Trigin Publisher

Available online at www.ijmcmr.com

Int. J. of Mechanical Computational and Manufacturing Research, Vol. 2. No. 4, (2013), 78 – 84, ISSN: 2301-4148

Investigation the Performance of EFI-SI Engine Using Water Injection

Edilan M.M. [1*], A.K.M. Mohiuddin[2], M.Arif A.H.P.[3], Nor Hisham M.M.[1] , Jufriadi [1], Bakar M.A.[4]

[1] *Automotive Engineering Section, Universiti Kuala Lumpur Malaysia France Institute, Bandar Baru Bangi, Selangor Darul Ehsan, Malaysia*

[2]*Department of Mechanical Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia*

[3]*Faculty of Mechanical Engineering, Universiti Teknolgi MARA, Pulau Pinang, Malaysia*

[4] *Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia*

Keywords:

Compressed Natural Gas (CNG)

Dedicated CNG system

Engine performance

Specific fuel consumption

Brake power

Brake mean effective pressure

Abstract: Few studies on the effect of water injection to combustion engine have been done for the last decades on carbureted single cylinder engine. The purpose of the present research is to investigate the effect of water injection on the performance and emission of an EFI-SI, CAMPRO 1.6L four stroke cycle engine. Water in mist form was supplied to the intake manifold through the nozzle which is located after the butterfly valve at the throttle body. The water will mix with the air fuel mixture before entering into the combustion chamber. A combination of modelling simulation followed by experimental validation was carried out with and without water mist addition to examine the performance produced by the engine. The simulation was carried out using GT POWER before the experimental investigation on performance with various load factors at different speed within the range of 1500 rpm to 4500 rpm. Thus, experimental result for the standard engine performance is used to validate the simulation model. Measurement of various parameters such as brake power, torque, volumetric efficiency and spark advance timing with water and without water injection to the engine was recorded. The experimental data obtained from the results by using the water injection method show an increase of power, torque and volumetric efficiency of the engine up to 10%. The fuel consumption is reduced about 3% to 6% when the speed is increase from 1500 rpm to 3500 rpm, then it increases up to 10% when the engine speeds up to 4500 rpm. The results obtained and analyzed will be useful for improving the engine performance for further developments.

1 Introduction

Water addition using water injection techniques as a separate liquid or emulsion with gasoline or as a vapour, has been thoroughly researched. If calibrated engines operate with a small amount of water, knock can be suppressed, hydrocarbon emissions will slightly higher, NO_x emissions decrease, CO does not change significantly and fuel and energy consumption are increased [1].

In 1999, a development of a new method is being done to predict the water injection method to the octane number (ON) that will increase replacement of the primary anti knock additive in petroleum refining technology and the reduction of NO_x emissions in the exhaust gas. Early designs of high compression ratio aircraft piston engines employed a water vapor induction system to increase the fuel anti knock rating and engine output [2]. In 1992, founds that an aqueous fuel comprising water and gasoline has about ½ the potential energy (BTUs) of gasoline but when used to operate an internal combustion engine, it will produce approximately as much power as compared with the same amount of gasoline [3].

Corresponding author: edilanmfi@gmail.com (Edilan M.M)
ICID: 1068209 (IndexCopernicus International)

Int. J. of Mechanical Computational and Manufacturing Research, Vol. 2. No. 4, (2013), 78 – 84, ISSN: 2301-4148

This is also supported the above with report that energy supplied to the engine as chemical energy of the fuel and leaves in the form of thermal energy in the exhaust gasses, cooling water and heat transfer. The remainder is transformed into brake work. Heat losses must be decreased to improve engine efficiency [4].

