WATER INJECTION SYSTEM DESIGN FOR SIX STROKE ENGINE

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ABSTRACT

The engine for automobile is developed rapidly from each year as to increase the performance and able to decrease the fuel consumption. Various method and concept had be proposed previously based on mechanism, new attachments and material usage for the engine. This thesis is about the water injection system design for currently new six stroke engine as one of development engine method. The objectives of this project are to design new water injection system and find suitable components that compatible with this system. This project describes about process for design and fabricated the water injection system based on selected concept design. Some of concept design were proposed earlier and compared together. Then, the concept with the good mechanism and able to built was selected and designed using Solidwork software. The concept was chosen by considering the capability to operate the system, functionality, area usage and material or components chosen. This concept is generated from the fuel injection system for diesel engine where the fuel injection was controlled through fuel pump and pumping operation driven by rotation of camshaft. Hence, the similar system was presented here by some component modification in order to produce the six stroke engine. The complete manufactured water injection system was analyze by testing them with experimental as to achieve best result. The fabrication process was conducted following the dimension of modeling design and some modification to the existing component. The complete water injection system was fabricated successfully and several analysis tests have been conducted to measure the capability of our system. Two testing have been made to determine the performance of water pump with different pressure and amount of water injected by water injector. The result showed that the injections pump produce different pressure with time duration and plunger pump compression. The water injector was modified to obtain the suitable opening pressure to inject specific amount of water into combustion chamber.

ABSTRAK

Pembangunan enjin untuk automobil dengan pesat dari setiap tahun untuk meningkatkan prestasi dan dapat mengurangkan penggunaan bahan api. Pelbagai kaedah dan konsep yang telah dicadangkan sebelum ini berdasarkan mekanisme, pembaharuan baru dan penggunaan bahan sesuai untuk enjin. Tesis ini adalah berkenaan reka bentuk sistem suntikan air untuk enjin enam lejang yang baru sebagai salah satu kaedah enjin pembangunan. Objektif projek ini adalah untuk mereka bentuk sistem suntikan air baru dan mencari komponen yang sesuai yang serasi dengan sistem ini. Projek ini menerangkan tentang proses reka bentuk dan pembuatan sistem suntikan air berdasarkan konsep reka bentuk yang dipilih. Beberapa konsep reka bentuk telah dicadangkan sebelum ini dan dibandingkan bersama. Kemudian, konsep dengan mekanisme yang baik dan dapat dibina telah dipilih dan direka dengan menggunakan perisian Solidwork. Konsep itu dipilih dengan mengambil kira keupayaan untuk mengendalikan sistem, fungsi, kawasan dan penggunaan bahan atau komponen yang dipilih. Konsep ini dijana dari sistem suntikan minyak untuk enjin diesel, yang mana suntikan minyak diesel dikawal melalui pam minyak diesel dan pam operasi yang didorong oleh putaran camshaft. Oleh itu, sistem yang sama telah dibentangkan di sini dengan beberapa pengubahsuaian komponen untuk menghasilkan enjin enam lejang. Pembuatan sistem suntikan air lengkap adalah menganalisis dengan menguji mereka dengan eksperimen untuk mencapai hasil yang terbaik. Proses fabrikasi dijalankan berdasarkan dimensi reka bentuk pemodelan dan beberapa pengubahsuaian kepada komponen yang sedia ada. Sistem lengkap suntikan air telah dijalankan dengan berjaya dan beberapa ujian analisis telah dijalankan untuk mengukur keupayaan sistem ini. Dua ujian telah dibuat untuk menentukan prestasi pam air dengan tekanan yang berbeza dan jumlah air yang disuntik oleh air suntikan. Hasilnya menunjukkan bahawa pam suntikan menghasilkan tekanan yang berbeza dengan tempoh masa dan pam pelekap mampatan. Suntikan air atau atomizer telah diubahsuai untuk mendapatkan tekanan pembukaan yang sesuai untuk menyuntik jumlah tentu air ke dalam kebuk pembakaran.

