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A Research on Specific Fuel Consumption and Emission Characteristics from Diesel Engines Used Palm Biodiesel

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Abstract— *Biofuels are mainly composed of bioethanol and biodiesel, biogas. In particular, biodiesel can completely replace diesel fuel based on similar properties of cetane value, specific calorific value ... and its environmental friendliness. Biodiesel is a liquid biofuel with similar properties and can be used as a substitute for conventional diesel oil. Tests using biodiesel (BDF) on internal combustion engines have also been conducted. The results of these tests show that BDF can be used on engines at any rate mixed with diesel fuel without changing engine structure. In addition, using BDF reduces harmful emissions into the environment such as CO, SO2, PM, CxHy .... [9, 10]. Emission factors of engine pollutants, combustion efficiency of fuel and engine power depend on BDF mixing ratio in fuel and engine load. Study to assess engine fuel consumption and ordinary emissions of palm oil biodiesel fuel (BDF palm oil) used on diesel generators. The experiments were performed at no-load and high-load mode with mixing ratios of BDF palm oil and diesel fuel (0%, 5%, 10%, 15%, 20%, 50%, 100% are equivalent to B0, B5, B10, B15, B20, B50, B100). Results showed that specific fuel consumption increased as volume of BDF palm oil increased in fuel. In idle mode, compared to diesel fuel, fuel consumption increased by 1.32%; 1.8%; 2.8%; 3.74%, 5.61%; 6.54% corresponding to B5, B10, B15, B20, B50, B100. In high load mode, fuel consumption increased by 1.51%; 1.86%; 2.18%; 4.78%; 5.36%; 6.76% corresponding to B5, B10, B15, B20, B50, B100 compared to diesel fuel.*

Keywords— *Particle emission, biodiesel, diesel engines, reduction of emissions.*

I. INTRODUCTION

Biodiesel is a liquid biofuel with similar properties and can be used as a substitute for conventional diesel oil. In the past time, with the goal of economical and efficient use of energy, minimizing the harmful emissions released into the environment, implementing the roadmap of applying the mixing ratio in biofuel according to Decision 53 / 2012 / QD-TTg of the government. There have been many ministerial and state research projects on the application and deployment of pilot application of mixing materials B5 (5% biodiesel + 95% normal diesel) and B10 (10% biodiesel + 90% conventional diesel) into transportation[1]. On average, from 2015 to 2018, harmful emissions released into the environment when using conventional diesel fuel are quite large, of which: CO is 1960.9 tons; NO_2 is 1018.19 tons; CO_2 is 262582.4 tons ... Testing and progressing the application of B5 and B10 fuels to HSR will reduce the amount of toxic emissions and replace exhausted petroleum and gas sources [2]. Moreover, many domestic and foreign scientific studies have shown that biodiesel is truly a clean green energy source because their use helps reduce emissions of serious pollutants such as CO, SO2, NOx, and CxHy compounds ...[3] However, the emissions from the combustion of biodiesel fuel in diesel engines of organic compounds are small but very toxic and affect the ambient air environment[4]. Around as carbonyl has not been fully studied in Vietnam and in the world.

Biofuels are produced from animal or plant-derived compounds such as animal fat, coconut oil, palm oil, grains (wheat, corn, soybean), agricultural residues (straw, corn stalks, beans), industrial waste (sawdust, waste wood). Compared to traditional fuels, biofuels have many outstanding advantages such as: no increase in branding greenhouse, reduce environmental pollution[5]. Moreover, biofuel sources are capable of regenerating from agricultural production activities, thus reducing dependence on traditional fuel sources that are unable to regenerate. Depending on the mode of production and the intended use, biofuels can be classified into the main categories: original vegetable oil and biofuel after processing. The extracted original vegetable oil is very simple, just go through the process of pressing oilseed nuts (palm, mustard seeds, sunflower seeds, sesame, peanuts ..), then filter out all the residue and the water is Can be used as a fuel. The first diesel engine first built by Rudolf Diesel in 1893 also runs on this fuel. Processed biofuels include biodiesel, biodiesel (ethanol) and natural gas (biogas). In these groups, bio-gasoline is commonly used for gasoline engines, biodiesel suitable for diesel engines[6].

In terms of structure, biodiesel has lower carbon content (C), sulfur (S) and water than diesel, but has more oxygen content in the component. Low carbon content will reduce CO, CO2 and soot emissions on the discharge road. The sulfur content is low and almost nonexistent, so it does not produce SO2, a gas that affects the respiratory tract, heart failure, pneumonia and causes acid rain. Oxygen components facilitate biodiesel to burn completely over diesel, reduce CO emissions and unburnt fuel (hydrocarbon-HC)[7].

