DEVELOPMENT OF 6-AXIS ROBOT ARM FOR TVET TRAINING

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering With Honours.

by

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DECLARATION

I hereby, declared this report entitled "Development Of 6-Axis Robot Arm for TVET Training" is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the Degree of Bachelor of Manufacturing Engineering with Honours. The member of the supervisory is as follow:

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(EN MAHASAN BIN MAT ALI)

ABSTRACT

From the start of the third industrial revolution, manufacturer has started to incorporate robotic arm to help them increase productivity, output consistency, the overall quality of end product and also bringing their manufacturing cost lower. Robotic arm is expected to resume their role in the next industrial revolution as well. Worldwide, the application of industrial robots has accelerated significantly in recent years and this is reflected by the increasing demand for robotics in Malaysia's manufacturing industry. With more industries expected to use robotic arm, more skilled workers are needed in order to maintain and operate the robot. Our nation has targeted to produce a large number of skilled workers in the robotic field through TVET initiative. TVET curriculum prepares students for a career that requires specific skill-set in electrical and electronics, computer systems, automation and robotics, and manufacturing technology. Current industrial robots for education purposes are expensive and yet the mechanisms are too simple thus not representing the actual robots being used in the industry. This is where this project comes in. Through this project, a 6 DOF robotic arm are being design and fabricated. The overall size of this robot arm is 0.8m height and width of 0.35m which can fit on a standard table. Even though the size of this robot is small, this robot retains the mechanical attribute of an industrial robotic arm. This project only focuses on the mechanical structure of the robot. Electronics and programming of the robot movement shall be done separately. The design of the robot has been done using SolidWorks. Through this software, the structure has been analysed thoroughly in order to ensure this robot are able to handle the intended load of 1 kg. Through the analysis, the maximum stress, maximum displacement, and maximum deformation are identified by input of 5 different payload. The robot has been fabricated using FDM technology for fast development time dan other conventional manufacturing for metal part. Finally, the robot will be 6 DOF which suitable for TVET training and analyse the capability to perform at 1 KG of payload by using finite element analysis.

ABSTRAK

Dari permulaan revolusi perindustrian ketiga, pengilang telah mula mengenalkan teknologi robot arm untuk meningkatkan produktiviti, pengeluaran yang konsisten, kualiti produk and juga mengurangan kos pembuatan. Robot arm ini jugak akan membantu mereka untuk berada dalam keadaan konsisten jika berlaku revolusi industri yang seterusnya. Aplikasi robot arm telah kembang jauh dengan pantas dan ini menyebabkan permintaan yang tinggi dalam industri robotic di Malaysia. Dengan angaran pengunaan robotik arm dalam industri meningkat, permintaan pekerja yang mampu menguna dan menyelenggara robot arm juga meningkat. Melahirkan pekerja yang mahir adalah salah satu sasaran kerajaan Malaysia dalam industri robotic melalui program TVET. TVET membantu pelajar untuk belajar kemahiran-kemahiran dalam elektrik, elektronic, komputer sains, automasi dan robotik, dan teknology pembuatan sebelem memulakan alam pekerjaan. Robot untuk pengunaan pembelajaran dan pratikal agak mahal dan setenggah robot arm tidak mempunyai keupayaan yang setanding dengan robot arm di industri jika bandingkan dari segi mekanisme. Melalui projek ini, 6 DOF robot arm telah di reka bentuk. Saiz robot tersebut lebih kurang ketinggian 0.8m dan 0.35 lebarnya dan ia sesuai untuk dia letak atas meja bersaiz standard. Walaupun saiz robot ini yang kecil, tapi mengunaan mekanisme kepada robot setanding dengan robot industri. Projek ini akan fokus dalam pembuatan mekanikal robot arm. Pemasangan elektronik dan programming akan dilakukan secara berangsingan. Proses reka bentuk robot ini telah dilakukan dalam CAD perisian SolidWork. Melalui perisian ini, analisa terhadap struktur robot jugak telah di lakukan untuk memastikan robot ini mampu beroperasi dengan muatan 1 KG. Melalui analisa ini, stress maksimum, displacement maksimum, dan deformation maksimum telah di kenal pasti dengan bandingan 5 jenis muatan. Pengunaan mesin FDM untuk proces fabrikasi struktur robot dan jugak mesin pembuatan yang lain untuk pengubahsuaian bahan besi. Akhirnya, projek ini akan mereka bentuk dan fabrikasi robot 6 DOF untuk pengunaan proses pembelajaran dan menganalisa keupayaan robot ini untuk beroperasi dengan muatan 1 KG dengan Finite Element Analysis.

