DESIGN AND ANALYSIS A CONTROL SYSTEM FOR 3 AXIS MECHANISM MACHINE

WAN AHMAD AMILIN BIN TENGAH @ WAN NGAH

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering .

…………………................

Name of Supervisor:
Position:
Date:

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurently submitted for award of other degree.

…………………………......

Name:

ID Number:

Date:

To my beloved father and mother

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ABSTRACT

A lot of applications using three axis mechanism machine to make the engineering process easier and efficiencies. Machine such as lathe, turning, milling and grinding are using this mechanism by applying automatic control system The thesis focus on the accuracy and positioning for AC Servomotor in three axis mechanism machine. All of the task would be control by Panasonic Driver which C programming language was utilized.This project is limited to low cost automation and low servo speed. The task of selecting one of which provides efficiently the required functionally for an application is a challenger. The ready availability of manufacturer product catalogues, outlining characteristics and rating of actuators helps in some cases. However, because of inconsistencies in manufacturer information, most engineers resolve to choose based an experience. From this project, the criteria in the selection aid focus in type of nature of control requirement by the application such as position control, speed control and torque control requirement. Proper actuator selection aids in achieving some low cost actuator goals and accuracy. Several term have been used to refer electric motor power electronics such as controller, amplifier, drivers, converter, and inverter depending on the drive of focus.

ABSTRAK

Aplikasi dalam mesin tiga paksi memberi kemudahan kepada proses kejuruteraan dan kejituan. Mesin seperti mesin pelarikan, pembelokan dan mesin pengisar yang menggunakan mekanisme ini selalunya terdapat dalam penggunaan sistem kawalan automatik. Tesis dalam kajian ini memfokuskan kepada kejituan dan keupayaan bagi AC Servomotor dalam penggunaan mesin 3 paksi. Segala tugasan dikawal oleh Panasonic Driver yang mana aturan C digunakan. Kajian ini terhad kepada aturan yang berkos rendah dan kelajuan motor yang rendah. Tugasan dalam menentukan kejituan dan ketepatan dalam penggunaan mesin kawalan merupakan satu cabaran. Garis panduan dalam kawalan motor yang disediakan oleh pembekal membantu dalam banyak kes. Bagaimanapun, disebabkan maklumat pembekal tidak konsisten, maka jurutera menyelesaikan masalah ini berpandukan pengalaman. Dalam kajian ini kriteria dalam pemilihan alatan kawalan memfokuskan kepada sistem kawalan, jenis kawalan seperti kawalan keupayaan, kawalan kelajuan dan kawalan tenaga putaran motor. Pemilihan aturan kawalan yang tepat memastikan penggunaan motor yang berkos rendah dan tepat. Beberapa penggunaan kuasa motor elektrik seperti pengawal aturan, amplifier,dan ’converter’, yang bergantung kepada fokus aturan.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Nowadays, three axis mechanism machine has been widely use in this world. A lot of applications are using this mechanism and make the engineering process easier and efficiencies. Machine such as lathe, turning, milling and grinding are using this mechanism by applying automatic control system and applied engineering devices with some sensors.

The introduction of three axis mechanism machine has changed the manufacturing industry by increasing the automation of manufacturing process which the improvements in consistency and quality has been achieved. In addition, these machines are more flexibility in time to produce different components.

Machine control is an important part in an automation control and the quality of the machining process is determined by machine control performance. Performing an optimum machine control is due to the complexity of machining process and hardware system. Considering both machining process and hardware system will make the machine control running better in real-time domain. Researcher investigated the use of linear motors as feed drives and showed that the quality of the machining are dependent on the interaction of the cutting process and the feed drive servo loop in a direct drive.

The main part in machining process is cutting force. A fundamental theory of model cutting force was developed by Martelloti and Tlusty. Tang et. al. and Zheng et. al. were focused on cutting force for end milling, while cutting force for face milling was obtained by Kim and Ehmann and Cheng et.

The dynamic behavior of the system must be considered in analyzing cutting force to come out with optimal cutting parameter. Sutherland and DeVor, Montgomery and Altintas, Budak and Altintas, and Ismail et al. were analyzing cutting force with the effect of machine tool spindle.

1.2 Project objective

1. Design a control system for three axis mechanism machine.
2. Predict a servo speed by analyze the parameters and characteristics of tracking control of feed drive in machine.
3. Analysis the parameter of controllability (position control) for AC servo.

1.3 Project Scope

1. Design a control system and analysis the error in machine.
2. Data collecting for the conceptual design such as linear motion guide.
3. Testing and programming for machining setup.
4. Automation application be limited for low servo speed.
5. Using software **PANATERM** Panasonic Digital AC Servo Amplifier for parameter analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of control system

A control system is a device or set of devices to manage, command, direct or regulate the behavior of other devices or systems. There are two common classes of control systems, with many variations and combinations like logic or sequential controls, and feedback or linear controls. There is also fuzzy logic, which attempts to combine some of the design simplicity of logic with the utility of linear control. Some devices or systems are inherently not controllable.[1]

The term "control system" may be applied to the essentially manual controls that allow an operator to, for example, close and open a hydraulic press, where the logic requires that it cannot be moved unless safety guards are in place.

An automatic sequential control system may trigger a series of mechanical actuators in the correct sequence to perform a task. For example various electric and pneumatic transducers may fold and glue a cardboard box, fill it with product and then seal it in an automatic machine.[1]

In the case of linear feedback systems, a control loop, including sensors, control algorithms and actuators, is arranged in such a fashion as to try to regulate a variable at a setpoint or reference value. PID controllers are common and effective in cases such as this. Control systems that include some sensing of the results they are trying to achieve are making use of feedback and so can, to some extent, adapt to varying circumstances. Open-loop control systems do not directly make use of feedback, but run only in pre-arranged ways. [1]

2.2 Components of 3 axis machine

An axis is a direction of motion controlled by the CNC machine control. It can be linear (motion along a straight line) or circular (a rotary motion). The number of axes a machine has determines it's machining capabilities. For machining centers, a three axis machine will have three linear axes. A four or five axis machine will have three linear axes as well as one or two rotary axes.

The 3-Axis machine was designed to provide a suitable entry-level mechanism for experimentation with 3-axis machining and CAD/CAMM systems. It has not been designed to replace existing, higher end machines such as those produced by industrial company. The emphasis is on accessibility and allows the user to completely modify the in-built firmware on the machine. [2]

In order to fabricate a three axis mechanism machine, there is a need to determine which the components have to utilized so that it can perform smoothly and efficiency.

2.2.1 Linear Motion Technology

The systems and component that move, support, and guide loads move in linear directions. Also the term used to describe automated and semi automated mechanical systems that create Cartesian x, y, z axes of motion. Modern manufacturing process incorporate the use of linear component to allow for rapid , low- friction precision movement. A liner system combined with servomotor, driver, and sensor makes filling these requirements possible. Gear motors and servomotors used as the driving and controlling mechanisms provide feedback, control, and power to the system. Linear motion systems can be divided into three basic subsystems:

1. The drive or control
2. The thrust mechanism or actuator
3. The guideline or support components

The drive or control devices include a variety of electric motors such as linear, stepper, and servodrivers. The thrust mechanism, in conjunction with the drive, provides the thrust and axial positioning accuracy of the load. The guidance mechanisms of the systems control the travel direction and linear accuracy, as well as support the load.[2]

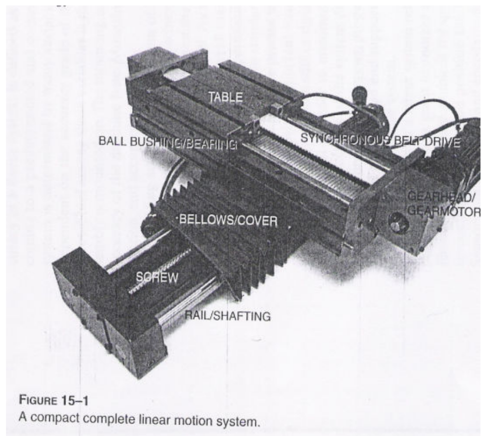


Figure 2.1 Linear Motor System

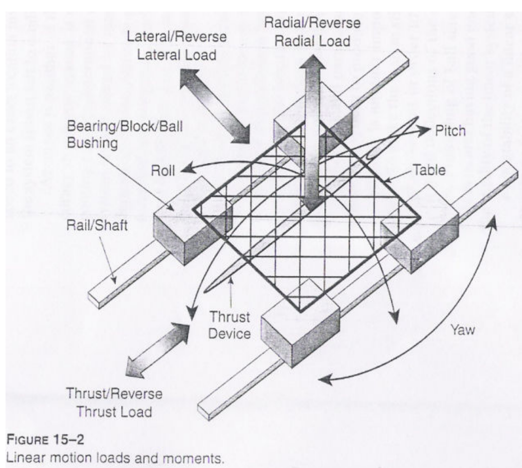


Figure 2.2 Linear Motion Load and Moment

2.2.1.1 Linear Slides

Linear slides is a precision products designed to control the physical movement of a manufacturing robot or an intermediate product under assembly. It can turn motion or torque into thrust. The actual directions and commands for the product positioning come from a computer that effectively control the entire manufacturing process. Application of' the linear slides is to move mounted mechanisms across a given axis either in one direction or combine of three or more directions. Complete linear slides normally consist of at least a base, a saddle, adjusting screws and a straight rib. Linear slides are resistant to contamination, extremely durable in shock load conditions and run smoothly on lightweight frames.

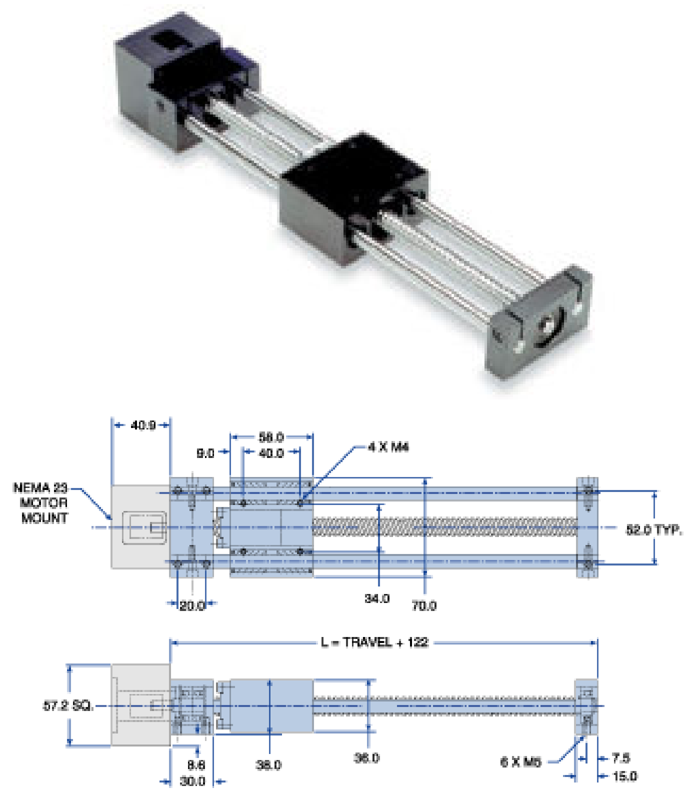


Figure 2.3 Linear Slides

By using linear slides,

(a) Products that having a wide range of weights, from lightweight miniatures to payloads of several hundred pounds can be move easily.

(b) Products can be move in distances that range from as little as 2.5 millimeters to 1.5 meters.

(c) Rapidly position their loads.

(d) They position their loads so precisely, that the final positioning can be measured in microns (millionths of a meter).[2]

Linear slides assemblies use non-recirculating precision balls and rollers that move against highly polished and hardened rod ways, greatly reducing friction. For immense loads and safe operation, dovetail linear slides will be appropriate. Ball bearing slides would be an appropriate choice if a self-lubricating slide with a smaller maximum load carrying capacity is required. Industries that require linear slides for high levels of precision in their manufacturing:

(a) lndustrial robots and machine tool assembly

(b) Fiber optics and photonics component building

(c) Manufacturing semiconductor and electronic equipment

(d) Medical equipment manufacture

2.2.1.2. Ball bearing slide (ball slides)

Most commons type of linear slides due to the self-lubricating qualities, which increase their reliability. Ball bearing slides are composed of two rows of balls on both sides of the base, the rows being contained by four rods. Functions of two rows of balls are to eliminate play and roll along the rods to create smooth, accurate, and low-friction motion. Thus, it can perform with a smooth linear motion; typically use four hardened and ground shafts that surround the balls at four different points.

