SIGNAL RESPONSE BASED ON SPEED AND REACTION OF OTTO CYCLE ENGINE

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SIGNAL RESPONSE BASED ON SPEED AND REACTION OF OTTO CYCLE ENGINE

by

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LIST OF ABBREVIATIONS

EMD	Engine misfire detection
OBD	On board diagnostic
AFR	Air to fuel ratio
ECU	Engine control unit
NOx	Oxide of nitrogen
CO	Carbon monoxide
HC	Hydrocarbon
CO_2	Carbon dioxide
CPS	Crankshaft position sensor
DWT	Discrete wavelet transform
DFT	Discrete fourier transform
IC	Internal combustion
TDC	Top dead centre
BDC	Bottom dead centre
NAP	National Automotive Policy
CPU	Central processing unit
ADC	Analog to digital converter
DAC	Digital to analog converter
PPM	Part per million
YSZ	Yttria stabilized zirconia
TPB	Triple phase boundary
SNR	Signal to noise ratio
IMM	Interacting multiple model
RPM	Revolutions per minute
CAD	Computer aided design

MIG	Metal inert gas
CFD	Computational fluid dynamics
DAQ	Data acquisition
USB	Universal serial bus
CSV	Comma separated values
EMF	Electromagnetic force
FPGA	Field programmable gate array
MOSFET	Metal–oxide–semiconductor field-effect transistor
PCB	Printed circuit board
FIR	Finite impulse response
IIR	Infinite impulse response
CWT	Continuous wavelet transform
FAR	False alarm rate
EGR	Exhaust gas reciculation

LIST OF SYMBOLS

R	Universal gas constant
P'_{O2}	Partial pressure of oxygen
μ	Chemical potential
F	Faraday constant
r_m	engine cycle frequency
f_s	Number of samples per engine cycle
m	Mass
v	Velocity
ω	Rotational velocity
I	Moment of inertia
T	Temperature
τ	Time constant
θ	Throttle angle
P_m	Manifold pressure
P_{amb}	Ambient pressure
$\dot{m}$	Mass flow rate
V_m	Manifold volume
$\dot{P}_m$	Rate of change of manifold pressure
N	Engine speed
m_a	Mass of air in cylinder for combustion
A/F	Air fuel ratio
σ	Spark advance
J	Engine rotational moment of inertia
$\dot{N}$	Engine acceleration
N_s	Samples number

N_o	Order number
Nc	Number of engine cylinders
ω_p	Passband frequency
ω_s	Stopband frequency
Ω_p	Passband pre-warping frequency
Ω_s	Stopband pre-warping frequency

