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# Experimental Investigation of Citronella Oil as Bioadditive in Biodiesel Fuel on Diesel Engine Performance, Vibration and Emissions

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***Abstract*— The depletion of fossil fuels is one of the reasons for using alternative fuels such as biodiesel fuel. However, biodiesel has disadvantages such as higher density, lower heating value, high fuel consumption, and high nitrogen oxide (NOx) content compared to diesel. To improve this, it can be done by increasing the cetane number of the fuel by adding citronella (C) oil as a bioaditive. The purpose of this study is to determine the characteristics of biodiesel fuel after adding citronella oil, and to determine the effect of citronella oil addition on engine performance, vibration, noise and emissions. This research was conducted experimentally by adding citronella oil with variations in composition of 0.5%, 0.75%, 1%, 1.25%, and 1.5% of the volume of Biodiesel fuel (B30). The fuel was tested on a Yanmar single-cylinder diesel engine. Experimental results showed that the cetane number increased with the addition of citronella composition, with the highest cetane number in B30+C 1.5% fuel, which increased by 25.9% when compared to the cetane number of B30. From the performance test results, the diesel engine experienced an increase in performance in the form of power, torque, BMEP, as well as a decrease in vibration and noise when compared to B30 fuel. The lowest NOx emissions occurred at 2000 RPM with the largest load produced by fuel that had added citronella 1.5% with a decrease of 21.6% when compared to B30 fuel..**

*Keywords*—Bioadditives, Vibration, Noise, Citronella Oil, Performance

## I. INTRODUCTION

For more than 100 years, petroleum has been consumed as a transportation fuel [1]. In 2015 the transportation sector contributed 31% to energy consumption in Indonesia. This energy consumption is the second largest after the household sector at 35% and has increased 5.2% per year in the last 5 years [2]. Energy consumption is still dominated by fuel oil, including diesel oil. Oil energy consumption continues to increase with a growth rate of 4.7% per year. The increasing consumption of petroleum-based fuels can cause the availability of fossil fuels as the main source of diesel fuel to be depleted. This is reinforced by the results of research that if no new petroleum wells are found, then national petroleum reserves can only meet the needs for the next 10-15 years [3].

From these conditions, Biodiesel was discovered as an alternative fuel derived from animal fats or vegetable oils. Biodiesel itself is non-toxic, biodegradable, contains no aromatics, no sulfur, and most importantly renewable [4,5,6]. However, biodiesel has some drawbacks such as higher density, lower heating value, high fuel consumption, high nitrogen oxides (NOx), higher molecular weight, lower volatility and higher pour point compared to diesel. These drawbacks lead to poor atomization. Poor atomization can cause a decrease in engine power and lead to incomplete combustion [1].

As a result of the above research, several studies were conducted to find a solution, which is one of the effective ways to improve the properties of biodiesel is by adding or mixing additives to the fuel. The addition of additives to fuel is used as an alternative to increase the efficiency of fuel combustion and reduce pollution. The addition of additives serves to enrich the oxygen content of the fuel. The 'oxygen provider' additives in diesel fuel play a role in increasing the cetane number, so that combustion becomes more complete and reduces exhaust emissions [7]. There are many types of fuel additives found that show positive results in improving fuel properties, engine and combustion performance and reducing emissions. Additives themselves consist of two types, namely synthetic additives (artificial additives) and bioadditives (organic additives). The addition of additives to fuel has also been done so far. However, some additives have a negative effect on engine performance. Among others, tetra methyl lead (TML) and tetra ethyl lead (TEL), which are both starting to be abandoned because they contain lead metal Pb and produce toxic exhaust gases [8]. Therefore, it is necessary to explore fuel additives by using a type of additive in the form of bioadditives. Bioadditives are used as additional compounds in fuel that are useful for improving combustion and reducing the negative impacts caused. One alternative additive that is good and environmentally friendly is essential oil.

Essential oils are soluble in diesel fuel and have a higher atomic oxygen content. Essential oils also have physical and chemical properties similar to fuels consisting of carbon (C), hydrogen (H), oxygen (O), and

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nitrogen (N) so that they are easily biodegradable and environmentally friendly (do not contain sulfur) [9]. One type of essential oil in Indonesia is citronella oil. Citronella itself has main compound components in the form of geraniol, citronellal, citronellil [10]. Compounds such as geraniol and citronellal contain oxygenate atoms. Oxygenate itself is a liquid organic compound with oxygen atom content that can be mixed in fuel.

In research Setyaningsih at all, on the utilization of essential oils as bioadditives to reduce biodiesel fuel consumption which states essential oils are oxygenated hydrocarbon compounds that are rich in oxygen. Oxygen is used to complete the combustion reaction in the engine. A perfect combustion reaction can save fuel consumption. Which is based on the results of the addition of essential oil-based bioadditives causing changes in fuel characteristics. However, these parameters still meet the quality requirements of biodiesel fuel.

