“ I hereby declare that I have read through this report entitle “Design of Slot-less Linear Actuator for Food Processing Application” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronics and Drives)”

Signature : ……..

Supervisor’s Name : ……..

Date : ……..

DESIGN OF SLOT-LESS LINEAR ACTUATOR FOR FOOD PROCESSING APPLICATION

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

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitle "*Design of Slot-less Linear Actuator 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 : ……..

Date : ……..

To my beloved mother and father, sisters and brother.

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ABSTRACT

This report is about designing a slot-less linear actuator for food processing application. Linear actuator is a device that produces linear motion without using any mechanical transmission to converts rotary motion into linear motion. The objective of this research is to design slot-less linear actuator for food processing application. People are still using traditional or conventional compression method by pressing hand in the moulding device. Samperit and tart cookies are examples of the food that requires this method to process it. But nowadays, this method is no longer practical as this method is not productive in handling large amount of dough. It takes a long time to press the dough as it requires human energy. So, a power moulding device embedded with slot-less linear actuator is proposed to help increasing the productivity as it use electrical as a source of force. The process flow for this project is firstly, to carry out preliminary experimentation using traditional moulding device to get the real dimensions and specifications of the moulding device. Then, the slot-less linear actuator has been designed using SolidWorks software and the modeling by using Ansys Maxwell software. There are two (2) models have been design; the model using one (1) coil and the model using two (2) coil. Next, the analysis of the coil sizing has been done. The analysis of the coil sizing includes the number of coil, the height of the coil and the varied gap of the two (2) coils. The result gain should fulfill the target design specifications and the expected thrust characteristic. Lastly, the best model of the slot-less linear actuator is chosen and the model is fabricated using rapid prototyping.

ABSTRAK

Laporan ini tentang mereka bentuk aktuator lelurus tanpa slot untuk aplikasi memproses makanan. Aktuator lelurus ialah peranti elektromekanikal yang menghasilkan daya berjarak pendek lelurus tanpa menggunakan sebarang transmisi mekanikal untuk menukar gerakan putaran kepada lelurus. Pada masa kini, manusia masih menggunakan peranti penekan doh yang menggunakan kaedah penekanan. Kuih samperit dan tat adalah contoh makanan yang menggunakan kaedah ini untuk dihasilkan. Tetapi, pada zaman yang serba canggih ini, kaedah penekanan yang menggunakan alat peranti penekan doh yang lama sudah tidak sesuai digunakan. Ini adalah kerana ianya tidak produktif apabila melibatkan doh yang banyak. Ianya mengambil masa yang lama untuk menghasilkan kuih yang banyak kerana ia menggunakan tenanga manusia. Jadi, peranti penekan doh berkuasa elektrik sebagai sumber tenaga yang menggunakan aktuator lelurus tanpa slot dihasilkan untuk membantu meningkatkan kadar produktif. Aliran proses untuk projek ini berjalan lancar adalah dengan menjalankan eksperimen kepada peranti penekan doh yang lama untuk mendapatkan dimensi dan spesifikasi yang sebenar peranti tersebut. Seterusnya, aktuator lelurus tanpa slot telah direka bentuk menggunakan software SolidWorks dan dimodel menggunakan software Ansys Maxwell. Terdapat dua (2) model aktuator linear telah dihasilkan iaitu model yang menggunakan satu (1) koil dan model yang menggunakan dua (2) koil. Seterusnya, analisis tentang saiz koil telah dilakukan. Analisis saiz kol termasuklah bilangan koil yang diperlukan, tinggi setiap koil dan jarak antara dua (2) koil. Hasil daripada analisis saiz koil mestilah memenuhi jangkaan cirri teras yang telah dibuat. Akhir sekali, model aktuator lelurus yang paling baik dan dikehendaki dimodelkan menggunakan ‘rapid prototyping’.

