UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PERFORMANCE EVALUATION OF WATER INJECTION SYSTEM FOR NATURALLY ASPIRATED ENGINE

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

by

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DECLARATION

I declare that this report entitled “Performance Evaluation of Water Injection System for Naturally Aspirated Engine” is the result of my own research except as cited in references.

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Date : 6/1/2020

APPROVAL

This report has submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of UTeM as partial fulfilment of the requirements for the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours. The member of the supervisory is as follow:

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ABSTRAK

Kajian sistem suntikan air untuk enjin semulajadi telah dilakukan untuk menilai perlepasan gas dan prestasi kenderaan telah dijalankan. Projek ini merangkumi pembangunan sistem suntikan air untuk kenderaan dan menguji prestasi. Prestasi kenderaan dari segi perlepasan gas, tork dan kuasa kuda dinilai. Prestasi sebelum dan selepas pemasangan sistem suntikan metanol air telah dibandingkan. Berdasarkan analisis, ia menunjukkan bahawa prestasi enjin dari segi tork dan kuasa kuda bertambah baik berbanding kenderaan tanpa sistem suntikan air metanol. Nilai pelepasan juga menunjukkan penurunan pada gas berbahaya yang menyumbang kepada pencemaran udara. Data untuk pelepasan gas diukur menggunakan penganalisis gas ekzos. Prestasi pelepasan mematuhi standard EURO 6B. Pengurangan ketara dalam pelepasan Hidrokarbon (HC) dan peningkatan nisbah bahan api udara (AFR) lebih dekat dengan nisbah stoikiometrik. Pengurangan HC adalah baik untuk persekitaran kita menunjukkan pembakaran sempurna telah dicapai oleh enjin kerana system suntikan metanol air. Projek-projek ini boleh dipertingkatkan pada masa akan datang untuk prestasi enjin yang lebih baik.

ABSTRACT

The study on water injection system for naturally aspirated engine was conducted in order to evaluate the emission and performance of test vehicle. This project includes the development of water injection system for vehicles and testing the performance. The vehicle performance in term of emission, torque and horsepower is observed. The performance before and after installation of water methanol system was compared. Based on the analysis, it shows that the performances of the engine in term of torque and horsepower is improving compared to standard vehicle. Emission value also shows a reduction on harmful gasses that contribute to the air pollution. The data for emission was measured using exhaust gas analyser. The emission performance complies with EURO 6B standard. Significant reduction in Hydrocarbon (HC) emission and improvement of air fuel ratio (AFR) closer to the stoichiometric ratio. Reduction on HC is good for our environment shows perfect combustion due to the water methanol system. These projects can be further improved in future for better engine performance.

DEDICATION

I dedicated this work to my family, lecturers, and friends that have played an important role in completing my bachelor's degree project. A special appreciation to my family especially my beloved parents, Suhaimi Bin Ali and Sarinah Binti Ab Rahman who give me moral support in the period of completing this project. Also, I dedicate my work to my supervisor En. Mohd Suffian Bin Ab Razak and my industrial co-supervisor En. Ahmad Syafiq Bin Yazid who has guided me from starts towards the end of this project. Besides, this appreciation also dedicated to my friends that always help me and sharing ideas in completing this project. Finally, this project won't be finished without all the support that has given from them.

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LIST OF ABBREVIATIONS

SAE	-	Society of Automotive
EGR	-	Exhaust Gas Recirculation
GDI	-	Gasoline Direct Injection
NEDC	-	New European Driving Cycle
EUDC	-	Extra Urban Driving Cycle
WLTP	-	Worldwide Harmonise Light Vehicle Test Procedure
HHO	-	Oxyhydrogen
ECU	-	Electronic Control Unit
DMCC	-	Diesel Methanol Compound Combustion
RPM	-	Revolution Per Minute
HP	-	Horsepower
NOx	-	Nitrogen Oxide
HC	-	Hydrocarbon
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
O_2	-	Oxygen
AFR	-	Air Fuel Ratio

STD	-	Standard
WMS	-	Water Methanol System

CHAPTER 1

INTRODUCTION

1.1 Background

A variety of fuel-saving technology to reduce consumption and emission have been introduced in the market. Afterall, the purpose of the new technology was introduced was to save fuel consumption and to prevent air pollution. Water injection system is one of the technologies for fuel saver device and can reduce emissions that cause air pollution and can improve fuel consumption at the same time.

