DESIGN REED CONTROLLER FOR MIDI AUTO-SAXOPHONE

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ABSTRACT

This project presents the method of designing reed controller for woodwind instrument that is Alto saxophone. In order to produce sound from saxophone, air pressure is blow into the mouthpiece and the reed will vibrate and produce sound wave. As the reed is springy and can bend, a simple mass-spring-damper system has been developed using Matlab Simulink to model the reed. The correct pitch can be produce by controlling the air pressure and frequency of vibration. Thus, an experiment to define frequency from the reed has been obtained by attached microphone to the mouthpiece. In this way, the physical system of the saxophone reed can be define clearly to provide better approximation parameters to the real instrument. A servo motor is used to control the vibration of the reed as it is moving up and down by receiving MIDI signal from the MIDI decoder. 12V solenoid valve is used to control air pressure come from the air compressor into the mouth cavity. The result is expected to be able to control the air pressure and the vibration of the reed then can produce a nice sound from the MIDI auto-saxophone.

ABSTRAK

Projek ini membentangkan kaedah merekabentuk pengawal *reed* untuk alatan muzik *woodwind* iaitu Alto saksofon. Dalam usaha untuk menghasilkan bunyi dari saksofon, tekanan udara dikenakan ke dalam muncung paip dan *reed* akan bergetar dan menghasilkan gelombang bunyi. Memandangkan *reed* kenyal dan boleh dibengkokkan, satu system mudah jisim-spring-peredam telah dibangunkan dengan menggunakan Matlab Simulink untuk modelkan *reed* itu. *Pitch* yang betul boleh dihasilkan dengan mengawal tekanan udara dan kekerapan getaran. Oleh itu, satu eksperimen untuk menentukan kekerapan *reed* dengan menyambungkan mikrofon kepada muncung paip itu. Dengan cara ini, sistem fizikal *reed* saksofon boleh ditentukan dengan jelas bagi mendapatkan anggaran ukuran yang lebih baik untuk instrumen yang sebenar. Motor servo digunakan untuk mengawal getaran *reed* ysng bergerak ke atas dan ke bawah dengan menerima isyarat MIDI daripada penyahkod MIDI. Injap solenoid 12V digunakan untuk mengawal tekanan udara dari pemampat udara ke dalam rongga mulut. Hasilnya dijangkakan dapat mengawal tekanan udara dan getaran *reed* lantas dapat menghasilkan bunyi yang baik dari MIDI auto-saksofon.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter presents about the overview of the project. There are five sub-chapters for the overview such as project background, problem statement, and objectives of the project, project scope, and thesis outline.

1.2 PROJECT BACKGROUND

Music is a sound art to express emotional feeling between humans by playing musical instrument such as saxophone, guitar and flute. A saxophone is a musical instrument usually made by brass and consists in woodwind family which produces sound by oscillating a reed. It is classified as single-reed instrument which the mouthpiece is the part of the reed is attached. The function is to produce an opening through which air enters the instrument and one end of an air chamber to be set into vibration by the interaction between the air stream and the reed. On the other hand, pressure is the most important aspect to be considered in order to produce a better sound from the mouthpiece. The correct pitch of the sound can be produce depend on the frequency of the vibration. Therefore, the pressure and frequency must be controlled from the air coming into the mouthpiece.

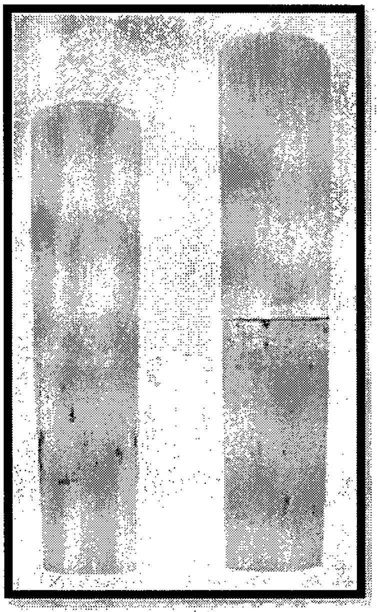

Figure 1.1 Single reed used for clarinets and saxophones

Reed is made up from a cane as shown in figure 1.1. It is classified in the different strengths from 1 to 5 measured from softest to hardest. The reed is design to be flat at the back to place closely to the mouthpiece. It is rectangular at one end and curved at the other end to match the mouthpiece shape.

