DESIGN OF ANKLE REHABILITATION SYSTEM AND CONTROL USING ANDROID PLATFORM

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"I remembered that the real world was wide, and that a varied field of hopes and fears, of sensations and excitements, awaited those who had the courage to go forth into its expanse, to seek real knowledge of life amidst its perils."

Dedicated especially to my beloved mother Salasiah binti Ali,
father Mohd Mokhtar bin Taib and my brothers who have helped me a lot in my journey through hardship and success

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ABSTRACT

One of the most common feet injury that can occur to anyone is sprained ankle. Whether the person is active in sports or not, if their have moved their ankle in a bad position, they might get the injury. The bad position that triggers the ankle sprain is when the person try to stretch their ankle beyond their limits, resulting a tear in the ligaments. Most sprains are minor injuries that can heal with continuous treatments and rehabilitation. Without proper treatment and rehabilitation, a more severe sprain can weaken the ankle, thus making it more likely to injure the same area again. Thus, rehabilitation excersises are a must to ensure no re injury happens. This project introduces a new Ankle Rehabilitation system that involves games and uses servo motors as the actuators for the device. The Ankle Rehabilitation prototype device is a user friendly device where it can move using the user‟s free will, thus giving the patient comfort in doing the rehabilitation process. The patient will put their injured feet on top of the Ankle Rehabilitation prototype, and controlling the tilt angle of the platform using their connected android phone. The device is powered using Arduino microcontroller, and the moving mechanism of the plane is three servo motors. A game on the phone that communicates with the device will make the patient feel more relaxed and happy while doing the rehabilitation exercise thus lengthen the usage of the device.

ABSTRAK

Kecederaan kaki yang sering berlaku dalam kehidupan seharian adalah kecederaan pada buku lali, iaitu terseliuh pada buku lali. Kecederaan seperti ini boleh berlaku kepada orang yang gemar bersukan, mahupun kepada mereka yang tidak gemar dengan syarat mereka telah gerakkan kaki mereka sehingga posisi yang tidak baik. Posisi tidak baik yang boleh mendatang kan terseliuh kaki adalah apabila seseorang tersebut cuba untuk menggerakkan kaki mereka di luar kebolehan biasa manusia, oleh itu menyederakan ligamen buku lali tersebut. Tereseliuh buku lali adalah sesuatu yang biasa terjadi kepada sesiapa tidak kira usia. Kebanyakan kes adalah kecedeaan yang kecil dan boleh dipulihkan dengan menjalani sesi rehabilitasi atau senaman. Tanpa mengamalkan cara perubatan dengan betul, kondisi kecederaan buku lali boleh menjadi lebih teruk dan dalam waktu yang sama melemahkan bahagian buku lali tersebut, seterusnya mengakibatkan pesakit akan mengalami kecederaan pada bahagian yang sama. Oleh itu, proses rehabilitasi dan eksersise adalah penting jika ada kecederaan berlaku. Dalam projek ini, prototaip baru bernama *Ankle Rehabilitation Prototype* akan diperkenalkan. Alat ini menggunakan tiga motor untuk menggerakkan tempat letak kaki tersebut. Prototaip ini boleh dimainkan bersama aplikasi permainan di dalam talifon atau tablet Android yang berkomunikasi dengan alat tersebut. Alat ini mengikut pergerakan pesakit dan boleh bergerak mengikut kelajuan pesakit sendiri yang sesuai dan akan memberi keslesaan kepada pesakit.