Aquamist's water injection system, the water is injected into the intake manifold, the internal temperature is reduced, immediately absorbing heat from the incoming intake stream, helping cool hot intake charge, the rest of the atomized water becomes steam in the combustion chamber, absorbing even more heat to dramatically lower the temperature and, therefore, better control the combustion or in other words suppress the detonation [5]. The experimental result found that the power output of the engine was increased on the order of 3.8 to 14% when the base fuel containing 5-15% of water [6]. The shaft efficiency of the engine suffers from injecting the water during the compression stroke because the cooling caused by water injection at the end stage of compression reduces the pressure of compressed air and or the fuel air mixture whereby the engine must perform compression work that cannot be utilized during the expansion stroke [7].

One of the strategies to improve engine performance that will be discussed in this paper is the water injection to the spark ignition engine as shown in Figure 1.
Technique of water addition technology either on SI engine or CI engine is nearly as old as the creation of engine itself. The techniques of water addition itself can be explained in many ways such as:

i. manifold injection or carburetion of water gasoline emulsions
ii. separate induction of water and gasoline
iii. direct cylinder injection of water
iv. manifold water vapor induction and
v. water induction into the air intake [8]

In this study, the water induction into the air intake system would be used to investigate the effect on the performance and emission produced by the engine.

2 Approach and Methods

2.1 Engine Test Setup

A 4-stroke spark ignition "CAMPRO 1.6L IAFM" fuel injection type of engine coupled to 150 kW dynamometer was utilized in this study. Standard instrumentation was used to measure engine power, torque, injection timing, pressure of oil, barometric, intake manifold, coolant inlet, exhaust, plenum and temperature of air intake, engine oil, water coolant, exhaust as well as brake specific fuel consumption and percentage of relative humidity. Engine torque was measured via a part load test which connected at the dynamometer coupling shaft. The reason why the testing is through a part load test is due to high vacuum pressure in intake manifold is needed to assist the water mist to flow into the combustion chamber. Firstly, the experiment is carried out to get the standard performance curve and actual parameters as an input for engine model simulation. After the model is generated, it has to be validated to make sure the accuracy of the model by comparing it with the result that we gain from the standard engine performance testing. Once the model was validated, the final goal was to use GT-Power to explore the abilities of adding the water mist to the engine system. By exploring all of the possible intake and exhaust manifold pressure, the optimum result would be chosen while trying to maximize specific quantities. The target parameters include volumetric efficiency, fuel efficiency, indicated mean effective pressure (IMEP) and others.

2.2 Engine Specification

The testing has been done at Proton Research Center in Shah Alam. The engine that has been used is a spark ignition, electronic fuel injection system with the model of CAMPRO 1.6 IAFM (Integrated Air-Fuel Module) Proton Engine. This engine is essentially a basic DOHC CAMPRO engine equipped with a variable-length intake manifold, developed under a joint fast track programmed which began in April 2005 by EPMB, Bosch and Proton. The details of the specification are shown in Table 1.

2.3 Engine measurement

In this experiment, the SAE J1349 standard has been used. Besides of the experimental procedure is explained, the SAE J1349 is also specify various ways to include the engine's internal losses, and therefore presents a more accurate indication of engine power. The standard CAMPRO IAFM engine testing was first conducted under several part load condition with variable engine speed started from 1000 rpm up to 4500 rpm at normal operating conditions without water mist addition. The engine was fixed at constant load factor started from 0.3, 0.4, 0.5 and 0.6 with wide open throttle position and engine speed is set to keep it increasing. This test was repeated by the advance of the ignition timing with the increasing of engine speed.

During the testing, the data for engine torque, brake specific fuel consumption, throttle position, exhaust temperature, plenum temperature, air intake temperature, fuel mass flow rate, barometric pressure, ignition timing etc. has been recorded.

Int. J. of Mechanical Computational and Manufacturing Research, Vol. 2. No. 4, (2013), 78 – 84, ISSN: 2301-4148

The final results were acquired from the average of two stable and continuously measured values, which do not vary by more than 2%. All the data recorded were used for modeling validation and comparison with the engine testing which use without water mist and with water mist addition.

Then the performance test was repeated as similar as testing the standard engine without the water addition but this time the water addition device has been installed. The data were recorded as similar with the standard engine performance testing for comparison purposes.

