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Effect the Addition of Biodiesel from Nyamplung Oil (*Calophyllum Inophyllum)* on Performance and Emission Characteristics of Diesel Engines

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ABSTRAK

Pada penelitian ini dipelajari pemanfaatan biodiesel dari minyak nyamplung *(Calophyllum Inophyllum)* melalui reaksi transesterifikasi menggunakan katalis heterogen CaO dari batu kapur yang berasal dari Pamekasan, Madura. Perbandingan komposisi yang digunakan antara minyak nyamplung terhadap metanol pada reaksi transesterifikasi adalah 1:12 (mol/mol) dengan penambahan 4% katalis CaO. Biodiesel yang terbentuk kemudian diuji kinerja dan karakteristik emisinya pada mesin diesel dengan variasi campuran bahan bakar antara solar murni dan biodiesel (B-10, B-20, B-30, B-40, B-100 dan S-100). Hasil pengujian campuran biodiesel dengan daya tertinggi dihasilkan dari bahan bakar B-10, B-20, B-30 dan B-100 masing-masing sebesar 0,26 kW pada beban 250 watt. Sedangkan pada beban 500 watt, daya tertinggi diperoleh pada bahan bakar B-40 yaitu sebesar 0,58 kW. Hasil pengujian kinerja menggunakan bahan bakar S-100 diperoleh nilai daya yang paling tinggi masing-masing sebesar 0,27 dan 0,58 kW dengan beban 250 dan 500 watt. Pengujian kinerja untuk campuran biodiesel, nilai torsi paling tinggi diperoleh ketika menggunakan bahan bakar B-10, B-20, B-30 dan B-100 yaitu masing-masing sebesar 1,65 N.m dengan beban 250 watt. Sedangkan pada beban 500 watt, torsi tertinggi diperoleh pada bahan bakar B-40 yaitu sebesar 3,69 N.m. Bahan bakar S-100 menghasilkan torsi masing-masing sebesar 1,71 dan 3,69 N.m dengan beban 250 dan 500 watt. Karakteristik gas emisi karbon monoksida (CO), nitrogen monoksida (NO) dan nitrogen oksida (NO_x) menunjukkan konsentrasi terendah diperoleh pada bahan bakar B-100 masing-masing sebesar 387 ppm, 92 ppm dan 96 ppm. Sedangkan konsentrasi gas emisi CO, NO dan NO_x tertinggi dihasilkan dari bahan bakar solar murni (S-100) yaitu masing-masing sebesar 574 ppm, 126 ppm dan 132 ppm.

***Kata kunci*:** biodesel, minyak nyamplung, kinerja, emisi, mesin diesel.

ABSTRACT

In this study, the use of biodiesel from nyamplung oil (Calophyllum Inophyllum) was studied through a transesterification reaction using a heterogeneous catalyst of CaO from limestone originating from Pamekasan, Madura. The composition ratio used between nyamplung oil and methanol in the transesterification reaction was 1:12 (mol/mol) with the addition of 4% CaO catalyst. The biodiesel that is formed is then tested for its performance and emission characteristics in diesel engines with various fuel mixtures between pure diesel and biodiesel (B-10, B-20, B-30, B-40, B-100 and S-100). The test results for biodiesel blends with the highest power produced from B-10, B-20, B-30 and B-100 fuels were 0.26 kW each at a load of 250 watts. While at a load of 500 watts, the highest power is obtained from the B-40 fuel, which is 0.58 kW. The results of performance testing using S-100 fuel obtained the highest power values of 0.27 and 0.58 kW, respectively, with a load of 250 and 500 watts. Performance testing for biodiesel blends, the highest torque value was obtained when using B-10, B-20, B-30 and B-100 fuels, which were 1.65 N.m each with a load of 250 watts. While at a load of 500 watts, the highest torque is obtained on B-40 fuel, which is 3.69 N.m. The fuel S-100 produces torque of 1.71 and 3.69 N.m, respectively, with a load of 250 and 500 watts. Emission gases characteristics of carbon monoxide (CO), nitrogen monoxide (NO) and nitrogen oxides (NO_x) showed the lowest concentrations obtained in B-100 fuel were 387 ppm, 92 ppm and 96 ppm, respectively. Meanwhile, the highest concentrations of CO, NO and NO_x emissions were produced from pure diesel fuel (S-100), namely 574 ppm, 126 ppm and 132 ppm, respectively.

