UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DESIGN IMPROVEMENT AND ANALYSIS OF 4 DOF PARALLEL ROBOT

This report submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering in Robotic and Automation (Hons.)

by

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2013

DECLARATION

I hereby, declared this report entitled "Design Improvement and Analysis of 4DoF Parallel Robot" is the results of my own research except as cited in reference.

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Date	:	18th JUNE 2013

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Robotics and Automation) (Hons.). The member of the supervisory is as follow:

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ABSTRAK

Projek ini mempunyai kaitan dengan manipulator selari di dalam industri robot. Projek ini adalah untuk penambahbaikan rekabentuk sambungan robot selari yang mempunyai 4 darjah kebebasan. Robot ini mempunyai masalah untuk membuat simulasi dengan menggunakan sambungan yang sebelumnya. Analisis statik di setiap bahagian yang kritikal apabila beban dikenakan juga dilakukan di dalam projek ini. Apabila lukisan dan simulasi selesai, projek perlu melalui ujian statik. Tumpuan diberikan kepada beberapa parameter seperti tekanan, ketegangan, anjakan dan juga faktor keselamatan (FOS). Objektif projek dan kenyataan masalah juga dinyatakan di dalam laporan ini. Kajian literatur adalah untuk mengkaji dan melakukan penyelidikan tentang informasi penting sebelum melakukan projek ini. Proses ini perlu dilakukan untuk mengetahui kebaikan dan keburukan projek sebelum ini. Semua kaedah kajian ini termasuk dalam metodologi, bab ini akan menerangkan prosedur yang perlu dilakukan sebelum menyiapkan projek ini. Dalam bab ini juga menerangkan bagaimana prosedur ujian statik, ia dilengkapi dengan carta aliran proses dan carta Gantt. Semua penemuan dan data dianalisis dan akhirnya kesimpulan dapat dibuat.

ABSTRACT

This project is strongly related to the parallel manipulator in robot industry. This project is to improve design of 4DoF parallel robots joint. This robot has a problem to simulate with the previous joint design. Static analysis also has been done in this project. Once the drawing and simulation is complete, project needs to go through a static test. These types of test are focus on several parameters which are stress, strain, displacement and also factor of safety (FoS). The objectives of this project and problem statement for the project are stated in this report. Literature review was to study and research about the important knowledge before doing this project. This process should be carried out to know the advantages and disadvantages of the project before. All of this study method are include in the methodology, this chapter describes the procedures that must been done before completing this project. In this chapter also explain how the static test procedures it's equipped with process flow chart and Gantt charts. All findings and data are analyzed and the conclusions are made.

DEDICATION

This report is specially dedicated to my parents Mohamad Akhir bin Abd Ghani and Rohanizan binti Abdullah whom has been there for me all the time no matter what.

ACKNOWLEDGEMENT

I would like to thank Encik Mohd Nazmin bin Maslan for being an excellent supervisor of the project. His overgenerous guide, conscious criticisms and tolerant support the writing of the report in inestimable ways. His support of the project was greatly needed and deeply be pleased about.

Other than that, thousands of gratitude dedicated to the technicians, friends and everyone that had given support the whole time in completing the project.

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DoF	-	Degree of Freedom
N	-	Newton
(N/m^2)	-	Newton per Metre

CHAPTER 1

INTRODUCTION

This chapter is about introducing the study of this project. The project is on research and analysis about the concept of the manipulator with four Degree of Freedom called 4 DOF. Also, it is stated the objectives of this project, problem statement and the scope of this research.

1.1 Introduction

Robots are awfully dominant fundamentals of today's industry. They are competent of performing many dissimilar tasks and operations accurately and do not require common safety and comfort elements human need. Though, it takes a lot endeavor and many resources to make a robot function well.

Although most robots today are put in factories or homes, performing labor or life reduces works, various new types of robot are being developed in laboratories around the world. Much of the research in robotics focuses not only on specific industrial tasks, but on explorations into new types of robot, different ways to think about or design robots, and new method to construct them. It is predictable that these new types of robot will be able to resolve real world problems when they are become conscious.