## II. METHOD

The research method is through experiments, by mixing citronella oil as a bioadditive into B30 fuel, after which testing the characteristics of the fuel, testing and analyzing the results of engine performance, fibration, noise and NOx emissions produced.

### 2.1. Blending of Citronella Oil in B30

The first step was to blend citronella oil as a bioadditive into B30 fuel. There are five variations in the composition of citronella oil addition, namely the addition of a percentage of 0.5%, 0.75%, 1%, 1.25% and 1.5% of the fuel by volume. For mixing, it is done manually by pouring citronella oil into a measuring cup first and then adding B30 fuel, this is done so that the fuel is more easily mixed, and after that it is just stirred slowly.

Figure 1. B30 after adding citronella oil at 0.5%, 0.75%, 1%, 1.25%, and 1.5% of the fuel volume.

### 2.2. Testing Fuel Characteristics

After adding citronella oil to biodiesel, the next step is to test the characteristics of the B30 fuel that has been added with citronella oil. For the characteristic test carried out in the form of a cetane number test which is measured by a cetane meter, and for the calorific value test measured using a bomb calorimeter. The tests were conducted at the ITS Energy and Environment Laboratory, Surabaya.

### 2.3. Engine Set Up

Before testing the engine, the Engine Set Up process is carried out which is the preparation of the required test equipment such as a single cylinder YANMAR diesel engine, Electric Dynamno to determine performance, a loading lamp, a fuel burette, and a tachometer used to measure rpm, and the installation of a BOSCH brand EGS-NX NOx emission sensor on the diesel engine exhaust where this sensor is connected to a monitor to read

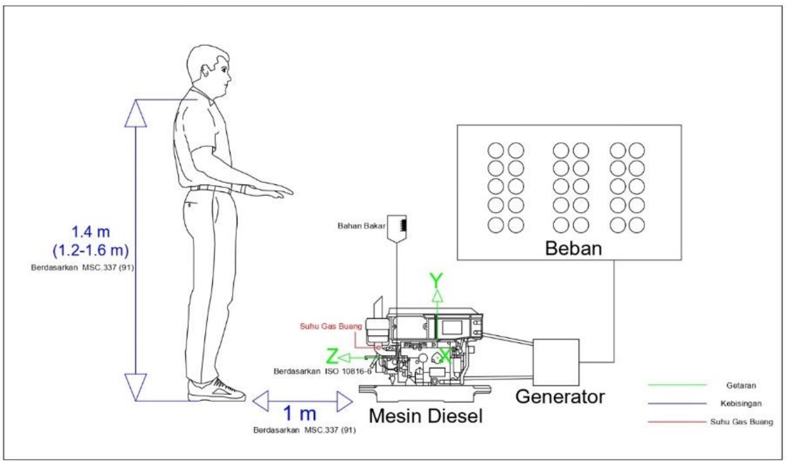


Figure 2. Engine Set Up

the NOx value released. The engine set up scheme can be seen in the figure, below:

- Performance Testing of Engine Fueled by B30+Bioadditive of Citronella Oil
  Performance testing was carried out on a single cylinder YANMAR diesel engine. Where data is taken in the form of engine speed, voltage, current, and time spent on fuel per 20 ml. The variables used during the performance test. As follows:
  a. Fixed Variables
  -B30 fuel that has been added with bioadditives
  - Engine speed: the speed that will be the benchmark is the top 5 speed points, which are at 1600, 1700, 1800, 1900, 2000 RPM.
  b. Variable Changes:
  -The dummy load used is 1000 Watt, 1500 Watt, 2000 Watt, 2500Watt, and 3000 Watt.

