TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 9
Number 4
December 2015
DOI: 10.12716/1001.09.04.08

A Study on applying the Catfish Biofuel in The Mekong Delta for The Marine Diesel Engine

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ABSTRACT: The manufacturing of Catfish products has been developed rapidly in the Mekong delta. Every year, about 1.2 million tons of Catfish and 150,000 tons of biofuel are produced. The biofuel B100 manufactures in Mekong delta satisfies the America standard ASTM D6751; EURO EN 14214 or Vietnamese standard TCVN 7717. Mekong delta, a lower land area, has a large inland water way system with around 100.000 river boats that operate with marine diesel engine. Using the biofuel for the marine diesel engine in area will reduce the HC, CO, SOx and NOx emission to the environment. Therefore, with a study on applying the catfish biofuel, it will reduce the climate change by the increasing of sea water level and save energy by using green energy to replace petrol oil.

1 INTRODUCTION

Using the biofuel to replace for the Diesel Oil (DO) for diesel engine has been researched and applied in the develop countries. In the United State, UK, Demark Canada and Netherland, the Biodiesel B20 [1] has been used for the diesel engine of automotive, truck and some of other industries.

Using the biofuel for diesel engine will reduce the emission gas exhausts to the environment such as HC, CO, SO_x and NO_x [1].

In the Mekong delta, about 1.2 million tons of the Catfish products are produced each year. Accompany with Catfish products, there is about of 12% Catfish fat for the manufacture of 150.000 tons of Catfish biofuel [3]. This amount of the biofuel is suitable to be use for the marine diesel engine on river boats in this area.

Figure 1. Using the Bio diesel B20 in the United State.

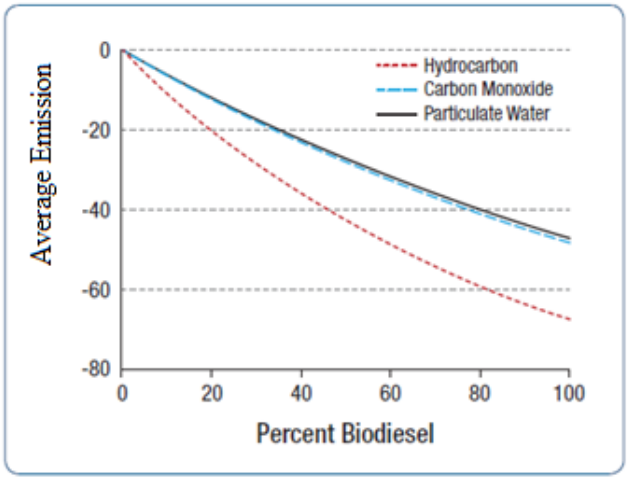

Figure 2. The average emission impact of the diesel engine

With the purpose of solving the problem of increasing of the sea water level over the world and energy consumption, we would like to study on applying the Catfish biofuel for marine diesel engine in the Mekong Delta. This energy resource is available in the Mekong delta; therefore it is suitable for supply to river boats without any transportation.

The Catfish biofuel manufactured in the Mekong delta meets the standards ASTM D6751 of the United State, EN 14214 of EU or TC 7717 of Vietnam.

The biofuel and sea food from Catfish has been producted by the factory of the Tan Vinh Hoan JSC in the Mekong delta [3].

Figure 3. The manufacturer Catfish biofuel TAN VINH HOAN JSC in Mekong delta

2 USING CASHFISH BIOFUEL FOR THE MARINE DIESEL ENGINE

2.1 *Methods for study on applying*

For the study on applying the Catfish biofuel for marine diesel engine of the river boats, we conduct the following:

- Selecting the Catfish biofuel from manufacturers in Mekong delta.
- Analyze the properties following standards ASTN D6751 or EN 14214.
- Selecting the type and the model of the marine diesel engine that are popular in the Mekong delta.
- Formulate difference theories by changing the parameters of the engine as there is the change from using DO to B5 and B10.
- Trial testing in the laboratory using the Catfish biofuel for the marine diesel engine.
- Actual trial testing in marine diesel engines of river boats.
- Carrying out the final valuation of the applying the Catfish biofuel for the marine diesel engine.