DEDICATION

Specially dedicate to my beloved family, supervisor, lecturer, technician and friends who have guided and inspired me through my journey in education. Also thank to their unstoppable support, beliefs and motivation.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

DOF	-	Degree of freedom
TVET	-	Technical and Vocational Education Training
PSM	-	Projek Sarjana Muda
FEA	-	Finite Element Analysis
CAD	-	Computer-Aided Design
FDM	-	Fused Deposition Modelling

CHAPTER 1
INTRODUCTION

Robotic industry is one of the major sectors in today's economy which will influence the job availability and income of the country. Day by day every machine and task are simplified and improved for higher profit to the company. Industry investor more prefer robots to do the task to avoid human error. The industry often using robot arm to handle the production which human cannot perform. Employer looking for graduates who has skill of handling and maintain the robot or at least has knowledge of robot arm, but students was not exposed to the environment of learning the robot arm because of the availability of robot arm in the institute. Some institutes have limited number of robot arm and some do not have. This makes students are not exposed to the robot arm usage.

1.1 Background

Manufacturing industries in the world keep improving and finding solution for better process to manufacture by saving time, money and work force. The invention of the Numerical controlled (NC) machines, computer on 1950 and the integrated circuit on 1970s all helped to make it possible to introduce the industrial robot. At the beginning robot was used to replace human for heavy, dangerous and monotonous tasks. However, they had zero external sensing and were used for simple tasks such as pick and place. George Charles Devol, also known as father of robotics was invent the very first industrial robot which called the ultimate in 1954.

Joseph Engelberger, a pioneer in industrial robotics, once remarked, 'I can't define a robot, but I know one when I see one.' The Cambridge Advanced Learner's Dictionary defines "robot" as, ‘A machine used to perform jobs automatically, which is controlled by a computer.’ In meantime, the International Standards Organization gives one definition to be used when counting the number of robots in each country. International standard ISO 8373 defines a "robot" as an automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either, fixed in place or mobile for use in industrial automation applications.

A robotic arm is a type of mechanical arm, programmable, with similar functions to a human arm. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or linear translational displacement. It can perform a wide variety of functions and perform the tasks where human cannot go. The robotic arm can handle the particles in the chemical laboratories and used it for security purpose. It can also helpful in the medical applications. Through programming arm can handled the whole automatic industrial process. Due to the lightweight of the structure and designed techniques the robotic arm can use for underwater applications in the underwater submarine. The robot arm can be used for learning process and exposing the robot technology to the kids where there can used to it as growing.

This project will be in designing and analyse of a robot arm that will suit for training and learning process for student in class room. In this project, the mechanism, design, material and cost will be studied. From this project, student able to expose with robotic environment and understand the robot easily with training kit robot arm.

1.2 Problem Statement

With the massive improvement of industrial evolution, most of the employer need their employee capable of handling their robots and operate them. To make student exposed with the robots, they need to be learnt the robot theoretically and practically. The availability of robot arm in institute is very low and because of this student unable to practice and operate the robot. Some of the commercial robot arm are not user friendly, so it needs professional operator to handle the robot arm. Besides that, the cost of the robot also expensive and makes institute to purchase limited units. For this project, student need a robot that suitable for learning and testing. Most of the robot in market is expensive and big because it meant to be in industry for heavy work. Institutes needs robot arm specifically for training and testing only. The robot arm no need to be heavy duty as it only handles light weight pick and place application. Student was not encouraged to handle the heavy-duty robot because it is not user friendly and need trained person to operate the machine. Purchasing a compact size 6-axis robot arm, it may cost high and end up purchasing only one or few. The impact of the problem is student may not have exposed much in robot arm handling and operating them. They may lack of knowledge and experience in robot arm industry.

1.3 Objective

The objective of this project includes:

I. To develop a mechanical structure of pick and place 6-Axis Robot Arm for TVET training purposes.

II. To analyse the capability of proposed Robot Arm.

1.4 Scope

The scopes of this project are as follows:

I. The design of robot arm will be done using SolidWork CAD software.
II. The fabrication of this robot will be done using FDM method.
III. The Finite Element will be done using SolidWork Simulation software.

