Application of jacket cooling water system recovery for fuel heating on diesel engine to reduce emissions

Barokah¹, Semin¹*, B Cahyono¹, Bambang Sampurno¹, M Tappy², J Huwae², J Ratela², and Y Wibisono³

¹Department of Marine Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
²Department of Marine Engineering, Politeknik Kelautan dan Perikanan Bitung, Bitung, Indonesia
³Engine Department, Politeknik Pelayaran Surabaya, Surabaya, Indonesia

E-mail: semin@its.ac.id

Abstract. The existence of a diesel engine is very necessary for life today. In development, the diesel engine is experienced many developments in all systems. In line with the development of the diesel engine can’t be separated from the impact of fuel use. This research was carried out to make a fuel heating system by utilizing jacket cooling water system recovery as a fuel heater and the method used in this research is an experimental method including making installation of a fuel heating system, testing on the diesel engine generator with specifications 4 strokes, 4 cylinders, 1500 rpm, 18 kVA using biodiesel (B20) fuel. The data were collected using a smoke opacity meter. The experiment was carried out by heating treatment of fuel starting from 30°C - 50°C at the interval of 5°C. Data analysis by describing experimental data. The result is showed that heating fuel can reduce the emission of the diesel engine.

1. Introduction
The diesel engine is an internal combustion engine which is a machine whose work process is through a compression process [1]. In the process of working, the internal combustion engine converts the chemical energy of the fuel into mechanical energy. The chemical energy of the fuel is converted into heat energy through combustion [2]. Diesel engines are machines that are widely used in the industrial and transportation world today. The problems with the use of diesel engines to date include the problem of exhaust gas emissions.

Exhaust gas emissions are the residual results of the combustion of fuel in the internal combustion engine that is removed through the engine exhaust system. The prevention of exhaust emissions from ships is an indispensable requirement to reduce the level of environmental pollution in air pollution. Related to this problem, air pollution prevention measures must be taken to minimize the
dangers due to air pollution or pollution. At this time, many researchers in all corners of the world are intensifying research related to air pollution issues originating from engine exhaust gases operating both on land and on ships.

IMO regulations on reducing hazardous emissions and ship waste are contained in (Marine Pollution) MARPOL Annex VI, which consists of regulations to reduce ship exhaust emissions, first adopted in 1997, entered into force on 19th May 2005 and revised in October 2008. The main focus is on SOx and NOx emission but also concern ozone-depleting substance, volatile organic compound, ship incineration, and others [3]. The main objective is to reduce the sulfur content of ship fuels from 4.5% to 0.5% by 2020 globally and from 1.5% to 0.1% in 2015 for Sulfur Emission Control Areas (SECAs) [4].

Based on research throughout 2014 in the Ningbo-Zhousan Port area of China, air pollution from ship exhaust emission reached 80%[5], besides that pollution is related to ship is a significant problem worldwide. So efforts to reduce emission and develop innovative solutions are very important [4]. The phenomenon of environmental pollution, especially air pollution, is getting higher and higher. Proactive steps to reduce air pollution researchers carry out various studies related to strategies, methods, techniques for preventing or reducing air pollution originating from ships. In his research related to the measurement of exhaust gas emission [6], he formulated a method of measuring exhaust gas emission from a diesel engine using the Tunable Diode Laser Absorption Spectroscopy (TDLAS) technique. This technique is quite simple, with a high level of precision and high time resolution. Exhaust gas emission can be reduced by increasing the exhaust gas after-treatment inlet flow temperature above 250°C by adjusting the initial and final closing of the intake valve after the treatment temperature of the exhaust gas from the engine[7].

Besides, NOx emissions are also limited based on engine speed on board [4]. NOx limitation can also be done using the Transient Torque Control method [8]. And now the Hydrogen Energy Share (HES) method by dual fuel are hydrogen and diesel has been found which is useful in reducing harmful emission at low and medium load [9]. Currently, marine diesel engine operations use a lot of fuel oil as fuel which is a source of exhaust gas emission. These exhaust emissions must comply with the provisions of the International Maritime Organization (IMO) and the World Bank. IMO set the limit for nitrogen oxide emission (NOx) = 45.n-2 in g / kWh where n is the engine speed in rpm. Meanwhile, the emission limit for NOx gas emission is following the provision of the World Bank NOx = 940 ppm. With 15% oxygen in the exhaust gas. And the particulate PM emission limit = 50 mg / m³ [10].

