ISBN 2354-0575

RESEARCH ON THE EFFECT OF FUEL INJECTION TIMING TO EXHAUST COMPONENTS OF DIESEL ENGINE USING BIODIESEL B20 DERIVED FROM FISH FAT

Nguyen Manh Cuong[1], Tran Van Nam[2], Duong Viet Dung[2]
[1]*Hung Yen University of Technology and Education*
[2]*Da Nang University*

Received: 01/10/2016
Revised: 31/10/2016
Accepted for publication: 15/11/2016

Abstract:

In recent years, the human has faced the pollutant emissions from vehicle engines that became a serious environmental problem in the world. Therefore, the targeted developments for future vehicles are how to reduce fuel consumption, pollutant emission while maintaining high level of engine performance. To deal with those issues, Bio-fuel has been greatly considered by scientists for a long period of time. Biodiesel is a renewable fuel produced by a chemical reaction of alcohol and vegetable or animal oils, fats, or greases. Biodiesel can be used as a 20% blend in most diesel equipment with no or only minor modifications. This paper presents summarized findings of utilization of biodiesel with 20% blend (B20) based fish fat in conventional diesel engines. Targeting this, The Mazda WL was used as an object for the application of dual fuels (diesel and biodiesel) conversion. Experimental were tested under standard conditions and part load conditions from 1000 rpm to 3000 rpm, respectively. Exhaust emissions of engine were investigated in this paper. Experimental results indicated that analysis on engine exhausted gas showed the decrease of CO, HC and %OPAC emissions. In addition, the engine using B20 fuel with $1^0 \div 3^0$ earlier advance injection timing compared to original one gives better results than the engine used traditional diesel fuel (DO) and B20 fuel without changing the advance injection timing.

Keywords: *Biodiesel B20, Diesel, Exhaust components, Fish fat, Advance injection timing.*

1. INTRODUCTION

Fresh fuel to come out two major issues of globalization. First, fossil fuels from increasingly scarce and incapable of regeneration leads to world hunger always fall in energy; second by renewable of fossil fuels is difficult to emissions from the engine will cause serious pollution to the earth specifically cause the greenhouse effect of CO_2, SO_x, NO_x cause acid rain, puncture ozone, CO, soot, soot, unburned hydrocarbons etc. cause respiratory illness, especially aromatic hydrocarbons unburned cause cancer. So in today's world the kind of research and application of bio-fuel alternative to traditional diesel fuel oil (DO) is imperative. Accordingly, several studies have found that diesel engines can run successfully with biodiesel and engine performances are compared with mineral diesel. Some studies have reported increased thermal performance effectively for diesel engines using bio-fuels, [9÷14]. Several other studies also indicate that the use of biodiesel as a fuel in engines can significantly reduce toxic emissions such as CO, HC and smoke, but increases NOx components [5, 6]. There have been a lot of research and application of biofuels has been published on the world in general and Vietnam in particular. The research related to biofuels as the ability of biofuel applications in internal combustion engines [1]. Research and development of biofuels and compare the characteristics with conventional fuels for diesel engines use [2, 3]. Studies on modulation of biofuels, fuel use are also mentioned [4]. Besides studying the possibility of using biofuel also studies comprehensive emissions of these fuels [7, 8]. In Vietnam there have been intensive studies for each type of biofuel [8]. The team led by Dr. Lam Son Ho - Institute of Materials Science City. Ho Chi Minh City Institute of Science and Technology VN - lead and assert qualified researchers produce biodiesel (Biodiesel) from vegetable oils in Vietnam. There have been a lot of research and application of biofuels has been published on the world in general and Vietnam in particular. The use of biodiesel in the engine can cause a number of problems related to incompatible materials, lube oil dilution, the apparatus of the fuel injection system and exhaust gas treatment equipment. To minimize the impact may occur and ensure the longevity of the engine manufacturers typically limited to using biodiesel blends at low levels. Comparison of the main characteristics of biodiesel and diesel are shown in Table 1.