The base length, base height, carriage length, carriage width, and top height specification to choose a particular ball slides. Larger slides can handle bigger loads, but the slide has to be able to fit into the housing or drive system. Ball bearing slides mostly use for delicate instrumentation, high-cycle applications, and clean room environments.

2.2.1.3 Dovetail slides

Dovetail slides are used in high load applications that require long travel distances and/or damping. Dovetail slides consist of a saddle or flaring tenor and a fixed base. Dovetail slides represent the simplest type of linear translation stages. They have relatively high stiffness and load capacity, and they can provide long travel. Dovetail slides are more resistant to shock than other bearings, and they are mostly immune to contamination.[4]

Compare to ball bearing slides, dovetail slides have direct contact between the base and saddle. Because of this fact, a greater farce is necessary to move the saddle and thus slowing acceleration rates. The amount of surface contact allows dovetail slides to be used in heavy load applications and various industrial uses. However, dovetail slides should not be used for high precision applications.

The dynamic load carrying ability, the number of inches per revolution of the screw (in dovetail slides with Acme, ball, or lead screws), maximum linear velocity of the carriage required, and the rate and distance of linear movement are an important specification when choosing a particular dovetail slide.

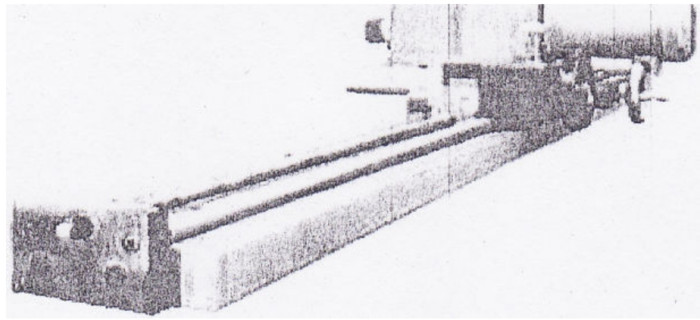


Figure 2.5: Dovetail Slides

2.2.1.4 Machine Slides

Machine slides are a type of linear slide that are used on various machines mostly in CNC machining. They are precision-designed to have close tracking tolerances. By using machine slides, high rigidity can be retained, which creates accurate linear motion for all applications. For machine slides, its have an adjustable ribs in order to make up for any irregular movements that may develop throughout an application.[4]

Machine slides can be single, double, or multi-axis, depending on their intended use. Mostly machine slides will conjunction with ball screws, lead screws, air cylinders, or hydraulic cylinders. Some of the standard types of machine slides include dovetail slides, hardened way slides, linear guide slides, and more.

Dovetail machine slides are used when occasional movement is needed in a positioning application for manual or powered movement. Hardened way machine slides are used in production for high-usage and heavy loads with little required maintenance for years. Of all machine slides, linear guide machine slides hold the highest load capacities for their size and have the lowest amount of friction.

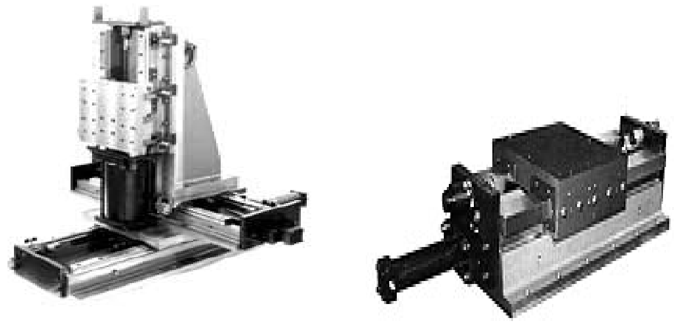


Figure 2.6: Machine Slides

2.2.1.5 Roller Slides

Roller slides, of crossed roller slides have a simple construction, which use perpendicular rollers with a stationary base and moving carriage with higher load capacity than ball bearing. Its utilize rollers that crisscross each other at a 90° angle and move between the four semi-flat and parallel rods that surround the rollers. The rollers are between "V" grooved bearing races, one being on the top carriage and the other on the base. The design of' crossed roller slides allows them to carry up to twice the load of ball bearing slides and to absorb larger impacts or stackable to create multi-axis linear motion. In addition, roller slides are very versatile, as they can be adjusted for different uses.[6]

Figure 2.7: Roller Slides

2.2.1.6 Roller tables

Roller tables are the quietest type of bearing table and made up of a front sliding surface and rear sliding surface that are longitudinally aligned. For secure to rear supporting group, lifting levers are pivoted on a bearing bar. The levers have feeler pins engaged in sliding manners along guiding grooves, which are shaped so that when the front and rear supporting groups are moved away from each other.

2.2.1.7 XY table

XY tables are composed of forces and platens that usually contain motor mounting plates, couplings, lead screws, and a large base and top plate. The forcer glides over the platen on frictionless air bearings and moves continuously in a linear motion across the platen. It is because of linear motoring modules, typically between two and four, responding to currents.[2]

Variations among XY tables include the ways and the drive mechanism. While the drive mechanisms determine smoothness and speed, the ways determine load capacity, straight-line accuracy, and stiffness. Other factors imperative to XY tables are the accuracy, repeatability, and resolution required, as well as the appropriate motor for the application and whether or not an encoder is needed.

XY tables are most often mounted horizontally. Mostly used in applications such as water jet cutting, milling, and table sawing. XY tables may also be used in microelectronics assembly, laser machining and factory automation but depending on the specifications.

Figure 2.8 : XY Table.

2.2.2. Introduction of the Motor

Direct Current (DC) and alternating current (AC) motors are the two main types of electric motor. Both of motors can be differential by analyzing the how the electrical current is transferred through and from the motor. Both types of motors have different functions and uses.

DC and AC electric motors are important to everyday life. DC motors were introduced and caused a great revolution in the way many things are done. When AC motors came on the market the way motors were looked at changed because of their amazing starting power potential. [6]

2.2.2.1 DC motor

DC motors are widely used in application requiring accurate speed control, for example in servo systems. Dc motors come in two general types, they can have brushes or be brushless.

DC motors feature a speed, which can be controlled smoothly down to zero, immediately followed by acceleration in the opposite direction without power circuit switching. Brush DC motors use rings that conduct the current and form the magnetic drive that powers the rotor. Brushless DC motors use a switch to produce the magnetic drive that powers the rotor. Direct current motors are often found in appliances around the home.

2.2.2.2. AC Motor

Alternating current (AC) motors come in two different types which can be single phases or three phases. Single phase AC motors work well in many different situations and known as general purpose motors. This type of motors need a lot of power up front and thus works great for system. For three phase, which also called polyphase are usually found in industrial settings. Mostly used in industrial setting due to these motors have high starting power built transmit lower levels of overall power. Amount of the power needed to operate the system determine the amount of power provided by AC motor.[8]

2.2.2.3. Linear motors

From linear system, the mechanical energy can take the form of rotary-to-linear or direct- to-linear motion. Two common rotary motors used in linear motion: the **stepper** and **servo** types.

The stepper motor is device that provide rotary motion to an actuator, jack , or ball screw to position a load by operating in discrete increments or steps. The stepping action is accomplished by electronically switching the power to the motor windings so that the motor phases are energized in a specific sequence. It can be incorporated into open loop (without position feedback) or closed loop system.

The servomotor is a device that positions a load by operating at a constant speed or torque with a feedback device on the motor. A servomotor is matched to an amplifier that produce power or amps to the power. The amplifier incorporates a microprocessor that implements torque angle control for maximum torque at high speeds. Servomotor generally have greater torque capabilities than stepper motor and run up to 7500 RPM.

With closed loop system, encoder will generate pulses as the motor rotates to indicate the exact position. Controllers and sensors will determine any error between the actual system position and the desired location.[8]

2.2.2.4 DC Servomotors

DC servo motors are normally used as prime movers in application such as computers, numerically controlled machinery, or other applications where starts and made quickly and accurately. Because of servomotors have lightweight, low inertia armatures so it can respond quickly to excitation-voltage changes. In addition, servomotors have a low electrical time constant that further sharpens servomotor response to command signals. The servo motor features a field, which is provided by cast Alnico magnets whose magnetic axis is radial.

Characteristics of DC servo motor including inertia, physical shape, costs, shaft resonance, shaft configuration, speed, and weight. Although these DC motors have similar torque ratings, their physical and electrical constants vary.

2.2.2.5 Stepper Motor

Stepper motors is an electromagnetic actuator which is an incremental drive actuator and is driven in fixed angular steps. It means that a digital signal is used to drive the motor and it receives a digital pulse every time, it rotates a specific number of degree in rotation. Stepper motors are usually operated in open loop mode and offer many advantages, for example, although feedback is not usually required, stepper motors are compatible with feedback signals, either -analog or digital. Error is non-cumulative as well as pulse-to-step integrity is maintained by the stepper motor. A stream of pulses can be counted into stepper motors, and the stepper motor's final position will be known within a small percentage of one steps.

Stepper motors have emerged as cost-effective alternatives for DC servomotors in high-speed, motion-control applications but except for the high torque-speed range with the improvement in permanent magnets and the incorporation of solid-state circuitry and logic devices in their drive systems.[8]

Stepper motors can easily accelerate a load since maximum dynamic torque occurs at low pulse rates. The stepper motor shaft stops and there is no need for clutches or brakes when the desired position is reached and command pulses cease. The stepper motor is generally left energized at a stop position. Once stopped, the stepper motor resists dynamic movement up to the value of the holding torque.

Stepper motors have inherent low velocity without gear reduction. However, the stepper motor's efficiency is low; most of the input energy must be dissipated as heat.

Table 2.1: Advantage and Disadvantage of Stepper Motor

Advantages	*Disadvantages*
Position error is noncumulative. A high accuracy of motion is possible, even under open-loop control.	*They have low torque capacity compared to DC rnotors.*
Large savings in sensor (rneasurement system) and controller costs are possible when the open-loop mode is used.	*They have limited speed (limited by torque capacity and by pulse-nursing problems due to faulty switching systems and drive circuits).*
Easily adaptable to digital control applications due to the incremental nature of command and motion.	*Large errors and oscillations can result when a pulse is missed under open-loop control.*
No serious stability problems exist, even under open-loop control.	

2.2.3 Ball Screw

Ball screws are used in the conversion of rotary movement to linear movement which translates torque into thrust. Assemblies of ball screw consists a screw and a nut. In order to produce a rolling friction between the nut and screw, a steel ball is encased within the round nut. The nut itself can be made of either plastic or metal. The ball screw assembly is powered by a motor. While the motor generates torque, the rotating screw pushes the nut along the screw shaft and producing linear thrust.

There are a few variations of ball screws available for use in industrial settings. The most common are ACME, Lead and Ground ball screws. Each of them different in size and efficiency output on application.

(a) Lead screws do not actually use rollers to create movement but are placed in the same category as ball screws due to their similar function and capacities.

(b) ACME screws most widely used power screw and are a type of lead screw which creates friction between ball and nut.[9]

The most common use for ball screws is in aspects where linear motion is needed. They are often used alongside linear slides and linear actuators to create movement necessary to move parts and devices along a single axis. Ball screws remain beneficial for a variety of reasons.

2.2.4 Lead Screw

Lead screws consist of a threaded shaft and nut to create friction through sliding rather than through the rolling friction characteristic of ball screws. While the lead increases, the efficiency of lead screws increases also. They are still placed in tile same category as ball screws even though they do not use rollers to create movement. It is because or their similar function and capacities. Since lead screws rely on a sliding action, their efficiency is rather low, typically between 25 and 75 percent. The most common type of lead screws is the ACME screw, which creates friction between the ball and the nut.By using lead screws, it will provide:-

(a) smooth operation and accurate positioning over long distances.

(b) self-aligning nuts and long life expectancy.

(c) lack of noise and high performance.

Lead screws are often used to move tables or other parts of a machine. Lead screws can also offer precision and accuracy for graphic imaging equipment, including color scanners, recorders, and printers. In addition, they also provide solutions in other applications, for example in wire bonders, disk drive testers, and linear slide.

2.3 Linear Motion Operating

2.3.1 Mechanism of Ball Screw

Generally, ball screw mechanisms are designed to convert rotary motion of the screw into slow linear motion of the mating member along the ball screw axis.The purpose of analysis the ball screw mechanism is to determine the kinematics and forces in this mechanism.

A basic understanding of the mechanics of a linear motion system is important. The imposed loads are determined by the mass and the center of the gravity location of the load, as well as any induced moments from machine operations. The time required to accelerate the mass of the object being moved will affect the power requirement and must be considered.

