Jurnal Teknik Mesin
Mechanical Xplore (JTMMX)
Mechanical Engineering
Vol. 3 No. 2 (2022) pp. 87-95
p-ISSN: 2746-0045 e-ISSN: 2746-3672

An Addition of Ethanol and Patchouli Oil on Pertamax: The Case Study of Their Effect on Exhaust Gas Emission for 4-stroke Engine

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ABSTRACT

Industrial sector has been focused on the transportation and automotive service due to their essential for many people in every daily life. Currently, almost everyone has a motorized vehicle which also has an effect on improving the country's economy. On the other hand, this raises concerns about the occurrence of a global warming phenomenon. The more motorized vehicles were extremely impact on increasing the exhaust gasses that also have a negative impact to the environment, including carbon monoxide (CO) and carbon dioxide (CO2). Hence, this work tried to reduce the exhaust gas emission through the addition of ethanol and synthetic additive, namely patchouli oil. This case study was conducted using pertamax fuel with octane number 92. We analyzed five different optimization sample that consisting of S1, S2, S3, S4, and S5. Then, the several characterizations also carried out to these samples for supporting the results obtained i.e. density, viscosity, and surface tension. Also, the variation of engine rotation speed (in rpm) is utilized to determine the performance or the impact of the samples made to the environment. The results indicate that the pertamax sample mixed with ethanol and patchouli oil showed an optimal performance in S5, there is no detect of CO emission. Then, S3 for the lowest emission of CO2. Also, S3 for the highest efficient in fuel consumption. Hoping this work has an extremely impact for the reducing an exhaust emission in fuels and increasing the energy efficient of internal combustion engines.

Keywords: *Ethanol, Exhaust Gas Emission, Patchouli Oil, Pertamax, 4-stroke Engine*

Article information:
Submitted: 23/10/2022
Revised: 31/12/2022
Accepted: 31/12/2022

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Type of article:
☑ Research papers
☐ Review papers

1. INTRODUCTION

Nowadays, several countries have boosted their economies by selling motorized vehicles at low prices and this has resulted in almost everyone owning a motorized vehicle, even more than three vehicles per household [1]. However, this case brought up the disadvantages for the environment. An uncontrolled vehicle number day by day will increase the emission of harmful gases and it causes global warming [2]. Hence, many people in every sector that consist of engineers or researchers have been focused on controlling the vehicles combustion due to their emission, including carbon monoxide (CO) and carbon dioxide (CO_2) [3]. They claim that the demand of vehicles in the public can not be reduced, but global warming can be overcome by focusing on developing fuel that does not cause harmful gases in emission [4]. It is in accordance with Ettefaghi's statement which also claims that developing fuels is the best method that can be considered for solving the problem. It no need modified the engine structures but can produce a good combustion quality [5]. These developing fuels can be conducted through the addition of bio-additives or referred to as biofuels.

Biofuel as an alternative energy can be used as a substitute to fossil fuels [6]. Biofuel that has been developed as a substitute for fuel at this time is a type of bioethanol [7], [8], [9]. Bioethanol was made by using biomass fermentation techniques from sugar cane [10], corn [11], cassava [12], and so on. Then, it is followed by the distillation processes. The utilization of bioethanol as a fuel is inseparable from its advantages, including in the economic sector and for environmental health. The use of bioethanol in the economic sector belongs to the development of rural areas, creating a job for job seekers, and growth of the agricultural sector. Then, for environmental health, the utilization of bioethanol will greatly impact the reduction of pollutants, emission of harmful gases that cause global warming, and for the renewable nature [13]. Further, the utilization of bioethanol as a fuel is caused by its properties that can reduce the harmful gases that are produced in exhaust emission, including the emission of CO_2. However, Celebi reported an increase in CO emission due to the addition of ethanol in fuels [14]. Therefore, further research is needed to reduce CO emissions. Some of researchers was adding an essential oil to the fuels. Several essential oils were used, including tea tree oil [15], pine oil [16], lemon peel oil [17], and soybean oil [18]. The essential oil was used due to their characteristics that have a highly oxygen content and lower viscosity that will improve the combustion of the engine [19], [20]. Moreover, the addition of bioethanol and essential oil also affected fuel consumption. As reported by Manigandan in 2020, the fuel has more efficiency of about 41% after the ethanol and essential oil was added [21].

