POTENCY OF CLOVE OIL AND TURPENTINE OIL AS A DIESEL FUEL BIOADDITIVE AND THEIR PERFORMANCE ON ONE CYLINDER ENGINE

Asep Kadarohman[1], Hernani, Fitri Khoerunisa, Rizki Maryam Astuti

[1]Chemistry Education Dept., Indonesia University of Education

Abstract

Diesel is a efficient engine. But, beside its speciality as a efficient engine, diesel also has a lack about gases emission. Additive usually is added to diesel fuel to reduce this emission. The function of additive is increasing the fuel quality. The basic characteristic of additive has to increase the combustion quality by increasing fuel reactivity or supplying of oxygen internally. Clove oil and turpentine oil are Indonesian natural product which have a potential to use as a bioadditive because the compounds in clove oil have a lot of oxygen, and compounds in turpentine oil have a bulky structure. This experiment can give information about bioadditive potential was based on clove oil and turpentine oil which are applicated to the fuel for diesel engine, and then, it can be developed on a large scale. In generally, this experiment was done in three steps. First step is bioadditive characterization, second step is composition of diesel oil-bioadditive optimazed and diesel fuel-bioadditive characterization, and third step is diesel oil-bioadditive performance test on one cylinder engine in laboratory scale. The experiment shows the clove oil and turpentine oil can decrese fuel consumption flow and gases emission rate.

Keywords: *clove oil, turpentine oil, diesel fuel, bioadditive, engine*

INTRODUCTION

Road vehicle and industry which make use of a diesel engine are the main source of pollutant which make a high contribution to air pollution. This is caused the emission contains some dangerous constituens for environmental, such as smoke, carbonmonoxide (CO), NOx and SOx. But the using of diesel engine in road vehicle and industry is prefer, because it is economically.

Emissions of diesel engine are caused by the use of bad diesel fuel quality, so the combustion is incomplete. The incomplete combustion causes increasing of smoke, particulates and gases emission. Beside that, the incomplete combustion also causes the use of diesel fuel uneconomically, so the way to reduce this problems is needed.

This gases emission can be reduced with reformulation of diesel fuel by addition of additive. Additive is a material which can complete the fuel combustion process. In generally, reformulation of diesel fuel makes use of synthesis additive, but the synthesis additive must be reduced because it made of limited materials and its environment savety cant be guaranteed.

Quality parameter of diesel fuel is influenced by specific gravity, viscosity, anniline point and diesel index (Callahan, 1987). Song (2001) proposes that the oxygens in additive can increase cetana number, so the combustion will be completely. This is according with Choi experiment (1999) who proposes the oxygens in additive can oxidized particulates and carbonmonoxide (CO).

Essential oils are alternative material which have potency to use as a bioadditive, because essential oils have cyclic compound and oxygens in large number. The analysis of essential oils shows that essential oils contain of oxygen (Kadarohman, 2003), which can increase the combustion of diesel fuel efficiency. Beside that, essential oils have 10-20 of carbons (Sastrohamidjojo, 2004). This is approaching with amount of carbon of diesel fuel, which the main component of diesel fuel contains 16 carbons. It is very important, because the structure of essential oils can decrease the strength of Van der Walls bond in diesel fuel, and chain of carbon, so the combustion process will be effectively. Based on this assumption, reformulation of diesel fuel with bioadditive can increase the number of oxygen and reactivity of diesel fuel. Beside that, essential oil is natural product, so this reformulation can get a value on essential oils, decreases dependence upon synthetic additive, and makes environment more healty. Clove oil and turpentine oil are potential essential oils to use as a bioadditive because their characteristic can increase the reactivity of diesel fuel in combustion process.

Clove oil is obtained by steam destilation from fruits or leafs of clove (*Eugenia caryophyllata* Tumberg). The dry fruits contain about 18,32% of essential oil with 80,94% of eugenol, whereas the leafs contain 2,79% of essential oil with 82,13% of eugenol (Agusta, 2000). Eugenol has a bulky structure with two oxygens, so eugenol can increase its performance as a bioadditive of diesel fuel.