Accuracy is another of the primary operating concerns with linear systems. Accuracy in a linear system is defined as how close the system is actually capable of coming to a predetermined and commanded position. The mounting accuracy of the linear guide usually copies the accuracy of the machine base. Mounting errors have an effect on three factors: life, friction, and accuracy.

Holding acceptable parallelism of the linear rails or shaft is imperative to maintain consistent performance and achieve design life. Running parallelism is defined as the error in parallelism between the datum planes of the rail and the block as it traverses over the length of travel.

Rigidity- one of the goals is to make the system stiff or rigid enough to prevent deformation in order to maximize static and dynamic rigidity performance. Unwanted deflections of the system during operation can result in manufacturing errors.

Repeatability of a linear system relates to the system's ability to have the components go from one point to another and back again consistently with little error. So, how much error is acceptable is the question. The servodrive as a device can provide feedback to the controller and drive mechanism, also to compensate for errors and position the table accurately. [9]

2.3.2 Speed and Feed Effect To Linear Motion

2.3.2.1 Cutting Speed (V)

One of the most important factors affecting the efficiency of a milling operation is cutter speed. If the cutter is run too slowly, valuable time will be wasted, while excessive speed results in loss of time in replacing and regrinding cutters. In order to be able to work economically and efficiently, it is important to select the cutting speed best suitable to the job.

The cutting speed of a metal is defined as the speed in metres per minute at which the metal can be machined efficiently. Its symbol is V. It is expressed in metre/min.

Formula:

Cutting speed = diameter of cutter x π x spindle speed

or

$V = d \times \pi \times n$ (m/min)

2.3.2.2 Feed drive

Feed drives produce slide traverse. The slides either move workpiece or tools during machining. When the drive motor rotates the screw, the nut moves longitudinally thereby traversing the slide together with the work table along the ways.

Figure 2.9 Feed Drive for Work Table

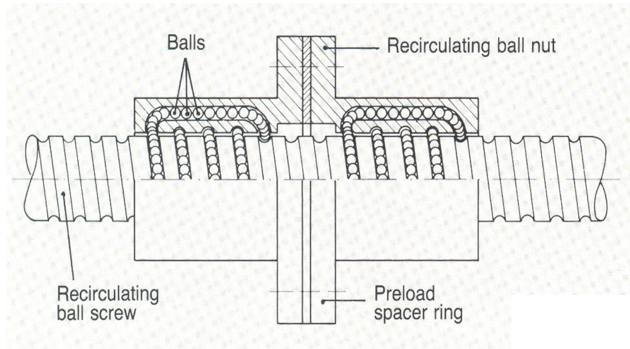


Figure 2.10 Recirculation Ball Screw Drive

The recirculation ball nut contains a system of balls [Figure 2.9] which ensures low-friction power transmission from the screw to the slide. The two halves of the nut are preloaded in relation to each other so that backlash is reduced to a minimum and slide traverses achieve high repetitive accuracy.

2.3.2.3 Feed

Feed in milling machine is defined as the distance in millimeters per minute that the work moves into the cutter. It is expressed in mm/min.

Formula:

Feed = number of teeth in the cutter x recommended feed per tooth x rpm

or

$$f = N \times \text{feed/tooth} \times \text{rpm}$$

Factors on which feed rate depends on

The feed rate used on milling depends upon several factors, such as:

- The depth and width of the cut.
- The design or type of the cutter.
- The sharpness of the cutter.
- The workpiece material.

- The strength and uniformity of the workpiece.
- The type of finish and accuracy required.
- The power and rigidity of the machine.

The table below give suggested feed per tooth for various types of milling cutter roughing cuts. For finish cuts, the feed per tooth should be reduced to half or even one-third of the value shown.

(FOR HIGH SPEED STEEL CUTTERS)

Type of tool		Feed/tooth
Cylindrical cutter		0.05 - 1
Shell-end cutter		0.05 - 0.15
Coarse-toothed shell-end cutter		0.05 - 0.08
Shank-end cutter	diam. 5 – 10	0.02 - 0.04
with 2-3 teeth	diam. 12 – 30	0.05 - 0.1
Multi-tooth shank-end cutter	diam. 5 - 12 diam. 16 - 40	0.01 - 0.03 0.04 - 0.05
Coarse-toothed shank-end cutter	diam. 10 - 20 diam. 22 - 40	0.01 - 0.02 0.025 - 0.04
Disc cutter		0.03 - 0.1
Profiling cutter		0.03 - 0.06
Slot saw		manual feed
Tools for hollow turning/drilling		0.03 - 0.1
Cutter head		0.06 - 0.1

Table 2.2 Recommended Feed Per Tooth

2.4 PANATERM for Panasonic Digital AC Servo Amplifier Analysis

One of project objective is to predict a servo speed by analyze the parameters and characteristics of tracking control of feed drive in machine. PANATERM® assists users in setting parameters, monitoring control conditions, setup support and analysing mechanical operation data on the PC screen when installed in a commercially available personal computer and connected to the MINAS series through the RS232C serial interface. As MINAS series amplifier has a function to establish serial communication with a marketed personal computer can change parameters and monitor a control status of the amplifier on personal computer.

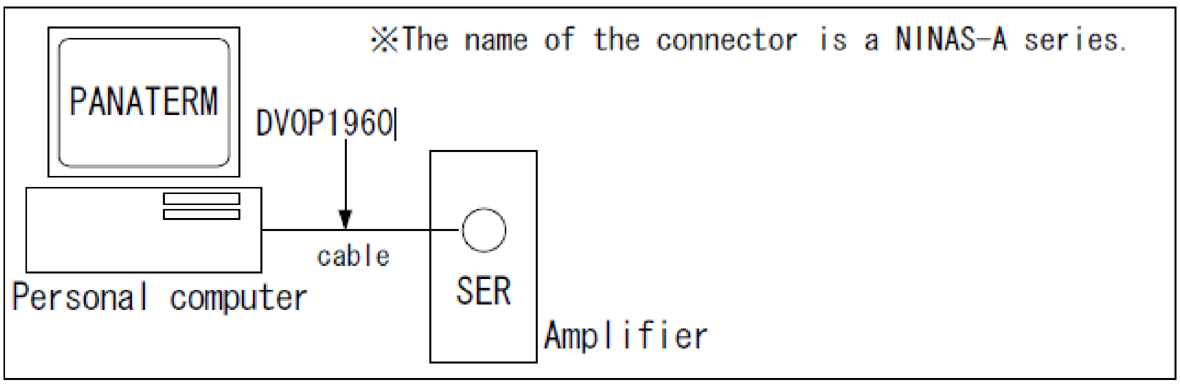


Figure 2.11 PANATERM serial communication

The advantages of PANATERM are numerous and important. It can conduct the following operations:

1) Setting the parameters for amplifier, storing them, and writing in the memory (EEPROM)

2) Monitoring input/output status, monitoring pulse input, monitoring load ratio.

3) Checking current error status and error history.

4) Measurement of wave form graphic data, and storage and reading of the data.

5) Automatic tuning.

6) Measurement of frequency characteristics.

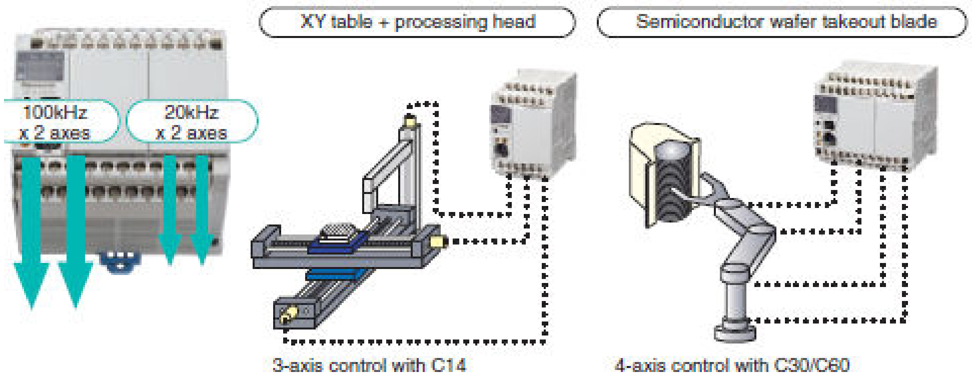


Figure 2.12 Multi-Axis Positioning Control in Small-Scale Equipment

2.4.1 Panaterm software.

Basic function Parameter setup

Once a parameter is defined, it will be automatically downloaded to the servo drive and unused parameters can be filtered out resulting in frequently used parameters only being displayed on the screen.

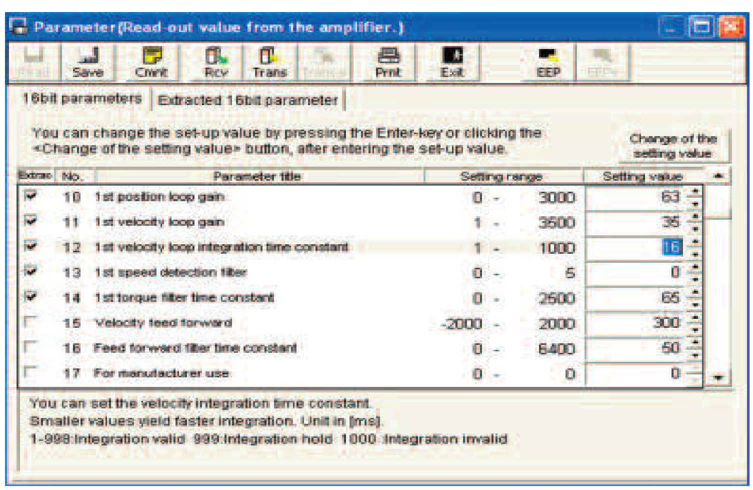


Figure 2.13 Parameter Setup

Monitoring control conditions

The PANATERM software can analyze the parameter of the design in detail such as in control conditions: control mode, velocity, torque, error and warning.

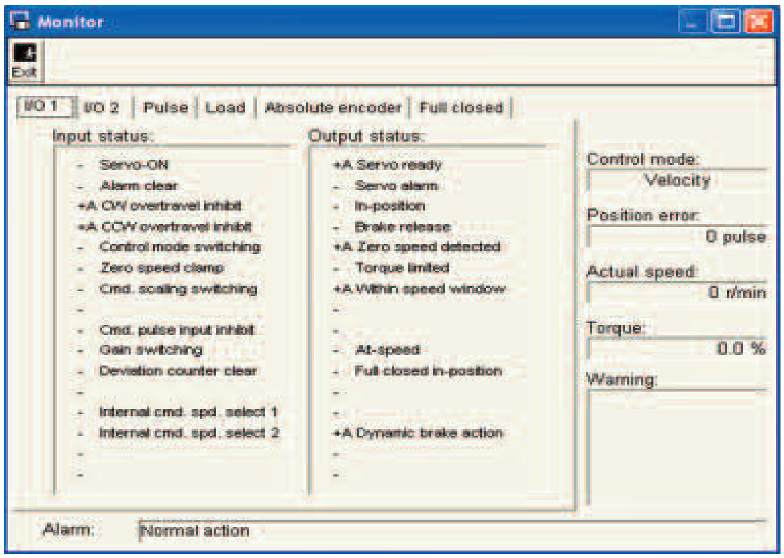


Figure 2.14 Monitor control conditions

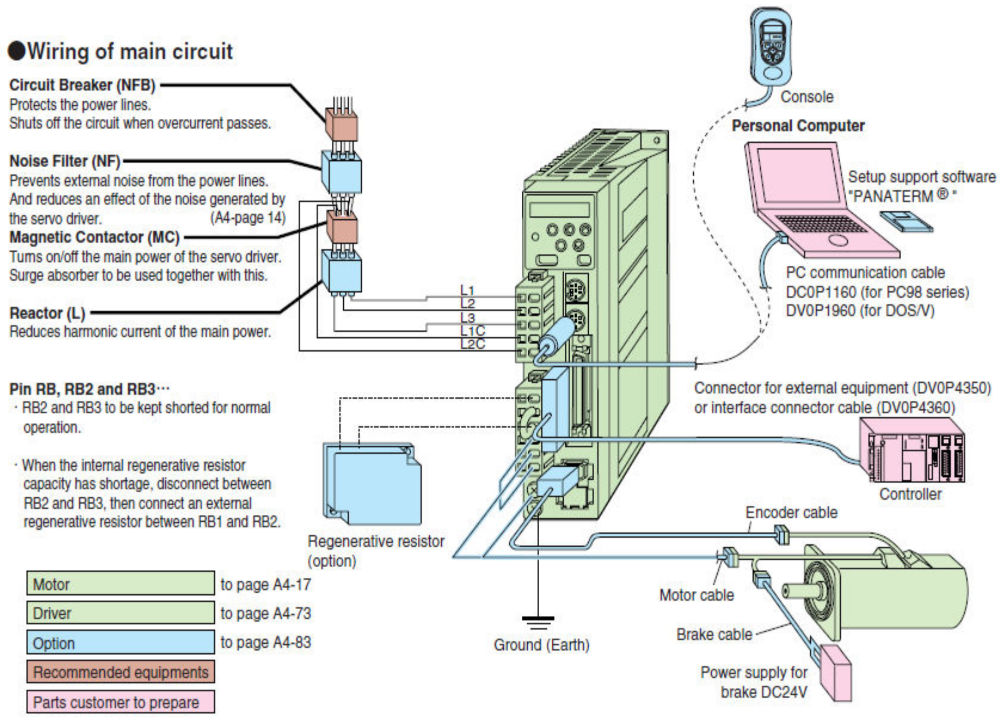


Figure 2.15 Wiring of Main Circuit

CHAPTER 3

METHODOLOGY

3.1 Concept Design

For achieving the goal and scope of the project, all the information about the components, principle and modeling of the three axis mechanism machine have been surveyed. Based on the literature review, the type of linear motion guide has been chose by considering the friction analysis. Other than consider the friction, position control is an important aspect to determine the velocity and type of linear slide guide. Then, by consider the power screw mechanism, determine the type of ball screw that needs to utilize for the project also. AC servomotor, lead screw and dovetail slide become the components of three axis mechanism machine. With all the information, the three axis mechanism machine concept design has been sketch and then discuss for any improvement.