Currently, the essential oil that many people are interest in is patchouli oil due to its characteristic As reported by Alfian in 2019, patchouli oil has a favorable impact on fuel economy through a higher oxygen content which comes from the compound that contains in patchouli oil [22]. However, it is conducted by mixture with pure fuel. Therefore, based on the previous explanation, this work will study a mixture of pure fuel, ethanol, and patchouli oil as an alternative fuel whis is expected to have efficient consumption. Pure fuel that used was pertamax. Hence, the aim of this study is to test the patchouli oil as a fuel mixture with ethanol and pertamax in reducing the emission of CO and CO_2. This study was tested using a 4-stroke engine to verify these fuels performance. Then, the variation of their mixture was prepared to investigate the optimal condition of patchouli oil as bio-additive in fuels. This test were conducted in various engine speed (1500 rpm, 2000 rpm, 2500 rpm, 3000 rpm, and 3500 rpm). The response expected for this study are reducing the exhaust emission and the efficiency of fuel consumption. Lastly, this study is expected to have an extreme impact on reducing the harmful gases that cause global warming and founding the renewable energy in fuel that has a good efficiency in consumption to applied in the future.

2. RESEARCH METHODOLOGY

This work was conducted according to the flowchart that shown in **Figure 1**. The experimental was specifically divided into two parts, i.e. physical-chemical characterization that consisting of density, viscosity, and surface tension, respectively for each fuel samples that prepared. Then, the second experiment is exhaust emission and fuel consumption testing that is conducted to analyze the efficiency of each fuel sample that is prepared.

1.1. Materials and equipment

This work was using three main materials that consist of pertamax with octane number 92, ethanol 96%, and patchouli oil. While the equipment was consisting of pycnometer and digital scales for the measurement of density. Then, the tube, ball, stopwatch, vernier callipers, and ruler was used for the measurement of viscosity. Furthermore, the surface tension measurement was done by using a set of surface tension equipment. The last, the main study of this research, it is the testing of exhaust emission and fuel consumption by using a set of gas analyzer and a set of dynamometer systems, respectively.

1.2. Physical-chemical characterization

This part was conducted to prove the characteristics of the samples that distinguished by a code of S1, S2, S3, S4, and S5. The different of every sample is their composition of pertamax, ethanol, and patchouli oil. The explanation of the differences in each sample code is shown in **Table 1**. Then, each sample were characterized to find out some characteristics of the samples that consisting of density, viscosity, and surface tension.

Firstly, the measurement of the density was adopted from an experiment that has been done by Junior in 2020 [23]. The measurement was carried out by using the pycnometer in two different conditions, it is in blank condition of pycnometer and with the materials or their mixtures in a certain volume. This condition respectively weighed to exhibited their weight in every conditions. Then, weight information that obtained was calculated using an Equation 1 to get the density of each sample.

Table 1. A code naming of the samples used.

Sample code	Explanations
S1	Pure pertamax
S2	The mixtures that consist of 70% pertamax and 30% ethanol
S3	The mixtures that consist of 70% pertamax, 25% ethanol, and 5% patchouli oil
S4	The mixtures that consist of 70% pertamax, 20% ethanol, and 10% patchouli oil
S5	The mixtures that consist of 70% pertamax, 15% ethanol, and 15% patchouli oil