1.5 Conclusion

In conclusion, this product will make a big impact among student as they able to handle and operate them in their institute. The institute also able to purchase the product with cheaper price than the commercial robot arm. Thus, the next chapter to be developed is literature review and project methodology.

CHAPTER 2

LITERATURE REVIEW

This chapter is mainly described the theory and research which have been defined and done by various researcher years ago. Related information of previous studies is extracted as references and discussion based on their research about Robot Arm, mechanism used in robot arm and kinematic movement.

2.1 Robot Arm Types

According to K. Hirai, and team,(1998) in the study of "The development of Honda humanoid robot," robot was used to replace human to perform work which human cannot do. There are few types of robot that been used in industry. Below are listed robot types that been use in industrial. Refer Figure 2.1 for Type of robot arms and possible workspace.

I. Cartesian robot or Gantry robot

The robot has three prismatic joints and its widely used for pick and place work, assembly operations, arc welding and handling machine tools.

II. Cylindrical robot

The robot has a combination of rotary joint and two prismatic joints to form a cylindrical coordinate system. This robot used most for assembly operations, handling at die-casting machines, spot welding, and handling at machine tools.

III. Spherical or Polar robot

The robot's position of wrist is determined by two rotations of rotary joints and one translation of prismatic joint. The robot is widely used for task such as handling at machine tools, gas welding, die casting, fettling machines, spot welding and arc welding.

IV. SCARA robot

The robot has two parallel rotary joints for compliance in a plane. The robot often used for task such as pick and place work, handling machine tools, assembly operations and application of sealant.

V. Parallel robot

The robot arms have concurrent prismatic or rotary joints. The robot used for a mobile platform handling cockpit flight simulator.

VI. Articulated robot

Articulated robots are often called jointed arm, revolute, or anthropomorphic machine. Articulated robots typically contain at least three rotary joints. The robot used for performing task such as line assembly operations, die-casting, gas welding, and arc welding and spray painting. The advantages of articulated robot are robot still can achieve deep horizontal reach although articulated robots use a minimum of floor space and high positioning mobility of the arm allows the robot to reach into enclosures. Besides that, the articulated robot required a higher cost.

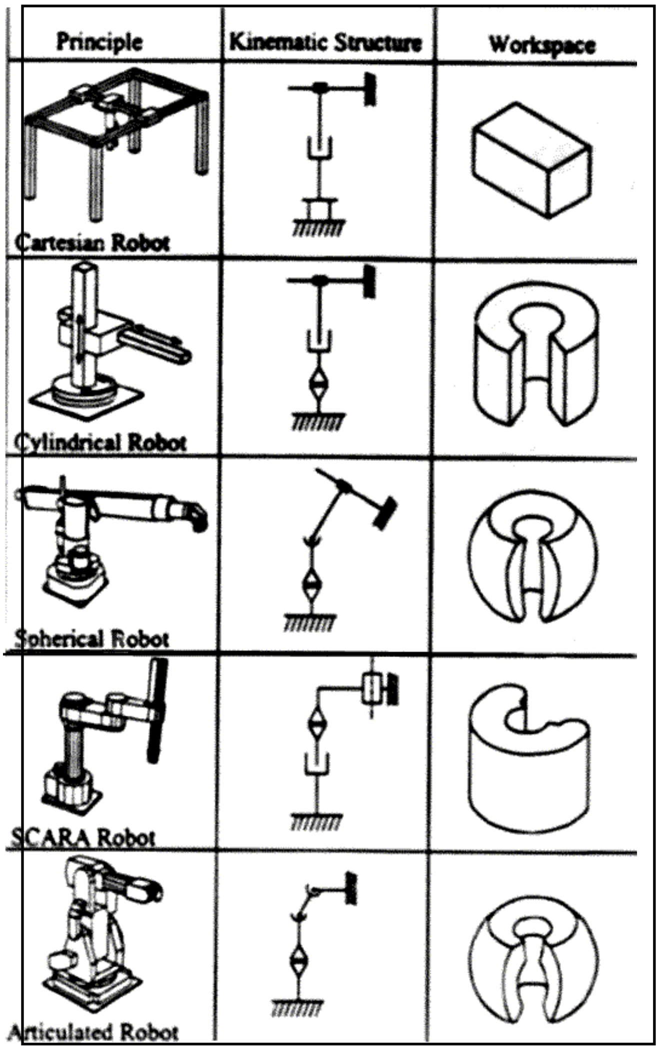

Figure 2. 1: Types of robot arm and possible workspace.