Most industrial robots equipped with serial technology, where each axis is in line relative to the preceding one. The parallel robot on the other hand has three or more prismatic or rotary axes which function parallel to one another. Examples of parallel robots are Tricept, Hexapod and Delta Robots. Both Tricept and Hexapod robots use linear motors to control the position of the tool. This type of robot also becomes more popular because of its high speed, high-accuracy and precision positioning with limited workspace, such as an assembly of PCBs. It is also as micro manipulators mounted on the end-effectors of larger but slower serial manipulators.

The result of the parallel design is a robot that has increased stability and arm rigidity, with faster cycle times than serial technology. As such there is less flexing of the arms which results in high repeatability. The end-of-arm flexing errors are cumulative with serial linked robots, even as in a parallel link structure they are averaged. However, one disadvantage of parallel robots is they tend to have a relatively large footprint-to-workspace ratio, for example, the Hexapod parallel robot, easily take up a sizable work area. The exception is the Triceps robot which requires less space. Another limitation of the parallel configuration is that it has a small range of motion due to the configuration of the axes when compared to a serial link machine.

1.2 Problem Statement

The previous design of this parallel robot had encountered an error to simulate. From the observation, the design needs some improvement to solve that problem. The development of this project is improving from time to time. The analysis for strength testing will be done using Solidworks software. The parameters for the analysis are stress, strain, displacement and factor of safety.

1.3 Objective

The main objectives of this project are to improve the design of the existing 4 DoF parallel robots.

A number of sub-objectives are considered:

a) To conduct the FEA ofthe 4 DOF parallel robots.
b) To identify the potential applications of a 4 DOF parallel robot.

1.4 Scope of Project

This project is design improvement of the previous partial developed parallel robotic system. The scope of this project includes study and analysis the 4 DoF parallel robot. By using Solidworks software, the finite element analysis are conducted to detect the stress, strain, displacement and factor of safety of the parallel robot design.

1.5 Summary

This chapter is to present a slight thought of the project to be done for final year project. This project is about design improvement and analysis of 4 degree of freedom (DoF) parallel robot.

CHAPTER 2

LITERATURE REVIEW

This chapter will present an overview of the robot, the type and its application. It is briefly enlightening about the robot mechanism, especially about the Parallel Robot which related to better explain for this project. This part also will introduce about Stewart Platform, which is an original idea of this 4-DOF parallel manipulator. The source of the literature reviews usually refers to the information obtained from official sources such as books, articles of relevance, published paper or any other source consider appropriate. Through the literature reviews it is able to learn the concept of doing the project. The literature will be reviewing the introduction of robot, development, characterization, advantage and a drawback. Also the briefly explanation about finite element analysis (FEA).

2.1 Definition of Robot

The word robot made its debut in 1921, in the play R.U.R. (Rossum's Universal Robots) by Karel Capek. It comes from the word "robota", a Czech term for forced labour. But definitions of what a robot actually is vary widely. According to the Alan Mackworth, the director of the University of British Columbia Laboratory for

Computational Intelligence and president of the American Association for Artificial Intelligence, state that it's a machine that can sense and act and react in the world and possibly involves some reasoning for performing these actions, and it does so autonomously.

Gregory Dudek, the director of the Centre for Intelligent Machines at McGill University in Montreal, sets three criteria for robots, they have to have a way of making measurements of the world, and they have to have a way of making decisions. In other words, something like a computer, you could call that thinking informally and they have to have a way taking actions. For Joseph Engelberger has been called the father of robotics said that "I can't define a robot, but I know one when I see one.". Rodney Brooks, the director of the Massachusetts Institute of Technology computer science and artificial intelligence laboratory, state a robot is something that has some physical effect on the world, but it does it based on how it senses the world and how the world changes around it.