- Emission Testing on Engine Fueled by B30+Bioadditive of Citronella Oil
  Emission measurements on the engine were carried out with six different fuel variations, namely, B30, B30+C 0.5%, B30+C 0.75%, B30+C 1%, B30+C 1.25%, and B30+C 1.5%.
- Measurements
  measurements were taken at the highest RPM of 2000 RPM at each load. The tool used to measure is the NOx emission sensor EGS-NX brand BOSCH which is done by placing the sensor close to the exhaust of the diesel engine.
- Noise Measurement Procedure (IMO - MSC.337 (91))
  Noise measurement was conducted on YANMAR diesel engine single cylinder-in using SMART SENSOR sound level meter. The unit used is decibel-A dB(A). Noise measurement is carried out to observe the noise due to the movement of the piston and crankshaft which causes collisions during the combustion process.
- The measurement uses the International Maritime Organization standard - Adoption of The Code on Noise Levels on Board Ships - Measurement, MSC.337 (91). Where the sound level meter used by the author is placed at a distance of 1 meter from the diesel engine with a height of 1.2-1.6 meters, taken 1.4 meters or equivalent to the author's shoulder. Illustration can be seen in Figure 2. In addition, noise measurements were taken for 15 seconds at each variable point.
- Vibration Measurement Procedure (ISO 10816-6 Standard)
  Vibration measurements were made on a YANMAR diesel engine single cylinder using a Benetech GM63A sound level meter. The unit of vibration chosen is vibration acceleration (m/s²). Vibration measurements were made to observe the vibration of the engine due to the reciprocating movement of the piston and also the rotation of the crankshaft.
  Measurements use the ISO 10816-6 standard. Where the vibration meter tool used by the author is affixed directly to the engine body with three main axes that are parallel to important parts in the engine, namely the cylinder head and crankshaft, as shown in Figure 3.3.
  - x axis (horizontal = engine body parallel to the crankshaft)
  - y-axis (vertical = engine body parallel to the crankshaft)
  - z-axis (engine body parallel to the cylinder head)

## III. RESULT AND DISCUSSION

- Characteristic Test
  Analysis of characteristic test results includes cetan number and calorific values. The cetane number test uses a cetane meter and the calorific value test uses a bomb calorimeter. The test samples were carried out in as many as five variations in the composition of lemongrass oil addition to B30, namely 0.5%, 0.75%, 1%, 1.25%, and 1.5% of the total fuel volume. The test results can be seen in Table 1.

TABLE 1.
RESULT CARACTERITIK FUEL

| Additional Composition | Test Type | Result | Unit | Test Method |
|---|---|---|---|---|
| C 0,5% | Cetane Number | 69,9 | - | Oktane Cetane Number |
| | Calorific Values | 10.465 | Kal/gr | Bomb Kalorimeter |
| C 0,75% | Cetane Number | 70,2 | - | Oktane Cetane Number |
| | Calorific Values | 10.452 | Kal/gr | Bomb Kalorimeter |
| C 1% | Cetane Number | 70,6 | - | Oktane Cetane Number |
| | Calorific Values | 10.447 | Kal/gr | Bomb Kalorimeter |
| C 1,25% | Cetane Number | 70,7 | - | Oktane Cetane Number |
| | Calorific Values | 10.454 | Kal/gr | Bomb Kalorimeter |
| C 1,5% | Cetane Number | 70,8 | - | Oktane Cetane Number |
| | Calorific Values | 10.475 | Kal/gr | Bomb Kalorimeter |

- Result of Cetane Number

Increasing the cetane value can be done in two ways, one of which is by increasing the availability of oxygen in the fuel. To enrich the oxygen content in the fuel can be done by adding additives. This is in accordance with the results of the cetane number test on fuel added with citronella oil as a bioadditive.

