The Effect of Fuel Temperature on Characteristics, Combustion Process, Emissions and Performance of Diesel Engine: A Review

Barokah[1], Semin[2], Beny Cahyono[2], Bambang Sampurno[1], Parabelem Tinno Dolf Rompas[3]
[1]*Department of Mechanical Engineering,Institut Sepuluh November, Surabaya, Indonesia*
[2]*Department of Marine Tecnology,Institut Sepuluh November, Surabaya, Indonesia*
[3]*Department of Informatic Engineering, Universitas Negeri Manado, Manado, Indonesia*

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Abstract: The enormous influence of diesel engines on both the industrial and transport world encourages to continue to be developed. Renewable technologies have been widely created to achieve optimum combustion efficiency, as well as diesel fuel that is dominant in exhaust emissions. Not all fuels with certain characteristics can burn perfectly. It is necessary to influence the temperature to achieve combustion as well as to produce optimal performance. This study discusses the effect of fuel temperature on both characteristics, combustion, performance and emissions in diesel engines. Some noticeable impacts of change such as kinematic viscosity, density, surface tension are able to make the combustion process such as spray shape, atomization form, and evaporation shape change. It was concluded that the fuel temperature affected the combustion, performance and exhaust emissions.

1 INTRODUCTION

The invention of diesel engines has a great influence on the civilization of industrial sectors worldwide. In operational terms, diesel engines are knowns for their tough engines and longer durations than other engines (Semin *et al.*, 2009a; Semin *et al.*, 2009b; Akasyah *et al.*, 2015). In terms of performance, this machine uses compression to produce combustion. As the compression required is very high, it creates significant differences as well as materials and fuel characteristics (Bakar *et al.*, 2015; Semin, 2008). The application of these machines is not only for the industrial sector and large-scale transportation but also up to household scale (Semin *et al.*, 2009a).

In its development, diesel engines have undergone significant changes in terms of shape to the technical or operational aspects. It aims to create the highest efficiency value in terms of its operations. In addition, exhaust gases from diesel engines have high emission values such as NOx, CO, unburn hydrocarbon (HC), and soot and nano particles (Semin *et al.*, 2009b; Gusti and Semin, 2018; Safarov *et al.*, 2018; Lindl, 2003). There have been many regulations regarding the threshold of exhaust both from standard of engine maker and state regulations. Numbers of effort have been made, such as some kind of changes in fuel system, air intake system, combustions system, drive system components (transmission) and many more.

However, from some of the advantages of diesel engines, there are some obstacles that are still in processed to be reduced until now, which the constraints are the fuel. The fuel characteristics of this machine differ from Otto machines, which have lower quality of the content (near the kerosene stage) (Sandu, 2016). To see the quality of fuel, it can be seen from the value of Cetane, where the value is defined as how much fuel would burn quickly. If the value of citation is high, then it can be concluded that the fuel is not flammable (Wei and Geng, 2016) Fuel used in diesel engines has different qualities and has provisions in accordance with the standards recommended by both fuel producers and engine makers (Andsaler *et al.*, 2016). Fuel levels are classified by their viscosity and energy content values. In fuels that have high viscosity, it is very important to do preheating.

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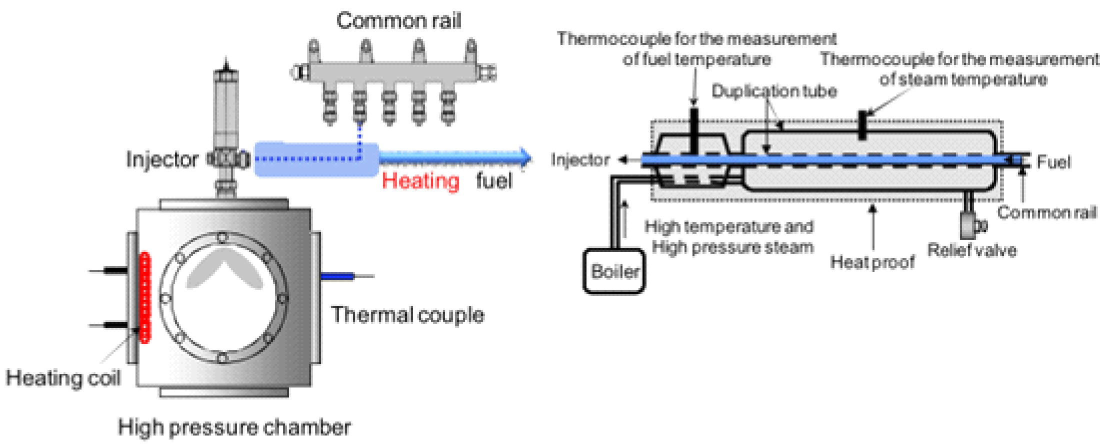

