DEVELOPMENT OF ROTATIONAL TO LINEAR ACTUATOR

BARTHOLOMEW ANAK DILOL

BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2020

DEVELOPMENT OF ROTATIONAL TO LINEAR ACTUATOR

BARTHOLOMEW ANAK DILOL

A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2020

DECLARATION

I declare that this thesis entitled "DEVELOPMENT OF ROTATIONAL TO LINEAR ACTUATOR 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 any other degree.

Signature :

Name : Bartholomew anak Dilol

Date : 5/7/2021

APPROVAL

I hereby declare that I have checked this report entitled "DEVELOPMENT OF ROTATIONAL TO LINEAR ACTUATOR" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

ACKNOWLEDGEMENTS

First and foremost, I want to express my sincere gratitude to my supervisor, Professor Madya Dr. Kasrul bin Abdul Karim, who has guided me from the very beginning to the very end of my research. He is a patient, friendly and passionate person who guides and inspires me in the undertaking. Moreover, he is well prepared to support my research, bearing in mind with his responsibilities as a lecturer and a father, which I appreciated so much because the report would not have been completed without his efforts in giving necessary details and materials for my work.

Not to forget, my first panel, Ir. Dr. Md. Hairul Nizam bin Talib, and my second panel, Mdm. Syahar Azalia binti Ab Shukor, who spent their time in the assessments and submission of my final report. Without their overall assertions, my research would not have been assessed and rectified based on their vast knowledgeable experiences.

In addition, I would also like to thank my beloved parents who have spent their time and energy ensuring that this research is well funded and has all the materials needed. In giving me moral encouragement to lift my spirits and motivation to pursue this research to the very end, they also play a significant role.

Finally, I would like to thank my future fellow engineers for being capable of helping me excel in this research. What really helps to complete this research is their beneficial inputs and tips, without them, I am unable to complete this report on time.

ABSTRACT

Linear and rotary actuators are used in many commercial and industrial processes from aircraft to automotive, and even in semiconductor manufacturing. The common mechanical device that converts rotary to linear actuator is a ball screw mechanism. This research, however, does not focuses on their complex design, but rather on the simplest representation of a rotational to linear actuator concept. Here, a prototype of a DC-driven rolling disk is proposed in this research. Using this innovation, it will allow the most simplified design to demonstrate their conversion of rotary to linear motion. By this mean, our main purpose of the study is to design a rotary-linear actuator based on the rolling disk principle of a roller bender, will be achieved. Developments of linear actuators using conventional DC motor are cited in literature review of this research. Later in research methodology, there are four main aspects to be consider, such as, the study of rotary-linear actuator based on fundamentals of roller bender using Arduino Uno, the analysis and design of controlling a DC motor using L298N motor driver, the analysis of limit switch towards the range and continuous linear motion, and the final hardware product using Solidworks simulation. In addition to the process flowchart, the research works must be carried out in a proper manner in order to avoid errors and to decrease the time taken for the research to finalized. Next, the experiment results will be tabulated and compared based on their analysis studies in the results and discussions section. In that section, analysis data of thrust or force will be observed and compared based on the power input and duty cycle of the DC motor. In order to identify the main purpose of this research, precautionary steps are also utmost important. Hence, this research study will focus on the development of a rotational to linear actuator.