Water injection also can reduce existing knock occurrence. “Knock” explains the unburned mixture of air and fuel through spontaneous ignition (Choi et al.,2017). Waters ability to prevent knocking can potentially allow for vehicle designs at higher compression and cylindrical pressures. Basically, potential of knocking higher when the engine operates in high speed. Downsized engines work at a very effective mean pressure which leads to higher cylinder pressure and can lead effectively to more abnormal combustion events such as knock and pre-ignition. The engine would be knocked off without water injection because it works under high load but in a low speed.

By injecting the water into the combustion chamber and it may produce perfect combustion for the engine. The maximum brake torque and perfect function timing are provided in all operating conditions (Choi et al.,2017). The reduction in water evaporation temperatures reduces the temperature at the end of the compression process and therefore reduces the exhaust gas temperature (Bozza, De Bellis, & Teodosio, 2016). This will cause the emission from the engine also can be reduced and it can prevent the air pollution that

causes from the vehicle emission. In order to reduce the concentration of oxygen and to increase the thermal capacity of the charges, the water may also be an excellent inert gas such as cooled Exhaust Gas Recirculation (EGR) (Bae, Choi, Kwak, Kim, & Park, 2015).

The positive effects of car-speed injection of water or increase engine torque because of the perfect combustion from water-methanol and air-fuel ratio. The weakening effect has also decreased NOx emission. Furthermore, volumetric efficiency also can increase due to the cooling effect of water injection (Hoppe, Thewes, Baumgarten, & Dohmen, 2016).

1.2 Problem statement

The vehicle is the most requirement of transportation in daily life. With the living cost in Malaysia increase, It may affect the financial problem among Malaysian people when we need to share monthly expenses to vehicle fuel consumption ("Top 15 Most Fuel Efficient Cars In Malaysia For Under RM100,000," n.d.). Furthermore, water injection system prevents from knock and pre-ignition. The driver cannot tolerate knocking noise and repeated exposure to extreme local pressures and temperatures can damage engine components (Choi et al., 2017). Air pollution from combustion of fuels from the vehicles one of the main causes in Malaysia. In 2011, more than 21 million vehicles register and the number will increase for now and all those car creating a dangerous gases and that is detrimental to our health(Watson, Bates, & Kennedy, 1988). Research shows that Gasoline Direct Injection (GDI) engines have an emission level similar to even higher to the GDI particulate mass and particulate numbers than diesel engines. Therefore, it is important to find alternative in reducing pollution emitted by GDI engines. The alternative solution to improve gas emission should be evaluated using established testing procedure such as chassis dyno test. This method can determine the level of pollutants, CO_2 emissions and fuel

consumption of normal passenger and hybrid cars, as well as the range of fully electric vehicles.

1.3 Objective

- Evaluate the engine performance of standard car in term of engine emission, torque and horsepower.
- Development of petrol engine water injection system.
- Analyze the performance of the engine with water injection system.

1.4 Scope

- To develop the water injection system for Perodua Myvi 2018.
- To analyze the performance of the engine before and after using water injection system on a chassis dynamometer.

1.5 Significance of study

- Able to measure the effectiveness of water injection system on engine performance.
- Improve fuel consumption of the vehicle and reducing NOx and carbon monoxide from the vehicle for a better environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, it will have the background information from the journal, books also articles about Water Injection System. Most popular fuel-saving technology is water injection system. This technology can reduce the fuel consumption of the engine and minimum the emission like Nitrogen Oxide (NOx), carbon dioxide and hydrocarbon. This chapter also will provide about part or component, the concept use and the parameter about this research.

2.2 Oxyhydrogen (HHO) gas.

HHO effect on the performance of four stroke gasoline engine to determine if the partial inclusion of hydrogen gas (HHO) in an engine for petrol-fuel internal combustion spark ignition (SI) would increase engine performance (West, Madyira, & Harding, 2014). Detailed and comprehensive experiments were carried out for engine speed of between 1000 and 3500 rpm while control was carried out on parameter like energy output, emission of exhaust gases and fuel consumption.