Figure 1: Fuel Heating system and high pressure chamber.

Figure 1 shows one form of preheating. In this preheated form uses the insulation method, in which the fuel is heated through the steam fluid. The preheated is located between common rails with injector (Park *et al.*, 2009) This is because the fuel in the engine in accordance with the reference that has been given and does not inhibit the combustion process that it can produce optimal performance (Lindl, 2003; Espinosa-Martinez *et al.*, 2016).

2 LITERATURE STUDY

2.1 Combustion Diesel Engine

The diesel engine invented by Rudolf Diesel 1892 which is a compression ignition engine which has been widely used today (Heywood, 1988). While the patent was obtained on February 23, 1893 related to Design Methods for Combustion Engines.

Diesel engines are, in principle, energy converters that convert chemically bound fuel energy into mechanical energy (effective work) by supplying the heat released by combustion in an engine to a thermodynamic cycle (Mollenhauer and Tschoeke, 2010).

2.2 Engine Performance

The performance levels of diesel engines are influenced by a changing fuel inlet temperature (Foster and Jung, 2002). With high fuel temperatures it causes high injection pressure resulting in shorter ignition delays which ultimately affect engine performance (Rahim *et al.*, 2012).

At present, diesel engines are getting attention because in addition to fuel efficiency also due to the high torque characteristics (Henein *et al.*, 1992; Han *et al.*, 2001)

2.3 Engine Exhaust Emissions

Exhaust gas emissions from diesel engines are a fatal problem in the use of diesel engines. With the development of modern society, environmental pollution has become one of the major problems for humans (Smith, 1993). Current industrial carbon emissions due to the burning of fossil fuels and the manufacture of cement numbering around 1,200 million tons of carbon (Mt.C) (Grubler, 1993).

Emissions from ships need to be controlled because they are ozone depleting substances. Among them are Nitrogen oxides (NOx), Sulfur oxide (SOx), volatile organic compounds (VOC) (Marpol, 2006)

3 METHODS

The method used is by reviewing several journals related to the effect of heating the fuel on the performance and exhaust emissions of diesel engines. The activity begins with formulating the problem, namely the problem of the need for heating the fuel. The next is collecting journals from several accredited publishers and indexed by Scopus.

From the journal discussed both the problem and the results then identified. The results of the review are concluded and will be followed up on the development of subsequent research (Figure 2).

4 RESULTS AND DISCUSSION

4.1 Influences on Fuel Characteristics

Conventional diesel fuel sources are classified as non-renewable energy. This has received special attention for oil and gas producers due to the depletion of source reserves. Several efforts have been developed, such as the application of fuels derived from vegetable oils, natural gas, and many more (note: normally we use “etc” rather than “many more”). From various sources of fuel, of course, have different characteristics, especially fuel made from vegetable oil. Fuel derived from these sources has higher viscosity value than conventional fuels due to the bonding of chemical chains, especially high fatty acids. In contrast, natural gas fuel is lighter and has smaller viscosity but has a very high calorific value compared to other fuels (Foster and Jung, 2002).

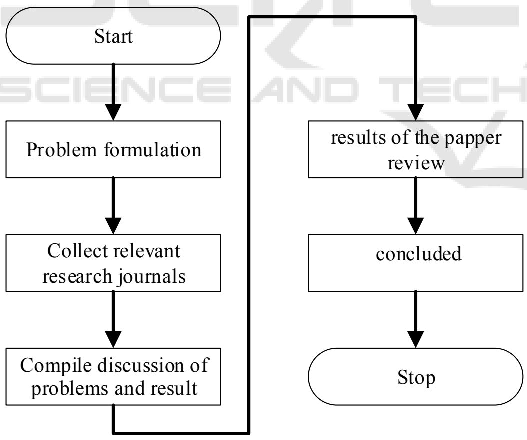

Figure 2: Flowchart of study.