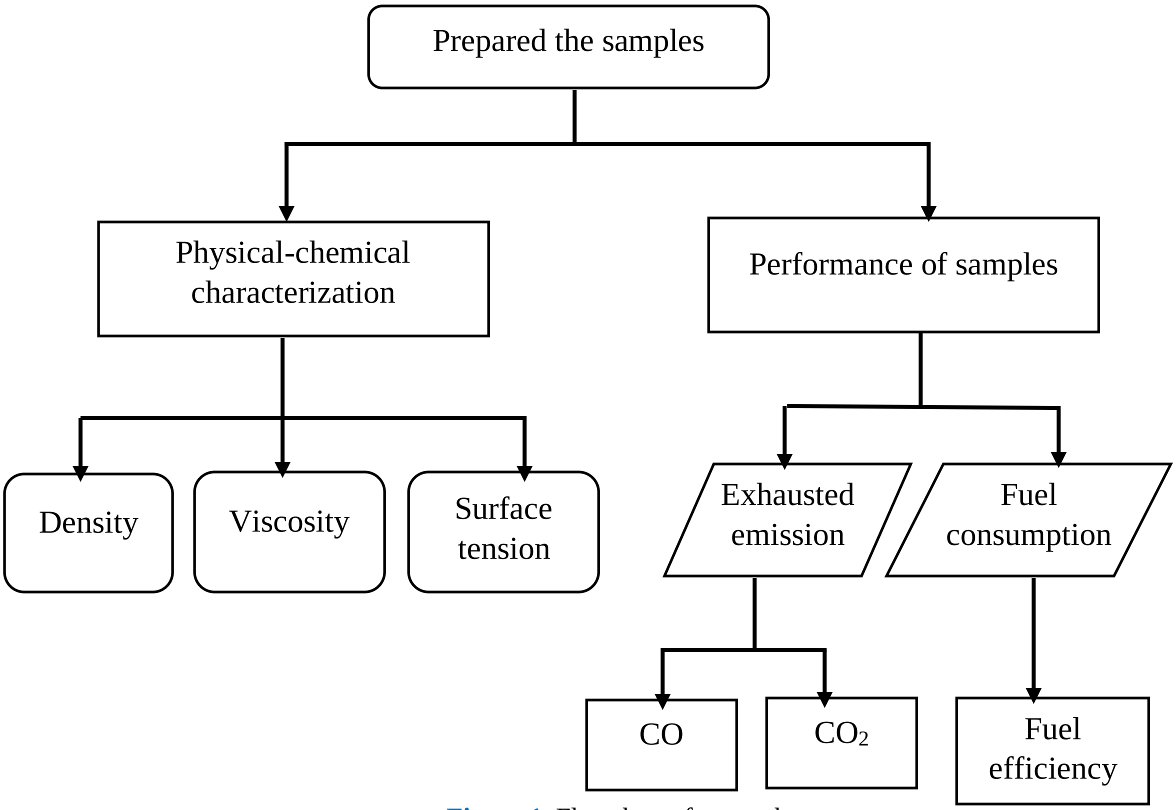

Figure 1. Flowchart of research.

$$\rho_{sample} = \frac{W_{p1} - W_{p0}}{V_s} \tag{1}$$

where ρ_{sample} is the density of each sample, W_{p1} is the weight of pycnometer with a certain volume of sample, W_{p0} is the weight of pycnometer in a blank condition, and V_s is volume of the sample.

Furthermore, the measurement of viscosity was conducted by using a falling ball method as illustrated in **Figure 2**. This method was adopted from an experiment that has been done by Ali in 2019 [24]. The procedure was starting with preparing a sample that consisted of S1, S2, S3, S4, S5 and measure with alternately. Put the sample into the tube and measure the height of the sample. This height value will be used for calculating the velocity of the falling ball. Then, the time of the falling ball is also measured using a stopwatch from the falling ball touching the surface until it reaches the base of the sample. With the assumption that the falling ball is having a uniform linear motion, the velocity was calculated by dividing the height value to the time of falling ball. Another variable also needed to calculate the viscosity is the density of samples, the density of ball, and the radius of ball. For the density of the sample obtained from the previous experiment that was explained and calculated using Equation 1, while the density of the ball obtained by dividing the mass value of the ball to volume of the ball.