2.2 Articulated robot arm

According to Nakano (1995) in study of ‘Mechanism and Control of Multi-jointed Manipulators’, robot arm was classified into few groups such as cartesian, spherical/polar, articulated and so on. Articulated robot also can call as 6-axis robot will allow for greater flexibility and can perform a wider variety of applications than robots with fewer axes. The articulated robot arm also known as pure spherical or anthropomorphic robot. The articulated robot has three rotary joints. This feature allows the articulated robot to have a relatively large work-space. Below shows the movement and purpose of each axis;

I. Axis 1

It is located at the robot base. It allows the robot to rotate from left to right. This sweeping motion extends the work area to include the area on either side and behind the arm. This axis allows the robot to spin up to a full 180 degree range from the centre point.

II. Axis 2

This axis allows the lower arm of the robot to move forward and backward. It is the axis powering the movement of the entire lower arm.

III. Axis 3

The axis moves the robot's vertical reach. It allows the upper arm to raise and lower. In several articulated models, it allows the upper arm to reach behind the body, further expanding the work envelope. This axis gives the upper arm great accessibility.

IV. Axis 4

Axis 4 works with axis 5, also known as the wrist roll, the upper arm will rotate in a circular motion which will move parts in horizontal and vertical orientation.

V. Axis 5

The axis 5 move the wrist of the arm to move up and down. This axis is in control for the pitch and yaw motion. The pitch, or bend, motion is up and down, much like opening and closing a box lid. Yaw moves left and right, like a door on hinges.

VI. Axis 6

This is the last axis in robot arm which control the movement of end effector. It capable more than 360-degree rotation in both directions clockwise and counter clockwise.

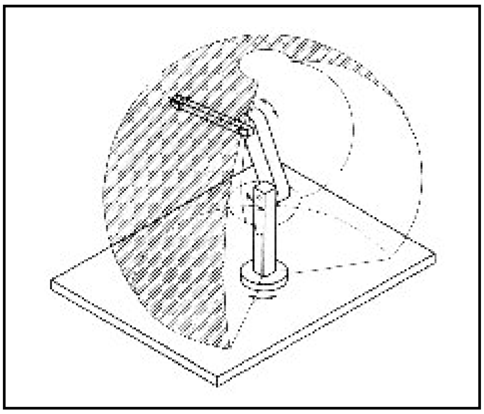

Figure 2. 2: Workspace of Articulated robot arm.

Articulated robot has two general classes of controller, non-servo controlled and servo controller. The non-servo-controlled is the simplest type. It was described as end robot, pick and place robot or bang-bang robot. The main characteristic of the non-servo-controlled robot is that their axes remain in motion until the limit of travel for each is reached. Only two positions for each axis are assumed. The non-servo nature of the control indicates that once the robot arm has begun to move, it will continue to do so until the suitable end stop reached. The controller is operating in open-lop mode, where there is no monitoring of the motion, the position or the velocity, via external sensors, at any intermediate points. The robot motion is then controlled by limit switches and mechanical stop. The simple control method enables this type of robots to provide relatively high-speed operation with high degree of reliability and accuracy, but they are limited to performing only simple pick and place operations. Refer Figure 2.3.

