# EXPERIMENTAL DESIGN, ANALYSIS AND SIMULATION OF HUMAN-LIKE HAND TREMOR BEHAVIOUR

AZIZAN BIN AS'ARRY

A thesis submitted in fulfillment of the
requirements for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

NOVEMBER 2009

To my beloved mother Pn. Jamilah Sahminan and my beloved father As'arry bin Johari, who now rest peacefully with Him. – Al Fatihah.

## ACKNOWLEDGEMENT

Alhamdulillah, all praise is due to Allah S.W.T, the Most Beneficent and the Most Merciful, who has taught me what I knew not.

I would like to express my deepest appreciation to my project supervisor, Dr. Mohd. Zarhamdy Md. Zain for all the advices, guidance and motivation given throughout this thesis. I also like to give my sincere thanks for giving me the opportunity to do the project on experimental analysis of human like hand tremor behaviour. This project has given me valuable experience especially in learning various aspects sensors, programming and simulation. Special thanks also to my co-supervisor Professor Dr. Musa Mailah for his inspiration, teaching and advices.

I would like to further extend my gratitude to all lecturers, researchers, my friends in FKM and FKE, all suppliers and technicians who has assisted me directly and indirectly throughout the progress in completion of my project. I will not forget all opinions and supports given.

Last but not least, I want to whole heartedly give my appreciations to my beloved mother and family for giving me the unlimited supports and motivation when I faced the difficulties in carrying out this project.

Thank You.

## ABSTRACT

The purpose of this study is to investigate human hand tremor behaviour in postural condition. In order to achieve the objective, an experimental rig is fabricated as an apparatus to emulate the tremor behaviour. The experimental rig is designed to induce vibration along the dummy hand-arm in postural condition. In this study, an Intra Vernacular (IV) Training arm is used as the dummy hand-arm. Two DC motors are used to spin unbalanced masses as the source of excitation to the hand-arm. The quantitative assessment of human hand tremor and dummy hand-arm are mainly measured and recorded at the palm hand using light-weight accelerometer and displacement laser sensor. The accelerometer converts the physical movement to the acceleration signal. A laser displacement sensor is used for precise measurement due to its high sensitivity in motion. The laser is directly targeted at the palm hand, adjacent to the location of the accelerometer. The displacement and acceleration signals were then examined in time and frequency domains. In addition to that, a mathematical model of a four degree-of-freedom (DOF) system is introduced to represent the simulation biodynamic response (BR) of the palm of the human hand. Simulation results found that the tremor at palm hand occur at 9 and 12 Hz while the frequency of actual human hand tremor was observed at 9 Hz. From the findings, it is found that the fabricated experimental test-rig is capable to simulate the behaviour of human postural tremor at 9 Hz when the unbalancing mass rotate by the DC motors at the range frequency of 67.91 Hz to 77.80 Hz. Both results of the experiment and simulation can be used for further analysis of human hand tremor; typically Parkinson's disease (PD) and this will help in the development of anti-tremor devices that can suppress tremor.

