UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGNING TWO DEGREE OF FREEDOM (2DOF) PNEUMATIC CONTROL TABLE USING SIMULATION SOFTWARE

Thesis submitted in accordance with the requirements of the Universiti Teknikal Malaysia Melaka for Bachelor of Manufacturing Engineering (Robotic and Automation)

By

Zakiah bte Ismail

Faculty of Manufacturing Engineering

May 2007

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS TESIS*

JUDUL: **DESIGNING 2 DEGREE OF FREEDOM (2DOF) PNEUMATIC CONTROL TABLE USING SIMULATION SOFTWARE**

SESI PENGAJIAN: 2/2006-2007

Saya **ZAKIAH BTE ISMAIL**

mengaku membenarkan tesis (PSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hak milik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
√	TIDAK TERHAD	

Disahkan oleh:

(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat Tetap:
476C, Bakar Arang,
08000 Sungai Petani,
Kedah Darul Aman.

Cop Rasmi:
KHAIROL ANUAR BIN RAKIMAN
Pensyarah
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka
Karung Berkunci 1200, Ayer Keroh
75450 Melaka

Tarikh: 15th May 2007

Tarikh: 23/5/07

* Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

APPROVAL

This thesis submitted to the senate of KUTKM and has been accepted as fulfillment of requirement for the degree of Bachelor of Manufacturing Engineering (Robotic and Automation). The members of the supervisory committee as follow:-

....

(MR. KHAIROL ANUAR BIN RAKIMAN)
Main Supervisor
Faculty of Manufacturing Engineering

DECLARATION

I hereby, declare this project entitled "Designing Two Degree Of Freedom (2DOF) Pneumatic Control Table Using Simulation Software" is the result of my own research expect as cited in the reference

Signature	:	....
Author's Name	:	ZAKIAH BTE ISMAIL
Date	:	19 May 2007

ABSTRACT

This proposes conceptual for two degree of freedom (2 DOF) pneumatic control table is how the movement of this design is successfully done by using the appropriate software. To approach this goal, the methodology proposed has certain method that were identifying such as design based on combination of table movement such as x y table and the serial robot manipulator. As a first step, idea had been translated into sketch, which then transferred into a detail design and visualized through drawing made using design software. Design combinations based on this concept and then create this design using the SolidWorks software. To know how this 2DOF Flexible Table able to move simulate this design using the Automation Studio software. This 2DOF Flexible Table designed, which has been successfully designed, is suitable for the welding process or painting process. The controller for two degree of freedom table designed used the pneumatic motor control. Pneumatic systems have been used in robotic systems when lightweight, small size systems are applied. Appropriate material selection has been selected to accomplish this design such material types, successful similar applications and emerging materials technologies. An example is analysis about load able to support from this design and stress of the bar.

ABSTRAK

Penggunaan perisian yang bersesuaian telah berjaya untuk mendapatkan sebuah model rekabentuk yang berkonsepkan 2 darjah bebas untuk kawalan meja pneumatik seperti mana tujuan projek ini dijalankan. Untuk mencapai objektif dan sasaran jangkamasa yang di rancang, penggunaan cara kerja atau kaedah yang teratur seperti membuat pengubahsuaian dan membuat rekabentuk berdasarkan gabungan pergerakan meja X Y dan kawalan robot sesiri. Semua idea dan perkiraan asal di tulis dengan membuat lakaran dan ini merupakan langkah pertama untuk memulakan projek ini di mana ia akan di pindahkan ke dalam lukisan yang lebih terperinci dengan menggunakan perisian mereka bentuk yang lebih teratur dan lengkap. Perisian yang digunakan dikenali sebagai SolidWorks di mana ia banyak di gunakan di dalam industri dan bidang kejuruteraan. Kemudian, untuk melihat atau mengetahui bagaimanakah sebenarnya pergerakan yang dilakukan oleh meja 2 darjah bebas ini, lukisan tadi akan dimasukkan ke dalam perisian Automation Studio. Antara penggunaan meja ini di dalam industri ialah untuk menjalankan operasi kimpalan atau membuat semburan cat pada produk. Konsep kawalan 2 darjah bebas untuk meja ini kebiasaannya digunakan di dalam operasi yang melibatkan kerja-kerja ringan dan saiz yang kecil. Pemilihan bahan yang bersesuaian untuk reka bentuk meja itu telah dilakukan seperti contoh memilih bahan yang tahan untuk menampung mahupun hanya menjadi tiang sokongan kepada tiang meja itu sendiri.

