# ANALYSIS OF PNEUMATIC VALVE CONTROL SYSTEM

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
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## ANALYSIS OF PNEUMATIC VALVE CONTROL SYSTEM

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

by

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# DECLARATION

I hereby, declared this report entitled Analysis of Pneumatic Valve Control System is the results of my own research except as cited in references.

Signature : ……………………………………….

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Date : ……………………………………….

# 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 (Robotic and Automation) (Hons.). The member of the supervisory is as follow:

……………………………

(Project Supervisor)

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TAJUK: **Analysis of Pneumatic Valve Control System**

SESI PENGAJIAN: **2014/2015 Semester 2**

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# ABSTRAK

Projek ini menerangkan kajian teori dan eksperimen terhadap pneumatik DCV yang digunakan dalam sistem pneumatik dan memberi tumpuan kepada sistem kawalan yang asas. Sistem kawalan pneumatik DCV ditakrifkan dengan sistem kawalan terbuka. Persamaan matematik dikembangkan dengan menggunakan asas undang-undang fizik dan prinsip-prinsip iaitu Kirchoff's current dan undang-undang Newton pada pneumatik DCV. Selain itu, persamaan yang diperolehi membantu dalam membina graf seperti step response dan nyquist, di mana analisis seperti masa tindak balas pergerakan, peratus lebihan pergerakan, nilai kestabilan dan kesalahan, kestabilan dan tindak balas kekerapan telah dijalankan. Teknik simulasi (MATLAB) komputer telah digunakan untuk menguji dan mendapatkan keputusan hasil teori sistem kawalan. Eksperiment terhadap sistem pneumatik dijalankan dan keputusan direkodkan. Dengan membuat perbandingan terhadap kedua-dua keputusan, kita dapat melihat keadaan pneumatik tersebut sama ada dalam keadaan baik atau tidak. Implikasi projek ini adalah untuk memberikan pemahaman terhadap sistem injap kalawan pneumatik yang bertujuan untuk meningkatkan prestasi injap pneumatik yang sedia ada.

# ABSTRACT

This project describes the theoretical and experimental study of a pneumatic valve utilized in the pneumatic system, focusing on its fundamental control system. The pneumatic valve control system is defined as an open loop control system. Mathematical equations are evolved by applying fundamental physical laws and principles namely Kirchhoff's current and Newton's law, on the pneumatic valve. Furthermore, the derived equations assist in developing curves like step response and nyquist where analysis such as rise and settling time, percent overshoot, steady value and error, stability and frequency response were carried out. MATLAB programming has be used in this project in order to test and get the theoretical result for the control system. Pneumatic system experiment are conducted and result are recorded. By comparing the theoretical and experimental result, we can see the behavior of the pneumatic valve either in a good condition or not. The implication of this project is for understanding the pneumatic valve control sistem in order to improve the performance of existing pneumatic valve.

# DEDICATION

This report is dedicated to my lovely father and mother, family and my supervisor for being an internal spirit and continual support to give big and deep effects to me when this project was held. Thank you.

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| | | |
|---|---|---|
| DCV | - | Directional Control Valve |
| FYP | - | Final Year Project |
| FBD | - | Free Body Diagram |
| FRL | - | Filter, Regulator and Lubricator |
| Max | - | Maximum |
| MIMO | - | Multiple Input Multiple Output |
| SISO | - | Single Input Single Output |
| SCFM | - | Standard Cubic Feet Per Minute |
| PSIA | - | Pounds Per Square Inch Absolute |

# CHAPTER 1

# INTRODUCTION

This chapter describes the introduction of the project of pneumatic valve control system. Begin with the introduction to current issues, followed by translation of the problem statement from the questions and identification of project objectives. Next, project scope and report organization will be discussed. Lastly, Gantt chart will be covered in this chapter.

## 1.1 Background

Pneumatic is one of the power sources that is widely used in automated machine equipment in performing various automation projects. Most of the industries prefer to use pneumatic because it is simple, cheap, easy to handle and maintenance and possesses a high level of controllability. In addition, pneumatic medium; the air are widely available and compressible (Majumdar, 1996).

In pneumatic system, pneumatic valve is a vital mechanical component. The Romans first founded the valve concept. They used bronze plug as cock in their aqueducts (Borden, 1998). In general, valve consists of a body and a moving part which control air passages within the body. The moving part is essential in controlling system pressure, direction of flow and rate of flow in the system.

Pneumatic valves are available in several types. The valve type depends on the internal construction, number of the flow path in the valve, number of position or square in the valve body, actuation and operation type (Lansky, 1986).