MIDI auto-saxophone is an autonomous Alto saxophone that plays via MIDI signal receiving from the computer. It is applying self playing concept controlled by Arduino MEGA. MIDI that stands for Musical Instrument Data Interface used to describe protocols, digital interface and connectors then allows variety of musical instruments and other devices to connect and communicate one another.

Generally, the reed controller for MIDI auto-saxophone is basically design to be able to control air pressure entering the mouthpiece and produce sound to the saxophone. The single reed instruments like clarinet and saxophone are tuned by using air resonance as a main control fundamental. So, the mouthpiece and embouchure needs to be well controlled to get a well tuned and nice sound.

1.3 PROBLEM STATEMENT

A saxophone is a quite complicated instrument that can be played only by who is willing to learn how to play, in which case it is a bit nuisance to whom does not like loudness. However, in other view, saxophone is a wind instrument that can played soft-like romantic melody which can give a relaxing mind to people. Thus, a MIDI auto-saxophone is applying self playing instrument which make people's life much easier to listen to the saxophone. In order to develop the musical instrument robot such as MIDI auto-saxophone, various aspects need to be considered to ensure the result played by robot same as human played. One of the important aspects is reed control.

According to all saxophonists, reed is the key to produce a sound in saxophone because it controls air flow into the saxophone. This project is focusing on reed controller for MIDI auto-saxophone. It is design based on pressure need to produce a vibration on the reed locating at the mouthpiece. The air come from the air compressor is very important to control the air pressure into the mouthpiece. Thus, the development of a control system of air pressure is important to produce a perfect pitch and sound.

1.4 OBJECTIVES

The objectives of this study are:

- To design reed controller for MIDI auto-saxophone
- To develop the air valve system to control air pressure entering the mouthpiece
- To implement a mouth-lip mechanism based on human-like

1.5 PROJECT SCOPE

The scopes of this project are focusing on:

- Developing an air valve system of air pressure to control air pressure entering the mouthpiece
- Design mechanical system of mouth-lip mechanism based on human-like for Alto saxophone
- Control the vibration of reed by using a servo motor

1.6 THESIS OUTLINE

Chapter 1 explains the physics of saxophone reed and introduction to the project. Objectives, problem statement, and scope of the project also stated in this chapter.

Chapter 2 presents review of the literature that related to the overall project. It is based from history of saxophone until the innovation of the robot playing saxophone. The mathematical equation and formula related to the research also included in this chapter.

Chapter 3 focuses on method used in a way to design the reed controller for MIDI auto-saxophone. This chapter will describe the procedure of experiment and the method to find the parameters needed for the controller.

Chapter 4 discusses the result obtained and the analysis of data from experiment conducted. The comparison between frequency note playing by human and air compressor are shown in this chapter.

Chapter 5 presents a conclusion to the project and recommendation for future research development to be done to improve this project for a better result.

CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

This chapter will covered on the literature review of the previous research done by others that is related to this project. The research on the fundamental of saxophone and mechanical reed will be the main project reference.

2.2 SAXOPHONE

Adolphe Sax (1814-1894) was a Belgian who invented a saxophone in 1840. His father, Charles Sax was a musical instrument maker has influenced him to set plans of improving the tone of bass clarinet. In 1841, Adolphe showed his great creation (a C bass saxophone) for the first time to his friend, a composer name Hector Berlioz. The uniqueness and versatility of the creation has impressed him greatly. Adolphe really wanted to create an instrument that would be the most powerful from other woodwind instruments. Other than that, unlike the clarinet, he wanted it to overblown at the octave, which rises in pitch by a twelfth when overblown. A woodwind instrument that over blew at the octave would have identical fingering for both registers.

