IOP Conf. Series: Materials Science and Engineering **807** (2020) 012006 doi:10.1088/1757-899X/807/1/012006

Optimization of Fuel Savers Preheater Water System (PWS) for Diesel Fuel

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Abstract. The present work aims to design and investigate the performance of diesel fuel heating system called Preheater Water System (PWS). The PWS is made of stainless-steel container, copper spiral pipe and electric heater. The container has a diameter of 140 mm and height of 170 mm. The tube has a diameter of 8.5 mm. This system heats the diesel fuel before entering the fuel injector pump. The system utilizes heat from the heat from radiator cooling water and also uses additional electrical heating. The system is equipped with temperature sensor to measure the diesel fuel entering the fuel injector pump. The results show that at engine speed of 800 rpm (idle condition), temperature of the fuel increases 55°C, fuel consumption is 26% more efficient. At medium speed of 1200 rpm, the temperature increases up to 55°C and fuel consumption is 15% less. Meanwhile at the engine speed of 2200 rpm, the temperature rises to 60°C and fuel consumption increases up to 15%. In can be conclude that the PWS works well and the optimum temperature of the diesel fuel is 50˚C.

1. Introduction

1.1. Combustion Process and Effect of Fuel Temperature on Diesel Engines

Many previous ways have been done as an effort to improve diesel engine combustion, such as fuel heating method, booster methods, magnetic and current power method. The advantages of those methods are engine performance increases, fuel consumption and damage risk reduce. This method able to prevent the engine overheating, over vibration, over noise and the most severe result in the engine breaking [1-3]. Another alternative that can be applied to all vehicles is by increasing the temperature of the fuel before be sprayed into the combustion chamber. From the working process of the engine, 30% of the heat produced by combustion is absorbed by the engine cooling system and wasted to the atmospheric air [4]. In the water-cooling system, it is known that the cooling water temperature is maintained between 83-93°C. While the temperature of diesel fuel accommodated in the tank is close to the temperature of the outside air which is around 20°C. Thus, the heat of engine cooling water can be used to raise the temperature of the fuel. This technology is useful for increasing the temperature of the fuel before being injected into the combustion chamber. Increasing the heat on the fuel is expected to facilitate the fuel evaporation process so that it makes the fuel easier to reach the flash point, in turns the combustion process getting better. The better the combustion process, the higher the energy produced and the less fuel is consumed [5, 6].

Figure 1 shows the combustion process in a diesel engine and the effect of temperature on spontaneous combustion. The combustion process of the diesel engine itself is divided into four periods which is delayed burning (AB), flame propagation (BC), direct combustion (CD), and continued combustion (DE). From gas equation of state, it is known that the higher the pressure, the higher the temperature produced. The diesel engine combustion occurs better at higher pressure and temperature.

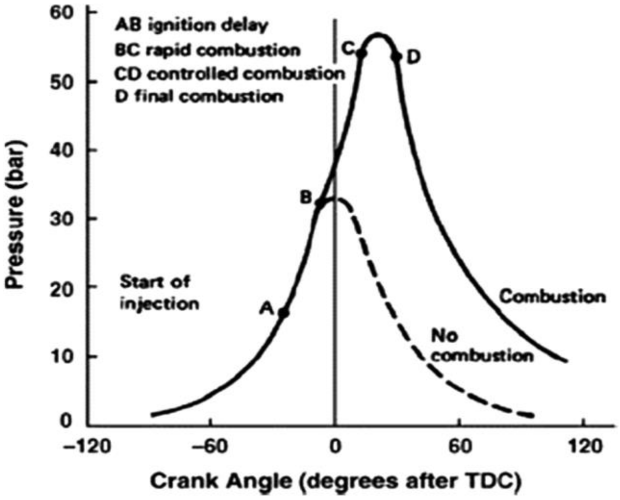

Figure 1. Diesel Burning Diagram [7]

Figure 2 indicates an effect of temperature on the power output of the diesel engine. Several problems often encountered in diesel engines are improper the amount of fuel in the combustion chamber with the load, poor injection process, and poor mixing between the fuel and air which causes the incomplete combustion process. To overcome these problems, the size of fuel spray into the combustion chamber have to be very tiny in order to obtain a more homogeneous mixture [8, 9].