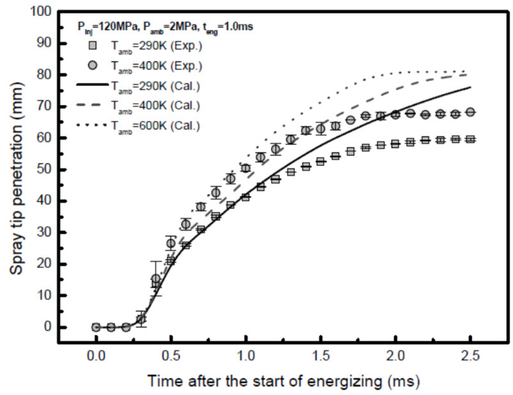

Figure 3: Effect of time after the start of energizing on spray tip penetration.

In diesel engines operation, the engine maker has determined the amount of viscosity of fuel (CSt) that must be obeyed. Specifically when the operational use blend fuel, the need for the treatment of viscosity and mixture is maintained (not separated or not settled). As has been done by (Park *et al.*, 2010) in which to keep the viscosity value fixed at optimum condition, the treatment is preheating. Figure 3 shows that the addition of some temperature variables ranging from 290K, 330K, 360K, 430K, to 500K. The effects on the direct characteristics are density, kinematic viscosity and surface tension. The result proves that the most optimal fuel in terms of spray penetration and spray angle cone is at a temperature of 290K and 360K. This is because the heat of the fuel generates the angular momentum during a small injection so that the energy to ignition is also getting smaller.

Figure 4 shows that changes in fuel temperature have shown a change in characteristics not only in the form of viscosity, density, fuel tension, but also the water content in the fuel is reduced (Akasyah *et al.*, 2015; Park *et al.*, 2010). This results in more optimal combustion in the combustion chamber. The effect temperature, density and water content can be seen in the graph below.

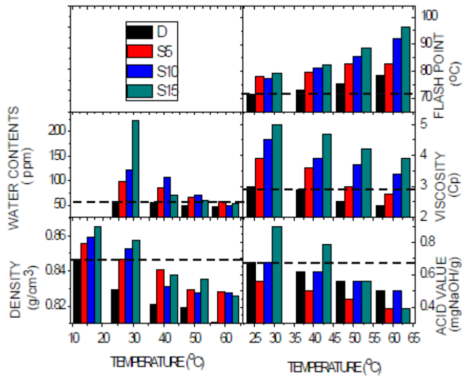

Figure 4: Effect of Temperature on density, acid value, viscosity, and flash point.

4.2 Effect on Combustion Process

Fuel having different characteristics will also impact on different combustion. This is because the components that become the basic principles of the formation of sparks such as the value of cetane number, flash point, viscosity, density, calor heat vaporization and etc. An uneven difference (e.g. blending) will result in less than perfect combustion when the mixture is not homogeneous (Prabu *et al.*, 2018).

Research conducted by (Park *et al.*, 2015), where one of the variables performed is a change in fuel temperature to see the effect on combustion, spray shape and characteristics that occur. Data of temperature variations are taken from 240K to 310K using diesel fuel (Figure 5). The result obtained showed that the temperature of fuel injected is increased and then the density, kinematic viscosity decreased. The quantity of injection per round also shows that the graph increases with increasing fuel temperature. The increase of some parameters above results in injection rate, start of injection also increases; this is due to decreased viscosity. In addition, other advantages obtained are the penetration of the delay spray resulting in perfect evaporation and optimal air-fuel ratio composition. Furthermore, a change in fuel temperature also affects in-cylinder pressure, maximum (peak) pressure, ignition delay and heat release rate (Nanthagopal *et al.*, 2017; Hafiz *et al.*, 2016). This occurs because in addition to the presence of viscosity and density, there is also a change of cetane values and lighter movement when injection occurs.

The same impact resulted from research conducted by (Park *et al.*, 2010) who conducting research to determine the effect of temperature changes on the characteristics of spray injection.

