Influence of Alternative Fuel Ratio on Turbocharger Combustor

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Abstract: *The present study investigates the effects of alternative fuel properties on combustion performance, in order to ensure reliable combustion performance using various fuel blends for powering an engine. The increasing rate of fuel cost and depletion of fossil fuels has led to the search for alternate fuels. Palm biodiesel derived from palm fatty acids meets the fuel requirements of an aircraft and is compatible with any engine without modifications. Viability of using a blend of present fossil fuels with biodiesel is studied. The engine was operated with petrol, diesel, palm biodiesel and a blend of these three fuels as a pair, with various ratios. The fuel was injected into the combustion chamber at an angle of 45^o to the airflow and ignited using a spark plug. The blended fuel is found to have better efficiency than petrol or diesel. Furthermore, the low cost and abundant availability of the biofuel make it a viable alternative to the petroleum-based fuels currently in use. The combustion time and ignition delay are decreased with efficient biofuel due to high oxygen content and high octane number of the biofuel.*

Key Words: *Performance, turbocharger, alternative fuels, biofuels, combustion chamber*

1. INTRODUCTION

Rising fuel prices on a daily basis lead to the development of alternative renewable fuel for combustion engines. The fossil fuel resource increases the price of fuel frequently and at one point the intact resources may be coming to an end. Turbocharger Jet Engine uses the compressor and turbine from a turbocharger. The performance testing identifies many aspects of turbocharger performance [1].

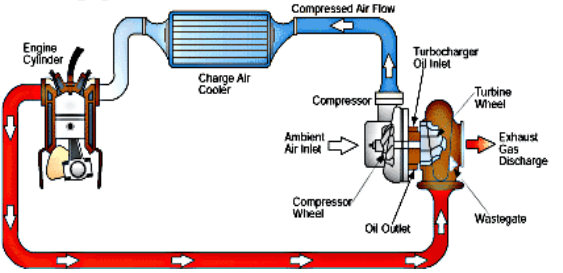

Fig. 1 Schematic diagram of Turbocharger

A turbocharger has the components of an air compressor and a turbine, which is allied by a common drive shaft as shown in Fig. 1. The compressor is the part of the turbocharger that takes more air and compresses it. The elevated pressure air is then ducted through an air pipe and into a combustion chamber. An air going through into the liner openings and fuel is blended with air and touched off with a flash attachment inside the liner. The consuming fuel warmed the air, makes it blow up and streak out of the fumes end of the chamber which is related to the turbine area of the turbocharger. As the exhaust gasses blow through the turbine area they turn the turbine wheel. Turbochargers are generally used in automotive production to improve volumetric efficiency and diminish the exhaust emissions [4]. Compared to a mechanically driven supercharger; turbochargers tend to be more efficient. Turbochargers are usually used on car, truck, train, aircraft and manufacture equipment engines [14-15].

2. BACKGROUND

As worldwide economies make every effort to wean themselves off the fossil fuels, one of the most intimidating challenges is to find a substitute for the liquid fuels that influence the world's aircraft [2]. Also, the global aviation industry uses a huge quantity of jet fuel energy-dense kerosene often referred to as Jet A1 fuel. Biofuels encompass the gaining recognition recently as an alternative fuel for the diesel engines [2].

Sustainable biofuels unlike other energy sources meet the unique requirements of aviation jet fuel. These include having the correct energy density, freezing points and high energy content per unit weight and volume. Palm oil is a particularly promising biofuel source and one which is found in abundance. This fuel when tested has energy content almost equal to the requirements of Jet A-1. These characteristics make it a very high quality fuel. Since initial testing of the biofuel cannot be done on real-time jet engine; a working model has to be used.

The fuel utilization area used for 2017-2018 is shown in Figure 2 [3]. Asia is seen to be the main buyer of coal, oil, renewable energy and hydroelectricity. The use of coal by Asia accounts for almost 74.5% of global coal consumption.