ACKNOWLEDGEMENTS

First of all, the author wishes to thank God Almighty for all knowledge, health and time given to him in preparing and completing this project report. The author would like to express gratitude to his project supervisor, Mr. Khairol Anuar Bin Rakiman, for the supervision and guidance as well as for the strong support and encouragement throughout the work. Also like to thank to all member, for their support in sharing precious knowledge and useful information regarding this robotics field as well as for their support. Last but not least, the author also wishes to thank all the individuals who either involved directly or not, and who have shared their knowledge and providing suggestions throughout this work.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

CHAPTER 1

INTRODUCTION

In mechanical engineering, aeronautical engineering, robotics, and structural engineering, degrees of freedom (DOF) are the set of independent displacements that specify completely the displaced or deformed position of the body or system. For example, a particle that moves in space has three translational displacement components as DOFs, while a rigid body would have at most six DOFs including three rotations. The translations represent the ability to move in each of three dimensions, while the rotations represent the ability to change angle around the three perpendicular axes. When the body is restrained in a certain manner, the number of true DOFs is reduced accordingly; however, the term DOF is also often used without regard to the actual constraints

A deformable body or system has an infinite number of DOFs unless it is idealized or approximated by a discrete system or a finite DOF system. When motion involving large displacements is the main objective of study, a deformable body may be approximated as a rigid body in order to simplify the analysis. However, for analysis of the detailed stress distribution in a body, that body must generally be considered deformable, and methods of structural analysis can be used.

The past few decades has seen a large increase of automated machines in the manufacturing environment. It is therefore important to know exactly what a robot is, and what makes it different from other automated machines, as robots come in many shapes and sizes. The most widely accepted definition of a robot was given by the Robotic Institute of America in 1979.

Pneumatic drive systems are found in approximately 30 percent of today's robots. These systems use compressed air as the medium of energy transmission. With pneumatic actuators, the pressure within the chambers is lower than that of hydraulic systems resulting in lower force capabilities. It is quite similar to the hydraulic counterpart; however, there are no return hydraulic lines for fluid. Pneumatic systems have been used in robotic systems when lightweight, small size systems are needed with relatively high payload-to-weight ratio. The main advantages of these hydraulic actuators are that they are non-flammable, suitable for clean environments, and easy to operate and maintain while the main disadvantages are that they do not have self lubricating properties and not suitable for harsh environments. Also, compressibility of air is seen as a disadvantage in view of the compressibility of air since it prevents easy control of speed and position of a robotic device, which are considered to be essential ingredients for any successful robot operation.

1.1 Problem Statement

This work will also analyze the new design application for painting processes include 2 Degree of Freedom (2DOF) movement. 2DOF Flexible Table is based on the other robot design and x y table concept. Propose for the 2DOF Flexible Table is for robot variety existing. It is true successfully that the 2DOF Flexible Table power source concept designed using the air to control the movement.

1.2 Objective

The main objective of the project is the following:

i. Design two degree of freedom (2DOF) table using the concept serial robot manipulator through simulation concept.
ii. Used the pneumatic control application for x-axis and y-axis

1.3 Scope of The Project

For scope and guidelines are listed to ensure the project is conducted within its interested boundary. This is to ensure the project is heading to right direction to achieve its intended objective. The first scope of this project is to design the two degree of freedom table used the serial robot concept. The table movement is simple movement such as for x-axis and y-axis curve of direction. That design using the SolidWork software. Secondly the scope of this project focuses for the painting process. That design is combination idea from robot concept and sliding table. Another scope for this project is that designed is using the pneumatic control.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Robots seldom function in an isolated environment. In order to do useful work, robots must coordinate their movements with other machines and equipment, and possibly with humans. A group of machines/equipment positioned with a robot or robots to do useful work is termed a workcell. For example, a robot doing welding on an automotive assembly line must coordinate with a conveyor that is moving the car-frame and a laser positioning/ inspection robot that uses a laser beam to locate the position of the weld and then inspect the quality of the weld when it is complete.