The parameters analyzed include spray penetration, atomization performance and evaporation characteristic. In addition, it also sees the phenomenon that occurs in SMD with a change in fuel temperature.

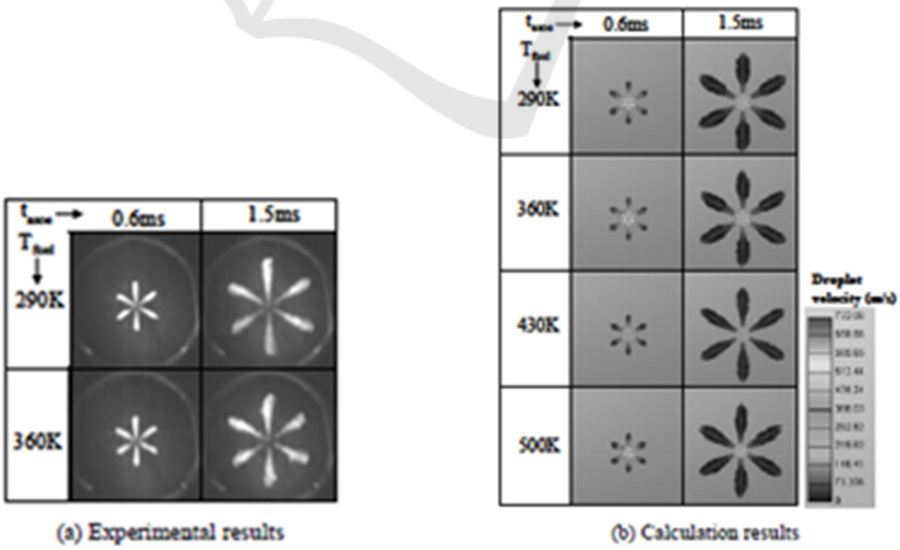

Figure 5: Comparison between the experimental and calculation results according to the variation of the diesel fuel temperature.

The results obtained from this research include changes in fuel temperature which decreases density, also decreases kinematic viscosity and surface tension (Figure 6). Then in terms of spray shape and develvzopment patterns of all temperatures are almost the same. Increasing fuel temperatures will make the spray tip penetration value smaller because density, viscosity, surface tension are smaller so that the value of injection momentum is small. In addition, those are also affected by injection pressure and ambient gas condition. Temperature also affects the spray cone angle, where the greater the temperature of the fuel produces the greater the degree (Li *et al.*, 2016). This is because the density is directly proportional to the cone angle. In addition, the change in fuel temperature also affects the spray momentum and SMD, which is the instantaneous decrease after fuel is injected due to the speed of injection. In general it shows that the temperature increases will decrease the SMD, this is due to the effect on the viscosity and the shape of the fuel during break up.

From some researches above, it can be concluded that the fuel temperature affects the combustion process in diesel engine. This is because with a change in temperature, it will change the characteristics of the fuel. In addition, the influence on the characteristics and the combustion process also affect the performance which will be discussed in the next paragraph.

4.3 Influences on Performance

The treated fuel that is heated before entering into the combustion chamber will affect the performance of the machine. As the research conducted by (Rahim *et al.*, 2012), which is about the influence of fuel temperature of biodiesel blends on performance. Parameters in the form of temperature variables used ranges from 300K to 500K using a machine with a turn reaching 4000 rpm. From these studies it is stated that high temperatures affect the amount of injection pressure into the combustion chamber. The greater the pressure given the greater the power generated by the machine. This is because the quantity of a large injection resulted in an injection period (ignition delay) faster. In addition, the higher the temperature will also affect the combustion energy such as thermal efficiency, torque, break mean effective pressure and fuel consumption (BSFC). This is certainly due to changes in characteristics such as viscosity, density, and heat energy.

Subsequent studies of the effect of fuel temperature on performance have also been performed by (Agarwal and Agarwal, 2007), as shown in Figure 6 where temperature variation coincides with the magnitude of injection pressure to see its effect.

