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MAKING BIODIESEL AND PERFORMANCE TEST OF A DIESEL ENGINE USING DIESEL -BIODIESEL BLENDS AS A FUEL WITH INLET AIR PREHEATING ATTACHMENT

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ABSTRACT

Saving of energy and reduction of CI engine exhaust emissions simultaneously is shown in this paper. Energy crisis all over the world and environmental pollution concern caused the research attention on alternative means instead of conventional fissile fuel and optimization of external attachment to the engine. In this investigation biodiesel was prepared from cultivable non-edible vegetable oil (neem oil) by transesterification process. In this study engine exhaust energy is used to preheat the inlet air passing through a newly designed air preheating passage. Counter flow heat exchanger was used in inlet air preheating attachment to transfer heat from exhaust gases to inlet air and inlet air temperature was raised up to 60^0 C by controlling the amount of exhaust flow through heat exchanger. Experiment was conducted in a four-stroke single cylinder naturally aspirated (NA) diesel engine. Different percentage of biodiesel (up to 20%) was mixed to the neat diesel and these diesel biodiesel blends were used in the diesel engine as a fuel. The experimental results were showed for medium load condition. It was found that after warming up period of the engine, oxides of nitrogen (NO_x), carbon monoxide (CO) and brake specific fuel consumption decrease with the increase of inlet air temperature. Significant amount of NOx reduction was found at the conditions of 20% biodiesel in diesel biodiesel blend with the pre heated inlet air at the temperature of 60^0C.

Keywords: Biodiesel, Transesterification, Inlet air preheating, Optimization of attachment, Exhaust emission, Ignition delay and Oxygen content.

1. INTRODUCTION

The non-renewable nature and limited resources of petroleum fuels has become a matter of great concern. The economic and political factors are greatly associated with their procurement. The combustion of these fuels in IC engines causes pollution. All these aspects have drawn the attention to conserve and stretch the oil reserves by way of alternative fuel research.

Vegetable oils and their derivatives (especially methyl esters), commonly referred to as “biodiesel”, are prominent candidates as alternative diesel fuels [1]. They have from being purely experimental fuels to initial stages of commercialization, technically competitive with or offer technical advantages compared to diesel fuel [2].

Several problems, however, have impaired the widespread use of biodiesel. They are related to the economics and properties of biodiesel. For example, neat vegetable oils use in engine to cause engine deposits. Furthermore, related to combustion and emissions remain to be solved. The problems with the use of biodiesel are thus very complex and no satisfactory solution has yet been achieved despite the efforts of many researchers around the world. Not only this but also the product of diesel combustion are not bio-degradable. They produce a lot of hazardous emission like carbon-di-oxide (CO2), carbon mono oxide (CO), sulfur-di-oxide (SO2), nitrogen-di-oxide (NO2), particulate matter, unburned hydrocarbon (UBHC), visible smoke, noise and odor [3]. Many researches have already accused Diesel combustion as the main reason of "Global Warming". On the contrary, biodiesel is biodegradable and they do not contain any sulfur, benzene group. As a result combustion of the bio-diesel does not produce no sulfur-di-oxide and no butadiene [4].

Bangladesh is an under developing country. Its energy demand increases day by day. Her annual demand of diesel fuel is about 37 billion liters. To meet up this demand she has to pay 1700 billion taka. Under this situation we need a new alternative resource for the mitigation of energy demand. This new alternatives resource may not be edible oil, because for meeting the local demand of edible oil a lot of gallons of oil have to import in every year from foreign countries and present price of oil is also higher price than diesel fuel. In aspect of Bangladesh *(Aiadiracta indica),* Neem (Local name) can play a vital role in the production of substitute of the diesel fuel. Neem is a non-edible oil seed, grows abundantly in Bangladesh especially in the rural areas. The climatic and soil condition of Bangladesh is also suitable for the production of Neem trees.

In the present situation the use of pure bio-diesel in engines may cause different types of problem. To compensate these problem blends of bio-diesel and diesel may be used as the alternative of diesel in diesel engine without changing engine design. By using diesel-biodiesel blend with inlet air preheating can reduce the NOx emission in a greater extent without hampering additional parameters, especially brake thermal efficiency [5].

