steam-powered lawnmower was built. In an agreement between John Ferrabee and Edwin Budding dated May 18, 1830, Ferrabee paid the costs of development, obtained letters of patent and acquired rights to manufacture, sell and license other manufacturers in the production of lawnmowers. (The agreement is housed in the Stroud Museum). One of the first Budding and Ferrabee machines was used in Regent's Park Zoological Gardens in London, in 1831.

Manufacture of lawn mowers began in the 1850s. By 1862, Ferrabee's company was making eight models in various roller sizes up to 900 mm (36 inches). He manufactured over five thousand machines until production ceased in 1863. Thomas Green produced the first chain driven mower in 1859, named the Silens Messor. On May 9, 1899, an improved cylinder mower was patented in U.S. Patent 624, 749, with the wheel placement altered for better performance. Amariah M. Hills went on to found the Archimedean Lawn Mower Co. in 1871. Around 1900, one of the best known English machines was the Ransomes' Automaton, available in chain- or gear-driven models. JP Engineering of Leicester, founded after World War I, produced a range of very popular chain driven mowers. About this time, an operator could ride behind animals that pulled the large machines. These were the first riding mowers.

The rise in popularity of sports such as lawn tennis, croquet, cricket, football and rugby helped prompt the spread of the invention. Lawn mowers became a more efficient alternative to simply relying on gardeners wielding the scythe (which, when placed in incompetent hands, left unsightly scars on and in the ground) or bare spaces caused by domesticated grazing animals. James Sumner of Lancashire patented the first steam-powered lawnmower in 1893. His machine burned petrol and/or paraffin oil (kerosene) as a fuel. After numerous advances, the machines were sold by the Stott Fertilizer and Insecticide company of Manchester and later, the Sumner's took over sales. The company they controlled was called the Leyland Steam Motor Company. Numerous manufacturers entered the field with gasoline-driven mowers

after the turn of the century. The first grass boxes were flat trays but took their present shape in the 1860s. The roller-drive lawnmower has changed very little since around 1930. Gang mowers, those with multiple sets of blades, were built in the United States in 1919 by a Mister Worthington. His company was taken over by the Jacobsen Corporation but his name is still cast on the frames of their gang units.

Rotary mowers were not developed until engines were small enough and powerful enough to run the blades at a high speed. In the 1930s, Power Specialties Ltd. introduced a gasoline-powered rotary mower. One company that produced rotary mowers commercially was the Australian Victa company, starting in 1947. Early in the 1930s, experiments in design of rotary mowing equipment were conducted by a farmer in the Midwest region of the United States, by the name of C.C Stacy. His concept was the use of a toothed circular saw blade mounted horizontally on a vertical shaft, which would be suspended at a height of approximately 2" and moved across a lawn to cut grass and other lawn vegetation at a uniform height. The power for his experimental mower was an electric motor.

The success of Stacy's design was limited by 2 factors: the relatively small diameter of the saw blades he used for his experiments, which were about 8"; and the fact that toothed circular saw blades were not really an optimum cutting tool for free standing grass and other plants. Stacy did not come up with any idea for a cutter similar to modern rotary mower straight blades, and soon dropped his experiments with rotary mowing. He never submitted any of his ideas for patent, although drawings of his ideas still exist and are in the possession of family members. Late in life, Stacy, deceased in 1993, asserted that his ideas for rotary mowing equipment originated with him, and he had never seen or heard of any mowing equipment other than cylinder or reel type mowers prior to formulating his ideas. He lamented jokingly that if he had pursued and patented the concept, his family name might have become as well known as Jacobson, that of a prominent mower manufacturer in the first half of the 20th century.

On May 9, 1899, John Albert Burr, an African American inventor, patented an improved rotary blade lawn mower. Burr designed a lawn mower with traction wheels and a rotary blade that was designed to not easily get plugged up from lawn

clippings. John Albert Burr also improved the design of lawn mowers by making it possible to mow closer to building and wall edges.

