



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**FLOW PROCESS MEASUREMENT AND CONTROL USING PID
CONROL SCHEME**

This report submitted in accordance with requirement of the Universiti Teknikal
Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology
(Industrial Automation & Robotics) (Hons.)

by

TANG SOON HENG

B 071310503

930516 – 10 – 5307

FACULTY OF ENGINEERING TECHNOLOGY

2016

DECLARATION

I hereby, declared this report entitled “Flow Process Measurement and Control Using PID Control Scheme” is the results of my own research except as cited in references.

Signature :

Author's Name :

Date :

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Automation and Robotic) with Honours. The member of the supervisory is as follow:

.....
(Project Supervisor)

.....
(Project Co-Supervisor)

ABSTRAK

Pengukuran Proses Aliran dan mengguna Skim Kawalan PID untuk kawalan adalah projek yang digunakan dalam sistem kawalan proses. Tujuan projek ini adalah untuk mengukur kadar air aliran dalam paip dan kadar air aliran ini akan dikawal oleh Skim Kawalan PID. Sistem ini menggunakan PID sebagai pengawal untuk mengawal keseluruhan sistem dan injap kawalan bermotor adalah elemen kawalan dalam sistem ini. Turbin meter aliran adalah elemen pengukur dalam sistem. Turbin meter aliran diguna dalam sistem kerana meter ini boleh mengesan aliran air dalam paip dan mengukur kadar aliran air yang alir dalam paip. Rotor yang berada dalam turbin meter aliran akan berpusing apabila mempunyai air mengalir melalui turbin meter aliran dan rotor itu akan berpusing pada kadar yang sama dengan kadar aliran isipadu. Injap kawalan bermotor adalah elemen kawalan dalam sistem kerana injap kawalan ini boleh buka atau tutup dengan sebahagian atau sepenuhnya. NI myRIO adalah pengawal yang diguna dalam sistem. NI myRIO punya input analog akan bersambung kepada turbin meter aliran manakala NI myRIO punya output analog akan bersambung kepada injap kawalan bermotor. Kesimpulannya, projek ini akan menggunakan perisian LabView untuk menunjukkan data kadar aliran.

ABSTRACT

Flow Process Measurement and Control Using PID Control Scheme is a project that used in the process control system. The purpose of this project is to measure the flow rate of fluid that flow in the pipeline and this will controlled by using a PID control scheme. PID is the controller of the system that control the whole system and the motorized control valve is the flow control element in the system. The measuring element in the system is turbine flow meter. Turbine flow meter is used in the system because it can detect the flow in the pipeline and measure the flow rate of fluid that flow in the pipeline. Once the fluid flow through the turbine flow meter, the rotor inside the flow meter will start rotate at a rate proportional to the volume flow rate. Motorized control valve is flow control element in the system because it can partially or fully opening or closing. NI myRIO is acts as the controller in the system. The analog input of NI myRIO is connecting to the turbine flow meter and the analog output of the NI myRIO is connecting to the motorized control valve. In conclusion, this project will developed by using LabView software to show the result of the fluid flow rate.

DEDICATION

To my lovely and beloved parent,

Looi Kim Chee

My siblings,

Tang Pei Theng, Tang Pei See, Tang Pei Pei and Tang Pei Pin

My supervisors,

En. Ahmad Muzaffar bin Abdul Kadir

and Pn. Rosnaini binti Ramli

Dedicated in thankful for the supporting, best wishes and encouragements.

ACKNOWLEDGEMENT

I would like to thank to everyone, who always around me, continuously supporting me, understanding and give distribution towards the successful completion of my final year project.

A special thanks to my supervisor, En. Ahmad Muzaffar bin Abdul Kadir and Pn. Rosnaini binti Ramli who had continuously give guidance and enthusiasm given throughout the progress of this project. Then, I'm also need thank to my friends, Siti Aznur binti Abu Talib, Muhamad Khairi bin Nazeri and Muhammad Iqbal bin Ilime who had been give help and assist throughout the progress of this project. It would be difficult to finish this project without their understanding and tolerance.

Lastly, a million thanks to my parent, my siblings and my friends, who always there for me in times of difficulties, happiness and for supporting me in my studies at Universiti Teknikal Malaysia Melaka.