Carbonyl compounds (CBCs - Carbonyl compounds) are organic compounds with a carbonyl functional group consisting of a carbon atom that is coupled to an oxygen atom. The simplest compounds of carbonyl groups are aldehydes and ketones. CBCs are considered toxic because they are capable of causing allergies or cancer in humans. Among them, formaldehyde, acetaldehyde, acrolein, propional dehyde and butanol have been listed by the US Environmental Protection Agency (USEPA) as toxic gases for human health[4]. Moreover, CBCs are also precursors that form ozone in the atmosphere [8]. Evaluation of carbonyl compounds emission from biodiesel diesel generator is conducted by the authors to provide a view more comprehensive emission of diesel engines using biodiesel to better manage air quality and promote research on carbonyl emissions[9]. The objective of this study is to assess dust emissions and emissions of CBCs in the emissions of diesel generators using palm oil as biodiesel fuel[10].

II. MATERIALS AND EXPERIMENTAL SETUP

A. Test Engine and Fuels

BDF palm oil used in the project was synthesized by a research team of the Department of Chemistry, Hanoi University of Science, Hanoi. BDF is synthesized by heat method with the effect of MeOH, KOH catalyst. The production process meets the BDF standard of Japan. The diesel fuel used in this research is commercial diesel fuel of 0.05% S. Mix BDF fuel and diesel fuel at the ratio: 0% (100% DO + 0% BDF), 5%, 10 %, 15%, 20%, 50%, 75% and 100% BDF. Stir the mixture at room temperature for 15 minutes at a speed of 500 rpm fueled by B0, B5, B10, B15, B20, B50, B75 and B100. The mixture is heated to eliminate emulsification, leave to stand for 1 hour, then store in a plastic can until testing. The volume of fuel mixture after mixing is 3 liters. The purity of BDF palm oil and some fuel properties are shown in Table 2.

Diesel engine generator (LAUNTOP LDG3600CLE) runs on a mixture of BDF and diesel fuel at no-load and high-load mode (80% of the total load). The emissions of these fuels are measured directly from the generator chimney. Concentrations of CO, CO2, SO2, NO, NO2 and CxHy were measured by Testo 360, model D - 79849 Lenzkirch, connected to CQ - Compaq 40 computer. CO, NO, NO2, SO2 in flue gas are measured according to the principle of 3-electrode probe. CO2 is measured by infrared probe. CxHy compound is measured by heat signal probe. Add fuel B0 and run the generator under idle for 10 minutes for the engine to run stably (stable CO and CO2 concentrations - the data is shown directly on computer). Next, we conducted a direct emission measurement from the engine with Testo 360 - D9849 Lenzkirch, Germany.

TABLE 1. Specifications of KDE3500T diesel engine

Parameters	Values	Unit
Frequency	50	Hz
Continuous power	2.8	kVA
Reserve power	3.2	kVA
Engine types	1-cylinder diesel engine, 4 stroke, direct fuel injection	
Bore x stroke	78 x 62	Mm
Piston displacement	0.269	L
Engine power	3.86	kW
Compression ratio	20:01	
Engine speed	3000	Rpm

TABLE 2. Properties of test fuels

Properties	Conventional diesel	Palm biodiesel
Heat value (MJ kg^{-1})	45.28	41.3
Cloud point (°C)	18	14
Density @ 15°C (kg/m^3)	853.8	867
Flash point (°C)	93	165
Pour point (°C)	12	15
Cetane Number	54.6	67
Kinematic Viscosity at 40 C (mm^2/s)	2.6	4.53
Sulfur content (mg/kg)	12	6
Carbon residue content (wt.%)	<0.01	<0.01