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LIST OF SYMBOLS

$\dot{V}$	volume flowrate
c_d	discharge coefficient
A_0	area of flow
ΔP	pressure of flow
ρ	density of water

LIST OF ABBREVIATIONS

EUI	Electronic unit injector
NOP	Nozzle opening pressure

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Probably the invention of the motor or even the introduction of its conception was the most important scientific event in the history of mankind. Replacing a car or riding a horse less carriage, as it was in the beginning, it was an event that may increase the distance from human activity in daily life. Engines are the basic mechanical devices, and they have numerous applications in stationary and mobile machinery. An engine is defined as the machine that converts the chemical energy liberated through combustion of a certain fuel, into a mechanical energy that is used to derive a certain vehicle. The definition highlights two important facts about the engines. First, an engine is a machine, hence a mechanism exists. This mechanism can vary, and thus it can have more than one mechanism of operation.

The two most famous mechanisms of actions are the two-stroke and four-stroke engines. As clear from its name, the only difference exists in the so-called stroke. A stroke is when the length of the path that gets defined by the piston into the cylinder. The upper end of the cylinder as the top dead centre (TDC), and the lower end are called the bottom dead centre (BDC). Use the crank mechanism is, the linear movement of the piston is converted by combustion into rotary motion. The rotary motion is required in order to derive the wheels. Internal combustion engines (ICE) still have potential for substantial improvements, particularly with regard to fuel efficiency and environmental compatibility. In order to increase the energy efficiency of internal combustion engine with reciprocating piston, the term six stroke have been developed since 1990's.

Numerous designs have been proposed based on the Otto or Diesel cycles and all of these include four sequential thermodynamic processes or ‘strokes’ of the piston.

The engine that has the same power or more, with higher fuel efficiency than existing ones began several years ago. Following these investigations a new engine concept was formed, which is one of six stroke engines. A lot of research on this issue at present and for the last as six types of two-stroke engines has been subjected to discover. For basic operation, during every cycle in a typical four stroke engine, piston moves up and down twice in the chamber, resulting in four total strokes and one of which is the power stroke that provides the torque to move the vehicle. But in a six stroke engine there are six strokes and out of these there are two power strokes. The several ways have been conducted to use the fresh air and water injection to act as additional power stroke agent. The water injection usage was invented by Bruce Crower with the simple design and mechanism. His principle of design about after the exhaust cycles out of the chamber, rather than squirting more fuel and air into the chamber with the design injects ordinary water. Inside the extremely hot chamber, the water immediately turns to steam expanding to 1600 times its volume which forces the piston down for a second power stroke. Another exhaust cycle pushes the steam out of the chamber, and then the six stroke cycle begins again.

Hence, the water injection system for six stroke engine would be designed with suitable and simple mechanism. The components chosen should be compatible with the system that can produce high efficiency water deliver and withstand with the long term damage to the engine.

1.2 PROBLEM STATEMENT

In order to improve the efficiency of internal combustion engines, the six stroke engine was introduced by makes several modifications to the current four stroke cycle engine. The main purpose is to designed new water injection system to allow entry of water into combustion chamber as additional two stroke cycles. The properties such as water pressure and water amount should be considered to produces more output work from the engine.

As a result, after the first system of design include several components and material selection, an extensive and time consuming trial was started to determine proper tool design and all other variables, leading to the desired product.

1.3 OBJECTIVES OF PROJECT

i. To design a water injection system for six stroke engine.
ii. Analyze the water injection system on the operating six stroke engine.

1.4 SCOPES OF PROJECT

i. Literature review, design concept generation with concept selection and structural modelling of water injection system component with Solidwork software.
ii. Manufacturing the water injection system with laboratory equipment and experimental analysis on the system.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In order to gain a better perspective of the development process of this project, research was conducted to obtain the best requirement that suitable for this system design. The literature review was conducted using variety of methods including library books, journal and articles. This chapter provides view the subject that involved with the process of water injection system in six stroke engine includes systems in internal combustion engine, the types of cycle, its relation with environment, improvement in engine efficiency and the components that compatible with this injection system.

2.2 INTERNAL COMBUSTION ENGINE

The internal combustion engine or called ICE is an engine wherein the combustion of fuel and oxidizer occurs in the combustion chamber which is the space where everything occur cause an exothermic reaction. The first internal combustion engine was built in 1859 by Etienne Lenoir by use a single cylinder two stroke engine. It ran on street lightning gas through combination of coal gas and air which was ignited by an electric spark. Unfortunately, it was not very powerful because the fuel and the air were not compressed so it did not burn fast enough. The development of engine was keep going in recent year with the large improvement and modification with modern technology as we looked at modern vehicle now. Some engines are classified as reciprocating or rotary, spark ignition (SI) or compression ignition (CI), and two stroke or four stroke. The most familiar combination, used from automobiles to lawn mowers is the reciprocating, spark ignited, four stroke gasoline engine. Other types of internal-combustion engines include the reaction engine (rocket) and the gas turbine (Heywood, 1988).

