



EXPERIMENTAL ANALYSIS FOR SUITABILITY OF ALGAE BIO DIESEL BLEND AS AN ALTERNATE FUEL IN CI ENGINE

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Abstract

Scientific community is facing a challenging issue of global warming which is in an alarming level. If it is not stopped at the earliest, existence of human life will be a big question. The reason for this global warming is emission of harmful green house gases which destroys the ozone layer and also do not allow heat to escape in outer atmosphere after heating surface of earth. It is found that fossil fuels used in automobiles and in industries are the major source of these harmful emissions. 20% blend of biodiesel extracted from Chlorella microalgae which is a renewable energy source used in this paper for determining its suitability as an alternate fuel in a compression ignition engine. Combustion characteristics obtained experimentally are compared with the corresponding characteristics of pure diesel. Blend B20 biodiesel extracted from the microalgae is found suitable to run the compression ignition engine at medium and higher loads.

Key words — Biodiesel, Friction Power, Friction Mean Effective Pressure, Air Flow, Brake Power etc.

I. INTRODUCTION

Environmental pollution has become a major concern for all environmentalists and engineers too. There is a strong requirement to find out a suitable replacement of fossil fuel at the earliest but not at the cost of compromising with thermal, mechanical and emission characteristics obtained with diesel. Chemical engineers along with automobile engineers and other scientists are working day and night to find out an alternate fuel which may take the place of fossil fuel diesel. It is due to the fossil fuel reserves are depleting at a faster rate and if a suitable replacement is not found very soon, there may be a situation where diesel or petrol will not be available at all and all forms of transport will come to a sudden halt which will be a dangerous situation and world cannot afford it at any cost. Simultaneously, emission of harmful pollutants due to use of these fossil fuels have increased to an alarming level and whole world is facing a challenge to reduce global warming. It has become very serious and requires immediately to reduce emission of greenhouse gases like carbon monoxide, methane etc. It is also required to find out a source of alternate fuel which can be produced using renewable energy sources and comparatively having lower production cost. Several blends of alternate fuels from sources like edible oil, rice bran oil, lemon grass oil, algae oil, used oil from restaurants and eateries, animal fats etc. have been tested by various researchers for its suitability with respect to combustion and emission characteristics. [1][2] [7] [11] Researchers have used fish oil, pongamia oil and Jatropha oil as biodiesels for analysis on performance and emission characteristics. [3][4][5][8][9] Researchers have used biodiesel and addition of additives for improvement in performance of the biodiesel and compared the corresponding characteristics obtained for pure diesel. Researchers have tested this biodiesel in blends like 10%, 20%, 40%, 100% etc. and compared combustion and emission characteristics obtained with the corresponding characteristics of pure diesel and recommended as per their findings. [6] The researchers used variation in

compression ratio for improvement in performance with good atomization. [10] The authors used ceramic coating as thermal barrier coating for retention of heat in the combustion chamber for complete combustion and thereby to obtain more brake power. Most of the researchers used emission analysis more prominently and some performance parameters for determining the suitability of the biodiesel. In this paper, 20% blend of Chlorella algae oil with 80% pure diesel is used for testing its suitability as alternate fuel taking into consideration thermal, mechanical and burning characteristics and an analysis is done to improve the blend for its replacement in a compression ignition engine. The experimental analysis is performed in a variable compression ignition engine and the results obtained are compared with the results of pure diesel. Mostly the losses with importance of fuel flow and air flow along with losses of heat in the form of radiation and in exhaust gases are addressed in this paper and comparative analysis is done to determine the suitability of algae biodiesel blend B20. It is found that blend B20 is suitable to run the diesel engine at medium and higher loads without any modification in the existing compression ignition engine.

II. MATERIALS - MICROALGAE – A RENEWABLE ENERGY SOURCE

The microalgae Chlorella can be grown in abundance in controlled conditions and is available as a renewable energy source. It is available as fresh water and brine water algae. In some countries, it is used as a source of food and even in medicines. The microalgae are rich in lipids which makes it suitable for extraction of biodiesel from it. Little fishy and pungent smell emanates from it due to which it is used less in direct edible food materials.