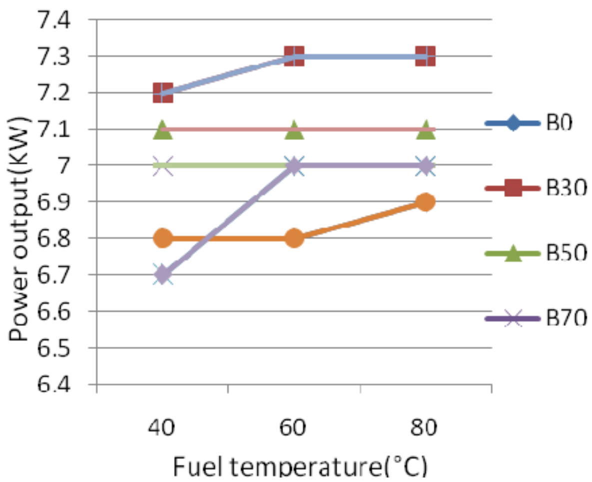

Figure 2. Effect of Temperature on Power Output [10]

1.2. Fuel and Diesel Heating Systems

Figure 3 shows the flow of in-line diesel fuel system. The systems consist of fuel tank, feed pump, filter, injection pump, high pressure line and nozzle where the tank is used as a reservoir or fuel provider to meet fuel needs while the engine is working, the feed pump, functioned to suck fuel from the tank then pump it into the filter to filter fuel from impurities contained in the fuel so as to prevent the occurrence of blockages in the fuel system channel, while injection pump, used for creating high-pressure fuel which is flowed towards the nozzle through the high pressure line to be sprayed into the combustion chamber by converting the pressurized fuel from the injection pump into fuel mist using nozzle.

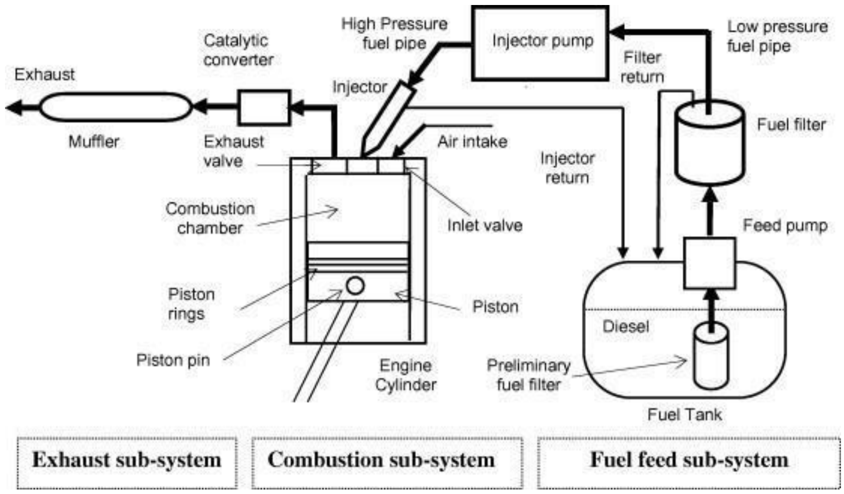

Figure 3. Fuel System of Diesel Engine [11]

Stages of combustion of diesel engines can be divide into 3 stages, namely heating, evaporation, and burning. The temperature of the fuel temperature affects the diameter of the spray. The smallest the diameter has the fastest ignition delay times. The ignition delay time are influenced by the size of the fuel spray size and by the fuel jet velocity and specific gravity of the fuel. Meanwhile, spontaneous combustion in diesel engines is influenced by fuel temperature and pressure in the cylinder. This is in line with that spontaneous combustion is influenced by cetane numbers, effective pressure, also influenced by fuel traction.

Previous work which comparing the effect of solar and biodiesel temperature on the performance of a constant-speed direct injection diesel engines concluded that the increase in temperature of biodiesel and diesel fuel resulted in 8% fuel consumption, 4% engine power, and diesel engine thermal efficiency of 23.7% [12]. Meanwhile other work on the performance of diesel motors with the addition of solar heaters shows that the changes in fuel diesel temperature injected in the combustion chamber affected the torque and power by 4.1%, fuel consumption by 7%, thermal efficiency by 23.4% [13, 14]. However, those two works still have the problem which the solar heaters produced are still less effective to produce the temperature needed in each condition, because it is very dependent on the heat of the radiator to the heater. To overcome the lack of the systems, an effective and efficient diesel fuel heating system has to be designed.