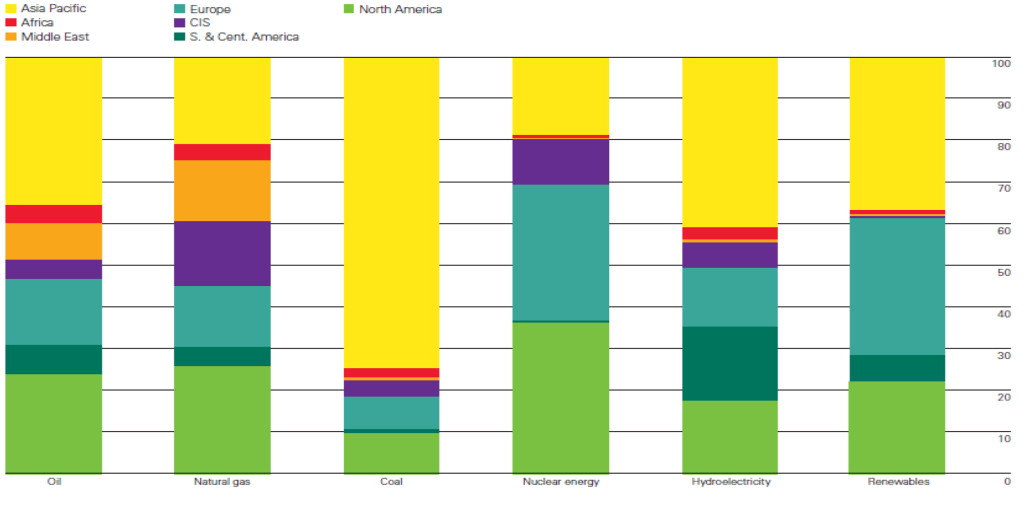

Fig. 2 Fuel utilization (%) area wise used for the year 2017 [3]

Any of today's large-scale biofuels should still be blended with jet fuel, as they have no aromatics.

"We fully expect that the first fuels will be 50–50 blends or less", says Boeing. The International Air Transport Association's objective is to observe that alternative fuels form 10% of aviation fuel utilization by 2017. Boeing company foresees them being used frequently within 3-5 years, whereas Airbus believes that by 2030, up to 30% of aviation fuel will be the substitute [3].

Table 1. Properties of Fuels

Properties	Petrol	Palm	Diesel
Density	711.22kg/m^3	860 kg/m^3	820 kg/m^3
Specific heat	2.22kJ/kg.k	1.68	1.9 kJ/kg.k
Calorific	48MJ/kg	37 MJ/kg	43.33MJ/kg

3. CRITERIA FOR SELECTION OF TURBOCHARGER

A major criterion for selecting the turbocharger is the larger diameter of the inducer, so that it has a large air flow and no waste gate is present. Considering the above criteria, K-27 turbocharger was chosen which finds application in large trucks and buses as shown in fig. 3.

Fig. 3 Artistic views of K-27 turbocharger

The Combustion Chamber has the complicated task of flaming huge amount of fuel, complete through fuel spray nozzles, with wide volumes of air, abounding by the compressor, and releasing the resultant heat in such a way that the air is extended and accelerated to provide a smooth flow of consistently heated gas.

Flame Tube

Flame tube is intended to blend the air that enters in a combustion chamber with the fuel-injected and to manage the burning process. From the Flame Tube Design Analysis, the length and diameter of the flame tube was obtained. For the compressor inducer diameter of 1.93 in = 4.9cm, the values are:
Length = 11.58in =29.41cm
Inner Diameter = 5in = 12.7cm

The flame tube fits within the combustion chamber and dimensions of holes given in table 2. It practically fulfills three major functions in the flame tube design, the size and number of holes required is obtained by the Jet specs software.

Table 2. Flame Tube Holes

Zones	Hole diameter	Number of holes
Primary	¼ in= 0.635cm	17.87 ~ 18

Secondary	3/8 in=0.95cm	5.29 ~ 6
Tertiary	5/8 in=1.59cm	4.76 ~ 5

Since the number of holes in relation to the hole area, is obtained as a decimal number, it is rounded to the nearest whole number, as shown above.

The holes in each zone are arranged around the circumference of the cylinder with equal spacing between them.

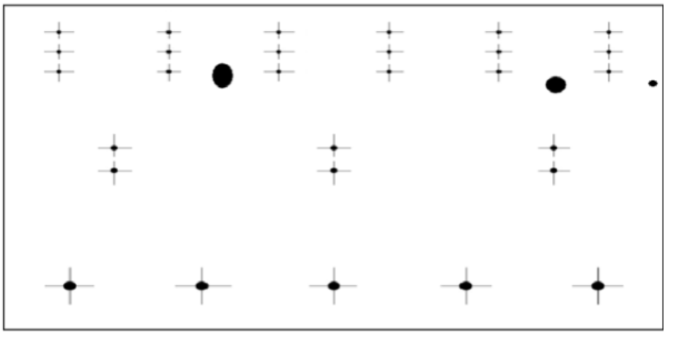

Fig. 4 Flame Tube Design

Each zone occupies a particular percentage of the length of the flame tube. The primary, secondary and tertiary regions occupy 30%, 20% and 50% of the flame tube length. Here, the circles represent the holes drilled in the flame tube as shown in figure 4.

