

Experimental Investigation of Operating Characteristics of Bio-Diesel on a Conventional Diesel Engine

R. P. Manorathna and N. K. B. M. P. Nanayakkara

Abstract—Humans have used fossil fuels as their main source of energy, since the industrial revolution. But, the remaining quantity of fossil fuels on the earth is limited. The dramatic increase in usage of fossil fuels has also caused unprecedented changes to the global environment and climate. A country like Sri Lanka which totally depends on fossil fuels has a main risk of running out of sufficient fuel by 2050. Therefore the requirement for alternative methods is immense. Use of bio-diesel is one of the answers found. However, pure bio-diesel is not recommended for conventional engines due to number of operational deficiencies. Therefore finding an optimal combination has been a concern over the years. In the presented paper different blends of bio-diesel and petro-diesel were tested in a conventional 2 cylinder Kubota tractor engine. Variations of speed versus torque, speed versus power and the environmental factors through emission levels were measured and presented. In addition fuel consumption, cost and engine vibration were also measured and presented. Considering all possibilities, a combination of 20% bio-diesel and 80% petro-diesel gives the optimum performance for a diesel engine with comparatively better performance than normal diesel. Further the study effectively discusses the results of environmental and economic advantages of bio-diesel made with waste cooking oil.

Index Terms—Bio-diesel, Kubota, Petro-diesel, Fossil-fuel, Emission

I. INTRODUCTION

Bio-diesel, by the name, is a clean burning alternative fuel for diesel which is distilled from renewable sources such as vegetable oils, animal fats and waste bio products. It is considered to be more environmental friendly compared to existing fossil fuels which is a limited resource. The raw materials required to produce bio-diesel is easily available around the agriculture sector. Therefore bio-diesel has been introduced to agriculture based machinery over the years.

However, pure biodiesel is not recommended by scientists for conventional engines due to number of operational deficiencies. Engine modifications are required to use pure bio-diesel which is a costly practice. Therefore, bio-diesels are generally mixed with petroleum diesel at predetermined percentages to create a “biodiesel blend”. But engine performance differs with the amount of concentration of bio-diesel used.

Torque & Power, Engine Vibration, Fuel Consumption

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and Emission are some of the standard parameters which determines the quality and performance of the fuel used. Fuel cost and consumption are direct measurements of the economy of using the fuel. Poor fuel performance will lead to frequent maintenance and more often replacement of the engine. Hence, finding an optimum combination of bio-diesel and petro-diesel which gives the best operating characteristics has been a requirement over the years.

Standard performance characteristics with various B factors were obtained and discussed in [1] [5] & [6]. A significant emphasis was given to investigate the emission levels in [2] [8] & [4]. In [3] authors investigated on engine vibration. In addition few have researched about the economic advantages and disadvantages of bio-fuels compared to fossil-fuels. But most of the researchers have studied only one or two possible performance characteristics at a time. This will not provide a full idea about the effects of using bio-diesel. It is not also possible to combine results of one research with another because, testing conditions differ. Therefore a complete test which analyses most of the engine performance parameters is needed.

Furthermore previous tests are mostly carried out in cold climates such as in Europe. Therefore a study is often required to prove the feasibility of previous results for an environmental condition in Sri Lanka. Hence, it was decided to explore the possibilities to introduce bio-diesel blends in an agriculture based engine to compare the performance with pure diesel.

II. MATERIALS AND METHODS

Bio-diesel, for this research made from waste cooking oil was manufactured at the Institute of Chemistry Ceylon and chemically proven that it is with reasonable substitute for petro diesel. Therefore the research was mainly concentrated on investigating engine performance to determine the optimum blend ratios for overall engine operation. As the initial step 5%, 10%, 15%, 20% and 25% of bio-diesel were measured and mixed with petro-diesel to make five different combinations.

Then they were tested in a conventional 2 cylinder Kubota tractor engine (Table I). Observed performances indices include the variations of speed versus torque, speed versus power and the environmental factors through emission levels of NO_x, CO₂, CO and SO₂.

A separate coupling mechanism was designed and one end was connected to the dynamometer and the other was coupled to the flywheel of the tractor as shown in Fig.1.

Flue gas analyzer (KM 9106, Kane May QUINTOX) was used to measure emission levels (Fig.4). Engine vibration

was measured using a Vibrometer (Fig.3) for different blends of bio-diesel. A separate fuel container (Fig.5) was coupled to the system to measure fuel consumption. Furthermore the purchase price of various combinations of bio-diesel was also compared. Even though the tests were carried out at temperature and pressure conditions available in Peradeniya, the results can be configured to any location in Sri Lanka since the conditions does not vary significantly from one place to another.