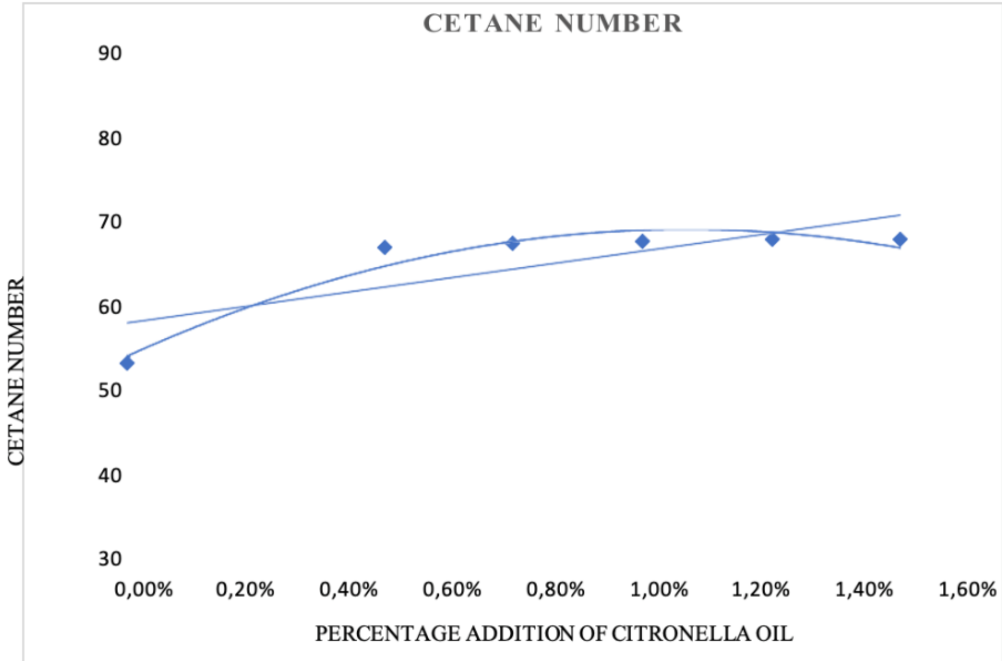


Figure 3. Graf of result cetane number test

According to research by Winny, et al (2018), the cetane value of biodiesel was 56.2. As for biodiesel after adding five variations in the composition of citronella oil addition, the cetane value increased successively with the results of 69.9, 70.2, 70.6, 70.7, and 70.8. From Figure 4, it can be seen that the increase is directly proportional to the number of variations in the composition of the addition of citronella oil, the greater the addition of citronella oil, the more the cetane number of the fuel increases. To predict the optimal result of bioadditive addition, a graph is made with a polynominal regression equation from the graph resulting in a value of=-128190x2 + 2776x + 56.951 with regression accuracy (R2) of 0.9444 which accuracy is declared good because it is above 0.75. From the experimental results, it is proven that citronella oil can increase the cetane value of fuel. The cetane value itself shows the quality of fuel combustion in diesel engines. A high cetane number can also indicate the high quality of the fuel. Increasing the cetane number can have an effect on reducing the exhaust emissions produced and can improve diesel engine performance such as ignition quality and reducing knocking in diesel engine.

- Result of engine performance

  Performance data was obtained from direct experiments on the Yanmar single cylinder engine at the Marine power plan ITS Worshop. For variable RPM is determined at 1600, 1700, 1800, 1900, and 2000. The fuel tested itself is B30, and B30 after adding citronella oil with 5 types of variants of the addition composition, namely the addition of 0.5%, 0.75%, 1%, 1.25%, and 1.5% of the total B30 fuel. The data obtained was then processed into a graph and analyzed with the following results.

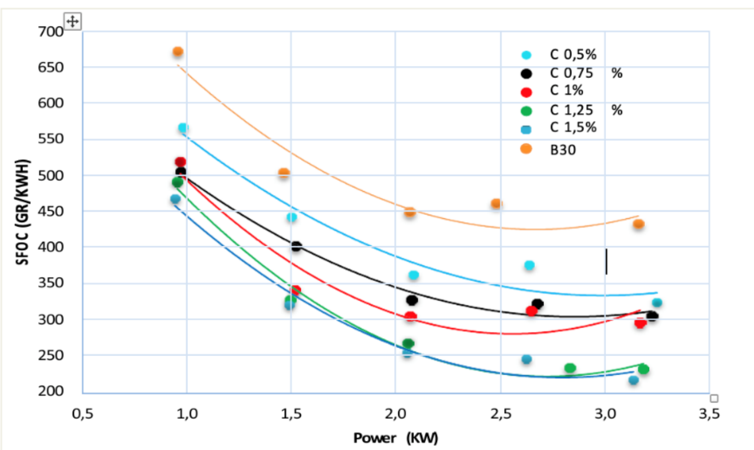


Figure 4. SFOC Performance with Fuel Power B30, SW 0.5%, SW 0.75%, SW 1%, SW 1.25% and SW 1.5% at RPM 2000

Figure 4 is a comparison graph of SFOC performance against power at 2000 RPM for six fuel variations. Based on the graph above, it can be seen that of the six fuel variations tested, fuel with the addition of lemongrass oil by 1.5% has the lowest SFOC value at the largest load of 217.2 gr/kWh. When fuel with the addition of 1.25% citronella oil, the resulting SFOC is 231.9 gr/kWh. When fuel with the addition of 1% citronella oil, the resulting SFOC is 297.5 gr/kWh. When fuel with the addition of 0.75% citronella oil, the resulting SFOC is 306.5 gr/kWh. When the fuel with the addition of 0.5% citronella oil, the resulting SFOC is 325.2 gr/kWh. When the fuel is B30, the resulting SFOC is 432 gr/kWh.

While the power generated by the six fuel variations above, the largest power generated at RPM 2000 is fuel with the addition of 0.5% citronella oil, with the resulting power of 3.244 kW. The power value increases when compared to when using B30, with the resulting power of 3.156 kW. However, from the test results, the higher the addition of citronella oil causes a decrease in power. When adding 0.75% citronella oil, the power generated was 3.221 kW. When adding 1% citronella oil, the power is generated at 3.164 kW. When adding 1.25% citronella oil, the power is generated to 3.179 kW. When adding 1.5% citronella oil, the power is generated at 3.131 kW.