***Keywords*:** biodiesel, nyamplung oil, performance, emission, diesel engine.

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1. INTRODUCTION

The human need for energy is currently increasing in line with the rapidly growing population. Petroleum is one of the energy that is needed in everyday life, one of the commonly used fuels is non-renewable fossil fuels [1]. Petroleum has become a basic need in life from year to year and continues to increase as fuel in both the industrial and transportation sectors. This can lead to an energy crisis. To anticipate this, it is necessary to search for alternative energy fuels that are feasible in today's modern world.

One example of a renewable alternative energy source that can replace petroleum is biodiesel [2,3]. Biodiesel is a fuel obtained from vegetable oils and has similar characteristics to diesel fuel but is non-toxic, renewable, sustainable and environmentally friendly. The steps in making biodiesel generally use a transesterification reaction because of the simple process route and the potential for decreasing viscosity [4,5]. Transesterification is the reaction of triglycerides in oil or fat and alcohol in the presence of a catalyst to form alkyl esters [6]. Most of the world's biodiesel production comes from vegetable oils, which currently or in the future will cause food shortages if the oil extracted from plants is consumed by humans [7]. It is necessary to use vegetable oils derived from plants that cannot be consumed as food or non-edible oil, so as to increase the benefits and also avoid food crises. [8]. Oils from non-edible resources get overall consideration because they can be found easily and more economically than vegetable oils [9,10].

Examples of non-edible plants that can be used in the manufacture of biodiesel include jatropha seed [11], kemiri sunan [12], kapuk randu seed [13], sunflower [14], kesambi plant [15] and one of the potential and abundant plants that can be used for biodiesel production is the nyamplung plant. Nyamplung *(Calophyllum Inophyllum)* is a type of plant that usually lives and grows in sandy areas such as riverbanks or coastal areas up to an altitude of 200 above sea level. The potential of nyamplung as a raw material for biodiesel production is very large because it contains high levels of oil of around 40-73%.

Several valuable studies have been carried out in recent years using biodiesel fuel from nyamplung oil as a diesel fuel mixture. Hendro Juwono et al [16], has conducted research on the manufacture of biodiesel from nyamplung oil. The results show that the viscosity, flash point, boiling point, cloud point, and pour point biodiesel obtained are higher than diesel fuel. Optimal engine power is achieved when using a 10% biodiesel composition. The 10% biodiesel blend has the same characteristics as commercial diesel oil, where the working value is up to 1800 watts. Ashok et al [17], have also conducted research into making biodiesel from nyamplung oil. The results show that the emission characteristics of CO and NO_x decrease with increasing the percentage of biodiesel in the mixture. This is due to the increase in the oxygen concentration of biodiesel with an increase in the percentage of biodiesel in the mixture which helps complete combustion in the engine. diesel.

Therefore, our aim in this study is to utilize nyamplung oil derived from the nyamplung plant for biodiesel production using a heterogeneous catalyst of calcium oxide from Madura limestone. Emission characteristics and performance of biodiesel from nyamplung oil applied to diesel engines were also studied.