Clove oil has dark brown colour, but with the repeatedly distillation the colour of clove oil be comes yellow clearness. Clove oil has η at 20°C = 1,530, density at 30°C = 0,9994 (Guenther in Sastrohamidjojo, 2004). Compounds in clove oil are divided into two groups. First group is fenolat compounds and eugenol, and second group is nonfenolat compounds. Nonfenolat compounds are β-cariofilen, α-cubeben, α-copaen, humulen, δ-cadien and cadina 1,3,5-trien (Sastrohamidjojo, 2004).

Turpentine oil is usually called spirits of turpentine, volatile oil, obtained from gum of pine, colourless, has a specific smelling (Sastrohamidjojo, 1981). Gum of pine contains about 14,2% of essential oil (Agusta, 2000). Turpentine oil has density (at 20°C) = 0,860-0,875, η (at 20°C) = 1,465-1,478, and temperature of first destilation is 150-160°C at 80 mmHg (Silitonga, dkk in Sastrohamidjojo, 2004).

In Indonesia, turpentine oil is obtained from *merkusii Jungh et de Vr* pine with α-pinen (70-85%) as a main component, and the other component such as β-pinen, Δ-caren and δ-longifilen in small number (Sastrohamidjojo, 2004). The bulky structure of α-pinen can be used as a bioadditive of diesel fuel to optimalized the fuel combustion process.

MATERIAL AND METHODS

This experiment is done in three steps. The steps are:

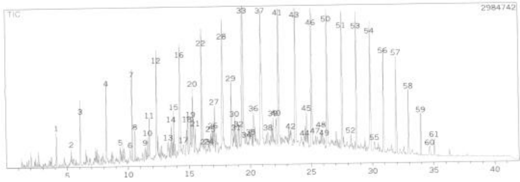
1. Bioadditive characterization
   In this step, diesel fuel, clove oil and turpentine oil are characterized using FTIR and GCMS spectrophotometer.
2. Physical characterization and composition of diesel fuel-bioadditive optimation.
   Physical characterization is obtained by specific gravity parameter, viscosity, anniline point, flash point, API gravity and diesel index. Data are compared with diesel fuel spesification of DIRJEN MIGAS. Optimum composition is determined by fuel consumption flow test in one cylinder engine (using KUBOTA engine).
3. Performance test in one cylinder engine
   Performance test is done in laboratory scale using one cylinder engine HATZ 677 cc 1D817, with testing parameters are fuel consumption flow and gases emission.

RESULT AND DISCUSION

Diesel Fuel And Bioadditive Characterization

In first step, characterization of diesel fuel, clove oil, and turpentine oil are done using GCMS and FTIR spectrophotometer. Clove oil comes from MITRA PALA MAS, Kampung Krajan Wanayasa, Purwakarta, and turpentine oil comes from PERUM Perhutani TPS Sindang Wangi Nagreg.

1. Diesel Fuel Characterization



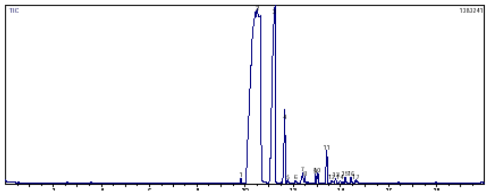
Picture 1. GC spectra of diesel fuel

GC analysis to diesel fuel shows that the diesel fuel contains 61 alkane compounds with the number of carbon is about 14-19.

Table 1. Some compounds in diesel fuel

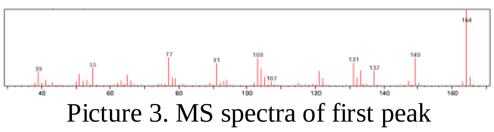
No	Molecular Formula	Name	Retention time (minutes)	Conc. (%)
1.	$C_{14}H_{30}$	Tetradekana	14,278	3,60
2.	$C_{15}H_{32}$	Pentadekana	16,071	4,18
3.	$C_{16}H_{34}$	Heksadekana	17,770	4,67
4.	$C_{17}H_{36}$	Heptadekana	19,428	9,28
5.	$C_{18}H_{38}$	Oktadekana	20,925	6,95
6.	$C_{19}H_{40}$	Nonadekana	22,363	5,03