2 METHODOLOGY

2.1 Making Biodiesel from Vegetable Oil

Transesterification is the process of using an alcohol (e.g. methanol, ethanol or butanol), in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to break the molecule of the raw renewable oil chemically into methyl or ethyl esters of the renewable oil, with glycerol as a by product. Bio diesel, define as the mono-alkyl esters of fatty acids derived from vegetable oil or animal fat, has demonstrated a number of promising characteristics, including reduction of exhaust emission. The transesterification reaction proceeds with catalyst or without catalyst by using primary or secondary monohydric aliphatic alcohol's having 1 – 8 carbon atoms as follows:

Triglycerides (vegetable oil) + Monohydric alcohol $\leftrightarrow$ Glycerine + alkyl esters (Bio fuel)

The process used for making laboratory quantities of vegetable oil esters is to first mix the proportion of anhydrous lye catalyst (NaOH) to Methyl alcohol (CH_3OH) and to then mix this combination with moisture free vegetable oil. The materials are maintained at 55-60^{0}C and allowed to settle by gravity for 24 hours. After that the translucent methyl esters of vegetable oil are produced and mix with diesel fuel up to 20% vol. proportion for better result, which is turned as Bio diesel [6]. In all causes 0.6% of lye catalyst as a regent and 20% methyl alcohol are used for making Methyl ester.

2.2 Investigation of Thermal Performance and Emissions

Experiments will be carried out on a single cylinder diesel engine and a four-cylinder diesel engine under different steady states. The steady states were following the Japanese 13-mode tests. The engine was run on a combination of biodiesel with ultra low sulphur diesel in different proportions. At each steady state and at each combination of diesel and biodiesel, the engine load, speed, fuel consumption, exhaust gas temperature, as well as the gaseous pollutants was measured. The gaseous pollutants was measured include NOx.

2.3 Investigation of Methods for Improving Engine Performance

The combustion of biodiesel might cause increase in NOx emissions and injection problem when high percentage of biodiesel is used [7]. Several methods for improving engine performance can be applied:

(i) Fuel injection time

(ii) Exhaust gas recirculation

(iii) Air preheating using exhaust gas

(iv) Fuel preheating using exhaust gas

The fuel can be preheated to reduce its viscosity and hence solve the injection problem, when high percentage of biodiesel is used.Papers, including figures and tables, should be limited to 6 camera-ready pages. Authors are requested to prepare the paper of the size 210 mm $\times$ 297 mm (A4) for typing the manuscript.

3. EXPERIMENTAL SETUP AND PROCEDURE OF EXPERIMENTATION

The experiment has been conducted to a four-stroke diesel engine. The specification of the tested engine is shown in Table 1. Conventional diesel fuel is used as fuel. The properties of the tested fuels are shown in Table 2. The figure 1 shows a schematic diagram of the attachment of inlet air preheating system by exhaust gas. The rpm was measured directly from the tachometer attached with the engine shaft. The outlet temperature of cooling water and exhaust gas temperature were measured directly by using thermometers attached to the engine. Thermometer-1 was used for measuring exhaust temperature after releasing heat. Inlet air temperature just before entering the combustion chamber was measured by thermometer 2. Thermometer-3 and thermometer-4 were used for measuring exhaust gas temperature with and without air preheating system respectively. A counter heat low heat exchanger was used to heat the inlet air utilizing the heat of exhaust gases.

Since heat transfer depends on heat transfer area so to extract maximum heat, the exhaust pipe surrounded with inlet air passage, the length of heat exchanger was maximized and pipes were arranged concentric. To minimize heat loss to atmosphere, the inlet passage was insulated by plaster of Paris, whose heat flow resistivity is comparatively higher [8]. In preheating attachment the exhaust gases out let pipe and inlet air out let pipe were 5.08 cm and 7.62 cm in diameter respectively. These pipes were made of GP sheet having thickness of 0.45 mm. Three gate valves were used in the experimental setup. The gate valve (A) was used for alternative passage of exhaust gases while the gate valve (B) is used for to control the direct passage of exhaust gases. The third gate valve (C) was used to control the EGR system.