2.2 *Selecting the Catfish biofuel*

We are carrying out the analysis and inspection on the quality and the capacity of almost every Catfish biofuel manufacturers in the Mekong delta. Some of them manufacture the biofuel B100 with the good quality reaching the standards ASTM D6751 or EN 14214 (table 1). Some Catfish biofuel products have been exported to Japan and Singapore such as Minh Tu, Thai Phuong Lam, Phuong Nam, Vinh Hoan, Hiep Thanh and Agrifish An Giang. After the preliminary analysis, we inspect the capacity and the quality of above manufacturers. Sample of Catfish biofuel of Minh Tu company [3] are selected for the analysis and inspection. Consequently, they meet the properties of ASTM D6751 or EN 14214 or TCVN 7717 completely (Fig 4).

Table 1. Specifications for Biodiesel (B100) by ASTM D6751 and EN 14214 Methods

Property	Test method	Specification limits
Acid Number	ASTM D664	0.50 max mg KOH
Calxi and Magnesium	EN 14538	5 ppm max
Carbone Residue Wt%	ASTM D4530	0.050 max
Cetan number	ASTM D613	47 min
Cloud point	ASTM D2500	Report in ^{o}C
Cold soak filterability	ASTM Annex A1	360^{o} max sec.
Copper strip corrosion	ASTM D130	No. 3 max
Distillation Atmospheric Equivalent Temperature 90% recovery	ASTM 1160	360 max oC
Flash point	ASTM D93	130 min ^{o}C
Glycerin Free	ASTM 6584	0.020 max Wt%
Glycerin total	ASTM 6584	0.240 max Wt%
Kinetic Viscosity 40oC	ASTM D445	1.9 – 6.0 mm2/s
Methanol content	EN 14110	0.2 max Wt%
Oxidation Stability	EN 14112	3 hours min
Phosphore Content	ASTM D4951	0.001Wt%/ 10ppm
Sodium & potassium	EN 14538	5.00 ppm max
Sulphated Ash	ASTM D874	0.020 max Wt%
Sulphur (S15)	ASTM D5453	15.00 ppm max
Sulphur (S500)	ASTM D5453	500 ppm max
Water and sediment	ASTM 2709	0.050 max Vol%

We are mix biofuel B100 of Minh Tu manufacturer with DO and get B5 and B10 (Fig 5).

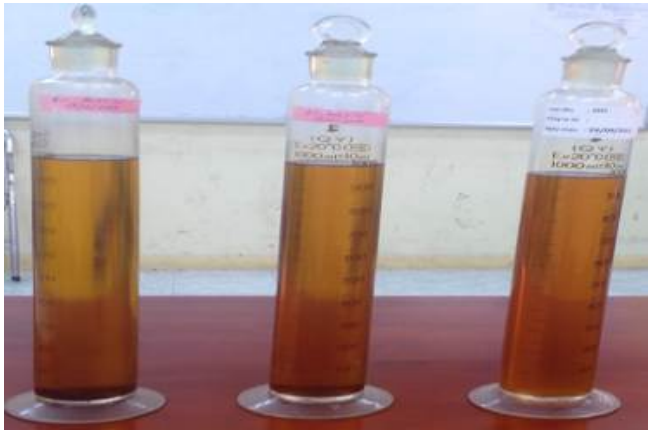

Figure 5 Samples of the Catfish biofuels B5, B10 and DO.

Otherwise, we analyze and compare selected properties of DO, B5 and B10 for our calculation as in table 2.