TABLE OF CONTENT

Abstrak	i
Abstract	ii
Dedication	iii
Acknowledgement	iv
Table of Content	v
List of Tables	ix
List of Figures	x
List of Abbreviations, Symbols and Nomenclatures	xiii
CHAPTER 1: INTRODUCTION	1
1.0 Introduction	1
1.1 Background of the Project	1
1.2 Problem Statement	2
1.3 Project Objective	2
1.4 Work Scope	3
1.5 Report Outline	3
CHAPTER 2: LITERATURE REVIEW	5
2.0 Introduction	5
2.1 Type of Flow	5
2.1.1 Laminar Flow	5

2.1.2	Transitional Flow	6
2.1.3	Turbulent Flow	6
2.2	Characteristic of Flow	7
2.3	Type of Flow Measurement	8
2.3.1	Mass Flow Rate	8
2.3.2	Volume Flow Rate	9
2.3.3	Pressure Loss and Head Loss	9
2.4	Viscosity	12
2.4.1	Newtonian	13
2.4.2	Time Independent Non-Newtonian	14
2.4.3	Time Dependent Non-Newtonian	14
2.5	Type of Flow Meter	15
2.5.1	Orifice Meter with Differential Pressure Transmitter	15
2.5.1.1	Principle Operation of Orifice Meter	16
2.5.1.2	Type of Orifice Meter	17
2.5.1.3	Advantages and Disadvantages of Orifice Meter	18
2.5.2	Turbine Flow Meter	19
2.5.2.1	Principle Operation of Flow Meter	20
2.5.2.2	How to use Turbine Flow Meter	20
2.5.2.3	Advantages and Disadvantages of Turbine Flow Meter	21
2.5.3	Magnetic Flow Meter	22
2.5.3.1	Principle Operation of Magnetic Flow Meter	22
2.5.3.2	Construction of Magnetic Flow Meter	24
2.5.3.3	Installation of Magnetic Flow Meter	24

2.5.3.4	Advantages and Disadvantages of Magnetic Flow Meter	25
2.5.4	Comparison between Flow Meter	26
2.6	Control Valve	26
2.6.1	Comparison between Motorized Control Valve and Manual Hand Valve	28
2.7	NI myRIO	28
2.7.1	Connector Pinout	29
2.7.1.1	MXP: Connector A & B	29
2.7.1.2	MSP: Connector C	31
2.8	PID as the Control Scheme for the System	32
CHAPTER 3: METHODOLOGY		34
3.0	Introduction	34
3.1	Project Planning	34
3.2	Overview of the Project	36
3.3	Construction Model of the Project	37
3.4	Hardware for the Project	39
3.4.1	NI myRIO	39
3.4.2	Control Valve	40
3.4.3	Turbine Flow Meter	41
3.4.4	Signal Converter	41
3.5	Software	42
3.6	Close-loop Diagram	42

3.7	Hardware Development	43
3.8	Software Development	45
CHAPTER 4: RESULTS AND DISCUSSION		46
4.0	Introduction	46
4.1	Tuning	46
4.1.1	Open Loop Tuning Method	46
4.1.2	Close Loop Tuning Method	51
4.2	Comparison between Temperature Process and Flow Process	55
4.3	Comparison between Level Process and Flow Process	61
CHAPTER 5: CONCLUSION AND RECOMMENDATION		71
5.0	Introduction	71
5.1	Conclusion	71
5.2	Recommendation	72
REFERENCES		73

LIST OF TABLES

- 2.1 Reynolds Number of Flow
- 2.2 Roughness of pipe with different surface
- 2.3 Values of viscosity for common fluids at room temperature
- 2.4 Difference between Flow Meter
- 2.5 Difference between Motorized Control Valve and Manual Hand Valve
- 2.6 Description of Signals on MXP Connectors A and B
- 2.7 Description of Signals on MSP Connector C
- 2.8 Comparison of Gain Response of P, PI and PID Controllers
- 3.1 Specification of NI myRIO

LIST OF FIGURES

- 2.1 Laminar Flow
- 2.2 Turbulent Flow
- 2.3 Various type of fluid based on viscosity
- 2.4 Change in viscosity of Time Dependent Non-Newtonian liquid
- 2.5 Schematic Diagram of Orifice Meter
- 2.6 Various type of Orifice Meter
- 2.7 Tap location of Orifice Meter
- 2.8 Orifice Flow Meter
- 2.9 Basic Structure of Turbine Flow Meter
- 2.10 Turbine Flow Meter
- 2.11 Schematic Diagram of Magnetic Flow Meter
- 2.12 Element of Magnetic Flow Meter
- 2.13 Magnetic Flow Meter
- 2.14 Motorized Control Valve and Manual Hand Valve
- 2.15 NI myRIO
- 2.16 Primary/Secondary Signals on MXP Connector A and B
- 2.17 Primary/Secondary Signals on MSP Connector C
- 2.18 Close-loop Diagram of the system
- 3.1 Progress to develop the system
- 3.2 Overall design to develop the system
- 3.3 Schematic Diagram of the set-up of the project