After all the variables that are needed for the calculation were obtained, all the variable values were substituted to the Equation 2 [25],[26],[27], where η is the viscosity of the samples, v is the velocity of the falling ball, r is the radius of the ball, g is acceleration of gravity (in this experiment using 9.81 m/s^2) [28], ρ_b is the density of the ball, and ρ_f is the density of the samples. The density measurement also conducted to each main materials, it is pertamax, ethanol, and patchouli oil as a comparison.

$$\eta = \frac{2}{9v} r^2 g(\rho_b - \rho_f) \quad (2)$$

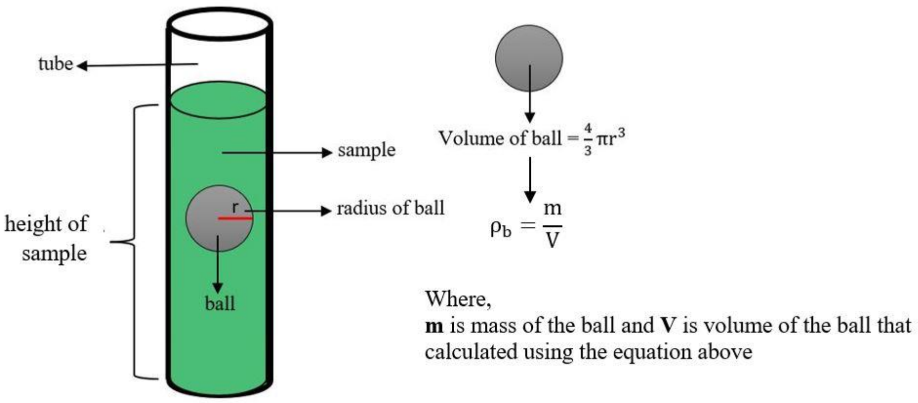

Figure 2. Illustration of falling ball method for the measurement of viscosity.

And the last characterization is the measurement of surface tension. This measurement was adopted from a study that has been explained by Estelle in 2018 and illustrated in **Figure *3*** [29]. The surface tension measurement was done via the ring method. This method was conducted by several steps to obtain some variables that are needed for the calculation, i.e. the tensile force, weight of the ring, and radius of the ring.

For the tensile force, it was obtained from the scale shown in the equipment when the ring was lifted. Then, the weight of the ring was obtained from the equipment specification and the radius of the ring was obtained from the measurement using vernier calipers. After all the variables are known, they all were substituted to the Equation 3 to obtain the surface tension.

$$\delta = \frac{F - F_R}{2\pi r} \quad (3)$$

where δ is the surface tension, F is the tensile force, F_R is the weight of the ring, and r is the radius of the ring.

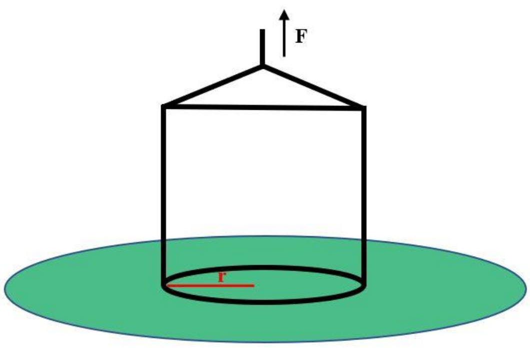

Figure 3. Illustration of ring method for the measurement of surface tension.

1.3. Exhausted emission and fuel consumption testing

This part was the main study of the research. Firstly, the testing of exhausted emission was conducted to analyze the content of exhausted gas and was limited to CO and CO_2 content only. This work was carried out using a set of gas analyzers. Secondly, the testing of fuel consumption was conducted to analyze the level of efficiency of the fuel used, and to find out the effectiveness of ethanol and patchouli oil addition to pertamax in fuel consumption. This work was carried out using a set of dynamometer systems. Then, both of testing was carried out to five samples of fuel that had been prepared as mentioned in **Table 1**. Every sample was tested at various rotation speeds of the dynamometer i.e. 1500 rpm, 2000 rpm, 2500 rpm, 3000 rpm, and 3500 rpm. This test occurred to verify the optimal condition of fuel between five samples that were prepared.