Table 1. *Comparison of the main characteristics of biodiesel and diesel.*

Fuel Properties	Diesel	Biodiesel
Fuel Standard	ASTM D975	ASTM D6751
low heat value, Btu/gal	~ 129 050	118 170
Kinematic viscosity @ 40^0C	1,3 -> 4,1	4,0 -> 6,0
Density, lb/gal @ 15^0C	7,079	7,328
Water content , % volume	0,05 max	0,05 max
C content, % mass	87	17
H content, % mass	13	12
O content, % mass	0	11
Sulphur max. % mass	0,05 max	0 -> 0,0024
Boiling Point, ^0C	180 -> 340	315-> 350
Flash Point, ^0C	60 –> 80	100 -> 170
Cloud Point, ^0C	-15 -> 5	-3 -> 12

(ASTM: American Society for Testing and Material)

This paper presents the results of comparison of the exhaust components of conventional diesel engines using biodiesel B20 and traditional diesel fuel (DO) made in the laboratory combustion engine of **University of Technology - Da Nang University.**

2. Experiment apparatus and procedures

2.1. Characterization of biodiesel fuel used for experiments

Fuel used for this study consists of two types: biodiesel B20 (20% biodiesel and 80% mineral diesel) derived from Basa fish fat and traditional diesel fuel: In this study, selected materials for the synthesis of biodiesel as fish fat by Agifish - An Giang offer. We have carried out a number of targets identified quality and fatty acid composition of this material. Specific data had given in Table 2 and 3.

Table 2: The composition of fatty acids in fish fat

Fatty acids	Formula	Notation	Content, %
Acid palmitic	$C_{16}H_{32}O_2$	$C_{16:0}$	27
Acid linoleic	$C_{18}H_{32}O_2$	$C_{18:2}$	10
Acid oleic	$C_{18}H_{34}O_2$	$C_{18:1}$	41
Acid stearic	$C_{18}H_{36}O_2$	$C_{18:0}$	6
Acid myristic	$C_{14}H_{28}O_2$	$C_{14:0}$	5

Analysis results show that fatty acid compositions of fish fat are very complex, with many different types of acids from C_{12} - C_{22}. However, they contain a number of key acid (containing large) indicated on table 2 and 3 and contains more unsaturated acids.

Table 3. Properties of fish fat

Properties	fish fat

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Acids number, mg KOH/g	3,60
Soap number, mg KOH/g	198,0
Iodine number, g I2/100g	88
Kinematic viscosity @40ºC, Cst	54
Viscosity	0,88
Cloud Point, ºC	25
Saline content, % mass	0
Water content , % volume	0,45
solid residue content, % mass	5,3
Colour	light yellow
Odor	Fishy, smelly

2.2. Experiment engine

The experiments were carried out with a Mazda WL-Turbo engine 4 cycles, 4 cylinders. Rated power of 85kW at 3500 rpm (rev / min); compression ratio ε = 19.8; 93mm diameter cylinder; Stroke 92mm. On full engine mounted sensors to record the parameters of the engine while working as pump fuel pressure before high pressure, fuel pressure on high-voltage lines, intake air pressure, exhaust pressure in the cylinder, the lift injectors, drill holes for the camera and lights etc. are shown in table 4.

Table 4. Engine Specifications

Engine Type	MAZDA WL
Cylinder No.	4
Bore x Stroke	93mm ×92mm
Compression Ratio	19,8
Net power	85 kW
number of revolutions	3500 rpm
Number of stroke	4
injection angle	10ºBTDC
Intake Valve Open*	40ºBTDC
Intake Valve Close*	50ºABDC
Exhaust Valve Open*	50ºBBDC
Exhaust Valve Close*	40ºATDC
Valve System	3 valves/cylinder
Fuel injection pressure (start)	114 - 121 bar
idling speed	700 ± 20 rpm
lubricating pressure at 3000 rpm	4,02 - 4,8 bar

2.3. Engine experimental method

The schematic diagram of the experiment setup is shown in Figure 1 and 2.