The top region of the design is that of the primary holes, followed by the secondary and tertiary holes, in that order.

Combustor

The combustor is the housing which carries the flame tube. The combustion occurs in this section where the temperature would reach up to 1073.15 K.

Fig. 5 Artistic View of Assembled Combustion Chamber is shown

4. EXPERIMENTAL SETUP

The experimental setup consists of many components of combustor like fuel system, lubrication and ignition system for the effective results. The various systems of the Turbocharger are:

Fuel System

The fuel system atomizes the fuel by effectively pumping it throughout a small nozzle under elevated pressure. The system consists of a reservoir, a 12V fuel pump, shut off valve, needle valve and a fuel nozzle. A 10 liter reservoir is used for the storage of fuel. Fuel is drawn from the tank by the pump which has a maximum pressure of 8 bar.

The fuel pump is driven by a 12V battery. The shut- off valve is used to cut the fuel supply in case of emergency. The needle valve is the main flow controller. The air fuel ratio is to be maintained at 60:1 using the control valves.

From this ratio, the fuel nozzle diameter is calculated to be 1 mm, as per the mass flow of rate of fuel. The mass flow rate of fuel can be changed by adjusting the diameter of the nozzle using the threads at the tip.

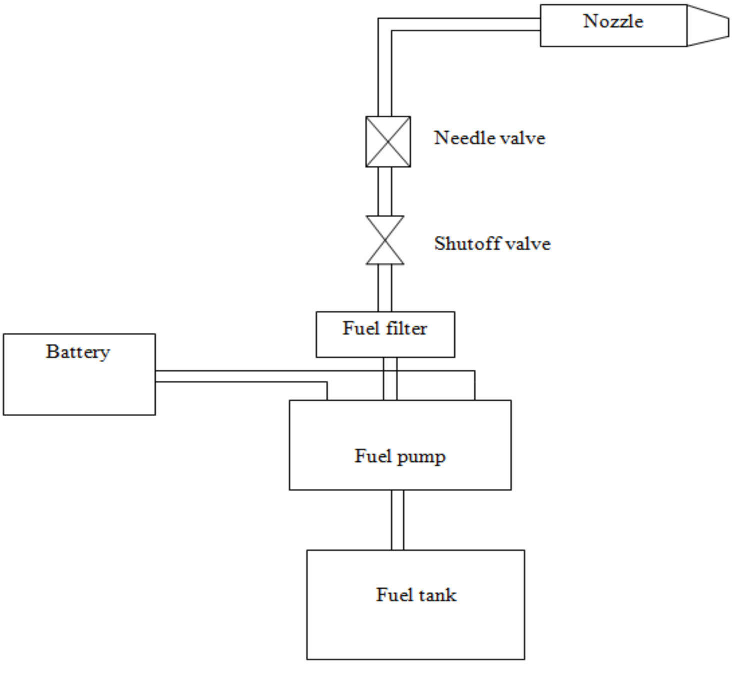

Fig. 6 Block Diagram of Fuel System

A 10 liter reservoir is used for the storage of fuel. Fuel is strained from the fuel tank by the pump which has a maximum pressure of 8 bar.

The fuel pump is driven by a 12V battery. The shut-off valve is used to cut the fuel supply in case of emergency.

Lubrication System

Most of the turbochargers are in operational with hydrodynamic bearings, made from an aluminum alloy. Lubrication system provides lubrication as well as cooling for the engine. Basically oil is force-fed into the bearing at high pressure by using an external pump. The lubrication system includes reservoir, oil pump, oil filter, shut-off value, 12V battery, connecting pipes and wires.

A 5 liter reservoir is used for the storage of oil. Oil can be pumped at a maximum pressure of 3.8 bar and is controlled using a needle valve. The shut-off valve is provided to cut off the oil in case of an emergency.