Saxophone is a conical-bore musical instrument that usually made by brass and categorized as a single-reed woodwind instrument. There are four types of saxophone commonly used by saxophonists. Soprano, Alto, Tenor and Baritone has different a different size, pitch and key even though there are categorized as a saxophone family. Alto has become the easiest saxophone member to play with especially for a beginner to master in saxophone. This project also focuses on Alto saxophone as a musical instrument used.

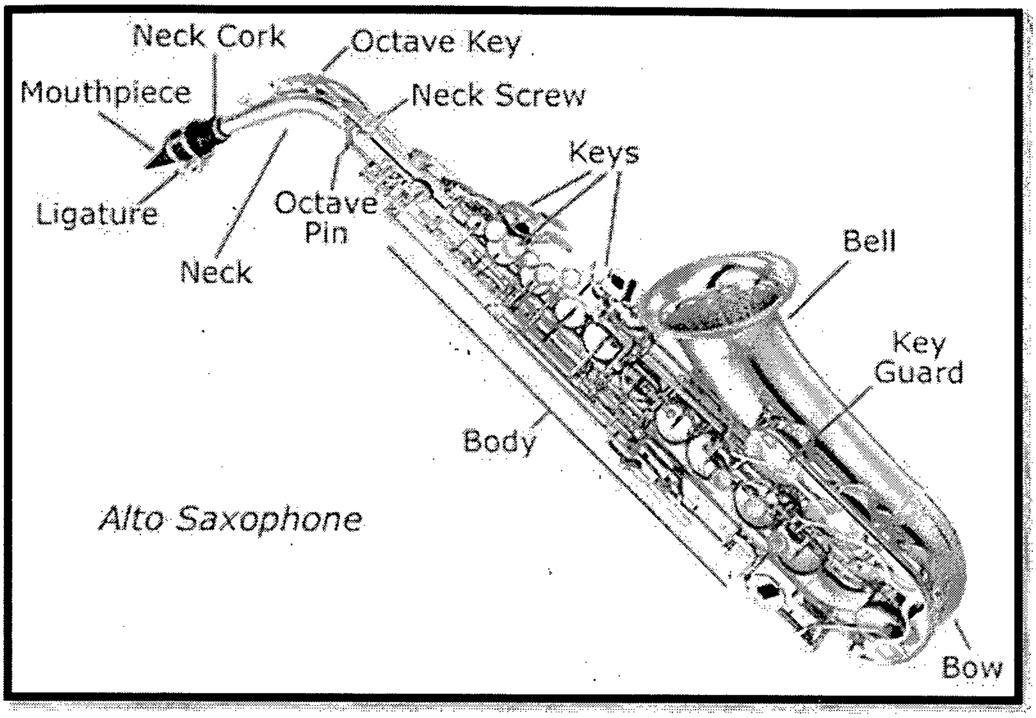

Figure 2.1 Alto saxophone parts name

2.2.1 The Mechanical of Reed

Instruments like the clarinet, oboe, saxophone, and bagpipes all have mechanical reeds that can be set into vibration by the player as he forces an air stream into the instrument ((R.Lapp, n.p., p. 75). Generally, the reed acts like oscillating controlled valve and produces an oscillating component of both flow and pressure. When the reed is vibrating the air, some of the energy is radiated as sound out of the bell and any open holes. In a meantime, a lot of energy is lost as a sort of friction (viscous loss) with the wall. The column of air in the saxophone vibrates much more easily at some frequencies than at others (i.e. it resonates at certain frequencies). The playing frequency and the pitch are determined by these resonances, and the player in effect chooses the desired resonances by suitable combinations of keys.