2. Clove Oil Characterization

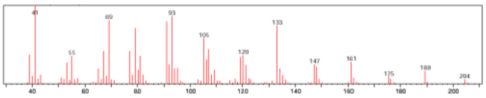


Picture 2. GC spectra of clove oil

Picture 2 shows two peaks in large concentration. First peak has concentration about 70,54% with retention time 10,515 minutes, and second peak has concentration about 21,54% with retention time 11,223 minutes. The MS analysis to peak 1 and 2 shows in picture 3 and 4.

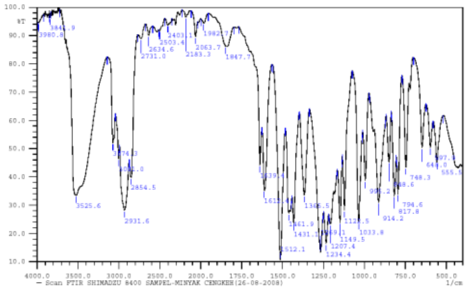


Picture 3. MS spectra of first peak



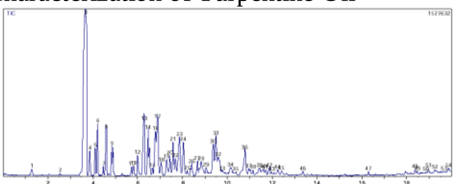
Picture 4. MS spectra of second peak

MS analysis shows that the first peak is eugenol, and second peak is cariofilen. Besides GCMS analysis, clove oil is analyzed using FTIR. The yield of IR analysis is showed in picture 5.



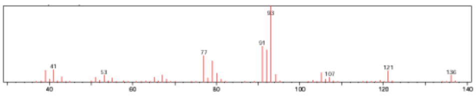
Picture 5. IR spectra of clove oil

3. Characterization of Turpentine Oil



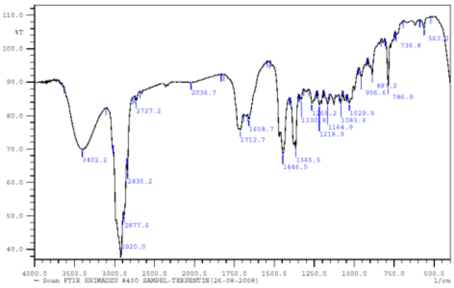
Picture 6. GC spectra of turpentine oil

GC spectra in picture 6 shows the highest concentration in turpentine oil is third peak (34,82%) with retention time 3,684 minutes. MS analysis to the third peak shows that this peak is alfapinen. Alfapinen is the main component of turpentine oil. The MS spectra of the third peak is showed in picture 7.



Picture 7. MS spectra of third peak

And IR spectra of turpentine oil is showed in picture 8.



Picture 8. IR spectra of turpentine oil

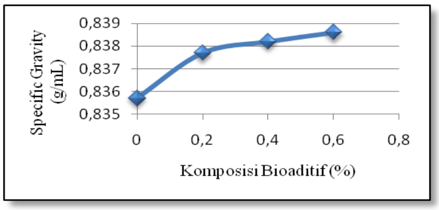
Physic Characterization and Composition Optimation of Diesel Fuel-Bioadditive

1. Diesel Fuel – Clove oil

Physic characterization of diesel fuel-clove oil is done in composition; 0%, 0,2%, 0,4% and 0,6%.

- Specific Gravity Determination at 25°C

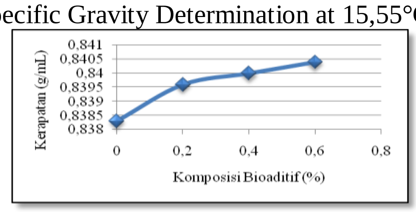
The influence of diesel fuel reformulation with clove oil to specific gravity is showed in picture 9.



