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Date : ……

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DESIGN AND ANAYSIS SLOTTED ROTOR DOUBLE STATOR PERMANENT MAGNET MOTOR FOR FOOD PROCESSING APPLICATION

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A report submitted in partial fulfillment of the requirements for degree of Bachelor of Electrical Engineering (Power Electronic and Drive)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

YEAR 2015

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I declare that this report entitle “Design and Analysis Slotted Rotor Double Stator Permanent Magnet Motor for Food Processing Application” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……...

Name : Nor Aishah binti Md Zuki

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DEDICATION

This report is specially dedicated to my beloved family

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ACKNOWLEDGEMENT

This part is dedicated from my thankfulness and gratitude to all the people, too numerous to mention by name who lend their support. Without hesitation especially in the process of finish this project. This project make us experienced a great deal of difficulties and hard times. But with the existence of strong will power and mutual understanding that we manage to overcome all the barriers with great patience.

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ABSTRACT

This project is about design and analysis the slotted rotor double stator permanent magnet motor for food processing application. In food processing application, the double stator permanent magnet is used as the electric motor for tart cookies moulding device. For the past decade ago, peoples are using hand pressing to the tart cookies. But the disadvantage of hand pressing is the cleanliness is low since it used man power energy. So, Malaysian entrepreneur used a moulding device that connected air compressor and an actuator for large scale production. But for the moulding device still has disadvantage such as the speed, torque and force are not suitable for high quantities of orders. After investigate the disadvantage of the traditional moulding device, a new power moulding device embedded with electrical motor will be introduced. The objective of this research is to design and analyze the best performance of double stator permanent magnet motor that will be used in the moulding device. The double stator permanent magnet motor (DSPMM) is an electric motor that can have high torque density which can it can save time and produce a large number of tart cookies in one time. Before design the DSPMM, the previous motor is studied to get their specification. Then, the DSPMM is design by using SolidWorks software and simulate by using the Ansys Maxwell. The parameter of the motor is divided into fixed parameter and variable parameter. The fixed parameter is diameter of outer coil and size of rotor while the variable parameter is are length of magnet, number of turns and diameter of the inner stator. In this project, when the ratio number of turns is increase, the value of back emf and torque is increase. The best model of motor is choosing when the flux density between outer stator and inner stator is same which 1.5 T. This mouding device that embedded double stator permanent magnet as electrical motor will be benefit to small and medium entrepreneur and good economic to country.

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ABSTRAK

Projek ini adalah mereka bentuk dan membuat analisis mengenai „slotted rotor double stator permanent magnet motor" untuk aplikasi pemprosessan makanan. Dalam pemprosesan makanan, „double stator permanent magnet" digunakan sebagai motor elektrik untuk pembuat tart nanas. Beberapa tahun dahulu, oran ramai menggunakan tangan untuk menakan membuat kuih tart. Tetapi keburukan menggunakan tangan adalah kebersihan adalah rendah dan menggunakan tenaga kerja yang ramai. Jadi, pengusaha di Malaysia mnggunakan pengacuan yang dilengkapi dengan pemampat udara dan penggerak untuk pengeluaran berskala besar. Tetapi pengacuan ini juga mepuyai keburukan seperti kelajuan dan kuasa tidak sesuai untuk pesanan yang banyak. Selepas mengkaji keburukan alat pengacuan tradisional, pengacuan yang baru yang mempunyai motor elektrik telah diperkenalkan. Tujuan utama kajian ini adalah untuk mereka bentuk and membuat analisis prestasi yang terbaik untuk double stator permanent magnet yang akan dignakan untuk pengacuan tart nanas. DSPMM adalah motor elektrik yang mempunyai kepadatan kuasa yang tinggi yang boleh menjimatkan masa untuk menghasilkan kuih tart yang banyak dalam satu masa. Sebelum mereka bentuk DSPMM, pengucuan yang lama telah dikaji untuk mendapatkan spesifikasinya. Selepas itu, DSPMM telah direka menggunakan perisian Solidworks dan simulasi menggunakan Ansys Maxwell. Parameter motor dibahagikan kepada parameter kekal dan parameter bolehubah. Parameter kekal ialah ukur lilit stator luar dan saiz rotor manakala perameter yang bolehubah adalah panjang magnet, nombor lilitan, dan ukurlilit stator dalam. Dalam projek ini, apabila nisbah nombor lilitan bertambah, voltan yang terhasil juga akan bertambah. Model motor yang terbaik yang akan dipilih adalah apabila ketumpatan flux diantara stator luar dan dalam adalah sama iaitu 1.5 T. Jadi, alat pengacuan yang mempunyai jenis motor ini akan memberi manfaat kepada pengusaha kecil dan sederhana and memberi ekonomi yang baik untuk negara.