2.3 TYPES OF STROKE CYCLE

The engine that exists now is operating with two stroke and four stroke cycle while the engine development was conducted many years to build the engine which is operating with six stroke cycle. The first invention of engine earlier was using two stroke cycles to produce one power. Figure 2.1 showed the engine operation based on the two strokes cycle. A working cycles of piston in an engine in which the piston during first stroke compresses the fuel mixture on one side while receive the expansion compressed gases on other side and during second draws in a fresh charge on one side while expel burnt gases out. The first operations are the intake and exhausts occur at bottom dead centre (BDC) which form of pressure is needed either crankcase compression. Next, in the compression stroke, fuel air mixture is compressed and ignited and in case for diesel the air is compressed, fuel is injected and self ignited. Then the power stroke occurs where piston is pushed downward by the hot exhaust gases (Brain et. al 2004).

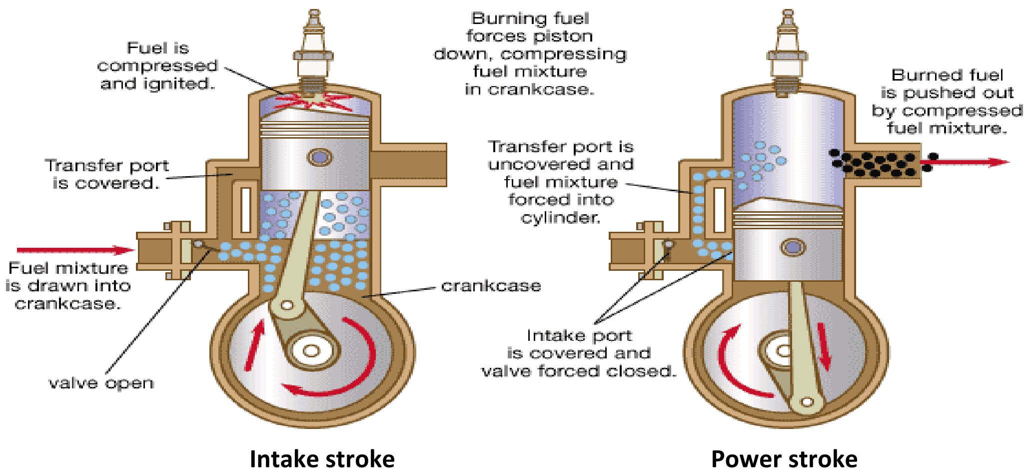

Figure 2.1: The two stroke cycle operation

Source: Heywood (1988)

The four strokes of a spark ignition (SI) engines operations was began with the piston sucks up an air-fuel mixture by going back and then compresses it by going fourth and fuel evaporates under the increase of temperature. When the piston comes close to top dead centre (TDC), an ignition plug ignites the mixture by means of spark which provokes sudden rise of temperature and pressure. The backward motion of the piston permits the combustion gases to expand and the usable work is produced at this moment. Finally, the forward movement of the piston expels the combustion gases. Therefore, the four strokes cycle operation are the intake, compression, power and exhaust as shown in Figure 2.2.