3. RESULTS AND DISCUSSION

The listed fuels that were prepared as samples were tested in physical-chemical characterization. This test was conducted to analyze the properties and their effect on the performance to be applied in a 4-stroke engine. Table 2 showed the physical-chemical characteristics of the samples that consist of density, viscosity, and surface tension. Furthermore, this work found that pertamax, ethanol, and patchouli oil have a different density, respectively 0.728 g/ml, 0.790 g/ml, and 0.940 g/ml. It informs that ethanol and patchouli oil have a higher density than pertamax. This means that the addition of additives in the form of ethanol and patchouli oil is able to change the density of pertamax. The density of pertamax was increased with the addition of ethanol and patchouli oil. The increase occurred from a density value of about 0.728 g/ml that obtained by S1 (pure pertamax) to 0.780 g/ml that obtained by S5 (the mixtures that consist of 70% pertamax, 15% ethanol, and 15% patchouli oil). Moreover, this work also carried out the viscosity measurement to find out the different characteristics of the samples prepared, including the main material fuels that consist of pertamax, ethanol, and patchouli oil. This test was informed that the viscosity values are 10.37 cSt, 9.87 cSt, and 19.02 cSt, respectively for pertamax, ethanol, and patchouli oil. Patchouli oil has a largest viscosity among pertamax and ethanol, consistent with the density measurement result that found patchouli oil also has a largest density among pertamax and ethanol as previously explained. The substance with a higher density will also have a higher viscosity due to their constituent molecules. However, from **Table *2***, it is known that the addition of ethanol to the pertamax was increased the viscosity, while the addition of ethanol and patchouli oil simultaneously decreased the viscosity of fuels. It has become a good thing and according to the statement that claims with Singh in 2020, a lower viscosity formed small droplets in atomization for proper combustion, and it also can improve the fuel consumption to be efficient [30]. Based on these explanations, it predicts that the addition of ethanol and patchouli oil will reduce the emission and obtain efficiency in fuel consumption.

Table 2. The characteristics of selected fuel that were prepared as the sample in this work.

Sample	Characteristics		
	Density (g/ml)	Viscosity (cSt)	Surface Tension (N/m)
S1	0.728	10.37	0.022
S2	0.752	11.74	0.022
S3	0.759	9.19	0.029
S4	0.777	7.62	0.029
S5	0.780	7.24	0.029

Then, the physical-chemical characterization that is conducted is surface tension. The first measurement is the surface tension of three main materials that consist of pertamax, ethanol, and patchouli oil, respectively 0.022 N/m, 0.025 N/m, and 0.041 N/m. The **Table *2*.** The characteristics of selected fuel that were prepared as the sample in this work., informs that the fuel composed from pertamax, ethanol, and patchouli oil has a higher surface tension than pure pertamax. It indicates that patchouli oil significantly increases the surface tension. Surface tension also has an impact on the emission and fuel consumption.

Moreover, to verify the performance of samples, five samples were prepared and mentioned in **Table *1***. A code naming of the samples used.. These samples were treated to obtain the CO and CO_2 emission that produce and also the fuel consumption. The result was informed that the CO emission was produced as shown in **Figure *4*a**, the higher CO emission was reached by S1 (pure pertamax), it is about 4.31%. It was tested at an engine speed of 3500 rpm. Then, the lowest was reached by S5 (the mixtures that consist of 70% pertamax, 15% ethanol, and 15% patchouli oil), it is 0% or it means that there is no detection of CO emission. Respectively, in the tested condition of engine speed in 1500 rpm and 3500 rpm. Then, for the CO_2 emission was shown in Figure 4b. **Figure *4*b.** This condition was tested in engine speed of about 3500 rpm and the CO_2 that produced of about 6.1%. While the lowest CO_2 emission was reached by S3 and tested at an engine speed of about 1500 rpm. It produced a CO_2 emission of about 2.3%. These results are in accordance with the physical-chemical characterization that measures and has been explained previously. It known that the addition of ethanol and patchouli oil were decreased the viscosity, and it is affected tio the reducing the CO and CO_2 emission.