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LIST OF SYMBOLS

d_c	Diameter of coil wire [mm]
ρ	Density [kg/m^3]
F	Force [N]
g	Gravitational constant [9.81 kgm^{-1}]
g_c	Gap between two (2) coil [mm]
h_c	Height of coil [mm]
h_s	Height of stator [mm]
I	Current [A]
l	Length [m]
m	Mass of the dough [kg]
N	Number of turns
P	Power [W]
r	Radius [mm]
R	Total resistance [Ω]
r_{mg}	Radius of magnet [mm]
r_{my}	Radius of moving yoke [mm]
T	Thrust [N]
v	Volume of the water change [*l*]
v	Voltage [V]
w_c	Width of coil [mm]
w_{mg}	Width of magnet [mm]
w_{my}	Width of moving yoke [mm]
w_s	Width of stator yoke [mm]
x	Displacement [mm]
x_{op}	Operating displacement [mm]

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CHAPTER 1

INTRODUCTION

1.1 Research Background

This research is about designing a slot-less linear actuator for food processing application. Linear actuator is a device that produces linear motion directly without using any mechanical transmission to convert rotary motion to linear motion in contrast with rotational motor that produce rotary motion [1]. The advantages of the linear actuator compared to the conventional actuators are it has a simple structure, better dynamical performance and have higher reliability. Linear actuator is widely used in power generation sector, factory automation sector and also used in household appliances. Slot-less type stator is the stator that has stator yoke without stator tooth. The coil in the slot-less type stator is wound around cylindrical shape. This slot-less type stator offers advantages such as can produce high speed and high efficiency.

The concept of conventional or traditional moulding device for food processing application is illustrated in **Figure 1.1**. The moulding device is divided into two main parts known as chamber and plunger. When dough is fully filled inside the chamber, the external force by human will push the plunger to compress the dough. The desired shape of dough will comes out from the bottom of the moulding device. This is not practical since it requires human energy and not productive when handling larger quantities of dough. Other issues such as improper handling and poor in cleanliness aspect will be rising up.

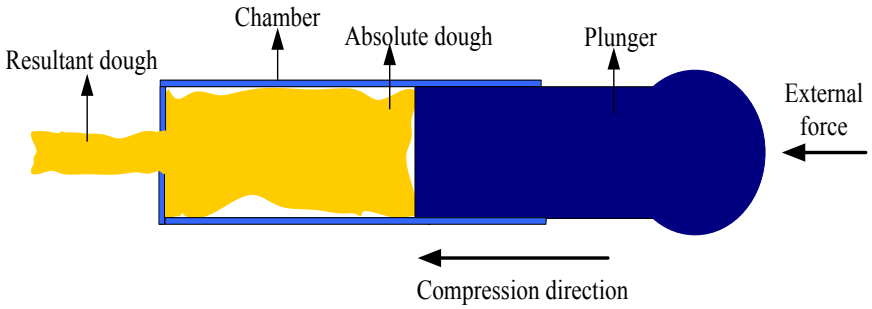


Figure 1.1: Concept of traditional moulding device for food processing application.

The concept of the electrical moulding device with slot-less linear actuator for food processing application is as shown **Figure 1.2**. As power is applied to the slot-less linear actuator, the mover will compress the dough inside the chamber to produce desired shape of dough. The mover is made up from permanent magnet which will be sealed by mover casing that made up from non-ferromagnetic material such as plastics to avoid contact and dough isolation. This research is more practical since it use less human energy and less hand contact with dough. So, cleanliness issues will not rise. The productivity also will increase as this device can handle a larger quantity of dough. The density of the dough whether the dough is hard or soft is also will be considered in this project.

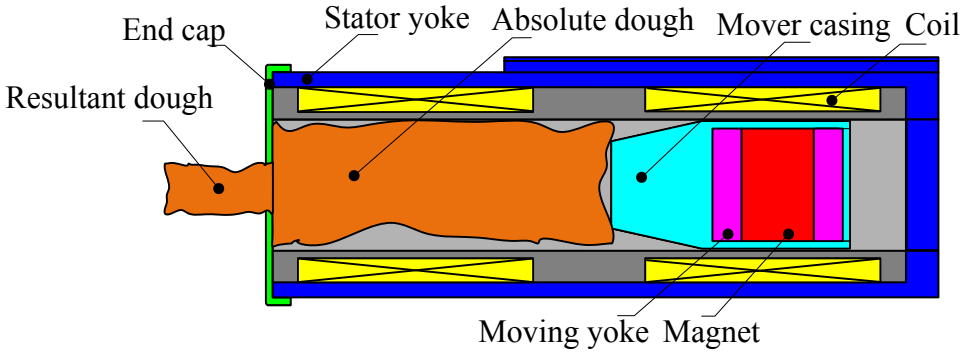


Figure 1.2: The concept of electrical moulding device with slot-less linear actuator.