1.3. Heat transfer
Heat is transferred from high temperatures to lower temperatures. The heat transfer rate will depend on the mode of transfer (conduction, convection, radiation) and the heat transfer medium.

a. Conduction heat transfer [15]

$$q = kA\frac{\Delta T}{L} \quad (1)$$

Where:
q = Conduction heat transfer rate (W)
k = thermal conductivity (W /mK)
A = cross-sectional area (m^2)
ΔT = Temperature difference (^{o}K)
L = Distance between hot and cold temperature (m)

b. Convective heat transfer [15].

$$q_c = hA\Delta T \tag{2}$$

Where:
q_c = Convective heat transfer rate (W)
h = Convection coefficient (W / $m^{2o}K$)
A = Heat transfer contact area (m^2)
ΔT = Temperature difference (^oK)

Fuel viscosity decreases as fuel temperature increases which causes the fuel flash point is also getting lower. So that it can make the fuel volatile and flammable. Diesel fuel that has been heated is sprayed into the pressurized and high temperature combustion chamber, result in better and faster combustion. Better combustion leads to increase the engine's efficiency.

1.4. Novelty and Purpose

The present work aims to design an effective and a low-cost Diesel Fuel Preheating System using the heat from radiator's heat via cooling water of the radiator. The system is called Preheating Water System (PWS). No works on utilization of heat of radiator for heating the diesel fuel have been reported so far.

2. Material and Method

Figure 4 displays the flow diagram of the present work.

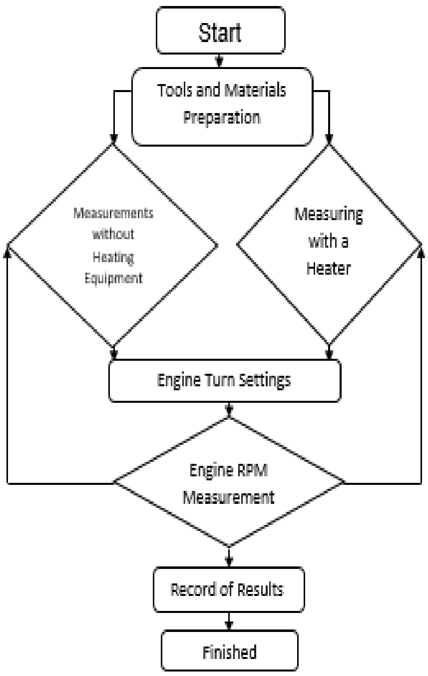

Figure 4. Flow diagram of the present work.

Meanwhile, Figure 5 shows the schematic diagram of the experimental setup of the preheater water system (PWS). The nozzle on the diesel fuel system will work if there is a pressure from the fuel injection pump both in-line models and distributors. Fine grains and whether or not spraying (injecting) the nozzle into the combustion chamber is influenced by the quality of the fuel.

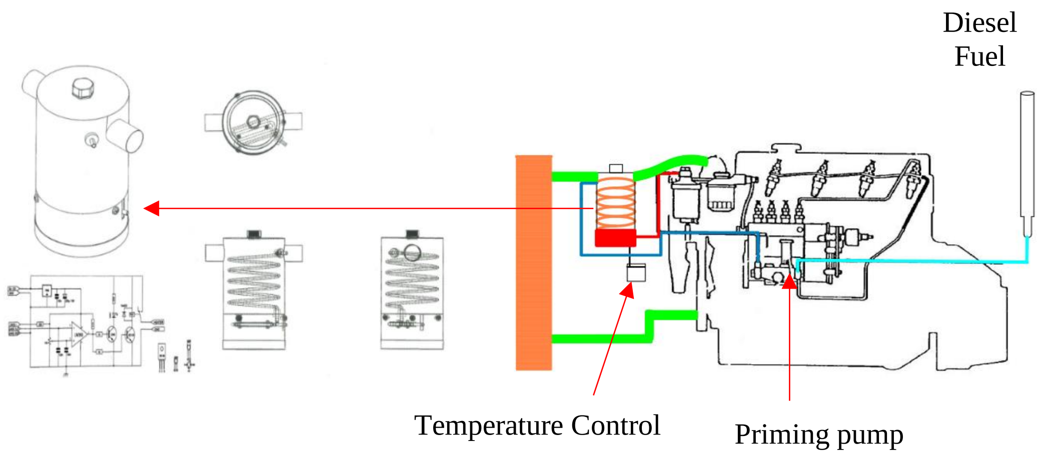

Figure 5. Installation and design of PWS tools.