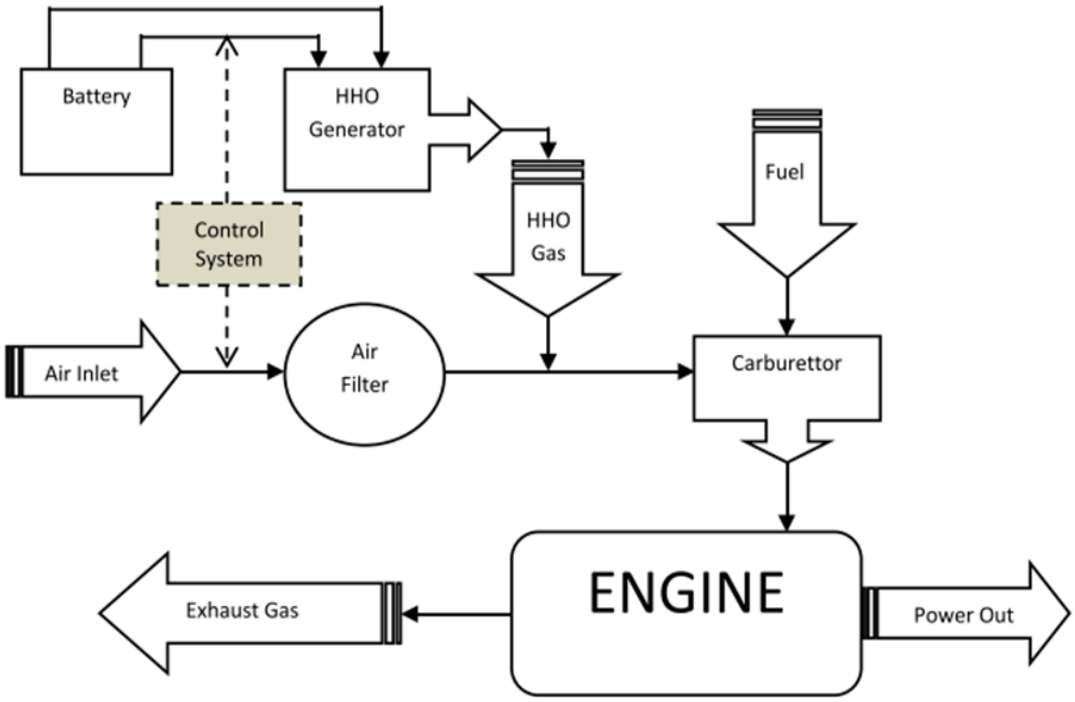

Figure 2.1: Schematic diagram for this experiment (West et al., 2014).

The vehicle power was measured using a road dynamometer. The power was specified as a fraction of the maximum dynamometer load. Nextech NGA 6000 automotive as analyzer measured the emission of exhaust gasses. The thermocouple of K-type exhaust gas ambient temperatures was monitored. The thermocouple for the measurement of the exhaust gas temperature was inserted into the exhaust collector to prevent the exhaust walls from being moved.

A gravity fed fuel supply system with an in-house made graduated fuel reservoir was used during the test. Fuel consumption was read off the graduated reservoir over a specified time span. A special orifice plate, that was also developed in-house, was used to monitor the air flow rate. This was implemented using an Arduino Uno prototyping platform. The air-fuel ratio of the engine was calibrated at 30% load to a value of 14.7. This was achieved by adjusting the carburetor float and monitored through exhaust gas composition. The HHO gas generator was also monitored under no load and the relationship between the current and gas

yield was determined. This was then implemented in the generator control system during the experiments. Baseline performance of the engine was determined prior to full testing. Tests were conducted for speeds of 1000, 2000, 2500, 3000 and 3500 rpm. For each speed, the load was varied in steps of 10 from 0 to 30 %.

Hydroxy gas has been used without modification and without need of a storage tank as additional fuel for a 4-cylinder, 4-stroke compression ignition (CI) engine (Yilmaz & Aydin, 2010). It investigated it impact on exhaust emission and engine performance. Experiment have shown that constant low-motor-hydraulic HHO (1750 rpm critical speed for this trial) flow rate has converted the advantages of HHO into engine torque, carbon monoxide (CO), hydrocarbon (HC) emissions and specific fuel consumption (SFC) disadvantages.

Studied showed that in relation to engine speed below 1750 rpm, the flow rate of HHO was to be reduced because of the longtime of opening of intake collectors at low velocity. This resulted in excessive hydroxyl volumes occupied in cylinders that avoided taking the right air into the combustion chambers and thus reduced volumetric efficiency. Without any changes the hydroxyl system was added to the engine. Different types of electrodes (reactors) in various molality aqueous catalyst solutions have created HHO gas in a reactor container (plexiglass). The positive current charged the anodes that resulted in the electrolysis reaction and finally released gaseous oxygen and hydrogen, which in their turn appeared at the top of the reactor container. Electric power supply was measured, and the reaction field was observed as a major contributor to the quantity of hydroxyl gas generated. An electronic control unit was designed and produced to reduce the HHO voltages and current by decreasing. Experiments showed that the motor speed values of approximately 7.3 v were suitable and the power of approximately 5.9 A was less than 1750 rpm.