III. CHEMICAL PROPERTIES OF CHLORELLA MICROALGAE OIL

The Biodiesel produced from Chlorella microalgae and as

shown in Figure 1 is tested for its combustion properties before its use in actual internal combustion engine to determine its performance and emission characteristics. The biodiesel extracted from these microalgae are tested in a laboratory and flash point and fire point are found to be 108 °C and 119 °C respectively with a gross calorific value of 39321.21 kJ/Kg. The kinematic viscosity is found to be 4.07 cSt at 40 °C atmospheric temperature.

IV. METHODOLOGY - ENGINE USED FOR EXPERIMENTAL OBSERVATIONS

Kirloskar TV1 Variable Compression Ratio (VCR) Engine which is a one cylinder four stroke, Water Cooled Diesel Engine with constant speed. The compression ratio of the engine is 17.5. Experiments are conducted at 200 bar injection pressure. The power produced by the engine at 1500 RPM is 5.2 kW. Fuels used for experimentation and comparison of performances are B20 (20% Biodiesel + 80% Pure Diesel) and D100 (Pure Diesel). The data obtained for combustion characteristics is at 200 bar injection pressure.

Figure 1: TV1 Variable Compression Ratio (VCR) Engine.



V. RESULTS AND DISCUSSION

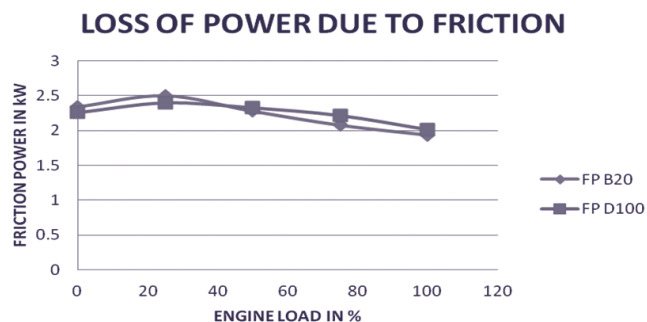
1. Friction Power

The total power produced by the engine due to complete combustion of fuel is called indicated power (IP). The power available for useful work is called brake power (BP) and the difference of these two powers i.e. IP-BP is called friction power (FP) which is indicating loss of power due to friction. Theoretically this loss should be zero which means 100% of developed power is converted into useful work but having such type of engine is not practical. The main purpose of this analysis is to reduce losses in the engine by identification of moving parts and components where excessive losses are taking place due to malfunctioning or wear and tear of bearings and gears etc. The result obtained for B20 and D100 are given in Table 1.

Table 1: Friction Power in kW at different loads.

Engine Load in %	FP (kW) – B20	FP (kW) – D100
0	2.34	2.26
25	2.50	2.40
50	2.28	2.33
75	2.08	2.22
100	1.94	2.02

Figure 2: Friction Power in kW



Discussion: At 0% engine load, 3.54% more loss has been found for B20 when compared with D100 which further increased to 4.17% at 25% load. The loss has reduced from 50% loading conditions. At 75% load, the loss has greatly reduced to 6.31% with B20 in comparison to D100 and at 100% load, the loss is reduced to 3.96%. The blend B20 has proved better at 75% and 100% engine load in comparison to D100. This excess power is available in the output shaft for doing useful work. The blend is recommended to run the engine at medium loading conditions preferably at 75% and 100% engine load and it is due to good combustion achieved at higher loads.

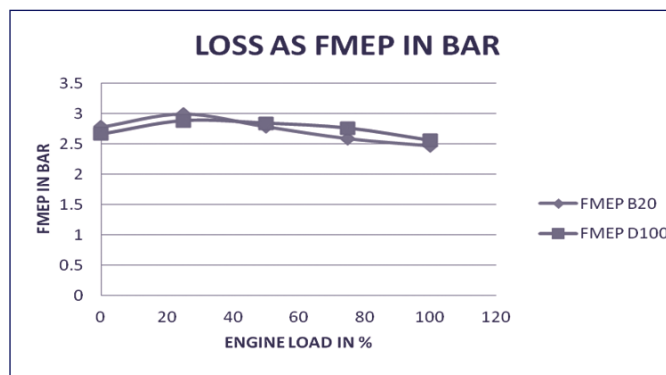
2. Friction Mean Effective Pressure (FMEP)

The pressure generated in the cylinder due to combustion of fuel is called indicated mean effective pressure and the pressure utilized to generate brake power is called brake mean effective pressure. Friction mean effective pressure (FMEP) represents loss of pressure which is to be minimized to a maximum extent in order to increase the efficiency of the engine. The test results obtained for FMEP are shown in table 2.