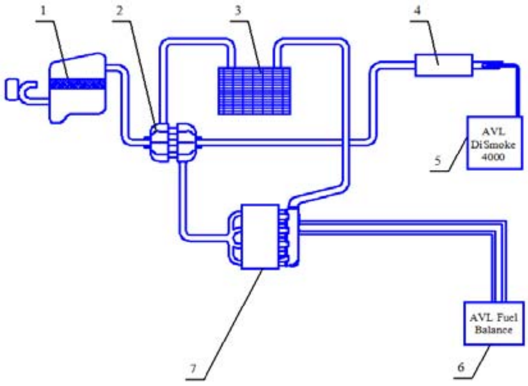

Figure 1. *Layout of the experiment*
1. Air filter; 2. Turbo; 3. Radiator cooler; 4. Three-ways catalytic converter (for ather experiment); 5. Exhaust measurement; 6. Fuel consumption measurement; 7. Engine

Figure 2. *Schematic diagram of experiment setup*

2.4. Experimental conditions

- The experiments using B20 biodiesel tested at two conditions: the rotation speed and load equivalent to the value of used vehicles.

1. Runs Mazda WL test engine with diesel fuel market and biodiesel B20:
- At 30% TPS (Rack position opening of the rack position sensor (%)) with speed range from 1000 ÷ 2500 rpm
- In the part load is 50% TPS with a speed range from 1000 ÷ 3000 rpm

2. In turn fuel change and spray soon as follows:
- B20 fuel injection with the initial angle denoted B20;
- Spray angle sooner or later than the initial spray angle 2 degrees, denoted B20-2º;
- Spray angle spray pattern sooner than the original one, denoted B20 +1^0;
- Spray angle sooner than 3 degree angle of the initial injection, denoted B20 +3^0;

ISBN 2354-0575

- Spray angle sooner than the initial spray angle of 5 degrees, denoted B20 $+5^0$.

3. Results and discussion

3.1. Hydrocarbon (HC) emissions

The results of Hydrocarbon (HC) emissions vs. engine speed at 30% and 50% TPS (Rack position opening of the rack position sensor (%)) shown in the Figures 3 and 4 respectively.

At 30% TPS, HC percentage in engine used DO and B20 is similar. But it reduces 60,0%, 45,3% and 53,3% in engine used B20+1^0, B20+3^0 and B20+5^0 respectively compared with using DO because of following reason. When advanced injection angle is increased, the burning process is good in accordance with high xetan number fuel B20, retarded burning time is shortened in order to reduce HC.

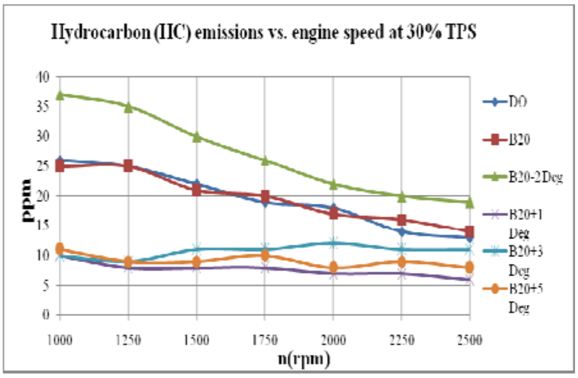

Figure 3. *Hydrocarbon (HC) emissions vs. engine speed at 30% TPS*

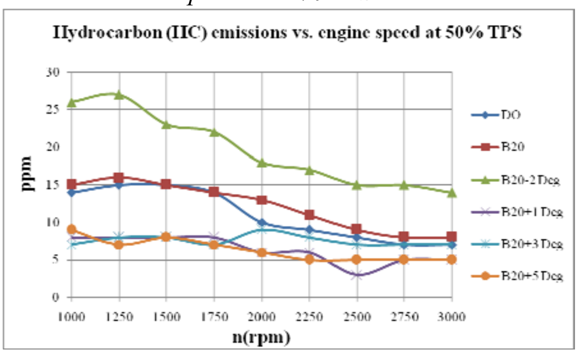

Figure 4. *Hydrocarbon (HC) emissions vs. engine speed at 50% TPS*

However, when injection angle is too advanced, injected fuel can stick on the combustion chamber surface and long burning time can generate HC. When advanced injection angle is reduced (2^0 smaller than initials), fuel is injected retard, burning process is lengthened to expanding stroke where burning condition is not good in order to generate incomplete burned HC. At 50% TPS, HC percentage in engine used B20+1^0, B20+3^0 and B20+5^0 reduces 42,4%, 31,3% and 42,4% respectively compared with using DO. But it increases 78,8% and 10,1% in using B20-2^0 and B20 compared with using DO.

