DEVELOPMENT OF BRAKE SYSTEM FOR REDUCED SCALE VEHICLE

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This Report for partial fulfilment for

Bachelor of Mechanical Engineering (Design & Innovation) with honours

Faculty of Mechanical Engineering

Universiti Teknikal Malaysia Melaka

JUNE 2013

DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledge."

Signature	:	....
Author	:	....
Date	:	....

To my beloved family

ACKNOWLEDGEMENT

The success of this group project depends largely on the encouragement and guidelines of many others. I take this opportunity to express my gratitude to the people who have been instrumental in the successful completion of this report.

I thankful to everyone who all supported and helped me, for me have completed my report effectively and moreover on time. I equally grateful to Mr. Amrik Singh A/L Phuman Singh. He guided me in different matters regarding the topics related. Furthermore, he had been very kind and patient while correcting my doubts. I thank him for his overall supports.

ABSTRACT

This project investigates on the development of the brake system for reduced scale vehicle on the field of vehicle structure, dynamics and control. Brake system is most important part in a vehicle safety. Due to the unpredictable of safety and high cost involvement for testing of brake dynamics which developed with control strategies in a full scale vehicle, a reduced scale vehicle with reduce scale brake dynamics is purposed in this project. A reduced scale brake system model is developed by using Bond Graph method. The brake torque tracking control is developed using the PID controller. The response of brake torque tracking control was evaluated by sinusoidal, square, saw tooth and random functions. The performace of the PID controller for sinusoidal, square, sawtooth and random inputs has shown the capability of the controller produce the braking torque close to desired braking torque. Antilock Braking System (ABS) for reduced scale vehicle is developed using PID and Fuzzy logic control. The simulation results PID in term of braking distance, stopping time shows better result in ABS braking compare to FLC.

ABSTRAK

Projek ini menyiasat tentang pembangunan sistem brek bagi kenderaan skala kecil dalam bidang struktur kenderaan, dinamik dan kawalan. Sistem brek adalah system yang paling penting dalam keselamatan kenderaan. Keselamatan seseorang pepmandu tidak dapat diramalkan dan kos untuk manghasilkan kawalan brek akan meningkat apabila mengunakan kenderaan yang sebenar. Oleh sebab itu, satu model brak dinamic skala kecil telah diperkenalkan dalam projek ini. Model sistem brek skala kecil dicipta dengan menggunakan kaedah 'Bond Graph'. Skim kawalan pengesan daya kilas brek akan dimajukan dengan menggunakan pengawal PID. Model brek dinamik tersebut dinilaikan melalui fungsi sinus, persegi, 'saw-tooth' dan rawak. Keputusan bagi skim kawalan pengesan daya kilas brek menunjukkan reaksi yang begitu sama sekali dengan input yand telah diberi. Antilock Braking System (ABS) telah dimajukan dengan pengawal PID dan Fuzzy Logic Control (FLC). Skim kawalan PID menunjukkan reaksi yang amat luar biasa apabila dibandingkan dengan reaksi skim kawalan FLC dalam brek ABS dari segi jarak berhenti dan masa berhenti.

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LIST OF SYMBOL

$\dot{x}$	-	Lateral velocity
$\dot{y}$	-	Longitudinal velocity
$\dot{\psi}$	-	Yaw rate
ω_{fl}	-	Wheel velocity – front left
ω_{fr}	-	Wheel velocity – front right
ω_{rl}	-	Wheel velocity – rear left
ω_{rr}	-	Wheel velocity – rear right
u	-	Input voltage
θ	-	Motor arm angle
K_p	-	Proportional gain
K_I	-	Integral gain
K_d	-	Derivative gain
τ	-	Torque
F	-	Force
v	-	Velocity
ω	-	Angular velocity
E	-	Young modulus
m	-	Mass
I	-	Inertia
λ	-	Slip
r	-	Radius

LIST OF APPENDIX

CHAPTER I

INTRODUCTION

1.0 INTRODUCTION

This chapter describes the background about development of brake system for reduced scale vehicle. The problem statement that proposed to the development of this project is explained. Next, by the objective and scope of the project were covered.