RESPON ISYARAT BERDASARKAN KELAJUAN DAN REAKSI ENJIN JENIS KITARAN OTTO

ABSTRAK

Sekian lama, enjin jenis kitaran Otto telah menjadi popular kerana teknologi moden telah menggantikan sistem enjin stim yang lama menyebabkan pencemaran akibat pembakaran arang batu untuk menjana gas wap Baru-baru ini, sebuah jurnal pengangkutan melaporkan bahawa statistik pengeluaran kenderaan telah meningkat setiap tahun kerana penduduk dan negara pembangunan yang semakin meningkat. Oleh itu, ia telah meningkat lagi pelepasan gas yang dihasilkan oleh pembakaran enjin. Pada masa ini. Enjin jenis kitaran Otto masih dalam siasatan untuk penambahbaikan kecekapan. Ekzos merupakan aspek utama yang perlu diberi perhatian kerana ia mengeluarkan gas berbahaya dan mempengaruhi persekitaran. Malah, pelbagai ciptaan telah dihasilkan untuk mengurangkan gas berbahaya daripada pelepasan ekzos enjin. Selain itu, kesan macet enjin telah didapati mengurangkan prestasi enjin dengan meningkatkan penggunaan bahan api, kuasa keluaran yang rendah, dan berisiko kepada penukar pemangkin dengan kerosakan yang disebabkan oleh pembakaran tidak cekap. Oleh itu, pengesanan macet pada enjin adalah penting untuk meningkatkan kecekapan enjin atau untuk mengurangkan masalah ini. Lebih-lebih lagi, dalam usaha untuk mematuhi peraturan kenderaan dan keselamatan, alat-alat diagnostik digunakan untuk mengesan secara automatik masalah kenderaan dengan menggunakan sistem komputer. Atas sebab ini, isyarat macet pada enjin perlu dikesan untuk sistem diagnostik supaya dapat mengenali masalah. Pelbagai deria boleh digunakan untuk pengesanan, tetapi persembahan dari segi tindak balas isyarat dan kelajuan adalah berbeza-beza. Dalam kajian ini, deria oksigen telah digunakan dan bukannya sensor lain kerana kelebihannya dari segi kos penyelenggaraan yang rendah. Di samping itu, keupayaan deria oksigen telah diuji melalui pemodelan matematik dan eksperimen dengan menggunakan model silinder enjin empat lejang tunggal dengan sistem suntikan bahan api. Dari eksperimen, macet berlaku disebabkan oleh beberapa faktor; sama ada masalah mekanikal atau keadaan alam sekitar yang menjejaskan pembakaran campuran bahan api. Secara umum, macet yang paling biasa yang sudah didapati berlaku kerana tidak keseimbangan udara kepada nisbah bahan api (AFR). Oleh itu, untuk menentukan parameter optimum dan keadaan, macet tiruan telah dibangunkan dengan mengenakan AFR yang tidak seimbang untuk pembakaran menggunakan komputer mikro. Selain itu, pelbagai penapisan isyarat digital telah digunakan untuk penyesuaian isyarat untuk menjelaskan isyarat keluar yang dihantar oleh sensor oksigen untuk pengesanan macet. Kemudian, diskret Fourier Transform telah dipilih untuk menganalisis isyarat AFR yang mempunyai macet. Untuk tujuan analisis, parameter penapis Digital Butterworth telah ditetapkan berdasarkan isyarat penganalisis itu. Di samping itu, untuk mengesahkan keputusan, Discrete Wavelet Transform telah dilaksanakan, dan juga untuk menilai isyarat macet. Di sini, pelbagai “mother wavelet” telah digunakan untuk menjelaskan isyarat supaya isyarat macet dapat disahkan dengan menggunakan pelbagai teknik pra proses isyarat pada keadaan enjin yang berbeza. Melalui simulasi eksperimen, keputusan dipaparkan prestasi yang bagus.

