UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

FORCE ANALYSIS ON ROBOTIC DEBURRING PROCESS

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

By

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April 2008

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PSM

JUDUL:

FORCE ANALYSIS ON ROBOTIC DEBURRING PROCESS

SESI PENGAJIAN: **Semester 2 2007/2008**

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DECLARATION

I hereby, declared this thesis entitled "**FORCE ANALYSIS ON ROBOTIC DEBURRING PROCESS**" is the results of my own research except as cited in references.

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ABSTRACT

Force and torque sensing is one of the important equipment for several automatic and industrial robotic application. Force and torque sensor use to measure the force and torque and as control mechanism. It almost use in application of finishing process and operation such as grinding, drilling and deburring In robotic deburring the force and torque sensing is use to control the force with the interaction between deburring tool and material part. In this project the use of the force and torque sensor is investigate to know its application from past researcher. The related equipment was identified for application the force and torque sensor in industrial robotic deburring. The relevant data that related to the experimental set up was analyses to know the measure of force and torque sensor in robotic deburring. The relationship is made for different selected material. The material that selected is aluminium, acrylic, copper and stainless steel. In theoretically the expected result was analyses for the selected material base on its mechanical properties.

ABSTRAK

Pengesan daya dan daya kilas adalah salah satu daripada peralatan penting untuk sesetengah automasi dan aplikasi robot industri. Pengesan daya dan daya kilas digunakan untuk mengukur daya dan daya kilas dan bertindak sebagai mekanisma kawalan. Kebanyakannya di gunakan dalam aplikasi proses 'finishing' dan operasi seperti 'grinding', 'drilling' dan 'deburring'. Dalam 'deburring' menggunakan robot, pengesan daya dan daya kilas digunakan untuk mengawal daya yang dikenakan antara alat 'deburring' dan bahan kerja. Dalam tesis ini, kegunaan pengesan daya dan daya kilas adalah untuk menyiasat aplikasinya daripada penyelidik yang lepas. Peralatan yang terlibat telah dikenalpasti untuk aplikasi pengesan daya dan daya kilas dalam industri menggunakan robot 'deburring'. Data yang relevan yang berkaitan dengan penyediaan ujikaji telah di analisa untuk mengetahui ukuran pengesan daya dan daya kilas dalam 'deburring' menggunakan robot. Satu perhubungan telah dibuat untuk bahan ujikaji berbeza yang telah dipilih. Bahan ujikaji yang telah dipilih adalah aluminium, perspek, tembaga dan keluli tahan karat. Secara teorinya, keputusan yang telah di jangka telah di analisa untuk bahan ujikaji yang berbeza berdasarkan kepada ciri-ciri mekanikalnya.

ACKNOWLEDGMENT

First of all, I want to thank The Almighty God because of His permission that gives me strength to finish this report with successfully even many difficulties that had come. For my beloved parents Hj Omar bin Musa, Hjh Wan Zainab bt. Wan Abdullah and all my family, thanks for all support that have been given in finishing this PSM.

Then, my PSM supervisor Mr. Khairol Anuar bin Rakiman that always gave guidance for me during this period and help me to complete this project. Beside that, I want to take these opportunities to thank to my entire lecture and technicians that teach me all the useful knowledge that I had used during this PSM.

Finally, thank to all people that I cannot mention that always gave me a support and cooperation during the finishing this report. All of the name will be remain in my heart always and may god bless everybody.

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, robotic application is already familiar with the industrial field. It helps human to do lots of certain task that cannot do by human. This integration between robots and human are very useful in the human life.

In industrial, there are many tasks that require mechanical interactions with the environment, such as assembly, grinding, or deburring. It is necessary to control this interaction force if the task is to be performed successfully.

The forces and torques that encountered with the robot arm can be measured by using force/torque sensor. It includes joint force sensing, wrist force sensing, and finger force sensing.

The advantage of measuring arm joint forces indirectly is that a separate system of force sensors is not required. The joint forces are simply determined by measuring load variables that already exist in the system.

The major disadvantages of sensing arm joint forces in a manipulator is that the resulting force measurements do not always provide an accurate indication of the exchange of forces between the robot end-effector and its surrounding objects.