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LIST OF ABBREVIATION

UI	-	User Interface
OS	-	Operating System
2-DOF	-	Two Degree of Freedom
3-DOF	-	Three Degree of Freedom
AC	-	Alternating Current
SCR	-	Silicon Controlled Rectifier
DC	-	Direct Current
RPM	-	Rotation per Minute
IoT	-	Internet of Things
HDMI	-	High-Definition Multimedia Interface
SPI	-	Serial Peripheral Interface
ADC	-	Analog To Digital Converter
VCC	-	Voltage at The Common Collector
GND	-	Ground
ICSP	-	In Circuit Serial Programming
TX	-	Transmitter
RX	-	Receiver
LED	-	Light Emitting Diode
EDR	-	Enhance Data Rate
SPP	-	Serial Port Protocol
APK	-	Android Application Package File Computing
3D	-	Three Dimension
TV	-	Television
PCB	-	Printed Circuit Board
IDE	-	Integrated Development Environment

CHAPTER 1

INTRODUCTION

1.1 Introduction

Ankle injury is a common injury that can happen to almost everybody and some of the injuries can be so minor that the person itself doesn‟t aware that he or she actually have it. Internal rotation of the ankle joint could be one of the causes of ankle inversion sprain injury [1]. We can conclude that active people also are vulnerable to ankle injuries.

Ankle rehabilitation systems are widely developing nowadays and are improving from time to time. Mobile phones are also getting smarter and smarter every day, thus it is believed that if the ankle rehabilitation device is connected to a mobile phone, users can easily trace their daily data using the ankle rehabilitation device. There are many advantages of using a smartphone as a user interface (UI) for the ankle rehabilitation system device. First, the user can keep their own rehabilitation data on their own personal smartphone. Moreover, users also can be occupied with interesting games on the smartphone that integrate with the ankle rehabilitation device. To achieve a positive result from doing a rehabilitation routine is to do it continuously and not stop the session for a long period of time. The user‟s continuity and dedication in using the ankle rehabilitation exercise is the key to achieve improvements on their own quality movements of their ankle.

1.2 Problem Statement

Most ankle rehabilitation system that exists widely on the market are independent and can only work on its own. It cannot connect with other smart devices as in a computer or any other operating system (OS) android or iOS. Thus to ensure the ankle rehabilitation system is able to interact with other intelligent device, an Arduino board will be used to design an embedded system between the ankle rehabilitation device and to a smart device. Usually, the main problem with a health based device is the user will easily get bored with the same routine and interface, thus when there is an interactive game are meant to be played with the ankle rehabilitation device. The thrill of using the system will be lengthened to a longer period of time, thus making the device to be used for a longer time before the user gets bored of the device.

1.3 Project Objectives

The project objectives are as follows.

i. To design and develop a prototype of ankle rehabilitation system
ii. To develop connections between the ankle rehabilitation system prototype with an android device.
iii. To develop a basic game that can be played by the ankle rehabilitation prototype

1.4 Project Scope

The project scopes are as follows.

i. This project will need to design a prototype of an ankle rehabilitation system using servo motors, a platform, an android device and also an Arduino UNO.
ii. The completed prototype of an ankle rehabilitation system will be connected to an android phone that the prototype can use the phone‟s accelerometer to calculate the tilt angle of the user‟s feet applied.
iii. A basic game will be designed to be used with the ankle rehabilitation prototype.

1.5 Thesis Outline

This report consists of five chapters that described the project of Design of Ankle Rehabilitation System and Control Using Android platform. In the first chapter, the objective and scope of this project and problem statement is discussed. While Chapter 2 will discuss more on theory and literature reviews that have been done, this includes a brief introduction to Arduino UNO, servo motors, and further explanation about the standard in detail. Finally, how the microcontroller board can connect to a smart android device.

In Chapter 3, the discussion is about the methodology of the project, which includes the hardware and software implementation of the project. The result and discussion will be presented in Chapter 4. Last but not least, Chapter 5 discusses the conclusion of this project and future work that can be done.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The project is needed to design and develop a prototype of an ankle rehabilitation system that can be played with an android phone as an interactive game in phase with the objective of this project. Three servo motors will be used that will move the prototype platform. This project also will be using a Bluetooth module (JH-05) that will connect to Arduino that can transfer data via Bluetooth to an Android phone. Figure 2.1 shows the block diagram of the overview process for this project.