From these results, it can be concluded that when compared to the power produced by B30, there is an increase in power in the fuel that has been added with citronella additives, but the increasing composition of citronella oil addition causes a decrease in power. This may be due to the cetane number value being too high. A high cetane number can affect the increase in engine power because it causes a short ignition period so that the fuel burns quickly. However, if the cetane number is too high, it can cause a decrease in power because it will cause combustion that is too fast.

- Comparative Analysis of Power Performance with RPM

Figure 5 The graph shows the comparison of power to RPM for the six fuel variants, namely B30, C 1.5%, C 1.25%, C 1%, C 0.75%, and C 0.5%. From the graph, it can be seen that the power produced will be higher as the RPM increases.

From the results of the six types of fuel tested, the greatest power was produced when carried out at the widest RPM and load test, namely 2000 RPM and 3000 watts load with the results of each B30 producing 3.16 kW of power, C 0.5% producing 3.24 kW of power, C 0.75% producing 3.22 kW of power, C 1% producing 3.16 kW of power, C 1.25% producing 3.18 kW of power, and C 1.5% producing 3.13 kW of power.

- A Comparative Analysis of BMEP Performance with RPM

Figure 6 is a graph showing the comparison of BMEP to RPM for the six fuel variants, namely B30, C 0.5%, C 0.75%, C 1%, C 1.25% and C 1.5%. The graph shows that the resulting BMEP will be greater as the RPM increases.

Based on the results of the graph above, the BMEP produced at 1600 RPM from each fuel from B30, C 0.5%, C 0.75%, C 1%, C 1.25%, and C 1.5% in total sequentially producing BMEP of 49954.04 Nm2, 54128.6 N/m2, 53712.5 N/m2, 52448.4 N/m2, 50830.4 N/m2, and 50535.56 N/m2. Meanwhile, the maximum RPM of the six fuel variations respectively produces torque of 61083.6 N/m2, 62784.3 N/m2, 62327.1 N/m2, 61240.4 N/m2, 61525.3 N/m2 , and 60596.4 N/m2. Based on these results, it can be seen that the addition of citronella oil to B30 fuel can cause an increase in the BMEP value, but the greater the amount of citronella oil added causes a decrease in the BMEP value..

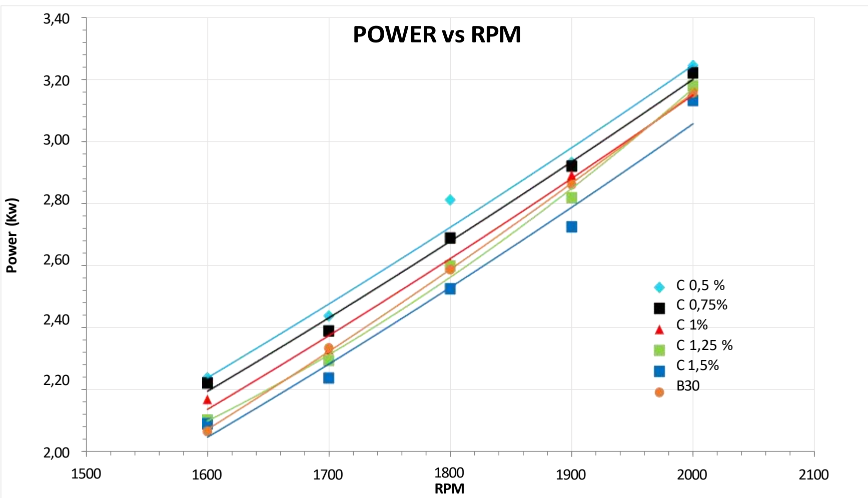


Figure 5. Performansi power vs RPM using varian citronela composition

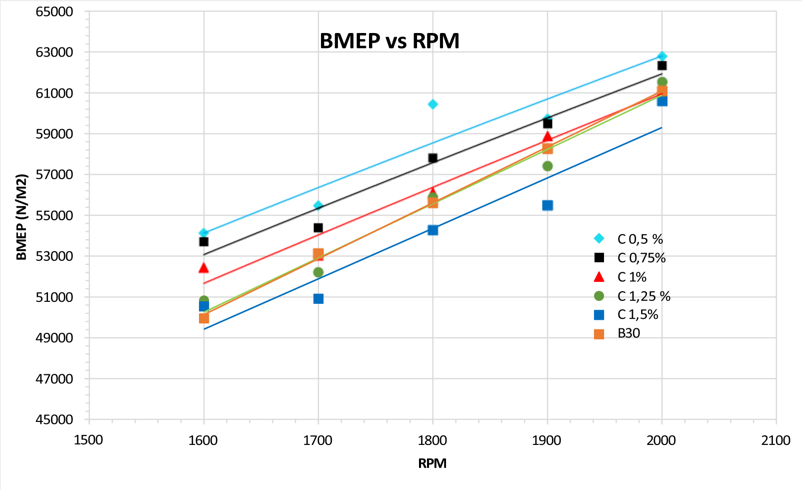


Figure 6. Comparison graph of BMEP performance with RPM using varian citronella composition