Oxford English Dictionary defines "robot" as an "apparently human automaton, an intelligent but impersonal machine." This seems too simplistic, and begs too many questions. According to the Australian Robotics and Automation Association, there is no standard definition. But the ARAA suggests that a robot has "three essential characteristics:

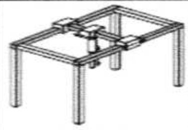
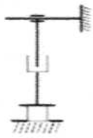
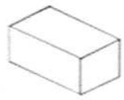
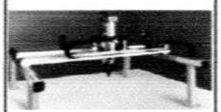
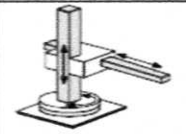
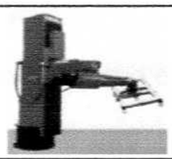
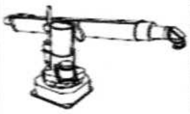
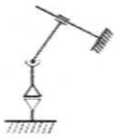
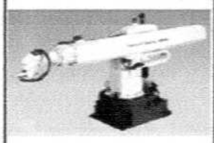
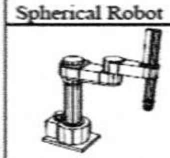
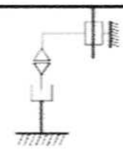
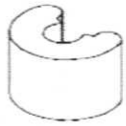
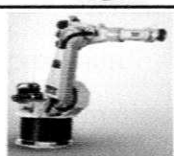
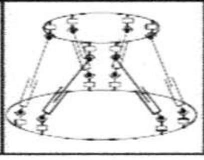
1. It possesses some form of mobility
2. It can be programmed to accomplish a large variety of tasks
3. After being programmed, it operates automatically.

The ARAA further remarks that: "The International Organization for Standardization (ISO) has developed an international standard vocabulary (ISO 8373) to describe 'manipulating industrial robots operated in a manufacturing environment'. According to this standard, such a robot must possess at least three programmable axes of motion." This technical definition helps ISO keep track of how many robots are in industrial settings, but seems too limited as a general definition.

According to The Tech Museum of Innovation, "A robot is a machine that gathers information about its environment (senses) and uses that information (thinks) to follow instructions to do work (acts)".

There are several types of robots that have been created and discovered. Each type has different function, axes, Degree of Freedom (DoF), and workspace. The category of robots are shown in Table 2.1 below.

Table 2.1: Category of robots

Robot	**Axes**		**Examples**
Principle	Kinematic Structure	Workspace	Photo
 Cartesian Robot			
 Cylindrical Robot			
 Spherical Robot			
 SCARA Robot			
 Articulated Robot			
 Parallel Robot			

There are some criteria must be considered or distinguish to select the proper suit robot to the application that are:

1. **Accuracy**: How close does the robot get to the desired point
2. **Repeatability**: The ability of a robot to return repeatedly to a given position.
3. **Degree of Freedom (DOF):** The number of DOF that a manipulator possesses thus is the number of independent ways in which a robot arm can move.
4. **Resolution**: The smallest increment of motion or distance that can be detected or controlled by the robotic control system. It is a function of encoder pulses per revolution and drive (e.g. Reduction gear) ratio. And it is dependent on the distance between the tool center point and the joint axis.
5. **Envelope**: A three-dimensional shape that defines the boundaries that the robot manipulator can reach; also known as reach envelope.
6. **Working Space**: The total space a robot can reach.
7. **Numbers of Axes: Two axes are** required to reach any point in a plane; three axes are required to reach any point in space. To fully control the orientation of the end of the arm, three more axes (roll, pitch and yaw) are required.
8. **Kinematics**: The actual arrangement of rigid members and joints in the robot, which determines its motion possibilities.
9. **Maximum Speed**: A robot moving at full extension with all joints moving simultaneously in complimentary directions at full speed. The maximum speed is the theoretical values which do not consider under loading condition.
10. **Payload**: The maximum payload is the amount of weight carried by the robot manipulator at a reduced speed while maintaining rated precision.
11. **Power Source**: Some robots use electric motors, others use hydraulic actuators. The former are faster, the latter are stronger and advantageous in several applications.