Picture 9. Influence of diesel fuel reformulation with clove oil to specific gravity at 25°C

Diesel fuel with high concentration of aromatic compound has a big density. It can be proved by increasing of specific gravity in every bioadditive composition. The increasing of specific gravity is caused by reforming of the radius of hydrocarbon compounds in diesel fuel and by substitution of diesel fuel component with clove oil component which have different density. The increasing specific gravity will influence to viscosity and diesel index.

- Specific Gravity Determination at 15,55°C



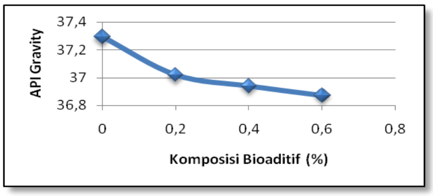
Picture 10. Influence of diesel fuel reformulation with clove oil to specific gravity at 15,55°C

In low temperature, specific gravity of diesel fuel-bioadditive is increasing. It is caused by the radius of molecule in diesel fuel be comes closer in low temperature.

Comparison of this specific gravity with DIRJEN MIGAS specification shows that specific gravity of diesel fuel-clove oil still complied with diesel fuel specification in DIRJEN MIGAS, which minimum specific gravity is 0,82, and maximum specific gravity is 0,87, so this bioadditive is savety.

- API Gravity Determination

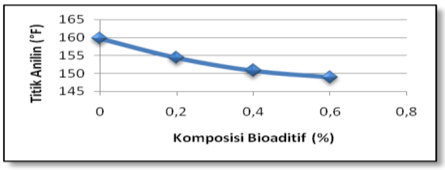
API gravity is conversion value from specific gravity in 15,55°C.



Picture 11. Influence of diesel fuel reformulation with clove oil to API Gravity.

- Anniline Point Determination

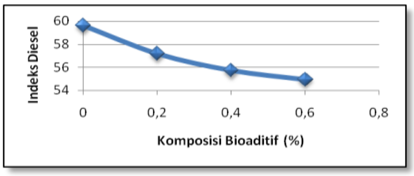
Aniline point shows containing of aromatic compound in diesel fuel. If aromatic compound in diesel fuel is in large number, so anniline point will decrease.



Picture 12. Influence of diesel fuel reformulation with clove oil to anniline point.

Addition of clove oil to diesel fuel causes the diesel fuel is easy to interact with the anniline in low temperature, because the clove oil contains aromatic compounds, so anniline point of diesel fuel-clove oil is decresing. But this anniline point is still in the upper minimum limit of DIRJEN MIGAS specification. The minimum limit of anniline point is 126,6°F.

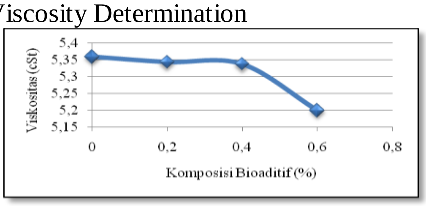
- Diesel Index Determination



Picture 13. Influence of diesel fuel reformulation with clove oil to diesel index.

Diesel index can determined from API gravity and anniline point. Picture 13 shows that addition of clove oil to diesel fuel gives decreasing to diesel index. The small diesel index indicates that diesel fuel can burn in high temperature. But this diesel index depends on diesel engine type.

- Viscosity Determination

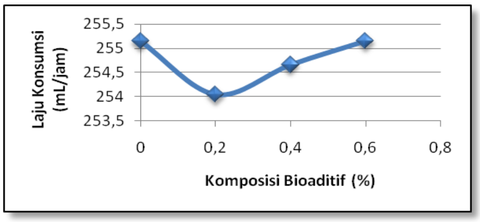


Picture 14. Influence of diesel fuel reformulation with clove oil to viscosity

Decresing of viscosity is caused by cyclic compounds in clove oil can change formation of hydrocarbon compounds in diesel fuel, so interaction in hydrocarbon compounds will be decresed. The viscosity of diesel fuel-clove oil still complied with DIRJEN MIGAS specification. The minimum limit of viscosity is 1,6 cSt, and maximum limit of viscosity is 5,8 cSt.