3.2. Smoke opacity percentage (% OPAC)

The results of Smoke opacity percentage (% OPAC) vs. engine speed at 30% and 50% TPS (Rack position opening of the rack position sensor (%)) shown in the Figures 5 and 6 respectively.

At 30% TPS, opac percentage is increased 178,1%, 129,7%, 10,2%, 32,4% and 333,2% in engine used B20-2^0, B20, B20+1^0, B20+3^0 and B20+5^0 respectively compared with using DO. It is caused by high density and viscosity of B20.

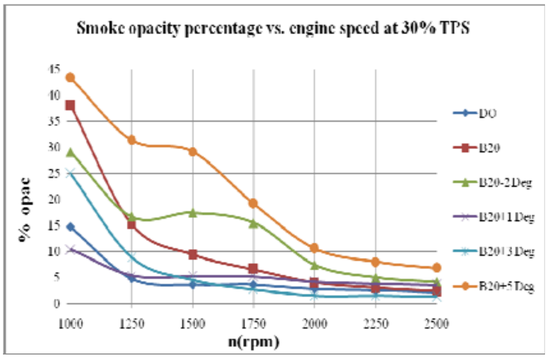

Figure 5. *Smoke opacity percentage (% OPAC) vs. engine speed at 30% TPS*

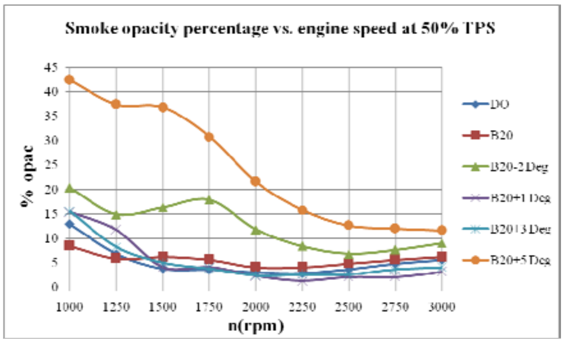

Figure 6. *Smoke opacity percentage (% OPAC) vs. engine speed at 50% TPS*

When using B20 at different injection angle, opac percentage is lowest in using B20+1^0. However, at 1750-2500 rpm revolution, opac percentage is lowest in using B20+3^0. When using B20 with advanded injection angle at 1^0-3^0

ISBN 2354-0575

(compared with initial angle), opac percentage is reduced compared with using B20. It can be explained by better air/fuel mixture. When advanded injection angle is changed in order to increase injection pressure, fuel is injected well in order to have better air/fuel mixture to be burned completely and reduce opac percentage. However, if advanded injection angle is too high (50 higher than initials), injection pressure is reduced, fuel is not injected well, so the air/fuel mixture is not constant, the opac is generated.

At 50% TPS, opac percentage is similar in engine used DO, B20+1^0 and B20+3^0, but it increases 7,9% in using B20 compared with using DO. It increases 140,9% and 371,2% in using B20-2^0 and B20+5^0 compared with using DO. At engine speed 2000-2500 rpm, opac percentage is lowest because of good burning process. And in engine used B20-2^0 and B20+5^0, air/fuel mixture is not constant and burning condition is not good.

3.3 Carbon monoxide (CO) emissions

The results of Carbon monoxide (CO) emissions vs. engine speed at 30% and 50% TPS (Rack position opening of the rack position sensor (%)) had shown in the Figures 7 and 8 respectively.

At 30% TPS, the lowest CO percentage is in engine used B20+3^0, followed by B20+1^0, B20, DO; it is higher slightly in the engine used B20-2^0 and B20+5^0 compared with using DO. It decreases about 20% and 25% in the engine used B20+1^0 and B20+3^0 respectively compared with using DO. And 5% decreasing is in the engine used B20 compared with DO. This can be explained by B20 characteristics, oxygen component in the biodiesel and high xetan number shorten retarded burning time in order to reduce CO.