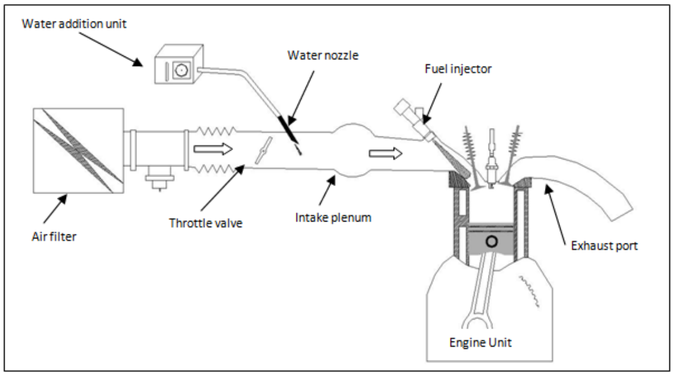

Figure 1: Water Injection Method

Table 1: Engine Specification

No	Description	Specification
1.	Valve Mechanism	16 Valve IAFM DOHC
2.	Total Displacement	1597cc
3.	Bore (mm)	76
4.	Stroke (mm)	88
7.	Fuel Type	Multi Point Injection Petrol
8.	Compression Ratio	10
9.	Horse Power	110Hp(82kW) @ 6500rpm
10.	Torque	148 Nm @ 4000rpm

Int. J. of Mechanical Computational and Manufacturing Research, Vol. 2. No. 4, (2013), xx –xx, ISSN: 2301-4148

3 Results and Discussion

3.1 Simulated Engine Model

The entire step by step that has been discussed above are used to make a complete model of the engine as shown in below figure 2. The complete model shown is referring to the original CAMPRO engine without adding the mist of water in to it.

3.2 Validation of GT POWER Model and Experimental Measurement Without Water Addition

After the simulation run on complete model, the data measured from the experiment, is to be used that make GT-Power graph as close as possible to the final experimental results shown in below figure 3.

There are difficulties to make the simulation graph as close as possible to the experimental result. This is due to the simulation run without the fuel energy losses by the engine. The way to make it as close as possible is to adjust the fuel burn rate of the engine.

The relative error between the measured data of the experiment and the GT-Power model are present as per formula follows:

$$\text{Relative error} = \left[\frac{(\text{maxvalue} - \text{minvalue})}{(\text{maxvalue})}\right] \times 100 \quad (1)$$

From the relative error above, the GT Power simulation of the engine can be considered almost 90% accurate.

3.3 Performance of Standard Engine without and with Water Addition

Several testing parameters have been done to get the performance of the engine. The testing is run under constant load test of 0.3, 0.4, 0.5, 0.6 factor condition which is wide open throttle is maintain and increasing gradually the speed of the engine started from 1500 rpm to 4500 rpm.

All the data and results of engine testing which use a water addition and standard engine without water addition have been recorded to facilitate analysis and discussion which will be explained in the following step.

3.3.1 Power and Torque

Test was done to determine the maximum torque increase with adding the water mist into the engine. Compared to standard engine without water addition, engine with water addition at load factor 0.3, 0.5 and 0.6 produces a bit increasing of power and torque started at 1500rpm till 3250 rpm. The increasing engine performance of the engine with water addition is mainly due to high volumetric efficiency of the dissociation of water converted into hydrogen and oxygen. Figure 6 shows that the engine operation with water addition produced on the average torque approximately 10.0% to 14.0%, respectively, compared to that of standard engine (without water addition).

The graph in Figure 4 also shows that the torque keeps reducing started from approximately 3250 rpm to 4500 rpm. From the experiment the volumetric efficiency also keep reduce. This is due to when high speed the vacuum suction inside the intake manifold were reduce and this will reduce the amount of water to get into the intake manifold thus reduce the performance.