Table 2. Selected properties of the DO, B5 and B10

Property	DO	B5	B10
Fuel Standard	ASTM 0975	ASTM D6751	ASTM D6751
Heating Value, Kj/kg	42670	42465	42260
Kinetic Viscosity 40oC	1.3 – 4.1	2	2.848
Specific Gravity, 15.5 oC	0.83	0.836	0.8389
Flash point, oC	57	61	63
Cetan Number	52.1	52.4	52.5
Cloulding point, oC	5	8	14

2.3 *Select testing marine diesel engine*

The Yanmar marine diesel engine is very popularly for the river boats in the Mekong delta. This type of engine design, with the fuel system of Bosch type fuel pump and injector, is designed for being used with the DO fuel.

This is the marine diesel engine, four cycles and have 6 cyliners (Fig. 6). The basic parametters of the engine are is showed in table 3.

Figure 6. The marine diesel engine Yanmar 6S185L-ST

Table 3. Parameters of the Marine Diesel Engine Yanmar 6S185L-ST [6]

Parameters	
Model of engine	YANMAR 6S185L-ST
Type of engine	4 Cycles
Number of cylinder	6
Air charge	Turbocharger
Diameter of cylinder	185 mm
Stroke	230 mm
Volume of engine	37.09 cubic cm
Power	600 HP
Consumption	180 g/hp.h

2.4 *Theories study on changing the parameters of engine*

For calculating and drawing the characterictics of pmax, We use the MATLAB program for calculating and programming the changing of parameters of the engine in running from using the DO, B5 and B10.

The use the Haizenbek formula for the marine diesel engine to determine the heat transfers to cylinder liner α_{mc} [2].

$$\alpha_{mc} = 2,47\sqrt[3]{C_m}\sqrt{p_{kc}^2 T_{kc}} \quad (1)$$

where

α_{mc}: transfer heat ratio of cylinder liner, kW/m2K;

T_{kc}: Temperature of burning gas in combustion chamber [^{o}K];

P_{kc}: pressure of burning gas, [Pa];

C_m: average velocity, [m/s];

And the performance power formula of diesel engine:

$$N_e = \frac{V_s.i.n.z}{60}.\frac{Q_H}{\mu_s.L_0}.\frac{\eta_i}{\alpha}.\eta_n.\eta_m.\rho_s \quad (2)$$

where

- i, z : number of cylinder and factor of stroke i = 6, with four stroke engine z = 0,5;
- V_s : Volume of performance;
- Q_H : Low heating value;
- η_n, η_m, η_i, : efficiency of performance, mechanical and calculation;
- n: Revolution Per Minute (RPM);
- α: Air ratio;
- L_o: The air amount for burning 1 kg fuel kmol/kg;
- μ_s = 28.9 kg/kmol: Density of 1 mol air.

Based on the formula for calculating of the marine diesel engine we develop the calculating program for the marine diesel engine (seeing Fig.7).

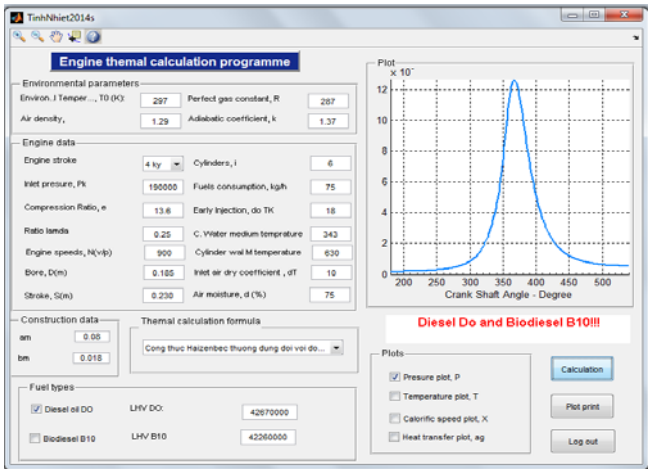

Figure 7. The engine thermal calculation programe

Entering the working parameters of the test engine Yanmar S185L-ST and the Low heat value (LHV) of DO, Catfish biofuel B5 and B10 such as: LHV_{DO} = 42.670 kJ/kg, LHV_{B5} = 42.465 kJ/kg and LHV_{B10} = 42.260 kJ/kg. Load of engine 75%.