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LIST OF ABBREVIATION

Dc	-	Diameter of coil
DSPMM	-	Double Stator Permanent Magnet Motor
F	-	Force
Hc	-	Height of coil
PMBL	-	Permanent magnet brushless
T	-	Torque

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays the power electronic technology has been growth rapidly and new applications in the area of food processing have been developed. The advancement of technology has brought the major impact to the industry. In order to match the rising of those application areas, more effective and efficient electric motor for food processing must be introduced.

This project is to design and analyzing the double stator permanent magnet motor for food application. Double stator permanent magnet motor has two stator and single rotor. The double stator permanent magnet motor is an electric motor that can produce high torque density because both outer and inner stator can produce electromagnetic torque and there are two air gaps to deliver the output torque thus improving the torque density [1]. Double stator permanent magnet motor is widely used especially in electric vehicles.

In food processing application, the double stator permanent magnet is used as the electric motor for tart cookies moulding device. For the past decade ago, peoples are using hand pressing to the tart cookies. Since Malaysian preferred handmade tart cookies especially during festive festival, the traditional moulding device is not suitable to do a lot of quantities orders in one time. Besides that, the cleanliness is low when they are using traditional moulding device because they are used man power energy.

So, Malaysian entrepreneur used a moulding device that connected air compressor and an actuator for large scale production. The process requires dough compression inside a small chamber for moulding proposes. But for the traditional moulding device, the speed, torque and

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force are not suitable for high quantities of orders. After investigate the disadvantage of the traditional moulding device, a new power moulding device embedded with electrical motor will be introduced.

Figure 1.1 shows the concept of double stator permanent magnet motor used in food processing application. When the power is applied to the motor, the motor will rotate and it will produce force as well as torque. This motor will produce high torque density. So, the speed and force also will increase and it can reduce time to do the tart cookies. The process of this presser works is a power will applied to the motor then the mover will compress the dough inside the chamber to produce perfect molded tart cookies.

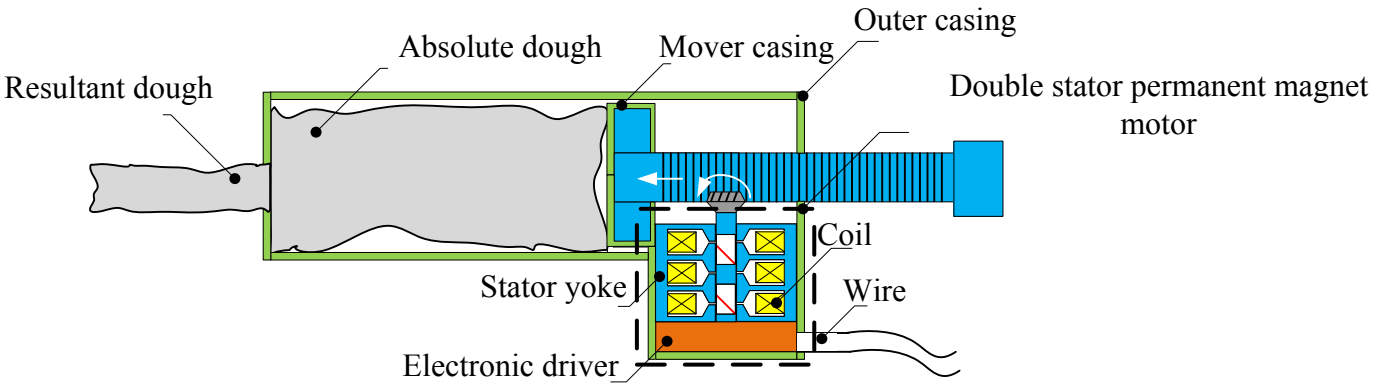

Figure 1.1: The concept of the double stator permanent magnet motor.