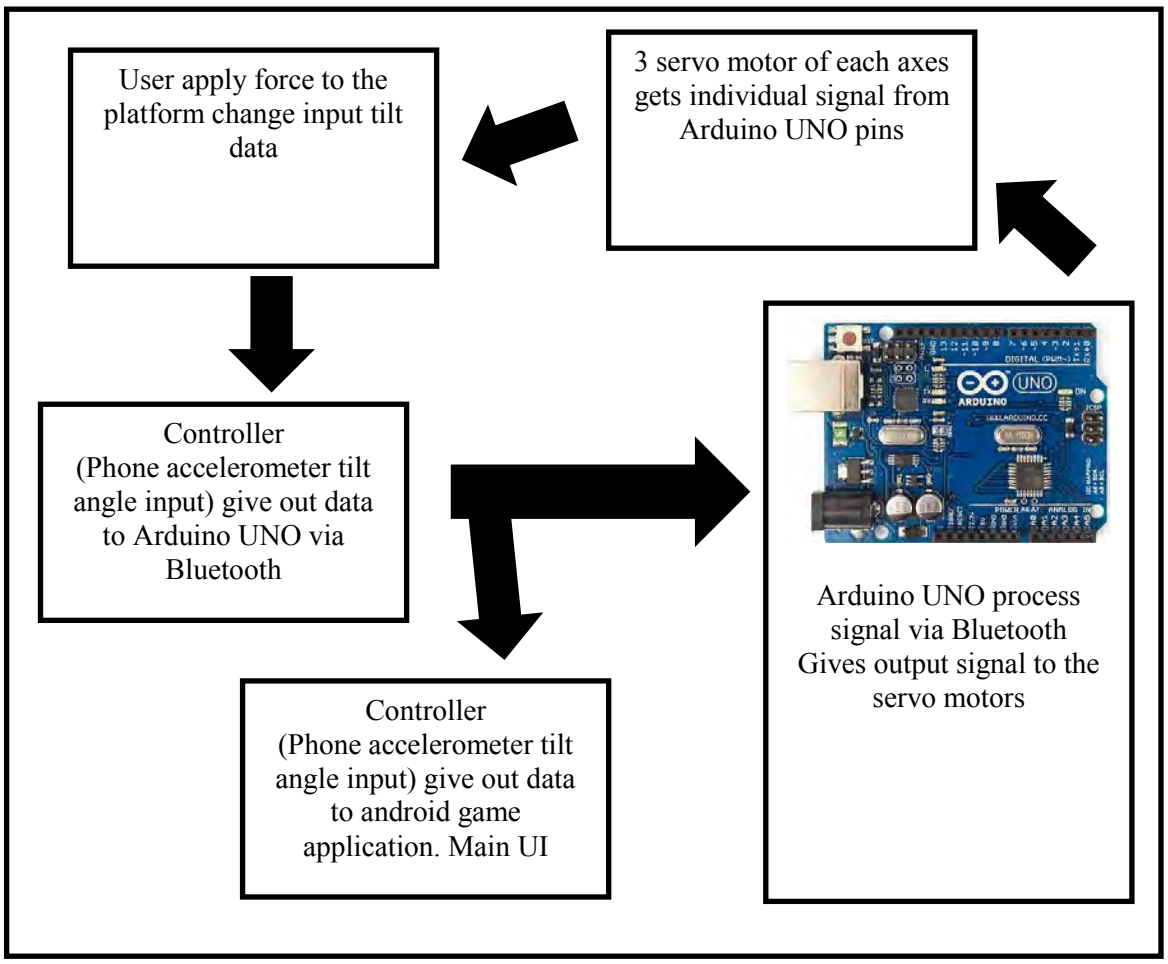


Figure 2.1: Block Diagram of The System

2.2 The Platform Design of The Prototype of Ankle Rehabilitation System.

In this sub topic explained the criteria of this platform design for the prototype. The most important aspect of this platform design, it should able to tilt as the user‟s feet tilt movement, and can be used with either right or left of the user‟s feet. Best type of

ankle rehabilitation system are user friendly, easy to car0ry anywhere, and also adjustable according to user comfort and safety [21].