Incase of without preheating of inlet air system, the gate valve B was closed and the gate valve A was opened. The inlet air (suction air) comes to engine cylinder through inlet and exhaust gases go out through the alternative exhaust passes. Again, incase of with preheating of inlet air, the gate valve B is opened and the gate valve A is closed. As a result heated inlet air (suction air) comes to engine cylinder with heated through a long passage of inlet pipe and exhaust gases go out through exhaust pipe. By controlling the opening of gate valves A and B, the amount of preheating of inlet air was controlled. On the other hand for the combined effect of inlet air preheating and EGR system both valves A and valve C were opened and valve B was closed.

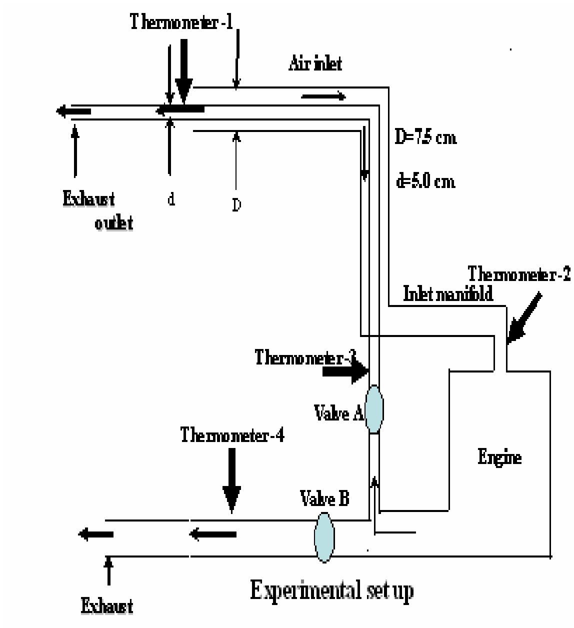

Fig 1: Experimental Setup

Firstly experiment was conducted without preheating while inlet air temperature was recorded as 32°C. After warming up period of the engine inlet air temperature was set at different elevated temperature (50°C, 55°C, 60°C) by controlling the amount of exhaust gas passing through the valve A and B. Then experiments were carried out individually with inlet air preheating arrangement and different percentage of biodisel in diesel biodiesel as a fuel and finally they were applied together to the engine to observe combine effects on engine performance. A digital exhaust gas analyzer was used to measure the exhaust emission parameters during the experimentation.

4. RESULT AND DISSCUSSION

Figure 2 illustrates the variation of NOx production at different speed with neat diesel and diesel-15% biodiesel blends. Inlet air temperature was raised by preheating attachment and fixed at 50^0 C. Effect of air preheating on NOx emission with neat diesel and diesel biodiesel blend was observed. From figure it is clear that the NOx emission increase with the increase of engine speed for both with and without air preheating attachment. When diesel-15% biodiesel blend is used as a fuel without preheating condition, the NOx emission is higher with respect to neat diesel without preheating condition even neat diesel with preheating condition. But when diesel-15% biodiesel is used as a fuel with preheating condition, the NOx emission is lowest than all others. Certain percentage of oxygen content in biodiesel overcomes the effect of lower volumetric efficiency due to air preheating. However air preheating reduced the ignition delay and viscous effect of biodiesel and oxygen content provides better local air fuel mixture and combustion those are dominating factors than production of NOx due to reaction of nitrogen with oxygen content in biodiesel whose may caused the overall lower NOx emission at preheating of inlet air with diesel biodiesel blend as a fuel.

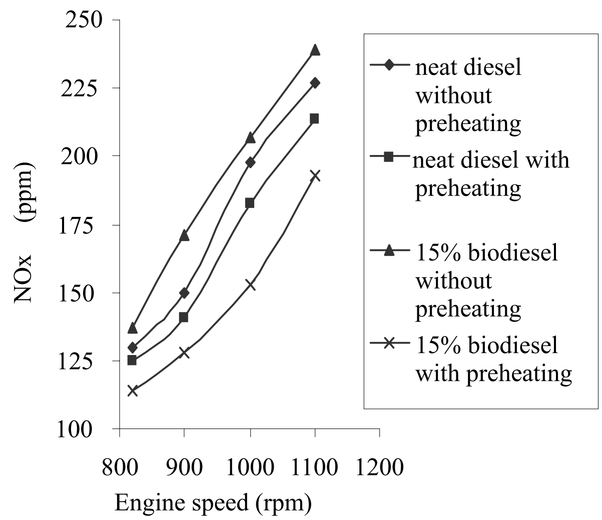

Fig 2: Variation of NOx emission with engine speed for neat diesel and diesel-15% biodiesel blends without and with inlet air preheating (50˚C) at fixed load 10kg.