Table 2: Friction Mean Effective Pressure (FMEP) in bar at different loads.

Engine Load in %	FMEP (bar) – B20	FMEP (bar) – D100
0	2.78	2.66
25	3.00	2.88
50	2.79	2.84
75	2.59	2.76
100	2.47	2.56

Figure 3: Friction Mean Effective Pressure (FMEP) in bar.



Discussion: At 0% engine load, 4.51% more loss has been found for B20 when compared with D100 which further increased to

4.17% at 25% load. The loss has reduced from 50% loading conditions. At 75% load, the loss has greatly reduced to 6.16% with B20 in comparison to D100 and at 100% load, the loss is reduced to 3.52%. The blend B20 has proved better at 75% and 100% engine load in comparison to D100. This excess pressure is converted to useful power in the output shaft. The blend is recommended to run the engine at medium loading conditions preferably at 75% and 100% engine load and it is due to good combustion achieved at higher loads.

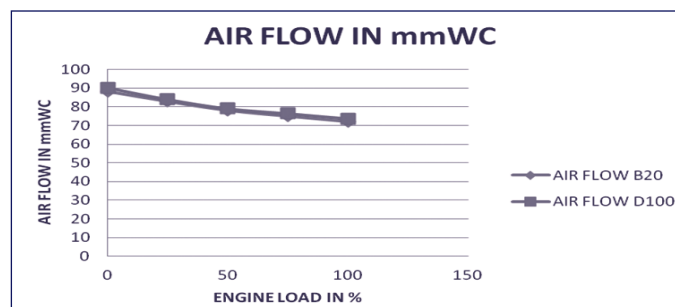
3. Air Flow

The air flow to the engine is measured in millimeters of water column (mmWC). The air flow is a parameter which plays major role in the working of a diesel engine. In a compression ignition engine, the air taken in the cylinder in induction stroke is compressed and then at the end of the compression stroke, fuel is injected and the heat developed in compression is sufficient to ignite the fuel. The amount of air determines the quality of exhaust gases and controls the emissions. Less air induction results in incomplete combustion and leads to the emission of harmful gases like carbon monoxide and hydrocarbons. The test results obtained for air flow are shown in table 3.

Table 3: Air Flow in mmWC at different loads.

Engine Load in %	Air Flow (mmWC) – B20	Air Flow (mmWC) – D100
0	88.11	90.19
25	82.78	83.91
50	78.06	79.04
75	75.00	76.41
100	72.12	73.68

Figure 4: Air Flow in mm WC.



Discussion: At 0% engine load, 2.31% less air flow is found for B20 when compared with D100 which further decreased to 1.35% at 25% load. At 75% load, it increased to 1.85% with B20 in comparison to D100 and at 100% load, the it is increased to 2.12%. Despite of less air flow at higher speed in case of the blend B20, it is found suitable at 75% and 100% engine load in comparison to D100. This is due to more oxygen content in biodiesel which is used to achieve good combustion.

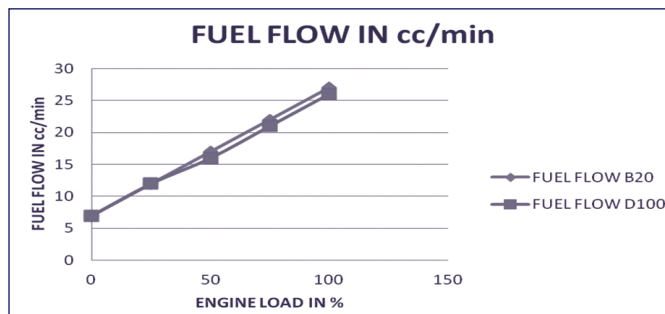
4. Fuel Flow

The volume of fuel flow to the engine is measured in cubic centimeters per min (cc/min). The fuel flow to the engine depends on the air flow in order to maintain required air fuel mixture. At higher engine loads, high fuel flow is required to maintain the desired speed. The test results obtained for fuel flow are shown in table 4.