# ABSTRAK

Tujuan kajian ini adalah untuk menyelidik sifat getaran pada tangan manusia dalam keadaan *postural* (kedudukan tangan dan lengan lurus dan juga bersudut tepat dengan badan). Untuk mencapai objektif ini, sebuah alat ujikaji telah difabrikasi sebagai alat untuk meniru sifat getaran. Alat ujikaji ini juga direkabentuk untuk menghasilkan getaran di sepanjang model tangan-lengan pada kedudukan *postural*. Dalam kajian ini, Intra Vernacular (IV) Training arm digunakan sebagai model tangan-lengan. Dua DC motor digunakan untuk memutar jisim yang tidak imbang sebagai punca getaran pada model tersebut. Kuantiti penilaian pada getaran tangan manusia dan model tangan-lengan diukur dan direkod pada tapak tangan dengan menggunakan meter pecut jenis ringan dan penderia kedudukan jenis laser. Meter pecut akan mengubah kedudukan fizikal kepada isyarat pecutan. Penderia kedudukan jenis laser digunakan untuk pengukuran yang tepat kerana sensitiviti yang tinggi terhadap pergerakan. Laser itu dipancarkan terus pada tapak tangan bersebelahan dengan kedudukan meter pecutan. Isyarat kedudukan dan pecutan kemudiannya dinilai dalam masa dan frekuensi. Sebagai tambahan, satu model matematik pada sistem empat darjah kebebasan telah diperkenalkan untuk mewakili respon biodinamik pada tapak tangan manusia. Keputusan simulasi mendapati bahawa getaran pada tapak tangan berlaku pada 9 dan 12 Hz sementara itu frekuensi getaran pada tapak tangan manusia adalah pada 9 Hz. Daripada hasil yang didapati, alat ujikaji ini berupaya untuk meniru sifat getaran tangan manusia pada 9Hz apabila DC motor membawa jisim tidak seragam pada frekuensi tabii dari 67.91Hz ke 77.80Hz. Keputusan hasil ujikaji dan simulasi boleh digunakan untuk analisis lanjut berkenaan getaran pada tangan manusia yang kebiasaannya orang yang menghidap penyakit Parkinson dan kajian ini boleh membantu dalam pembagunan alat anti getaran yang boleh mengurangkan getaran.

# TABLES OF CONTENTS

# LIST OF TABLES

## LIST OF FIGURES

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| BR | - | Biodynamic Response |
| CAD | - | Computer Aided Design |
| CNS | - | Central Nervous System |
| DAQ | - | Data Acquisition Card |
| DC | - | Direct Current Motor |
| DOF | - | Degree of Freedoms |
| EMG | - | Surface Electromyography |
| ET | - | Essential Tremor |
| FFT | - | Fast Fourier Transformation |
| IV | - | Intra Vernacular Training Arm |
| MEMs | - | Microelectromechanical |
| N | - | Newton |
| PD | - | Parkinson’s diseases |
| PID | - | Proportional-Integral-Differential |

## LIST OF SYMBOLS

| | | |
|---|---|---|
| F, f | - | Force |
| *g* | - | Gravity = 9.81m/s |
| *l* | - | Length |
| *m* | - | Mass |
| c | - | Damper |
| k | - | Spring |
| *x* | - | Displacement |
| *t* | - | Time |
| Hz | - | Frequency unit |
| A | - | Ampere |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 General Introduction

Recently, the biomechanics study has been expanded to improve the life of people with different capability. Integration of medical and engineering fields promises great inventions in the enhancement of technologies that benefit both professionals. This study is intended to analyze and assess human hand tremor and Intra Vernacular (IV) Training Arm that simulate vibration using an experimental rig. Various studies and researchers have been carried out in this area of human hand tremor. Most of them used accelerometer as a sensor for measuring acceleration and displacement. However, the displacement result was unfavorable due to excess noise which occurred after using double integration method on the acceleration results. Therefore, this study has used two different transducers, 1) accelerometer for measuring acceleration and 2) laser displacement for precise measurement of displacement hand tremor. Prior to the actual measurement of human hand tremor, an experimental test rig is designed and fabricated for the purpose of experimental data collection on the IV Training Arm. In simulation environment, a mathematical model of four degree-of-freedoms (4-DOFs) system is introduced to represent the biodynamic response (BR) of the palm of the human hand. The parameters which have been included in this project were amplitude of displacement and acceleration of hand tremor's oscillation that has been measured and recorded in the time and frequency domain. Both results of the experiment and simulation can be used for further analysis of human hand-arm tremor; typically Parkinson's disease (PD) patient. In addition, the rig also gives great advantage in determining human hand-arm behaviour especially when applying anti-tremor device such as anti-vibration

glove, piezoelectric or electrostrictive actuators which possible to reduce or cancel the vibration of IV Training Arm.

## 1.2 Background of the Problem

Tremor or involuntary disorder movement occurs in about two-thirds of people with Parkinsonism and is often the most visible and obvious sign of the disease. While the Parkinson tremor usually affects the hands and feet, it sometimes involves the lips, tongue, and jaw [1]. People who had Parkinson Disease experience difficulties which interfere when doing personal activities, especially in writing and holding something. In addition, the person also feels embarrassed to face other people and worse they prefer to stay at home rather than outside. Consequently, it may negatively impact their quality of life, mood and independence [2].