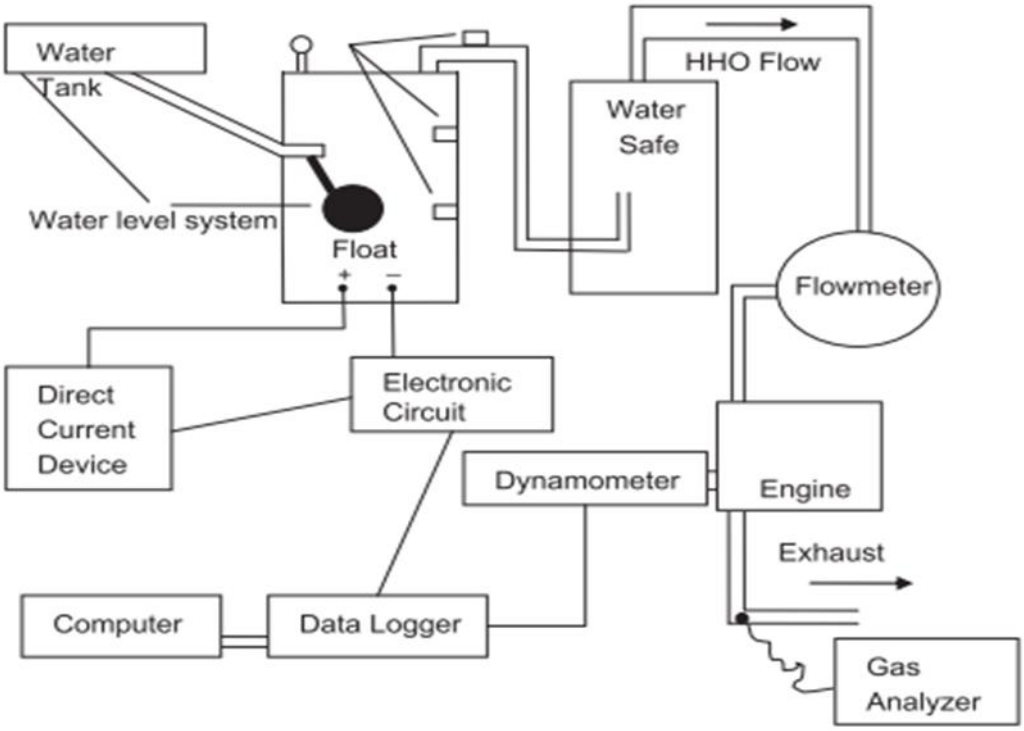

Figure 2.2: General setup for HHO generating device experiment (Yilmaz & Aydin, 2010).

2.3 Water methanol

The experiments improves the result obtained full load thermal efficiency, improves the full load motor output and reduces the full load exhaust gas temperature (Naber & Atkinson, 2017). As a result, net mean efficient pressure has improved to up to 5% and thermal efficiency has improved to up to 34% compared to ECU production calibration. The water supply system was manufactured to supply pressure which supports either direct injection or port injection. Each of the 4 intake runners has a production Bosch EV41 PI fuel injector. A mounting boss and rail were designed and manufactured for mounting. The boss was made of aluminum and soldered to the intake manifold in aluminum. The mounting boss had been designed to supply the water rail with an attachment point that retained the injector. The injector was designed of the spray into the intake door, just above the septum.

This study examined the effect of water-methanol injection on the torque output, temperature of the air intake and temperature of the exhaust gas in a natural suction engine (R & C, 2018). At the port of entry just before the throttle body, the water was injected. In addition, the effect of water-methanol injection on detonating was also investigated. In the investigation, the engine is left to run for 10 minutes before any measurements were taken. This method will be incorporated in this project to ensure the engine operates in a steady state condition and essentially obtain accurate measurements. The fuel-methanol mixture is stored in a tank for injection during the engine inlet process. The petrol 4 stroke engine has four processes like Suction, Compression, Power, and exhaust. During the suction process, the petrol is let inside the combustion chamber. During this process, the water -methanol is sprayed during the fuel petrol mixture. This is done to cool parts of the induction system in which premature ignition can be caused by “hot points”. In engines, the drives of the engine is increased at low speeds and when picked up.