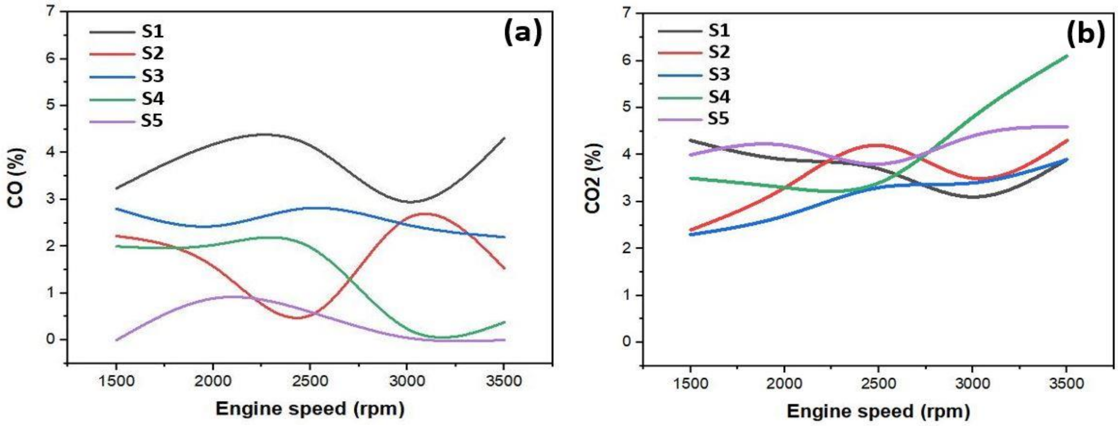

Figure 4. (a) CO and (b) CO_2 emission.

Figure *5* showed the fuel consumption of the samples. The increased graphic indicated that the samples were wasteful and it is caused by the lower oxygen content of the fuels. These conditions caused the combustion to occur rapidly. **Figure *5*** also inform that the S3 (The mixtures that consist of 70% pertamax, 25% ethanol, and 5% patchouli oil) has the highest efficiency than other samples. These results also provide information regarding the optimal conditions of the composition of the addition of ethanol and patchouli oil to pertamax in order to produce efficiency in fuel consumption. This finding showed that patchouli as a bioadditive has a good impact on environmental performance. This result is consistent with previous research [8-9].

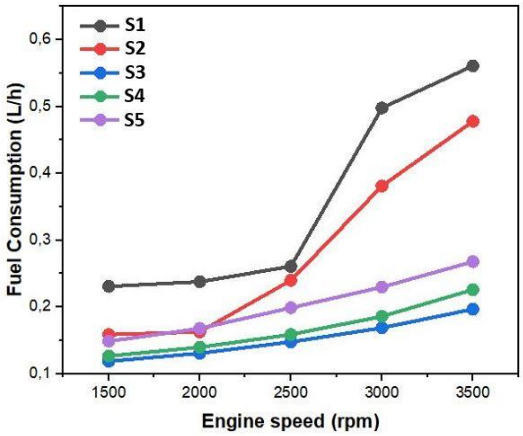

Figure 5. Fuel consumption of the sample's fuels.

4. CONCLUSION

An addition of ethanol and patchouli oil to the pertamax with octane number 92 has been conducted in five samples. The physical-chemical characterization was informed that pertamax that mixture with ethanol and patchouli oil has better properties, it shown from the lowest viscosity that indicate the higher content of oxygen. It also verified by the optimal condition of samples, that pertamax with mixture with ethanol and patchouli oil has a lowest CO and CO_2 emission, also has the highest efficiency in fuel consumption that reached by S3. Lastly, it concluded that ethanol and patchouli oil can reduce the emission of harmful gases like CO and CO_2 in the combustion processes.

AUTHOR'S DECLARATION

Author's contribution and resposibilities

The authors declare that every participant took an contribution and responsibilities to finishing this research. These parts were consisting of the design of study, data analysis, interpretation and discussion, also for final reading for the manuscript.

Acknowledgement

The authors would like to thankful for the financial support on carried out this research which provided by Jakarta Global University.

Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

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