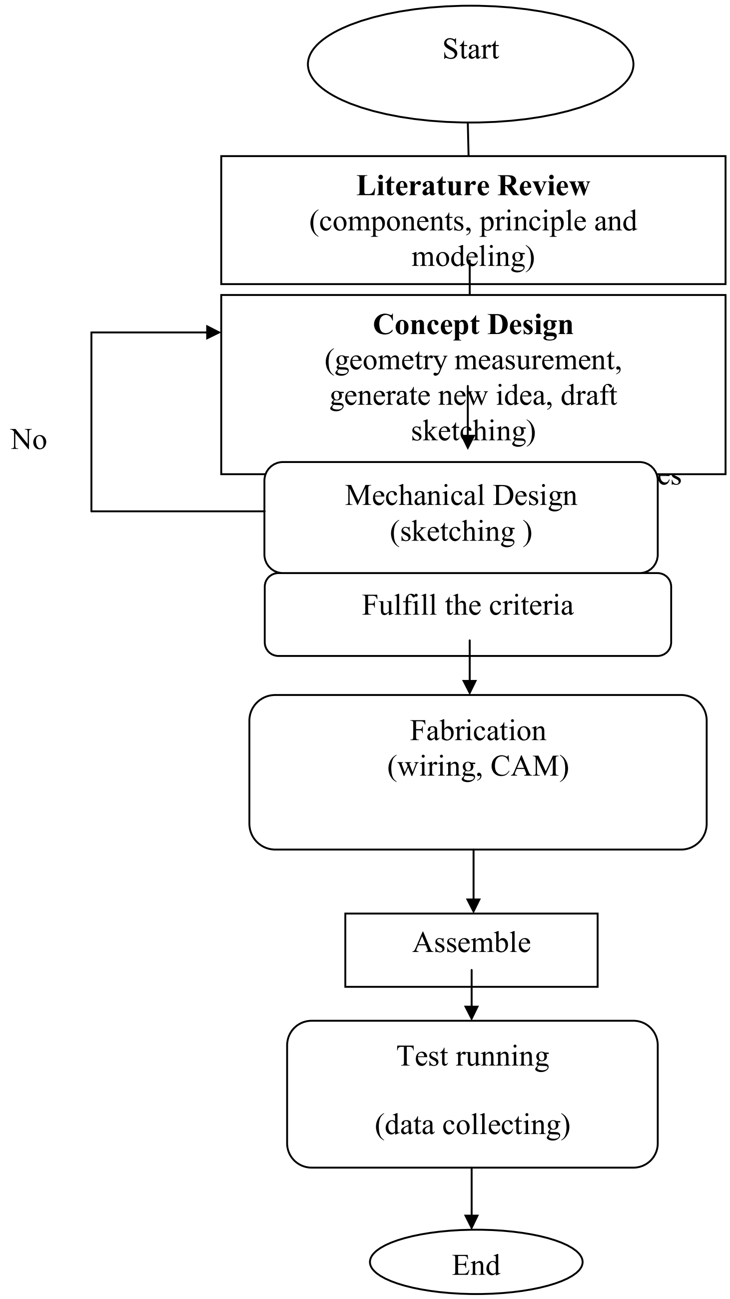


Figure 3.1: Flowchart of overall methodology

3.2 Mechanical Design

After sketch out the concept design, the linear motion guides has been designed for the fabrication process. After fulfill all the criteria of the concept in three axis mechanism machine, the geometry measurement of the components such as AC servomotor and lead screw have been took by using vernier caliper. Thus, to draw out the three axis mechanism machine for the mechanical drawing.

For the first step, the arrangement of wiring at distribution boards have been sketched. The wiring shall be so arranged or marked that it can be identified for inspection, testing, repair or alteration of the installation. For example the wire marked to make sure the component will be at right connection.

For motion part of wiring, the component include of noise filter, converter 240V, driver for each motor and also encoder to attach with the motor. From the distribution board that have been marked, the wiring make easy to attach with each components.

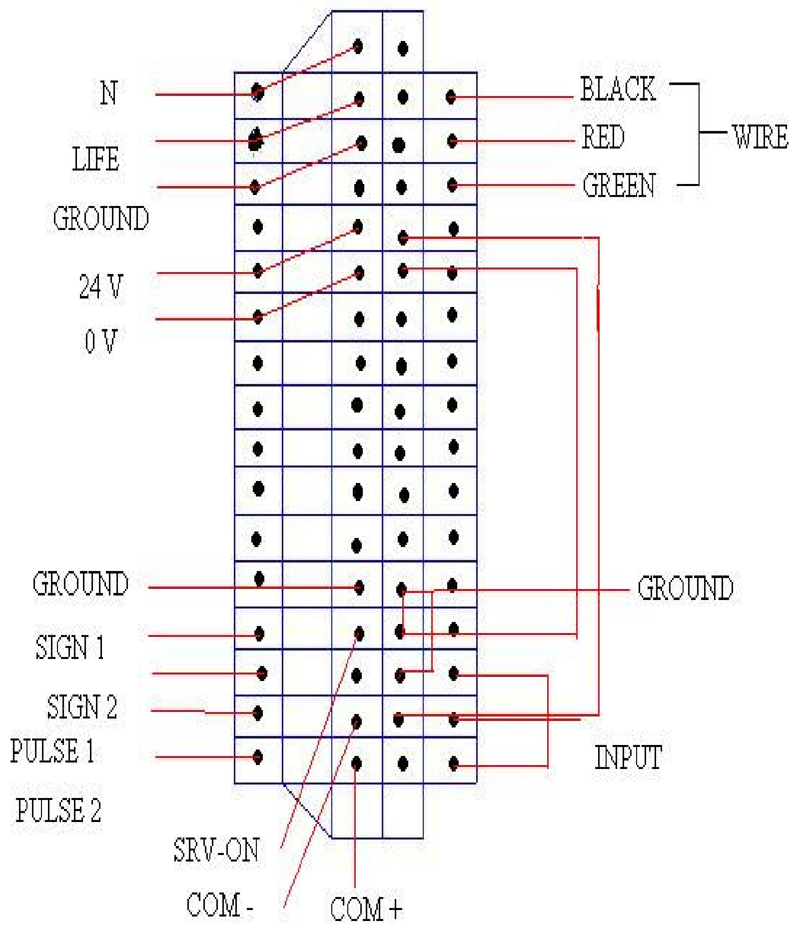


Figure 3.2 The arrangement of wiring at distribution boards

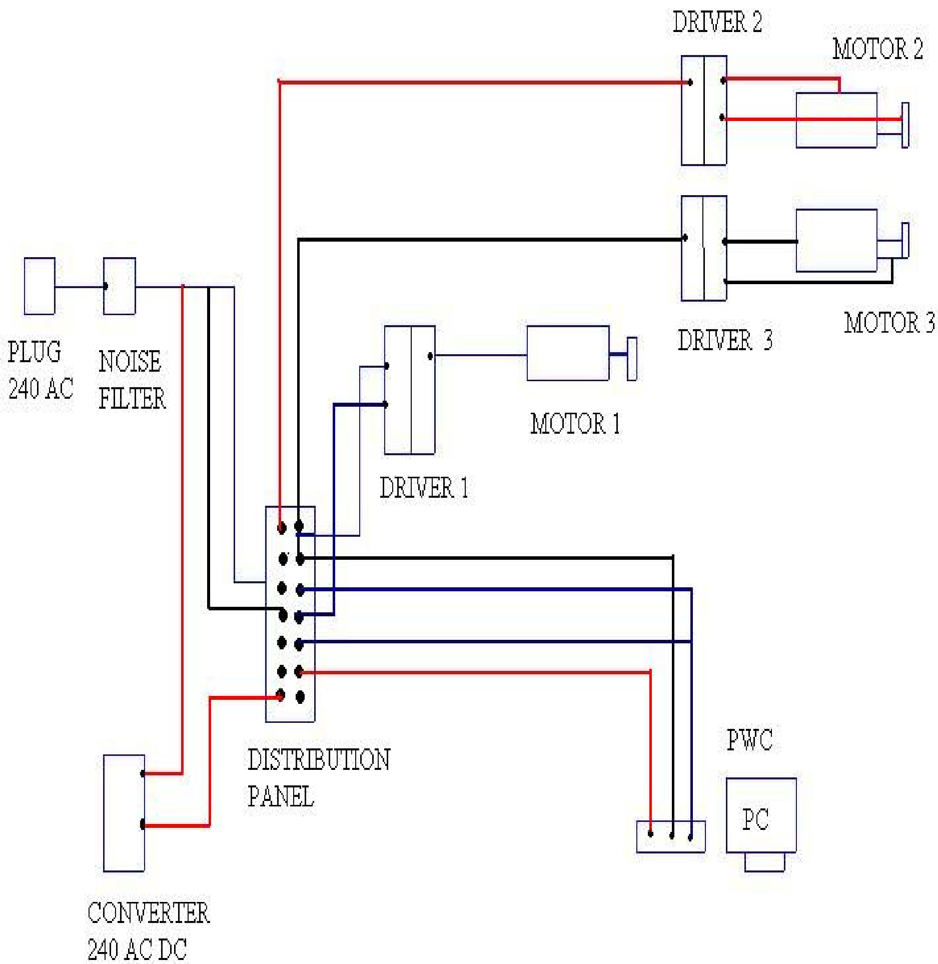


Figure 3.3 The configuration of the control system

3.3 Fabrication of Components of Three Axis Mechanism Machine

After the concept design and mechanical design, fabrication work will be started to make a coupler for ball screw for connecting the gear box and AC servomotor. In this fabrication work, software Computer Aid Manufacturing (CAM) will be used to operate.

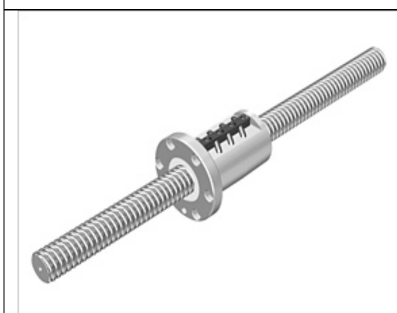
3.4 Structure Part

The structures part may include extrude aluminum bars, mild steel plates and aluminum plates. By using these materials, it can be assembled with iron key screws and phillip screws and a table structure will be produced. For overcome the vibration while the incremental rig test running, the table structure will be assembled with another eight extrude aluminum bars to hold it tightly. By the way, aluminum plates and mild steel plates will be assembled on the extrude aluminum bar for holding the fix supports at the x, y and z-axis.