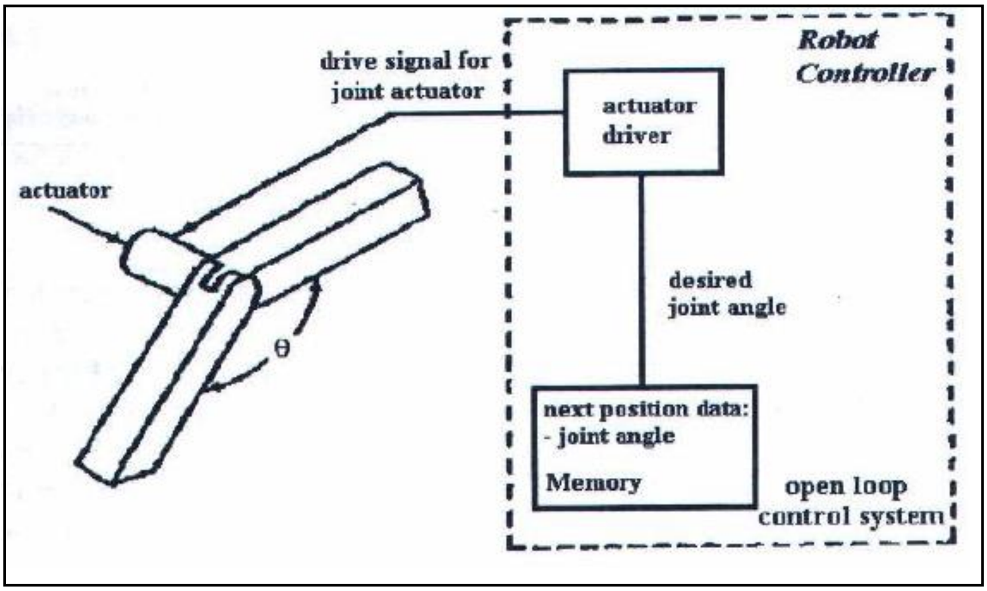

Figure 2. 3: Non-servo-controlled arm.

Servo-controlled robots can be continuous path or point-to-point devices. In both case, information about the position and velocity is continuously monitored and fed back to the control system related with each of the joints. In a simple word, each axis loop is closed loop. The control system is based on close-loop servo, whereby the position of a robot's axis is measured by feedback devices and compare with a pre-determined point store in the controller's memory. Only the extreme axis could be programmed. Moreover, it is possible to control the acceleration, velocity, deceleration, and jerk for the various joint between the end. Robot arm vibration can be reduced significantly. Refer Figure 2.5 for more information.

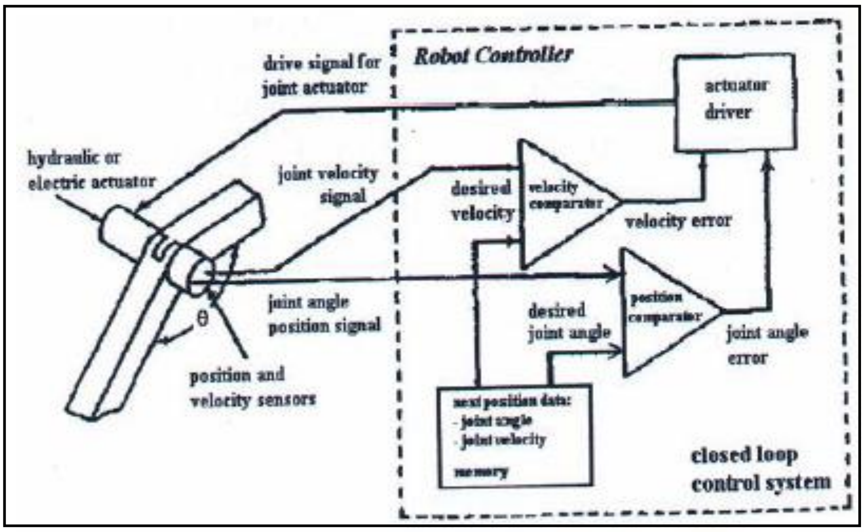

Figure 2. 4: Servo-Controlled arm.

Robot arm was designed to help people with tasks that human cannot perform, lack of safety, or repetition of task makes people boring. Robots are more likely to be used in industry to perform high-precision job such as welding and riveting because of its consistency and accuracy. Robots are also used in serious situation that would be dangerous for human like cleaning toxic waste and defusing bombs. Robots can be used in many conditions even underwater work task that human cannot explore because of too deep.

Machine loading, where robots supply parts to or remove parts from other machines. In this type of work, the robot may not even perform any operation on the part, but only a means of handling parts within a set of operation.

In pick and place application, robot picks up parts and place them anywhere within the radius of arm accessibility. Task that include are palletizing, placing cartridges, simple assemble parts, placing and removing treated parts from the oven, or other similar routines. The applications of robot arm vary from industry to industry, here some of the major applications;

I. Manipulator (pick and place)
II. Machine assembly
III. Industrial spray painting
IV. Arc Welding