- Result of Emisi NOx

NOx emission testing was carried out at the MPP Workshop using a tool in the form of a BOSCH brand EGS-NX NOx emission sensor. By using 6 types of fuel variations, namely B30, B30 after adding citronella oil with additional compositions of 0.5%, 0.75%, 1%, 1.25% and 1.5%. Measurements were carried out at the highest RPM conditions with five loading variations. NOx measurements are carried out by placing the sensor close to the diesel engine exhaust and the NOx value will be read on the PC screen.

Figure 7 is a bar diagram of NOx emissions produced at 100% RPM conditions, namely 2000RPM with 5 loads varying from 1000 to 3000 per 500 increments on diesel motors with different types of fuel composition. The addition of citronella oil is intended to increase the cetane value so that it can have an effect on reducing NOx emissions. Based on the graph above, it can be seen that the greater the load given, the greater the NOx produced by each fuel. B30 fuel produces NOx between 224 ppm to 392 ppm, for B30+C 0.5% fuel produces NOx between 193 ppm to 348 ppm, B30+C 0.75% fuel produces NOx between 188 ppm to 335 ppm, B30+C fuel 1% produces NOx between 163 ppm and 344 ppm, 1.25% B30+C fuel produces NOx between 170 ppm and 329 ppm, and 1.5% B30+C fuel produces NOx between 166 ppm and 307 ppm. From the data above it can also be seen that the addition of 1.5% citronella oil produces the lowest NOx. For example, at the largest load of 3000 watts, B30+C1.5% fuel produces NOx 307 ppm, which when compared to B30 base fuel with NOx 392 has decreased by a percentage of 21.6%.

From these results it can be concluded that the greater the load given, the greater the NOx produced and the addition of citronella oil can influence the reduction in NOx emissions produced. This can be predicted, seen from the previous cetane value test where increasing the amount of added citronella composition can increase the cetane value. Increasing the cetane number can affect the reduction of NOx because a high cetane number can reduce the ignition delay so that the mixing time for air and fuel is shorter (shorter premixed combustion). The maximum combustion temperature will decrease which suppresses the formation of NOx. [15]

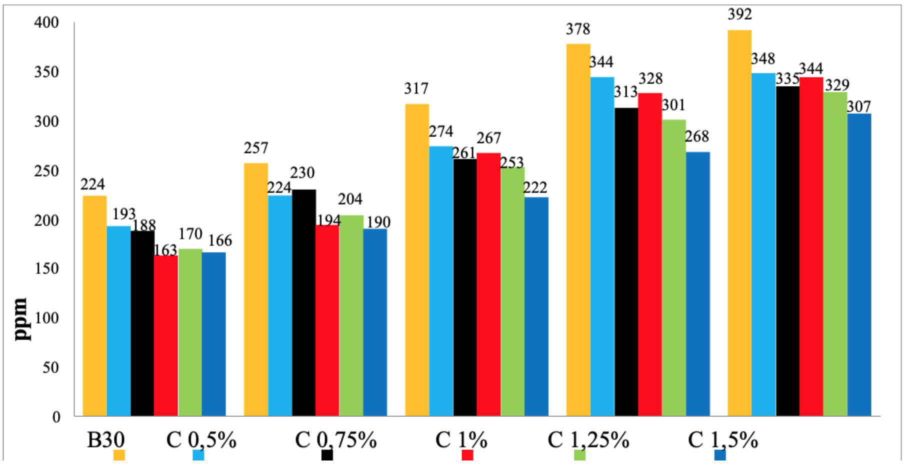


Figure 7. Graph of NOx Emission Test Results

- Effect of citronela addition on noise and vibration

As can be seen from the trendline, the addition of citronella oil can reduce the noise produced by the engine. This can be seen from a load of 1000 watts to 3000 watts, in general there will be a decrease. This is comparable to a decrease in SFOC. These two conditions indicate an increase in the combustion process. So that combustion efficiency increases in terms of SFOC, power and torque.

Based on experimental results, adding citronella oil to B30 fuel can reduce the noise level produced by diesel engines. The noise captured by the sound level meter is a combination of sounds resulting from vibrations of engine components, explosions from the combustion process coming out of the exhaust, sounds from several moving engine parts, and objects around the engine that vibrate and move, causing sound. The largest decrease occurred with the addition of 0.5% citronella oil, and in general it had a decreasing trend of 0.9-2.6% from B30, especially the lowest noise level was C 0.5%.