SIGNAL RESPONSE BASED ON SPEED AND REACTION OF OTTO CYCLE ENGINE

ABSTRACT

Over the decade, the Otto Cycle engine has become popular since the modern technology has replaced the old steam engine system that caused more pollution due to coal burning to generate steam gas. Recently, a transport journal reported that the statistics of vehicles production has been increasing annually due to the increasing populations and country development. Therefore, it has further increased gas emission produced by the engine combustion. Currently, the Otto cycle type of engine is still being investigated for its efficiency improvement. Exhaust emission is a major aspect that needs to be given attention because it emits harmful gases and influences the surrounding environment. In fact, numerous inventions have been generated to reduce harmful gases from the exhaust emission of an engine. Moreover, the effect of engine misfire had been found to reduce the performances of engine by increasing fuel consumption, exerting low output power, and imposing risk to catalytic converter to damage due to inefficient combustion. Thus, engine misfire detection (EMD) is important to compensate or to reduce the problem. Moreover, in order to adhere to the vehicles regulation and safety, diagnostic tools or on board diagnostic (OBD) is used to automatically detect faulty of the vehicles by using computer system. For this reason, a signal of engine misfire needs to be detected for the OBD system to recognize the problem. Various sensors could be used for EMD, but the performances in terms of signal response and speed are varied. In this research, narrowband oxygen sensor was applied instead of wideband set due to its advantages in terms of low maintenance and cost which is 70% cheaper. In addition, the capability of the narrowband oxygen sensor was tested via mathematical modelling and experiments using a model of single cylinder four-stroke engine with fuel injection system. From the experiment, engine misfire occurred due to a number of factors; either mechanical problems or environmental condition that affected the fuel mixture combustion. In general, the most common misfire had been found to occur because of unbalanced air to fuel ratio (AFR). Therefore, in order to determine the optimal parameters and condition, an artificial engine misfire was developed by exerting unbalanced AFR for the combustion using a microcontroller. Moreover, various digital signal filtering had been employed for signal conditioning to clarify the output signal transmitted by the narrowband oxygen sensor for EMD. Later, Discrete Fourier Transform was chosen to analyse the AFR signal which include misfire. For analysis purpose, the Digital Butterworth filter parameters were set based on the analyst signal. In addition, in order to verify the results, Discrete Wavelet Transform was implemented, as well as to evaluate misfire signal. Here, various mother wavelets were used to clarify the signal in order to verify misfire signal using various method of signal pre-processing at different engine conditions. Through the experimental and simulations, the results displayed a good agreement of signal features pattern while average EMD accuracy are 91.67% using Butterworth filter and 86.67% using DWT on experimental signal output.

CHAPTER ONE

INTRODUCTION

1.1 Background of research

Engine is widely used for vehicle manufacturing around the world. In fact, there are many types of engines, such as steam, internal combustion, and electric/hybrid engine. The internal combustion engine, nevertheless, is the most popular and widely used. In Malaysia, the number of vehicles on the road has rapidly increased over a year. Based on the statistics provided by the Malaysian Road Transport Department, the chart shown in Figure 1.1 is evident to verify the growing number of vehicles in this country.

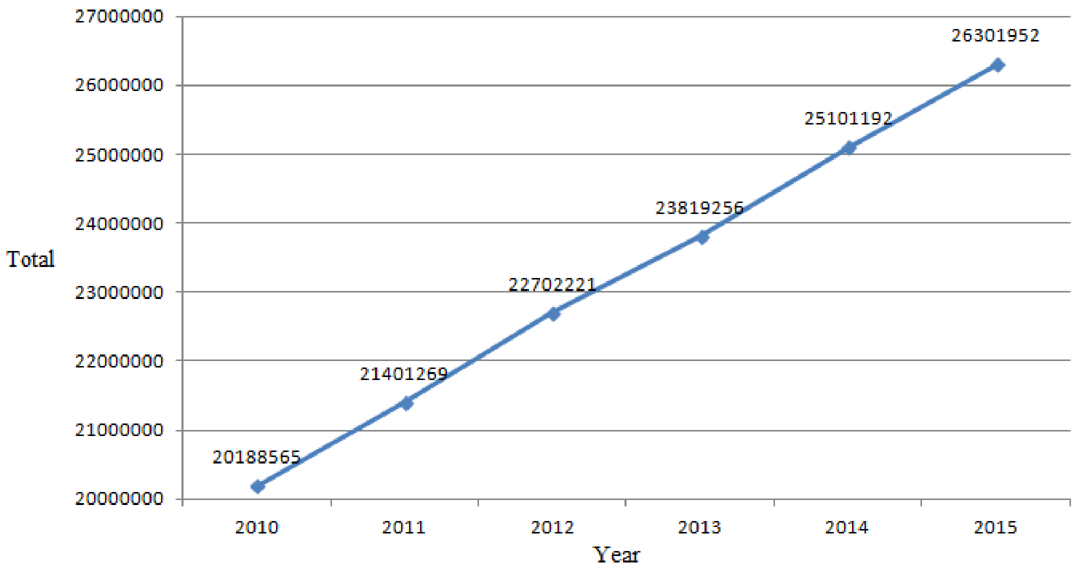

Figure 1.1 Statistics of vehicles in Malaysia (Malaysia, 2015)

Besides new vehicles, old vehicles are still in existence and are widely used by Malaysians. Thus, pollution potentially occurs since old engines have low efficiency in emission control. It leads to failure in the subsystem of some vehicles or limitations of control system to manage the aged engine. Furthermore, based on an investigation done by the Malaysian Department of Environment, air pollution is mostly contributed by vehicles, instead of other industries, as shown in Figure 1.2. Thus, it is important to look into this issue towards improving the air quality in our country.

