



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Design of Safety System for Industrial Robots Work Cells

Thesis submitted in accordance with the partial requirement of the
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By

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ABSTRACT

The use of industrial robots in manufacturing system has increasing. Robots keep workers safe by taking over hazardous or repetitive jobs that lead to injuries and workers compensation claims, but like all moving machinery, robots also introduce hazards into the work area, especially with work cells that are tended by human operators.

This report presents the research on the safety system for industrial robots work cells. The literature review chapter described all the related topics related to the project. These include the physical safety guards, safety sensory guards and signals and safety awareness guards and signals. Besides that, there also stated the newly standard for safety systems of robot work cells and the standard that related to it. A description of current level safety system of industrial robots work cells in Malaysia also has been described.

There were some methods and tools used in order to complete the project which included the design and development of the system. The methods and tools used are described in the methodology's chapter.

The discussions, conclusions and suggestions are provided in the last chapter. The discussions described the significant findings of the work done. The conclusions conclude the results get by the work done. Suggestions for further work are also has been described.

ABSTRAK

Penggunaan robot industri dalam sistem pembuatan semakin meningkat. Robot memastikan pekerja selamat dengan mengambil alih kerja-kerja berbahaya atau berulang yang menyebabkan kecederaan dan tuntutan insuran daripada pekerja. Walaubagaimanapun, seperti kebanyakan mesin yang lain, robot juga memperkenalkan bahaya ke dalam persekitaran kerja, lebih-lebih lagi ruang kerja yang di masuki oleh pekerja manusia.

Laporan ini mempersembahkan kajian berkenaan system keselamatan untuk ruang kerja robot industri. Bab Kajian Literatur menerangkan tajuk-tajuk yang berkaitan dengan projek. Ini termasuklah penjagaan keselamatan fizikal, penjagaan keselamatan menggunakan sensor dan signal. Selain itu, terdapat juga standard terbaru untuk system keselamatan ruang kerja robot industri dan standard-standard sedia ada yang berkaitan. Huraian mengenai aras system keselamatan semasa di Malaysia juga telah diberikan.

Terdapat beberapa kaedah dan alat yang digunakan untuk melengkapkan projek ini, yang melibatkan rekaan dan pembaharuan system. Kaedah-kaedah dan alat-alat yang digunakan dihuraikan dalam bab 'Methodology'.

Perbincangan, kesimpulan dan juga cadangan bagi projek telah disediakan dalam bab terakhir.

DEDICATION

I dedicate this PSM thesis to my beloved parent, Shaharudin Hj. Juri and Saliah Hj. Kuasah, my beloved brothers and sister, Afandi, Azizah and Mohd Nazri.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

AS	-	American standard
FKP	-	Fakulti Kejuruteraan Pembuatan
ISO	-	Industrial Organization of Standardization
JIS	-	Japanese Industries Standards
NC	-	Normally Closed
NO	-	Normally Open
PSM	-	Projek Sarjana Muda
RIA	-	Robotic Industries Association
UTeM	-	Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.1 Introduction

An industrial robot can be defined as a position controlled, reprogrammable, multifunctional manipulator having a number of degrees of freedom in three-dimensional space and capable of handling materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks (Dhillon, 1991).

Due to the characteristic of the industrial robot, it can present two opposing viewpoints in terms of industrial safety. The application of industrial robots permits the removal of the need for humans to perform certain dangerous and harmful operations, hence increasing safety. Applications in areas like welding, forging, sandblasting, painting, etc., enable workers to be free from adverse and unsafe working conditions.

However, on the other hand, the industrial robots themselves can also create dangerous conditions and threaten human safety. Accidents and even fatalities as reported from overseas have proven that industrial robots can be hazardous if no safeguard is provided to eliminate the potential hazards. Therefore, it is essential that robot users and manufacturers recognize the potential hazards and implement safeguards to eliminate the hazards.

1.2 Problem Statement

The use of robots in industry is growing at a significant rate. Robots have been used by decades in a wide variety of manufacturing industries, ranging from car assembly plants and carton building to circuit board manufacture (RIA, 1986).