- Composition Optimazed of Diesel Fuel – Clove Oil

Optimation of diesel fuel-clove oil composition is determined by fuel consumption flow rate.



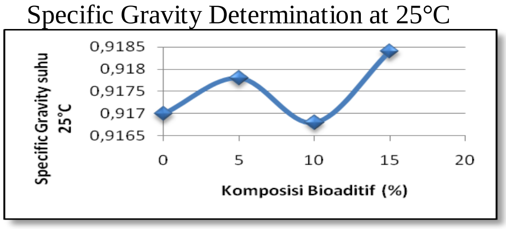
Picture 15. Influence of diesel fuel reformulation with clove oil to fuel consumption flow rate

Picture 15 shows that the optimum composition of clove oil is 0,2% with the fuel consumption 254,05 mL/hour. This phenomenon is in accord with physic characterization data.

2. Diesel Fuel – Turpentine Oil

Physic characterization of diesel fuel-turpentine oil is done in composition: 0%, 5%, 10% and 15%.

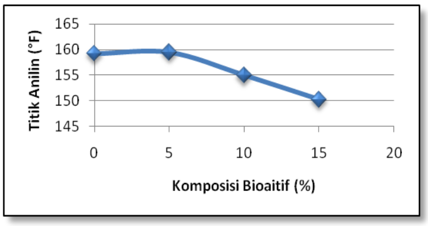
- Specific Gravity Determination at 25°C



Picture 16. Influence of diesel fuel reformulation with turpentine oil to specific gravity

In 10% of turpentine oil addition, specific gravity is lowest. The low specific gravity indicates in every once combustion process, mass of burning diesel fuel and the output of emissions will be small. If the specific gravity is compared, the specific gravity of diesel fuel-turpentine oil still complied with DIRJEN MIGAS specification (0,82 – 0,87), so the turpentine oil is savety to use as a bioadditive of diesel fuel.

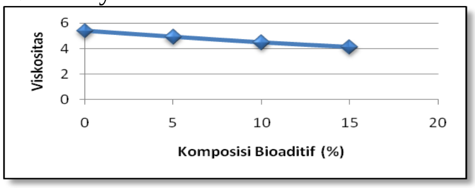
- Anniline Point Determination



Picture 17. Influence of diesel fuel reformulation with turpentine oil to anniline point

The decreasing of anniline point is caused by high contribution of aromatic compounds from turpentine oil. But this decreasing is still in the upper minimum limit of DIRJEN MIGAS specification (129,6°F), so turpentine oil can use as a bioadditive.

- Viscosity Determination

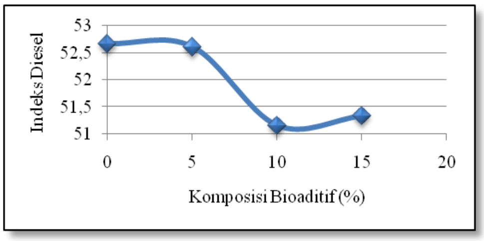


Picture 18. Influence of diesel fuel reformulation with turpentine oil to viscosity

The viscosity determination shows that reformulation of diesel fuel with turpentine oil causes decreasing of viscosity value. This decreasing gives advantageous for engine performances in fluidity and distribution of diesel fuel. Maximum fluidity will give ideal atomization in cylinder of engine. Beside that, the low viscosity makes a mobilization of diesel fuel easily, so continuation of combustion process can be kept. The other advantage is decreasing of fuel's crust in distribution pipe. Although this viscosity value is decreasing, but it still complied with DIRJEN MIGAS specification (1,6 cSt – 5,8 cSt).

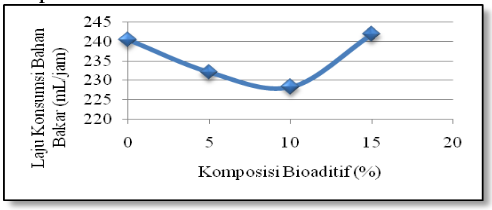
- Diesel Index Determination

Diesel index has correlation with viscosity and anniline point. A high viscosity and anniline point will increase diesel index of diesel fuel.