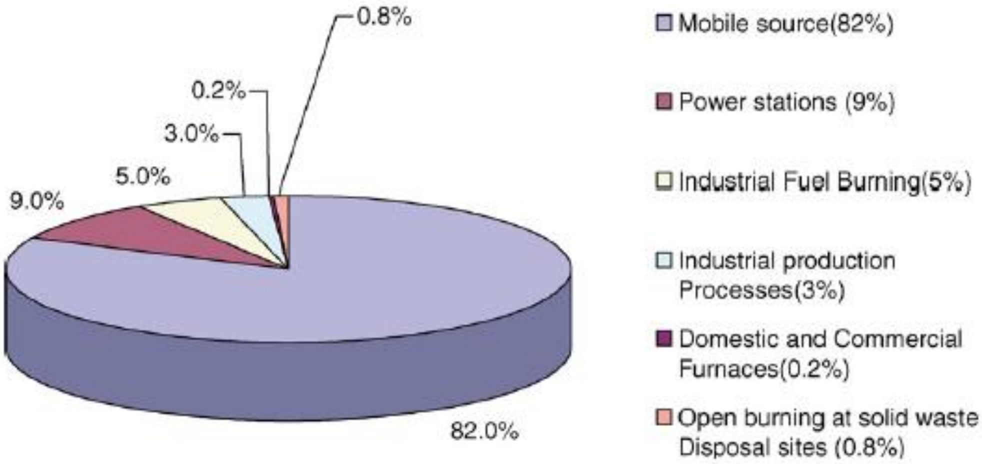

Figure 1.2 Statistics of emission of pollutants into the atmosphere in Malaysia (Department of the Environment, 1997)

Engine management system is indeed among the most important subsystems that have to be considered for enhancement as it controls the condition of the engine while it is running. In fact, some sensors are used to detect and record the parameters of an engine at various conditions. For instance, engine control unit (ECU) is a process for engine actuation based on the signals received by engine reactions. One common problem that could be controlled by using the electronic control system is engine misfire. Misfire is defined as the mixture that fails to properly combust in the combustion chamber at power stroke in an engine.

Therefore, it is important to control the mixture of air and fuel in the intake stroke to be fed into the combustion chamber. Enough mixture will burn the fuel completely; otherwise, unburnt fuel, due to mixtures that are too lean, increases the occurrence of misfire. Moreover, good fuel combustion avoids the engine running at high temperature where it could break some engine parts, such as valve seal and piston ring, which are delicate to very high temperature. Besides, engine misfire reduces the power of engine since some power strokes are missed to combust the mixture appropriately. In this circumstance, the vehicles would experience jerking, while acceleration is uncomfortable when a driver drives the vehicle. On top of that, it is dangerous for motorcyclists while taking a corner that needs smooth engine running.

In terms of emission produced by the internal combustion engine, incomplete combustion produces harmful gases, such as oxide of nitrogen (NOx), while the engine is running on lean condition and high temperature. This gas is formed by the reaction of oxygen and nitrogen and it has more nitrogen atoms, as nitric oxide is produced by the engine. Furthermore, incomplete combustion emits carbon monoxide (CO) when the combustion has insufficient oxygen because the carbon atom is not fully oxidized into carbon dioxide (CO_2). Other than that, emission of hydrocarbon (HC) could occur as well during this condition. HC is a raw fuel that is not burnt and it is produced by exhaust emission. The variation in emission product due to incomplete combustion can contribute to engine misfire. Figure 1.3 illustrates high NOx when the engine is running slightly lean, while HC and CO are high in a rich mixture condition. Hence, in order to avoid excessive incomplete combustion, the engine needs to run at a stoichiometric ratio, which is 14.7 of air to 1 part of fuel.

