DESIGN AND FABRICATION OF THREE AXIS MECHANISM WITH AC SERVO MOTOR IN APPLICATION OF PERSONAL COMPUTER NUMERICAL CONTROL

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A report submitted in partial fulfilment of the
requirements for the award of the degree of
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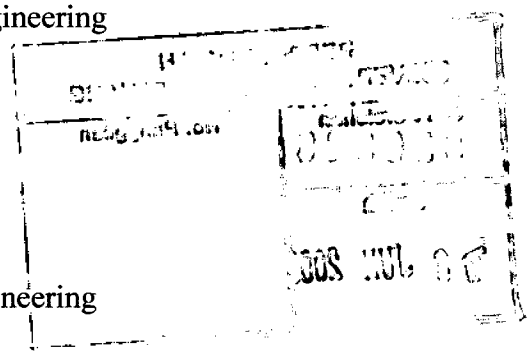

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ABSTRACT

This project was carried out to develop the accuracy and efficiency of the three axis mechanism with AC servomotor in application of personal computer numerical control. For running the incremental forming rig test is the main objective of this project. This three axis mechanism prototyping had been involved designed, analyzed, simulation approach, fabrication and assemble work. The structure part is one most important design part to minimize the vibration and friction. Extension simulations were performed to consider the failure analysis of the structure. The table structure found that it is strong enough to support the force and load which cause it bends about 3.11 mm and maximum stress applied is 5.11 MPa. The ultimate tensile strength is far higher than maximum stress applied. This three axis mechanism machine is successful develop. High technology electrical devices and good control system used to increase the accuracy and efficiency of the product.

ABSTRAK

Projek ini dibangunkan adalah bertujuan membangunkan mesin pergerakan tiga paksi yang jitu dan cekap dengan berbantuan arus ulang alik dan diapplikasikan "Servomotor" dalam computer peribadi. Tujuan pembagunan mesin ini adalah untuk menjalankan eksperimen pembentukan berperingkat. Projek ini dimulakan dengan melakar model projek, melukis model dalam perisian komputer, menganalisis sistem model, proses simulasi dan proses fabrikasi. Struktur mesin adalah bahagian yang paling penting supaya getaran dan geseran antara bahagian-bahagian dapat dikurangkan. Kerja simulasi harus dijalankan supaya dapat mengawal had kegagalan struktur mesin itu. Dalam menganalisis struktur ini, didapati bahawa tekanan maksimum yang dialami oleh struktur adalah sebanyak 5.11 MPa dan lenturan sebanyak 3.11 mm sahaja. Jika dibandingkan dengan maklumat tekanan maksimum sebenar, didapati struktur adalah cukup teguh untuk menyokong eksperimen ini. Kesimpulannya, mesin tiga paksi pergerakan ini berjaya dihasilkan. Alat teknologi elektrikal yang canggih dan sistem kawalan yang mantap digunakan untuk meningkatkan kejituan dan kecekapan produk.

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CHAPTER 1

INTRODUCTION

1.1 Project Objective

(a) Design and fabricate the three axis mechanism of incremental forming rig test by applying personal computer numerical control.
(b) Analyzing the three axis mechanism structure.

1.2 Project Scopes

The scopes of the project are cover from

(a) data collecting for the conceptual design such as linear motion guide
(b) geometry measurement of the components of the three axis mechanism machine such as AC servo motor and ball screw
(c) design the algorithm by using Solid Work and Computer Aid Manufacturing (CAM)
(d) analysis the velocity, life of the linear guide motion and ball screw by numerical method
(e) result validation while performing the project test running

1.3 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.

Incremental forming, which is a variety of forming processes characterized by the fact that the product is not formed as a whole, but that at any time only a small part is actually being deformed. For special interest is called incremental sheet forming (ISF) of which several varieties exist, that are carried out by moving a steel punch or roller by a CNC-machine over a metal sheet.

The principal directions in forming are an orthogonal set of directions in the material that remain orthogonal in the forming operation. The strains in these principal directions are called principal strains. This may seem academically to many readers but it is of importance when one wants to carry out a more fundamental analysis of the process, specially if this is related to material behaviour.

1.4 Problem Statement

Problem statement of the project:

(a) High demand for more and more complex products to be forming.

(b) Cost of making the tool is high; therefore, the cost of the products will be higher also.

(c) Incremental forming also applies high vibration force and pressure to the tool platform of three axis mechanism machine.

CHAPTER 2

LITERATURE REVIEW

2.1 Components

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

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 controls 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 gib. Linear slides are resistant to contamination, extremely durable in shock load conditions and run smoothly on lightweight frames.

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).

There are two principle types of linear slides:

(i) Ball bearing auto-slide (the most common variety)

(ii) Auto-slide uses crossed rollers.

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) Industrial robots and machine tool assembly

(b) Fiber optics and photonics component building

(c) Manufacturing semiconductor and electronic equipment

(d) Medical equipment manufacture

2.1.1.1 Ball Bearing Slides (Ball Slides)

Most commons type of linear slides due to their 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 are important 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.