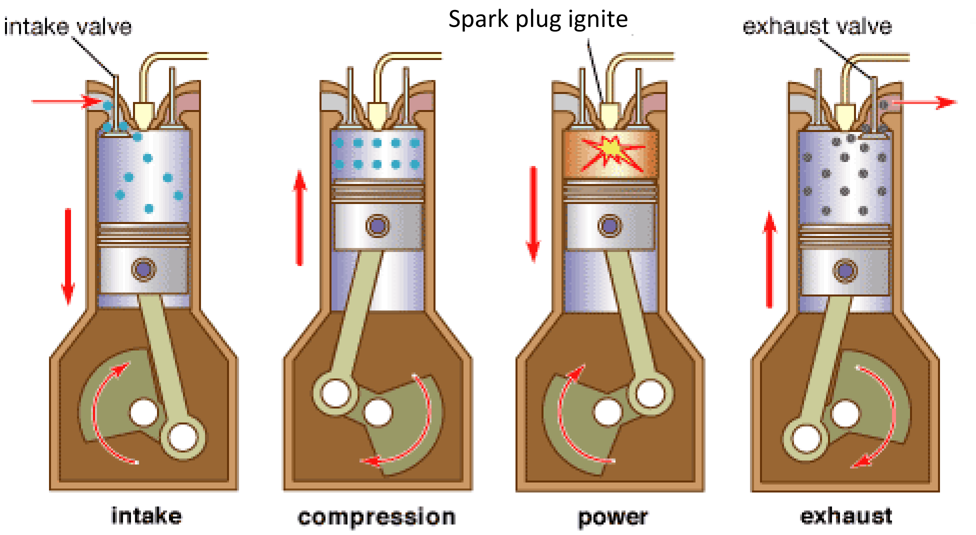

Figure 2.2: The four stroke cycle operation

Source: Heywood (1988)

The six stroke engine describes different approaches to the combustion engine, since the 1990's designed to improve their efficiency and reduce emissions. The engine catches the most heat from the four stroke cycle and converts it to power an additional power and exhaust stroke of the piston in the same cylinder. Design of such an engine which is suitable either steam or air as working medium for the additional power stroke. These six stroke engines have two power strokes, one because of the fuel and one by the vapour of the air. Figure 2.3 showed the operations in six stroke engine, the first four lines, intake, compression, ignition and exhaust strokes occur in the normal four-stroke engine. After the exhaust stroke, distilled water is injected into the combustion chamber. The water expands to 1600 times in its own band and learns superheated vapour. The sudden expansion of the volume generates a second power stroke, and this consists of the fifth stroke. In the sixth stroke, the steam used is emitted. As the heat from the cylinder is used, no additional cooling is required. The design also helps reduce fuel consumption by 40%. The latest invention of six stroke engine designs in this class are the Crower's six stroke engine, invented by Bruce Crower of the USA, the Bajulaz engine by the Bajulaz S A company of Switzerland, and the Velozeta six-stroke engine by the Colege of Engineering at Trivandrum in India (Paswan, 2008).

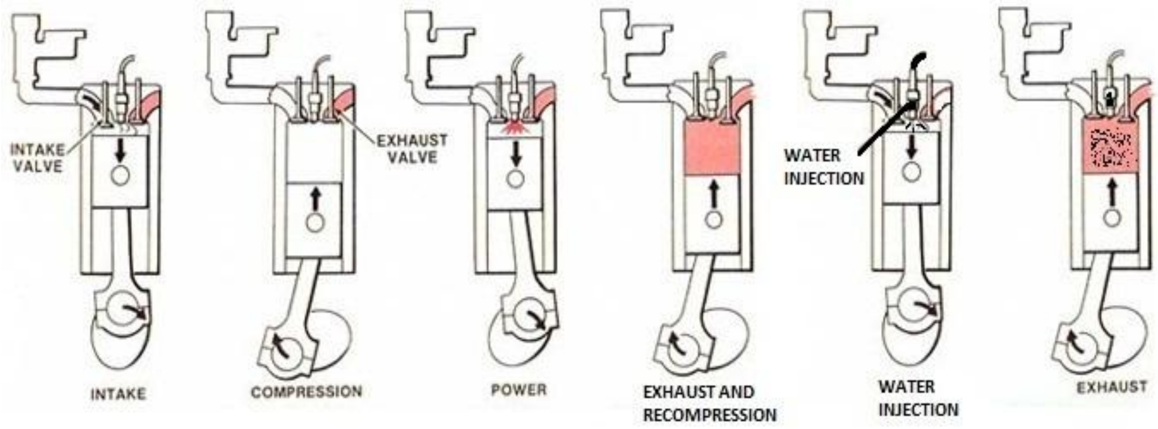

Figure 2.3: The operation of six stroke cycle

Source: Paswan (2009)

Improving the efficiency of internal combustion engines is an ongoing area of research where numerous design have been proposed based on traditional Otto or Diesel cycles and all of these include four sequential thermodynamic process or strokes of the piston. The performance of four stroke engine could be observed on Figure 2.4 that illustrates a schematic of the typical four-stroke sequence for an Otto cycle and Figure 2.5 illustrates the corresponding pressure-volume trace.