1.2 Problem Statement

In past decades ago, peoples are still using traditional or conventional method in the moulding device for food processing application. Tart and samperit are the example foods that used this kind of method. This is not practical since it require human energy and not productive when having larger quantities of cookies especially during festive season. Furthermore, other issues such as improper handling and poor of cleanliness because a lot of man power energy is used. Therefore, am assisted power moulding device embedded with electrical motor for tart cookies should be introduced to solve this issues. The double

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stator permanent magnet motor is used as electrical motor since it have high torque density. A suitable moulding device that use less amount of human energy and less hand contact to dough should be developed. As a result, a proper presser device that is clean, save and could increase productivity of cookies should be introduced.

1.3 Objective

The main aims for this project are:

1. To design the double stator permanent magnet motor for food processing application.
2. To analyze the best performance of double stator permanent magnet motor.

1.4 Research Scopes

This project covers the scope of designing and analyzing the double stator permanent magnet motor food processing application. Then, the double stator permanent magnet motor is analyzed in order to get the best performance of the motor. The best performance of motor is measured when the flux density between outer and inner stator is 1.5 T. This project can be divided into several stages. The first stage is do the specification and justification of the linear motor in order to get the real specification before the double stator permanent magnet motor is designed. The performance of the motor is need to analyze in order to get specifications such as the force required and the displacement of the linear motor. Based on the specification, the double stator permanent magnet motor is designed by using Solidwork software and transferred to Ansys Maxwell software to simulate the design in order to get the desired specification of double stator permanent magnet motor. Next, based on simulation the best designed model of double stator permanent magnet motor can be determined. Lastly, the best designed of double stator permanent magnet motor will be model by using rapid prototyping. Unfortunately, this project has their limitation. It is not includes the driver and there is no field test.

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1.5 Report Outline

This report consists of 5 chapters. The first chapter of this report covers the research background, problem statements and objective of this project. The scope and report outline also included in this chapter.

The second chapter covers the literature review. All the theory that used to do analyze part is included in this chapter. The overview and operation of permanent magnet motor is also cover in this chapter. Besides, the description of the double stator permanent magnet motor is cover in this chapter. The comparison between single stator and double stator also cover in this chapter. The related research of double stator permanent magnet motor is also cover in this chapter.

The next chapter is the methodology which explains in detail the procedures and steps for this research and project. Design and simulation software that are used to complete this project are also explain in this chapter.

The fourth chapter will be discussing about the result that obtain from the simulation. The final specification of the motor also discussed in this chapter. Lastly, the fifth chapter will be the conclusion for the project. The recommendation to improvise the design of the motor is also discussed in this chapter.

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CHAPTER 2

LITERATURE REVIEW

This chapter discusses about the double stator permanent magnet motor in general. This includes the traditional devuce available, permanent magnet motor and its basic operation, the comparison between single stator and double stator permanent magnet motor and the overview on related research of double stator permanent magnet motor.

2.1 Introduction of moulding device

Figure 2.1 shows several available products that related to presser device. The traditional presser device basically consists of two parts as shown in **Figure 2.1(a)**. The wooden cylinder shape is called compressor while the aluminum on the bottom is called a chamber. Dough is put into the chamber and compressor will compress until the dough come out from the bottom with shape. If the dough is harder, it needs a large force to compress. In **Figure 2.1(b)** the modern tart moulding devices have the same shape as the traditional one but involving gear mechanism. So, less force is required to compress the dough but it takes a longer time to produce compare with the traditional one. **Figure 2.1(c)** and **(d)** show available assisted power presser device that available in the market. Both traditional and modern presser devices usually used in small and medium food processing industries. It can produce a lot of tart cookies in short time. However, it uses air compressors which make it not portable and practical for homemade tart cookies user. **Table 2.11** shows comparison between the traditional and modern tart moulding device.

