# THE EFFECT OF INJECTING WATER TO THE AIR FUEL MIXTURE IN A SPARK IGNITION ENGINE

Diya ARAFAH, Ala QARQASH, Mahmoud ABU TALEB

* Palestine Polytechnic University, P. O. Box 198, Hebron, Palestine, darafah@ppu.edu

## Abstract

*It is known that the development and improvement of the Internal Combustion Engines are moving rapidly and continuously. The main concerns of the developers are to reduce the fuel consumption as well as to increase engine performance and efficiency. Many methods can be used to achieve these goals such as (Turbo charging, Exhaust Gas Recirculation EGR), But recently another method of injecting water into ICE is getting more attraction.*

*Water injection can be done by many methods. It may be a spray inside the cylinder or at the intake manifold. In the present study, Water Injection System (WIS) at intake manifold will be designed and implemented for gasoline engine (SI). In the experiments, engine operating conditions will be measured with and without (WIS), and the results will be compared to investigate the effect of (WIS) on engine performance and emissions. Based on the experimental data the water injection increases the engine output power and reduces exhaust emissions: CO by 3-7% and NOx by 25%.*

**Keywords: NOx, WIS, Knock, Water injection**

## 1. Introduction

The injection of water date back to the 1930s when the manufacturers had to find a solution for the Knock of the aircraft engines at high power. In the World War Two, the use of water injection becomes greater especially in the aircrafts which all powered by piston engines. Also, water injection was used by Renault and Ferrari in Formula One to improve engine performance, until a few years ago (when it was banned), most World Rally Championship cars used water injection systems.

In fact, there are many benefits for the use of water injection system. The main reason is to solve the problem of Knock "detonation" in the engines especially for engines working at high compression ratio and also to get more efficiency and fuel economy which leads to greater output power obtained [1]. Another benefit of water injection is cooling the combustion chamber of the engine because the heat is transferred from the hot chamber into the water to evaporate. A lot of studies discovered many environmental benefits of cooling the combustion chamber through reduction of Carbon Monoxide and Nitrogen Oxides [2].

## 2. Experiment Design

The water injection system is designed and implemented on 4 cylinder 1.6 L naturally aspirated SI engine with multi-point fuel injection. The engine is mounted on metallic frame using rubber mountings to reduce vibration, see Figure 1.

Figure 1: Engine metallic test rig

The water injection system is built using simple components that are controlled easily by mechanical methods, the diesel distributing rotary pump with mechanical governor, takes the water from the water tank and then provide the water injection to the injection nozzles (injectors) which are mounted on the intake runner of each cylinder, therefore, a multi-point water injection system is created. The distributor pump takes the rotational speed from a pulley fitted on the cam shaft by using timing belt; the cam shaft rotation is used in order to synchronize the water and fuel injection in terms of injection timing, as well as injection quantity. The direct connection of the distributor pump with cam shaft rotation allows a flow rate that depends on the number of cycles (engine rpm), as a result, any increase in engine speed causes an increase in the water flow rate.

In the present study the water to fuel ratio is set about 1:10 and the injection pressure is set about 8 bar; these modifications are done through adjustment (tuning) of the distributor pump using injection service station. The experiment begins when the engine reaches warm up, the coolant temperature sensor is used for this purpose. A tachometer is used to measure engine rpm, and a gas analyser is used to collect emission levels of NO, CO. The collected data obtained at four different throttle angles: 20-30-40-50%, at each throttle angle two runs performed. The first one is without water injection system, while the second one is with water injection system.

## 3. Results and Discussion

The purpose of the experimental work was to show the effects of water injection on a gasoline SI engine, the collected data are summarized in Table 1 and Table 2. Figure 2 shows the difference in engine speed at the same throttle angle with and without water injection, the engine speed is increased about 5% with water injection, which indicates an increase of the engine output power due to water injection.

Table 1: Experimental results without water injection

| Throttle angle [%] | Engine Speed [rpm] | Fuel Consumption [mL/s] | CO [%] | $NO_X$ [PPM] |
|---|---|---|---|---|
| 20% | 1100 | 0.800 | 0.062 | 550 |
| 30% | 2000 | 0.869 | 0.13 | 603 |
| 40% | 3000 | 1.02 | 0.26 | 638 |
| 50% | 4000 | 1.21 | 0.29 | 697 |

Table 2: Experimental results with water injection

| Throttle angle [%] | Engine Speed [rpm] | Water Consumption [mL/s] | Fuel Consumption [mL/s] | CO [%] | $NO_X$ [PPM] |
|---|---|---|---|---|---|
| 20% | 1150 | 0.07 | 0.800 | 0.060 | 413 |
| 30% | 2100 | 0.085 | 0.869 | 0.11 | 462 |
| 40% | 3200 | 0.102 | 1.02 | 0.23 | 480 |
| 50% | 4250 | 0.127 | 1.21 | 0.27 | 540 |