Robots have many different applications such as material handling, welding, painting, machine tool load and unload, assembly, and so forth (OSHA, 1999). They are generally used to perform tasks, in hazardous environments, highly repetitive, and requiring heavy lifting. Therefore, the introduction of robots into the workplace reduces exposures to some common industrial hazardous situations with the potential to cause operators injuries. Nevertheless, it has also introduced new risks.

Robots are complex and sophisticated machines with the ability to move at various speeds along many axes. Such characteristics increase their flexibility and functions, but they also increase the hazards and the potential of accidents.

This project is done to determine the latest and new variety of safety system for industrial robots work cells. The latest technology on safety system will be researched such as the latest sensor and the problem faced by existing work cells. Automation and Robotic Laboratory of UTeM will be a case study. This project can be a reference to other universities or industries to improve their existing work cells or installed a new safety system for their industrial robots.

1.3 Objectives

The objectives of the project are:

1. To obtain the latest technology of safety systems installation for industrial robots work cell.

2. To design and develop a safety system for industrial robot work cell.
3. To identify hazards associated with applications of industrial robots.

1.4 Scope

The scopes of the project are:

1. The design and develop safety system that will be implemented and installed at the Fakulti Kejuruteraan Pembuatan (FKP)'s Automation and Robotic Laboratory of Universiti Teknikal Malaysia Melaka.
2. To come out with the latest technology of safety system installation for industrial robots work cells.

1.5 Benefit of the Project

The contributions of the project are mainly practical by nature. It involves the design and development of certain elements of safety system for industrial robots work cells.

The benefits of the project are:

1. The design and development of a safety system will be applied at Automation and Robotic Laboratory of Universiti Teknikal Malaysia Melaka.
2. The design and development of the safety system for industrial robots work cells can be a reference to other universities or industries for the improvement of their work cells or for installation of a new safety system.
3. The project can be a reference to industries or universities for the latest technology of safety system.
4. The hazard study will be a precaution for the industrial robots users.

1.6 Layout of the Thesis

The next chapter provides a literature review in area relating to industrial robots, safety system of industrial robots work cells, the comparison of current safety system of companies' industrial robots work cells in Malaysia and safety standards and regulations of industrial robot work cells. The literature review provide the understanding and enhance the knowledge of the past, current and potential technologies of safety system that are applicable to the industrial robots work cells, for achieving the objectives of the project. The key points of the literature review are summarized at the end of the chapter.

Chapter 3 describes the methodology how the data related to the project was collected and also how was it generated. It shows how the result was obtained because the methods used in conducting the project affect the result. There are different methods to conduct the project and the methodology state clear reasons why the method is chose. The methods used are appropriate with the objectives of the project the problems occurred and ways to overcome them are discussed.

The safety study method and analysis of the case study are reported in Chapter 4. The study is carried out at the Automation and Robotic Laboratory of Universiti Teknikal Malaysia Melaka. The main aim of the study is to have better understanding of the safety problems that may occurred on the robots and to provide the recommendation and design a better safety system for the robots work cells.

Chapter 5 describes the design and development of the safety system for industrial robots work cells in the Automation and Robotic Laboratory of Universiti Teknikal Malaysia Melaka. The design and development includes floor marking safety zones, fixed fence and selection of safety sensors.

The final chapter concludes the results of the projects and suggestions for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Studies in Sweden and Japan indicate that many robot accidents do not occur under normal operating conditions but, instead during programming, program touch-up or refinement, maintenance, repair, testing, setup, or adjustment. During many of these operations the operator, programmer, or corrective maintenance worker may temporarily be within the robot's working envelope where unintended operations could result in injuries (OSHA, 1999).

Typical accidents have included the following:

1. A robot's arm functioned erratically during a programming sequence and struck the operator.
2. A materials handling robot operator entered a robot's work envelope during operations and was pinned between the back end of the robot and a safety pole.
3. A fellow employee accidentally tripped the power switch while a maintenance worker was servicing an assembly robot. The robot's arm struck the maintenance worker's hand.

