UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Development of Safety System for XY-Table

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with Honours

By

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APPROVAL

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ABSTRACT

Motorized positioning XY-tables are essential components of electromechanical systems such as machine tools, laser welders, wire bonders, Cartesian type robots and measurement equipment. In these applications, the vital requirement is a good system performance includes the safety system for the XY-table. This project will cover about research survey and analysis regarding to a safety system for an XY-table and introduce the whole safety system development consists of installation device and an integration between the device, emergency stop function and machine interface. Beside that, this project will also introduce the suitable sensing device to prevent damage occurred during machining process. At the end of this project, electromechanical limit switch is use for development of safety at the XY-table. In order to develop the effective safety system for the XY-table, several important processes will be carried out such as mounting, wiring and programming process. Several tests will be conducted such as contact test and connection test to make sure that the safety system functioned well.

ABSTRAK

“XY-table” merupakan salah satu alatan yang penting dalam sebuah sistem elektromekanikal seperti pengendalian alatan mesin, kimpalan laser, robot “Cartesian” dan juga alatan pengukuran. Di dalam aplikasi ini, apa yang paling diperlukan adalah sebuah sistem pengendalian yang baik termasuklah sistem keselamatan bagi “XY-table” itu sendiri. Projek ini adalah berkenaan dengan kaji selidik dan analisis berkaitan dengan sistem keselamatan dan juga turut menerangkan tentang keseluruhan proses pemasangan sistem keselamatan bagi “XY-table”. Projek ini juga turut memperkenalkan alatan pengesan yang paling sesuai untuk digunakan bagi tujuan mencegah berlakunya perlanggaran. Pada peringkat akhir projek ini, “electromechanical limit switch” telah digunakan bagi mengelakkan berlakunya sebarang pelanggaran pada “XY-table”. Dalam proses untuk membina sebuah sistem keselamatan yang benar-benar berkesan, beberapa proses penting seperti proses pemasangan, pendawaian dan juga pengaturcaraan turut terlibat. Ujian khas seperti ujian sentuhan dan ujian penyambungan turut dijalankan bagi memastikan fungsi “electromechanical limit switch” adalah benar-benar berkesan.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

HMI	-	Human Machine Interface
CNC	-	Computer Numerical Control
DC	-	Direct Current
I/O	-	Input/Output
IC	-	Integrated Circuit
AC	-	Alternating Current
NO	-	Normally Open
NC	-	Normally Close
COM	-	Command
EL	-	End Limit
GND	-	Ground
PEL	-	Plus (+) End Limit
MEL	-	Minus (-) End Limit
GUI	-	Graphic User Interface

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CHAPTER 1
INTRODUCTION

1.1 Background

During the past decade, global manufacturing competition has increased significantly. So, the manufacturing industries around the world have been making some fundamental changes including a move to low cost and high quality production. In order to satisfy today's customer the industry needs its product to be in extremely high quality and at the same time can be affordable. In order to achieve this quality product, the industry must apply more automation in manufacturing.

Nowadays, manufacturers use various tools to produce the high quality of product. While using these tools the positional accuracies for them have to be much higher. Machine tool manufacturers are continually searching for greater position accuracies. It is important to ensure the dimensional accuracy of the manufacturer's products or parts.

The numerically controlled XY-table using the conventional lead screw is quite popularly used as the application to achieve the greater position accuracies. But this is not the economical option as there are numerous light duty operations where the power capacity of the lead screw becomes unnecessary. In some cases belt-driven positioning table can be considered as the perfect alternative to traditional lead screw driven tables because the low stretch timing belts can provide suitable condition for light duty operation and have significant accuracy at speeds compared to the lead screw model.

The application of limit switch at the XY-table currently is very popular among the manufacturer. Limit Switches turn off the motor when activated. They are usually used to prevent over-travel of the slider or send an event signal. Nowadays, the manufacturers have an initiative to make the integration between limit switch and human machine interface (HMI) to develop the user friendly safety system at the XY-table.

1.2 Problem Statement

XY-table is equipment that is widely used in industry for need of automation in machining application. For this project, an XY-table has already been given but did not have safety system for the table. A safety system needs to be developed in order to avoid damages and repair cost.

Generally, the XY-table includes motor mounting plates, coupling, lead screws and large base with large top work surface area. The top work surface area can be travel in four directions which are left or right at X-axis and upward or downward at Y-axis. The table will stop traveling when the end of work surface area collides with the edge of an XY-table. Damage will be occurred if the X-axis or Y-axis collides to the edge of an XY-table frequently.

