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Performance Analysis of Blended Tyre Pyrolysis Oil (TPO) Against Diesel in A YANMAR TF-120 Single Cylinder Diesel Engine

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***Abstract*--This paper experimentally investigates the performance of blended tyre pyrolysis oil (50% diesel / 50% TPO) against pure diesel in a YANMAR TF-120 single cylinder diesel engine. The brake power and torque were measured to calculate the brake thermal efficiency and brake specific fuel consumption for the purpose of making a comparison. It was observed that the 50% diesel / 50% TPO fuel produced a lower torque of 20 Nm in contrast to diesel of 32 Nm. On the positive note, the TPO fuel shows a fewer fuel consumption compared to the diesel to produce the required energy to drive the engine speed. The calorific value of the TPO oil differs by 3% compared to the diesel fuel which does not much impact the performance of the engine. The TPO managed to produce the similar amount of brake power output in comparison to diesel while simultaneously being more fuel efficient. Conclusively, the use of the TPO as an alternative fuel for diesel is indeed promising. For the future, it is recommended that a different blend of TPO is tested against pure diesel.**

***Keywords*-- Alternative fuel, Renewable energy, Blended Tyre Pyrolysis Oil, Diesel**

INTRODUCTION

Diesel fuels are limited in resources as the petroleum harvested could not be replenished which would be a problem towards the transportation sectors (An et al. 2011). In the modern ages, researchers have been looking for alternative fuels with better sustainability due to the increase in fuel demand in the market (Chala et al. 2018; Ma'arof et al. 2020). Some of the waste products such as plastic, papers and wood are non-bio-degradable which have been put to good use by converting them into fuel for energy. Over the years, people often face difficulty in eliminating waste tyres as they occupy spaces through illegal dumping and with toxic fumes released, leading to various types of environmental pollution. This waste product can be eliminated through pyrolysis methods which will break down this material into carbon powders, tyre oil and combustible gases (Antoniou et al. 2013).

The tyre oil extracted out of the tyres can be blended with diesel oil and used as a fuel to run the diesel engine without any engine modifications.

This paper experimentally investigates the performance of blended tyre pyrolysis oil (50% diesel / 50% TPO) against pure diesel in a YANMAR TF-120 single cylinder diesel engine. The brake power and torque were measured to calculate the brake thermal efficiency and brake specific fuel consumption for the purpose of making a comparison. The finding for this paper could showcase the possibility for the commercial use of blended tyre pyrolysis oil.

LITERATURE REVIEW

Pyrolysis is an endothermic process and an environmentally attractive method of getting rid of non-biodegradable waste products such as waste tyres (Baggio et al. 2008). It is commonly used for the production of charcoals through biomass for years. The pyrolysis process of coal and biomass is used further on the developments of fuel gas (Uddin et al. 2018). The pyrolysis process is carried out in a fluidized bed reactor under extreme temperatures to extract out the pyrolytic oil and combustible gases (Raj et al. 2013). Limited amount of oxidation is allowed in the system for combustion to be carried out efficiently with the injection of inert gases to decrease the oxides produced from combustion. Firstly, the steel wire is mechanically removed from the tire before grinding it to chips to send it to the reactor. The reactor is closed to operate for 90 minutes at a temperature of 400- 500 degrees burning the tyre chips. The gas produced from the combustion is circulated to the storage tank and the condenser. Some molecules of the gas are too small to be condensed as they are stored to be used as gas fuel. The gas will be condensed to the pyrolysis oil and the remaining tyre chips out of the combustion would be carbon black powders.

Brake specific fuel consumption and brake thermal efficiency would be evaluated using the results obtained through the experimental testing such as brake power, mass flowrate and some of the physical properties of the fuels. Brake thermal efficiency is the ratio of the brake power produced by the dynamometer and the energy content injected into the engine (Celikten et al. 2010; Tadesse 2009). Desmond et al. 2018 stated that higher BTE is preferred as it highlights efficient conversion of energy output in the engine. Jaichandar et al. 2016 stated that reduction of BTE could lead to the result of poor air-fuel mixing, lower volatility and lower calorific value of the fuels. Brake specific fuel consumption is the amount of fuel energy needed to be produced to run the engine shaft. These parameters are related to the physical properties of the fuel which would be the most likely factor to affect the performance of the engine. Zaharin et al. 2017 stated that smaller bsfc indicates more effective use of the fuel to generate power.