2. RESEARCH METHODS

2.1. TOOLS AND MATERIALS

The tools used for the biodiesel production are as follows: separating funnel, three neck flask reactor, hotplate, analytical balance, beaker glass, water pump, hose, bucket, thermometer, stirrer, dropper pipette, spiral condenser, separating funnel, tachometer and diesel engine. While the materials used for the biodiesel production include nyamplung oil as a raw material purchased from Jarak Lestari Company. Nyamplung oil is

composed of glycerol molecules and long carbon chain fatty acid molecules, with a fatty acid composition. Physically, the seeds of the nyamplung fruit are spherical, thick, hard, brownish white. H_2SO4 98 %, limestone from Pamekasan, Madura (furnace at 900°C for 3 hours to form a CaO catalyst) and methanol (CH_3OH-merck).

2.2. BIODIESEL PRODUCTION FROM NYAMPLUNG OIL

2.2.1 ESTERIFICATION REACTION

In the esterification process, nyamplung oil (94 grams) is reacted with 98% methanol (170.67 grams) using a stoichiometric ratio of 1:16 (mol/mol) with the addition of 4% H_2SO_4 catalyst (2 ml) from the nyamplung oil volume. The esterification reaction was carried out at temperature of 60 ^oC for 1 hour with a stirring speed of 800 rpm. The results of the esterification reaction were then left in a separatory funnel for 24 hours until two layers were formed. The esterified oil formed is then used for the transesterification reaction

2.2.2 TRANSESTERIFICATION REACTION

In the transesterification process, methanol (128 grams) is reacted with a CaO catalyst from Madura limestone as much as 4% (2.82 grams) by weight of oil (70.5 grams) while stirring. The ratio between nyamplung oil and methanol is 1:12 (mol/mol). The resulting mixture is added to the esterified oil. Then stirred at temperature of 70 ^oC for 2 hours at a speed of 1000 rpm and let stand for 24 hours to form two layers. The transesterified biodiesel oil formed is applied on the diesel engine to determine the performance and emission characteristics. The scheme for biodiesel production can be seen in Figure 1.

2.3 PERFORMANCE AND EMISSION CHARACTERISTICS TESTING OF DIESEL ENGINE

Performance testing on a diesel engine, first preparing a sequence of series and parallel lamps and then connecting them to the generator. A mixture of biodiesel from nyamplung oil and diesel fuel is prepared in volume percentages of 10%, 20%, 30%, 40%, 100% and pure diesel is denoted as B-10, B-20, B-30, B-40, B-100 and S-100. The diesel engine is then started by turning the crank. After the diesel engine starts, set the engine speed to 1500 rpm. Then turn on the series of lights with a load of 250 watts. The above procedure is repeated with a 500 watt lamp load to obtain voltage and current data. The data obtained from the test results are then processed to calculate the power and torque values with variations in the fuel mixture.

Testing of gas emissions on diesel engines is carried out with variations of the percentage of biodiesel in the fuel as above using a gas analyzer instrument. Based on this test, data on the emission gas content of carbon monoxide (CO), nitrogen monoxide (NO) and nitrogen oxides (NO_x) will be obtained. Performance and emissions testing of diesel engine are illustrated in Figures 2 and 3.

3. RESULTS AND DISCUSSION

The power generated in a diesel engine coupled to an electric generator can be calculated based on the load of the electric generator and expressed as the effective power on the generator. The relationship between engine power and the fuel mixture is shown in Figure 4. Based on the graph, it is explained that for S-100 fuel with a load of 250 watts, the power obtained is lower than that of a 500 watt load. The greater the increase in load, the greater the overall power. This is due to the change in power proportional to torque. Figure 4 shows that with a load of 250 watts, the lowest power is generated in the B-40 fuel, which is 0.25 kW, while the highest power is generated in the S-100 fuel of 0.27 kW. When the diesel engine is loaded with 500 watts, the lowest power is generated in the B-30 fuel of 0.55 kW, while the highest power is generated in the B-40 fuel of 0.58 kW.

