UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND SIMULATION STUDIES OF 3-AXIS ARTICULATED ROBOTIC ARM WITH PID CONTROLLER

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Robotics & Automation) with Honours

by

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DECLARATION

I hereby, declared this report entitled “Design and Simulation Studies of 3-Axis Articulated Robotic Arm with PID Controller” is the results 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 UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Robotics & Automation) (Hons.). The member of the supervisory is as follow:

……

(En. Shariman bin Abudullah)

ABSTRAK

Dalam projek ini, satu prototaip maya yang melibatkan tiga paksi lengan robot ditelah dijalankan dengan melaksanakan teknik simulasi yang melibatkan perisian ADAMS dan MATLAB Simulink . Pada mulanya, pemodelan robot tersebut telah dibina menggunakan SolidWorks , diikuti dengan mengeksport kepada ADAMS dan menubuhkan badan simulasi yang menghubungkan kepada MATLAB Simulink . Terdapat dua kes proses simulasi tersebut , di mana salah satu daripadanya adalah simulasi robot tanpa gangguan, dan kes lain adalah simulasi yang berlaku dengan gangguan. Semasa proses simulasi, didapati bahawa ada pertukaran data antara dua perisian dalam masa tersebut. Akhirnya, keputusan diperoleh daripada simulasi termasuk seperti daya kilasah masukan, sudut sendi dan kesilapan setiap sendi robot. Keputusan simulasi membuktikan bahawa teknik bersama simulasi mampu memudahkan proses reka bentuk, dan dapat digunakan sebagai data yang boleh dipercayai untuk kerja-kerja penyelidikan masa depan.

ABSTRACT

In this project, a virtual prototyping of three-axis articulated robotic arm has been carried out by implementing co-simulation technique which involved ADAMS and MATLAB Simulink. Initially, the modelling of articulated robot was constructed in SolidWorks, followed by exporting to ADAMS environment and established the co-simulation plant that links to the MATLAB Simulink. There were two cases of co-simulation process, where one of it was the robot co-simulation without disturbances, and the other was the case with disturbances. During co-simulation, there were data exchang between two softwares within the simulated time. Eventually, the result such as input torque, joint angle and tracking error of each robot joint, is acquired. The simulation results proved that the co-simulation technique is able to simplify the design process, and served as dependable data for future research work.

DEDICATION

For my beloved family, final year project supervisor, lecturers and friends that trust me in completing this project.

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3D	-	3 Dimensions
BC	-	Before Christ
AFC	-	Automatic Frequency Control
CNC	-	Computer Numeric Control
2D	-	2 Dimensions
CAD	-	Computer-aided design
PID	-	Proportional–integral–derivative
FEA	-	Finite Element Analysis

CHAPTER 1

INTRODUCTION

1.1 Background

Robot is widely used in various field of industry since it has been invented centuries ago. The word robot is originates from the screenplay "Rossum's Universal Robots (R.U.R.), which is wrote by a Czechs, Karel Capek. It is translated from Czech word, Robota, which means the force labor that perform manufacturing task in Capek's play (Angelo, 2007).

In 1956, Unimation acquired the first ever robotics patents and thus it was the first company that produced robot. It is followed by the participation of Europe companies in this sector, where ABB Robotics and KUKA Robotics, have developed robot for the commercial usage for the first time in 1973. As the times goes by, there are more companies that involved in the sector of producing robot, most notably Adept Technology, KUKA Robotics and Comau (Hashmi, 2014).

Articulated robot is a robot which its constructed parts based on numbered of joints and links. There are two types of joint, which are known as prismatic joint and revolute joint. Prismatic joint enable the robot components to move in linear direction whereas the revolute joint permitted rotation about single-axis. Articulated robot is able to perform operation, moving from one location

to another, without hindrance or overcome the obstacle by any means. As a result, it is demanded highly in the manufacturing field such as assembly, welding and so on.

1.2 Problem Statement

Nowadays, articulated robot is broadly implemented in the industry, where it is employed to perform tasks which are previously conducted by human workers. In conventional design method, 3D modelling of the robot is carried out initially by using modelling software such as SolidWorks or Catia, along with the inclusion of kinematic modeling. Through this software, the appearance of the robot is presented in the physical form. Yet, there are certain limitation, where the dynamic and control aspect of the robot design procedure is beyond the capability of the 3D modeling software. In real life, most of the design process of the robot requires the fabrication of the actual prototype, follow by the experimental testing that performed on it in order to obtain the information regarding the dynamic and control feature of the robot. The actual prototyping consumes high cost and manpower resource, together with the highly chances to reproduce the prototype if there are occurrence of errors that caused it. Concern to the problem that is raised above, a numbered of researchers have implemented virtual prototyping of the robot which includes the simulation of the dynamic and the control model of the robot in the development stage of the robot.

In this study, there is a unique method of virtual prototyping which is known as co-simulation, was suggested to simplified and accelerate the design process of the 3-axis articulated robot.