3.3.2 Fuel Consumption

The reduction of brake specific fuel consumption shows the overall performance of an engine. It shows that with the high torque produces by the engine, its use less fuel consumption. This experiment is to get the fuel consumption rate with an experiment with and without adding water mist to the system. During both of the experiment the throttle angle is fix by varying the load to the engine according to the various speed started from 1500 rpm to 4500 rpm.

From Figure 5, it shows that the b.f.s.c somehow reduce dramatically for the testing with load 0.3 with water addition and the other load factor looks a bit reduce with and without water addition to the engine. The less fuel consumption about 3% to 6% was obtained started at 1500 rpm up to 3000 rpm. It also indicate that increasing in engine torque with water addition shows the fuel consumption keep increasing after the speed reach more than 3500 rpm.

3.2.3 Torque with and without Adjustment of Spark Timing

Spark timing is considering the correct timing of the spark plug to ignite the air fuel mixture in the combustion chamber. The powers output of the engine, with and without water added, therefore depend strongly on spark timing setting relative to MBT [9].

An experiment has been conducted with an adjustment of the degree for the spark plug to ignite. With the engine with multipoint injection used, the controlling is being done by electronically control by certain control device. The advances of the ignition timing are approximately 6 degree every time the speed of the engine increasing gradually (1500 rpm, 2000 rpm, 3000 rpm, 3500 rpm, 4000 rpm and 4500 rpm).

Figure 6 shows the effect of the advances of ignition timing to the engine with adding water addition to the system. The comparison is focused on standard ignition timing and advances ignition timing with and without water addition to

Trigin Publisher
Available online at www.ijmcmr.com

Int. J. of Mechanical Computational and Manufacturing Research, Vol. 2. No. 4, (2013), 78 – 84, ISSN: 2301-4148

the engine. From the figure 6, shows that the advance of ignition timing is given about 10% improvement to the engine performance with adding the water mist to the system. The reason for the above is when advancing the ignition timing, knocking will occur. Therefore with adding water mist, it would suppress the knocking thus improve the performance. This is also supported [5], that the combustible fuel is exploded by the high voltage spark, which helps to crack the water molecule into hydrogen and oxygen which are in turn exploded to not only give a cleaner burn but also to add considerable thrust to the piston.