ABSTRAK

Penggerak putar dan linear digunakan dalam banyak proses komersial dan perindustrian dari pesawat ke automotif, dan bahkan dalam pembuatan semikonduktor. Peranti mekanikal yang biasa digunakan untuk menukar putaran ke penggerak linear adalah mekanisme skru bola. Walau bagaimanapun, penyelidikan ini tidak menumpukan pada reka bentuk kompleks mereka, melainkan pada perwakilan konsep penggerak putaran ke linear yang amat sederhana. Di sini, prototaip cakera penggulung yang didorong oleh motor DC dicadangkan dalam penyelidikan ini. Dengan menggunakan inovasi ini, ia akan membolehkan reka bentuk yang paling mudah untuk menunjukkan penukaran gerakan putaran kepada gerakan linear. Dengan maksud ini, tujuan utama kajian kami adalah untuk merancang penggerak putar-linear berdasarkan prinsip cakera bergolek roller bender, akan tercapai. Perkembangan penggerak linear menggunakan motor DC konvensional disebutkan dalam tinjauan literatur penyelidikan ini. Kemudian dalam metodologi penyelidikan, terdapat empat aspek utama yang perlu dipertimbangkan, seperi, kajian penggerak putar-linear berdasarkan asas-asas roller bender menggunakan Arduino Uno, analisis dan reka bentuk pengendalian motor DC menggunakan pemandu motor L298N, analisis had beralih ke arah julat dan gerakan linear berterusan, dan produk akhir menggunakan simulasi Solidworks. Selain bagan alur proses, karya penelitian harus dilakukan dengan cara yang tepat untuk menghindari kesalahan dan mengurangi waktu yang diperlukan agar penelitian dapat diselesaikan. Seterusnya, hasil eksperimen akan dijadualkan dan dibandingkan berdasarkan kajian analisis mereka di bahagian hasil dan perbincangan. Pada bahagian tersebut, data analisis ‘thrust’ atau daya akan diperhatikan dan dibandingkan berdasarkan input daya dan kitaran tugas motor DC. Untuk mengenal pasti tujuan utama penyelidikan ini, langkah pencegahan juga sangat penting. Oleh itu, kajian penyelidikan ini akan memberi tumpuan kepada pengembangan penggerak putaran ke linear.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

DC	-	Direct Current
CAD	-	Computer-aided Design
MCU	-	Microcontroller Unit
IC	-	Integrated Circuit
PWM	-	Pulse Width Modulation
N	-	Newton
RC	-	Remote Control
ECM	-	Electronic Control Module
EMF	-	Electromagnetic Field
RPM	-	Revolutions Per Minute
TTL	-	Transistor-transistor Logic

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter includes the project background, motivation, problem statement, objective, scope of research, and thesis outline.

1.1 Project Background

The actuators can be divided into two groups based on their movement. There are two primary actuator types, rotative and linear. Rotary actuators turn several degrees in a circle where there may be a limited number or an infinite number. Evidently, linear actuators usually move things in a straight line, back and forth. A rotating actuator example is, of course, the electric DC motor, an actuator which turns an electric signal into a rotating shaft motion. When current is applied to the motor, the rotor interacts with the magnetic field, causing it to rotate in either a clockwise or counterclockwise direction, producing magnetic flux within the surface of the permanent magnetic motor.

The mechanisms for mechanical levers have the advantage of decreasing rotary velocity and torque combined with several rotary actuators. The output of this unit still is a rotating actuator when the result is a rotative motion. In addition, rotary actuators are frequently attached to rotary motion transforming structures called linear actuators. These linear mechanisms are mechanical devices, such as ball screws, belts and pulleys, and racks and pinions, which in some way convert energy.

For a constant linear movement of rotary motion, ball screws and roller screws are typically utilized, such as in machining industry. The rotating motion of the motor can be transformed into linear motion by the belts and pulleys, for example, a conveyor. Torque is usually multiplied by racks and pinions which decrease the speed of rotating motion but also can be used together with a device which turns rotation movement into linear movement. This research therefore proposes a prototype of a rotary-linear actuator based on a roller machine.

1.2 Motivation

Precise two-dimensional motions, whether linear or rotary, are required in this modern industrial environment. Here we take the mechanism of the ball screw as an example for this application. A ball screw is a linear mechanical actuator that transforms rotation into linear movement with small friction. It is now the most popular application in the industry. The threaded shaft offers a helical track for ball rollers to work as a precision screw. They can withstand high thrust loads and with minimal internal friction.

They are designed to be very tolerant and are ideal for use in situations where high precision is needed. While the threaded shaft is a screw, the ball mechanism behaves like a nut. The ball screws appear to be very bulky compared to conventional leadscrews as a result of the mechanism to recirculate the ball. Therefore, this research proposes a new structure to use a motor driven rolling disk to implement the development of a small-scale rotational to linear actuator.

