DRIVING CYCLE FOR SMALL AND MEDIUM DUTY ENGINE: CASE STUDY OF IPOH

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Dedicated to my beloved mother, Faridah Bt salleh, my wife Yusira Bt Rippin
To my supervisor, Dr. Mohd Faisal Hushim, lecturers and friends for all of their love, endless support and encouragement.

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ABSTRACT

Driving cycles is a series of data points representing the speed of vehicle verses time sequenced profile developed for certain road, route, specific area or city. It is widely used of application for vehicle manufacturers, environmentalists and traffic engineers. The purposes of this study are; to analyse the real world driving pattern and to develop a driving cycle for small and medium duty engines in Ipoh, Malaysia. This study carried out a survey to describe the motorcycle and car driving cycle on the selected three routes in the peak hour periods of the traffic condition, which are morning, afternoon and evening peak periods. The study used a GPS equipment to record vehicle travel speeds (second by second). The driving characteristics were analysed from speed time data and its target statistic parameters were defined. The method for generating the driving cycle has been described. The analysis results show that there are significant difference of driving characteristic and driving cycle between motorcycle and car for Ipoh city. The characteristic of the developed driving cycle for car was compared with three well established worldwide driving cycles. This information gives a clear message that those driving cycle such as ECE driving cycle (for instance) is not suitable to predict the emission standard in Ipoh. The driving cycle for motorcycle also had been compared with existing motorcycles driving cycles for Malaysia. It shows that the average speed of the developed Ipoh motorcycles driving cycle is higher than motorcycles driving cycle for Malaysia. The result clearly shows the driving cycle is dependent on specific area or city due to the different of traffic flow.

ABSTRAK

Kitaran pemanduan adalah satu siri data yang mewakili kelajuan kenderaan melawan masa yang dihasilkan untuk jalan,lokasi, kawasan tertentu atau bandar. Ia digunakan secara meluas dalam penggunaan pembuatan kenderaan, persekitaran dan kejuruteraan trafik.Tujuan kajian ini adalah; untuk menganalisis paten pemanduan secara semulajadi dan menghasikan kitaran pemanduan untuk enjin berkapasiti rendah dan sederhana di Ipoh Malaysia. Kajian ini dijalankan untuk menggambarkan kitaran pemanduan kereta dan motorsikal ke atas tiga laluan puncak yang terpilih dalam tempoh keaadaan trafik, iaitu pagi, tengahari dan waktu petang. Kajian ini menggunakan peralatan GPS untuk merekod kelajuan perjalanan kenderaan (saat per saat). Ciri-ciri pemanduan dianalisis dari data masa kelajuan dan parameter statistik yang telah ditetapkan. Kaedah untuk menghasilkan kitaran pemanduan telah diterangkan. Analisis daripada keputusan menunjukan bahawa terdapat perbezaan ketara ciri-ciri pemanduan dan kitaran pemanduan diantara motorsikal dan kereta untuk bandar Ipoh. Ciri-ciri kitaran pemanduan untuk kereta dibandingkan dengan tiga kitaran pemanduan dunia yang sediada. Maklumat ini memberi mesej jelas yang kitaran pemanduan seperti ECE (sebagai contoh) adalah tidak sesuai untuk mengkaji pencemaran di Ipoh. Kitaran pemanduan untuk motorsikal juga dibandingkan dengan kewujudan kitaran pemanduan yang sediada untuk malaysia. Ia menunjukan purata halaju bagi kitaran pemanduan motorsikal adalah tinggi dibandingkan dengan kitaran pemanduan motorsikal untuk malaysia. Hasil kajian secara jelas menunjukan bahawa kitaran pemanduan adalah bergantung pada kawasan tertentu atau bandar disebabkan oleh perbezaan aliran trafik.

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LIST OF ABBREVIATIONS

CAD	-	Computer Added Design
CAN	-	Control Area Network
COV	-	Coefficient of Variations
DCR	-	Driving Conditions of Recognition
DMDC	-	Delhi Driving Cycle
ECE	-	Economic commission Europe
EMDC	-	Edinburg Driving Cycle
EUDC	-	Extra Urban Driving Cycle
FTP	-	Federal Test Procedure
GIS	-	Geographical Information System
GPS	-	Global Positioning system
NEDC	-	New European driving Cycle
PKE	-	Positive Kinetic Energy
RMS	-	Root Mean square acceleration
SAFD	-	Speed Acceleration Frequency Distribution
SD	-	Standard Deviation
UDDS	-	Urban Dynamometer Driving Schedule
US	-	United State

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Driving cycle is a graph of speed of vehicle versus time obtained from the real live situation or real world. This cycle is usually developed for a specific area or city, certain road and routes. With the production of driving cycle, it represents a typical driving pattern for the population a place or city whether it involves the free flow or saturated traffic. Definition of driving cycle also based on operating conditions such as the idle state, acceleration, deceleration and steady state to represent the type of pattern in an area of the city (Y. Liu *et al.*, 2014).