3.4.1 Motion Part

The motion parts of the three axis mechanism machine are work as a human body. It function as controlling the movement of the tool holder of machining rig test at x, y and z-axis. Its may include:

Table 3.1: Motion Part Components

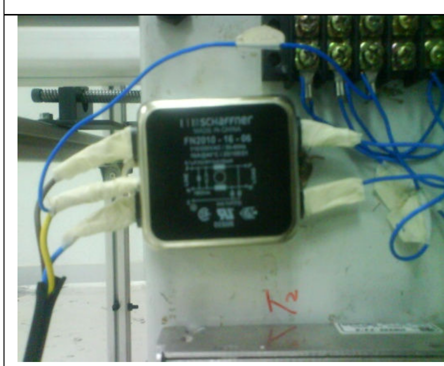
Component	Parts	Definition and functions
	Ball screw	Convert the rotary movement to linear movement, which translates torque into thrust.
	Linear Motion Guides	Control the physical movement of three axis mechanism machine and turn motion or torque into

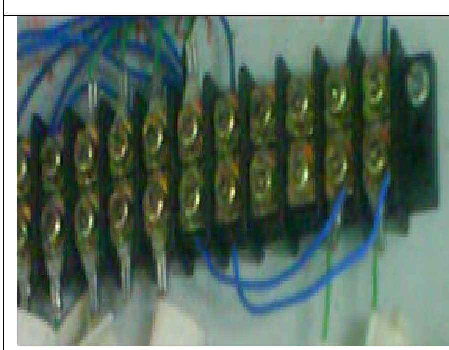
		thrust.
	T-slot Table	Clamping unit will mount on it to clamp the specimens for running the machine rig test.

3.4.2 Control Part

Control parts, which is the main part that function as a human brain, it will send the message or order to the motion parts to run the machining rig test. These control parts may include:

Table 3.2 Control Part Components

Component	Parts	Definition and function
	Noise filter	To prevent electrical shock For signal lines to all cables (power cable,motor cable, encoder cabel and interface

		cable)
	1) Interface cable: DV0P0800 2) Encoder cable (5m) : MFECA0050EAM	As a connector kit for driver power supply connection
	Motor cable (5m) : MFMCA0050AEB	To connect supply from AC Servo Motor and Panasonic Driver also as a connector kit for driver power supply connection
	Distribution Boards	To make a connection between a wire with other power supply and each

		component.
	Converter 240 AC to 24 DC INPUT: 0.35 A	To convert input from power supply 240AC to 24DC
	AC Servo Motor	Provide low inertia for fast starts, stops, and reversals.
	Panasonic Driver	An electronic device to be set for produces an accuracy positioning with constant velocity.

3.5 Assemble of 3 axis mechanism machine

After purchase all the material, fabrication and component work, assemble work is started to produce a three axis mechanism machine which can suit for the machine 3 axis rig test tool. Thus, a prototype can be produce and then, check the machine with supervisor so that can eliminate the any error and problems. Finally, discuss with supervisor for next move.

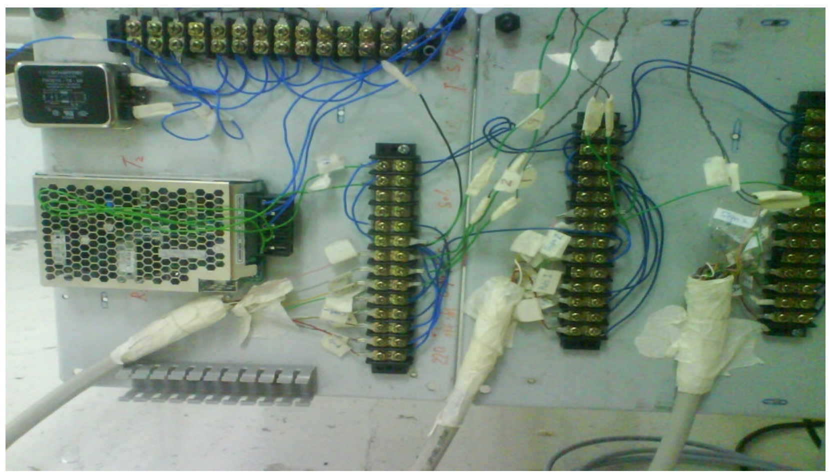


Figure 3.4 Complete design for the circuit

3.6 Test Running

After finish all the fabrication and assemble work, the three axis mechanism machine will merge with a machine language to control the motion of three axis mechanism machine. Borland C is used to write out the programming and then transfer into machine language. Keep on repair and compile it until it appears the word "success". Thus, the final year project is complete and starts testing the three axis machine to collect the data for comparing the theoretical result. A result validation can be performing now.

3.6.1 Programming for machining setup

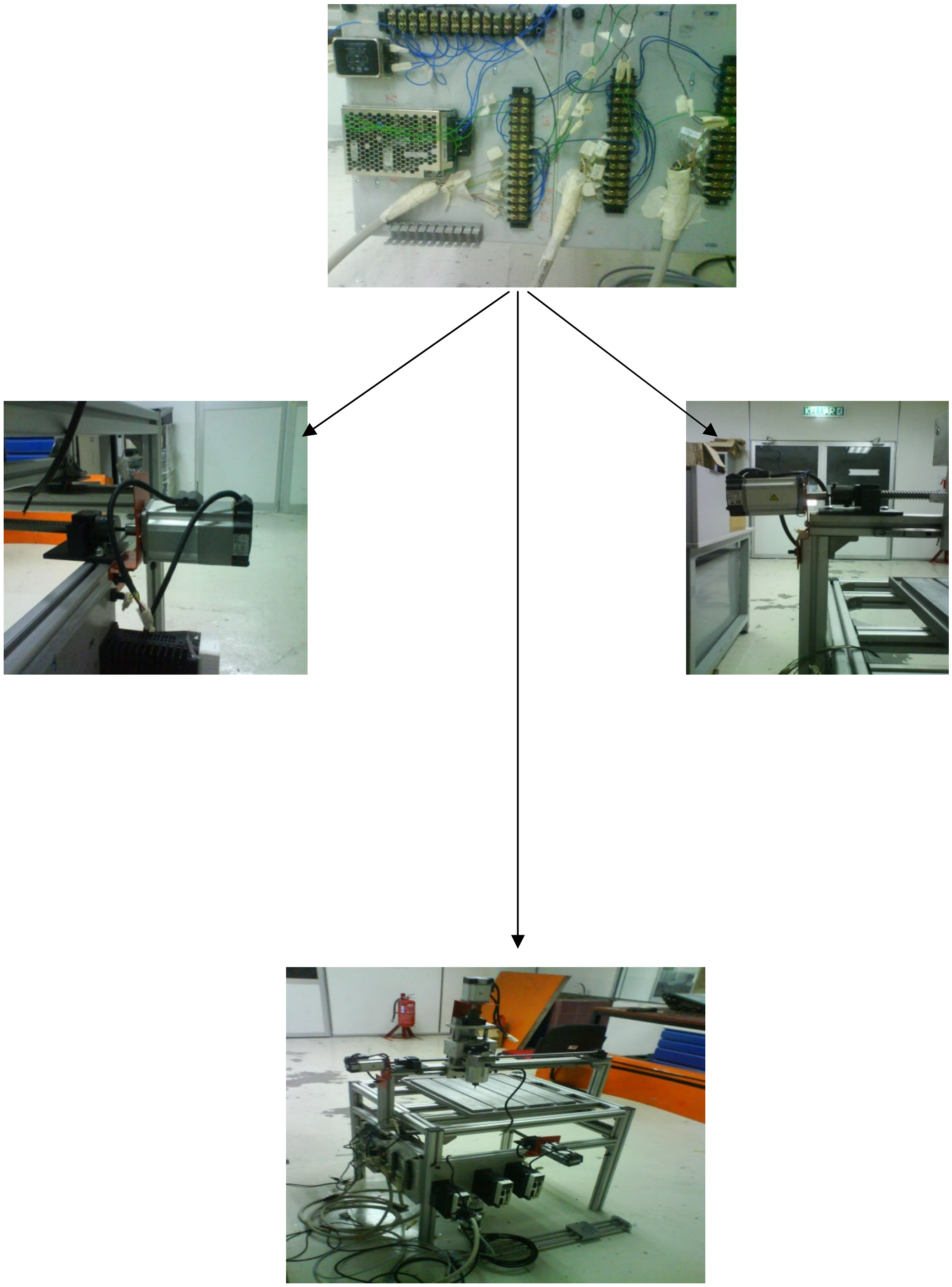
Figure 3.5 Arrangement the component to PC (PANATERM Software)

By using the above programming, it will transfer with a machine language to control the motion of three axis mechanism machine.

```
#include "iocpp.h"
#include <stdio.h>
#include <conio.h>

// 1,0 belakang (hala komputer)
//3,2 depan
//4,0 kanan
//12,8 kiri
int main()
{
int laju =100
;;
        LoadIODLL();
                while (!kbhit())
                {
                printf("Running...\n");
                PortOut(888,3);  // kiri
    Delay(laju);
    PortOut(888,2);
    Delay(laju);
                }
        PortOut(888,0);
        UnloadIODLL();
return 0;
}
//pulse cw+1 and ccw+1
//sign  cw-1 and ccw-1
```

3.6.2 Testing stage for the wiring of main circuit



3.7 Position control experiment

Experimental procedure

Quantitative data that can be used as a basis for the selection of drive configuration. In order to evaluate servo and AC driver's performance. Positioning accuracy of the drives was expressed as absolute error in m/minutes, while accuracy of speed operation was expressed as a function of percentage speed deviation.

i. Certain condition were necessary in order to make appropriate and meaningful measurement.
ii. Maximum linear speed by the servo at 1500rpm and all the experiments were conducted at this linear speed.
iii. The distance travelled was limited to about 620mm by test dimension.

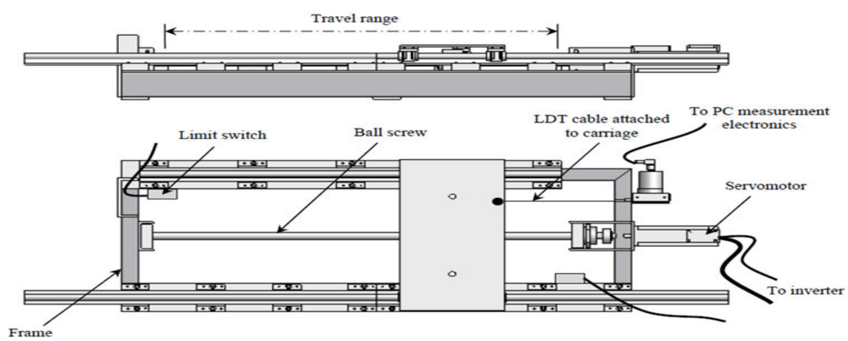


Figure 3.6 Experiment set up for position control

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter will discuss about the result analysis for control system included the ball screw mechanism, AC Servomotor analysis and consideration while doing wiring process and the result of the construction the all components. In order to know the kinematics and forces in a screw mechanism. The analytical technique is used to calculate the motion of ball screw. For AC Servomotor analysis, the PANATERM software will be used to obtain speed control and positional accuracy data. It provides a means to parameterize and start up the motor, as well as an oscilloscope function to monitor (speed control and positional accuracy data) and diagnose the drive.

4.1.1 Details for the flow of the system.

For the first step, the arrangement of wiring at distribution boards have been sketched and shall be arranged or marked. The wire include :

1. From the power supply (marked for neutral, life and ground).
2. For the other component like noise filter, converter , AC Servomotor and drivers. (marked for sign 2 , sign 1, pulse 1, pulse 2, SRV –ON, COM-, COM +, and GROUND).

In this project, three AC Servomotor and drivers will be used. For improving the accuracy and efficiency of the servomotor, gear box of each AC Servomotor will be provided. The flow of the system works start from the power supply which produce 240 AC current to the system. The current connected to noise filter which to prevent the electrical shock. In this system, the current of 240AC should be convert to DC input. The device that will be used is a converter (240AC to DC). All the component will be connect with distribution boards that have been marked. For the start up the motor and to make a running test, Panasonic Driver which C programming language was utilized. To analyze the position accuracy of the AC Servomotor, the PANATERM software will be attach with the system. The data from software was compared with the value of the experiment and from the SEW datasheet. After finishing the data preparation, the matching process starts. The records of the SEW datasheet and the value calculated from experiment are matched with the position control and speed control parameter.

4.2 Motor Selection

The motor selection has to be done carefully because the motor must perform definitely better then the existing one in many areas. And there are some basis requirements in choosing new one. Based on careful consideration, these factors will be base lines for selecting new motor.

- 1. Load
- 2. Reliability
- 3. Lifespan
- 4. Cost
- 5. Installation

During the conceptual design phase it is usually of great importance to determine the proper actuation system to be used. An important reason for proper motor selection is because the choice actuation solution may define the structural design layout and low cost require that design cost be kept to a minimum.