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Figure 2.1(a): Traditional portable presser

Figure 2.1(b): Modern portable presser

Figure 2.1(c): Semi auto food processing

Figure 2.1(d): 3 in 1 food processing

Figure 2.1: several available products that related to presser device

Table 2.1 shows the comparison between the traditional and modern tart moulding devices. It can be seen that the traditional moulding device requires larger external force for compression. However, the compression time is small and the chamber displacement. Both of traditional and modern moulding devices has bad productivity and practically since it requires human force and not suitable for bigger quantities of cookies. The proposed moulding device is powered by electrical and does not requires human energy. Besides, more tart cookies can be made since it will have small compression time and short chamber displacement.

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Table 2.1: Comparison between the traditional and modern tart moulding device

Comparison	Traditional	Modern	Semi auto	3 in 1	Proposed
Source of Force	Human	Human	Electro-mechanical	Electro-mechanical	Electro-mechanical
Human force	Larger	Small	None	None	None
Compression time	Larger	Small	Smaller	Smaller	Smaller
Displacement	Short	Long	Longer	Longer	Longer
Estimate productivity (pcs/h)	50	100	1000	1000	200
Machine Weight (kg)	<1	<1	<50	<50	<1
Accessibility	Portable	Portable	Permanent	Permanent	Portable
Practically	Bad	Bad	Bad	Bad	Good

2.2 Permanent Magnet Motor

The permanent magnet (PM) motor is a dc motor whose poles are made of permanent magnet. The basic structure of permanent magnet motor consists of stator and rotor. Permanent magnet device has some advantage in some application compared to shunt DC motor. Since these motor do not require an external field circuit, it do not have the field circuit copper loses associated with shunt DC motors [2-3]. The basic configuration of permanent magnet is shown in **Figure 2.2.**

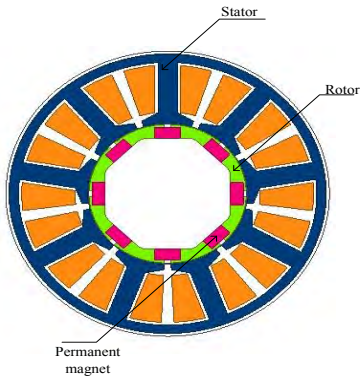

Figure 2.2: Basic structure of Permanent Magnet Motor

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2.3 Basic Operation of Permanent Magnet Motor

The basic operation of the permanent magnet motor is basically similar to the DC motor. The direction of magnetic pole can be determined by using right hand grip rule and the current is following the Fleming Left Hand rule. In a PM motor, the rotor is moved through the action of the permanent magnet, rather than through "teeth" as in the classic variable resistance step motor [3]. All the permanent magnet motor has their advantages. The permanent magnet motor can be highly effective and is good effective and is a good choice for people. However PM motor also has disadvantages. PM cannot produce high flux density and have lower induced torque. PM rotors are radially magnetized, north and south poles alternating along the circumference of the rotor. A pole pitch is the angle between two poles of the same polarity, north to north or south to south. Both the rotor and the stator assemblies of PM motors are smooth.

2.4 Double Stator Permanent Magnet Motor

Dual stator topology has been widely used in motors for different applications where power segmentation and reliability are main concern. Dual stator configurations are already being used in induction, synchronous motors for applications like wind-mill generators, aircrafts, electric vehicles and automation. The new double stator permanent magnet motor synchronous motor concept is proposed for integration in an electric vehicle, in order to increase the vialibility, flexibility and high level of precision and system control due to higher electromagnetic useful torque, comparing to a standard permanent magnet synchronous motor [4]. As any electrical machine, a double stator permanent magnet synchronous motor is mainly composed by two principle components, the fixed and non-fixed, respectively designated the stator and the rotor. The source of the electromagnetic flux is a set of high performance permanent magnet that is installed on the rotor surface, or inside it. For this study it will be assumed the configuration with surface mounted permanent magnets. The magnetic interaction between the stator and rotor field will result in electromagnetic useful torque. This

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torque will be responsible to drive the entire mechanical component composed by the rotor, the transmission axle, the wheels and the external load [5].

In these dual stator machines, there are two stator windings which share the same magnetic and mechanical structures. These machines are typically used in high power applications. The stators may consist of two identical windings with or without phase shift [6]. The two windings may have different number of poles, number of phases and ratings. In dual stator machine, the output torque corresponds to the algebraic sum of two independent torques.