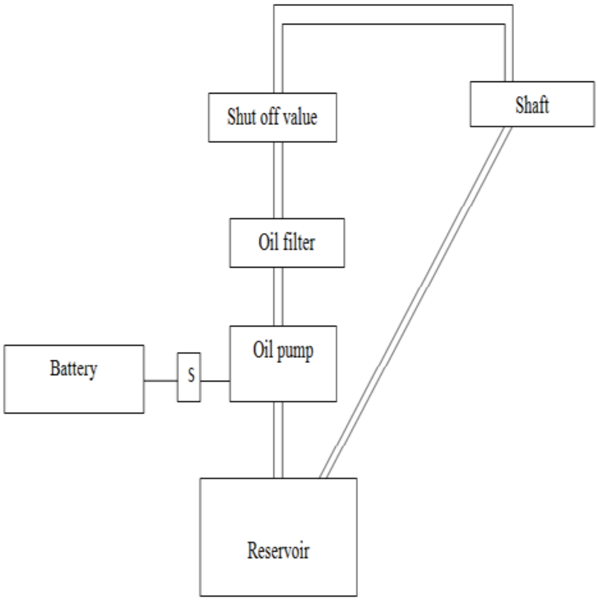

Fig. 7 Block Diagram of Lubrication System

Engine oil of grade 20-40 is used for lubrication purpose. The pump is run by 12V battery. The oil drain from the shaft has to be at 30^0 such that it drains out in a controlled manner due to gravity. Teflon hoses have been used for oil lines as they can withstand temperatures up to 423.15 K.

Ignition System

The ignition system shown in figure 8 is used for igniting the air-fuel mixture. The ignition system includes: spark plug, ignition coil and LPG. As spark plug in an electrical device which produces an electric spark. The plug linked to the ignition coil which generates an elevated voltage for the system.

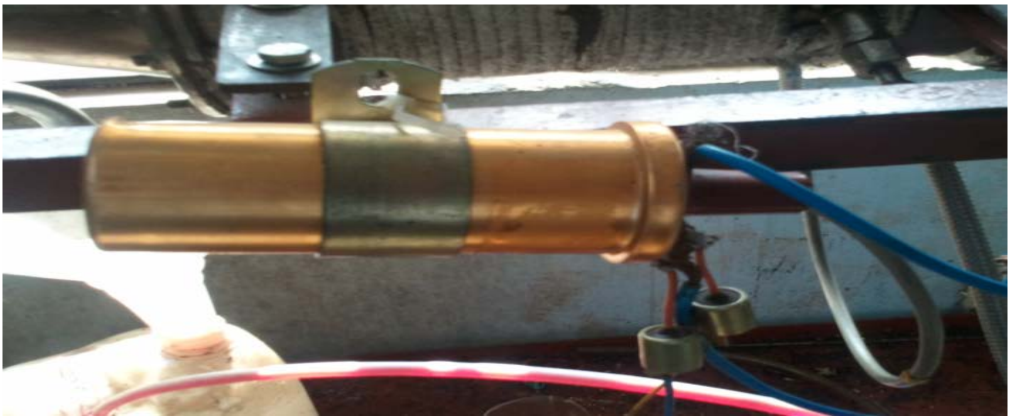

Fig. 8 Ignition System used for combustion is shown

An ignition coil used for an automobile, ignition transforms the batteries of 12V to thousands of volts essential to turn out the spark. Since the intensity of spark is too low to ignite the fuel, LPG is provided for preheating the fuel.

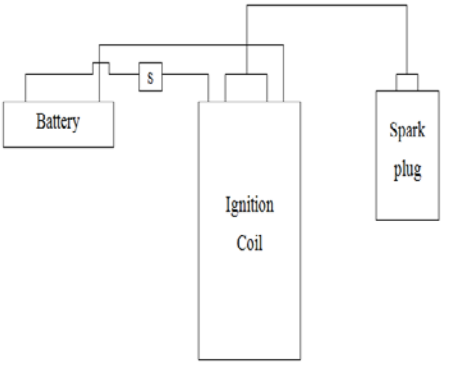

Fig. 9 Block Diagram of Ignition

5. EXPERIMENTAL WORK AND CALCULATIONS

The testing was carried out initially bypassing air into the compressor inlet section. Gas is made to pass into the combustion chamber by opening the gas valve. Ignition is started by using the spark plug.

The total assembly of all the systems along with the turbocharger and the combustion chamber is shown in figure 10.

Fig. 10 Experimental Setup of the turbocharger

Fuel is sprayed into the combustion chamber with the water misting nozzle. The fuel flow is controlled by using the needle valves. The temperature at the combustion chamber is noted using the thermal sensor fixed at that end. Continuous oil supply is provided at the shaft of the turbocharger for the purpose of lubrication and cooling.