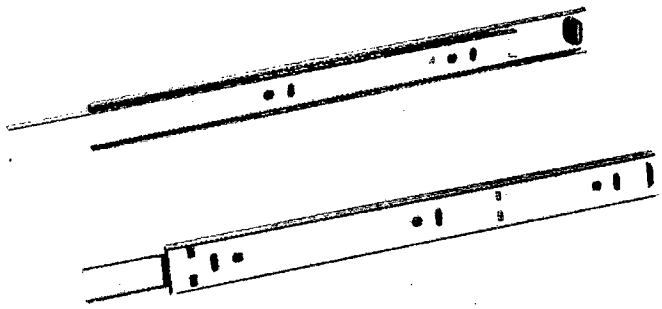

Figure 2.1: Ball Bearing Slides

2.1.1.2 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 tenon 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.

Compare to ball bearing slides, dovetail slides have direct contact between the base and saddle. Because of this fact, a greater force 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.

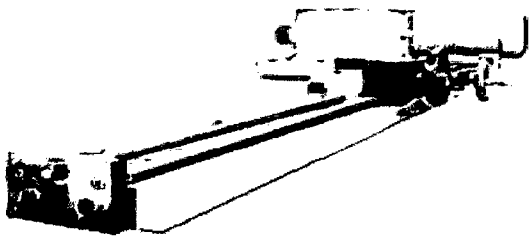

Figure 2.2: Dovetail Slides

2.1.1.3 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 gibs in order to make up for any irregular movements that may develop throughout an application.

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.

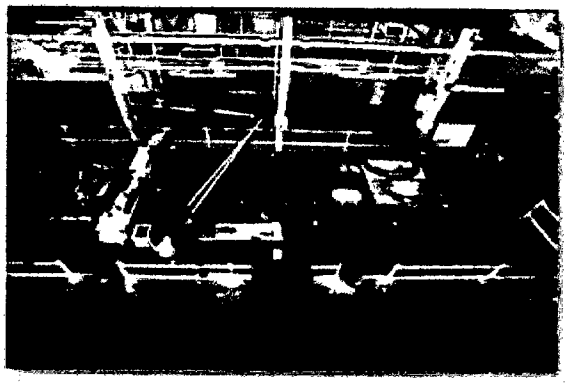

Figure 2.3: Machine Slides

2.1.1.4 Roller Slides

Roller slides, or 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.

Figure 2.4: Roller Slides

2.1.1.5 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, the

rollers are lifted one by one and led to the level of the front and rear sliding surfaces. This allows the roller table to support a product between the spaced sliding surfaces while it is working.

Roller tables are the quietest type due to the containing linear bearings that provide the least mechanical noise of any bearing table. By using the cylindrical rollers and rods rather than balls, roller tables can handle twice the load capacity as ball bearing tables. Industries such as building assembly, inspection, dispensing, pick and place, milling, drilling, material handling, and industrial automation equipment are using roller tables.

Many roller tables are also adjustable to fit different applications and have the ability to be assembled into multi-axis systems. Benefits of using roller tables:-

(a) Low cost

(b) high accuracy

(c) high load capacity

(d) resistance to corrosion

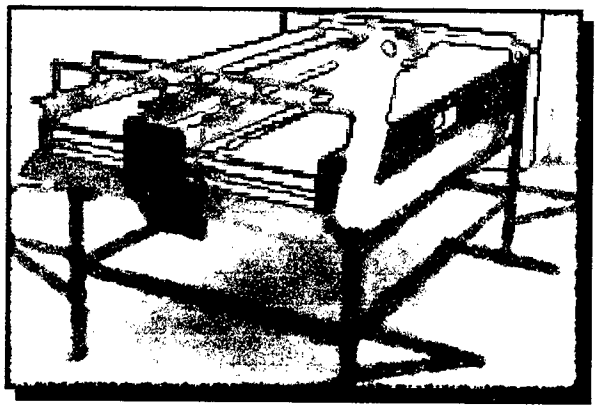

Figure 2.5: Roller Table

2.1.1.6 XY Table

XY tables are composed of forcers 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.

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.

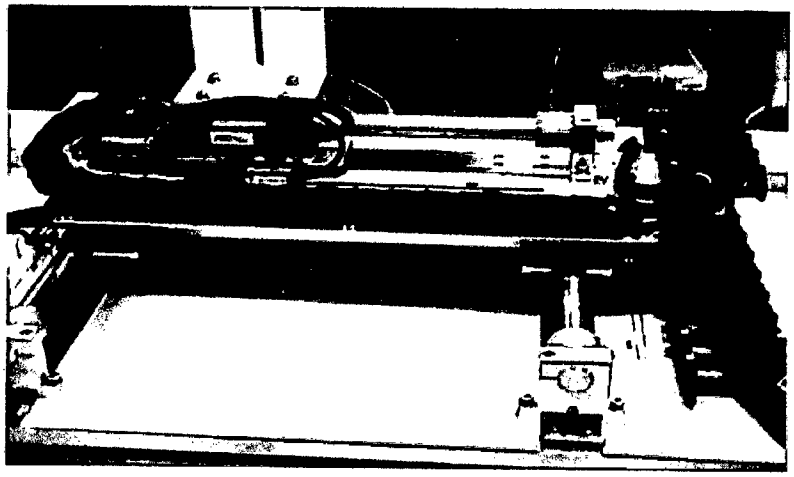

Figure 2.6: XY Table

2.1.2 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. Figure 2.7 illustrates most of the standard thread forms used for ball screws.

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 differ 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.

Industries that utilize ball screw in product application including aerospace, computer, electronic, automotive, and medical industries. Most of its used in medical equipment, material handling equipment, conveyors and machine tools, among many other product applications.

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. For example:-

(i) Ball screw assemblies maintain high levels of efficiency, measuring