Running the calculation program, we receive the characteristics of the changing burning pressure in the cylinder liner of test engine as per Fig. 8 for DO & B5 and Fig. 9 for DO & B10.

Following the Fig 8, we record the Pmax of the engine when using the DO and B5 change ΔPmax = 1.2 MPa. The changing value is very small, this is accepted.

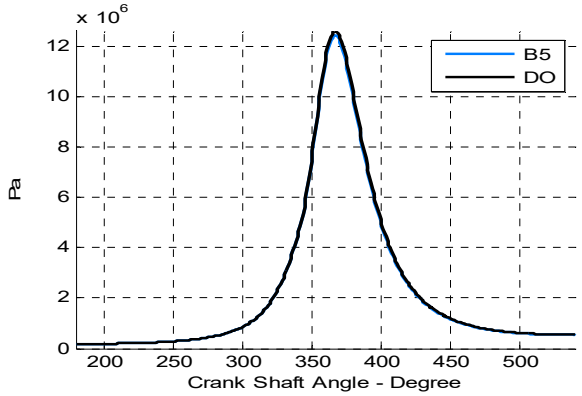

Figure 8. The changing burning pressure in the cylinder liner as DO & B5 are used.

Following the Figure 9, changing the LHV and running the program we receive characteristics of Pmax. The changing of Pmax in this case higher than in this case using B5 about 3 MPa. This value is accepted. It is confirmec that the changing of engine power is small. We can use the B10 to replace the DO in the marine diesel engine of river boats.

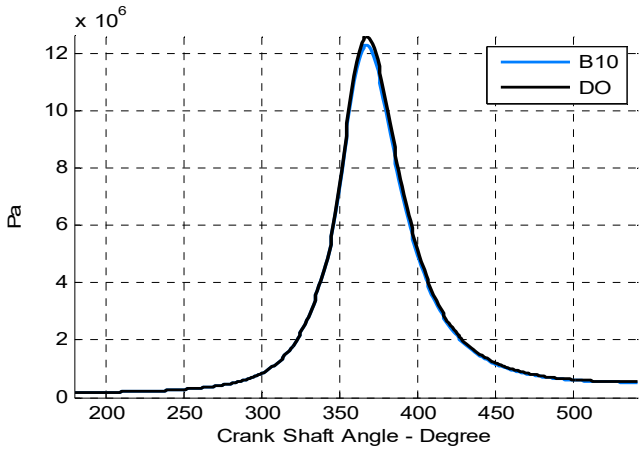

Figure 9. The change burning pressure in cylinder liner with using DO & B10

2.5 *Modeling the test*

2.5.1 *Test engine*

Following above instruction, we use the Yanmar 6S185L-ST (as per Fig.6) for the actual testing with Catfish biofuel [3].

2.5.2 *Dynamometers*

For putting the load on the test engine, we are use the dynamometers ATE-705LC and the load control system (see Fig.10).

Figure 10. The dynamometer Accurate Model: ATE - 705LC

Basic parameters of ATE-705LC:
- Max Power: 750 HP.
- Maximum Moments: 3457 N.m.
- RPM: 900 – 6000.

2.5.3 *Measuring the Pmax and Tmax equipment*

For measuring the Pmax we use the DPI Digital pressure indicator with software LAUTERT 50 (see Fig.11 and 12).

Figure 11. The DPI LAUTERT 50

The range of measurement of DPI 50 as below:
- Pressure range: 0 – 250 Bar
- RPM of engine: 50 – 5,000 RPM
- Temperature : 0 – 350 oC.