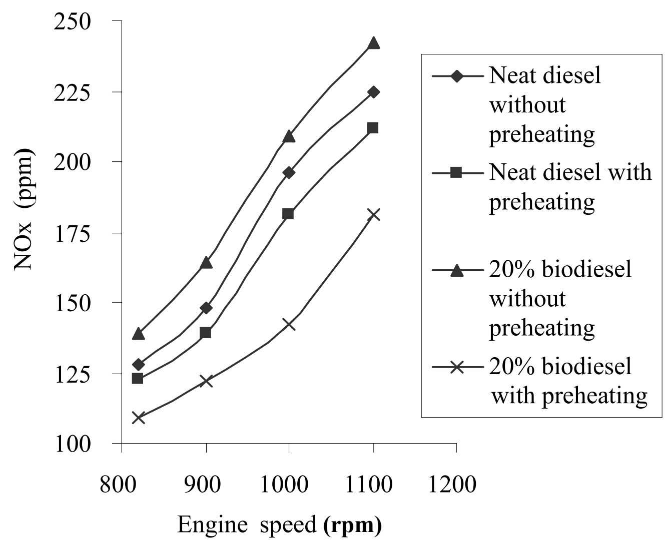

Fig 3: Variation of NOx emission with engine speed for neat diesel and diesel-20% biodiesel blends without and with inlet air preheating (50˚C) at fixed load 10kg.

Figure 3 compares the variation of NOx on different speed with neat diesel and diesel-20% biodiesel blends. Here effect of inlet air preheating was compared with no preheating for neat diesel and diesel biodiesel blend individually as earlier figure no. 2. But in this case, percentage of biodiesel in blend was increased by 5%. From figure it was shown that 20% biodiesel with air preheating reduced NOx emission on average 5% than 15% biodiesel in blends. Higher percentage of biodiesel in blends provides more overall oxygen content in the combustion chamber which compensates the reduction of volumetric efficiency. Whatever more increasing the percentage of biodiesel in blend may not be better as fuel.

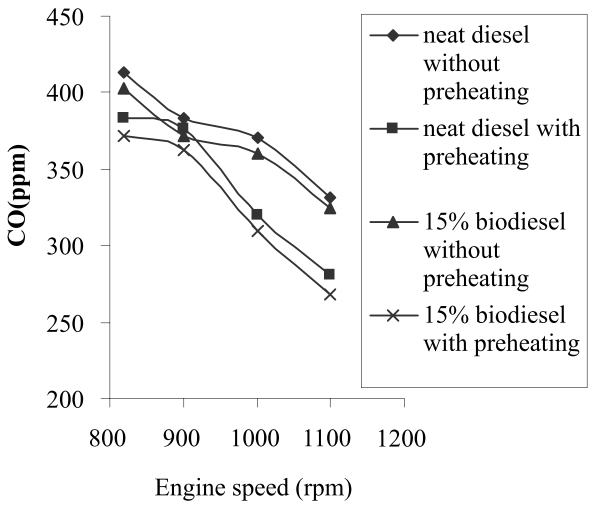

Fig 4: Variation of CO emission with engine speed for neat diesel and diesel-15% biodiesel blends without and with inlet air preheating (50˚C) at fixed load 10kg

Figure 4 depicts the trends of the CO emission at different speeds with neat diesel and diesel-15% biodiesel blends. From figure it is clear that the CO emission decrease with the increase of engine speed for both with and without air preheating attachment. When diesel-15% biodiesel is used as a fuel without preheating condition, the CO emission is lower than with neat diesel without preheating condition but higher than neat diesel with preheating condition. When diesel-15% biodiesel is used as a fuel with preheating condition, the CO emission is lowest than all others. At higher temperature due to higher speed, oxidation of CO takes place and produced CO_2 which is accelerated due to the oxygen content in the biodiesel. As a result lower amount of CO emission is emitted when biodiesel is used as fuel with inlet air preheating at higher engine speed.