Table 4: Fuel Flow in cc/min at different loads.

Engine Load in %	Fuel Flow (cc/min) – B20	Fuel Flow (cc/min) – D100
0	7.00	7.00
25	12.00	12.00
50	17.00	16.00
75	22.00	21.00
100	27.00	26.00

Figure 5: Fuel Flow in cc/min.



Discussion: At 0% and 25% engine loads, 0% variation is found for B20 when compared with D100. The fuel flow demand in case of B20 increased at higher loads. Maximum fuel flow demand is 6.25% at 50% engine load. The fuel flow has increased at 50% and at higher loads is due to meet the power demand of the engine at higher loads as B20 has less calorific value than D100.

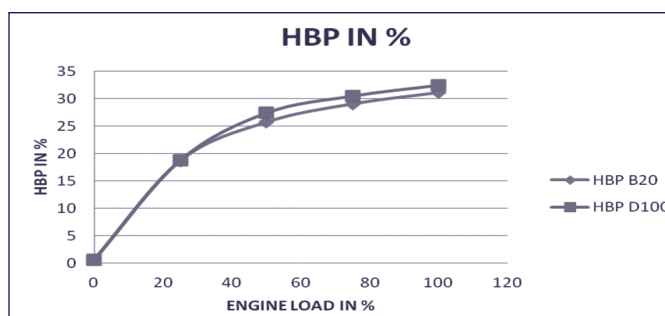
5. Heat - Brake Power (HBP)

The heat generated in the cylinder is converted into work. The heat used to generate brake power is defined as HBP. The test results obtained for HBP are shown in table 5.

Table 5: Heat rejected in generating Brake Power in % at different loads.

Engine Load in %	HBP (%) – B20	HBP (%) – D100
0	0.63	0.58
25	18.67	18.73
50	25.70	27.39
75	29.03	30.49
100	31.09	32.46

Figure 6: HBP in %.



Discussion: At 0% engine load, 8.62% excess heat is used in case of B20 for generating brake power in comparison to D100. As B20 has less calorific value than D100, at higher loads, less heat is generated and less amount of heat is utilized for brake power in comparison to D100. At 50% engine load, 6.17% less

heat is used for brake power in case of B20 in comparison to D100

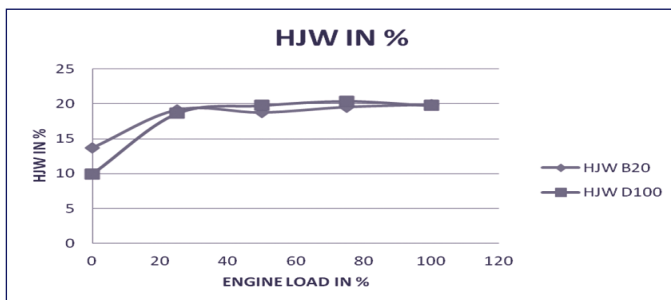
6. Heat rejected in water for cooling (HJW)

The engine used is a water cooled engine and some amount of heat is dissipated as radiation and also in the water used to provide cooling effect. The test results obtained for HJW are shown in table 6.

Table 6: Heat rejected to the water used for cooling of the engine in % at different loads.

Engine Load in %	HJW (%) – B20	HJW (%) – D100
0	13.71	9.95
25	19.13	18.64
50	18.76	19.79
75	19.54	20.40
100	19.90	19.76

Figure 7: HJW in %.



Discussion: At 0% engine load, 37.79% excess heat is rejected to the cooling water in case of B20 in comparison to D100. Heat rejection reduced at higher loads for B20. Heat rejection in cooling for D100 is found to be more above 25% engine loads. At 50% engine load, 5.20% less heat is rejected than D100 and very less variation of 0.71% is found for B20 at 100% engine load.