In previous platform technology that are used in ankle rehabilitation system, are mostly in two degree of freedom, that is the user are only allowed to tilt their feet using the platform to x-axis, and y-axis or any other combination of two axis (2-DOF) only [2] [3] [4] [17], without combining all three axis together, that are x-axis, y-axis, and z-axis. The combinations of these three movements are also known as three degree of freedom (3-DOF) [12] [14] [19]. The advantage of using 3-DOF is, it can imitate the real movement of a normal human ankle, thus provide smoothness in the ankle rehabilitation process.

An example for movements of human ankle joints, 2-DOF tilt angle that is commonly used by 2-DOF ankle rehabilitation systems. Figure 2.2 shows the main rotation of the foot for two axes of the ankle:-

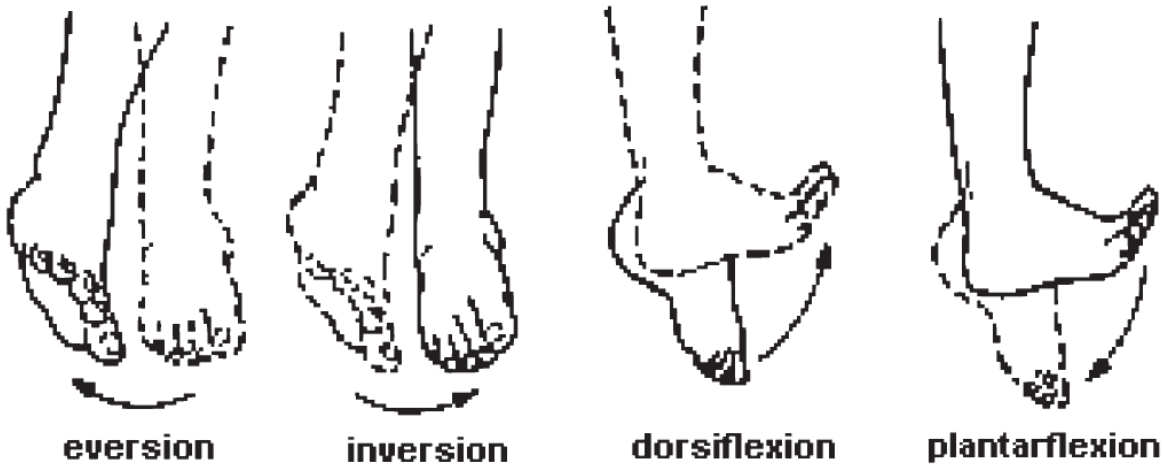
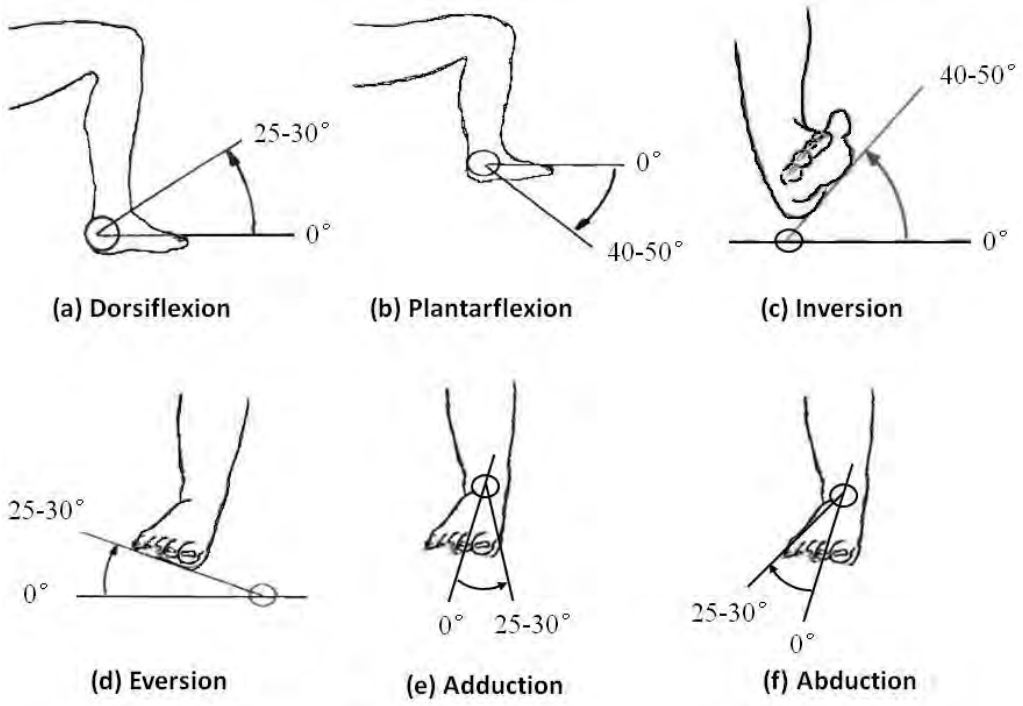