Standard driving cycle such as Japanese and Europe driving cycle widely used in manufacturing vehicles, environmentalist and traffic engineer. For manufacturing vehicles, driving cycle used to provide a long term basic for design, tooling and marketing. Vehicles Traffic engineers require driving cycles in the design of traffic control systems and simulation of traffic flows. Environmentalists are concerned with the performance of the vehicle in terms of the pollutants generated based on specific driving patterns.

In addition, a speed time profile of driving cycle can be used to estimate fuel consumption and emissions of vehicles using dynamometer test. Researchers such as Faiz *et al*. (1996) and Hui *et al*. (2007) have carried out this system in their field. The driving cycle is also important to evaluate the driver's behaviour in a study area. For instance, Andry *et al*. (2013) have developed the motorcycle driving behaviours on heterogeneous traffic for Makassar, Indonesia.

Generally, there are two categories of driving cycle, legislative and non-legislative. Legislative cycles is to control emission by authorities from motors vehicle so as not to exceed the statutory emission standard. For example, the U.S

FTP 75 cycle are currently is used in the United State of America and also Japan 10-15 mode cycles is used in Japan to control vehicle emissions. Non–legislative cycles are developed for estimation of exhaust emission and fuel consumption. The Europe cycle and Sydney cycle, are some of the examples.

The development of driving cycles of vehicle involves three steps: test route selection, data collection, and cycle construction, as mentioned by Amirjamshidi (2013). Table 1.1 presents a summary of studies of real world driving cycles in the literature, including location, study objective, data collection that are used to development of the driving cycle.

Table 1.1: Development methods and objectives of selected driving cycles

Study	Location	Main study Objective	Data collection Method
Amirjamshidi (2013)	Toronto Waterfront Area	Develop and demonstrate a method for efficiently developing driving cycles that represent specific combination of roadways class, time of day and vehicles attributes.	Traffic simulation model and GPS receivers recording data
Y. Liu *et al*. (2014)	Guangzhou China	Analysis Driving cycle of long distance based on principal component analysis and cluster Algorithm (kinematic fragments)	GPS Data acquisition system (vehicle tracking method)
Tamsanya *et al*. (2006)	Bangkok Thailand	Develop driving cycles for used in the assessment of exhaust emission and fuel consumption	A real time logging system
Saleh *et al*. (2010)	Edinburgh and Delhi	An investigation of real world driving cycle motorcycles	Advanced GPS techniques

Table 1.1: (continued)

M.Syafriza *et al.* (2014)	Semanggi intersection	Develop the driving cycles and analysis emission and fuel consumptions for light duty trucks, heavy duty trucks, light duty bas, heavy duty bus and motorcycles.	GPS equipment and chassis dynamometer
Andry *et al.* (2013)	Makassar city Indonesia	Analyse acceleration and deceleration parameters as dominant behaviour on the driving cycles.	GPS equipment (Garmin Etrex 30)

1.2 Statement of the problem

Driving cycle is a represent of traffic behaviour in an area or certain city. Various standard driving cycles have been developed such as Japan cycle, Indian cycle, European cycle, and so on. However, each one of the developed driving cycle is not representing the actual situation in Ipoh, the capital city of the state of Perak, Malaysia. Therefore, a driving cycle in Ipoh is needed to provide information related to the actual driving cycle. With the developed of this driving cycle can help other researchers to continue the studies related to exhaust pollution and fuel consumption in Ipoh city.

1.3 Objectives of the study

This study will develop real world driving cycles for the city of Ipoh. The specific objectives of this study are:

i. To understand and analyse the real world driving cycle pattern for small and medium duty engines.
ii. To develop a driving cycle for small and medium duty engines.

1.4 Scopes and limitations of the research

i. Driving cycle has been simplified because of time and budget constraints. Classification of drive cycles and related factors (e.g. urban/rural, time of day, speed, engine size and the characteristics of the driver) could have been extended to include more factors, the types of roads, time, vehicle type, and other. For this study, only one type of vehicle for car and motorcycles was used in all runs to avoid discordance in the data and to try to minimise errors.

ii. This research will only focus on 4-stoke gasoline engine with capacity of 100 cc for small duty engine and 1500 cc for medium duty engine.

iii. The number of routes was limited to three of roads. Three peak-hour periods of the traffic condition were measured in this study which are: morning, afternoon, and evening peak periods. The routes that have been studied are an urban route in Ipoh, the capital city of the state of Perak.

iv. The GPS system was used as a tracking and recording the driving pattern along the study area.

1.5 Structure of the thesis

Following this introductory chapter, the thesis begins by a review of the past research in developed of driving cycles. The literature review reported chapter two is focused on details several of driving cycles, definition of driving cycle, data collection and methodology to development the driving cycles.

Chapter three discusses the data collection in this work. The selected of routes, piloting the data collection is firstly presented and then, the equipment used for data collection, the routes and assessment parameter are used in the study will be discussed. This chapter also discuss the developing of the driving cycle.

Chapter four present results and the preliminary analysis obtained from monitoring and measuring of car and motorcycles and using the GPS on selected routes in the study. Chapter four also has further analysis of the results which are presented and investigated using techniques of regression analysis. Finally, chapter five concludes for the research of this study. A summary of the findings of each

chapter is discussed, and finally suggestions for future work and a summary of the thesis as a whole are presented.