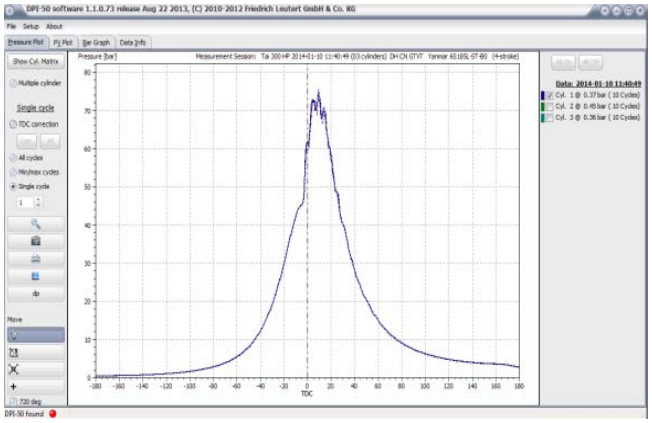

Figure 12. The interface graphic P-V and P- φ of Lauter DPI50

The software used the DPI Lautert 50 for restoring and ploting the characteristics in order to describe the changing of the engine is show in figure 12. To use this program, we install the program in the PC with operation system Win 7 or higher [5].

After installing the softwave in the PC, we connect the PC with the hand help for tranfer the data from the hand help to the PC by the USB cable. On the interface of the PC we will call the Data and can plot the change of the pressure in the burning chamber of the engine follow the crank angle.

2.5.4 *The biofuel blending system*

To use the biofuel for diesel engine, we can use one of the following blending methods: online blending, inline blending or offline blending [5].

Online blending method will blend the Biofuel and DO online via the fuel pumps with the flow control, the blending tank and come to engine (Fig. 13). We can adjust the mixing percent of the biofuel and DO by the flow control. The biofuel with made blending from B5 to B20 depent on the mixing ratio used for the engine.

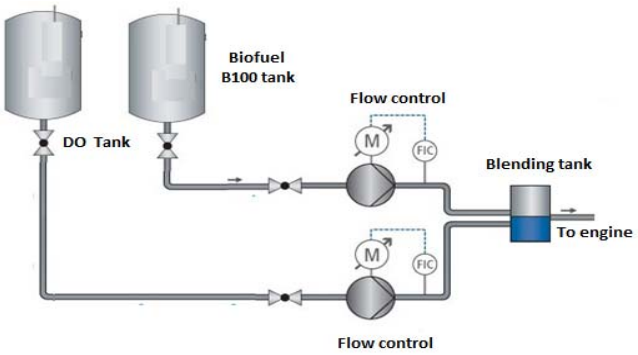

Figure 13. The biofuel on line blending system

The inline blending system will mix the biofuel B100 and DO in line and in the pump impellers (see Fig. 14).

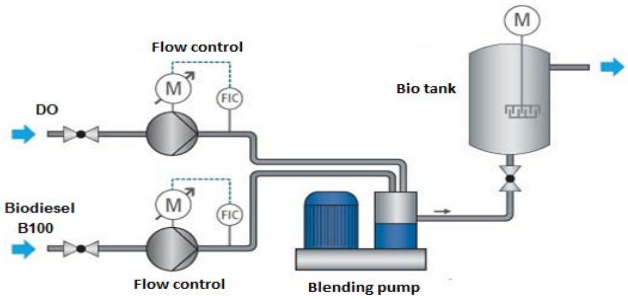

Figure 14. The biofuel inline blending system

For carrying out blending the Biofuel, this method will use two tanks (one for DO and one for Catfish biofuel B100) and gear pump or screw pump with the suitable capacity. On the line connection from DO and biofuel B100 tank, we will install the control flow.

For the determined the temperature for mixing biofuel with the inline method in the cool weather area, we carry out blending the biofuel base on the notion of the Catfish biofuel has the clouding point at 14^{o}C. To avoid the clouding point, keep blending the Catfish biofuel above 14^{o}C.

Splash blending or intermediate blending method will blend the DO and biofuel B100 manually, mix the DO and the biofuel in the tank by hand.