In short, these literatures are a vital reference for this study. Brake power and torque are measured to calculate brake thermal efficiency and brake specific fuel consumption to make a comparison on the performance rate between both fuel. Further improvements and recommendations would be suggested to be involved into the experimentation stages to improve the scope of this project

METHODOLOGY

Diesel fuel is loaded into the storage tank and the engine is started to run for a few minutes to stabilize the coolant and oil temperatures. The engine speed is set upon to decelerate from 2400rpm to 1600rpm as the output results are much more precise in decreasing order. The volumetric fuel consumption rate is set constant for 10ml for every sample. Time taken for the fuel consumption is recorded for every speed using stopwatch. The speed of the engine changes every 30 seconds automatically. Diesel oil is flown into the engine after every test to flush out the fuel lines and injection system to prevent any harm to the injector thus reducing the impact on the engine performance. The brake power produced by the engine for each speed is observed closely for fluctuations in the performance curve. The steps above are repeated to measure every samples.

RESULTS AND DISCUSSION

Figure 1 shows engine brake power output over various engine speeds. It was found that there is a positive correlation between the power output and the engine speed. In order to achieve the relatively higher power output demand, a higher amount of fuel is consumed in every cycle. However, at lower engine speeds, engine knocks could be heard due to the pre-ignition of the air-fuel mixture in the combustion chamber which could be to higher cylinder pressure and increase in friction generating the knock sound.

The sample fuel with 50-50 mix is tested in comparison with the superior diesel which provided closer to similar output with 50-50mix to be slightly lower.

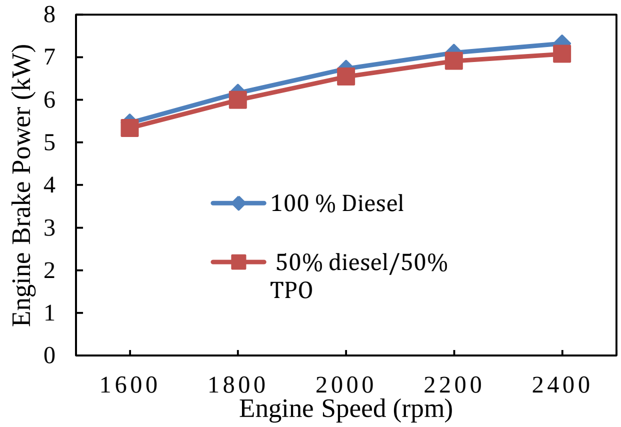

Figure 1 Engine brake power versus engine speed.

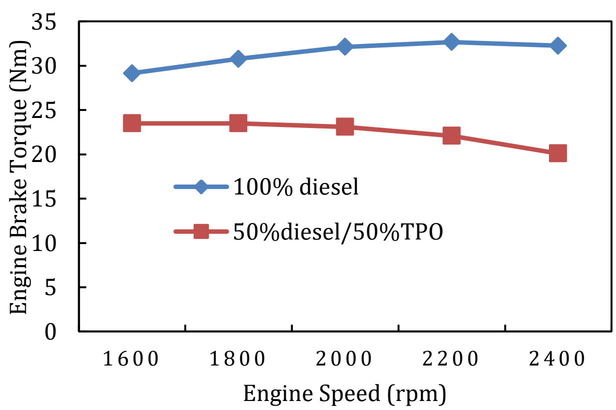

Figure 2 Engine Brake Torque versus engine speed.

According to Figure 2, it can be observed that as the engine speed increases there is a declination in the brake torque produced with the usage of the 50-50 mix compared to the pure diesel which increased but with degradation in the rate. For the highest speed recorded, the tyre oil blend fuel produced a lower torque compared to the pure diesel which was 20Nm and 32Nm, respectively. This is due to the lower calorific value of the blended fuel which results in lower energy produced and lower combustion pressures which results in the lower torque values recorded.