1.6 Novelty of the research

The novel aspects of this work include:

i. Development of driving cycles for cars and motorcycles on the same routes for Ipoh, the capital city of Perak.
ii. The will be analysis of parameters and investigation of driving cycle.

CHAPTER 2

LITERATURE REVIEWS

2.1 Definition of a driving cycle

The literature review shows that there is a collective opinion among experts regarding the definition of the driving cycle. A driving cycle for a vehicle is defined as "*a represent speed-time profile for a study area within which a vehicle can be idling, accelerating, decelerating, or cruising"* Amirjamshidi (2013). Andry *et al*. (2013) define a driving cycle as represent *"a speed time sequenced profile developed for certain road, route, specific area or city"*. Tamsanya *et al*. (2006) states that a driving cycle is "*represent a typical driving pattern for population of a city"*. Naghizadeh (2003) define "*a drive cycle is a speed-time sequence developed for a certain type of vehicles in a particular environment to the driving pattern with the purpose of represent measuring and regulating exhaust gas emissions and monitoring fuel consumption*".

2.2 The use of driving cycle

Drive cycle is used to estimate emissions pollutant and analysis of fuel consumption for vehicles. There have been studies around the world to determine the driving cycle for private cars, light duty vehicles, trucks and motorcycles. Watson (1978) used the emission data obtained from the car drive cycle for predicting air pollution. The test procedures included 40 cars and based on tree driving cycles; AS 2077 city (US city), Melbourne peak, and Melbourne cold start. The test also performed in steady speed cruising within 120 km/h. All of the above procedures are performed on the chassis dynamometer. Literature review indicates that the emission is dependent on the number of variables. The variables involved include speed, vehicle, fuel, road,

traffic volume, and others. Morey (2000) stated that vehicle emissions are affected by acceleration. The data collected on the basis of the concept of non-lock condition, where there is no target of vehicles in use.

Faiz *et al*. (1996) also mentioned that pollutant emission of vehicle levels depending on vehicle characteristics, operating conditions, level of maintenance, fuel characteristics, temperature, humidity, and altitude as presented in Table 2.1.

Table 2.1: Factors that affect the pollutant emissions of vehicles (Faiz *et al*., 1996)

Characteristics	Description
Vehicle	• Engine type and technology-diesel, two strokes, four strokes, Otto, types of transmission system. • Exhaust, crankcase and evaporative emission control system in place • Engine mechanical condition and adequacy of maintenance • Air conditional, trailer towing and adequacy of maintenance
Fuel	• Fuel properties and quality • Alternative fuel
Fleet	• Vehicle mix (number and type of vehicles in use) • Vehicle utilization (Kilometres per vehicle per year) by vehicle type • Age profile of the vehicle fleet • Traffic mix and choice of mode for passengers • Clean fuels program
Operating	• Altitude, temperature, humidity (for NO_x emissions) • Vehicle use pattern – number and length of trips, number of cold starts, speed, loading, aggressiveness of driving behaviour. • Degree of traffic congestion, capacity and quality of road infrastructure and traffic control system. • Transport demand management program

Driving behaviours and patterns differ according to venue or city and also country. It is therefore difficult to use driving cycle developed for one city to another city, even in the same country. In this regard, the release of the study to be done by producing driving cycle in real world driving tests in specific areas.

According to Barlow *et al*. (2009), there are several factors which affect the emission levels. Among them are vehicle-related factors such as model, size, fuel type, technology level and mileage, and operational factors such as speed, acceleration, gear selection and road gradient. However, the factor stated also depends on different types of vehicle such as cars, vans, buses, trucks and motorcycles. In Malaysia, vehicle emission regulations based on United Nations Economic Commission for Europe specification ECE 15 were introduced in September 1992 (Faiz *et al*.,1996).

Tamsanya *et al*.(2006) have developed a driving cycle for vehicular to study the emissions and fuel consumption in Bangkok. The vehicle was measured on a standard chassis dynamometer. Based on the study conducted, emission factor and fuel consumption will be affected by the average speed. Fuel consumption is closely linked to carbon dioxide (CO_2) emission factors. The higher the fuel consumption resulted in the higher the CO_2 emission factor, as shown in Table 2.2. This table also shows the results of the fuel consumption according to different driving cycle.

Table 2.2: Total emission and fuel consumption of the test vehicle under specified driving cycle (Tamsanya *et al*.,2006)

Driving cycle	Total time (s)	Distance (km)	Cruise period (%)	Idle period (km/h)	Average speed	HC	NO_x	CO	CO_2	Fuel consumption (l/100 km)
						(g/km)				
BDC	1160	5.71	23.8	37.7	17.7	0.13	0.557	2.093	206.3	8.48
ECE15	780	4.05	32.3	30.8	18.7	0.12	0.409	0.714	187.7	7.63
EUDC	400	6.85	67.5	10	62.6	0.04	0.564	0.470	155.7	6.32
ECE15 -EUDC	1180	10.9	42.2	23.7	33.4	0.07	0.506	0.561	167.6	6.81

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