Fig.1. Testing Equipment / FROUDE hydraulic dynamometer



Fig.2. Tractor Coupled to testing equipment



Fig.3. Vibrometer

TABLE I: TRACTOR ENGINE SPECIFICATIONS

Item	Specification
Engine model	TD 1700
Compression ratio	375 (cm ³)
Combustion chamber type	21

$$\text{Break Horse Power (B.H.P)} = (\text{Torque measured} \times \text{Speed}) / 4500$$

(01)



Fig.4. The Flue Gas Analyzer



Fig.5. Separate Container for Fuel Consumption Measurement

III. RESULTS

A. Torque Vs Speed

As shown in the Fig.6, it was observed that the variation of torque increases gradually with the speed up to around 2000 rpm and then decrease with further increase in speed. With all the speeds, the torque for B20 and B25 was greater than the normal diesel and for lower B ratios the torque speed performance was generally lower than the normal diesel. The maximum torque has been achieved around 2200 rpm.

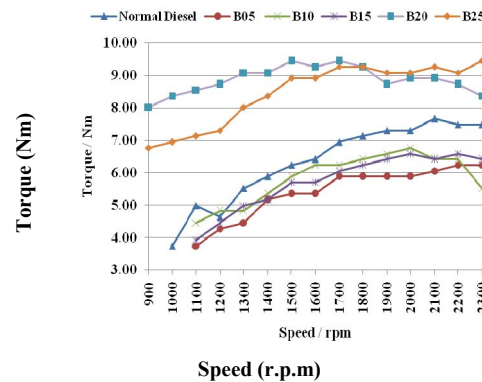


Fig.6. Torque Vs Speed Curve for Different Blends of Bio-diesel

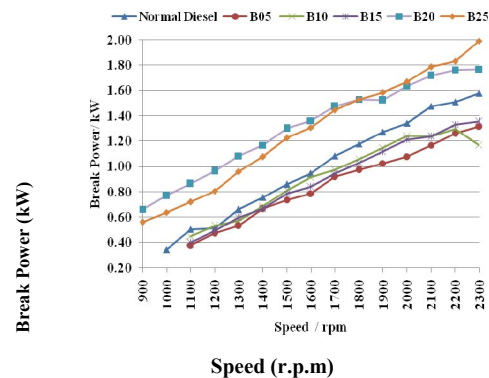


Fig.7. Power Vs Speed Curve for Different Blends of Bio-diesel

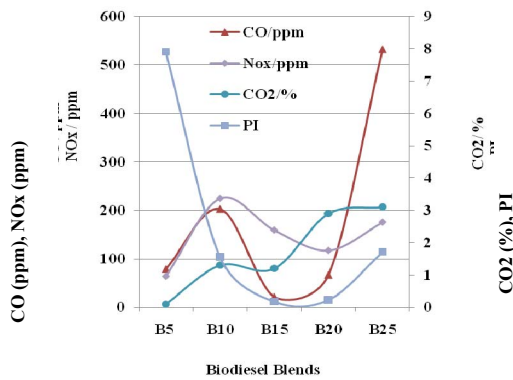


Fig.8. Emission Characteristics for Different Blends of Bio-diesel

B. Power Vs Speed

Power-speed characteristics for different blend ratios (Fig.7) were calculated and analyzed. It was observed that Break Horse Power (B.H.P) of B20 and B25 combinations was greater than normal diesel and B05, B10, B15 combinations showed inferior performance compared with normal diesel. The increment in power and torque in B20 and B25 is a significant amount compared to other combinations of bio-diesel and petro-diesel.

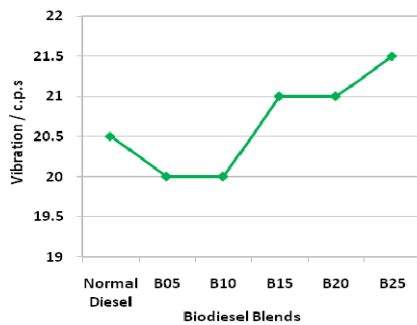


Fig.9. Engine Vibration Test Results for Different Blends of Bio-diesel

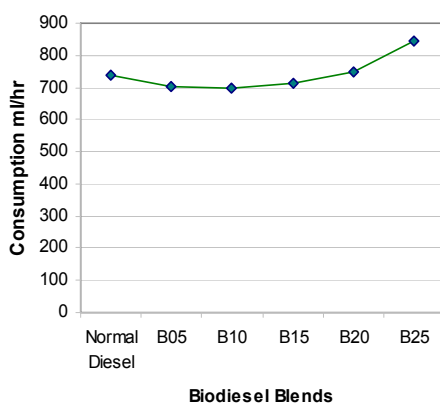


Fig.10. Fuel Consumption Characteristics for Different Blends of Bio-diesel

C. Emission Test Results

The critical emissions were analyzed (Fig.8) and it was observed that PI (Position Index, CO/CO₂ ratio x 100) goes down gradually until B20 and it started to increase beyond B20. It was evident that B20 has considerably lower PI and NOx. However, B15 is also at reasonable levels comparable

with B20 with these emissions. It is clear that CO and CO₂ emission levels increase with the mixed amount of bio-diesel.

D. Engine Vibration

Vibration levels for different blends were measured (Fig.9) and analyzed. It was evident that engine vibration increases with bio-diesel percentage. But the deviation from normal diesel is not a large amount. Furthermore grey smoke, Engine miss-firing and knocking was observed visually at higher bio-diesel levels.