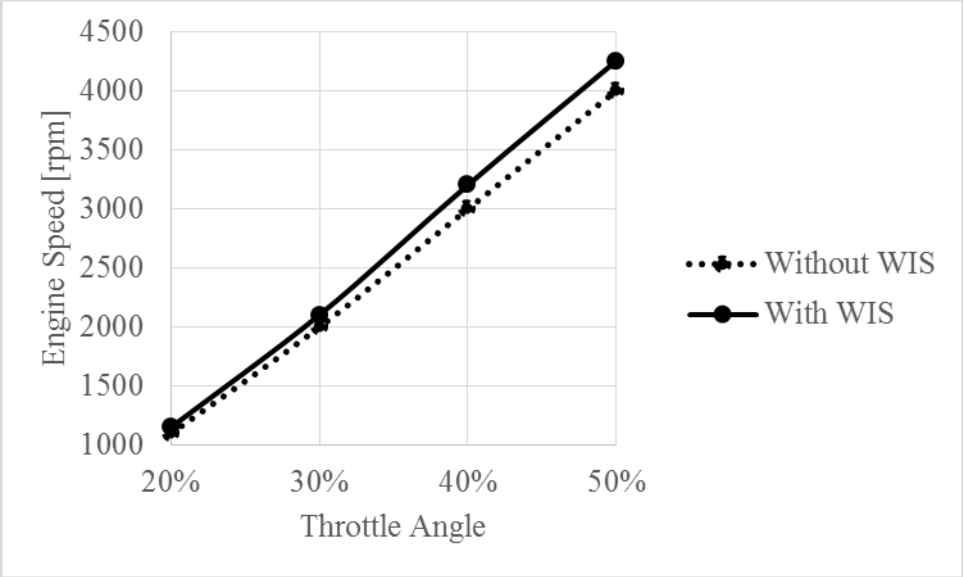


Figure 2: Engine speed vs. throttle angle

Figure 3 shows the Carbon Monoxide (CO) exhaust emission of the engine when operated with and without water injection, the volume of (CO) decreased about (3-7%) in exhaust gases depending on engine speed and injected water quantity. Figure 4 shows the Nitric Oxides (NOx) exhaust emission of the engine when operated with and without water injection, the (NOx) content in the exhaust gas dropped by 25% when water is injected, this due to the cooling effect of the injected water on the combustion chamber.

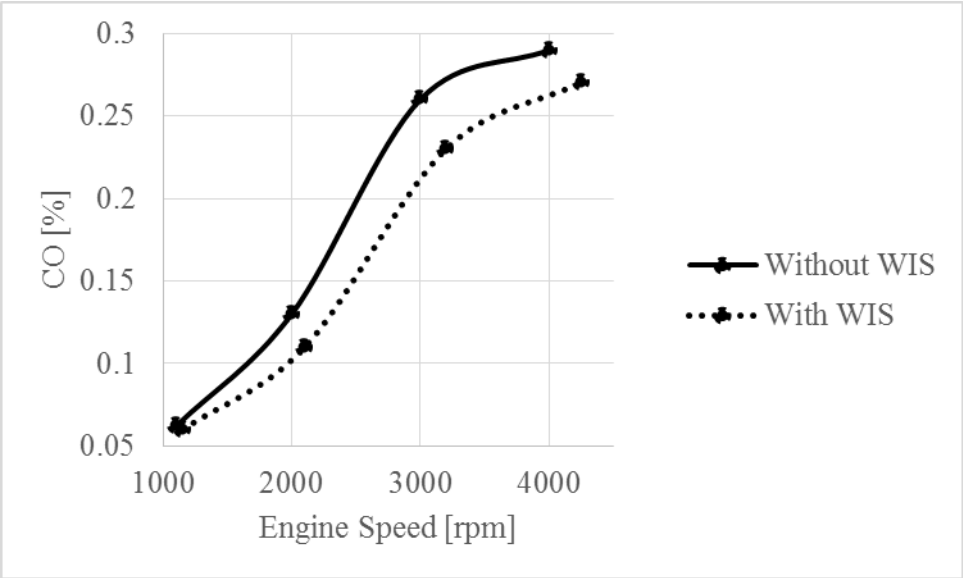


Figure 3: CO exhaust emission vs. engine speed

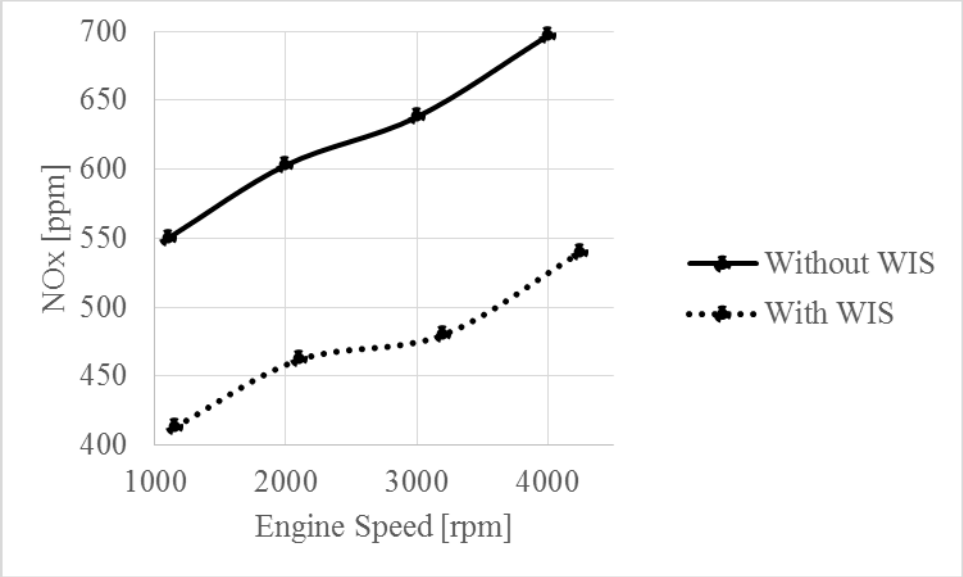


Figure 4: NOx exhaust emission vs. engine speed

## 4. Conclusions

Based on the experimental data it is concluded that the effects of water injection on SI engine will increase the engine output power, reduce exhaust emissions: CO by 3-7% and NOx by 25%.

## References

1. Brusca S, Lanzafame R. Water Injection in IC-SI Engines to Control Detonation and to Reduce Pollutant Emissions. SAE Technical Paper; 2003 May 19.

2. Wilson JP. Effects of water injection and increased compression ratio in a gasoline spark ignition engine (Doctoral dissertation, University of Idaho).