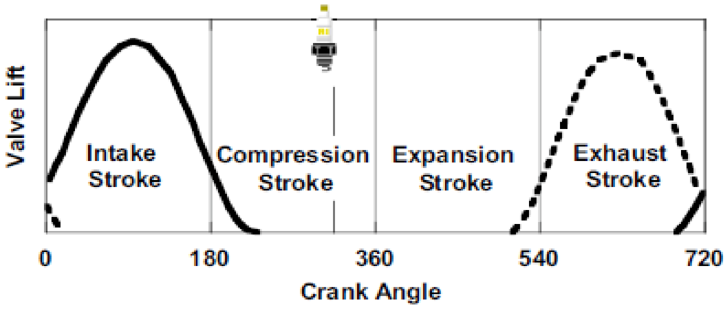

Figure 2.4: Schematic of typical intake and exhaust valve events for a petrol engine Otto cycle

Source: James C. Conklin (2010)

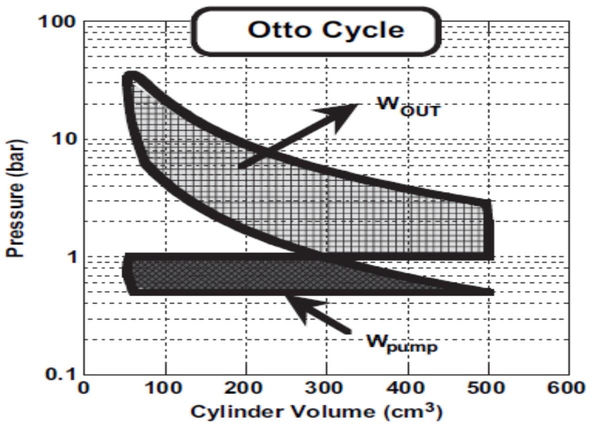

Figure 2.5: Schematic of pressure vs. volume for a typical petrol engine Otto cycle

Source: James C. Conklin (2010)

In six stroke engine, the cycle here proposed change additional two new strokes that increase the work extracted per unit of fuel energy input. These additional strokes include the capture and recompression of some of the exhaust stroke of the fourth, followed by a water injection and the resulting expansion of the vapour or exhaust mixture. The residual exhaust gas is trapped in the cylinder by closing the exhaust valve earlier than usual before top centre (TC). The energy of the exhaust gases trapped recompressed transferred to liquid water, causing it to evaporate and increase the pressure. The increased pressure causes more work than other expansion process. The mixture of steam exhaust gases are expelled atmospheric pressure near the point of maximum expansion. The modified sequence of six strokes is illustrated in Figure 2.6 and the corresponding pressure-volume trace is shown in Figure 2.7.

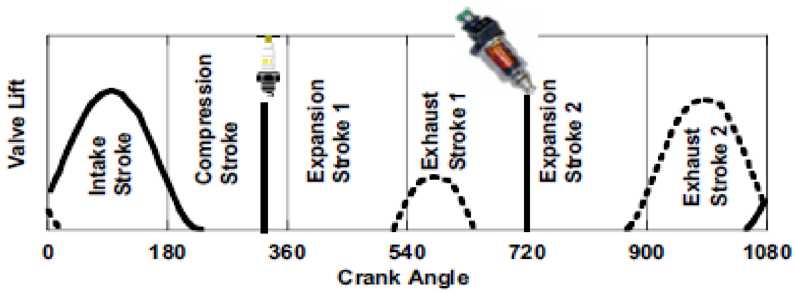

Figure 2.6: Schematic of typical intake and exhaust valve events for the six stroke engine cycle

Source: James C. Conklin (2010)

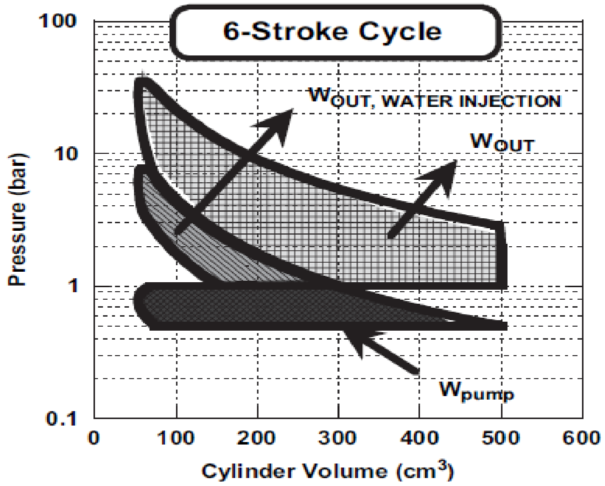

Figure 2.7: Schematic of pressure vs. volume for a six stroke engine cycle

Source: James C. Conklin (2010)