The flow and reed movement are controlled by the difference in pressures on the upstream and downstream sides of the reed channel, $p\Delta = p_u - p_d$. The upstream pressure is typically assumed constant or slowly varying and tends to force the reed toward the mouthpiece lay. Negative pressure in the mouthpiece tends to reinforce this action, pulling the reed toward the lay, while positive pressure in the mouthpiece, if acting alone, tends to push the reed away from the mouthpiece lay. The single-reed valve is initially open but can be blown shut against the mouthpiece lay by an appropriate pressure difference $p\Delta$.

The reed is often modeled as a mass/spring/damper oscillator. However, because of a resonance frequency (≃ 2000Hz) large compared to the first harmonics of typical playing frequencies, inertia and damping is often neglected. This hypothesis leads, considering that reed dynamics is governed by the pressure difference across the reed, to

$$k_s(z - z_0) = (p_{jet} - p_{mouth})$$

where z (respectively z_0) is the reed position (respectively at rest). The reed is closed when $z = 0$ and opened when $z > 0$. k_s is the reed surfacic stiffness, p_{mouth} and p_{jet} are the pressure deviation in the mouth and under the reed tip, respectively (Noreland and Bellizzi et al., 2009).

The reed has some non-zero mass because the effective mass may vary with displacement and lip position so that some phase delay will occur as the vibrating frequency of the reed increases. In this way, the response of the instrument may be effect by this behavior.

2.2.2 The Fundamental Of Mouthpiece

Saxophone mouthpiece is made by variety of material such as ebonite, plastic, and metals such as bronze or surgical steel. However, some mouthpieces are made by wood, glass, crystal, and porcelain but it is not very commercial to saxophonist. These materials give a specific psychological effect on the player but it is difficult to the listener to differentiate the materials use if the dimensions are the same. The mouthpiece material has little, if any, effect on the sound, and the physical dimensions give a mouthpiece its tone color (Larry Teal, 1963).

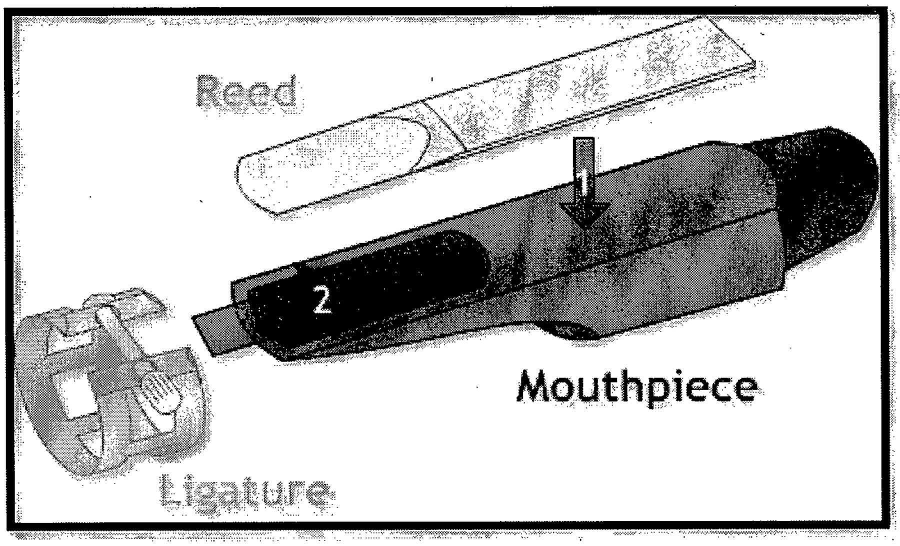

Figure 2.2 Saxophone Mouthpiece Parts

In general, the mouthpiece with a wider tip opening requires a lighter reed same as the mouthpiece with smaller tip opening requires a heavier reed. There are many factors to take consideration for a mouthpiece produce a nice sound such as baffle, chamber and the facing curve. Tip opening is known as the gap between the tip of the mouthpiece and the reed. The tip opening effects greatly to the tone produce by saxophone. The ligature used to hold the reed tightly to the mouthpiece. The saxophone ligatures are commonly made of good quality of metal or plastic.