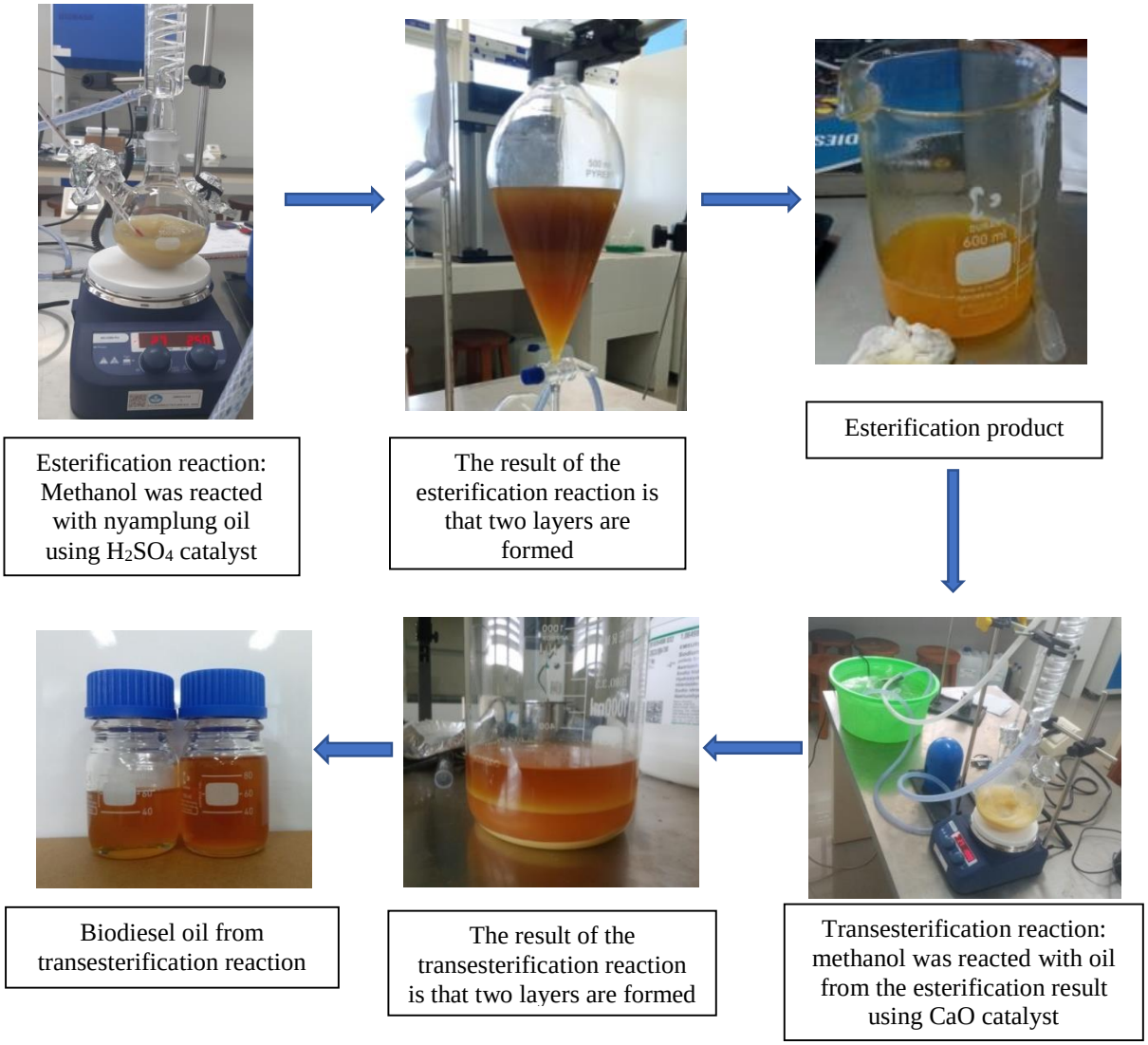

Figure 1. Scheme for biodiesel production from nyamplung oil

Torque is the engine's ability to cope with loading. The relationship between the fuel mixture and torque is shown in Figure 5. Based on the graph, it shows that the torque value increases with increasing load. This is because with the addition of the load, the fuel consumption will increase. With the addition of fuel, the combustion that occurs is greater, so that the heat energy from the fuel which is converted into mechanical energy is also greater which is the thrust on the piston. If the thrust on the piston is getting bigger, the torque value will also be bigger. Based on figure 5, it is explained that the more load on the engine, the torque produced will also increase. So that the pressure and heat energy resulting from combustion have increased which causes the torque produced to also increase. Figure 5 shows that with a load of 250 watts, the lowest torque is produced in the B-40 fuel of 1.59 N.m while the highest power is produced on the S-100 fuel of 1.71. When the diesel engine is loaded with 500 Watts the lowest torque is produced in the B-30 fuel of 3.50 N.m, while the highest torque is produced in the B-40 fuel of 3.69 N.m. In general, the calorific value of pure diesel is higher than biodiesel. The higher the calorific value of the fuel, the greater the thrust of the piston. So that the resulting torque is higher.