Yasuo Yamauchi gives four major reasons why Nissan use automation and in particular industrial robots. These are quality improvement, improvement of working environment, better cost effectiveness and lastly flexibility to change. An industrial robot is a re-programmable device designed to both manipulate and transport parts, tools, or specialized manufacturing implements through variable programmed motions for the performance of specific manufacturing tasks. For certain tasks robots can be superior to humans in terms of the quality of the work that is produced. This has been found to be the case where one or more of the following are required. There are high positioning precision, high repeatability, no deviation due to fatigue and lastly highly accurate inspection and measurement using sensors. (Warwick, 1993)

2.1 Robot Manipulator

Manipulator is the mechanical unit which performs the movement function in the robot. It consists of a series of mechanical links and joints capable of producing controlled movement in various directions. These applications largely dictate the choice of various design parameters of the manipulator, including its kinematic structure. Robot manipulators can be classified by several criteria, such as their geometry, or kinematic structure, the type of application for which they are designed, the manner in which they are controlled, etc. Most industrial manipulators at the present time have six or fewer degrees-of-freedom. These manipulators are usually classified kinematically on the basis of the arm or first three joints, with the wrist being described separately. (Oguz at al, 2000) A serial robotic manipulator can basically be thought of as an electromechanical system consisting of two basic building blocks: links and actuators. Currently, many tools exist to model serial manipulators at the system level as well as actuators independently from one another with a high level of detail and accuracy. Although it is well known that the properties of the actuator define the character of the manipulator that houses it, a limited amount of work has been done to treat the central issue of modeling the combination of the two. (J.J Pickle, 2004)

Each manipulator is required to have three degree of freedom (DOF) control. It is required to move up and down along the z-axis (linear/prismatic), back and forth along the x-axis (linear/prismatic) and rotate about the z-axis (rotation). A manipulator with these three degree of freedom is called to have LLR or a PPR configuration. LLR manipulators are relatively accurate and easy to control. (Venugopal at al, 2005)

The articulated manipulator is also called a revolute or anthropomorphic manipulator. Two common revolute designs are the elbow type manipulator and the parallelogram linkage. The elbow manipulator configuration provides for relatively large freedom of movement in a compact space. The parallelogram linkage, although less dexterous typically than the elbow manipulator configuration, nevertheless has several disadvantages that make it an attractive and popular design. The most notable feature of the parallelogram linkage configuration is that the actuator for joint 3 is located on joint 1. Since the weight of the motor is born by link 1, links 2 and 3 can be made more lightweight and the motors themselves can be less powerful. Also the dynamics of the parallelogram manipulator are simpler than those of the elbow manipulator, thus making it easier to control. (Oguz at al, 2000)

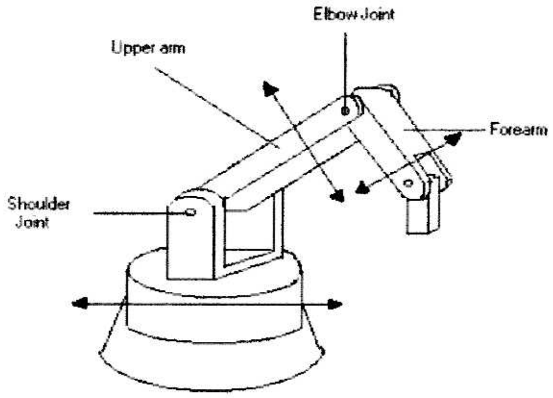

Figure 2.0: Articulated manipulator

Robot manipulators can be easily reprogrammed to perform different tasks, yet the range of tasks that can be performed by a manipulator is limited by its mechanical structure. For example, a manipulator well-suited for precise movement across the top of a table would probably not be capable of lifting heavy objects in the vertical direction. Therefore, to perform a given task, one needs to choose a manipulator with an appropriate mechanical structure. This is only possible when the task requirements are known beforehand, which often not the casein unpredictable is and changing environments, such as space stations or nuclear facilities. In most industrial manipulators, the controller is a separate unit housing the sensor interfaces, power amplifiers, and control processors for all the joints of the manipulator. A large number of wires is necessary to connect this control unit with the sensors, actuators and brakes located in each of the joints of the manipulator. The large number of electrical connections and the non-extensible nature of such a system layout make it infeasible for modular manipulators. (Christian J.J at al, 1996)