- 3.4 NI myRIO
- 3.5 Electro-Pneumatic Positioner Control Valve
- 3.6 Turbine Flow Meter
- 3.7 Signal Converter
- 3.8 LabView Software
- 3.9 Close-loop diagram of the system
- 3.10 Converter convert Voltage to Current
- 3.11 Wiring part of the NI myRIO and the sensor
- 3.12 Whole Plant
- 3.13 The part of block diagram created for the whole system
- 4.1 The control display for open loop tuning method
- 4.2 The chart of the sensor response when using open loop tuning method
- 4.3 The graph of the sensor response when using open loop tuning method
- 4.4 The control display for open loop tuning method
- 4.5 The chart of the sensor response when using open loop tuning method
- 4.6 The graph of the sensor response when using open loop tuning method
- 4.7 The control display for the close loop tuning method
- 4.8 The chart of the sensor response when using close loop tuning method
- 4.9 The graph of the sensor response when using close loop tuning method
- 4.10 Find T_u by using the sensor response graph
- 4.11 The graph of the sensor response with $P = 0.727$, $I = 0.069\text{min}$
- 4.12 Control display with $K_c = 0.7$, $T_i = 0.06\text{min}$, $SP = 3$
- 4.13 The temperature of the motor and the flow rate of the water in the chart
- 4.14 The temperature of the motor and the flow rate of the water in the graph

- 4.15 The control display with $K_c=0.8$, $T_i=0.07\text{min}$ and set point, $SP=3$
- 4.16 The temperature of the motor and the flow rate of the water in the chart
- 4.17 The temperature of the motor and the flow rate of the water in the graph
- 4.18 Control display with $K_c=5$, $T_i=0.190\text{min}$, $SP=2$
- 4.19 The water level in the tank and the flow rate of the water in the chart
- 4.20 The water level in the tank and the flow rate of the water in the graph
- 4.21 Control display with $K_c=5$, $T_i=0.190\text{min}$, $SP=3$
- 4.22 The water level in the tank and the flow rate of the water in the chart
- 4.23 The water level in the tank and the flow rate of the water in the graph
- 4.24 Control display with $K_c=5$, $T_i=0.190\text{min}$, $SP=4$
- 4.25 The water level in the tank and the flow rate of the water in the chart
- 4.26 The water level in the tank and the flow rate of the water in the graph

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

A	-	Cross-sectional area of flow
B	-	Strength of the magnetic flux
D	-	Diameter of pipe
E	-	Induced voltage
L	-	Length of pipe
K _c	-	Proportional gain
PE	-	Polyethylene pipe
Q	-	Volume flow rate
Re	-	Reynolds number
SP	-	Set point
T _i	-	Integral time
V	-	Volume of fluid
f	-	Friction factor
g	-	Gravitational force
k	-	Proportionally constant
t	-	Time taken
v	-	Average velocity
h _L	-	Head loss
ΔP _L	-	Pressure loss
ṁ	-	Mass flow rate

ρ	-	Density of fluid
v	-	Velocity of fluid
μ	-	Dynamic viscosity of fluid
ν	-	Kinematic viscosity of fluid
\dot{W}_{pump}	-	Pumping power

Chapter 1

Introduction

1.0 Introduction

The purpose of this project is to design a flow process system to do the flow process measurement and control using PID control scheme. This chapter will briefly discuss the overview of this project. Measurement is the act or process of measuring something that we want to know about the system. In this project, flow rate of the water flow in the pipeline will be measured and controlled via PID control scheme. Nowadays, flow process play an important role in the industry area as the flow process measurement is the quantification of bulk fluid movement, either liquid or gas. Flow process measurement is very important in industry area because some application require the ability to conduct accurate flow measurement to such an extent that they influence product quality. Therefore, this process cannot be neglected. In this chapter, the background of the project, problem statement, project objective, work scope and report outline will be discussed.

1.1 Background of the Project

The title of this project is Flow Process Measurement and Control using PID Control Scheme. This project is to measure the flow rate of fluid flow in the pipeline by using a sensor and maintain the fluid at a certain flow rate that required. Since the fluid need to maintain at a certain flow rate, therefore a PID control scheme will be used to control the flow rate of fluid. The raw material used in this project is tap water because the viscosity of water is low and easy to measure as compared to other type

of liquid. The flow rate of fluid will be measure by using industrial type of flow meter called turbine flow meter. This flow meter is the sensor in the flow process. The details about the turbine flow meter will be discussed in Chapter 2.