The Brake Specific Fuel Consumption (BSFC) is considered to be a performance indicating parameter to compare between the blended fuel and the pure diesel. The results obtained is similar to Ruhul et al. 2016. Figures 3 and 4 demonstrate the trend of Brake Specific Fuel Consumption at various engine speeds and brake powers respectively. In a glance it can be seen that both the varying engine speed and brake power resulted in a similar trend for each respective fuel.

This is due to the positive correlation between the engine speed and brake power. It can be observed that the pure diesel had almost a linear decrement in BSFC as the brake power and engine speed continues to increase unlike the 50-50 mix that resulted in various slopes of BSFC. At lower initial speed, it was noted that the 50-50 required 0.987kg of fuel for every kWh produced and pure diesel consumption being lower at 0.991kg. However, at maximum engine speed, the 50-50 mix consumed lesser in comparison with 0.638kg per kWh while pure diesel was consuming 0.679kgs. In addition, this can be observed that at around 1800rpm the BSFC slope of the 50-50mix drops and eventually bringing down the BSFC to be lower than the pure diesel. Even though it was shown the pure diesel had a higher fuel consumption, the brake power that was able to be produced was also noted to be higher compared to the 50-50 mix fuel. Besides that, during the testing it was found that the ignition delay for the 50-50 mix samples is longer at lower engine speeds resulting in more fuel injected into the combustion chambers before the combustion process begins. In return, this results in rougher operation as the pressure is significantly higher due to the presence of large amounts of fuel. This leads to the development of a knocking sound known as "diesel knock". Based on Herzman (2018), the diesel knock can be heard at the lowest speed of the engine when the blended fuel is used.

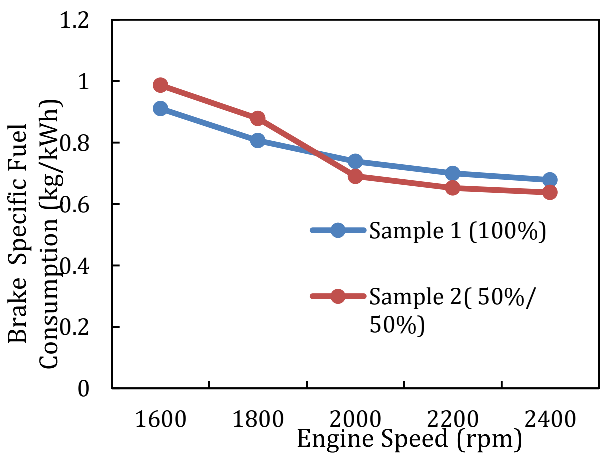

Figure 3 Brake Specific Fuel Consumption versus engine speed.

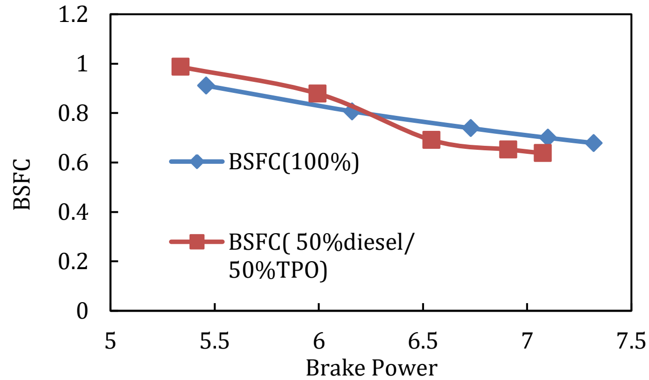

Figure 4 Brake Power versus Brake Specific Fuel Consumption.

Figure 5 shows brake thermal efficiency over engine speed. Effect of brake power on brake thermal efficiency is depicted in Figure 6. Similarly, due to the positive correlation between the engine speed and brake power almost similar trends can be observed in the Brake Thermal Efficiency (BTE) for varying engine speed and brake power for the respective fuels. The pure diesel was observed to have a steady increase in BTE as the engine speed increases up till 2000rpm when it starts to settle down. This trend also applies to the 50-50mix fuel. The results obtained were found to be similar with Islam (2016) where with increase in engine speed and brake power the BTE increases. Based on the graphs above, it can be clearly seen that the 50-50mix fuel has achieved a significantly higher efficiency compared to the pure diesel fuel. The 50-50fuel mix was found to have a steeper increment in efficiency with the increase in rpm which eventually allowed it to perform better than the pure diesel from around 1800rpm. However, based on the results obtained by Azhar (2005) it can be noticed that the efficiency is lower for the blended fuel as the colorific value is lower. Since the difference in the colorific value isn't significant there isn't much difference in the efficiency. The energy losses in the cylinder are typically due to the friction between the cylinder wall and piston which generates heat and is lost to the surrounding. As the engine speed increases, the heat generated would also increase as the shaft rotation would be higher which will allow better atomization of the 50-50 fuel mix allowing the air fuel mixture to improved resulting in better combustion rates compared to pure diesel.