1.1 BACKGROUND

When it comes to vehicle safety, the braking system is one of the most important parts to be considered. Owing to the need for road safety, a majority of cars and SUVs come equipped with Anti-lock Braking System (ABS). However, there are still some cars using the conventional braking system. The braking force is applied to all four wheels in conventional braking system, while in ABS equipped cars, the braking force distributed to all four wheels. In conventional braking, when the brake pedal pressed, the wheels tend to stop rotating which results in skid marks. The driver is unable to steer the car once the wheel is fully locked up which lastly will result in skidding, increased braking distance and loss control. So for the emergency braking, the momentary wheel rotation is required. ABS helps in pumping and releasing the brakes automatically whenever required. ABS can prevent cars or SUVs from skidding during braking. Moreover, ABS allows the driver to stop a vehicle more rapidly and maintain steering control even during situations of panic. Brake-by-wire is a new technology that implemented in the field of vehicles active safety. This system uses a motor to transmit the braking force by eliminating the conventional hydraulic braking system in order to improve the response speed and increase braking performance. Moreover, this system helps to reduce the time taken for assembly and maintenance which usually consumes a lot of time in the conventional braking system. Brake-by-wire system promises to increase the safety and cuts off cost related to manufacturing and maintenance. This braking system is concerned as most important in every vehicle where its improved efficiency and stability of brake control.

1.2 PROBLEM STATEMENT

Currently, most of the researches on vehicle dynamics is being conducted by virtual simulation. This is mainly due to the cost associated with the research. There is a number of approach that helps for testing vehicle handling behaviour in low cost. So one of the approach that used in this project is the reduced scale vehicle dynamic testing. As in this project the focus on the brake dynamics. The brake dynamics is one of the sub from the vehicle dynamics. This approach allows the researchers to predict the behaviour of the brake dynamics based on the data collected. Even the validating of control strategies also can be conducted on the reduced scale vehicle without the fear of injury to the personnel or damage to property. Besides that, the reason of choosing a reduced scale vehicle is the relatively low initial purchase and maintenance costs. Moreover, the ease of modification on the reduced scale brake dynamics is much easier compare to the full scale vehicle and it will require much time to develop. In fact, it is requires less space for field testing. At the same time, the advantage if the scale vehicle testing is its ability to push the vehicle to its handling limits in order to evaluate the performance, which would otherwise be too dangerous for traditional full scale vehicle testing.

1.3 OBJECTIVE

The objective of this project is to develop reduced scale vehicle dynamics model. Besides that to develop Antilock Braking System (ABS) control scheme using PID and fuzzy logic control.

1.4 SCOPE

The scope of this project covers the development of brake dynamics model in Matlab/SIMULINK environment. Besides that, there will be development of brake torque tracking control using PID controller. Lastly, the development of Antilock Braking System (ABS) for reduced scale vehicle using PID and fuzzy logic control.

1.5 THESIS OUTLINE

Chapter One describes the main objective of this project and its scope of study. The complete literature review on scaled vehicle, control strategies, multi-body dynamics and methods, brake system which related to this project is described in Chapter Two. Chapter Three describes the methods that used to conduct and achieve the objective of this project. In Chapter Four, the results and the discussion made based on the overall result obtained is explained in detail. The conclusion and recommendation is stated in Chapter Five.

CHAPTER II

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter covers the literatures of brake system that's available in markets. Besides that, the control strategies are also discussed. Moreover, the Bond Graph Method, MSC ADAMS software and Universal Mechanism multi body software also reviewed in detail.

2.1 MULTI-BODY DYNAMICS AND SOLUTION METHOD

Multi-body system is define as a collection of bodies that are coupled together via joint constraints. Kortelainen (2010) noted dampers, springs and actuators are applied on the system to describe as forces in order to actuate the motion of the bodies.

Schiehlen (1997) describe that multi-body dynamics system is directly involve the classical mechanics as well as computation dynamics. Besides that, the equation of motion is must needed part when analysing the dynamic response of the multi-body system and can derived using global or topological formulations.

2.1.1 MSC ADAMS

There are a lot of software packages available to solve multi-body system analysis. Adams is one of the famous multi-body dynamic software which use to make motion analysis too. Blundell (2004) noted that software has become one of the mediums for engineers to do their task in an easy way to study the dynamics of moving parts and forces distributed through mechanical system. Autoun et al. (2002) stated that the large usage of the MSC ADAMS in automotive industry is to study the suspensions or to study the ride and handling performance of the vehicle.

"Build and test" is a traditional way to get findings on the multi-body problems. This method is much expensive and at certain times it is impossible to get the results. MSC ADAMS software helps engineers to create a virtual prototype of mechanical systems in a short period of time and in lower cost to test it. This software is able to solve the physics of the system together with the equation for kinematics, statics, dynamics and quasi-statics.