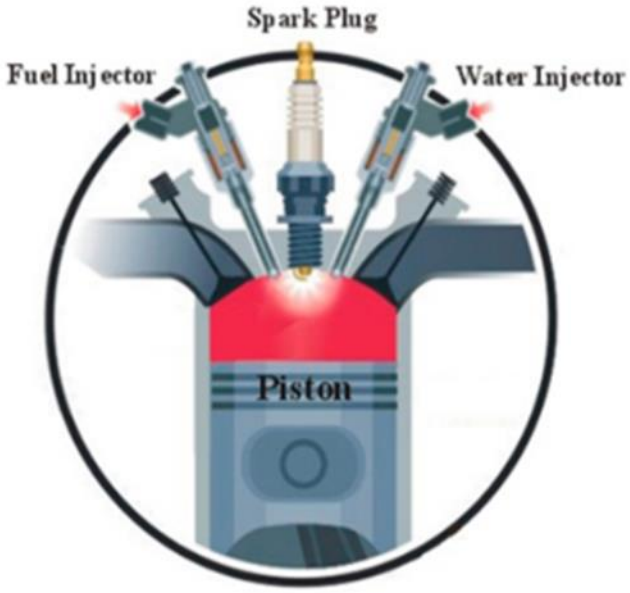

Figure 2.3: Experimental on water-methanol injection diagram (R & C, 2018).

2.3.1 Turbocharger engine

Examines the use of water injection in turbo-loaded, direct injections and ethanol powered spark ignition where port water injections are numerically effective in increasing charging performances, reducing knock tendencies and controlling gas temperature at turbine (Boretti et al, 2013). In the turbo era of the 80s, water injections were major enabler of high- power F1 vehicles. Water injection in internal combustion engine also known as anti-detonant (ADI), is a method for refreshing the combustion chambers in the motor by adding the water to the mixture of the cylinder or incoming air fuel. The injection by the port of water significantly cools the fuel air mixture, which increases the amount of mixture entering the cylinder.

During the combustion process a further influence may occur if water absorb large quantities of heat during its vaporization, reduces the peak temperature and the resulting NOx formation and reduces heat energy in the cylindrical walls. It is important to control water injection. Only when the engine is heavily loaded, and the throttle is wide open must it be injected. It is also possible to directly inject water at a late stage of the stroke or during the exhaust stroke.

Currently turbocharged SI engines are normally operated with large fuel enrichment and delayed spark progress to reducing increasing risk or pre-ignition or knock and spark advanced (Breda et al., 2015). The objective of the work is to substitute the rich mixture of petrol only with a global stoichiometric mixture while avoiding power loss and fuel consumption. Water, methanol or a combination of both are then added to the intake port to maintain the same knock trend in order to ensure the same charge of the original rich mix. In this project, a PFI 8-hole injectors injects methanol water or water into the ports of inlet. Water acts as Exhaust Gas Recirculation (EGR) species, and introduction of it in the combustion chamber reduces the chemical reactivity of the latest gas while reducing the burn

rate, on the other hand, encouraging a knock occurrence. The methanol is characterized by a greater octane number and laminar flammable speed than pure gasoline and has various consideration. The limitation of this study, which is the result of direct injecting methanol into the combustion chamber. Furthermore, the effect on a methanol of the engine part, and lastly on the volumetric efficiency of the engine with methanol.

2.3.2 Diesel engine

Combustion system Diesel Methanol Compound Combustion (DMCC) for diesel and methanol and its application to and without a catalytic oxidation converter on a natural aspiration diesel engine was investigated (Yao et al., 2008). At idle and five engine loads, experiment were performed at two levels of engine speed to compare emissions of engines to compare emissions of engines from pure diesel and DMCC operations with or without the catalytic transducer. The experimental evidence indicates that a diesel engine which is DMCC friendly can simultaneously reduce soot and NOx emissions while increasing HC and CO as compared to the original diesel engine. The DMCC method combined with the oxidation catalyst could however reduce emissions of CO, HC, NOx and soot. Diesel and methanol have poor miscible. A methanol mixed with diesel must therefore be added to the engine. Research of the emission characteristic of a natural aspirated six cylinder diesel engine with a mixture of diesel with up to 15% by additive-containing methanol volume (Yao et al., 2008). The experimental research on naturally aspirated, modified diesel engine was carried out on a four cylinder. Below is a schematic of the test setup.