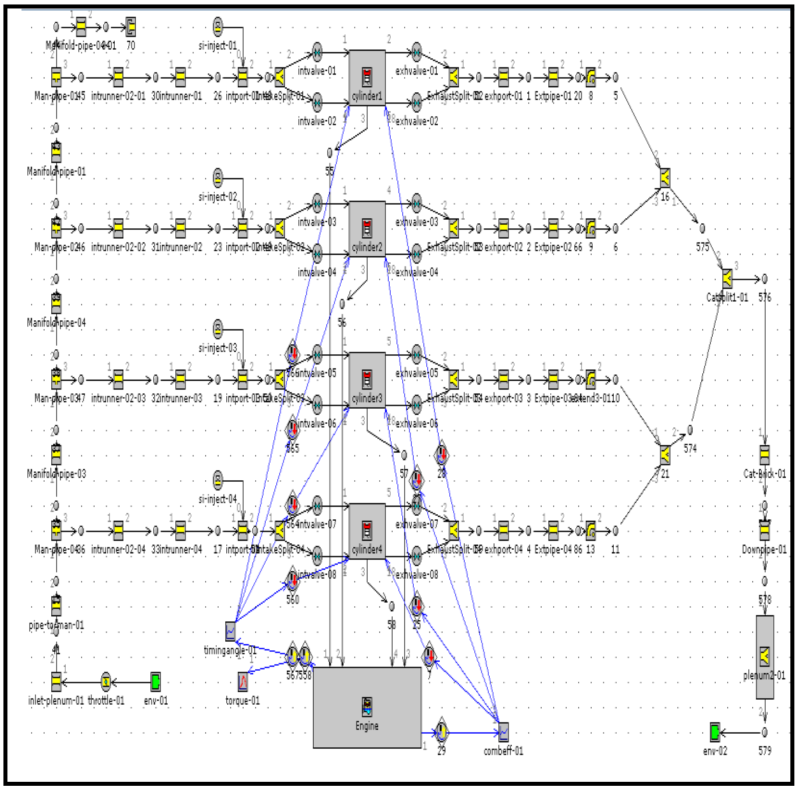

Figure 2: Complete Engine Simulation model

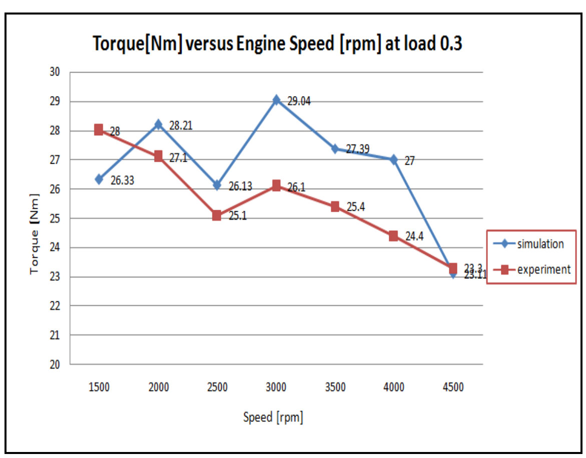

Figure 3: Validation of GT Power Modelling with Experimental Result On Base Engine

Trigin Publisher

Available online at www.ijmcmr.com

Int. J. of Mechanical Computational and Manufacturing Research, Vol. 2. No. 4, (2013), 78 – 84, ISSN: 2301-4148