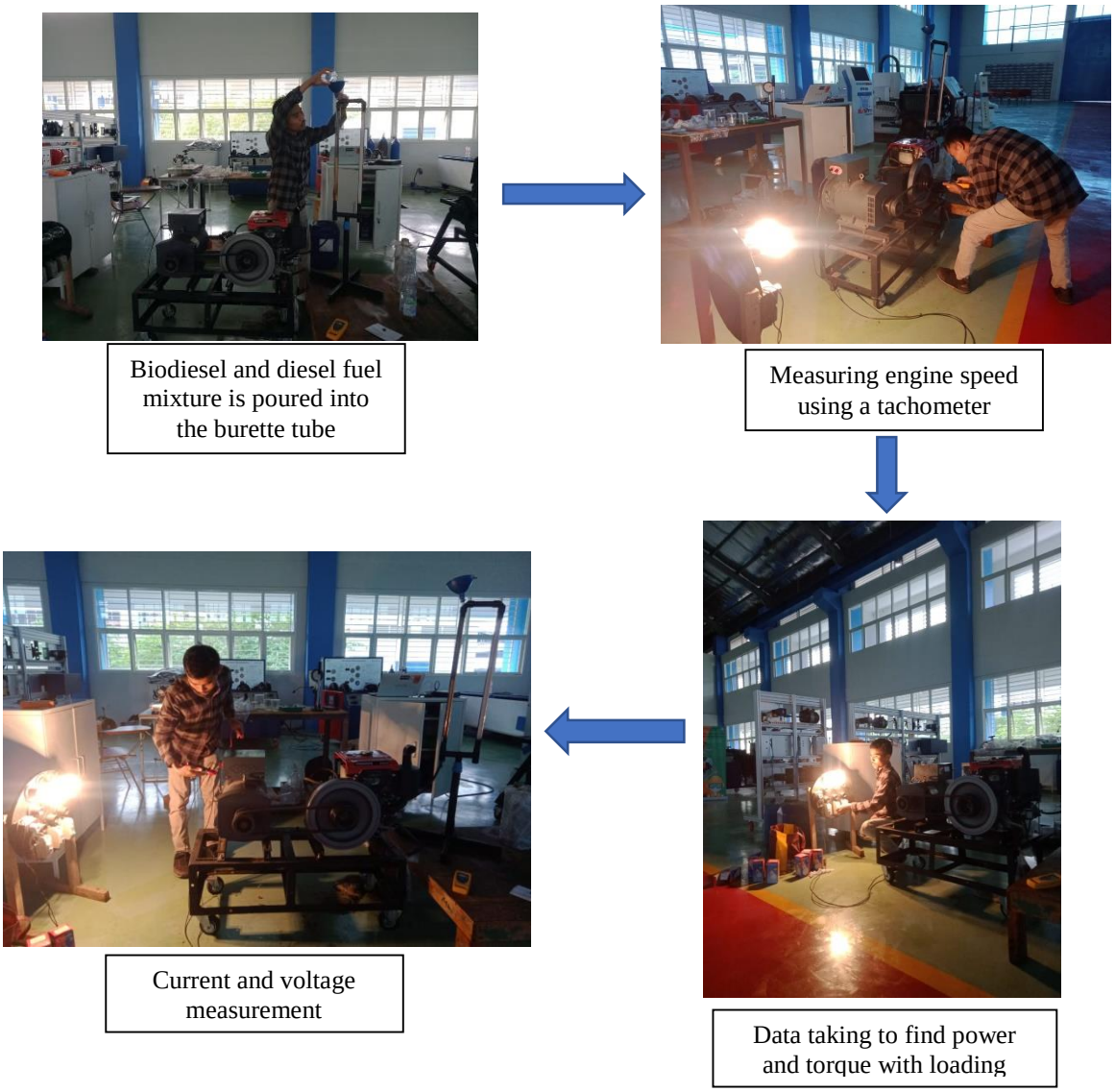

Figure 2. Diesel engine performance data taking scheme

Figure 3. Emission testing using a gas analyzer

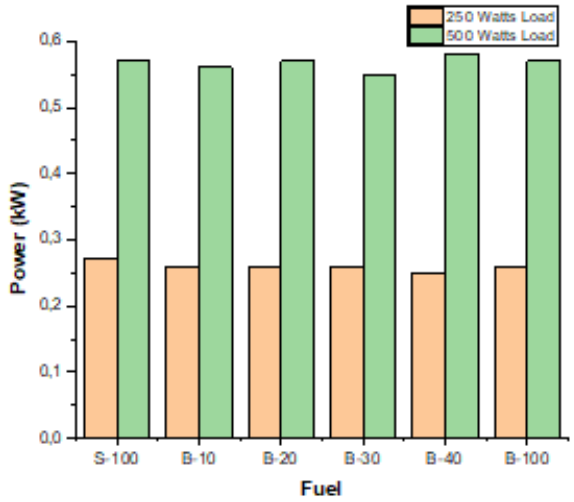

Figure 4. The relationship between the percentage of biodiesel in the fuel on the power

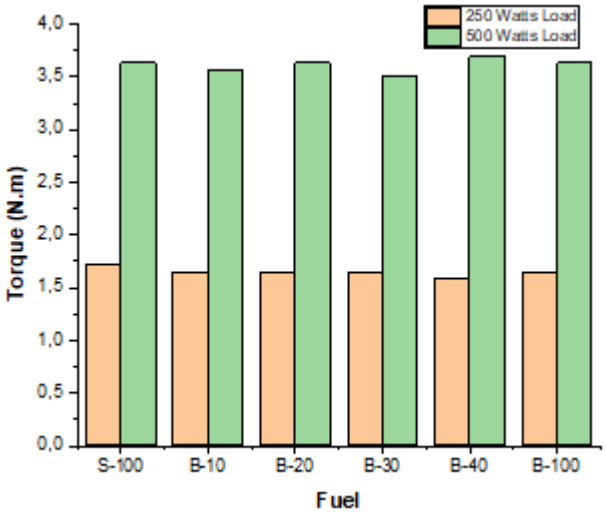

Figure 5. The relationship between the percentage of biodiesel in the fuel on the torque

The graph of the relationship between the fuel mixture and the CO emission content is shown in Figure 6. The more biodiesel fuel mixture, the lowest the CO emission gas. The lowest CO emission gas content is produced in B-100 fuel, while the highest CO emission gas content is produced from S-100 fuel. The high CO emission gas content in S-100 fuel occurs because pure diesel has a very low oxygen content, so the combustion process is incomplete because many carbon atoms do not get enough oxygen to form CO_2 gas . The lowest CO emission gas content was obtained when using the B-40 fuel mixture, which was 387 ppm, while the highest CO emission gas content was obtained at 574 ppm when using S-100 fuel.