To get accurate force information, one must evaluate things like the inertial forces created through arm movement, joint friction, and the load of the arm itself.

1.2 Problem statement

Most of the robot tasks require contact with the surrounding environment. That interaction generates contact and surface forces that should be controlled in order to finish the task correctly. Those contact forces depend on the stiffness of the tool and working objects, and surface of the material. It should be properly controlled.

The difference of the mechanical properties effected the measurement of the force and torque sensor. It is cause of the strength of the material. The force torque sensor is attached at the end of six degree of freedom (DOF). It is most suitable part to place the force torque sensor.

In surface finish process, the surface is cleaned from the burr or thin. This operation is integrating force torque sensor at the end of end-effector. These sensors allow the measurement of the force between the workpiece and the surrounding environment. Surface finish has to done in order to get good product, safety, etc.

1.3 Objectives

The main objectives of this project are:

1.3.1 To integrate particular application of force/torque sensor with robotic application

1.3.2 To understand the force behavior in the surface finish process

1.3.3 To understand the force and torque sensor use in surface finish process

1.4 Scope of the project

The scopes of the project are:

1.4.1 Do planning for the experiment of setup for robotic surface finish process base on the force/torque sensor by using some different material selection
1.4.2 Design the path planning for the experiment
1.4.3 Investigate the problem occur in experimental setup planning
1.4.4 Do analysis on the result of force and torque especially for different material

1.5 Project outline

This report is split into seven chapters. The chapter is described as follows:

Chapter 1 is discussing the objective, scope and problem statement.
Chapter 2 is relates the literature review to the variety of uses and application of force torque sensor in surface finish process.
Chapter 3 is described the proposed methodology in the experimental setup. It includes the proper and optional methodology.
Chapter 4 is discussing planning the experimental setup.
Chapter 5 is shows the result from the experiment.
Chapter 6 is analyzing and discussion of the data. Make a comparison between theoretical and the actual result.
Chapter 7 is summarizes the overall analysis of the study and suggests tasks that can be carried in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, robotic is widely used around the world. It used to help people do the job that cannot do by human kind. According to the Robot Institute of America (1979), robot is "A reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks."

Force is one of the important elements in human life. According to the Webster Dictionary, force is "Any physical cause capable of modifying the condition of movement or of rest of a body, or of deforming it." It also define as "A torque exerted on a gimbal, gyro rotor or accelerometer proof mass, usually as a result of applied electrical excitations exclusive of torquer command signals."

Force sensor is one of the main elements in the robot system. It plays important rules in robot mechanism. It will be function as a receptor in human body.

In general, deburring is one of the finishing processes. Deburring is done by cut off the burr that found at the product. Finishing of the machine part is required to remove material in small amounts to bring the part to the required tolerance.

For industrial robotic applications force/torque sensors are usually placed near the working tool, generally in the manipulator wrist. This means that the sensor must be reasonable small, built in several sizes to adapt to different robot bolt patterns and load capacities, and mechanically resistant (Pires et. all).

2.2 Previous Achievement

The use of robotic manipulators has been growing up dramatically in the last decades. Common applications range from the assembling and welding of different parts in the automotive industry to the manipulation of unknown objects in space missions. The broad spectrum of applications has lead to a quite big number of different and specific designs for such robotic manipulators. Main differences are found in their architectures: number and type of degrees of freedom (DOF), dimensions of its links, actuators or sensors employed.

There are few types of finishing process. It includes grinding, chamfering, polishing, and deburring. All these types of finishing process are supposed to shape a part to its desired geometry.