For motor selection, the task of selecting one of which provides efficiently the required functionally for an application is a challenger. The ready availability of manufacturer product catalogues, outlining characteristics and rating of actuators helps in some cases. By the way, a lot of criteria that have been make consideration. For example, literature describes software based procedures which aid the purchaser in selection, in term of types, product avaible, characteristics, energy saving, and cost analysis. Literature with similar selection aids have a somewhat wider application set, however the motor are restricted to the company's models. One such software application is the MSelect3E developed by PANASONIC 2007.

4.3 Ball Screw Analysis

Figure 4.1 Ball screw

For the three axis mechanism machine, ball screws are important parts to convert the rotary movement to linear movement and translate the torque into thrust. Analyze the ball screw mechanism which can show how efficiency and torque can be produced by it. The information of FSW lead screw for x-, y- and z-axis is show as below:

HIWIN Code	R16-16S2- DFSH-621-0.21 R16-16S2-DFSH-200- 0.21
Shaft outer Diameter	16 mm
Lead Angle	30º
Total Length	620 mm for x and y –axis, 200 mm for z axis
Lead	16 mm

Base on the information above, the screw kinematics can be calculated and understand the mechanism.

The pitch diameter of threads,

$$D = \frac{L}{\pi \tan \lambda}$$

$$= \frac{16}{\pi \tan 30^{\circ}}$$

$= 8.82$ mm

When $\mu = 0.20$ (Machined screws with ordinary surfaces)

$\alpha = 30°$ (Metric thread)

The efficiency of power that is transferred through the threads to the nut,

$$e = \frac{l}{\pi D}\left[\pi D\cos\alpha - \mu l \frac{1}{\pi\mu D + L\cos\alpha}\right]$$

$$= \frac{16}{\pi 8.82}(\pi\cos 30^{o} - 0.2x16)\frac{1}{\pi 0.2 \text{ x } 8.82 + 16\cos 30^{0}}$$

$= 0.5774 \text{ x } 20.7966 / 19.3982$

$= 0.6190$

An efficiency of 0.6190 reveals that 61.90% of the power transferred to the nut delivered into lifting or moving the weight. The remains 38.10% is loss in friction. This friction occurs due to the rolling and sliding motion which in contact with the couplers and couplings. These values are considered as acceptable. To obtain higher efficiency, a ball screw can be substituted to another type of threads or ball screw with the lead more than 16mm. However, the cost will be significantly high.

4.4 AC Servomotor Analysis

AC servomotor and Driver are the main parts of the three axis mechanism machine. It controls the movement of ball screw at three axes. By adjusting the parameter of the Driver and AC Servomotor, the force and torque can be control too. Thus, from that, we can calculate the force and torque apply to the specimens with the data below.

AC Servomotor Properties:

Model No.	MSMD04ZPIU
Motor Series	Low Inertia
Power Supply	Single Phase
Input 39AC	106 V, 2.6 A
Rated Output	0.4 kW
Rated Rotational Speed	3000 r/m
Static Friction Torque	0.29 N.m
Rotor Inertia	0.002 x 10-4 m

The angular velocity of AC Servomotor

$$w = \frac{2\pi n}{60}$$

$$= \frac{2\pi(3000)}{60}$$

$$= 314.16 \text{ rad/s}$$

The torque of AC Servomotor

$$T = \frac{P}{W}$$

$$= \frac{400}{314.16}$$

$$= 1.273 \text{ N.m}$$

The force apply of AC Servomotor

$T = Fr$

$F = T/r$

$= 1.273/7.58\times10^{-3}$

$= 169.73$ N

From the calculation above, the angular velocity provide by AC Servomotor is approximately 314.16 rad/s. However , the maximum force provide by AC Servomotor is approximetaly 167.73 N with 1.273 N.m torque. From the equation, it indicated that the rotation speed of selected motor was the main factor with influence the angular velocity of AC Servomotor and hence infects the force and torque also. When rotation speed increase, angular velocity will increase, torque of the AC servomotor will be decrease but force increase.

4.5 Position control experiment

Accuracy of a measurement refers to an ability to indicate a true value exactly. Absolute error (ε) is defined as the difference between the actual value and measured value. Resolution refers to the smallest change in the measured variable that can be obtain from experiment.

ε = | Actual value – measure value |

From this accuracy (A) is found by :

A = 1 - ε / actual value

4.5.1 Motor sensors Analysis

The section gives a brief description of the motor sensor used. The resolution of the encoder on the motor 1024 and for pulley of diameter 76.42 mm, its resolution for a revolution of the shaft is given by :

Resolution in mm = π x 76.42mm / 1024 = 0.235

The resolution for the servo encoder is 32708 and is determined programmatically within the PANATERM software. For a ball screw of pitch 15 mm, its resolution in mm is given by:

Resolution in mm = 15 / 32708 = 0.000458 mm.

4.5.2 Result of position control experiment

- One of the objective is analysis the parameter of controllability (position control) for AC servomotor.
- To determine of positioning accuracies AC servomotor.
- The position control experiment include of ;
  - Determination of actual output position (final rest position)
  - Determination of positioning absolute error (εp) in milimetres.
  - Ep = | final rest position – setpoint target|

TIME (S)	DISPLACEMENT (MM)
0	0
1.0	100
1.5	150
2.0	200
2.5	250
3.0	300
3.5	320
4.0	350
4.5	375
5.0	400
5.5	450
6.0	500
6.5	550
7.0	600
7.5	615
8.0	620
8.5	620
9.0	620
9.5	620
10.0	620

Table 4.1 Data from PANATERM software for 50 rpm

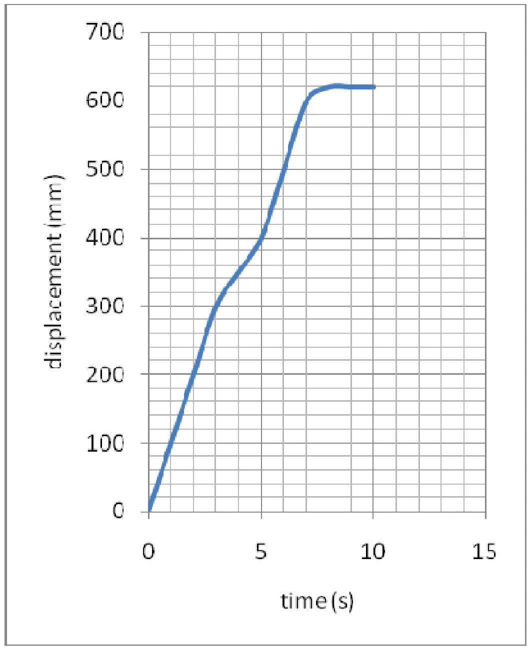


Figure 4.2: Graph displacement (mm) vs time (s) for 50 rpm

Determination of actual output position (final rest position)

Determination of positioning absolute error (εp) in milimetres.

Ep = ׀ final rest position – setpoint target׀

Ep = ׀ 620.5 mm – 620 mm ׀

= 0.5 mm

Figure 4.2 shows the graph of displacement (mm) vs time (s) for speed servo 50 rpm. For this speed, the value of displacement from the zero point of travel range along the linear shaft and the travel length for this experiment was calibrated to 620 mm. After the motor running, the value for displacement and time has been store using the PANATERM Software and this software provides data storage in Excel and other format. For this experiment, the final rest position is 620.5 mm and the calculation of positioning absolute error (εp) is 0.5 mm. The graph show that the displacement increase if time running fast.

TIME (S)	DISPLACEMENT (MM)
0	0
1.0	200
1.5	250
2.0	350
2.5	400
3.0	450
3.5	475
4.0	500
4.5	525
5.0	550
5.5	575
6.0	600
6.5	610
7.0	620
7.5	620
8.0	620
8.5	620
9.0	620
9.5	620
10.0	620

Table 4.2 Data from PANATERM software for 100 rpm

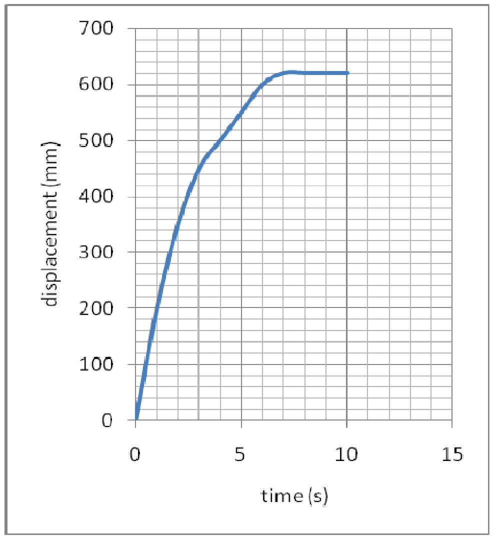


Figure 4.3: Graph displacement (mm) vs time (s) for 100rpm

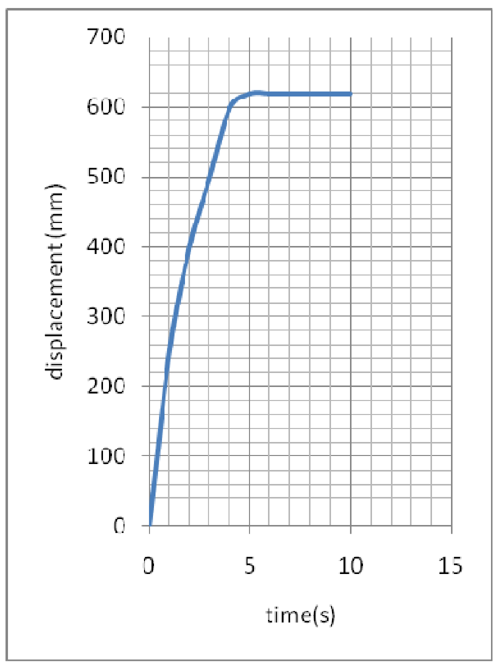


Figure 4.4: Graph displacement (mm) vs time (s) for 150 rpm

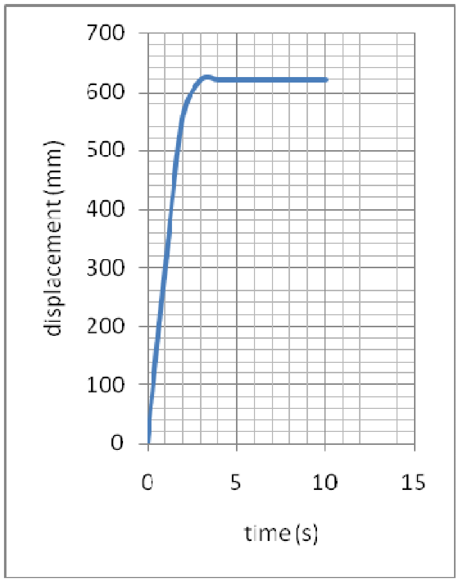


Figure 4.5: Graph displacement (mm) vs time (s) for 200 rpm

Calculation for determination of positioning absolute error (εp) in milimetres. (100 rpm)

Ep = ׀ final rest position – setpoint target׀

Ep = ׀ 620.5 mm – 620 mm ׀

= 0.5 mm

Calculation for determination of positioning absolute error (εp) in milimetres

(150rpm)

Ep = ׀ final rest position – setpoint target׀

Ep = ׀ 620 mm – 619 mm ׀

= 1 mm

Calculation for determination of positioning absolute error (εp) in milimetres

(200rpm)

Ep = ׀ final rest position – setpoint target׀

Ep = ׀ 617.5 mm – 620 mm ׀

= 2.5 mm

SERVO SPEED (RPM)	ABSOLUTE ERROR EP (MM)
50	0.5
100	0.5
150	1.0
200	2.5

Table 4.5 Absolute error readings

The displacement versus time graph (**Figure 4.2, 4.3 4.4 4.5**) above is representative of that encountered with servo drive. The calculation give a summary of the resulting positioning data for AC Servomotor with encoder. From that value, the displacement will increase when the value of servo speed increase, and the absolute error also increase with time. The position control value refers to angular error of motor shaft.

From this experiment, the accuracy of the carriage stop position was observed to be dependent on a combination of several factors. These factor includes the response of the feedback sensing equipment, creep speed , the ramp down and stop time programmatically set on the PANATERM Software.

The distance between the speed change trigger and stop limit switch also effects the stop position, however if this distance is sufficient to allow a complete transition from rapid to creep speed, its effect is minimized. The ramp up or down and stop times were set to zero as the fastest response that can be provided by the SEW data.

From the value of PANATERM software, we can estimate the table and graph provides absolute error for varying rapid and creep speed value for AC Servomotor.