2.6 *The test on the Catfish biofuel B5 and B10 on the Yanmar 6S185L-ST*

Run the engine and put load on the engine: 0%, 25%, 50% and 75%. Measures the change of burning pressure when change the supplying fuel from DO to B5 and B10. Measure and record the testing results of the process as below:

2.6.1 *With the load of P ≈ 0%, the fuel DO,B5&B10*

Run the engine with no load position from dynamometer; change the fuel from DO to B5 and B10 we have the record as Fig. 15 [3].

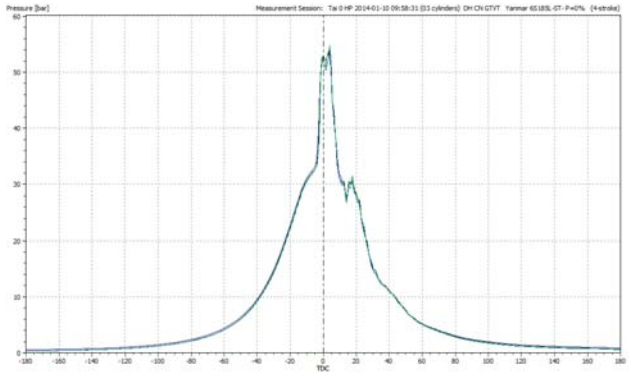

Figure 15. A Trial test on the engine with fuel: DO, B5 and B10 at n = 900 RPM, the load P ≈ 0%.

– Pmax change around 2% since there is a change of the fuel from DO to B5 and B10.
– The exhaust gas temperature and the fuel rack position show very small change with Tmax = 453oK, h = 0.9
– The revolution of the engine reflects the very small change clearance limit.

Following above results, in this case without the load putting to the engine, the performance parametters of engine are not changed and are the same when we changed the fuel from DO to B5 and B10.

2.6.2 *With the load of P ≈ 25%, n = 900 RPM, and the change in the fuel from DO to B5 and B10*

Increase the load to 25%, after 10 minutes for the engine to working stably, we measure Pmax of the engine by DPI and record as below:
– Pmax decrease under 2% when we change the fuel from DO to B10 and B5.
– Exhaust gas temperature Tmax = 493oK, and fuel rack position h = 1.25.
– RPM of the engine also decrease to a very small around 2 – 3 RPM.

With the load of 25%, Pmax, Tmax and Fuel rack position of test Engine change is very slightly.

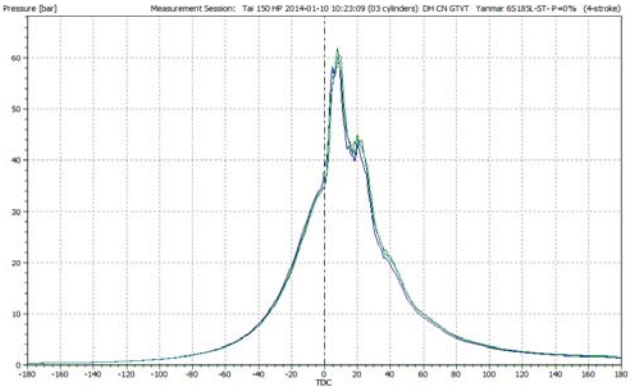

Figure 16. The test on the engine with fuel: DO, B5 and B10 at n = 900 RPM, the load of P ≈ 25%.

2.6.3 *With the load of P ≈ 50%, n = 900 RPM and the change in the fuel from DO to B5 and B10*

Increasing the load to 50%, run the engine with the DO, B5 and B10 we have the burning pressure characteristics as Fig. 17.

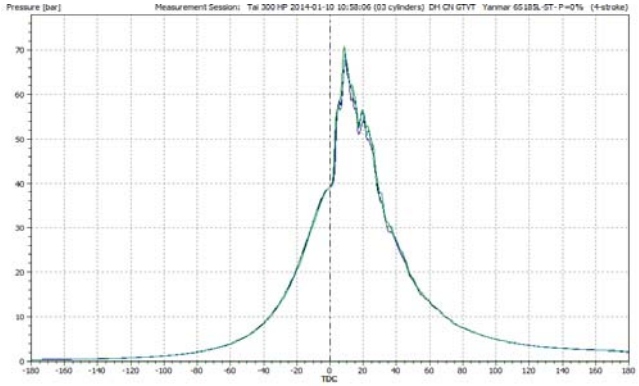

Figure 17. The test on the engine with fuel: DO, B5 and B10 at n = 900 RPM, the load of P ≈ 50%.