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1.3 Objective

The objectives for the projects are:

- To design 3-axis articulated robotic arm using the co-simulation technique which utilizes the Adams and MATLAB Simulink software
- To analyze and evaluate the main parameter obtained from the co-simulation of 3-axis articulated robot arm such that the effectiveness of co-simulation technique can be justified.

1.4 Scope

The scope of this study is defined as:

- To design an articulated robot with 3 degree of freedom without specific end-effector
- Construct 3D modeling of the articulated robot with SolidWorks in condition where the fabrication of the model is excluded
- Conduct simulation of the articulated robot by using MSC ADAMS and Matlab Simulink
- Implement the control of the articulated robot with PID controller
- Perform tuning of the controller by using manual tuning method

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, there will be discussion and description of information that is related to the objectives of studies. The section includes the following elements such as the robot, simulation, modelling and control. In the robot section, history, definition, type and application of robot will be described. Issue regarding the theory of simulation, co-simulation and 3D modelling prior to simulation are going to be illustrated at simulation part. Kinematic modeling and dynamic modeling will be depicted under the subtopic of modelling. Lastly, the field of control is going to cover about the background of the controller implemented in articulated robot, type of controller and composite control mode.

The information is acquired from various sources, for instance books, journal articles, relevant previous research papers and online articles. Most of the references are based on the previous similar project that is conducted, which are related to this study. Besides, some of references provide the basic knowledge and theoretical facts for elements that are need in the research.

The background of the reading materials are about the co-virtual prototyping of the articulated robot. Elements obtained from the materials, provide hindsight and clearer understanding regarding the project which is going to be studying.

2.2 Robot

Robot is a programmable machine that is tasked to replace humans in order to perform duties which they are conducted. In this section, there is detailed explanation regarding the history of robot, definition of robot, types of robot and eventually the application of robot.

2.2.1 History of Robot

History of robot can be traced back to 1300 BC, where one of the first automated machines was built. In Theban necropolis of Egypt, two massive stones statues (known as Colossi of Memnon) had been made by Amenhotep, which could produce sounds by its own (Patel, 2011).

In 428 BC, Greek mathematician Archytas had invented a self-propelled flying mechanical bird, which was known as "The Pigeon". The Pigeon was designed based on the structure of bird as well as the flying mechanism of bird (Haughton, 2009)

In between 1768 and 1774, Pierre Jaquet-Droz had constructed three automata, deemed as the Writer, Draftsman and the Musicians. The Writer was able to write a text of 40 characters, in the form of letter by letter. For the Draftsman, its design was similar to the Writer but it was able to perform four

different designs via three sets of cams home. The Musician was able to perform the instruments based on the melodies that are composed by Henri-Louis Jaquet-Droz (Kim, 2013)

In 1958, General Motors designed a robot for the application of heated die casting machines and welding. It was the first robot designed for this type of application. Three years later, it was installed on one of the Unimate factories and its usage was widely expended in multiple factories in 1968 (Faust, 2007).

In the research of the simulation and experimental work of manipulator, KUKA KR 5 SIXX R650 robot was used as the subject for the studies. It is a six degree-of-freedom manipulator. The robot was tasked to perform movement in three different paths (Sulaiman *et al.*, 2013). In the investigation of the tracking control of a robot arm, a two degree-of-freedom robot arm was modelling in the virtual environment and simulated (Luo *et al.*, 2013).

2.2.2 Definition of Robot

The word of "robot" originates from the drama which was created by Karel Capek, a Czech playwright that direct the science fiction play titled "Rossunis Universal Robot" in 1921. In the drama, the robot was the slave worker that was made of artificial synthesized organic material which was similar to protoplasm. From the drama, the term "Robota" was introduced and subjected to the meaning of "slavery work". "Robota" was translated into English, which is the term Robot that is known commonly today (Wilson *et al.*, 2011)

According to the Robot Institute of America (RIA), a robot is a programmable, multifunctional manipulator designed to move material, parts, tools, or specialised devices through variable programmed motion for the performance of variety of tasks (Kurfess, 2004).

The British Association (BRA) defines a robot as a reprogrammable device to both manipulate and transport parts, tools, or specialized devices through variable programmed motions for the performance of specific manufacturing tasks (Kuttan, 2007).

2.2.3 Type of Robot

In the industry, robot is categorised into a few types based on the different types of arm geometry, power sources, applications, control techniques, and path control. It is due to the fact that robots are designed to perform required tasks in any particular situation. However, the types of robot that would be discussed below is the types of robot which is classified based on the arm geometry.

2.2.3.1 Cartesian Robot

Cartesian robot, also be referred as gantry robot. It contains prismatic joint which enable it to perform linear movement on three dimension *XYZ* axis. Cartesian robot can be divided into two types of layout, which are gantry and cantilevered. It depends on the way the arm segments of Cartesian robot mounted. In gantry type, the arm segment is mounted on the component, where both ends of the component are supported by horizontal members. For the cantilevered type, the arm segment is mounted in front of the robot. The application of Cartesian robot is for material handling, part handling and assembly operations (Sandin, 2003).