RAMP TIME (S)	% SPEED DEVIATION AT			
	50 RPM	100 RPM	150 RPM	200 RPM
0.03	0.25	0.42	0.73	1.19
0.50	0.16	0.31	0.71	1.15
4.00	0.07	0.12	0.05	0.57

Table 4.6 Speed deviation for varying ramps an AC Servomotor speed with encoder

The minimum and maximum speed deviation obtained for this configuration are 0.07 % and 0.25 % for 50 rpm. For speed of servomotor for 100 rpm, we get for the minimum and maximum speed deviation are 0.12 % and 0.42 %. This speed deviation range (0.07 % to 0.42 %) is much tighter than those obtainable with SEW data and from this results (PANATERM software) which can conclude that speed control indicates provide speed control better when AC Servomotor inverters with encoders.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The main objectives of this study are to design a control system for three axis mechanism machine. From the experiment was conducted, a servo speed predicted by analysis the parameter of controllability (position control) for AC servo. From the information gathered, to design and fabricate a three axis mechanism machine which suited for machine control rig test, the type of motor, linear slide and ball screw are important criteria to determine. For this project, AC servomotor is already fixed due to its extremely high performance and accuracy. In addition, it can provide low inertia for fast starts, stops, and reversals. However, the high resistance provides a nearly linear speed-torque relationship for accurate control. Lead screw is an advantageous screw and more suitable for the design. It can provide smooth operation and accurate positioning over a long distances while it is lack of noise and high performance. Thus, AC servomotor, dovetail slide and lead screw are utilized for the design.

Furthermore, this experiment is focus on the accuracy and positioning for AC Servomotor. The decrease of absolute error (εp) will give the AC Servomotor running fast and accuracy. All of the task would be control by Panasonic Driver which C programming language was utilized. Hence, the experiment could be perform smoothly and efficiency.

5.2 Recommendation

To improve this project and make it more effective, recommendation are needed for further research. Several recommendations are stated as below :

- Range of motion
- Avaible power supply – type of power (AC or DC)
- Load characteristic- nature of load imposed by system / driven load

  System control –type of nature of control requirement by the application such as position control, speed control, open / closed loop, torque control and overshoot
  requirement.
- Noise and thermal emission consideration
- Environmental consideration
- Speed variation
- Starting current, start duty and duty cycle

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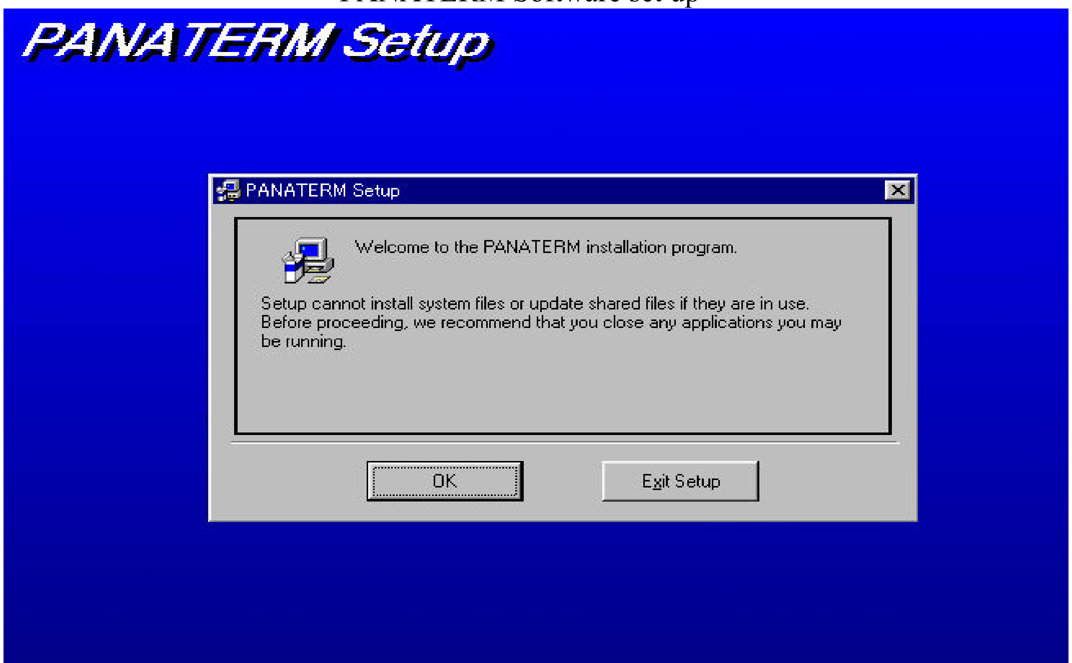
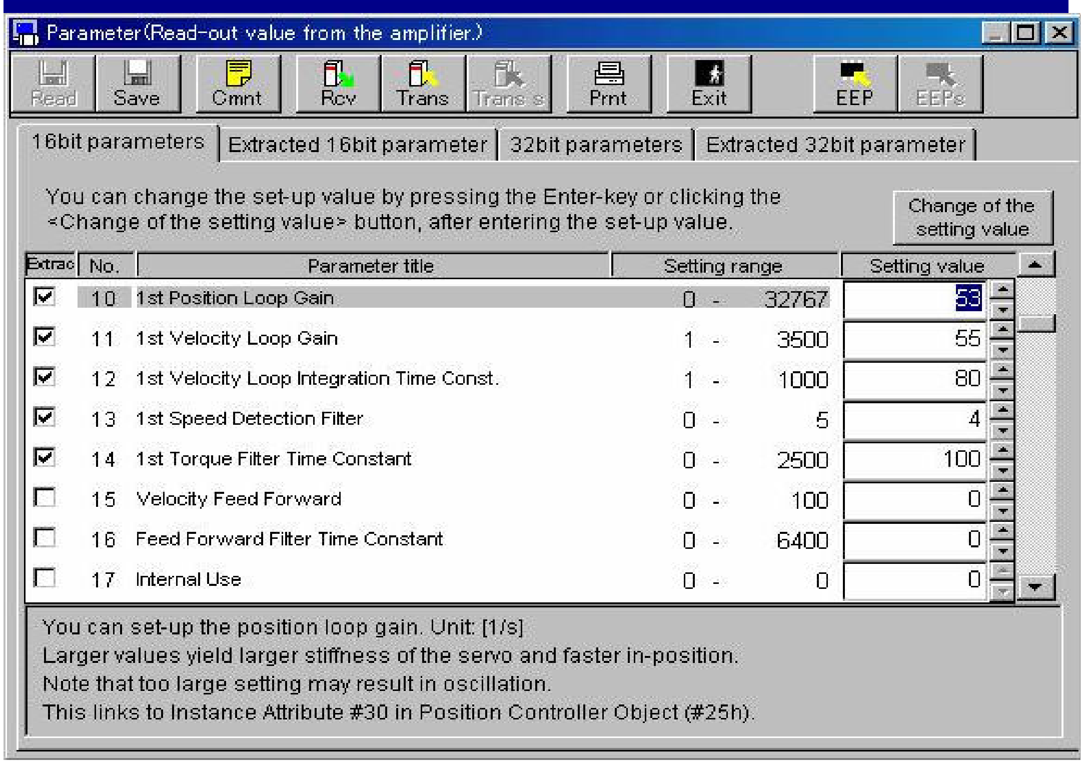
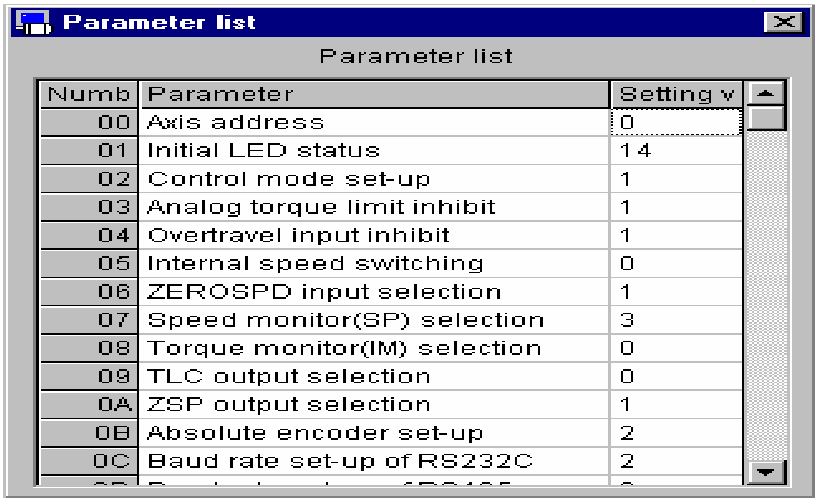
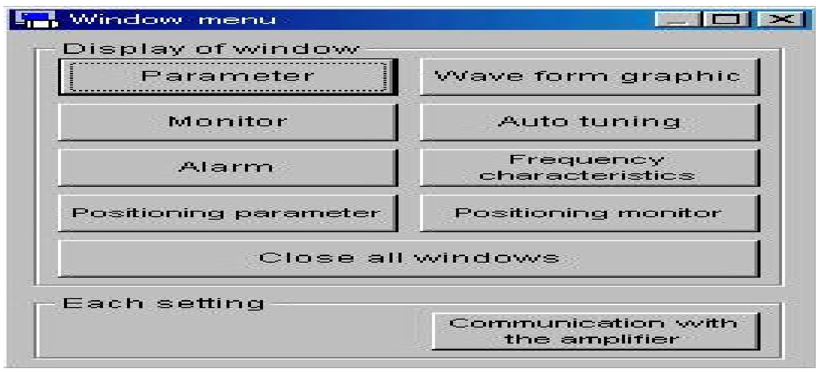
APPENDIX A