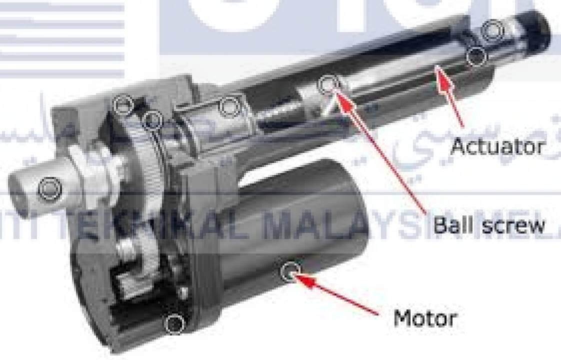

Figure 1.1 A Ball Screw Mechanism

1.3 Problem Statement

A ball screw mechanism was used for the most part by the rotative to linear actuator. This actuator is equipped with an electric motor with a set of gears to drive the application. The manufactural structure is very complex. Depending on the lead angle, the ball screws can be driven back due to their low internal friction. The screw shaft can be driven linearly, to rotate the ball mechanism. Cost is also an important factor, as the production of Acme screws is cheaper, but the overall production of the device is expensive. Hence, this study proposes a new design for the use of a rolling disk driven by a DC motor because it is adapted to industrial applications with respect to speed and direction that can be controlled easily.

1.4 Objectives

Parametric design, modelling, and prototyping in Solidworks, and controller design in Arduino are the major objectives of this research. In detail, they are described as follows:

1. To design a rotary-linear actuator based on the principle of rolling disk as in a roller bender.

2. To develop simulation on a new rolling disk structure driven by a DC motor using Solidworks and Arduino.

3. To construct an appropriate DC motor controller capable of influencing its speed and direction.

4. To analyze the thrust or force based on their input power and duty cycle of DC motor.

1.5 Scope of Research

The research goals must first be defined in order to determine the scope of this study. This project aims to create a new concept for the purpose of introducing other alternative to replace those high-cost devices. The CAD modelling of this product is simulated using Solidworks whereas the electrical part of this research was designed using an Arduino Uno microcontroller with a L298N motor driver for controlling the speed and direction. The circuit simulation is tested using Proteus to compare with the outcome results. Hence, this conceptual design is based on three rotating disks to achieve the purpose of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Linear actuator

A linear actuator is an actuator that generates motion in one direction with respect to the circular motion of a typical electric motor. Linear actuators are used in industry machines, mostly hardware devices such as hard disks and printers, rotors and dampers, and many other aspects of linear motion. Hydraulic or pneumatic valves also generate linear movement. Hence, there are many other applications used to generate linear motion from a rotary motor. [1]

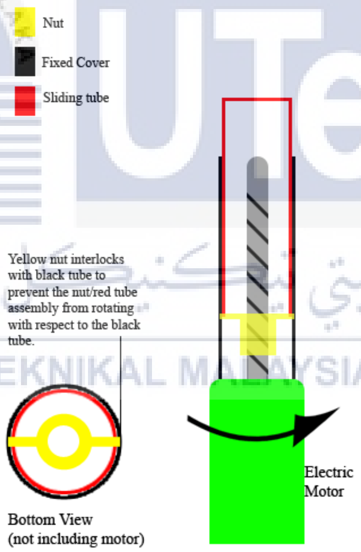

Figure 2.1 A basic traveling-nut linear actuator concept model

2.2 Mechanical actuators

Usually, mechanical linear actuators work by converting rotary motion to linear motion. In general, conversion takes place through a few basic forms of process, namely:

- Screw: The concept of simple screw mechanism is based on a lead screw, screw jack, ball screw, and roller screw drive. The screw shaft moves in a line by rotating the actuator bolt.