1.2 Problem Statement

For over so many years, peoples are still using traditional or conventional compression method by pressing hand in the moulding device for food processing application. Foods such as samperit and tart cookies are the examples of foods that require this method in processing it. But, this method is no longer practical as it requires human energy and this method is not productive when handling larger amount of dough. Thus, this will caused a problem to the entrepreneur when customers order large quantities of cookies. Furthermore, in cleanliness aspect, this method is in the poor level as there is frequent hand contact with the dough itself. Improper handling of the device is also a problem when using this conventional compression method. Therefore, a power moulding device for food processing application should be introduced to solve these problems. A power moulding device that use less amount of human energy and less hand contact to the dough should be developed. As a result, a proper moulding device that can increase the productivity, save to handle and have high cleanliness level should be introduced.

1.3 Objectives

The objectives of this project are:

i. To design a slot-less linear actuator for food processing application.
ii. To model the best design of slot less linear actuator for food processing application using rapid prototyping.

1.4 Scope

This project covers the scope of designing the slot-less linear actuator as the device that converts rotary motion to linear motion for food processing application. The slot-less linear actuator is then been examine and analyze. This project can be divided into several stages. The first stage of this project is to carry out the preliminary experimentation using traditional moulding device to get the real specifications and dimension of the device. The specifications and dimension needed such as the height of the device, the volume of the dough that can be filled in the chamber of the moulding device and the force needed to push the dough. The next stage is to model the actuator. The modeling of the actuator by using SolidWorks software and the design is transferred to Ansys Maxwell Software to get the desired specifications of designed linear actuator. Then, the model of the actuator will be analyzed in order to get the best model of the actuator. Lastly, the best designed model of the actuator will be model by using rapid prototyping. However, this project do not covers designing motor driver and field testing.

1.5 Report Outline

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

The second chapter covers the literature review. All the theory that used to do analysis part is included in this chapter. The overview about linear actuator and the operations is described in this chapter. Besides, the comparison between slot-less and slot-type linear actuator is described in this chapter. The related research of linear actuator is also presented in this chapter.

The next chapter is the methodology which explains in detail about the whole workflows and method used to accomplish this project. Design and simulation software which are used to complete this project are also explained in this chapter.

The fourth chapter will be discussing about the recent progress of the project. Lastly, the fifth chapter will be the conclusion for the whole project. Besides, some recommendations to improvise the design of the actuator is also stated in this chapter

CHAPTER 2

LITERATURE REVIEW

This chapter discusses the slot-less linear actuator in general. This includes the overview about traditional device available, the basic operation of slot-less linear actuator, the comparison between slot-type and slot-less linear actuator. Besides, the overview on related research of slot-less linear actuator is also shown.

2.1 Overview about Traditional or Conventional Moulding Device Available

Figure 2.1 shows the traditional or conventional moulding device for food processing applications that available in the market. The presser device is basically consists of two parts; compressor and chamber. Amount of dough is put in the chamber and the compressor will compress until the dough come out from the bottom with desired shape. The shape of the dough that will come out can change as there is multiple design of mould. If the dough is hard, the force used to compress the dough is larger.

Figure 2.1: Traditional or conventional moulding device.

Table 2.1 shows the comparison between the traditional and proposed moulding device. 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 is short. Meanwhile, the proposed moulding device is powered by electrical and does not require human energy. Besides, more cookies can be made since it has smaller compression time and short chamber displacement.

Table 2.1: Comparison between traditional and proposed moulding device.

Comparison	Traditional	Proposed
Source of force	Human	Electrical
Quantity of force	Larger	Larger
Compression time	Small	Small
Displacement	Short	Short
Productivity	Bad	Good
Practically	Bad	Good

2.2 Slot-less Linear Actuator

Linear actuator is basically a mechanical device that converts various type of energy to mechanical energy in a small movement. It creates motion in a straight line. The examples of motion that uses linear actuator include ejecting, lifting, pulling and pushing. The basic structure of the linear actuator is shown in **Figure 2.2**. The structure consists of stationary part and moving part. The stationary part includes stator yoke and coil. Meanwhile, the moving part includes moving yokes and permanent magnet. The moving yokes must be design quarter of the size of the permanent magnet. The moving yoke is used to channel all the flux to the coil, so that the flux will be distributed to the desired parts without any losses.