Following the Figure 17, with the load of the engine 50%, use the fuel DO, B5 and B10 we have results as below:
– Burning Pressure of the engine change is slightly less than 2.5 bar (about 3%) with the fuel changed from DO to B5 and B10.
– The exhaust gas temperature changes slightly and has value of Tmax = 563oK with fuel rack h = 1.9.
– The RPM of the test engine changes is also very small proportions with the change of Pmax

With the load of P = 50%, the test engine works with the slightly changed burning pressure with the fuel changed from DO to B5 and B10.

2.6.4 *With the load of P ≈ 75%, n = 900 RPM and the change in the fuel from DO to B5 and B10*

Similarly with the load put in the engine 50%, we run test engine with the load increases up to 75%, the burning pressure and temperature we have results in DPI as in fig.18.

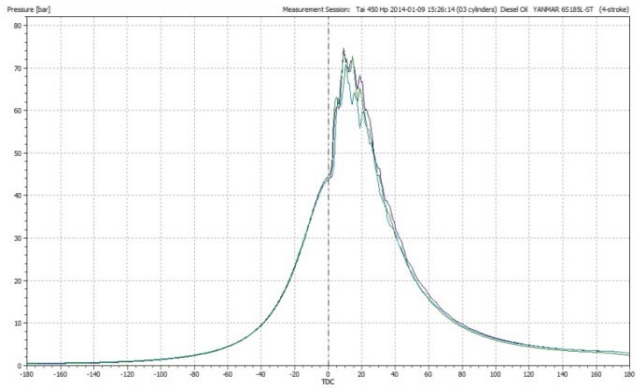

Figure 18. Test engine with fuel: DO, B5 and B10 at n = 900 RPM, load P ≈ 75%.

Follow the characteristics in figure 18, we have some presentation concerning performance of the engine at 75% of the load as using theree types of fuel DO, Biofuel B5 and B10 as below:
– The burning pressure or Pmax of the engine with 75% load changes very slightly and lower than 1 bar, around 1.5%.
– Tmax and Fuel rack change is very slightly with Tmax = 613oK, h = 2.2.
– The RPM of the engine decreases slightly from DO to B5 or B10. However all the changes are in the limited clearance of measurement equipments.

For safety in the testing process, we can not run the test engine with full load 100%.

Base on the testing results of using Catfish biofuel for Yanmar 6S185L-ST we confirm that:

With the load changing from 0% to 75%, the Pmax should be changed with the type of fuel. However the change is very small. This result keeps the engine parameters constant. These test results confirm that the Catfish biofuel B5 and B10 to be used for the marine diesel engine in the Mekong delta.

3 CONCLUSIONS

For the study on applying the Catfish biofuel for the marine diesel engine in the Mekong delta, we carry out researching from the theory to the test on the actual marine diesel engine that uses the catfish biofuel B5 and B10. The results of the study proves that working parameters of the engine would changed with the small and stay in the allowed limit, following the decrease of the heat value of fuel since the heat value of biofuel is lower than the heat value of DO. However the decreased of the heat value is too small and not to be changed to the output power of the the engine.

Using the Catfish biofuel in the Mekong delta, we could solve two importance problems: first is the reducing the HC, CO, SO_x and NO_x [1] in exhaust gas of the marine diesel engine that affects the environment. And the second is that using Catfish biofuel to replace the petrol oil.

With all of the above results, we confirm that using the Catfish biofuel for the marine diesel engine in the Mekong delta is suitable to the output power of the diesel engine. However for fully resolving this problem we still need more time to test and evaluate the effects of Catfish biofuel on the wear of the cylinder liner, piston ring, fuel system and other parts.

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