Greenhouse gas emission from the transportation sector and how to reduce them are a major challenge for policymakers [11]. When the ship maneuver in the port area, that is when there is an increase in the concentration of NOx and SOx emission [12]. CO2 emission from maritime transport represents approximately 3% of total annual anthropogenic greenhouse gas (GHG) emission. These emissions are assumed to increase by 150-250% in 2050. GHG emissions contribute to international ambitions to limit the effects of climate change [13]. That the shipping sector can always contribute to efficient global emission reduction and thus can always achieve global cost-saving, but also that the size of the contribution and the measure of cost savings are highly dependent on the assumed MACC case [14].

The International Maritime Organization (IMO) has recently proposed several operational and technical measures to increase shipping efficiency and reduce of Green House Gas (GHG) emission. The reduction potential estimated for these measures has been further used by many organizations to project future GHG emission reduction and plot for Marginal Abatement Cost Curves (MACC) [15]. Motor vehicle pollution and environmental degradation are on the rise with the increase of vehicles and to stop these strict regulations have imposed motor vehicle emission. Also, it is getting thinner [9]. The remainder of the combustion product from a diesel engine is in the form of several substances which are known, among others, CO is also called poisonous carbon monoxide, CO2 is also called carbon dioxide which is a greenhouse gas, NOx nitrogen oxide compound, HC is a charcoal hydrate compound as a result of imperfect combustion processes and loose particles.
The research that has been done is similar to that of [16], where preheating biodiesel fuel, namely CPO, Jatropha, and WCO. Research produces data on changes in emissions. Heating the fuel can change the composition of NOx and CO to a smaller one in the mixture of about 5%. Heating fuel shows the presence and reduces emission, carbon monoxide, and hydrocarbon [17][18]. Research on fuel with preheated fuel treatment using magnetic fuel has resulted in a change in exhaust emission levels. From the comparison between preheated and untreated fuel, it shows lower levels of CO, HC, and CO2 [19]. The same result is shown by research from [20] where Jatropha fuel oil treated with preheater produces a lower emission level than Jatropha fuel oil that is not preheated. The test parameters are CO2, Smoke Opacity, CO, and HC. To heat fuel, generally using a heater or heat exchanger.

Related to the above research, it is necessary to research the emissions produced by biodiesel which is currently being widely used by another method. However, fuel combustion in naturally aspirated diesel engines produces 100% energy, but what is actually used to power the engine is 35%. While the rest of the energy is distributed at 8% radiation, 5% lubrication, 15% cooling and 37% exhaust gas [23]. Based on these references, the researchers conducted experiments on a heat recovery jacket cooler to heat the fuel to reduce emissions.

### 2. Method

To support the research, several tools and materials are needed including Diesel engine, Generator Unit, and Gas Analyzer, Fuel. Heater unit consists of Shell and Tube Heat Exchanger, Piping Equipment Material, Computer, Camera, Thermometer, Digital Flow Rate, Manometer, Thermostat, Solenoid, Measuring Cup [21] and Fuel (Biodiesel B20) produced by Pertamina. Standard of Biodiesel (B20) according to table 1.

| No | Characteristic | Unit | Min | Max |
|----|----------------|------|-----|-----|
| 1  | Cetane Number  | -    | 48  | -   |
| 2  | Density @15°C  | Kg/m³ | 815 | 860 |
| 3  | Viscosity @40°C | mm²/sec | 2.0 | 4.5 |
| 4  | Sulphur Content | % m/m | - | 0.25 |
| 5  | Distillate 90% evaporation | °C | - | 370 |
| 6  | Flash Point    | °C   | 52  | -   |
| 7  | Pour Point     | °C   | -   | 18  |
| 8  | Carbon Residue | % m/m | - | 0.1 |
| 9  | Water Content  | mg/kg | - | 500 |
| 10 | Biological Growth | - | - | - |
| 11 | FAME Content   | % v/v | - | - |
| 12 | Methanol Content | % v/v | - | - |
| 13 | Ash Content    | % v/v | - | 0.01 |
| 14 | Sediment Content | % m/m | - | 0.01 |
| 15 | Strong Acid Number | mgKOH/gr | - | 0 |
| 16 | Total Acid Number | mgKOH/gr | - | 0.6 |
| 17 | Particulate    | mg/l  | -   | -   |
| 18 | Visual Appearance | - | Bright and clear |
| 19 | Color          | No.ASTM | - | 30 |
| 20 | Lubricity      | micron | - | 460 |
Experiment activity using four-stroke and four-cylinder diesel generator engines. The diesel engine uses a direct combustion system where the settings are shown in figure 3. Generator diesel engine specifications are listed in table 2.