Negrut (2006) noted that most of the analysis types are available in MSC ADAMS software where it require computation of partial derivatives of all quantities that define the model, including forces, variables and differential equations. The computation of the accurate partial derivatives is a must for fast and accurate simulation in MSC ADAMS.

2.1.2 Universal Mechanism

Universal Mechanism (UM) is a software which intended for simulation of kinematics and dynamics of planar and spatial mechanical systems. UM said to be an advanced postprocessor which includes the linear analysis, statistics, multi-variant calculation and optimization and export of results. Universal Mechanism (2012) stated that this software able to solve both direct and inverse kinematic, dynamic and control problems. As an advantage UM can load any of the body shapes and automatically calculate inertia parameters of the system that inserted. The joints and constraints that can be applied using UM is rotational, translational, cylindrical, gimbal, general and quaternion joints. Besides that, forces available to do fix is general, bipolar, contact and special. As the key point where the measurable parameters are reaction forces and moments and other normal parameters such as linear and angular coordinates, velocities and acceleration.

2.1.3 Bond Graph Method

Bond Graph is method to modelling the dynamic systems which was established by Paynter (1992). The bond graph idea is developed as a powerful tool in modelling system by Karnopp and Rosenberg in their researches. This bond graph method is a modelling based on the assumption that the possibility to define the characteristics of the system and subsystems, the connection between the subsystems and energy exchange between the subsystems. Antic et al. (1999) stated that, the bond graph is a directed graph to where the nodes represent the transfer of energy between subsystems. In Figure 2.1 shows the transfer of physical model to mathematical model.

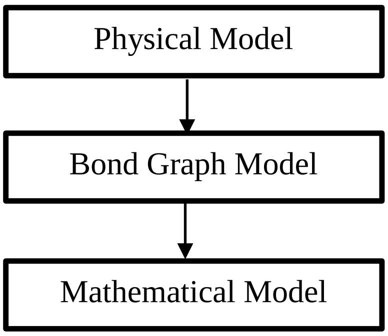

Figure 2.1: Process in bond graph.

Liming (2012) stated that nowadays there are a number of software available to generate and process bond graphs which have a capability to generating of symbolic representation, model inversion, and parametric identification and also produce simulation. The bond graph elements are drawn as latter combinations indicating the type of element. The bond graph elements are in Table 2.1.

Table 2.1: Bond graph elements

Elements	**Description**
C	Storage element for a q-type variable
I	Storage element for a p-type variable
R	Resistor dissipating free energy
Se, *Sf*	Sources
TF	Transformer
GY	Gyrator

Figure 2.2 shows the examples of *C*-elements are given with equivalent block diagram. For the capasitor, *C* is the capacitance and for spring, *K* is the stiffness and *C* the compliance.

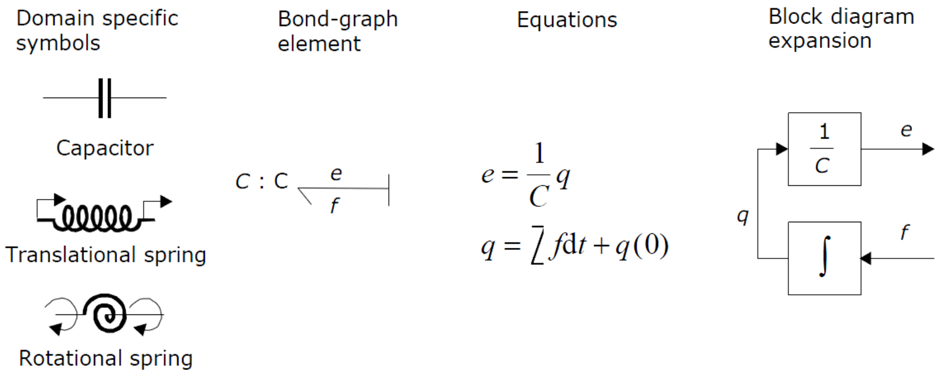

Figure 2.2: Example of *C* elements

(Source: Broenink, 1999)

Figure 2.3 shows the examples of *I*-elements are given with equivalent block diagram. For the inductor, *L* is the inductance and for mass, m is the mass.