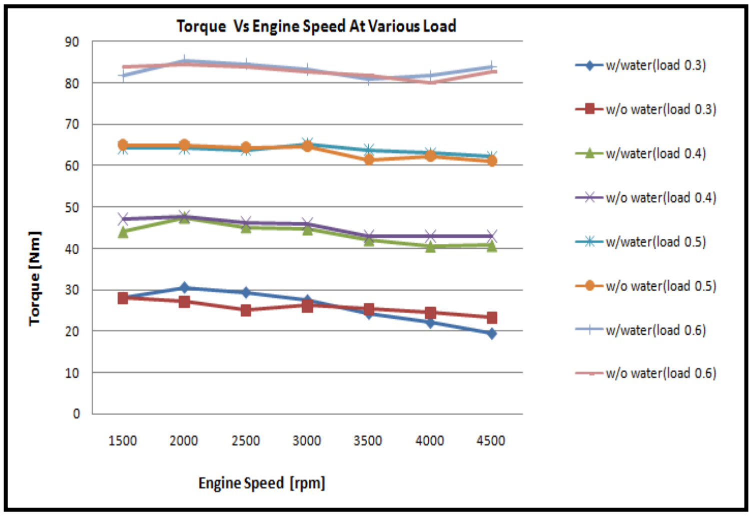

Figure 4: Torque Vs Engine Speed at Various Load Condition

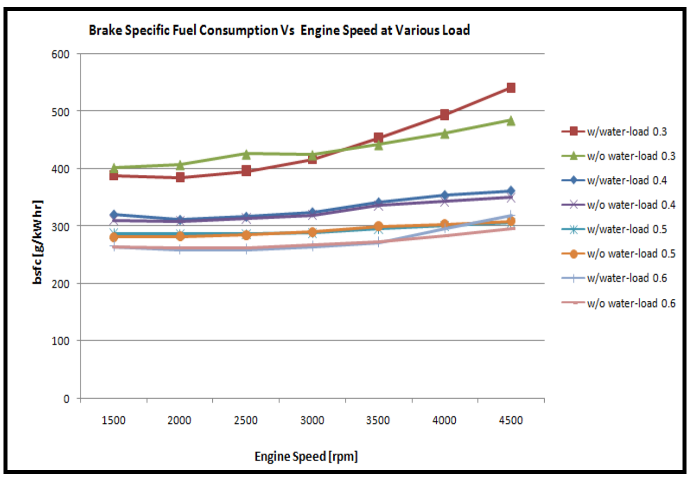

Figure 5: Brake Specific Fuel Consumption vs Engine Speed

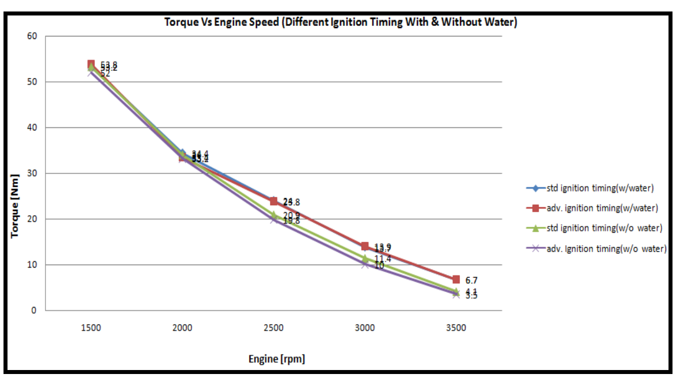

Figure 6: Engine Torque vs Engine Speed with Spark Advance

Int. J. of Mechanical Computational and Manufacturing Research, Vol. 2. No. 4, (2013), xx –xx, ISSN: 2301-4148

4 Conclusion

The contribution of this research can be summarized as follows:

1. Developed simulation model for EFI SI CAMPRO 1,6 L 4-stroke cycle engine with/without water addition.
2. Validated simulation model through experimental investigation.
3. The result has shown up to 10% increase of power, torque and volumetric efficiency using water addition into the engine.
4. There was a decrease of fuel consumption by 3% to 6% when engine runs from 1500 rpm to 3500 rpm using water addition.
5. The result has shown up to 10% increase of power and torque during advances of ignition timing with water addition.

Overall result indicates that water addition leads to an increase of the performance of the engine.

Acknowledgement

The authors would like to thank PROTON Bhd. for allowing doing the project testing and University of Kuala Lumpur Malaysia France Institute for financial support. The authors would also like to express their gratitude to whosoever had contributed to their work either directly or indirectly.

References

[1] Harrington, J.A. 1982. Water Addition To Gasoline – Effect On Combustion, Emissions, Performance and Knock. *Society of Automotive Engineer (SAE) Technical Paper*, NO: 820314.

[2] Lanzafame, R. 1999. Water Injection Effects In A Single Cylinder CFR Engine. *Society of Automotive Engineer (SAE) Technical Paper Series NO:* 1999-01-0568.

[3] Gunnerman, Rudolph W. 1992. Aqueous Fuel For Internal Combustion Engine And Method Of Combustion. (U.S Patent NO: 5156114).

[4] Hakan Ozkan & M.S Soylemez. 2004. Thermal Balance of a LPG Fuelled Four Stroke SI engine With Water Addition. *Society of Automotive Engineer (SAE) Technical Paper*, NO: 570581.

[5] Tsao, K.C., and Miller. EM. 1984. Performance of Gasoline Water Fuel In Modified SI Engine. *Society of Automotive Engineer (SAE) Technical Paper*, NO: 841399.

[6] Goran Hellen, Seppo Tiensuu, Juha Kytola, Tapani Humalamaa. 2002. Method of Reducing Nitrogen Oxide (NOx) Emissions of Piston Engine, *Society of Automotive Engineer (SAE) Technical Paper*, NO:6415745.

[7] Bignardi, L.,Cau, G.,Pelagagge, P. 1981. Products Of Combustion Of water In Fuel Emulsion. *14th International Congress on Combustion Engine*, vol. 98 of D.

[8] Covey, R.R. & Donnelly J.J. 1982. Assessment of Water Addition to Spark Ignition Engines. El Segundo, USA: Technical Report Aerospace Corp.

[9] Harrington, J.A. (1982). Water Addition To Gasoline-Effect On Combustion, Emissions, Performance and Knock. *Society of Automotive Engineer (SAE) Technical Paper*, NO: 820314.