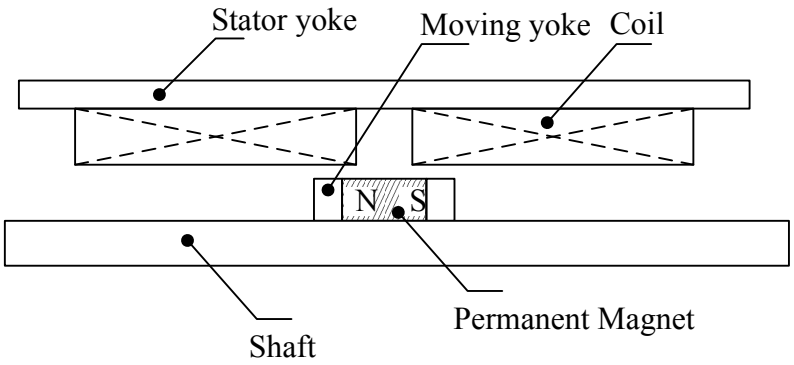


Figure 2.2: Basic structure of linear actuator.

Figure 2.3 shows the basic operation of linear actuator. Based on the Fleming's left-hand rule, the force will be produced when the current carrying conductor is placed inside the magnetic field [2]. The coil must be applied with different direction as it will produce flux. The coil current will flows perpendicularly to the flux of permanent magnet. The current will flow from the North pole to the South pole. So, as the current flows through the coils, the mover will move to the left direction.

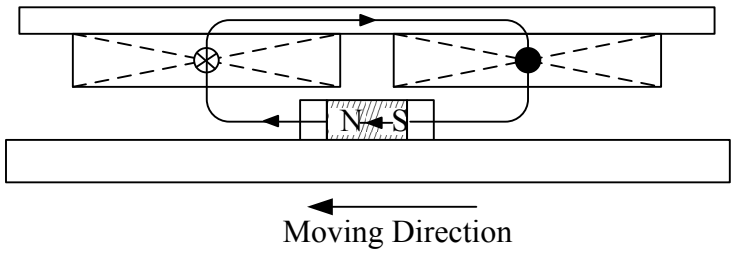
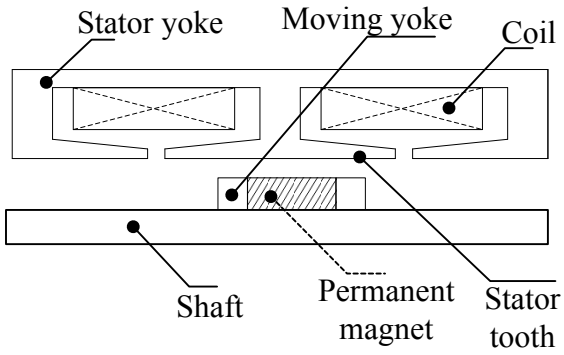


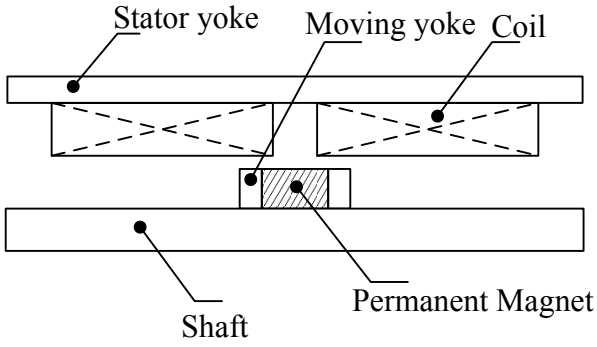
Figure 2.3: Basic operation of linear actuator.

2.3 Comparison between Slot-type and Slot-less Linear Actuator

Figure 2.4 (a) and **(b)** shows the basic structures of slot-less and slot-type linear actuator. Based on the structures, the main difference between the two structures of the linear actuator is the structure of the stator yoke. Slot-less type of stator yoke do not have tooth and slots. Meanwhile, the slot-type stator has the stator tooth and slot. The coil in the slot-less type stator is wound cylindrically around the shape of the stator and the coil in slot-type stator is wound around the stator tooth in between the slots.



a) Slot-type stator



b) Slot-less stator

Figure 2.4: Basic structure of slot-less and slot-type stator.