Figure 2.2: Main rotation of the foot about two axes of the ankle. [2]

Moreover, the platform should able to perform or tilt according the tilt limit of the ankle joint movements of a normal human ankle structure and the degree of tilt limit. These are some basic ankle joint‟s movement; Figure 2.3 shows the movement of the ankle joint movement.



a)	Dorsiflexion	0° - (25° - 30°)
b)	Plantar flexion	0° - (40° - 50°)
c)	Inversion	0° - (35° - 40°)
d)	Eversion	0° - (25° - 30°)
e)	Abduction (right)	0° - (25° - 30°)
f)	Abduction (left)	0° - (25° - 30°)

Figure 2.3: Movement of Ankle Joint. [5] [16]

In a nutshell, we can conclude that with a 3-DOF design, we can have more flexibility in putting all of the foot capabilities to tilt in maximum angle that can achieve an effective ankle rehabilitation process. One of the famous 3-DOF platform design is the Stewart platform that is now evolving in the market in many fields and not only for ankle rehabilitation purpose.

The key for the Stewart platform is that it uses a 6 points of controller either using motors or it can also use pneumatic actuators. Thus, it must have 6 actuators to achieve 3-DOF. Figure 2.4 shows an example of Stewart platform that are used in the ankle rehabilitation field using pneumatic cylinder actuators to move the platform, in this case, the platform is a shoe so that it can be worn more firmly without easily being detached during the rehabilitation process.