Table 3. Calculations of performance a parameter of Petrol and Diesel

Sl. No	**Mixing Ratios**	**Temperature T_{01} (K)**	**Temperature T_{02} (K)**
1	0-100	307	1153
2	20-80	307	1123
3	30-70	307	1031
4	40-60	307	1097
5	50-50	307	1028
6	60-40	307	1008

7	70-30	307	1113
8	80-20	307	997
9	100-0	307	958

Table 4. Calculations of performance parameter of Biodiesel and Petrol

Sl. No	Mixing Ratios	Temperature T_{01} (K)	Temperature T_{02} (K)
1	0-100	307	958
2	20-80	307	978
3	30-70	307	931
4	40-60	307	1013
5	50-50	307	963
6	60-40	307	1073
7	70-30	307	1043
8	80-20	307	1032
9	100-0	307	1153

Table 5. Calculations of performance parameter of Biodiesel and Diesel

Sl. No	Mixing Ratios	Temperature T_{01} (K)	Temperature T_{02} (K)
1	0-100	307	1153
2	20-80	307	1135
3	30-70	307	1028
4	40-60	307	1029
5	50-50	307	1218
6	60-40	307	1061
7	70-30	307	1105
8	80-20	307	1179
9	100-0	307	1153

Performance parameters of petrol, diesel and biofuel are calculated and compared. The efficiency versus mixing ratio and the efficiency versus fuel cost are discussed in result and discussion section.

6. RESULTS AND DISCUSSIONS

Three types of fuels with three different cases are taken into account for investigation of their properties and compared.

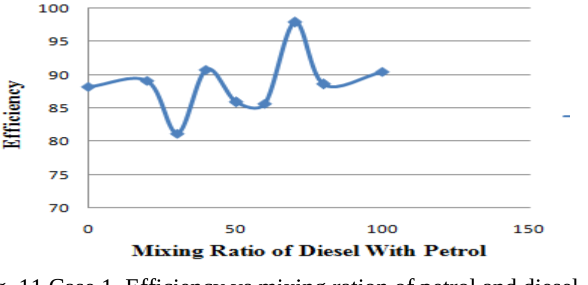

Fig. 11 Case 1. Efficiency vs mixing ration of petrol and diesel

Fig. 11 depicts mixing ratio of diesel and petrol and their efficiency. It is also evident that ratio 70:30 is cost-effective and efficient in terms of energy power output. Also, it can be seen that the peak value in efficiency is obtained at 70:30. The dip inefficiency can be noticed at higher fuel ratios (diesel: petrol) which is clear indication of energy loss.

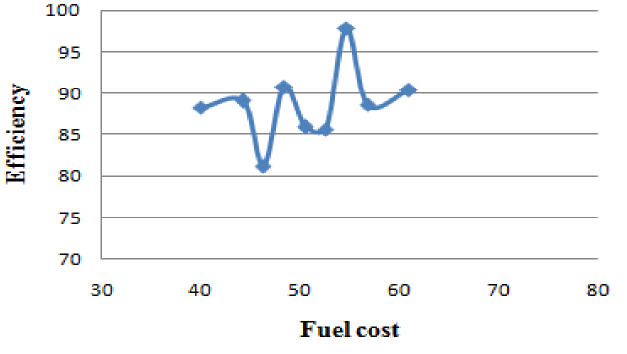

Fig. 12 Case 1. Efficiency vs fuel cost of Petrol and diesel

Fig. 12 illustrates the efficiency versus the fuel cost. In the diagram, it is obvious that to achieve efficiency greater than 97% the fuel cost is about INR 55. Also, it is clear that at higher fuel ratios the cost tends to increase with reduced efficiency. Therefore, it is advisable that ratio of 70:30 may be treated as the optimized ratio for diesel and petrol.

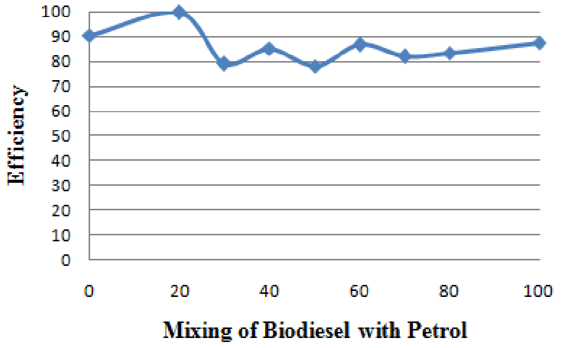

Fig. 13 Case 2. Efficiency vs mixing of Biodiesel with Petrol

Fig. 13 explains the mixing ratio of biodiesel and petrol and its efficiency. An energy loss is predominant at higher ratios therefore setting a limit for the mixing ratio. The maximum efficiency achieved is approximately 99.69% at 20:80 mixing ratio.