2.2 Parallel Robot

A generalized parallel manipulator is a closed-loop kinematic chain mechanism whose end-effectorsis linked to the base by several independent kinematic chains. A parallel manipulator, also called a parallel robot, consists of a fixed "base" platform, connected to an end-effectors platform by means of a number of "legs". These legs often consist of an actuated prismatic joint, connected to the platforms through passive (Not actuated) spherical and/or universal joints. Hence, the links feel only traction or compression, not bending, which increases their position accuracy and allows a lighter construction.

This definition of generalized parallel manipulators is very open: it includes for instance redundant mechanisms with more actuators than the number of controlled degrees of freedom of the end-effectors, as well as manipulators working in cooperation.

It is deal mainly with mechanisms with the following characteristics:

1. At least two chains support the end-effectors. Each of those chains contains at least one simple actuator. There is an appropriate sensor to measure the value of the variables associated with the actuation (rotation angle or linear motion).
2. The number of actuators is the same as the number of degrees of freedom of the end-effector.
3. The mobility of the manipulator is zero when the actuators are locked.

This type of mechanism is interesting for the following reasons:

1. A minimum of two chains allows us to distribute the load on the chains
2. The number of actuators is minimal.
3. The number of sensors necessary for the closed-loop control of the mechanism is minimal.
4. When the actuators are locked, the manipulator remains in its position; this is an important safety aspect for certain applications, such as medical robotics.

A parallel robot is a device for performing manipulations, where the end-effector is connected to the base via multiple kinematic chains. Any two chains thus form a closed loop. This is opposed to classical open loop mechanisms such as the serial robot robotic arm (e.g. articulated robots such as jointed arms).

The actuators for the prismatic joints can be placed in the motionless base platform, so that their mass does not have to be moved, which again makes the construction lighter. Parallel manipulators have (in principle) high structural stiffness, since the end-effector is supported in several places at the same time. All these features result in manipulators with a wide range of motion capability.

2.2.1 Parallel Kinematics Mechanisms

The conceptual design of PKMs can be dated back to the middle of the last century when Gough established the basic principles of a mechanism with a closed-loop kinematics structure and then built a platform for testing tyre wear and tear (Gough, 1956). A sketch of the mechanism is shown in Figure 2.1. As shown in the figure, that mechanism allows changing the position and the orientation of a moving platform with respect to the fixed platform

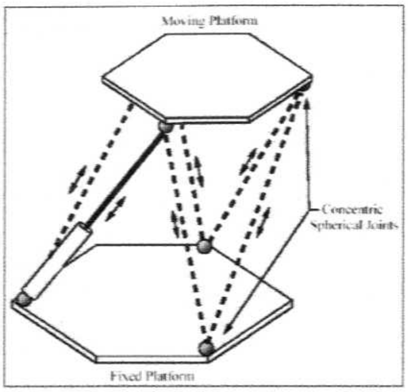


Figure 2.1: Gough Platform

Many have roughly analyzed Gough/Hexapod platform (Hunt, 1983, Fichter 1986, Griffis and Duffy, 1989; Wohlhart, 1994). One problem with these six-DOF platforms is the difficulty of their forward-kinematics solution, because of the nonlinearity and the highly coupled nature of their governing equations. This difficulty has been overcome by introducing some assumptions (Zhang and Song, 1994) and a closed-form solution can be found in (Wen and Liang, 1994). Others introduced some sensors to measure at least one of the variables of the platform and hence reduce the unknowns of the governing equations (Merlet, 1993; Bonev et al, 1999). The above mechanisms are six DOFs mechanisms because each of them allows the moving platform to move arbitrarily (within the limit of the workspace) in the six DOF space.

Having had a look at the mechanisms above one can now introduce a formal definition of parallel-kinematics mechanisms; a parallel-kinematics mechanism (or parallel manipulator) is a closed-loop mechanism. That is, a moving plate (end-effector) is connected to the stationary base by at least two independent kinematic chains, each of which is actuated. On the other hand, a serial-kinematics mechanism (or serial manipulator) is an open-loop mechanism in which each link is connected to only two neighboring links.