2.3 MODELING THE SINGLE-REED

In reed instruments, as well as many vocal systems, air pressure from a source such as the lungs controls the oscillation of a valve by creating a difference between its upstream (incoming) and downstream (outgoing) pressure (Smith and Abel, 2007). The interactions between the mouthpiece lay and player lips can cause the reed exhibit a mechanical nonlinearity. Thus, a suitable modeling method has to be chosen wisely based on the reed model characteristics.

As the reed dimensions are small, a lumped modeling is suitable to simulate the oscillation of the reed when force applied to it. Furthermore, many researchers also used this method of modeling (Backus, 1963; Wilson and Beavers, 1974; Schumacher, 1981; Gilbert et al., 1989; Hirschberg et al., 1990; Gazengel et al., 1995). However, the simple method to model the reed is a simple damped mechanical oscillator as shown in Figure 2.3

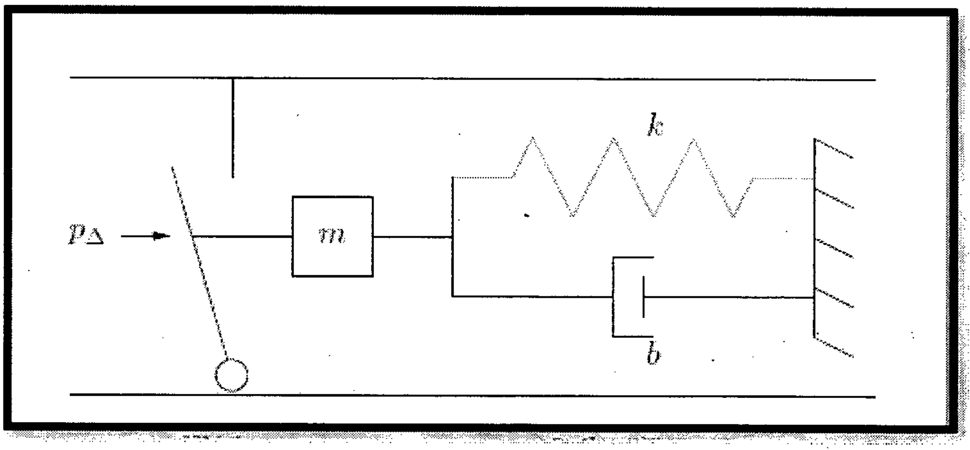

Figure 2.3 A single-reed as a mass-spring damper model

The equation of motion of a single mass-spring-damper model of the reed is

$$m \frac{d2x}{dt2} + b \frac{dx}{dt} + k\{ x(t) - H\} = -Ar\, p\Delta\, (t)$$

where m is the equivalent reed mass, k is the reed spring constant, and b is the damping factor. The natural frequency of the system in the absence of damping and for constant reed parameters is $\omega_r = \sqrt{k/m}$, thus the equation become

$$\ddot{x}(t) + gr\,\dot{x}(t) + \omega 2r\{x(t) - H\} = -\frac{p\Delta(t)}{r}$$

where g_r is the reed damping coefficient and μ_r is the reed's dynamic mass per unit area.

2.3.1 BERNOULLI'S THEOREM

Relation between pressure and velocity involve in the reed-mouthpiece system is given in the Bernoulli's equation

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

where ρ is fluid density and g is the acceleration of gravity. This expression is based on continuity of volume flow and conservation of energy.

2.4 PRESSURE CONTROLLED VALVE

Pressure-controlled valves are responsible for sound production in musical instruments of the woodwind and brass families, and in animal vocalization. In musical instruments the operation of the valve is usually controlled by feedback from a passive resonator, the instrument horn, while in vocal systems the valve itself is the controlling entity and the horn resonator serves primarily as an acoustic filter (Fletcher, 1992).