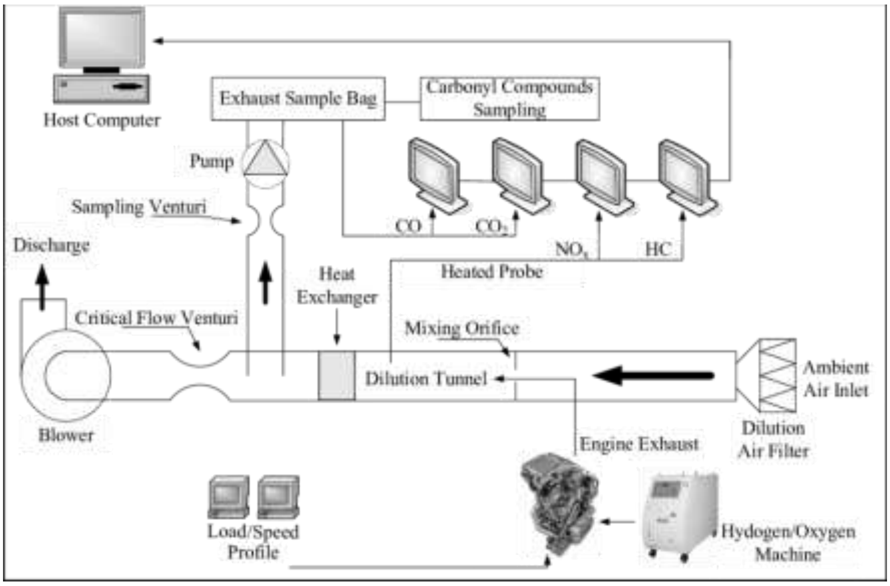

Fig. 1. Engine test bench for evaluating particulate emission characteristics

B. The Process of Sampling Emission Particles

Prepare filter paper: GF / C 47 mm glass fiber filter paper (47 mm filter paper diameter) Whatman - Japan, heated at 450 0C for 8 hours to remove organic matter. Then, the filter paper is wrapped in aluminum foil and placed in a desiccator for 48 hours. After dehumidifying, weigh the filter paper to determine the weight.

Preparing the cartridge: Using SiO2 cartridge - C18 has already prepared 2,4-DNPH of Waters, USA. Sampling: Add fuel and run the generator for 15 minutes to stabilize the

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engine.

The exhaust gas entering the sampling pipeline (the end of the pipe) is diluted 10 times with clean gas (the surrounding air has been removed impurities and moisture by silica gel column - activated carbon) in Teflon tubes. by Mass Flow Controller (MFC) as follows: first, use MFC control system to adjust the flow of clean gas to dilute (MFC 1) to 0.36 L / min and final flow Pipeline (MFC 2) is 0.4 L / min. The head pipe exhaust flow is the difference between MFC 2 and MFC 1 flow of 0.04 L / min, respectively. The dilution factor is the numerical quotient between the end pipe flow and the first pipe gas flow of 10. The exhaust gas temperature after dilution is 50 0C (to avoid the melting of DNPH). After 10 minutes, start turning on the suction pump to take the sample, first the exhaust gas after being diluted by clean air will then pass through a 47 mm diameter fiberglass filter paper to retain the total amount of dust present in the exhaust gas, after going through the exhaust air filter paper will go through ozone scrubber to remove ozone (to avoid the influence of ozone on compound 2,4 - DNPH and DNPH hydrazine derivatives), followed by carbonyl compounds in the waste gas will be retained in 2,4-DNPH impregnated cartridge, eventually exhaust after cartridge will go into the suction pump and exit. Sampling speed is 0.4 L / min, the sampling time is 10 minutes, the experiment is repeated 3 times.

C. Determination of Mass of Particle Emissions and Carbonyl Analysis

After sampling, the filter paper sample is doubled, wrapped in aluminum foil to avoid photochemicals and placed in a desiccator at room temperature for 48 h. Then, the filter paper is placed on the electronic scale to determine the amount of dust on the filter paper.

For the cartridge after sampling, it will be wrapped in aluminum foil, put in ziplock bag and stored at -4°C in a cooler, until analyzed. Carbonyl compounds adsorbed in SiO2 - C18 cartridge will react with 2,4 - DNPH in the cartridge to form stable derivatives of 2,4-dinitrophenylhydrazone. These derivatives will be eluted from the cartridge with 5 mL of acetonitrile and analyzed by high-pressure liquid chromatography of UV probes of Shimadzu (Japan).

In this study, the study focused on 15 carbonyl compounds: Formaldehyde (For), acetaldehyde (Acetal), acetone (Ace), acrolein (Acr), propionaldehyde (Pro), crotonaldehyde (Cro), butyraldehyde (But), benzaldehyde (Ben), valeraldehyde (Val), iso-valeraldehyde (iso-Val), o-tolualdehyde (o-To), m-tolualdehyde (m-To), p-tolualdehyde (p-To), hexaldehyde (Hex), 2.5– dimethylbenzaldehyde (2.5-Dim). These carbonyl compounds are chosen because they are potentially harmful to human health, typically five compounds of formaldehyde, acetaldehyde, acrolein, propionaldehyde and butanone are listed by USEPA as toxic pollutants.