2.4 ENGINE EFFICIENCY

The engine efficiency of thermal engines is the relationship between the total energy contained in the fuel, and the amount of energy used to perform useful work. Improving internal combustion engine efficiency is a prime concern today. Engineers have devised many methods like turbo charging, cam-less engines, direct fuel injection, regenerative braking and recently about modified the stroke of cycles in the engine. That is the reasons there are exists the change in sequence the stroke of cycle from two stroke to four stroke, four stroke to five stroke and currently is six stroke cycle.

Based on four stroke engine, the average internal combustion engine (ICE) has efficiency between 20 to 30%, which is very low for both of petrol and diesel engine. Mohit Sanguri had stated that in heat balance sheet of the internal combustion engines for a spark ignition or petrol engine founded that the brake load efficiency is between 21 to 28%, whereas loss to cooling water is between 12 to 27%, loss to exhaust is between 30 to 55 %, and loss due to incomplete combustion is between 0 to 45%. Similarly with analyze the heat balance sheet of a compression ignition or diesel engine could be founded that it has a brake load efficiency between 29 to 42 % and loss to cooling water is between 15 to 35 %, losses to exhaust is between 25 to 45 %, and losses due to incomplete combustion is 0 to 5 % (Mohit Sanguri, 2010).

The principal presents in six stroke design is the engine ability to extract work from heat that otherwise lost through the cooling system. For exchanger powers and maximal pressures this absolutely admissible, the increase of efficiency is about 25 to 30% for spark ignition engine. The presence of low pressure discharge cylinder is beneficial to the efficiency since it ensures a total expansion ratio higher than total compression ratio. A second lower compression ratio from four strokes until six stroke phases and distribution of the expansion over a complete turn of the crankshaft reduces the unfavourable effect on internal conversion of a non-instantaneous combustion for high rotation speed (Schmitz, 1990).

The additional of water injection system also provide an advantage to the engine efficiency. The ranges of net mean effective pressure (MEP_{steam}) for one typical of steam combustion engine produce about 0.75 to 2.5 bar meanwhile the mean effective pressure of naturally petrol engines are up to 10 bar. Thus, this concept has the potential to show a very significant increase in engine efficiency and fuel economy (James C. Conklin, 2009).

2.5 WATER INJECTION SYSTEM

The main additional system that would be installed in six stroke of internal combustion engine is water injection system which is similar with fuel injection system. The types of fuel injection system that widely used are mechanical fuel injection, central port injection (CPI), continuous injection system (CIS), electronic fuel injection (EFI), multipoint fuel injection and direct fuel injection. The concept of water injection was based on direct fuel injection system in diesel engine and there are some modification on the components will be involved. Major components that will be modified are fuel pump, fuel injector, fuel tank and types of fuel piping connection. Figure 2.8 showed the illustration of water injection system design for six stroke engine.

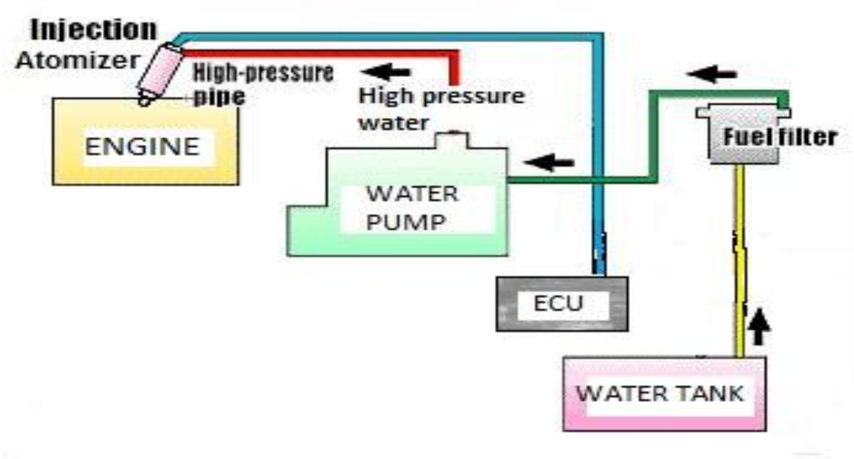

Figure 2.8: Water injection system

Source: Dempsey (2008)

The most important criteria in this system are the water injection timing and the duration of injection, the water distribution in the combustion chamber, the moment in time when combustion starts, the amount of particle of water metered to the engine per degree crankshaft and the total injected water quantity in accordance with engine loading during fifth stroke.