In order to help this kind of people, lots of ideas and research surfaces and finally, this project aims to investigate the behaviour of human hand tremor. In the final chapter, some recommendations were proposed to suggest a suitable anti-tremor device to be developed. However, this study only focuses on measurement of tremor hand at postural condition in z-axis because the tremor amplitude is most significant at the axis [3].

## 1.3 Statement of the Problem

Human hand tremor cannot be cured but it has treatments that may alleviate the symptoms. However, most treatment methods have their own weaknesses, for example drug therapy may give a negative long term side effect while surgical therapy may give a high risk to a patient life because it involves operating on the brain. Therefore, this study is attempted to introduce a mechanical based non-invasive treatment by developing an experimental rig that can approximately emulate human hand tremor. Prior to that, this study will conducted tremor data collection to

investigate human hand tremor behaviour. The development of experimental rig is important in utilizing engineering methods such as conduct tests with other suitable anti-tremor devices (e.g. piezoelectric actuator, electrostrictive actuator, anti-tremor glove and etc.) at the IV Training Arm before applying at actual human hand tremor.

Besides that, suitable accelerometers in terms of their size, weight and also accuracy should be considered because these sensors will be placed on the glove. For example, it is not appropriate to choose the piezoresistive accelerometer because its height or size is not suitable to be positioned on a glove and the weight may contribute a considerable effect during the measurement.

## 1.4 Aim of Research

The aim of this research is to develop an experimental rig and simulation of human hand tremor to investigate human hand tremor behaviour at palm hand.

## 1.5 Scope of the Study

The scope of study is as follows:

a) Literature review of human hand tremor
b) Simulation biodynamic response of human hand tremor
d) Development of experimental rig
e) Data collection on the hand model
f) Data collection on actual human hand tremor
g) Measurement of tremor behaviour at palm hand.
h) Measurement of tremor hand at postural condition in Z-axis

## 1.6 Significance of the Study

Studies on the measurement of human hand tremor have flourished but most of researchers are more likely to investigate the behaviour of tremor before and after medication. Therefore, research on reducing tremor from an engineering view would be possibly study. The obvious difference between medical and engineering approach is that the medical method targets more on the brain, such as surgical and using levadopa drug but engineering method focuses more specific to the location where the actuator should be applied for example at the wrist, fore arm, hand etc.

In that case, this project can be used as an important source to look for possible way for suppression of hand tremors by using anti-tremor device. This project also would be very useful to those who are interested in measuring and conducting analysis on human hand tremor which specifically using accelerometer and displacement laser sensor. Besides that, this study might be used as a reference for Biodynamics Response (BR) of human hand tremor and development of experimental rig.

## 1.7 Methodology of the Study

This study focused on the investigation of human hand tremor by simulation and experiments. The methodologies of the study were divided into four major sections:

a) Literature Review – This section will discussed on human hand tremor, types of tremor, source of tremor, tremor treatment, measuring on involuntary hand tremor and application measuring hand tremor.

b) Modeling and Simulation – This section will discussed on the modeling and simulation environment which include mathematical equations and biodynamics response specifically at the human hand. Simulation work is performed using the MATLAB and Simulink software packages.

c) Experimental Study – This section will discussed on development of the experimental rig, equipment preparation, experimental setup, performs experiment. Besides investigating the IV Training Arm, measurement of actual human hand tremor is also addressed. Both experiments were conducted using accelerometer and laser displacement sensor.

d) Simulation and Experimental Analysis – This section will discussed on the results of simulation and experimental in time and frequency domains. The outcome of simulation and experimental hand tremor behaviour will be compared.

The methodology study can be clearly seen in step by step process as shown in Figure 1.1. In the flow chart, the simulation and experimental process will be done in parallel. Thus, monitoring both processes are needed. Finally, some recommendations will be proposed which are experimental rig improvement and anti-tremor device.