1.2 Problem Statement

As the flow process play an important role in industry area, thus the measurement of flow rate of fluid flow in the pipeline must be accurate and consistent. If not, inaccurate measurement of flow may cause a serious or even disastrous results and affect the system. Therefore, to avoid this problem happen in the project, calibration of sensor need to be done before taking the measurement of flow rate of fluid. Calibration is the process of making an adjustment or marking a scale so that the reading of an instrument agree with the accepted and the certified standard. Without calibration, measurement result may be false and misleading.

Since the flow process is the secondary process in all the system, so how this secondary process can affect and relate to the main process. Therefore, the problem statement is how does the main process affect the secondary process and what is the effect to the secondary process.

1.3 Project Objective

The objectives of this project is to design a system that can:

- (a) measure the flow rate of fluid that flow in a pipeline by using industrial type of flow meter
- (b) control the fluid at a certain flowrate that required by a PID control scheme
- (c) investigate the effect of the flow rate to the level process and temperature process

1.4 Work Scope

The work scope of this project is to design a system that can measure the flow rate of fluid that flow in pipeline and control it so that can maintain at a certain flowrate required. Besides that, the minimum and maximum flowrate due to the accuracy of the sensor will be investigated too.

NI myRIO is the controller that will be used to control the system and the control element is the flow control valve. Motorized control valve is the flow control element used in the system. This control valve will control the fluid flow in the pipeline and when the control valve is opened in the condition of 50% and 100%, the flowrate of the fluid will be measured and compare it. This result will be shown in the software LabView.

The sensor that will be used is the industrial type of flow meter is called turbine flow meter. It will be used to take the measurement of the flowrate of fluid flow in the pipeline. This flow meter is operated by a rotor blade that is made of ferromagnetic material. When the fluid flow through the rotor, the rotor will start rotating and then a voltage pulse is induced. The transmitter processes the pulse signal to determine the flow rate of the fluid flow in the pipeline.

1.5 Report Outline

This report is divided into five chapters and each of the chapter is explained briefly as below.

In Chapter 1, this is introduction about the project. In this chapter, background of the project, problem statement, objective and the work scope of the project will be discussed.

In Chapter 2, this is the literature review of the project. In this chapter, all the information about the project will be explained and discussed.

In Chapter 3, is the methodology of the project. In this chapter, it will shows how the project will be carried out and explain in detail the methods that been used in project.

In Chapter 4 is the project result. This chapter consists of discussion and results of the project.

Chapter 5 is the conclusion of the project. This is the last chapter of the project. The conclusion of the whole project will be discussed in this chapter.

Chapter 2

Literature Review

2.0 Introduction

In this chapter, all the information related to the flow and the components that involve in the Flow Process Measurement and Control using PID Control Scheme are described. This project is to measure and control the flow in the flow process. This chapter is the literature review to get an idea about the specification of sensor, theory of flow, concept of flow and any information that related to the project.

2.1 Type of flow

There are 3 types of different flow of fluid in pipe:

- (a) laminar flow
- (b) turbulent flow
- (c) transitional flow

2.1.1 Laminar Flow

Laminar flow is a flow that happen when the fluid flow in parallel layers or move slowly in layers in pipe with no mixing between the layers. The velocity of the fluid flow the fastest in the centre part of the pipe flow and cylinder touching the pipe

isn't moving at all (Vinodh Reddy Chennu 2016). This flow is highly ordered fluid motion. Figure 2.1 show the form of laminar flow.



Figure 2.1: Laminar Flow

2.1.2 Transitional Flow

Transitional flow happen when the laminar flow and turbulent flow is mixing together with turbulent flow in the centre of the pipe and laminar flow near the edge of pipe (Vinodh Reddy Chennu 2016).

2.1.3 Turbulent Flow

Turbulent flow happen when the fluid is moving fast with mixing between layers (Vinodh Reddy Chennu 2016). The speed of fluid is continuously changes in both magnitude and direction. This flow is highly disordered fluid motion. Figure 2.2 show the form of turbulent flow.



Figure 2.2: Turbulent Flow

2.2 Characteristic of Flow

Since different types of flow have different characteristics. Therefore, Reynolds Number (Re) is used to determine the types of flow whether the flow is laminar, turbulent or transition. Reynolds number (Re) defined as the ratio of inertial force to the viscous force. It is used to forecast the velocity of fluid flow at which turbulent occur.

$$\text{Re} = \frac{\text{Inertial force}}{\text{Viscous force}} = \frac{\rho v L}{\mu} = \frac{v L}{\nu}$$

ρ = density of fluid (kg/m^3);

v = velocity of fluid (m/s);

L = length of pipe (m);

μ = dynamic viscosity of fluid (kg/m s);

ν = kinematic viscosity of fluid (m^2/s)