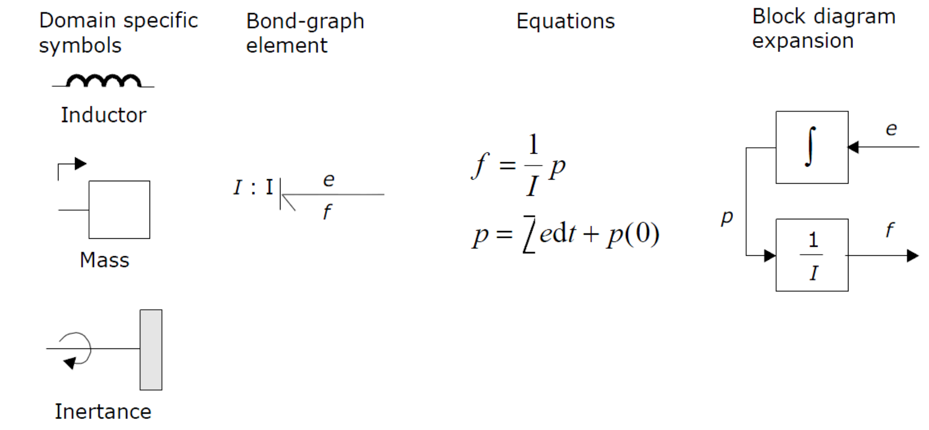

Figure 2.3: Example of *I* elements

(Source: Broenink, 1999)

Figure 2.4 shows the examples of dampers, frictions and electric resistors. The energy flow towards the resistors as always positive.

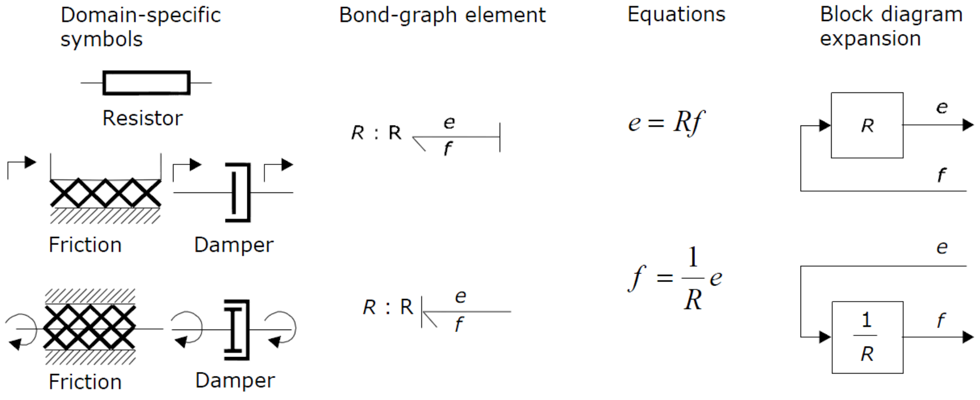

Figure 2.4: Example of resistors

(Source: Broenink, 1999)

Figure 2.5 shows the modulated source driven by some signal form and the standard symbols for that source.

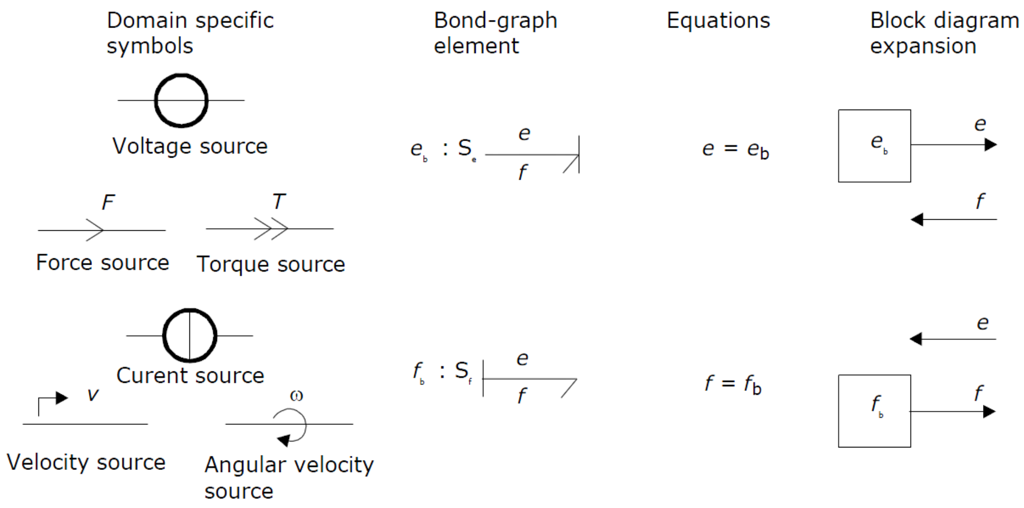

Figure 2.5: Example of modulated voltage source

(Source: Jan F. Broenink, 1999)