In terms of construction, there are two air gaps instead of one as the conventional motor, because the rotor is positioned between the outer between the outer and inner stator. It has the advantage that currents of both the inner and outer stators produce electromagnetic torque and there are two air-gaps to deliver the output torque, thus improving the torque density. **Figure 2.3** shows the basic structure of double stator permanent magnet motor

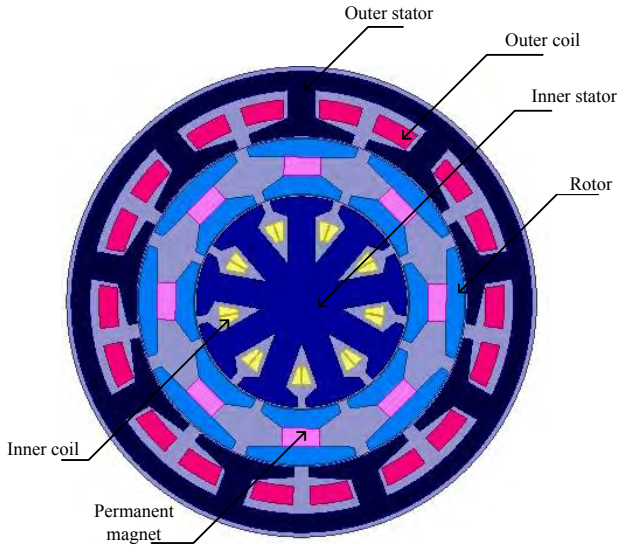

Figure 2.3: Basic structure of permanent magnet motor

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2.4 Comparison of single and double stator permanent magnet motor

Figure 2.4(a) and **Figure 2.5(b)** show the basic structure of single stator permanent magnet motor and double stator permanent magnet motor respectively. Based on the structure the main difference is the single stator permanent magnet motor has only single stator and single rotor while the double stator permanent magnet has two stator which is inner stator and outer stator and single rotor. The single stator only has 1 air gap but the double stator has two air gaps. Based on the research, the double stator has two stator, the torque produced is higher compared to the single stator. This is because both outer and inner stator can produce electromagnetic torque and there are two air gaps to deliver the output torque thus improving the torque density.

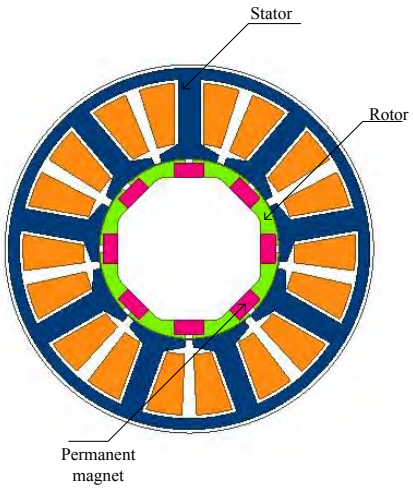

Figure 2.4(a): Single stator permanent magnet motor

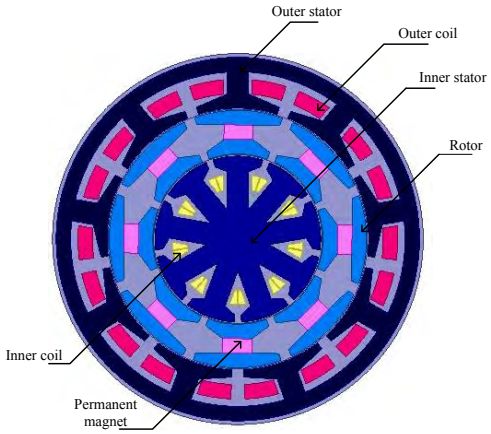

Figure 2.4(b): Double stator permanent magnet motor

Figure 2.4: The basic structure of Single Stator and Double Stator Permanent Magnet Motor

2.5 Configuration of the Double Stator Permanent Magnet Motor

This motor consists of double stator which is inner and outer stator and a single rotor. This DSPMM consists of 9 slot 8 pole configurations. The DSPMM is designed in three phase system and outer and inner is connected in series. In the structure of double stator permanent magnet motor, the rotor with permanent magnet located in the middle of the motor and the

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