The fuel used is jatropa oil and then compared to diesel fuel. With preheater treatment where it is heated to a temperature of 100 ° C, jatropa oil fuel has a smaller viscosity and greater power with less fuel consumption compared to jatropa oil without preheated treatment. Similar results were performed by several researchers including (Foster and Jung, 2002; Khalid *et al.*, 2003), by heating the fuel from 25 ° C, 35 ° C, 55 ° C, 65 ° C, 75 ° C to 80 ° C. The optimal temperature with proof of power and the energy generated increased by 5%. However, fuel heating above 55 ° C indicates a power down to 7.5% even though the fuel consumption used is constant. It can be concluded that the effect of changes in fuel temperature has an effect on the performance of diesel engines. The changes occur in power, torque, fuel consumption (BSFC), thermal efficiency, and break mean effective pressure (BMEP) (Yilmaz, 2012; Feroskhan *et al.*, 2018; Tajuddin *et al.*, 2016)]. This is due to changes in fuel characteristics that result in performance is also changed.

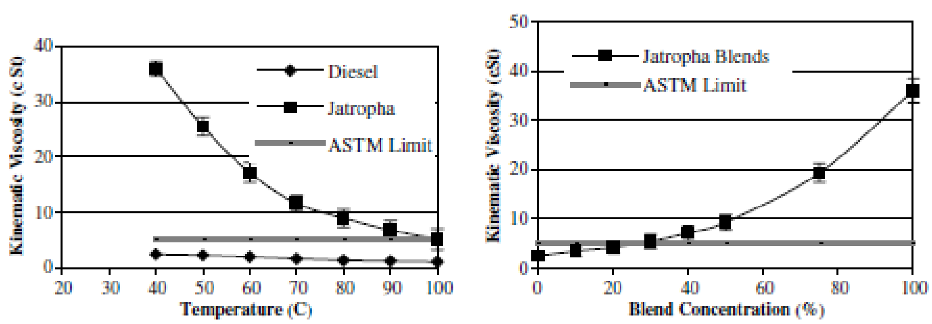

Figure 6: Effect of temperature and with mineral diesel on viscosity of Jatropha oil.

4.4 Effect on Exhaust Emissions

The final stage of the effect of changes in fuel temperature is on the flue gas. In some studies, it has been stated that preheat of fuel also has an effect especially on emission gases which have potential emission such as NOx, CO, hydrocarbon, particulate and others. Emission of preheated as shown in Figure 7 where preheated biodiesel fuel i.e. CPO, jatropa, and WCO. The results obtained from these studies include the changes in NOx, CO, CO2 and HC. The preheated fuel that reached is able to change the composition of NOx and CO becomes smaller when mixing occurs around 5%. Then the CO2 composition is getting bigger along with the preheated. But with the increase in the mixing ratio between vegetable oil fuel and diesel fuel will result in greater emissions.

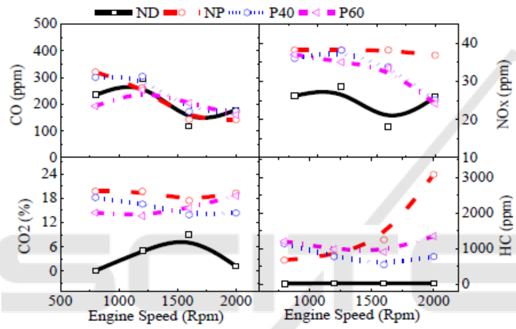

Figure 7: Emission of preheated WCO 5 at 50% load conditions.

5 CONCLUSIONS

The temperature change (after preheat) can give significant changes such as characteristic shape, combustion process, performance result and exhaust emission generated. The results of these studies are expected to be developed more specifically in order to achieve optimal operational results.

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Research with preheated treatment of fuel using magnetic fuels has resulted in changes in exhaust emission levels (Salih and Al-rawaf, 2015). From comparison between preheated treated and untreated fuels showed lower CO, HC and CO2 levels. Similar results are shown by research from (Agarwal and Agarwal, 2007) where jatropa oil fuels treated in preheater produce lower emission levels than jatropa oil fuels that are not given the preheater treatment. The results are CO2, Smoke Opacity, CO, and HC. From the review of several research above, it can be concluded that temperature change (after preheat) can give significant change such as characteristic shape, combustion process, performance result and exhaust emission generated. With the results of these studies are expected to be developed more specifically in order to achieve optimal operational results.

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