Figure 5 describes the effect of the variation of biodiesel percentage in blend on overall CO emission with previous figure (15 % biodiesel). Here 20% biodiesel was taken in blend. Here CO emission trends is same as previous figure no. 4 but on an average 4% CO emission was reduced with air preheating when 20% biodiesel in blend is used instead of 15% biodiesel in blend. Whatever more increasing the percentage of biodiesel in blend may not be better as fuel.

Figure 6 illustrates the effect of engine speed on brake thermal efficiency at constant load (10kg) for neat diesel and different % of diesel-biodiesel blends without inlet air preheating. It was observed from the figure that the brake thermal efficiency of engine is lowered for diesel biodiesel blends than neat diesel as fuel. Thermal efficiency decreased with the increased of percentage of biodiesel in diesel-biodiesel blends. This drops in efficiency due to the higher density and viscosity, poor volatility, lower heating or calorific value of biodiesel than neat diesel. As a result, for same amount of power production, mass of fuel consumption for biodiesel is greater than that of conventional diesel fuel.

Figure 7 shows the effect of engine speed on brake thermal efficiency at constant load (10kg) for neat diesel and different % of diesel-biodiesel blends with inlet air preheating at 50˚C. The brake thermal efficiency of engine with air preheating is higher compared to the previous figure no. 6. At higher inlet air temperature due to air preheating, lower CO emission and better air fuel mixing and shorter ignition delay and shorter premixed combustion duration has occurred as described earlier are the main causes for improving engine brake thermal efficiency.

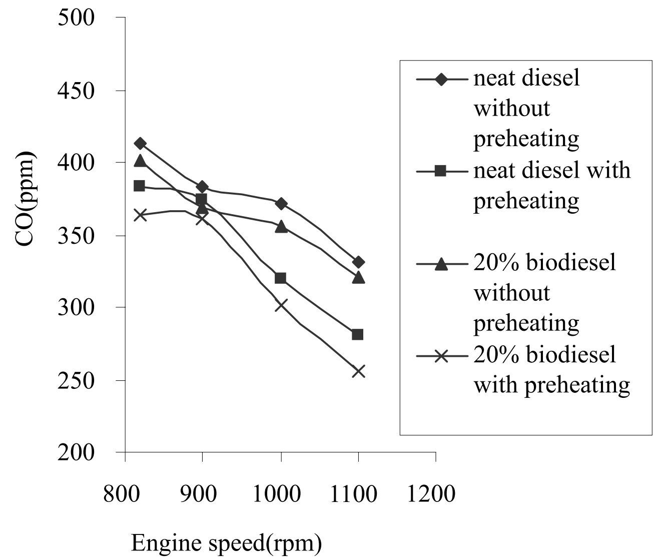

Fig 5: Variation of CO emission with engine speed for neat diesel and diesel-20% biodiesel blends without and with inlet air preheating (50˚C) at fixed load 10kg.

Figure 8 illustrates the effect of engine speed on brake specific fuel consumption (BSFC) at constant load (10kg) with neat diesel fuel and different % of biodiesel in diesel-biodiesel blends. It is seen from the figure that the BSFC decreases with the increases of engine speed and then increases with the increase of engine speed.

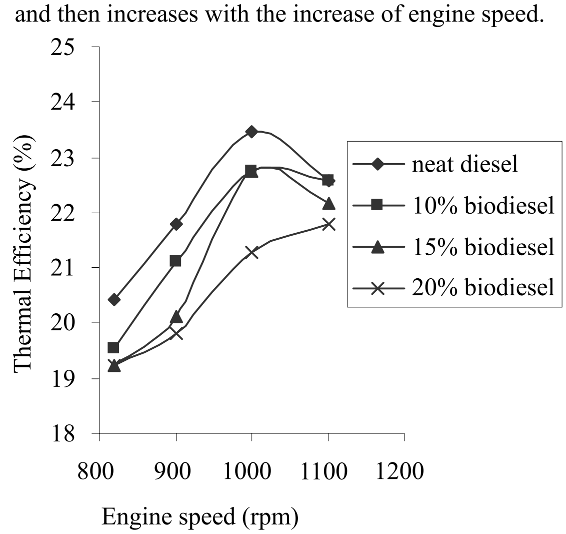

Fig 6: Effect of engine speed on brake thermal efficiency for diesel-biodiesel blends without inlet air preheating.