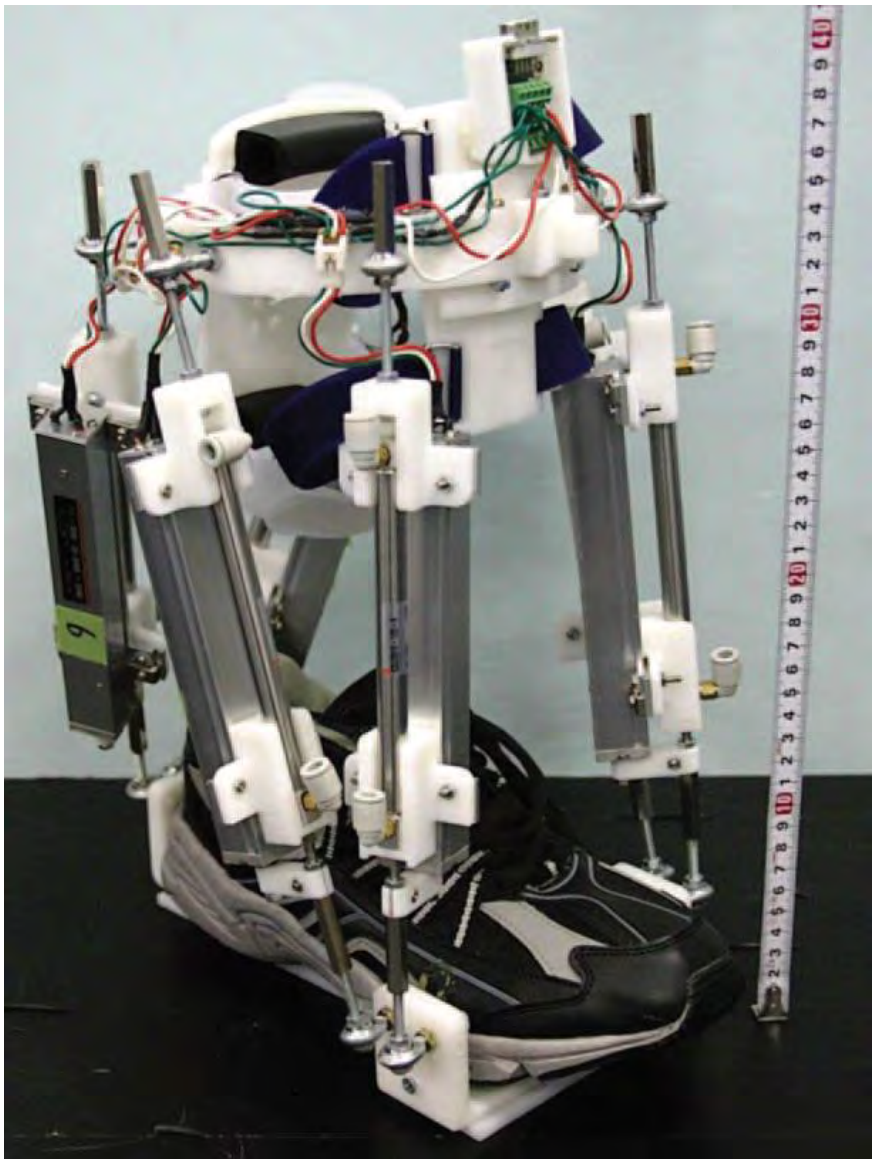


Figure 2.4: Ankle-foot Assist Device [6]

The Stewart platform has a slight drawback in terms of cost and complexity, thus to simplify a 3-DOF design, 3 points of contact to a platform is enough to make the platform having a 3-DOF. Because it uses a 3 point of contact, it only uses 3 motors or actuators thus making it more cost effective than the Stewart platform. For the 3 points of contact, servo motor will be used in this design because of its Arduino friendly and easy to understand.

2.3 Servo Motor As The Platform Actuator.

Servo motor as the suitable motor to connect between the Arduino UNO and the platform to control the tilt angle because, one of the advantages of the servo motor is

it easy to manipulate and programmed by the Arduino board. Moreover, the maximum operating servo motor angle is 180° thus sufficient to work with the ankle rehabilitation system that only needed less than 180° movements all in 3 axes.

Furthermore, servo motors can provide applications with higher controllability and performance [7] [15]. In compare to a stepper motor, servo motor is smaller in size and still can handle the work given. Pneumatic cylinder can also be used as an actuator for this project, but the main drawbacks of using it is that the pneumatic cylinder is it is quite costly, and also it needed some extra components to make it functional, thus make it quite hard and complicated to implement in the system. The pneumatic cylinder is usually heavy in weight, thus it might be difficult to assembly or even to maneuver it around.