The PWS is installed before the injection pump. Fuel is transfer to the injection pump via copper tube through the cooling water Stainless Steel container. Heat from radiator is transfer to the fuel via radiator cooling water. As a result the fuel that enters the injection pump will become hot, so that the viscosity will decrease as a result of the fuel spray size through the nozzle decreases and homogeneous.

Figure 6 shows the design and a photograph of the PWS. Heating container is made of stainless steel. The reason for using stainless steel is due to its corrosive resistant and has high heat conductivity which allows to maintain at high temperatures. Stainless steel used is 0.5 mm thick.

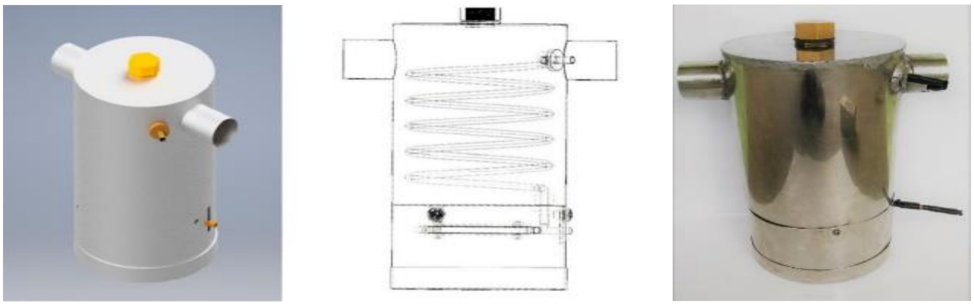

Figure 6. Heating Container

Whereas, the spiral copper tube is shown in Figure 7. Copper is selected due to its high heat conductivity, Heat transfer rate between the hot water to the fuel is high. This heat is used to heat diesel fuel that will be used for combustion. The spiral copper tube has a diameter of 6.5 mm and a length of 750 mm.

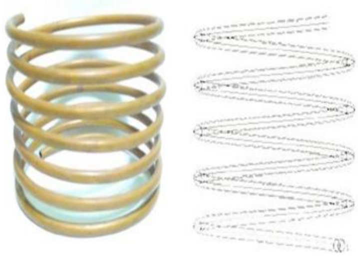

Figure 7. Spiral Copper Tube

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Electric heater tube is also made of Stainless Steel. The use of the electric heater aims to prevent the heat sensor readings from disturbance of air temperatures outside the specified system. The dimensions of this electric heater tube are 50 mm in height and 140 mm in diameter. This dimension is accordance to the size of the PTC heater which is used as an electric heater when the system temperature condition has not yet worked.

Figure 8. Electric Heaters and Trolleys

3. Result and Discussion

Figure 9 to Figure 11 presents the results of the present work. The graph show that a very significant difference between diesel engines without and using a fuel heater (PWS) is observed.

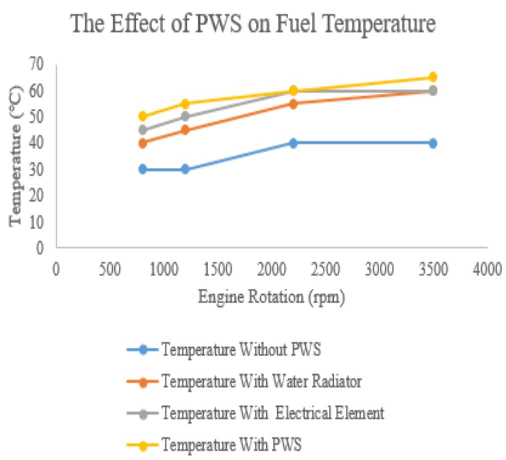

Figure 9. The structure with bolted joints.