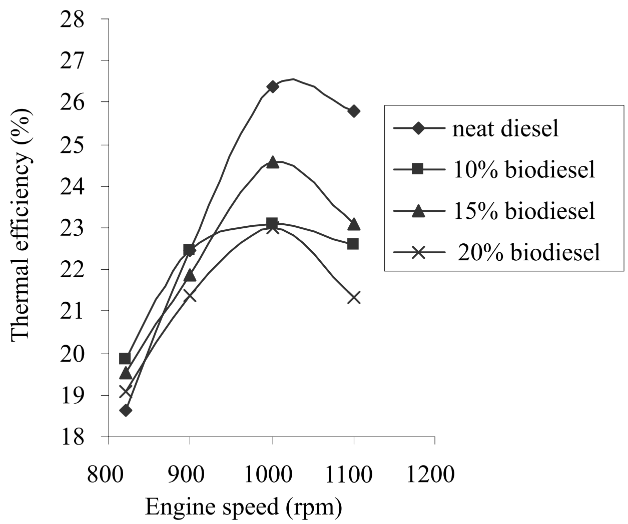

Fig 7: Effect of engine speed on brake thermal efficiency for diesel-biodiesel blends with inlet air preheating at 50˚C (constant load 10kg).

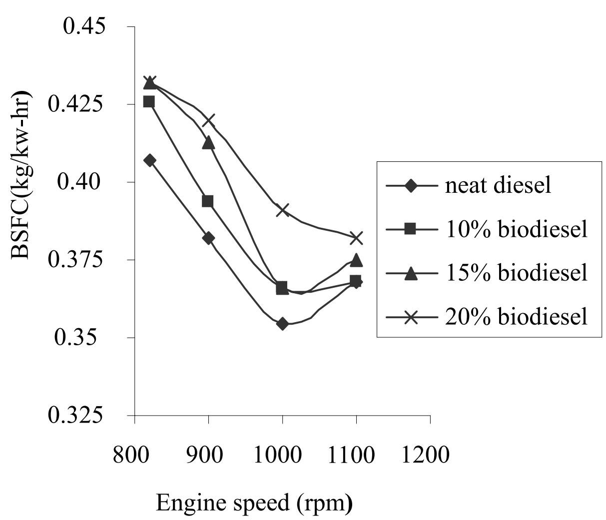

Fig 8 Effect of engine speed on BSFC for diesel-biodiesel blends without inlet air preheating at constant load of 10kg

The BSFC for the same amount of power production, for biodiesel is higher compare to conventional diesel fuel. This may be associated with the evidence of previous figure no.6. Another reason is that calorific or fuel value of biodiesel is lower than conventional diesel fuel due to reduction of carbon and hydrogen fraction in fuel as the presence of oxygen in the fuel.

5. CONCLUSION

In this work, combustion and exhaust emissions with neat diesel fuel and blends of diesel-biodiesel with and without inlet air preheating were investigated. The study consists of two phases. In first phase, bio-diesel was prepared from non edible vegetable oil and in next phase combustion and emissions were investigated when diesel biodiesel blends are used as fuel. NOx emission increased with the increased of the percentage of biodiesel in blends but with inlet preheating, biodiesel up to certain percentage of biodiesel in blends reduced NOx and CO emission simultaneously. Although brake thermal efficiency of the engine is lower compared to conventional diesel fuel but biodiesel renewable in nature and commercial use of biodiesel with inlet air pre heating attachment reduce the air pollution and also can increase the R/P of the conventional diesel fuel.

The results this research work can be summarized as the followings:

1.Bio-diesel was prepared by transesterification process.
2. Properties of diesel and bio-diesel were determined.
3. Compared the boidiesel performance with neat diesel in engine.
4. Air preheating effects was observed for both neat diesel and diesel biodiesel blends when used as fuel.

20% of biodiesel in diesel biodiesel blends with air preheating (temperature raised to 50^0 C) shows the better emission parameters than others conditions even neat diesel.

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7. NOMENCLATURE

Symbol	Meaning	Unit
T	Temperature	(^{0}C)
rpm	Revolution Per Minute	Numerical Number
PPM	Parts Per Million	Numerical Number
BSFC	Brake Specific Fuel Consumption	Kg/kwhr