The safety system supposes to have a device that can monitor the position of work surface area plate. In this problem, the observation should be focus on the edge of work surface area plate. For that reason, the most suitable device is limit switch. Limit switch sense the edge of work surface area plate and produce the signal to the system to stop the motor.

The limit switch should be integrated with emergency stop function during the machining application. To make the system more autonomous the system should be integrated with Human Machine Interface (HMI).

1.3 Objectives

The main objective of this final year project is as followed:-

1) To identify the components involved in the safety system developed for an XY-table.
2) To study the integration between sensing devices, emergency stop function and human machine interface (HMI).
3) To install the sensing device and make integration with emergency stop function and machine interface as well.

1.4 Scope

The scopes of this project will cover:

1) **Research Survey, Data Collection and Analysis:**

   From the research survey and analyzing the data collection, it helps author to get important information in developed the safety system for an XY-table. For this scope, necessary data on safety system for XY-table topic was collected by conducting case studies, analyzing journal, book and past researches and searching from internet source which are related to safety system for XY-table.

2) **Installation of limit switch**

   Installation process will considered about some application parameters:

   - **Electrical endurance**

     Along with the current, voltage and type of electrical load (motor, resistive, inductive), the duty cycle should be considered.

   - **Circuit type**

     The type of circuit that is to be used; either normally open or normally closed.

- **Mechanical endurance**

  How many times will this component be actuated to full travel? How will this component be actuated? Interface with the limit switch actuator, and how forces are applied to the switch will affect endurance.
- **Actuator style**

  Decide the actuator that is to be used such as plunger, lever, roller-lever and ball.
- **Travel parameters**

  Parameters such as pretravel, actuation point and overtravel must be considered and the different between each point must be understood clearly.

3) Integration between interface and the system

Integrate limit switch with emergency stop and make some modification at user interface (inserting new option).

1.5 Thesis Content

For introduction chapter, it generally introduces and describes about the project title "Development of Safety System for XY-Table". Student need to write about the background of study and state the problem statement. Here, the objective of the project had been stated clearly for proper project flow. Beside that, the scopes of the project also being notify. So the overview of the project will easy to understand.

Through the literature review chapter, the title had being factually discussed word by word. In addition, the whole thing that related to the project title being discussed in order to make sure the well understanding about the topic could be achieve. Beside that, student needs to discover the previous research that have related with the project.

Methodology chapter discussed about the method of conducting the research. In other words, the chapter will widely brief about the process flow from the beginning till the end of the project that will be use to run the project analysis. Gantt chart as the process planning also being part of this chapter to sure the project has the proper planning for achieves good result.

In result and discussion part, the result of the developing safety system for XY-table will be show in data either in numerical, calculation or figure. The results being analyze to evaluate the performance of the safety system. The result obtain will be discussed either it achieve project target and objectives. This chapter also will discuss briefly about finding and it significant in industrial world. The problem that have been occurs when running through this project also been discussed. Generally, this chapter also will discuss about the whole project that being conduct until that stage.

Finally, this report will conclude about the project that being run either all objectives has been achieved or not. Beside that, this part also summarizes the entire topic that covered in this project. In addition, the chapter will suggest for improvement if have any weakness that being discussed.

CHAPTER 2
LITERATURE REVIEW

2.1 Work Positioning Device

2.1.1 Terms and Definitions for Work Positioning Device

There are many terms that are commonly used in industry that are not always understood by designers, end users, and other technical persons. Although some of the terms take on obvious meanings, others may not. Having the following terms explained and understood allows for a more efficient design process, and a more cost-effective solution.

a. Point to point accuracy

Defined as the difference between the statistical mean of a series of measurements and the theoretically correct position. Another way of stating this is to say that point to point accuracy is the ability to travel to a desired point or series of points with respect to some known reference.

b. Straight line accuracy

The ability of a machine to accurately travel in a straight line with respect to a known reference plane, and the specification refers to the maximum possible deviation from the desired straight line path.

c. Repeatability

Defined as the degree to which repetitive measurements on a single system are in agreement. Another way of stating this definition is to say that repeatability is how close a system returns to a desired location or locations time after time under repeated cycling. Major contributing factors to repeatability are the precision of the bearing ways and the amount of play, or backlash in the system. Repeatability affects how identical parts may differ slightly.