Picture 19. Influence of diesel fuel reformulation with turpentine oil to diesel index

- Composition of Diesel Fuel-Turpentine Oil Optimazed



Picture 20. Influence of diesel fuel reformulation with turpentine oil to fuel consumption flow rate

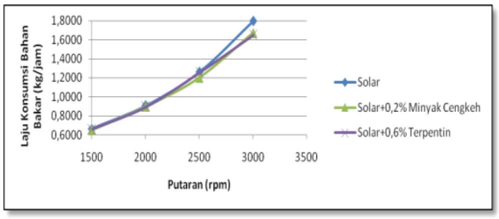
Graphic in picture 20 shows that the optimum number of turpentine oil composition is at 10% of bioadditive addition with the fuel consumption 228,28 mL/hour.

Diesel Fuel-Bioadditive Performance Test on One Cylinder Diesel Engine

1. Fuel Consumption Determination

The performance testing is done using one cylinder engine HATZ 677 cc 1D817 with torque and weight variation.

In this performance testing, the experiment uses clove oil in 0,2% composition, and turpentine oil 0,6%. The use of turpentine oil is different with the yield in composition optimation. It is caused in 5% addition of turpentine oil, the fuel combustion has decresed about 3,5%. It shows that the bulky structure of compounds in turpentine oil able to increase effectiveness of combustion process, so to test turpentine oil performance as a bioadditive, the experiment is done at 0,6% composition, in the hope of lower using of turpentine oil, the fuel consumption flow and gases emission can be reduced, and the use of bioadditive will be economically. The fuel consumption flow rate determination is showed in picture 21.

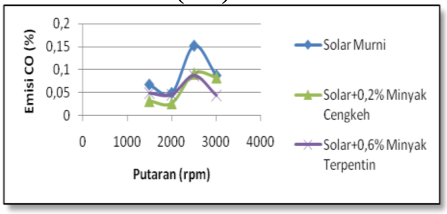


Picture 21. Fuel consumption flow rate of diesel fuel, diesel fuel-clove oil 0,2%, and diesel fuel-turpentine oil 0,6%.

At 2500 rpm, reformulation of diesel fuel with clove oil has a lowest fuel consumption flow rate. It proves that the bulky structure and oxygens in clove oil able to increase the combustion reactivity, with supplying of oxygen internally.

2. Gases Emission Determination

- Carbonmonoxide (CO)



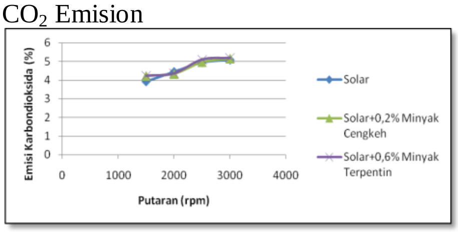
Picture 22. CO emission rate in combustion of diesel fuel, diesel fuel-clove oil 0,2%, and diesel fuel-turpentine oil 0,6%.

Addition of clove oil and turpentine oil can decrease CO emissions. In simplicity, the carbon is burned in two steps. First step is carbon converting to intermadiet product of CO, and second step is the next reaction of CO into CO_2. The reaction is showed in the below equation.

$$2C + O_2 \longrightarrow 2CO$$
$$2CO + O_2 \longrightarrow 2CO2$$

Ratio of air (oxygen) and diesel fuel determines the product of combustion. To reduce CO emission, the air should be superfluous. But clove oil can supplying of oxygen internally, and the bulky structure of compounds in turpentine oil able to increase the combustion reactivity, so the lack of air can be surpassed and the combustion will be completely. Beside CO, concentration of CO_2, hydrocarbon and smoke (particulates) also will be decreased automatically.

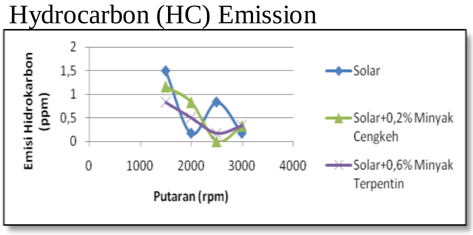
- CO_2 Emision



Picture 23. CO_2 emission rate in combustion of diesel fuel, diesel fuel-clove oil 0,2%, and diesel fuel-turpentine oil 0,6%.