The evolution of complex processes in industries and necessity to reduce production cost, a study approach is required to monitor the valve operating condition. Thus, it is important for engineers to analyze significant issues of the pneumatic valve to prevent the pneumatic valve from the damaged working condition. Several new methods have been implemented to maintain the pneumatic valve in good condition.

**Table 1.1:** Developments on pneumatic valve

| No. | New Development | References |
|---|---|---|
| 1. | Unconstrained vibrational pneumatic valve | (Uehara & Hirai, 2005) |
| 2. | Flow control valve using a vibration motor | (Akagi et al., 2008) |
| 3. | Pneumatic valve with biomorph type PZT actuator | (Yun et al., 2006) |
| 4. | Pneumatic actuator control system using PZT impact force | (Liu & Jiang, 2007) |
| 5. | New flow control valve is driven by PZT vibrator | (Hirooka et al., 2009) |
| 6. | Design and control of direct drive servo-valve operated by the piezostack actuator | (Jeon, Nguyen, & Choi, 2013) |
| 7. | Design of a High-Speed Electromagnetic Control Valve Using the Numerical Analysis | (Han, 2014) |

Uehara and Hirai invented an unconstrained vibrational pneumatic valve that has an orifice 2.0 mm in diameter and a metal poppet 6.0 mm in diameter (Uehara, & Hirai, 2005), Akagi invented a flow control valve utilising a vibration motor (Akagi, Dohta, Katayama, & Engineering, 2008), Yun invented a pneumatic valve along with biomorph type PZT actuator (Yun, Lee, Kim, & So, 2006), Liu et al. invented a pneumatic actuator control system using PZT impact force (Liu & Jiang, 2007) and Hirooka, Suzumori and Kanda developed a new flow control valve driven by PZT vibrator (Hirooka, Suzumori, & Kanda, 2009). Furthemore, Jeon, Nguyen and Choi designed and controlled direct servo-valve by piezostack actuator (Jeon, Nguyen, & Choi, 2013) and Han designed a high speed electromagnetic control valve using numerical analysis (Han, 2014). Refer Table 1.1.

**Table 1.2:** Pneumatic valve issues

| No. | Issues | References |
|---|---|---|
| 1. | Size, weight, safety | (Akagi et al., 2008) and (Hirooka et al., 2009) |
| 2. | Flow capacity, dirty air, vibration, leaking, controllability | (Hirooka et al., 2010) |
| 3. | Performance | (Yun et al., 2006), (Liu & Jiang, 2007) and (Akagi et al., 2008) |

However, there is problem on size, weight, safety (Akagi et al., 2008) and (Hirooka et al., 2009), flow capacity, dirty air, vibration, leaking, controllability (Hirooka, Suzumori, & Kanda, 2010) and performance in pneumatic valve system (Yun et al., 2006), (Liu & Jiang, 2007) and (Akagi et al., 2008) as stated in Table 1.2.

Analyzing pneumatic valve control system has attracted considerable work to enhance its responsiveness based on the design of pneumatic valve and input signal parameter in this project. The pneumatic valve control system will be studied by utilizing basic information and control system of pneumatic valve and evaluation using both MATLAB and experiment.

**Table 1.3:** Input and output signal parameter

| No. | Input Signal Parameter | Output Signal Parameter |
|---|---|---|
| 1. | Electrical Supply, I | Magnetic Force, F |
| 2. | Magnetic Force, F | Spool Movement, X |
| 3. | Supply Pressure, P | Response Rate, t |

Continuation to this, analyzed data will be used further in controlling and monitoring the operation of the pneumatic valve to prevent the pneumatic valve from the damage operating condition. Table 1.3 above indicates the important parameters for input and output (performance) signal for this project.

## 1.2 Problem Statement

Directional control valve (DCV) has been widely used in industry in various applications. The increasing of the complex process and the necessity to scale down production cost has increased the demand on the good quality valve. Hence, it is important for engineers or designers to develop new methods of managing pneumatic valve issues. Size, weight, current capacity, dirty air, vibration, leaking, controllability and performance are the most frequently recorded issue on the pneumatic valve. This project intends to analyze the pneumatic valve control system to get an advance understanding in several typical valve issues that may cut system setup time and attain more precise motion.

## 1.3 Objectives

The objectives of this project are to:

a) Identify the DCV,

b) Model the control system of the DCV, and

c) Evaluate the DCV control system.