Fletcher uses the couplet ($\sigma 1$, $\sigma 2$) to describe the valve behaviour, with $\sigma i = +1$ signifying an opening of the valve, and $\sigma i = -1$ signifying a closing of the valve, in response to an upstream (i = 1) or downstream (i = 2) pressure increase.

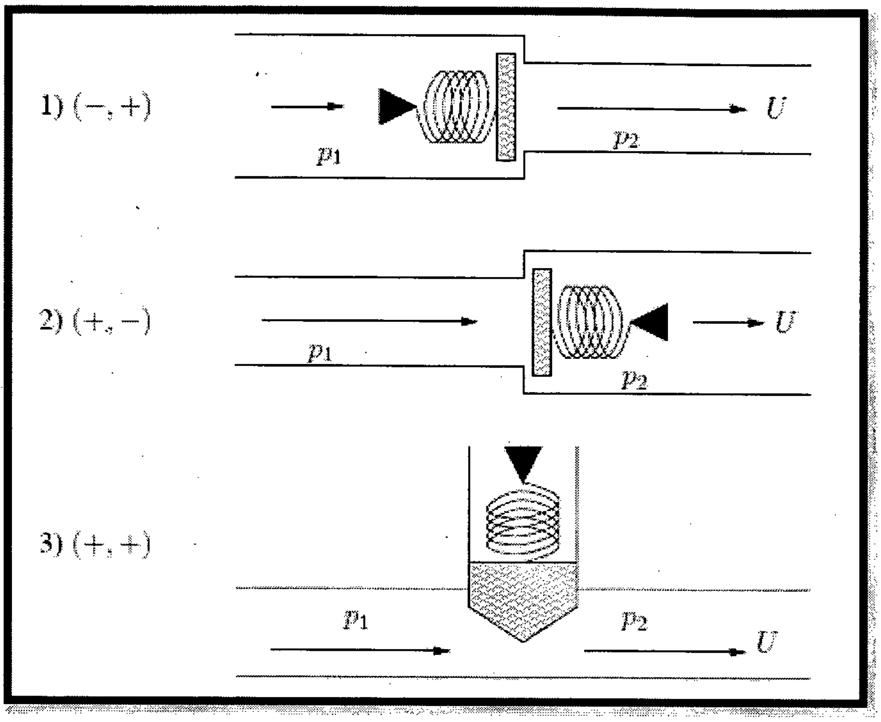

Figure 2.4 Simplified models of common configurations of the pressure-controlled valve (Smith.T et.al)

According to Smith.T, Abel.J in *Extending the Generalized Reed Model with Measured Reflection Functions,* if an increase in blowing pressure causes the valve to close further, and a bore pressure increase causes the valve to open further, the reed is said to be blown closed, the classification of most woodwind instruments. If a blowing pressure increase causes the valve to open further, and an increase in bore pressure causes the valve to close, the reed is blown open, the typical configuration of brass (lip reed) instruments, and the human voice. A swinging door or "transverse" reed, typically found in the avian syrinx, is one where a pressure increase from either side of the valve will cause it to open further.

In order to develop a sound-making device such as MIDI auto-saxophone, all the factors of controlling air pressure must be emphasized. Actually, if we analyze the performance of a human playing the saxophone, the distance between the lungs and the oral cavity there are a few dozens of centimeters. (Solis. J. et al.,2009). From the physics view, the air will flow through the high pressure to the low pressure. When the chest cavity is enlarged, the air is rushing in because the pressure is lowered. Then, when blowing the air, air is flowing out because the pressure becomes higher.

In brass instruments the nature of the motion of the player's lips determines the flow of air between the player's mouth and the instrument. It is a complicated feedback system, in which the motion of the lips controls the air flow, which itself affects the behavior of the lips. Because of the highly non-linear actions involved even a seemingly insignificant change in any part of this system of player and instrument can result in a significantly different output sound (Bromage, 2007).