Moving on back to the type of motor being used, the servo motor is smaller in size, but still can give the same output torque, the list of different 1 horsepower motor in comparison with its size in diameter are as follows:

i.	AC induction motor	7 – 8 inches (177 – 203mm) in diameter
ii.	SCR motor	4.5 inches (114 mm) in diameter
iii.	DC servos	4 inches (102 mm) in diameter
iv.	AC brushless	3.5 inches (90mm) square

Servo motors also can reduce costs because it can improve efficiency because it‟s only uses energy when energized, unlike hydraulic or pneumatic systems that uses energy continuously (to maintain pressure, the pump must keep going) [7].

Figure 2.5 shows the Servo Motor Efficiency table, it states that the efficiency curve is quite flat in between 40% - 90% range of the motor‟s continuous stall torque, and the efficiency throughout this range is over 85%.

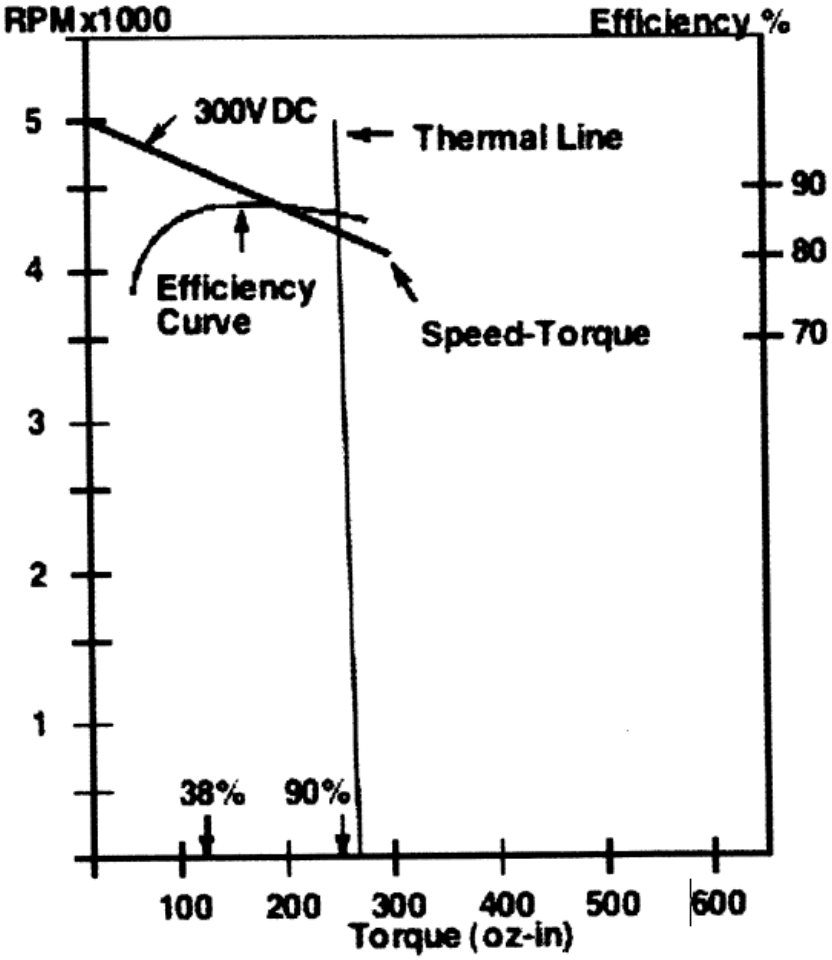


Figure 2.5: Servo Motor Efficiency [7]

As a conclusion, Servos have high force feedback, hence improving productivity, and improving the machine‟s reliability and piece part quality. Servos represent the best long term productivity investment [7]. Thus, for this project, servo motors will be the 3 actuators that will move the platform in all three axes that are x-axis, y-axis, and z-axis

2.4 Arduino UNO As The Controller of The Actuators.

Arduino UNO is one of the easiest to use and it is a flexible, programmable hardware that can control any function that we desired. A dedicated hardware for a specialized function is usually a bit costly and requires additional software to control the needed behavior [8]. Unlike the Arduino board, if there‟s an error in the program, it can be