Apart from that, the addition of citronella oil to B30 fuel can also reduce the vibration level produced by diesel engines. Where the biggest decrease occurred with the addition of 1% citronella oil. Increased vibrations result in increased noise as well as a result of explosions and friction of components in the combustion chamber. Because basically the sounds that make noise are vibrations that move and are received by the ear. [2]

Reducing noise, reducing vibration, and increasing performance by adding citronella oil to B30 fuel can be caused by two different indications. The first indication is that the addition of lemongrass oil increases the cetane number. This is confirmed by previous research, where increasing the cetane number will improve the combustion process [2]. Another indication is that the oxygen content in fuel that has been added with citronella oil has increased. So that the combustion process takes place perfectly. Because one of the efforts made to make the combustion process run perfectly in a diesel engine is to enrich the oxygen source in the fuel. [7]

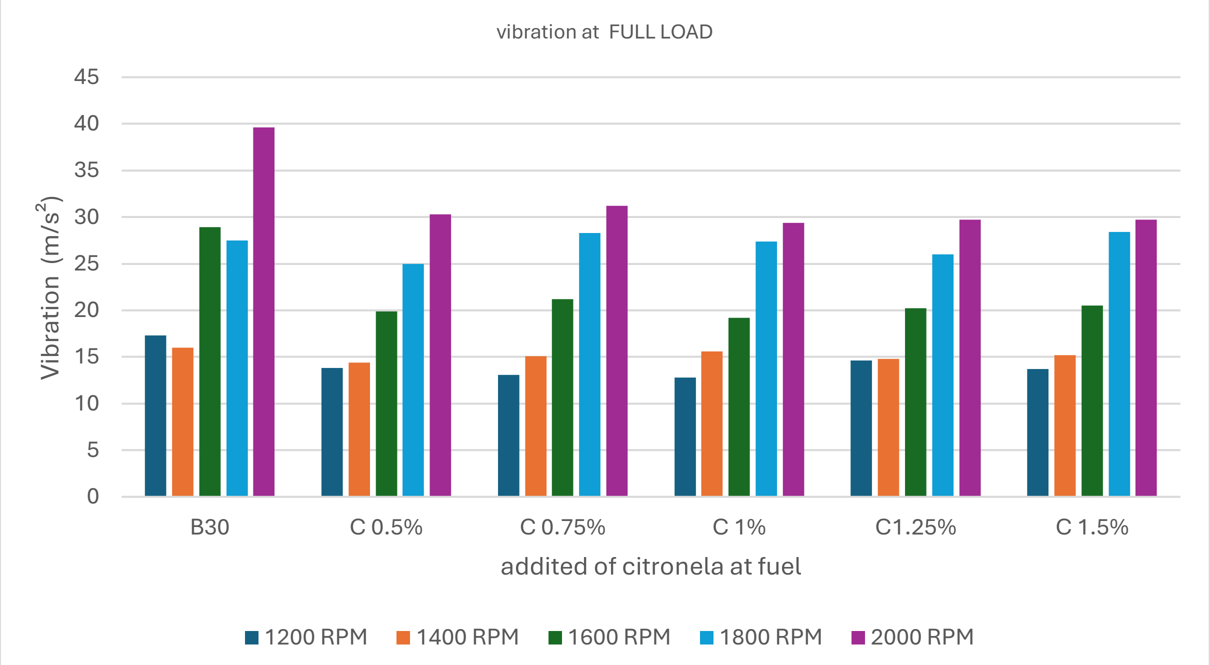


Figure 9. effect of citronella addition on vibration diesel engine

- CONCLUSION

Based on the results of the research that has been carried out, namely the effect of the addition of citronella oil as a biodiesel bioadditive on diesel motors, the following conclusions can be drawn:

1. The addition of citronella oil affects the change of B30 characteristics. The highest cetane value when B30 + C 1.5% with a cetane value of 70.8 when compared to B30 with a cetane value of 56.2 increased by 25.9%. For the results of the highest calorific value in B30 + C 1.5%, it increased by 2.7% when compared to the calorific value of B30.
2. The results of the performance test can be seen that the addition of citronella oil can improve performance in the form of power, torque and BMEP when compared to B30 fuel. However, the increasing composition of citronella addition can reduce performance in the form of power, torque, and BMEP. As for SFOC, the increasing variation of citronella oil addition decreases SFOC.
3. The addition of citronella oil can reduce NOx emissions when compared to B30 fuel. At the highest load, the lowest emission was produced by B30+C 1.5% fuel at 307 ppm which decreased by 21.6% when compared to B30 emissions of 392 ppm.
4. The addition of citronella oil bioadditive can reduce noise 0.9-2.6% from B30. The lowest noise level occurs in B30 fuel plus 0.5% C.
5. The addition of citronella oil bioadditive can reduce vibration by 2.2-34% from B30. The lowest vibration level occurred in B30 fuel plus 1% C.