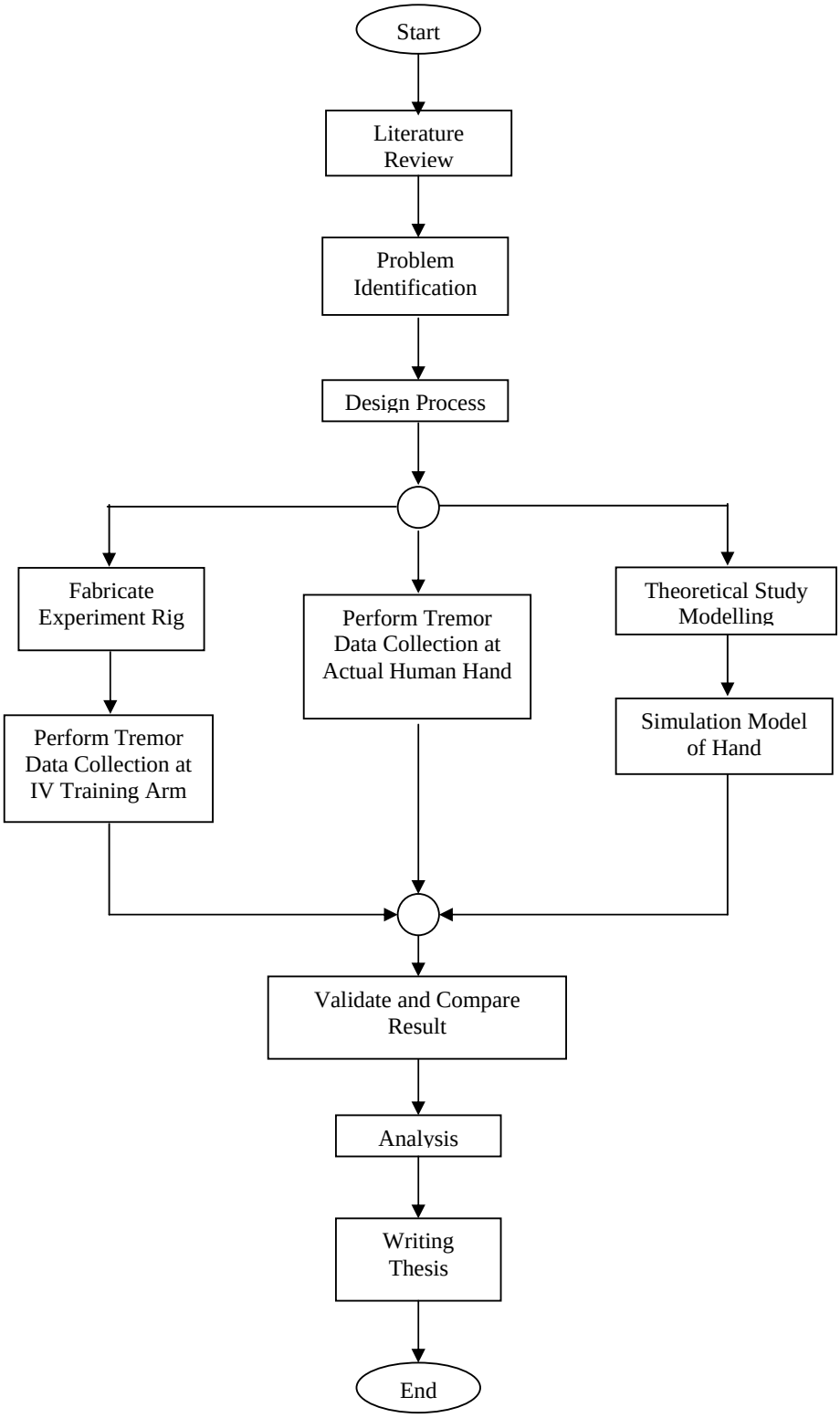


**Figure 1.1**: Project flow chart

## 1.8 Summary

The background and statement of the problem in this study has been discussed and considered. The outcomes of this study are including a complete analysis on experimental human hand tremor and IV Training Arm and simulation study on human hand.