## 1.4 Scope

This project is about analyzing the pneumatic DCV control system. It analyzes the stability issues by using a basic mathematical model of pneumatic DCV, control system, suitable MATLAB program and input parameter. This project will focus on the 5/2 way double solenoid-spool-sliding type valve and three primary operations; actuation valve, internal (spool movement) and emission gaseous operation. The basic mathematical model of the magnetic circuit, mechanical subsystem, and the air flow path will be encompassed in this project. Transient and frequency response, air flow rate, cylinder response rate, and power supply response will be used as evaluation measurement.

## 1.5 Organization of Report

The beginning chapter of this report describes the introduction of the pneumatic valve control system. It is followed by the description of the literature review. Next, this report proceeds with the explanation of the methodology used. Subsequently, the next chapter elaborates the results and discussion. In the end, the last chapter discusses the conclusions and recommendations of this report.

## 1.6 Gantt Chart

This project consists of two phases that are Final Project (FYP) 1 and FYP 2. The time allocated for completion of each stage of the project is one semester that equivalents to 14 weeks (Figure 1.1 and 1.2). Meanwhile, the time allocated for the entire project is equivalent to two semesters of 28 weeks, excluding semester break (Figure 1.3).

### 1.6.1 Project Schedule 1

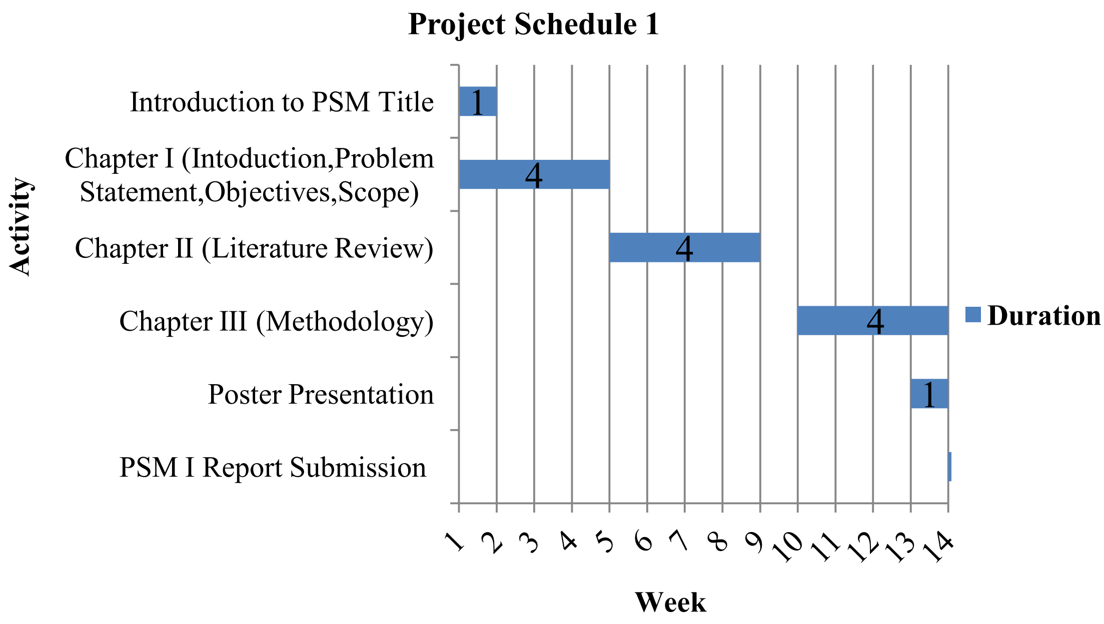


**Figure 1.1:** Project Schedule 1

### 1.6.2 Project Schedule 2

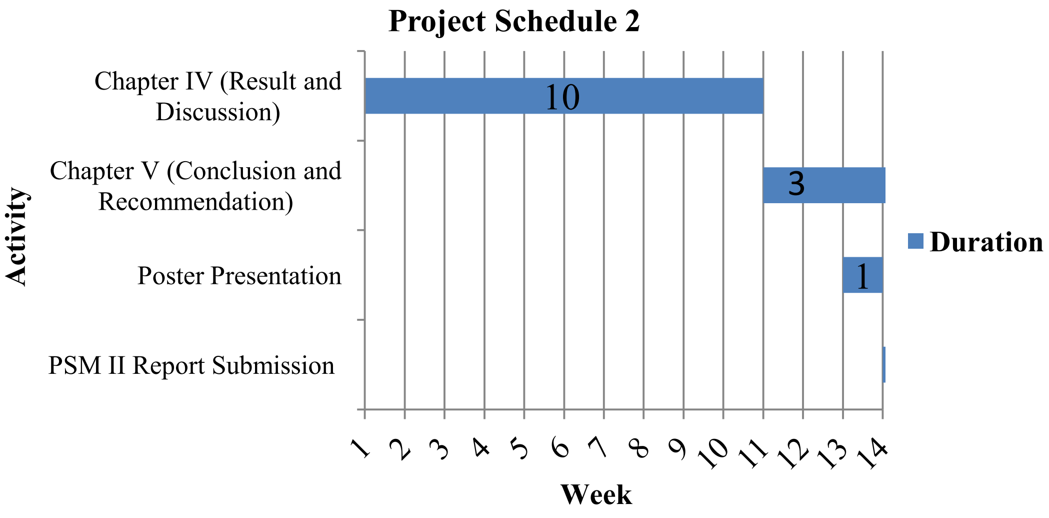


**Figure 1.2:** Project Schedule 2

### 1.6.3 Project Schedule for Entire Project (Project 1 and 2)

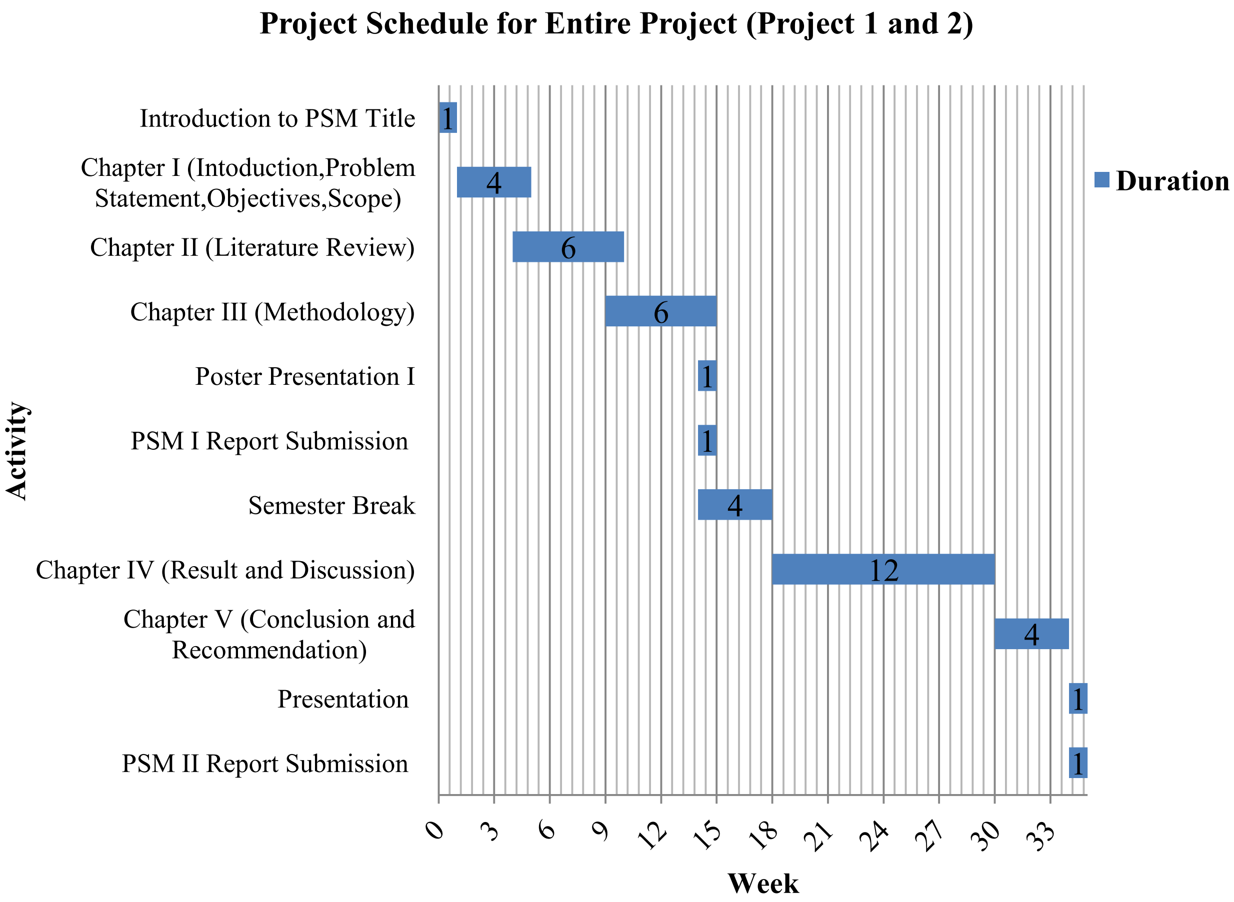


**Figure 1.3:** Project Schedule For Entire Project (Project 1 and 2)