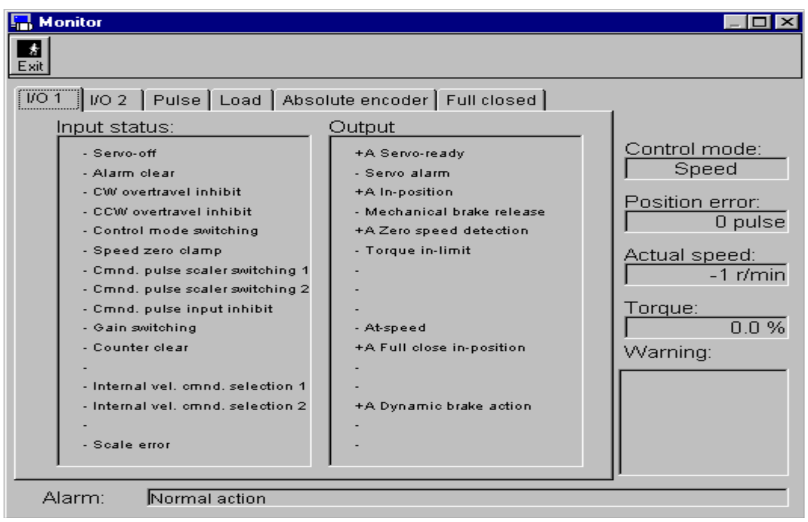
PANATERM Software set up

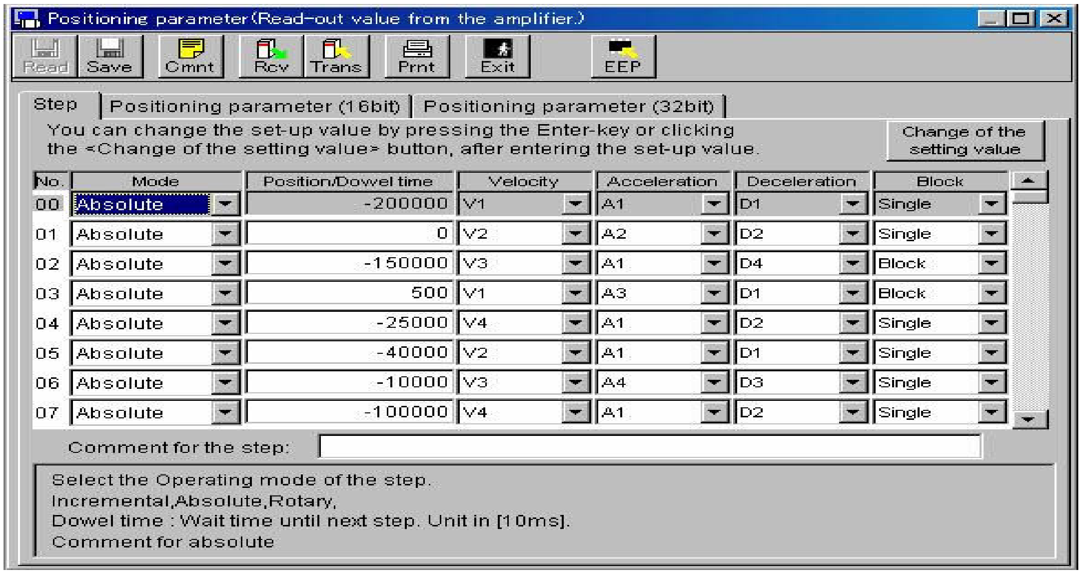


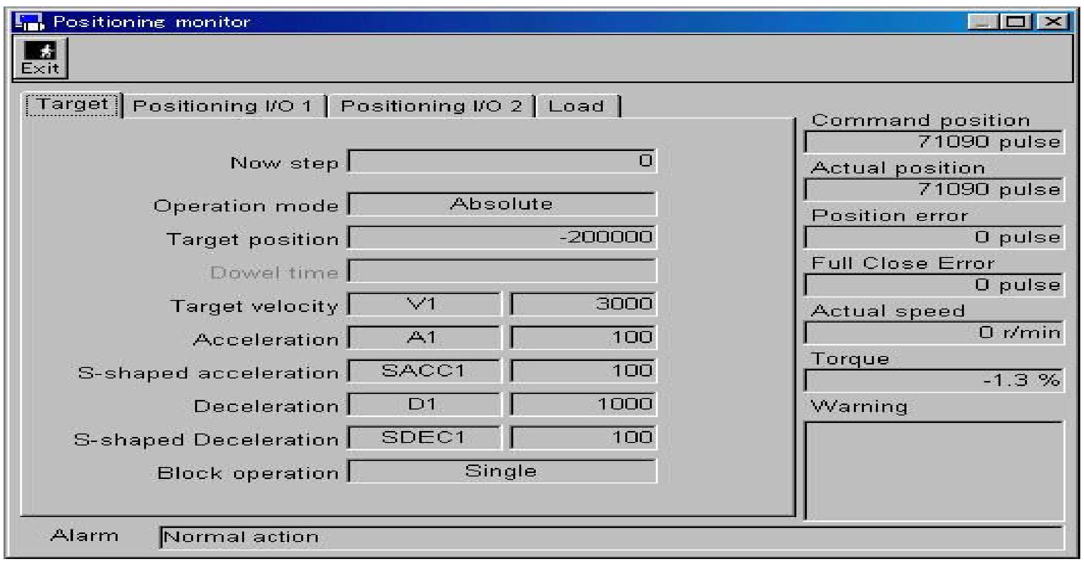



Parameter list
Parameter list
Numb
Parameter
Setting v
00 Axis address 0
01 Initial LED status 14
02 Control mode set-up 1
03 Analog torque limit inhibit 1
04 Overtravel input inhibit 1
05 Internal speed switching 0
06 ZEROSPD input selection 1
07 Speed monitor(SP) selection 3
08 Torque monitor(IM) selection 0
09 TLC output selection 0
0A ZSP output selection 1
0B Absolute encoder set-up 2
0C Baud rate set-up of RS232C 2


Window menu
Display of window
Parameter
Wave form graphic
Monitor
Auto tuning
Alarm
Frequency characteristics
Positioning parameter
Positioning monitor
Close all windows
Each setting
Communication with the amplifier


Monitor
Exit
I/O 1
I/O 2
Pulse
Load
Absolute encoder
Full closed
Input status:
- Servo-off
- Alarm clear
- CW overtravel inhibit
- CCW overtravel inhibit
- Control mode switching
- Speed zero clamp
- Cmnd. pulse scaler switching 1
- Cmnd. pulse scaler switching 2
- Cmnd. pulse input inhibit
- Gain switching
- Counter clear
- Internal vel. cmnd. selection 1
- Internal vel. cmnd. selection 2
- Scale error
Output
+A Servo-ready
- Servo alarm
+A In-position
- Mechanical brake release
+A Zero speed detection
- Torque in-limit
- At-speed
+A Full close in-position
+A Dynamic brake action
Control mode:
Speed
Position error:
0 pulse
Actual speed:
-1 r/min
Torque:
0.0 %
Warning:
Alarm:
Normal action


Positioning parameter(Read-out value from the amplifier.)
Read
Save
Cmnt
Rcv
Trans
Prnt
Exit
EEP
Step
Positioning parameter (16bit)
Positioning parameter (32bit)
You can change the set-up value by pressing the Enter-key or clicking the <Change of the setting value> button, after entering the set-up value.
Change of the setting value
No. Mode Position/Dowel time Velocity Acceleration Deceleration Block
00 Absolute -200000 V1 A1 D1 Single
01 Absolute 0 V2 A2 D2 Single
02 Absolute -150000 V3 A1 D4 Block
03 Absolute 500 V1 A3 D1 Block
04 Absolute -25000 V4 A1 D2 Single
05 Absolute -40000 V2 A1 D1 Single
06 Absolute -10000 V3 A4 D3 Single
07 Absolute -100000 V4 A1 D2 Single
Comment for the step:
Select the Operating mode of the step.
Incremental,Absolute,Rotary,
Dowel time : Wait time until next step. Unit in [10ms].
Comment for absolute


Positioning monitor
Exit
Target
Positioning I/O 1
Positioning I/O 2
Load
Now step 0
Operation mode Absolute
Target position -200000
Dowel time
Target velocity V1 3000
Acceleration A1 100
S-shaped acceleration SACC1 100
Deceleration D1 1000
S-shaped Deceleration SDEC1 100
Block operation Single
Command position
71090 pulse
Actual position
71090 pulse
Position error
0 pulse
Full Close Error
0 pulse
Actual speed
0 r/min
Torque
-1.3 %
Warning
Alarm
Normal action

APPENDIX B

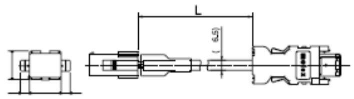
Minas A4/A4N Series Servo Drives (Basic specification)

Basic specifications	**Input power**	**Main circuit**	**Frame A, B**	Single phase, 200–240V $^{+10\%}_{-15\%}$ 50/60Hz
			Frame C, D	Single/3-phase, 200–240V $^{+10\%}_{-15\%}$ 50/60Hz
			Frame E, F	Single/3-phase, 200–240V $^{+10\%}_{-15\%}$ 50/60Hz
		Control circuit	**Frame A to D**	Single phase, 200–240V $^{+10\%}_{-15\%}$ 50/60Hz
			Frame E, F	Single phase, 200–230V $^{+10\%}_{-15\%}$ 50/60Hz
	Environment	**Temperature**		Operating: 0 to 55°C , Storage: -20 to +80°C
		Humidity		Both operating and storage : 90%RH or less (free from condensation)
		Altitude		1000m or lower
		Vibration		5.88m/s² or less, 10 to 60Hz (no continuous use at resonance frequency)
	Control method			IGBT PWM sinusoidal wave drive
	Encoder feedback			17-bit (131,072 resolution) absolute/incremental encoder (on demand only) 2500P/r (10,000 resolution) incremental encoder (standard)
	External scale feedback			Compatible with AT500 series, ST771 by Mitsutoyo
	Control signal	**Input**		10 inputs (1) Servo-ON, (2) Control mode switching, (3) Gain switching/torque limit switching, (4) Alarm clear other inputs vary depending on the control mode, (5) CW drive prohibition, (6) CCW driver prohibition
		Output		6 outputs (1) Servo alarm, (2) Servo ready, (3) Release signal of external brake (4) Zero speed detection, (5) Torque in-limit. Other outputs vary depending on the control mode
	Analogue signal	**Input**		3 inputs (16Bit A/D : 1 input, 10Bit A/D : 2 inputs)
		Output		2 outputs (for monitoring) (1) Speed monitor (actual motor speed or command speed). Select the content and scale with parameter. (2) Torque monitor [torque command (approx. 3V/rated torque)], deviation counter or full-closed deviation is enabled. Select the content or scale with parameter
	Pulse signal	**Input**		2 inputs Select the exclusive input for line driver or photo-coupler input with parameter
		Output		4 outputs Feed out the encoder pulse (A, B and Z-phase) or external scale pulse (EXA, EXB and EXZ-phase) in line driver. Z-phase and EXZ-phase pulse is also fed out in open collector
	Communication function	**RS232C**		1:1 communication to a host with RS23C interface is enabled
		RS485		1:n communication up to 15 axes to a host with RS485 interface is enabled
	Front panel			(1) 5 keys (MODE, SET, UP, DOWN, SHIFT), (2) LED (6-digit)
				[illegible]

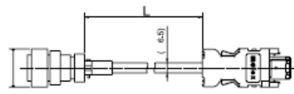
Accessories

Encoder Cables, Motor and Brake Cables

■ ENCODER CABLES



MFECA0□□0EAM

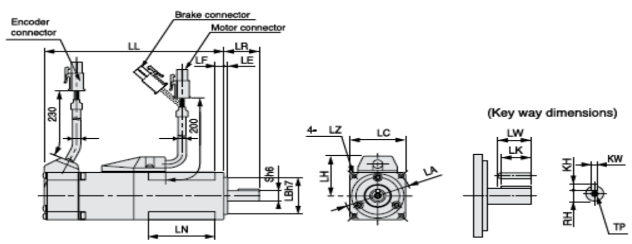


MFECA0□□0ESD

MFECA0□□0EAB

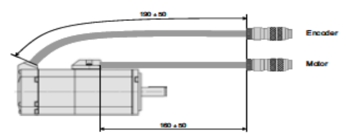
Motor Dimensions

■ MSMD 50W–750W (LOW INERTIA)

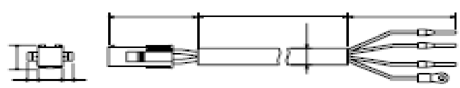


Dimensions are subject to change without notice. Contact us or a dealer for the latest information.

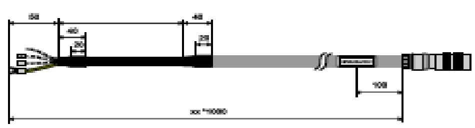
■ HIGH QUALITY CONNECTORS

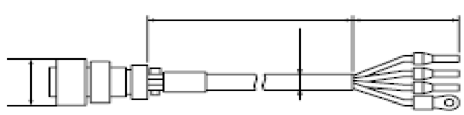


■ MOTOR CABLES



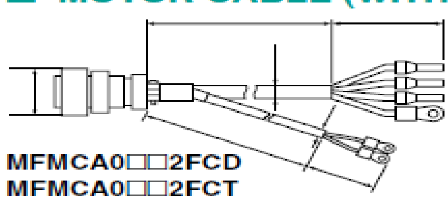
MFMCA0□□0EED





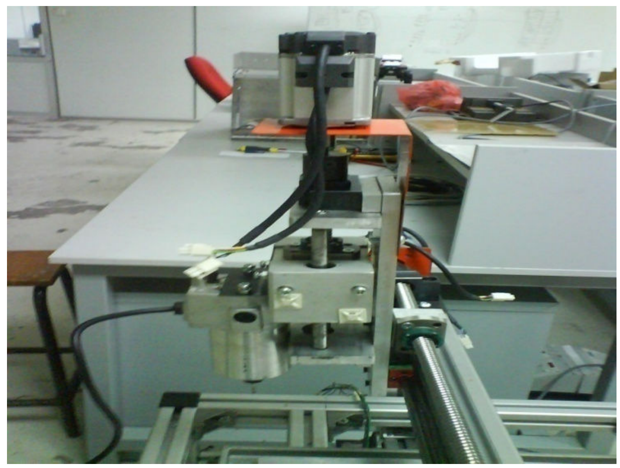
MFMCD0□□2ECD MFMCD0□□2ECT

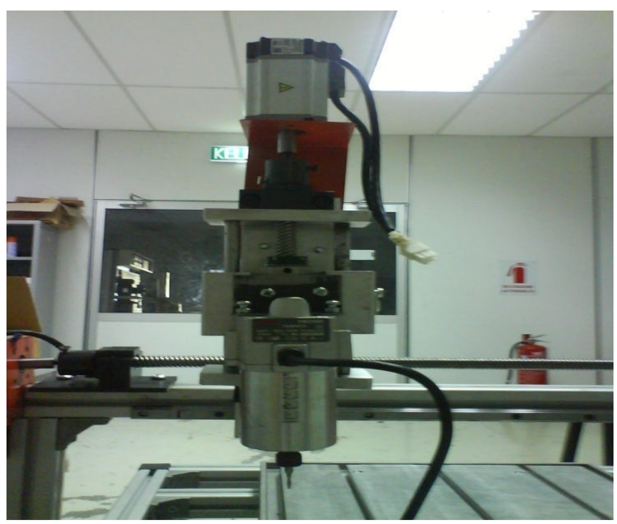
■ MOTOR CABLE (WITH BRAKE)



MFMCA0□□2FCD
MFMCA0□□2FCT

APPENDIX C






KELUAR