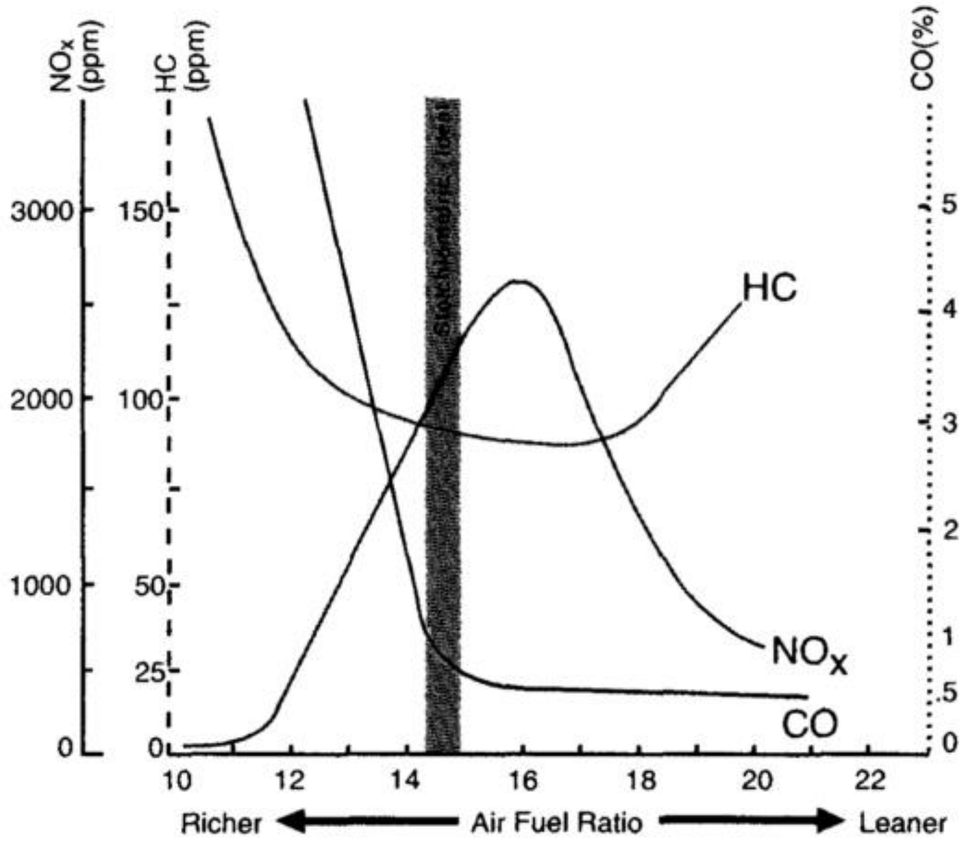

Figure 1.3 Types of compounds emitted by the exhaust at different conditions (To, 2012)

1.2 Problem statement

The accuracy of on board diagnostic (OBD) in detecting many problems in the engine system is important so that it complies with the standard of regulation. At present, most vehicles with internal combustion engine employ crankshaft position sensor (CPS) to detect the occurrence of misfires while the engine is running. However, some limitations have been discovered that contribute to false misfire alarm or the inability to detect precisely. This has been due to the failure of the sensor to rightly detect the tooth of flywheel when the sensor is dirty or some teeth are misshaped and increase the tendency of false alarm rate (Naik, 2004). Moreover, misfire detection using CPS based on engine speed would share a similar signal with engine misfire when the vehicle has intermittent braking due to uneven road.