[History – retrieved on 17<sup>th</sup> July 2007, from  
[http://en.wikipedia.org/wiki/Lawn\\_mower#History](http://en.wikipedia.org/wiki/Lawn_mower#History)]

## 2.0.2 Criticism design issues and problems

The two main issues with the popular gas (petrol) mower are air pollution and safety. Studies have shown that such a mower emits the same amount of pollution in one hour as driving a car for 650 miles. (In fairness, however, it must be noted that lawn mowers are not usually serviced with the same frequency as cars, probably due to their lower cost.) In addition, rotary mowers can also throw out debris with tremendous force. In the US, there are over 80,000 people per year who are hospitalized due to mower accidents. The vast majority could be avoided by the judicious choice of footwear while mowing. In addition to that, mowing blade is also has to take consideration when a lawn is being design.

[Criticism and problem – retrieved on 17<sup>th</sup> July 2007 from  
[http://en.wikipedia.org/wiki/Lawn\\_mower#Criticism\\_and\\_safety\\_problems](http://en.wikipedia.org/wiki/Lawn_mower#Criticism_and_safety_problems)]

## 2.0.3 Operation

Two cutting mechanisms are in common use:

- Reel or cylinder mowers, those with a set of spiral-cylindrical blades spinning on a horizontal axis. Cutting is by a scissor-like action between the moving spiral blades and a single stationary horizontal blade, or "bed knife". The axle is attached to a gear that is then mounted on one of the wheels in order to spin the blades rapidly for good grass cutting action even when the mower is moving slowly.

- Rotary mowers, those whose blades spin horizontally on a vertical driveshaft. Cutting is due to a horizontal blade striking the grass at a high speed.

The two cutting mechanisms can lead to different results. On rotary mowers, the blade is usually not sharp enough to cut the grass cleanly. The speed of the blade simply tears the grass resulting in ragged tips. By contrast, the cylinder-type reel lawn mowers and manual lawn mowers usually work by scissor action on the blades and a cleaner cut is achieved.

Rotary lawn mowers often allow the height of the lawn mower to be adjusted to control the height of the cut grass. On older or less expensive lawn mowers, this is accomplished by manually moving each wheel to a different slot on the chassis. A more recent innovation in rotary mowers is a "one-touch" height-adjust mechanism where the blades are mounted on a frame separate from the rest of the lawn mower and the frame can be raised and lowered. On hover mowers, height adjustment is provided by the use of removable spacing washers that fit between the blade and the motor spindle, since the mower body must remain at the same height above the grass in order to preserve the air cushion.

Lawn mowers need power for two purposes: to cut and to move. The act of pushing or pulling a reel mower provides power for cutting and moving at the same time. For rotary mowers, the power sources may vary: grass-cutting may be powered by either an internal combustion engine or an electric motor, while propulsion may share that power source or be supplied by the user or another external source such as a tractor. Wheel-driven gear systems allow for cutting to be powered by the same external source as that used to propel the mower.

[Operation – retrieved on 17<sup>th</sup> July 2007 from  
[http://en.wikipedia.org/wiki/Lawn\\_mower#Operation](http://en.wikipedia.org/wiki/Lawn_mower#Operation)]

## 2.0.4 Types of Lawn Mower

### Reel (cylinder) mowers

There are four major types of reel mower: push, walk behind power, ride-on power, and tow-behind gang mower. Push mowers are powered by people pushing them and are usually used on very small lawns. The walk power reel mower can be divided into two types: a (largely obsolete) powered version of the push mower, used for residential lawns and a 'greens mower' used for the precision cutting of golf greens. Riding power reel mowers can also be divided into two types: the 'triplex' which has three hydraulically driven independent cutting heads and is used for golf greens, and the larger 'fairway' machine that has five or seven hydraulically driven cutting heads. Gang reel mowers are towed behind a tractor in sets (gangs) of three, five, or seven. They are 'ground-powered' that is, the tires of each cutting unit are geared to drive the reel. Gang mowers are used to mow large areas of turf such as sports fields or parks.

Presently several companies are producing cordless electric reel mowers. The performance of the batteries vary in terms of how long the batteries can power mowers and the recharging cycles. An hour and a quarter (75 minutes) to half an hour (30 minutes) is the range of running time. Six hours to twenty-four hours is the range of time required to fully recharge batteries. Most batteries can be recharged several hundred times. Cordless electric reel mowers weigh 30 – 35 pounds.

The scissor-like action of a reel mower provides a much cleaner cut on the blades of grass than a rotary mower, avoiding damaged tissue.