E. Fuel Consumption

Fuel consumption was also increased with the addition of more bio-diesel as shown in Fig.10. But the maximum deviation is around 50ml/hr which is not that significant.

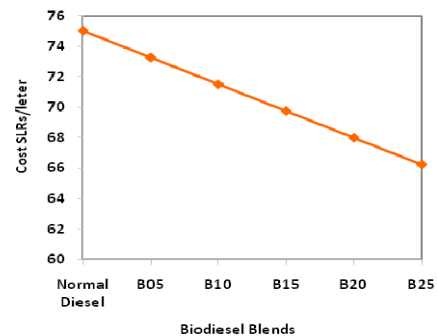


Fig.11. Fuel Cost for Different Blends of Bio-diesel

F. Cost of Fuel

Cost between different blends (Fig.11) was also compared since the economic advantage of bio-diesel is also an important factor when introducing it as an alternative fuel. It was clear that the cost reduces with more bio-diesel addition.

IV. DISCUSSION

It was shown that B20 and B25 displayed better performance to petro diesel in terms of power and torque characteristics. B25 even better than B20 in high engine speeds beyond 1800 rpm. When the results were related with the emission levels, it was clearly seen that B20 gives considerably lower emissions than B25 especially, CO₂ levels.

In a previous study described in [4] which was carried out with three biodiesel blends (B20, B50 and B100) derived from soya beans, authors found that B20 performed better in terms of fuel efficiency and NOx emissions. In our study, the B ratios tested were much closer to each other and consistent and finally, our overall recommendation on B ratio is in line with the above literature. Results in another research given in [5] which was very similar to ours in terms of the testing material and the engine type, but experimented only B20 and B100, in which it was found that B20 is better than B100. In that particular work exhaust emission levels were not tested, but can be coupled with our work where B15 and B20 both showed reasonable emission levels. Therefore, combining with the results on emission levels in our work, justifies the fact that B20 is a better substitution for petro diesel.

In another research described in [6] done on bio-diesel which is produced using rice bran oil and tested for B20, B30, B50 and B100 have found that the torque and power characteristics slightly increased when B20 was used when compared to other B ratios they have tested and confirmed our findings in current study.

When considering the vibration levels of different blends, it is clear that engine vibration increases with the addition of bio-diesel. The reason for this increase might be the engine miss-firing and knocking at higher bio-diesel portions. This may have occurred because of some deposits on the fuel injector. If these deposits are drawn into the engine it is too viscous to pass through the engine's fuel filter and the engine will usually cease to run until the filter can be changed. This will also reduce the fuel flow rate and cause engine misfiring. Therefore frequent fuel filter changes are possible with the use of bio-diesel.

Fuel consumption was also increased with the addition of bio-diesel. This states that the energy content per unit volume of bio-diesel is slighter compared to that of pure diesel. Further the results prove that the cost of manufacturing a litre of bio-diesel is considerably low than a litre of pure diesel in Sri Lanka.

It was observed that a significant amount of smoke with bio-diesel. The reason for gray smoke is the high carbon content of bio-diesel compared to normal diesel. Therefore the CO₂ emission increased with more bio-diesel content. But, it does not imply that bio-diesel is not eco-friendly. The viscosity of bio-diesel was also higher than petro-diesel which also leads to engine miss-performances.

Results imply that for higher concentration of bio-diesel a conventional engine cannot be used as it is and it requires modification.

V. CONCLUSIONS

It was proven that a normal diesel engine can be run with comparatively better performance using biodiesel produced from waste cooking oil. The overall suitability considering the performance analysis with torque and the power with vary, blend B20 was proven to have better performance. This was further supported with emission levels, especially with PI and NO_x levels. Finally, the results were proven in line with previous researches on different bio diesel products in a more justifiable manner. Both economically and environmentally it is proven that bio-diesel is a very good alternative for petro-diesel.

The data obtained on fuel consumption can also be used to point out the thermal efficiencies of the engine when running on each type of fuel which will be our next task.

If an engine is to be used with a blend higher than B20, the engine needs modification. Future research work should be focused on finding modifications and experimenting more specific reasons for engine miss-firing. Methods should be developed to measure engine wear rate and also temperature since they are major indices when analysing engine performance.

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Ravindra Prashath Manorathna, was born on 16th September 1985 in a city called Hatton in central province of Sri Lanka. He did his basic studies at Dharmaraja College, Kandy which is one of the most reputed schools in Sri Lanka. He received his graduation in Production/Manufacturing engineering from University of Peradeniya, Peradeniya, Sri Lanka, in 2010.

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After completing the PhD, in late 2006, Dr. Nanayakkara returned back to the Faculty of Engineering and recommenced the service at the Department of Production Engineering. He was promoted to Senior Lecturer Grade II position in 2007 and was exposed to administration in early in his career where he was appointed as the Acting Head of Production Engineering in 2007 for three months. In June 2008, Dr. Nanayakkara was appointed as the Head of Production Engineering and in addition he has been serving in a number of committees in the faculty level.