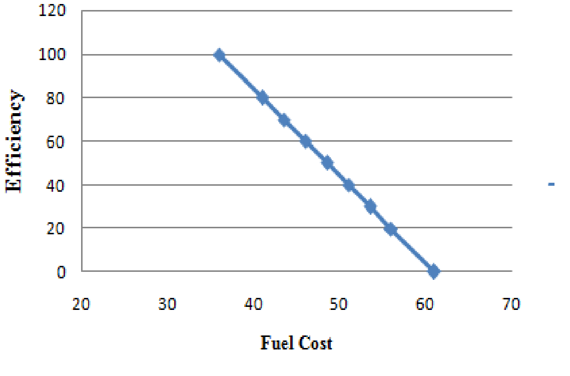

Fig. 14 Case 1. Efficiency vs fuel cost of Biodiesel with Petrol

At the same time, the cost of the fuel is almost INR 56 as shown in fig. 14. Also, the decrease in efficiency is attributed to incomplete combustion.

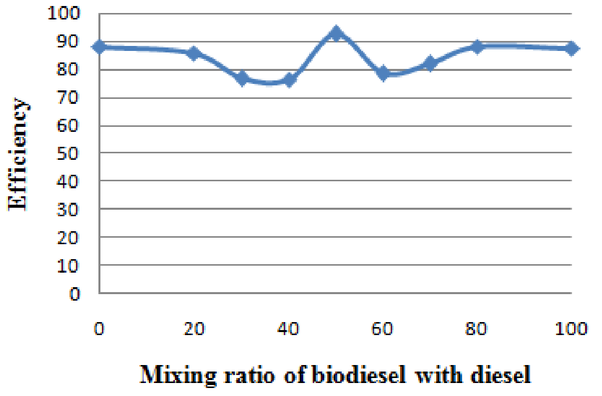

Fig. 15 Case 3. Efficiency vs mixing of Biodiesel with diesel

Fig. 15 demonstrates the efficiency versus the fuel cost for biodiesel and diesel. It is obvious that the maximum efficiency obtained is 92.59% at mixing ratio of 50:50, while the cost estimation is INR 38.

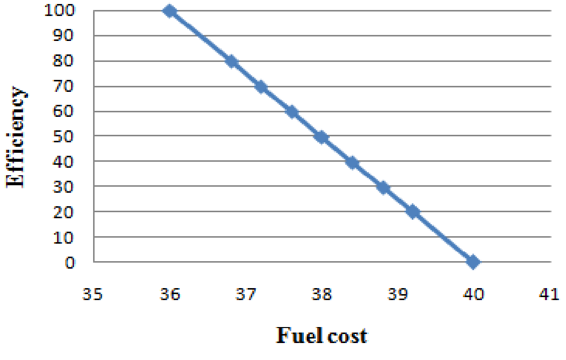

Fig. 16 Case 3. Efficiency vs. fuel cost of Biodiesel with diesel

It is seen that dip in efficiency is regained to 88.12% at mixing ratio of 80:20 at the cost of INR 36.8 as indicated in fig. 16. The dip and rise in efficiency is an indication of stable combustion at higher mixing ratios.

7. CONCLUSIONS

From the experimental results of the combustion efficiency of the various fuels blends, it turns out that the B20 or palm biodiesel blend with petrol (20:80) has the maximum combustion efficiency of 99% which is greater than any other blends. Combustion instability is reduced which in turn reduce the noise, hence enhancing the combustion efficiency. Hence the blend can be used as an alternative to conventional fuel as it offers some performance improvements through a 1%-2% decrease in fuel economy is found.

Among the various blends tested, the Diesel-palm biodiesel blend (B50) is economic with a good combustion efficiency of 92%. Kerosene based fuel can be saved when using a mix of 50% bio-fuel to 50 % diesel. By using the biodiesel blends a 60-65% reduction in greenhouse gas (GHG) emissions relative to petroleum-derived jet fuel can be achieved. Biofuels are the most proficient type of sustainable power source.

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