d. Backlash

Defined as the "dead band" experienced when changing directions. This phenomenon is caused by a clearance between interactive elements in a drive train and/or bearing system. Backlash is typically found between gears or between a nut and screw. A common and less technical description of backlash is defined to be the amount of "play" or "slop" in a system. The largest contributing factors to backlash stem from the drive train and bearings being imprecise or worn. Preloading the drive train and bearings will remove excess play in a system, and this type of system is generally referred to as "anti-backlash".

e. Resolution

Defined as the smallest attainable increment of adjustment or positioning. The minimum amount that a positioning system can be moved is referred to as the system resolution. Among the factors that determine resolution are the type of motor and control used, and mechanical advantages found within the drive train.

f. Lifetime

Defined as the cumulative number of linear inches of travel guaranteed by the manufacturer of a linear motion system. This specification varies greatly with load and speed so care should be taken to confirm operating conditions.

g. Friction

Defined as a nonconservative force that acts in the opposing direction of a motion. By means of heat dissipation, friction results in the loss of useful energy and contributes to system wear. As a result of friction, systems become inefficient, inaccurate, and expensive to maintain.

h. Static analysis

Defined as force and torque analysis of a body or system of bodies when they are at rest (or when they are at "equilibrium"). Although acceleration forces are present in all gravitational fields, they are counteracted by equal and opposite forces in a static system and motion is constrained. A static load is load acting on a body or system of bodies that is supported by an equal and opposite force. This type of system is analyzed using Newton's 2nd Law in the case where the accelerations acting on all bodies are equal to zero.

i. Dynamic analysis

Defined as force, torque and motion analysis of a body or system of bodies when they are not at rest (or when they are not at "equilibrium"). A dynamic system will have force and torque acting that is not counteracted, resulting in motion of the body or bodies. A dynamic load is a load that is not supported by an equal and opposite force and results in a dynamic or changing system with respect to motion. This type of system is analyzed using Newton's 2nd Law in the case where the accelerations acting on all bodies may be nonzero. Note that dynamic conditions complicate load and life calculations because of shock loads and vibrations.

Accuracy affects how closely parts are made to specifications. There are many factors that contribute to the accuracy of a system, but the most significant ones are the accuracy of the drive mechanism, the accuracy of the motor, and the presence of play, or backlash. Accuracy may also be referred to as “system error”.

There is a direct relationship between system cost, accuracy and repeatability; therefore it is essential that the terms are understood. If an application involves a motion stopped by an operator, a position sensor, or a mechanical stop, then the application requires only repeatability. Similarly, if an application requires that the same location be found time after time as with inlay applications, then only repeatability is needed. If an application involves cycled point to point motion or exact length motion as with high-precision parts machining, then both accuracy and repeatability are required.

2.2 XY-Tables

2.2.1 Drive Mechanisms

Ideally, a drive system should not support any loads, with all the loads being handled by a bearing system. Some of the terms used with screws, the most common drive component, are as follows:

a) Lead - advance of the nut along the length of the screw per revolution

b) Pitch - distance between corresponding points on adjacent thread forms (Pitch = lead / no. of starts)

c) Number of threads - number of teeth found along a unit length of the screw (1 / pitch)

d) Number of starts - number of helical grooves cut into the length of the shaft

e) Outer diameter - largest diameter over the threaded section (at top of threads)

f) Root diameter - smallest diameter over the threaded section (at base of threads)

g). Stub - specific type of ACME thread where the root diameter is larger to provide for a more heavy duty screw (the threads look “stubby”)

h) Critical shaft speed - operating speed of spinning shaft that produces severe vibrations during operation. This is a function of Length, diameter, and end supports.

i) Maximum compressive load - maximum load that can be axially applied to the screw before buckling or permanent deformation is experienced.

Although shafts, gear trains, belt and pulley, rack and pinion, and chain and sprocket drives are practical in other applications, they require special consideration when used in CNC machinery. This is because there is typically backlash associated with these types of drives, which increases the system error

2.2.1.1 Lead Screw

Lead screws are threaded rods that are fitted with a nut (Figure 2.1). There are many types of threads used, but the most prevalent in industry is the ACME lead screw. Because the ACME thread is an industry standardized thread style, it is easily interchanged with parts from various manufacturers. The basic function of a screw is to convert rotary input motion to linear output motion. The nut is constrained from rotating with the screw, so as the screw is rotated the nut travels back and forth along the length of the shaft. The friction on the nut is a function of environment, lubrication, load, and duty cycle; therefore, practical life cycle is difficult to quantify.