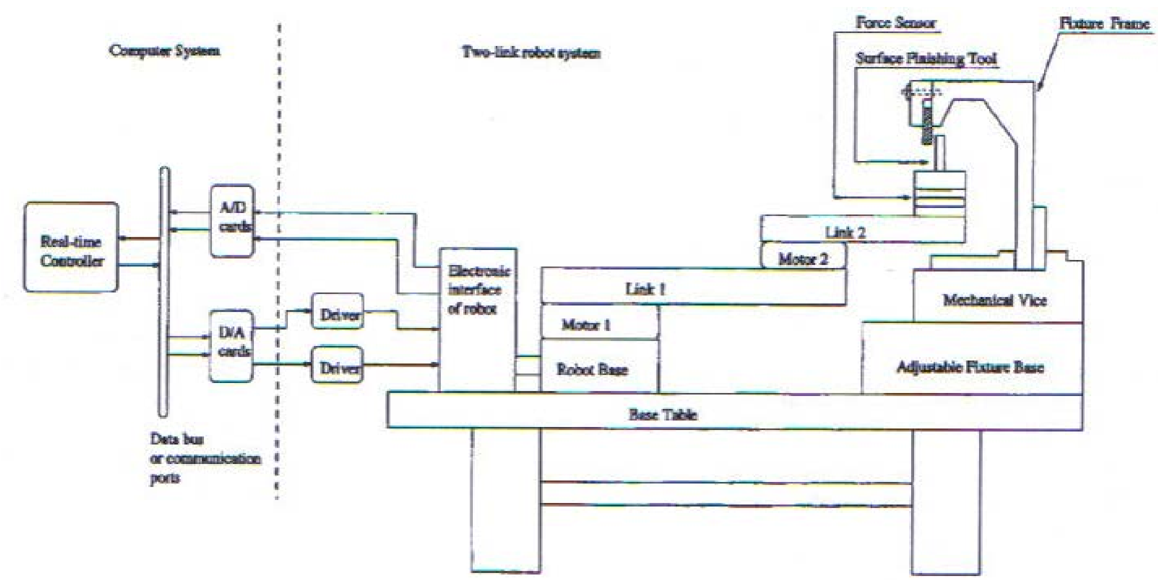

Figure 2.1: Schematic of Robotic Surface Finish System

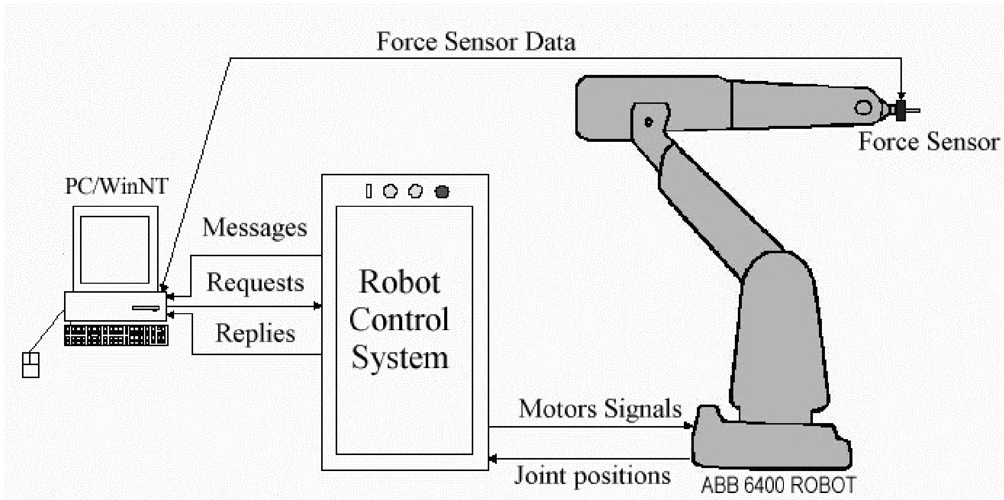

Figure 2.2: Sensorization System (Ricardo Araújo et all, 2002)

In this section, a set of software tools designed to program, control and monitor the industrial robot (ABB IRB 6400). The main objective is to design tools to add force control capabilities to the original setup (robot and controller). A PC based wrist mounted force/torque sensor (from *JR3* Inc.) was installed on the robot. The basic setup is shown on Figure 2.2. The software is divided into four main parts which are robot communication software, force/torque sensor access and configuration software, connectivity to windows applications and force control application software.