2.2 Industrial Robots

Robots are programmable multifunctional mechanical devices designed to move material, parts, tools, or specialized devices through variable programmed motions to perform a variety of tasks (Dhillon, 1991). A robot system consists of three elements: human operator, the industrial robot, and a communication system or human-robot interface (Graham, 1991). They are available in a wide range of shapes, sizes, and forms to perform a variety of functions.

The robotic arm can have from one to six axes of movement: Roll (clockwise or counterclockwise at the wrist), yaw (left or right at the wrist), pitch (up or down at the wrist), elbow extension (in or out), shoulder swivel (up or down) and arm sweep (left or right of the entire arm). The number of axes is normally refers as the number of degrees of freedom of the robot. "Degrees of freedom" refer to the directions of motion inherent in the design of robot mechanical systems (DOE, 1998). A robotic arm may be driven by hydraulic, pneumatic or electric power. The way the robot moves is controlled by computerized systems (RIA, 1986).

This mode of operation points at unique characteristics of robots compared to other automated devices, addressing a very common confusion between those terms. The difference between robots and traditional automated machines are 1) its flexibility in spatial movement for a quick and inexpensive change and 2) its programmability to perform a wide variety of complex tasks. The entire movement of robots needs to be programmed and record in advance for each operation they perform (Nagamachi, 1986)

2.2.1 Type of Industrial Robots

Industrial robots are available commercially in a wide range of sizes, shapes, and configurations. They are designed and fabricated with different design configurations and a different number of axes or degrees of freedom. These factors of a robot's design influence its working envelope (the volume of working or reaching space).

Typical industrial robots do jobs that are difficult, dangerous or dull. They lift heavy objects, paint, handle chemicals, and perform assembly work. They perform the

same job hour after hour, day after day with precision. They don't get tired and they don't make errors associated with fatigue and so are ideally suited to performing repetitive tasks. The major categories of industrial robots by mechanical structure are:

1. Cartesian robot /Gantry robot
2. Cylindrical robot
3. Spherical/Polar robot
4. SCARA robot
5. Articulated robot

2.2.1.1 Cartesian robot/ Gantry robot

Used for pick and place work, application of sealant, assembly operations, handling machine tools and arc welding. Cartesian robots (rectangular coordinate robots, rectilinear robots) have three prismatic joints whose axes are coincident with a Cartesian (X, Y, and Z) coordinate system. These robots may also have an attached wrist to allow rotational movement. Gantry robots are a specific type of Cartesian robot.

2.2.1.2 Cylindrical robot

Cylindrical robots have at least one rotary joint and at least one prismatic joint. The space or coordinate system in which these robots operate is cylindrical in shape. Used for assembly operations, handling at machine tools, spot welding, and handling at diecasting machines. It's a robot whose axes form a cylindrical coordinate system.

2.2.1.3 Spherical/Polar robot

Used for handling at machine tools, spot welding, die casting, fettling machines, gas welding and arc welding. Spherical or polar robots have an arm with two rotary joints and one prismatic joint. The axes of a spherical robot form a polar coordinate system.

2.2.1.4 SCARA robot

Selectively compliant arm for robotic assembly (SCARA) robots are cylindrical and have two parallel joints to provide compliance in one selected plane. SCARA robots are commonly used in assembly applications. Used for pick and place work, application of sealant, assembly operations and handling machine tools.

2.2.1.5 Articulated robot

Used for assembly operations, die casting, fettling machines, gas welding, arc welding and spray painting. It's a robot whose arm has at least three rotary joints.

2.2.2 Robots Working Envelope

Robots working envelope or working area is a three-dimensional shape that defines the boundaries that the robot manipulator can reach, or volume of space that encloses the maximum designed reach of the robot manipulator including the end effector, the work piece and the robot itself. All interaction between the robot and other machines, parts and processes must take place in within the working envelope. By using limiting device, the working envelope can be reduced or restricted. The working envelope is influenced by some factors of robot's design such as the configuration, axes or degrees of freedom. The