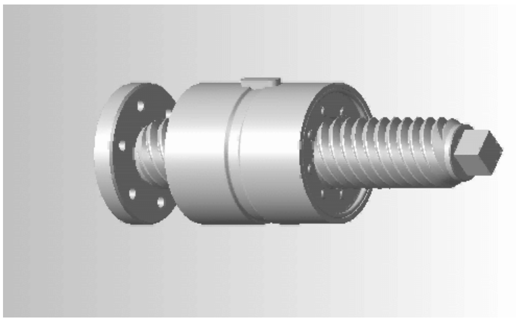

Figure 2.2 Roller screw motion with moving bolt

- Wheel and axle: The process of wheels and axles is supported by applications such as hoist, rack and pinion, chain drive, rigid chain, and chain drive actuators. A rotary wheel moves a cable, a rack, or a belt to produce linear motion. [1]

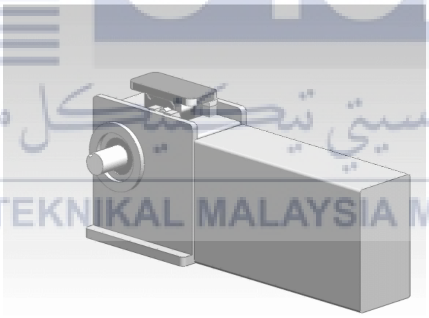

Figure 2.3 Rigid actuator with chain

- Cam: Cam actuators work with the same wedge theory but have a relatively higher sensitivity. Its exceptional shape gives the base of the shaft an impetus when the wheel-like cam rotates. [1]

Figure 2.4 Constantly spinning cams that produce the supporters of the cam's rotating linear motion

Various other linear mechanical actuators, such as hoist, chain and belt units, are pulling type force. Others, like a cam actuator, use pushing force. Pneumatic and hydraulic pipes can be built to produce force in both ways. Mechanical actuators generally convert the rotor movement of the control button or grip to a linear displacement via screws with or without gears into which a button or handle is assembled. The common mechanical actuator is a jack or carjack on the basis of a segmented spindle.

The acceleration of the jack's handle is mechanically converted into a linear motion of the jack's head. The most widely used mechanical actuators in the beam and glass applications are the linear stages, rotating stages, mirror fixtures, and other positioning instruments. Datasets can be used in the connectivity options for precise and reliable placement. For some actuators, they use an integration and a wireless position control unit. They are comparable to the adjustment knobs used on micrometers, except that their role is to change the position rather than to determine the position.

2.3 Hydraulic actuators

The hydraulic actuator consists of a rotating motor or fluid engine that can be operated by hydraulic force. Mechanical energy generates linear, rotating, and oscillating outputs of motion. As liquids are almost always hard to compress, the hydraulic actuator can generate a lot of energy. The disadvantage of this method, though, is its limited speed. The hydraulic cylinder consists of a cylindrical pipe through which the piston flows.

The term ‘single-acting’ is used where the fluid force is applied to only one side of the pistons. The piston can move in the right direction, and the spring will also give the piston a reversal stroke. The term ‘double action’ is used because friction takes place on both sides of the piston, which is any force change between the two sides of the piston forces the piston on either side. [2] The hydraulic carjack is a common configuration of a hydraulic actuator. The term ‘hydraulic actuator’ refers generally to an air compressor-controlled system.

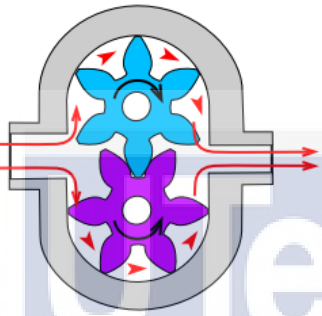

Figure 2.5 Motor with hydraulic gear

2.4 Pneumatic actuators

Without the use of compressed air to generate power, pneumatic actuators would be like hydraulic actuators. They work just like a piston in which the air is pumped and pushed out of the chamber from the other side of the chamber. Air actuators are usually not used in highly durable machines and where large volumes are present. One of the reasons why linear pneumatic actuators are preferred to other types is the fact that the power supply is simply an air compressor. It can be used in many mechanical wear areas as air is the source of input.

The downside is that most air compressors are large and loud. Once installed, they are hard to store in other areas. It also leaks, making it less efficient than linear mechanical actuators. Furthermore, due to relatively minor pressure changes, significant forces can be developed. Pneumatic energy is desirable for key motor controls, so it can be quickly adjusted when switched as the power supply does not