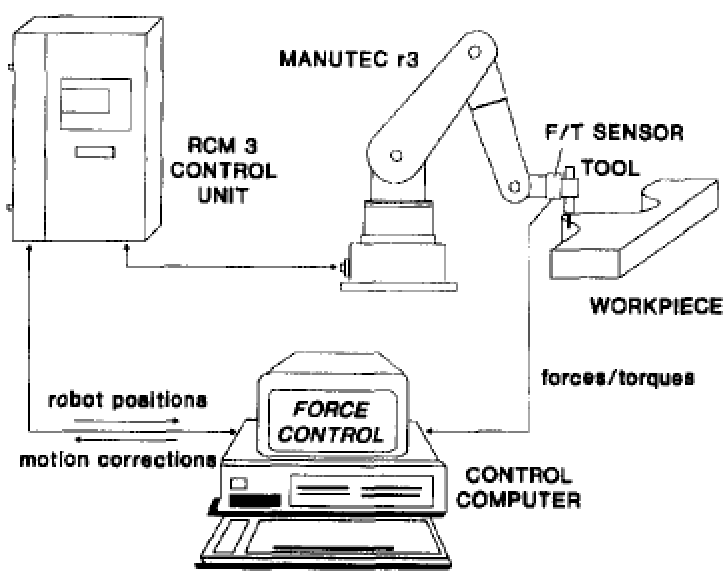

Figure 2.3: Force/Torque Sensor Setup (Liu. M. H, 1995)

Figure 2.3 shows the force/torque sensor setup. The computer will control the robot position. Sometimes the robot motion will not follow the direction and instruction that had programmed before. In order to overcome this situation, the computer will be act to make robot motion corrections. It also controlled the forces and torques whiles the deburring process in progress.

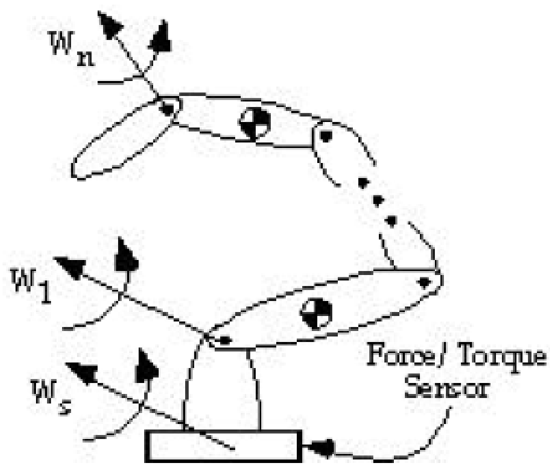

Figure 2.4: N-Joint Manipulator Mounted on a Force/Torque Sensor (Liu.G. et all, 1998)

An n-joint manipulator mounted on a six-axis base force/torque sensor as shown in Figure 2.4. The manipulator is mounted on a base force/torque sensor. Sensor measurements and joint velocities recorded during manipulator motion are used to identify the inertial parameters.

The sensor measurements are used to identify the inertial parameters. The manipulator has n+1 links, where link 0 and link n is the base and the terminal link, respectively. The wrench measured by the base force sensor is denoted as Ws. (Liu.G. et all, 1998).

These parameters can be estimated using the manipulator's joint torques and forces along with the joint positions and velocities. Most robot manipulators are not equipped with joint force/torque sensors. A typical estimate is from the motor current. A major difficulty with this method is that the joint force/torque estimation accuracy is limited by unmodeled joint friction and actuator dynamics. A base-mounted force/torque sensor has been used to estimate mass properties of a manipulator statically.

The manipulator is mounted on a six-axis force torque sensor. Sensor measurements and joint velocities recorded during manipulator motion are used to identify the inertial parameters. The inertial parameters of robot manipulators can be estimated using the manipulator's joint torques and forces along with the joint positions and velocities. A major difficulty with this method is that the joint force/torque estimation accuracy is limited by unmodeled joint friction and actuator dynamics.