Robot manipulators are inherently flexible when subjected to a load disturbance. A robot will deform, and as a result the end-effector pose will change. The deformation is manifested by compliance in the drive trains, links, and bearings, and is not fully accounted for in present-day robot control algorithms. Standard kinematic representations for rigid-link manipulators ignore much of the physical detail of a robot's construction. Two kinematically similar robots can have considerably different structural characteristics. In order to derive a static compliance model, we must provide a kinematic model that more completely describes the physical robot structure. The standard rigid-body kinematic modeling is used to characterize the nominal configuration of a robot's links and joints. The classification of compliant link structures is applied to define the additional kinematic relationships necessary for static compliance modeling. (Jeff Hudgens at al, 2002)

2.2 Degree of Freedom

The number of DOF that a manipulator possesses is the number of independent position variables that would have to be specified in order to locate all parts of the mechanism. In other words, it refers to the number of different ways in which a robot arm can move. In the case of typical industrial robots, because a manipulator is usually an open kinematic chain, and because each joint position is usually defined with a single variable, the number of joints equals the number of degrees of freedom. (J.J Pickle, 1993)

A system with several bodies would have a combined DOF that is the sum of the DOFs of the bodies, less the internal constraints they may have on relative motion. A mechanism or linkage containing a number of connected rigid bodies may have more than the degrees of freedom for a single rigid body. Here the term degrees of freedom are used to describe the number of parameters needed to specify the spatial pose of a linkage. (http://en.wikipedia.org/wiki/Degree_of_freedom)

The DOF is defined as the number of independent coordinates that are needed to describe the movement of the machine. It is therefore also the number of actuators which are necessary to drive the end effectors of the machine to the desired positions and orientations. It is also the number of independent inputs required to drive all the rigid bodies in the mechanical system. (V.Kumar, 1997)

- A good manipulator design combines strength and rigidity with minimal geometric volume and great agility.
- Influence from load and acceleration forces tends to bend the manipulator links affecting negatively the accuracy of the robot.

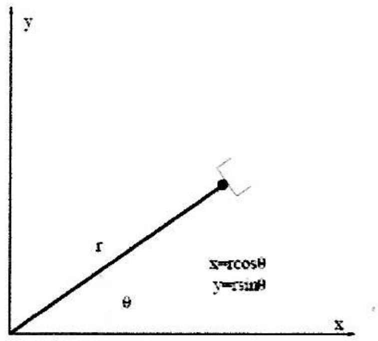

Figure 2.1: 2-DOF Polar, planar manipulator. The endpoint has coordinates (rCosθ ; rSinθ)

Figure 2.2: 1DOF serial robot. (Ting Y at al, 1995)

This level of fault tolerance involves the type of links used in the robot structure. The simplest and most common link type is the serial link. Similar to the single actuator, the serial link is the simplest and cheapest to incorporate. Also, a serial link does not provide any fault tolerance to the robotic system in this level. Fault tolerance at this level can be included by the use of parallel mechanisms, such as a four-bar mechanism as in Figure 1, to drive one DOF of the robot. (Ting Y at al, 1995)

If only 3 legs and a rotating head with 2 or 3 degrees of freedom is used, the kinematics and the control unit become simpler. With 3 struts only 3 degrees of freedom can be realized. Using an additional rotating head unit a 5-axis movement can be accomplished.