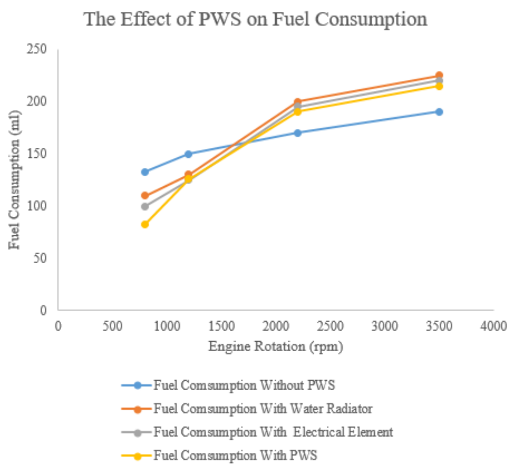

Figure 10. Cross-section of the bolted joints.

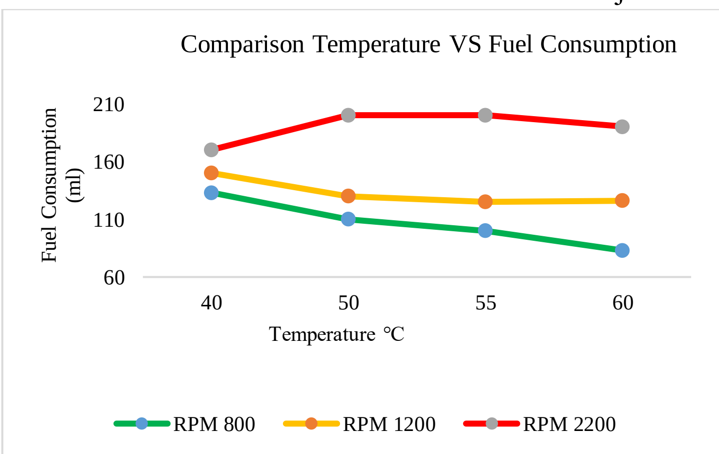

Figure 11. The Effect of Temperature of Diesel Fuel on Fuel Consumption

This fuel heater is a device to increase the temperature of diesel fuel. With higher diesel fuel temperatures, better combustion occurs. This can minimize fuel consumption, because with less diesel fuel and in one attempt to get the same amount of energy. From the results of the experimental data, it can be seen that the PWS able to save the fuel consumption. This can be known by the following calculation [15];

$$E = \frac{C_{start} - C_{finish}}{C_{start}} x100 \quad (3)$$

Where: E = Efficiency (%)
C = Fuel consumption

The data shows that there is a relation between fuel temperature and viscosity and also fuel flash points. If the fuel temperature increases, the viscosity of the fuel will decrease where the fuel flash point is reached. For high fuel viscosity, the combustion process will be more difficult. Hence, by increasing the temperature of the fuel, the fuel viscosity decreases that make the fuel combustible [16-17]. As a result of the heated fuel has been sprayed into a pressurized and high temperature combustion chamber, it will produce better and faster combustion.

Increasing the amount of fuel efficiency in each engine RPM condition is influenced by the movement of the piston, where the greater the RPM, the higher the fuel injection [18]. With faster flow, fuel circulation is also faster, this affects the difference in fuel temperature, so the fuel increases at higher temperature. The system proven to produce higher power and less fuel consumption. The system able to safe a fuel 9-16%.

4. Conclusion

The design of the Preheating Water System in this study can be made easily and work well. The system has two chambers, namely heaters with water radiators and controlled electric heating elements. In can be concluded that the PWS works well and the optimum temperature of the diesel fuel is 50°C. At engine speed of 800 rpm (idle condition), temperature of the fuel increases 55°C, fuel consumption is 26% more efficient. At medium speed of 1200 rpm, the temperature increases up to 55°C and fuel consumption is 15% less. Meanwhile at the engine speed of 2200 rpm, the temperature rises to 60°C and fuel consumption increases up to 15%.

Acknowledgements

The authors would like to thank profusely to Institut Sains & Teknologi AKPRIND that has given funding of the conference activities, and to all member of Mechanical Engineering Department for all of their support during the project.

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