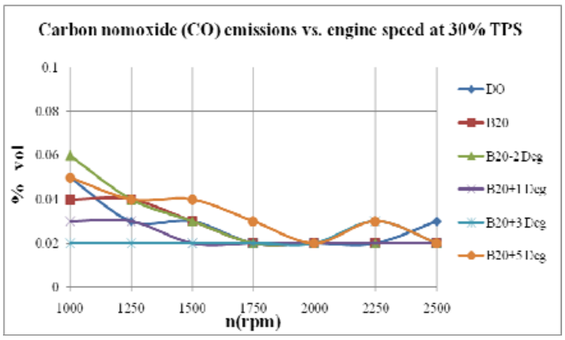

Figure 7. Carbon monoxide (CO) emissions vs. engine speed at 30% TPS

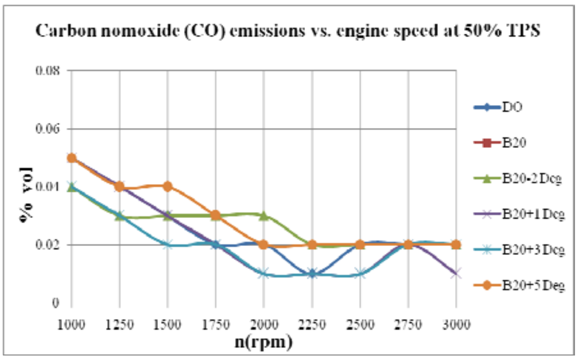

Figure 8. *Carbon monoxide (CO) emissions vs. engine speed at 50% TPS*

CO emission is reduced in engines used B20+1^0 and B20+3^0, but it is increased in engine used B20-2^0 and B20+5^0 because of following reason. When advanced injection angle is increased (5^0 higher than initials), the retarded burning time is lengthened, the mix of fuel amount and high extra oxygen amount makes it difficult to burn in order to generate CO. When advanced injection angle is reduced (2^0 smaller than initials), lengthen burning time on expanding stroke and bad burning condition and uncompleted burning fuel generate CO.

At 50% TPS**,** the CO percentage is lowest in the engine used B20+3^0, followed by B20+1^0, B20, DO. CO emission in engine used B20-2^0, B20+5^0 increase 4,3 % and 13% respectively compared with using DO. It reduces 21,7 %, 13% and 8,7 % in engine used B20+3^0, B20+1^0 and B20 compared with using DO. This can be explained by better burning process and complete burned fuel.

3.4. Carbon dioxide (CO_2) emissions

The results of Carbon monoxide (CO) emissions vs. engine speed at 30% and 50%, (Rack position opening of the rack position sensor (%)) had shown in the Figures 9 and 10 respectively.

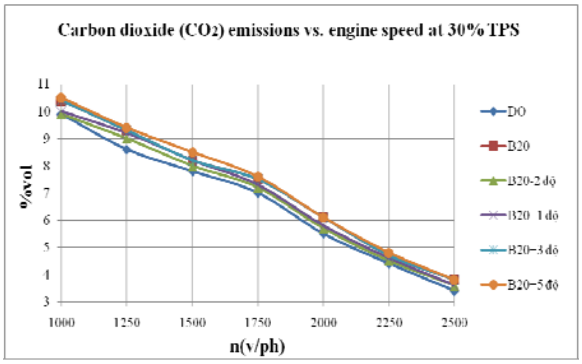

Figure 9. *Carbon dioxide (CO_2) emissions vs. engine speed at 30% TPS*

Carbon dioxide (CO_2) is formed during combustion of hydrocarbon and reversible reaction between CO and CO_2. When fuel burns completely, the Carbon in the fuel completely transforms CO_2.

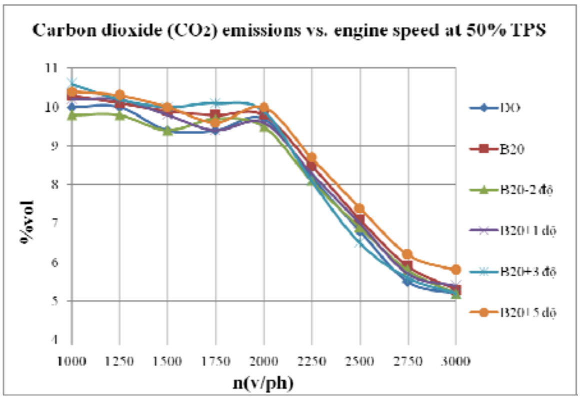

Figure 10. *Carbon dioxide (CO_2) emissions vs. engine speed at 50% TPS*

At 30% TPS, the results in the Figure 8 shows the concentration of CO_2 decreases with increasing number of revolutions (engine speed). When using B20 fuel with different advanced injection angles increase in CO_2 emission levels than when using the DO. Specifically, there are the B20-2^0, B20, B20+1^0 and B20+3^0 and B20+5^0 with CO_2 emission level of 2.8%, 7.3%, 4.5%, 7.3% and 8.8%, respectively. CO_2 emission level increase is explained for better combustion process. But the amount of CO_2 which can be absorbed easily greenery thus CO2 levels are kept in balance.