| No | Specification | Parameter |
|----|---------------|-----------|
| 1  | Merk          | Krisbow   |
| 2  | Type          | KW26-1052 |
| 3  | Model         | KF 820    |
| 4  | Series        | A12091918 |
| 5  | KVA           | 18        |
| 6  | HZ            | 50        |
| 7  | RPM           | 1500      |
| 8  | Volt          | 230/400   |
| 9  | Phase         | 3         |
| 10 | Ampere        | 24.5      |
| 11 | Combustion System | Direct Injection |

The research procedure is a sequence of activities carried out so that the research was done regularly and systematically so that the research objectives can be achieved. The procedure is carried out from the beginning to the end of the research process including:

a. Formulate the problem as related to current issues related to a global problem, namely the diminishing reserves of energy, especially petroleum.

b. Tracing literature studies on several similar studies were conducted to enrich the literature review that underlies research on fuel heating techniques and reducing emission.

c. Various kinds of equipment are used in advance to be prepared and confirmed to function or operate properly.

d. Before taking data, the equipment is calibrated first to avoid error or deviation that is too large than it should be.

e. Retrieval of data by conducting direct trial experiments. By installing a shell and tube heat exchanger on the fuel system and cooling system. Adjusting the heating of the fuel at a temperature of 30°C, 35°C, 40°C, 45°C, 50°C by controlling the jacket cooling flow that comes out of the engine and then enters the heat exchanger. In this system, a thermostat and solenoid are installed, as shown in figure 1. The engine operates at 1500 rpm.

f. Measure Emission by using opacity smoke meter from exhaust gas manifold, as figure 2.

The data obtained in the field were analyzed using the descriptive data analysis method. The data described are in the form of a percentage, tabulation, and graphical form.

Figure 1. Schematic of Experiment
3. Discussion

Exhaust gas emission is emitted as a result of the combustion of fuels such as natural gas, gasoline, petrol, biodiesel blends, diesel fuel, fuel oil, or coal. According to the type of engine, it is discharged into the atmosphere through an exhaust pipe. The emission testing is conducted to collect data on the exhaust gas opacity from the diesel engine. The test set at temperature variation ranging from 30°C to 50°C with an interval of 5°C. The gas smoke opacity is calculated in%. In the test carried out, it is set up at 1500 RPM engine speed at no load engine condition. Exhaust smoke opacity data are presented in Figure 4.

The graph in Figure 4 shows that the opacity at 30°C is the highest at 35.3%, then at 35°C, it decreases to 28.8%. At a temperature of 40°C, there was a slight decrease, is 28.6%, then at a temperature of 45°C it dropped a bit sharply, is 23.8, while at 50°C it was the lowest opacity, is 20.3%

From the description, it can show that there is a decrease in exhaust emission opacity in line with the increase in fuel temperature. So it can be concluded that the increase in fuel temperature affects the decrease in opacity in exhaust emission.

According to the results of research conducted by several researchers related to emission [22] that the implementation of preheating can reduce emissions. Likewise [19] stated that fuel with preheated
fuel treatment has resulted in a change in the level of exhaust emission to be lower when compared to without heating. The same result is shown by research from [20] where heated fuel oil produces a lower emission level than fuel oil that is not heated.

4. Conclusion
The fuel heating system using a shell and tube heat exchanger with the jacket cooler recovery method installed on the diesel generator engine at the Docking & Ship Yard at Polytechnic of Marine and Fisheries of Bitung can be done well. In stationary conditions, it can increase the heat of the fuel from a current temperature of 30°C to 50°C.
Fuel heating at 50°C can reduce exhaust gas opacity by 15% compared to the normal temperature, which is 30°C with an opacity level of 35.3%.

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