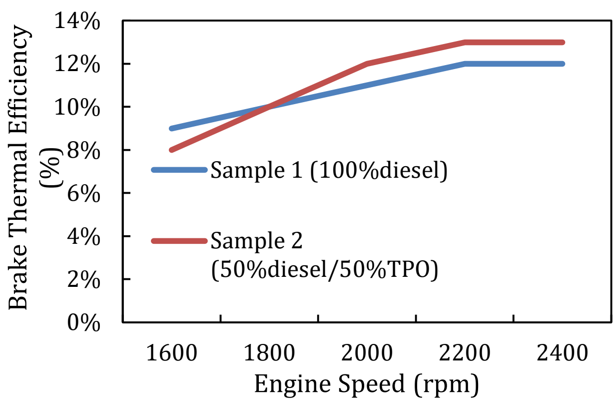

Figure 5: Brake Thermal Efficiency versus Engine Speed.

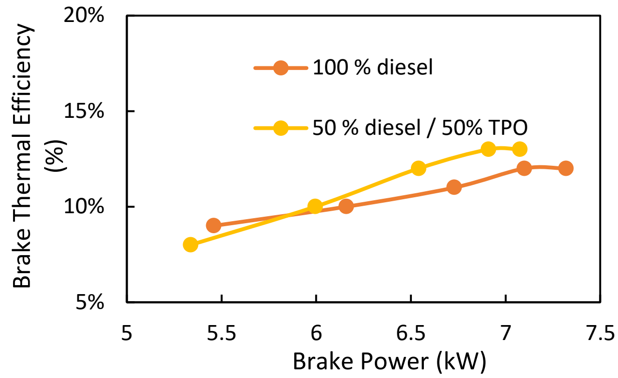

Figure 6: Effect of Brake Power on Brake Thermal Efficiency.

Decrement of BSFC at higher speeds of the 50-50 mix fuel is able to prove that the chemical and physical properties are stable for improvement of the combustion rates at higher speeds. Similarly, it was observed that the BTE of the 50-50 mix fuel took the lease at higher engine speeds compared to the pure diesel. However, the lower calorific value, results in lower energy input causing the brake power to be slightly lower. This could be due to the higher viscosity of the 50-50 mix fuel compared to the pure diesel which less viscous and has a better flowability and atomization. However, viscosity of fluids typically drops with increase in temperature which makes the 50-50 mix to be suitable to be ran for higher engine speed which has warmer operating temperature resulting in better atomization of fuel and a reasonable amount brake power output. The 50-50 mix fuel may not be suitable for the lower engine speed usage as the heat generated is lower and is able to be lost hence reducing the temperature and turbulence in the combustion chamber leading to incomplete combustions. It can be deduced that operations of the 50-50 mix fuel will result in a higher amount of fuel wastage at lower speeds. Based on the past studies, lower fuel consumption is a good sign of using the fuel efficiently to give out a better performance especially at maximum speed. Based on the results obtained, the 50% diesel / 50% TPO has the slight advantage compared to pure diesel as it consumes lesser fuel to produce the brake power which is closer to pure diesel.

CONCLUSION

In this study, the performance of blended tyre pyrolysis (50% diesel / 50% TPO) in a YANMART TF-120 single cylinder diesel engine was investigated and compared to pure diesel. The TPO blend has managed to produce almost the similar amount of brake power output in comparison to diesel while being more fuel efficient especially at higher engine speeds. Hence, this study serves as the evidence that the use of the TPO as an alternative fuel for diesel is indeed promising. For the future, it is recommended that different blends of TPO are tested against pure diesel.

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