The increasing of CO_2 concentration is caused by the next reaction of CO into CO_2.

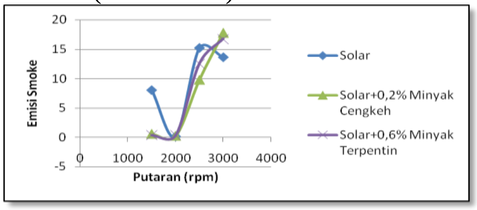
- Hydrocarbon (HC) Emission



Picture 24. HC emission rate in combustion of diesel fuel, diesel fuel-clove oil 0,2%, and diesel fuel-turpentine oil 0,6%.

At 2500 rpm, reformulation of diesel fuel by clove oil gives the lowest hydrocarbon emission rate. It is caused by the oxygens in clove oil give high contribution to complete the diesel fuel combustion process.

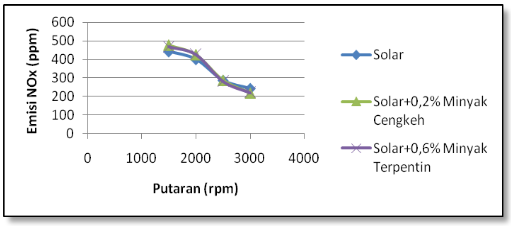
- Smoke (Particulates) Emission



Picture 25. Smoke (particulates) emission rate in combustion of diesel fuel, diesel fuel-clove oil 0,2%, and diesel fuel-turpentine oil 0,6%.

Particulates are yielded by residues of diesel fuel combustion. Graphic in picture 25 shows that the optimum of smoke emission decreasing rate for reformulation by clove oil and turpentine oil are at 1500 and 2500 rpm.

- NOx Emission



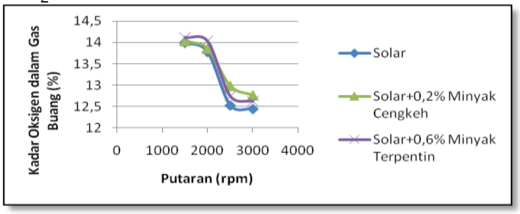
Picture 26. NOx emission rate in combustion of diesel fuel, diesel fuel-clove oil 0,2%, and diesel fuel-turpentine oil 0,6%.

Indicator of concentration of CO, HC and smoke decreasing can be seen from increasing of CO_2 and O_2 concentration. But it result in increasing of NOx. In generally, NOx emission concentration of diesel fuel-bioadditive is higher than the unreformulation diesel fuel. The increasing of NOx emission is caused by the use of air, so at high temperature, N_2 and O_2 will be react into NO.

$$N_2 + O_2 \longrightarrow 2\ NO$$

The next reaction of NO in the air will form into NO_2. The increasing of NOx is according with Klell theory (1998) who proposes that the decreasing of CO and HC emission rate will be followed with increasing of NOx concentration.

- O_2 Emission



Picture 27. O_2 emission rate in combustion of diesel fuel, diesel fuel-clove oil 0,2%, and diesel fuel-turpentine oil 0,6%.

Reformulation of diesel fuel with clove oil or turpentine oil give highest concentration of O_2 than the unreformulation diesel fuel. At 3000 rpm, clove oil has a better performance than turpentine oil. It is caused by containing of oxygens in clove oil able to increase diesel fuel reactivity.

CONCLUSION

1. Clove oil contains of eugenol (70,54%) as a main component. And turpentine oil has alfapinen as a main component about 34,82%.
2. Optimum composition of clove oil is 0,2%. And optimum composition of turpentine oil is 10%, but the composition still can be reduced.
3. In generally, clove oil and turpentine oil able to decrease the fuel consumption flow rate and CO, HC and smoke emissions.
4. The work of a clove oil and turpentine oil mechanism is by containing of oxygens, and the bulky structure of compounds inside the bioadditive.

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