CHAPTER 3

PROJECT METHODOLOGY

3.1 INTRODUCTION

Project methodology is a procedure to solve a problem by collecting data and making an observation from other researches. This chapter will explain detail methods of carrying the project with specific techniques and tools involve that will accomplish a perfect result. Three important steps must be taken in order to run the project smoothly. Planning, implementing, and analysis are the flow steps of methodology used in this project.

3.2 GUIDELINE METHODOLOGY

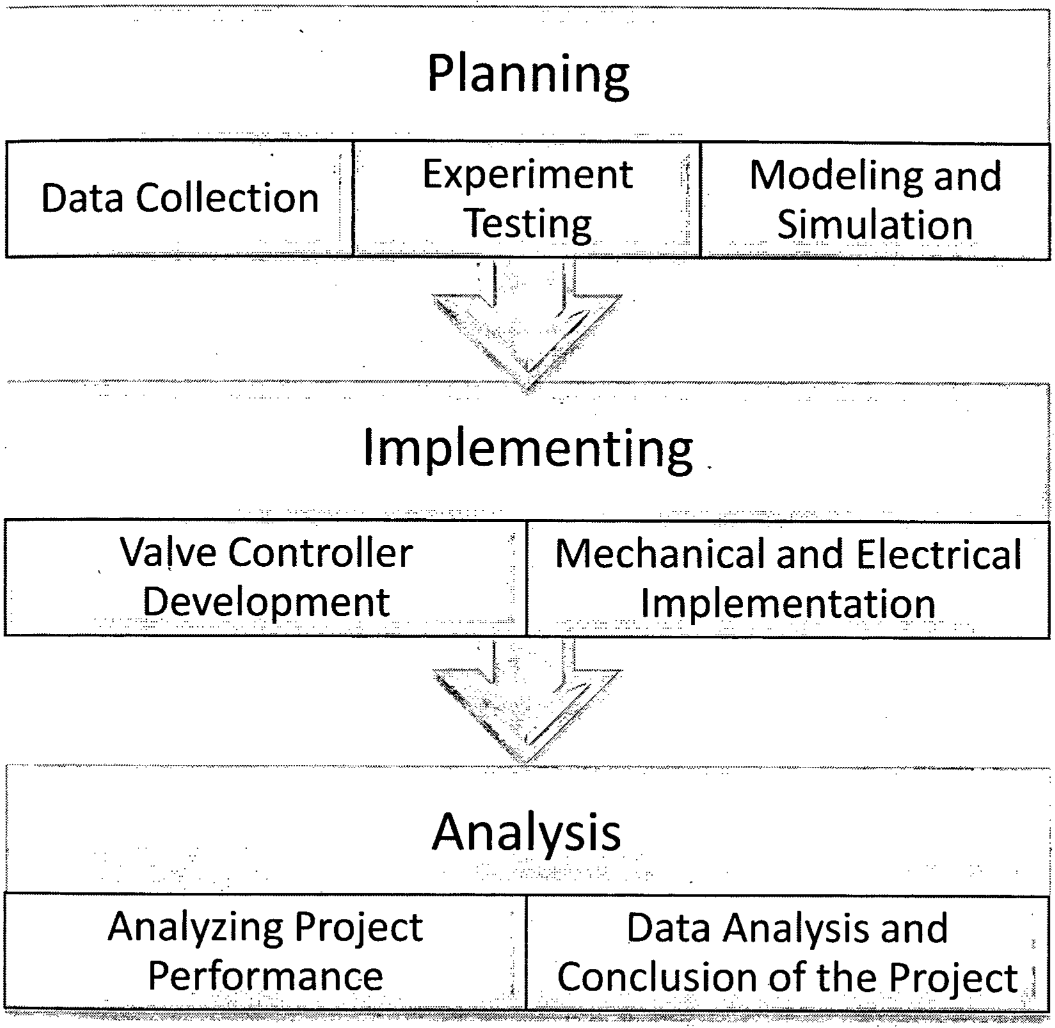

Figure 3.1: Flowchart of the methodology