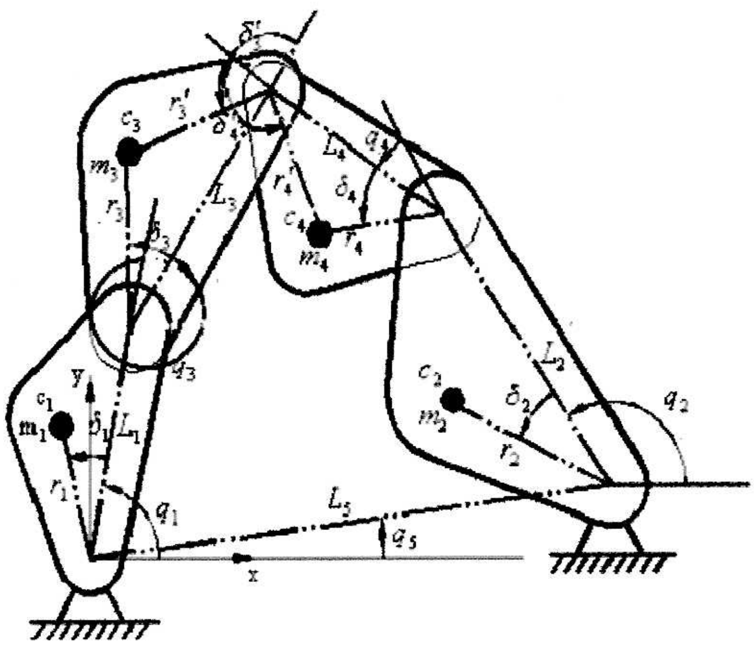

Figure 2.3: Structure of a 2 degrees-of-freedom. (Pei Yean, Lee, Yong Keat, Lee)

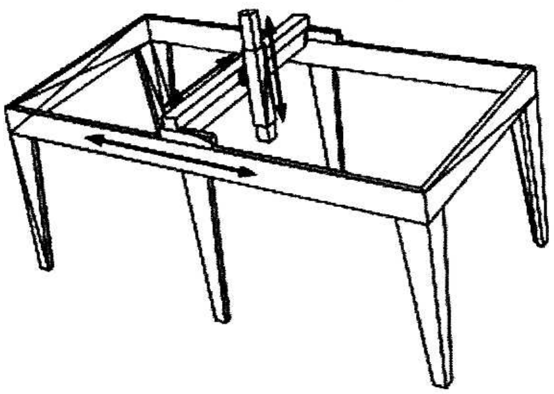

Figure 2.4: A gantry robot only the first three prismatic degrees of freedom

They have three prismatic joints to position the wrist, and three revolute joints for the wrist. Strictly speaking, a gantry robot is a combination of a parallel XYZ translation structure with *a* serial spherical wrist. The parallel construction is very stiff (cf. metal cutting machines) so that these robots are very accurate. In large industrial applications (such as welding of ship hulls or other large objects) a serial manipulator is often attached to a two or three degrees of freedom gantry structure, in order to combine the workspace and dexterity advantages of both kinematics structures. (Dong Hun Shin†, 1997)

2.3 Kinematics' Structure

The disadvantages of this kinematics are the following:-

- Weak torsion rigidity
- The struts have to take the torsion load as a bending moment.
- Less load can be allowed because of the bending moment.

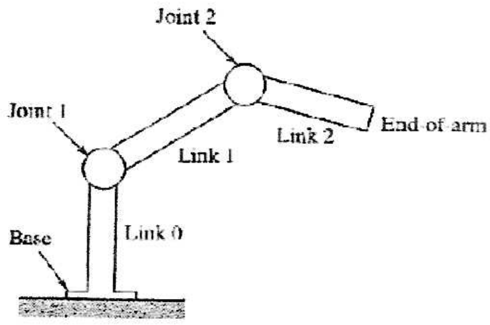

Figure 2.5: Robot Anatomy (Lars Holst and Magnus Holm, 2006)

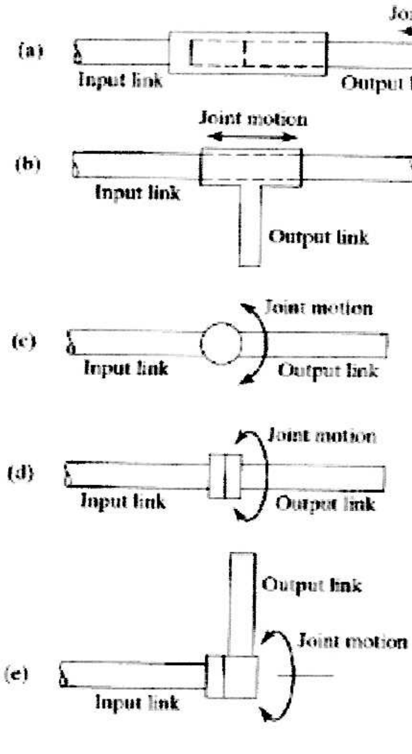

Figure 2.6: Robot Anatomy (Lars Holst and Magnus Holm, 2006)

• Prismatic joints (sliding joints) P:

a) Linear joint (L) - sliding movement with the axis of the two links being parallel.

b) Orthogonal joint (O) - sliding movement, but the input and output links are perpendicular to each other.