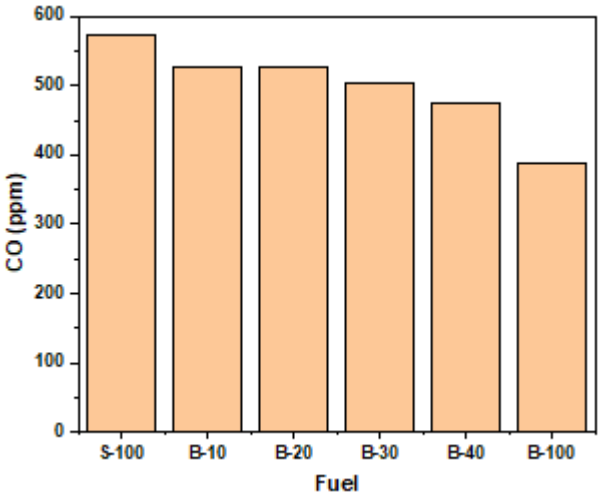

Figure 6. The relationship between the percentage of biodiesel in the fuel on the CO content

The results of the test of NO and NO_x emission gases from the biodiesel fuel mixture are shown in Figure 7. The more biodiesel mixtures, the lower the NO and NO_x emission gas content. This result is in accordance with research conducted by Kataria et al [18] which shows that the more biodiesel blends, the lower the NO_x emission gas content compared to pure diesel. The formation of NO_x emission gas in diesel engines is an adiabatic function of the flame temperature which is closely related to the cylinder peak temperature [19]. NO_x emission gas is also formed from the reaction of nitrogen gas and oxygen in the air during combustion [18]. The lowest emission gas content of NO and NO_x is produced from B-100 fuel, which is 92 and 96 ppm, respectively. Meanwhile, the highest emission gas content of NO and NO_x is produced from S-100 fuel, which is 126 and 132 ppm, respectively.

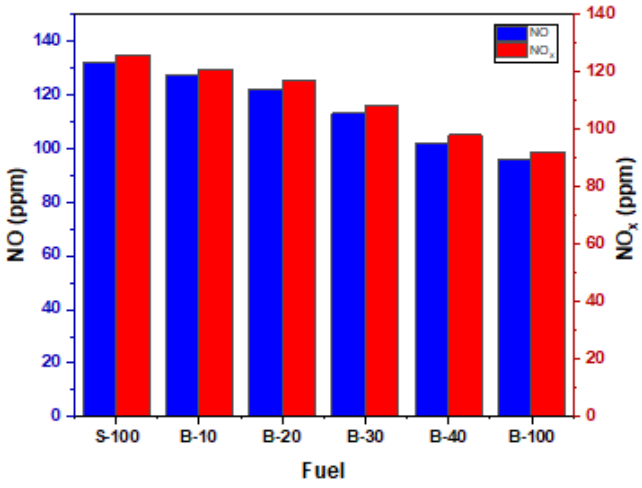

Figure 7. The relationship between the percentage of biodiesel in the fuel on the NO and NO_x content

4. CONCLUSION

Oil from the nyamplung plant has been successfully used as raw material for biodiesel production using CaO catalyst from limestone originating from Pamekasan, Madura. The results of the diesel engine performance test show that the highest power is obtained when using S-100 fuel of 0.27 and 0.58 kW, respectively, with a load of 250 and 500 watts. The highest torque is obtained when using S-100 and B-40 fuels of 1.71 and 3.69 kW, respectively, with 250 and 500 watts of load. Characteristics of CO, NO and NO_x emission gases indicate that the more biodiesel fuel mixture, the lower the emission gas content produced. The lowest CO, NO and NO_x emission gas contents were obtained using the B-40 fuel of 387 ppm, 92 ppm and 96 ppm, respectively.

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