At 50% TPS, the results in the Figure 9 shows that when using B20 fuel with different advanced injection angles increase in CO_2 emission levels than when using the DO. Specifically, there are the B20-2^0, B20, B20+1^0 and B20+3^0 and B20+5^0 with CO_2 emission level of 0%, 3,4%, 1,9%, 2,7% and 5,7%, respectively.

4. CONCLUSIONS

The researching results lead to conclusion. Using biodiesel B20 based on Basa fat fish on the engine Mazda WL can ensure engine efficiency such as torque, exhaust emissions and fuel consumption. However, it does not meet the requirement of engine emission unless using some effective improvements.

Diesel engine on Mazda WL using B20 based on Basa fat fish needs to be changed advanced injection angle.

Engine using B20 with higher advanced injection angle (1^0-3^0 higher than initials) gives better result compared with using DO and using initial advanced injection angle.

The future works can be defining optimal advanced injection angle in conventional diesel engine using biodiesel.

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NGHIÊN CỨU VỀ ẢNH HƯỞNG CỦA GÓC PHUN NHIÊN LIỆU TỚI THÀNH PHẦN KHÍ XẢ CỦA ĐỘNG CƠ DIESEL KHI SỬ DỤNG NHIÊN LIỆU SINH HỌC B20 CÓ NGUỒN NGỐC TỪ MỠ CÁ

Tóm tắt:

Trong những năm gần đây, con người đã phải đối mặt với ô nhiễm môi trường từ khí thải động cơ đốt trong và đã trở thành một vấn đề môi trường nghiêm trọng trên thế giới. Do đó, sự phát triển cho các loại xe tương lai đều nhắm mục tiêu làm thế nào để giảm mức tiêu thụ nhiên liệu, khí thải gây ô nhiễm, trong khi duy trì mức độ cao về hiệu suất động cơ. Để đối phó với những vấn đề này, nhiên liệu sinh học đã được các nhà khoa học cân nhắc rất nhiều trong một thời gian dài. Nhiên liệu sinh học là một loại nhiên liệu tái tạo được sản xuất bởi một phản ứng hóa học của rượu và các loại dầu thực vật hoặc động vật, chất béo, hoặc mỡ. Nhiên liệu sinh học có thể được sử dụng với tỷ lệ pha trộn 20% cho động cơ diesel không có hoặc chỉ thay đổi một chút về kết cấu. Bài báo trình bày tóm tắt kết quả của việc sử dụng nhiên liệu sinh học có nguồn ngốc từ mỡ cá với tỷ lệ pha trộn 20% (B20) dùng cho động cơ diesel thông thường. Hướng tới mục tiêu này, động cơ Mazda WL đã được dùng cho thực nghiệm sử dụng nhiên liệu kép (diesel và biodiesel sinh học) chuyển đổi. Thực nghiệm đã được thực hiện trong điều kiện chuẩn và chế độ tải nhỏ tại số vòng quay từ 1000 rpm đến 3000 rpm, tương ứng. Khí thải của động cơ cũng đã được nghiên cứu trong bài báo này. Kết quả thí nghiệm nhằm phân tích về khí thải động cơ cho thấy sự sụt giảm của CO, HC và % OPAC (độ khói). Ngoài ra, động cơ sử dụng nhiên liệu B20 với góc phun sớm $1^0 \div 3^0$ hơn so với góc phun ban đầu cho kết quả khí xả tốt hơn so với động cơ sử dụng nhiên liệu DO và B20 mà không thay đổi góc phun sớm.

Từ khóa: *Biodiesel B20, Diesel, Thành phần khí xả, Mỡ cá, Góc phun sớm.*