REFERENCES

[1] A.D. Agustian, S Dwi Anggtyani, B. Hendro, A. Khoirunnisa, P. Isti, and S. Fariza (2014) "Formulasi Bioaditif Super 'Ron Booster' Pada Bahan Bakar Minyak melalui Ekstraksi Minyak Sereh Wangi (Citronella Oil) Menggunakan Gelombang Mikro," Jurusan D III Teknik Kimia, Fakultas Teknik, Universitas Diponegoro

[2] Arif, S. (2004). Analisa Getaran Dan Kebisingan Pada Motor Diesel Dengan Menggunakan Bahan Bakar Jelantash Ethyl Ester. Tugas Akhir

[3] Anny Sulaswatty, e. a. (2019). QUO VADIS MINYAK SERAI WANGI DAN TURUNANNYA JAKARTA: LIPI Press

[4] A.Purwandono, "PEMBUATAN ADITIF METIL ESTER NITRAT UNTUK MENINGKATKAN CETANE NUMBER DAN CETANE INDEKS PADA BAHAN BAKAR SOLAR," Teknik Kimia Fakultas Teknik Univcrsitas Mwbammad tyah Palembang, 2016.

[5] Setyaningsih, D., Faiziin, M. N., & Muna, N. (2018). Pemanfaatan Minyak Atsiri sebagai Bioaditif Penghemat Bahan Bakar Biosolar. INDONESIAN JOURNAL OF ESSENTIAL OIL, 45-54.

[6] Choi, C.H., Reitz, R.Y. (1999)."An Experimental Study on The Effects of Oxygenated Fuel Blends and Multiple Injection Strategies on Diesel Engine Emission".Journal of Fuel.(78),1303-1317

[7] Fitriana I, dkk. 2017. Inisiatif Pengembangan Teknologi Energi Bersih. Outlook Energi Indonesia 2017. Pusat Teknologi Sumber Daya Energi dan Industri Kimia. Badan Pengkajian dan Penerapan Teknologi

[8] Khalid, A., Nursal, R. S., Tajuddin, A. S. A. & Hadi, S. A. (2016). Performance and Emissions Characteristics of Alternative Biodiesel Fuel on Small Diesel Engine. Journal of Engineering and Applied Sciences.

[9] M. Vijay Kumar. (2016)." The impacts on combustion, performance and emissions of biodiesel by using additives in direct injection diesel engine. Research Scholar, Department of Mechanical Engineering, NIT warangal, Warangal, Telangana 506004, India

[10] Nofendri, Y. (2016). Efek Penambahan Oksigenat Kedalam Bahan Bakar Diesel Pada Prestasi Mesin. Jurnal Kajian Teknik Mesin.

[11] G. R. Faulhaber, "Design of service systems with priority reservation," in Conf. Rec. 1995 IEEE Int. Conf. Communications,3-8

[12] Kadarohman, A. (2003). EKSPLORASI MINYAK ATSIRI SEBAGAI BIOADITIF BAHAN BAKAR SOLAR. Program Studi Kimia, FPMIPA, UPI Bandung.

[13] Penyusun, T., 2020. Pedoman Penanganan dan Penyimpanan Biodiesel dan Campurannya (B30). Jakarta: Direktorat Jenderal Energi Baru, Terbarukan Dan Konversi Energi Kementerian Energi Dan Sumber Daya Mineral.

[14] Stefanus Unjanto, M. H. (2015). EMISI CO DAN NOX PADA GAS BUANGKENDARAAN MENGGUNAKAN KATALIS TEMBAGA BERPORITERMODIFIKASI. Pros iding SNATIF Ke -2.1

[15] Tandon, A., Kumar, A., Mondal, P., Vijay, P., & Bhangale, U. D. (2011). Tribological Issues Related to the Use of Biofuels: A New Environmental Challenge. British Journ. of Environment & Climate Change,

[16] Valipour, A. (2014). A Review on Effect of Fuel Additives on Combustion, Performance and Emission Characteristics of Diesel and Biodiesel Fuelled Engine. International Journal of Application or Innovation in Engineering & Management (IJAIEM).

[17] Z. Zhu, H. J. Guo, A. P. Zhou, D. K. Li & S. H. Liu. (2016). "One way to reduce the NOX Emission of biodiesels:The increase of cetane number," INTERNATIONAL JOUR OF GREEN ENERGY, Vols. VOL. 13, NO. 9, 957–962, p. 1