The robot manipulator is mounted on an external base force/torque sensor. The force torque sensor measures a wrench that corresponds only to the forces and torques effectively applied to the manipulator's links. (Liu.G. et all, 1998)

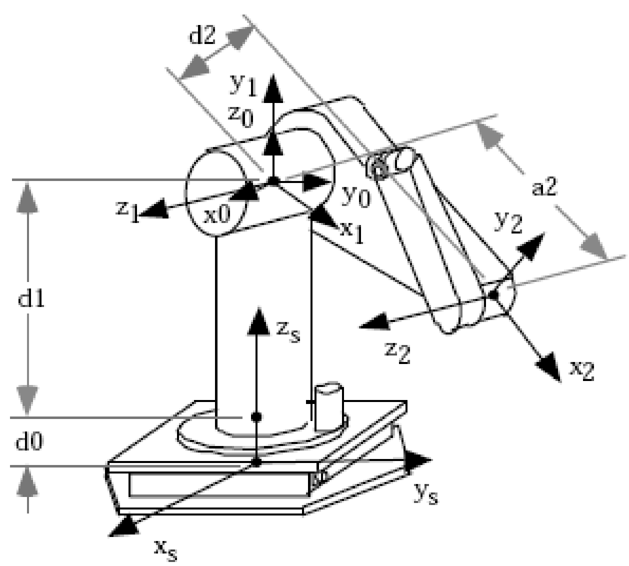

Figure 2.5: A PUMA 550 Manipulator Mounted on a Six-Axis Force/Torque Sensor (Liu.G. et all, 1998)

A PUMA 550 robot has been implemented and tested in proposed inertial parameter estimation method. The proposed inertial parameter estimation method has been implemented and tested on a PUMA 550 robot. The manipulator was mounted on an

AMTI six-axis force/torque sensor as shown in Figure 2.5. Only the first two joints of the PUMA were actuated, in order to reduce model complexity. The other joints which are joints three, four, and five were immobilized.

The base force/torque sensor is external to the manipulator. The same sensor can be used for parameter estimation for different robot manipulators. The accuracy depends on the measurement accuracy of the force/torque sensor.

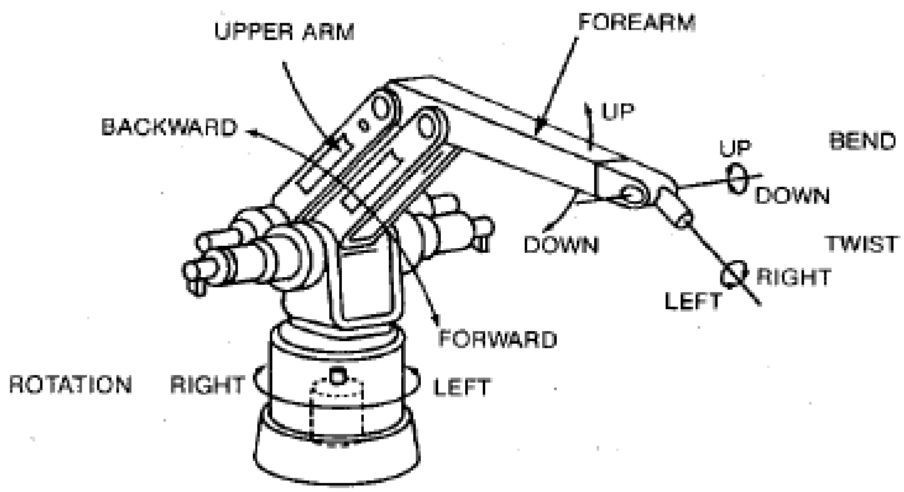

Figure 2.6: Multi Degree of Freedom Robot Manipulator (Stephien et al, 1987)

As a starting point for developing a multi-degree-of freedom force controlled manipulator, force control was implemented on single axes of the robot. The five robot axes, shown in Figure 2.6, may be classified into two types: resonant and non resonant. Resonant axes include rotation, upper arm, and forearm exhibit significant dynamic coupling between motor and load through compliant harmonic drives. Non resonant axes which are twist and bend do not exhibit such coupling.

The 6 DOF robots are equipped with position sensors and 6 DOF force/torque sensor, which are integrated in two separate feedback paths. The proposed control concept was developed to implement the following features to force/position control of robot manipulators. The control concepts are Cartesian space data processing of sensor and trajectory data, singularity robust inverse kinematics, adjustment of desired trajectories to