III. Results and Discussion

A. Fuel Consumption and Discharge of Smoke

The discharge of flue gas from diesel generators is measured in Testo 512-2 (Germany), and the fuel consumption rate is measured by determining the volume of fuel consumed by the generator for a certain period of time. It can be seen that: for the fuel consumption rate of diesel generator (F) when increasing the blended biodiesel content, the fuel consumption rate of the machine at 1.5 kW load mode does not change. much (range from 10.72 mL / min to 13.40 mL / min). Besides, the discharge of flue gas from diesel generators (Q) has not changed significantly (ranging from 1.75 m3 / minute to 1.81 m3 / minute). From this, it can be concluded that when increasing the amount of biodiesel in fuel used to run diesel generators, the amount of emissions and fuel. The consumption of diesel engines has not changed much.

B. Total Amount of Particulate Emissions of Fuel

The emission of particulate matter (PM) consists of three main forms: soot, sulfate particles formed during combustion and high-volume hydrocarbons derived from fuel or shaped finished during combustion adsorption on soot. Emission dust of fuels B0, B10, B20, B30, B50, B75, B100 from diesel generator engines running at medium load conditions (1.5 Kw) is held by GF / C fiberglass filter paper 47 mm Whatman. The dust content of the emission is determined based on the weight of the filter paper before and after sampling. In total dust emission of diesel generators, dust concentration varies with each type of fuel, ranging from 168.59 mg / m3 to 522.98 mg/m^3.

It can be seen that the particulate emission concentration of B10, B20, B30, B50, and B75 is less than that of B0, but the dust emission concentration at B100 is larger than that of B0. In summary, PM emissions decrease when the rate of biodiesel increases from 0 to 20% in the fuel mixture and gradually increase when biodiesel rate increases from 20-100%. The cause of the change in dust emissions can be explained as follows: Biodiesel Fuel (BDF) is of biological origin so it does not contain aromatic hydrocarbons and sulfur compounds in its burning composition in the combustion chamber of diesel engines, biodiesel does not form sulfate and hydrocarbon particular. Therefore, in fuel mixes containing BDF (B10, B20, B30, B50, B75) dust emissions decrease compared to diesel fuel (B0). However, the viscosity of the fuel mixture increases in proportion to the percentage of BDF in the diesel and biodiesel mix. This has affected the fuel injection in the engine, thereby hindering fuel combustion in diesel combustion chambers and increasing dissolved organic compounds (solube organic fraction - SOF). adsorption on dust particles emitted by generators increases dust mass. That is why the concentration of dust begins to increase gradually from B30 onwards until it exceeds the dust concentration of B0 at B100. The results achieved in this study are similar to those of Yuan-Chung Lin and Charles Peterson. Lin and collaborators conducted a study to assess dust emissions from biodiesel oil palm oil on generators at a load of 75%, the results showed that compared to conventional diesel fuel, dust emissions decreased from fuel B10, B20, B30 respectively 51.0%; 21.4%; 4.6%, whereas dust emissions increased at B50, B75 and B100 at 10.9%; 26.9% and 29.3%. Similarly, the research results led by Charles Peterson showed that dust emissions of palm oil from rapeseed decreased by 6.08% at B20 and increased by 4.1% at B50, 16.8% at B100 compared

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to B0.

C. The Concentration of Carbonyl Compounds in the Emissions of Each Fuel

The total carbonyl concentration emitted in diesel emissions gradually increases as the proportion of biodiesel palm oil increases at 1.5 kW except for the fuel use regime at B50. Compared with B0, the increase is 28.61%; 45.75%; 48.49%; -3.24%; 50.49% and 50.58% correspond to B10, B20, B30, B50, B75 and B100 in 1.5 kW load mode.