2.5.1 Water Tank

This is the obvious place to start in any full system explanation. The latest fuel tank model was different with the tanks on early carburettor equipped vehicles which it is a sealed unit that allows the natural gas of the fuel to delivery to the pump by slightly pressurizing the system as shown in Figure 2.9. Present fuel tanks for internal combustion engines are rigid containers made of metal or plastic. These fuel tanks are vented to atmosphere or in some cases are pressurized so that a vacuum is not built up in the tank as fuel is used by the engine (Chris Shou, 1969). The fuel tank can be replaced as water tank to keep the amount of water before it is delivered to the water pump.

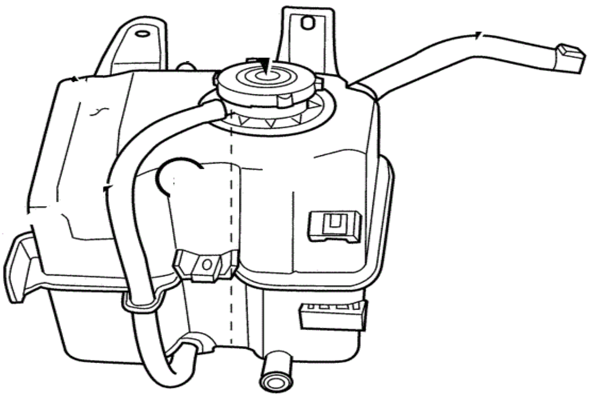

Figure 2.9: Example of water tank

Source: Chris Shou (1969)

2.5.2 Types of Injection Pump

The main component in fuel injection system recently is injection pump and its function as the device that delivery fuel from fuel tank into the cylinder of petrol engine or diesel engine. The history invented the injection pump by Robert Bosh in early 1927 that used in car diesel at that time. Generally, most of the injection pump in an engine only can deliver the fuel (petrol or diesel). However, there is the injection pump that available to deliver any liquid such as water that will be applied in six stroke engine.

Some of fuel pumps are suitable as well as to deliver the water around of injection system. Two types of fuel pumps are used in modern automobile are mechanical and electrical pumps. Mechanical fuel pumps are diaphragm pumps mounted on the engine and operated by an eccentric cam usually on the camshaft as shown in Figure 2.10. A rocker arm attached to the eccentric moves up and down flexing the diaphragm and pumping the fuel to the engine. Most of carburetted automobile engines used mechanical fuel pump to transfer fuel into fuel bowls of the carburettor. The mechanical pumps operate on pressures of 4-6 psi (pounds per square inch). Thus, this pump are not suitable to deliver the water because the low pressure. (Bordoff et al,. 1995)

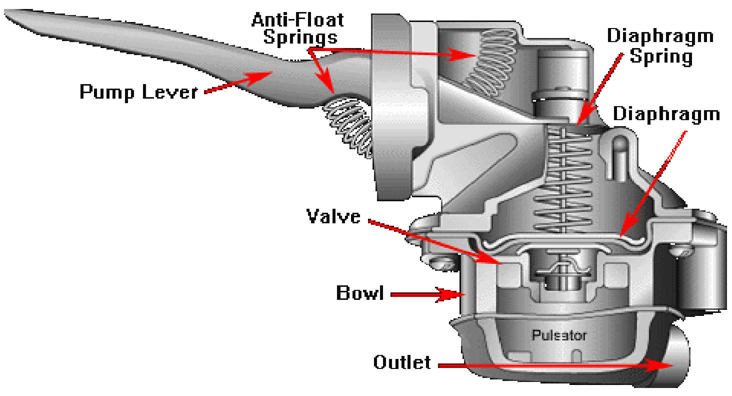

Figure 2.10: Configuration components in type of mechanical fuel pump

Source: Bordoff (1995)