This result can be explained by considering the carbonyl concentration from B0 to B30. For pure diesel fuel (B0), the formation of carbonyl compounds in engine exhaust is the result of incomplete combustion of hydrocarbon compounds in the fuel. Normally, when burning straight-chain alkane compounds (commonly found in fossil fuels) under oxidation conditions, these alkanes are in turn transformed into alcohols, carbonyl compounds, and then carbides. acid, then ester types and finally CO2. However, no engine with a combustion efficiency of 100% and therefore incomplete combustion of diesel fuel will produce a multitude of toxic compounds such as carbonyl compounds. As for the fuel mixes between diesel into biodiesel (B10, B20, B30) although in the city. The part of biodiesel does not contain carbonyl compounds and therefore in theory when BDF is burned, it will not produce carbonyl compounds, but as mentioned above the concentration of carbonyl increases gradually from B0. to B30. Therefore, the gradual increase of carbonyl compounds in engine exhaust at B10, B20 and B30 fuels compared to B0 is due to the combustion of ester compounds in biodiesel fuel because biodiesel fuel combustion is the process of cutting carbon vessels of ester molecules with long carbon chains into hydrocarbon compounds with shorter circuits and during the circuit breaker of the ester molecule (R1 – CO – O – R2) The C – O bond is the most frequently disconnected link during the circuit cut and forms carbonyl compounds (R1 – CHO). So burning ester molecules in biodiesel is the main cause of carbonyl emissions from biodiesel fuels.

Next is the explanation of carbonyl concentration in B50 fuel. The carbonyl concentration at B50 is the lowest compared to other fuel levels. The results of this study are similar to the results of the study from Hoang and colleagues. In which the fuel levels B0, B2, B5, B10, B20, B50, B75, B100 are studied in turn to investigate the change of carbonyl emissions. The results show that the B50 has the lowest carbonyl emissions (lower than carbonyl emissions at fuel B0) in all the studied fuels. This result can be explained by biodiesel fuel with high cetane index (Table 2) and oxygen content that exist more than diesel. Fuel with a high cetane index will reduce the delay time of the fuel in the engine and make the combustion process more radical, causing the emission content of the hydrocarbon compounds to decrease, and the high oxygen content. will help increase the efficiency of combustion and emission reduction. However, Only when B50, carbonyl content declines clearly, but in previous fuels (B10, B20, B30), there is a tendency to increase the carbonyl content of emissions. This can be explained as follows: when the ratio of mixing fuel reaches B50 (with 50% diesel and 50% biodiesel), it is enough biodiesel content in the fuel mixture to promote the burning process in a way more comprehensive and reduce carbonyl emissions.

Finally, the explanation of carbonyl emission concentrations at B75 and B100. Although the percentage of biodiesel fuels in B75 and B100 fuels is 75% and 100% (higher than B50), the carbonyl emission concentration of B75 and B100, which still follow the higher and higher trends. compared to the remaining fuels (as opposed to the B50 trend). The cause of this phenomenon is because the viscosity of BDF palm oil is larger than DO so when the ratio of BDF palm oil is high in the fuel mixture (B75 and B100), the viscosity of the fuel mixture is also High and affect fuel injection process of engine, making fuel burn more slowly than normal. This makes the combustion of the engine fuel incomplete and thus creates more emissions, especially the emission of carbonyl compounds. Research by Hoang and colleagues also showed an increase in carbonyl emissions compared to B50 when diesel engines operate in B75 and B100 fuels.

IV. Conclusion

The study carried out the measurement of normal air emissions of BDF palm oil with diesel fuel at the mixing ratio of 0%, 5%, 10%, 15%, 20%, 50% and 100% (corresponding to fuel). (B0, B5, B10, B15, B20, B50, B100) used on diesel generators in no-load and high-load mode. Through measurement results, the study draws some conclusions as follows:

Fuel consumption of the engine ranges from 6.45 to 7.35 mL / minute and from 19.35 to 21.65 mL / minute respectively in high idle and high-load mode. In both load modes, as the BDF mixing ratio increases in fuel, the engine's fuel consumption increases.

Measurements show that high concentrations of carbonyl compounds are formaldehyde, acetaldehyde and acetone. In particular, the formaldehyde, acetaldehyde and acetone compounds account for three quarters of the total carbonyl compounds emitted, the remaining 12 carbonyl compounds account for only 25% of the total carbonyl compounds emitted. Besides, the analysis results of carbonyl emission concentration showed an increase of 27.47%, 42.72%; 45.74%; -4.21%; 51.39% and 53.35%, respectively, with B10, B20, B30, B50, B75 and B100 compared to B0.

CxHy in the engine exhaust decreases as the BDF ratio in the fuel increases. In contrast, the concentration of CO2, NO and NO2 in the exhaust of the engine decreases. BDF palm oil is synthesized from vegetable oil so the molecule contains many oxygen elements and does not contain sulfur. Therefore, when burning in the engine, the fuel containing BDF will burn more completely and emit less CO, SO2. The NOx in the engine exhaust is derived from BDF and the oxidation of nitrogen in the air at high temperatures in the engine combustion chamber.

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