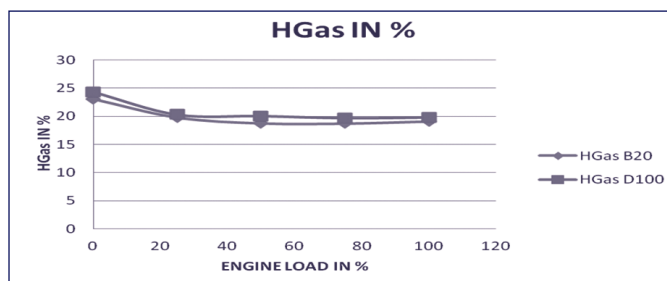
7. Heat rejected in Exhaust Gases (HGas)

The heat developed in the cylinder is utilized for extracting work and also gets rejected in cooling and in exhaust gases which moves out in open atmosphere. Less the heat rejected in exhaust gases, more heat utilized for generating brake power. Due to high calorific value of D100 in comparison to B20, more heat is generated in the cylinder in case of D100 and also heat rejected to the atmosphere through exhaust gases is also more almost at all engine loading conditions. Blend B20 rejects less heat in exhaust gases is a good indication of lessening the global warming effect by reducing atmospheric temperature. The test results obtained for HGas are shown in table 7.

Table 7: Heat rejected to exhaust gases in % at different loads.

Engine Load in %	HGas (%) – B20	HGas (%) – D100
0	23.03	24.36
25	19.81	20.33
50	18.79	20.09
75	18.75	19.72
100	19.13	19.85

Figure 8: Heat rejected in exhaust gases (HGas) in %.



Discussion: At 0% engine load, 5.46% less heat is rejected in the exhaust gases in case of B20 in comparison to D100 whereas it is 6.47% at 50% engine load. Variations of 2.56% and 3.53% are found at 25% and 100% engine load respectively.

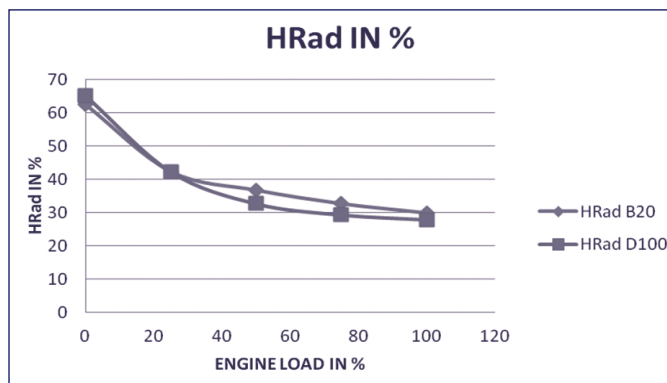
8. Heat rejected as Radiation (HRad)

The cooling effect provided to the engine by air cooling is always more than liquid cooling system in which lubricating oil is circulated through pipelines and internal passages using a proper lubrication system. Though the heat generated in diesel engine using D100 is more, the heat rejected to atmospheric air in the form of radiation is also more at almost all engine loads. The reason of producing more heat with D100 is high calorific value of diesel in comparison to B20. It is also observed that above 25% engine load, the heat lost is more in case of B20 in comparison to D100. The test results obtained for HRad are shown in table 8.

Table 8: Heat rejected in the form of radiation (HRad) in % at different loads.

Engine Load in %	HRad (%) – B20	HRad (%) – D100
0	62.63	65.12
25	42.39	42.30
50	36.75	32.73
75	32.68	29.39
100	29.88	27.93

Figure 9: Heat rejected in the form of radiation (HRad) in %.



Discussion: At 0% engine load, 3.82% less heat is rejected in the form of radiation in case of B20 in comparison to D100 whereas more heat is lost at above 25% engine load. Maximum rejections of 12.28% and 11.19% are found at 50% and 75% engine loads. Variations of 2.56% and 3.53% are found at 25% and 100% engine load respectively.

VI. CONCLUSIONS

There is a strong need to have an alternate fuel from renewable energy sources. Researchers and Scientists are working day and night to find a suitable fuel which can replace fossil fuels like petrol and diesel. Chlorella microalgae is also one of the renewable energy source having high lipid content making the biodiesel extracted from it a strong promising source of alternate fuel. In this paper, blend B20 biodiesel is used to determine its suitability as an alternate fuel taking into consideration of combustion characteristics. With respect to loss of power in the form of friction and mean effective pressure, B20 has proved better at medium and higher loads with minimum loss 6.31% and 6.16% at 75% engine load for power and mean effective pressure. The micro alga is rich in oxygen and therefore needs less external air for combustion. Based on the findings, it is found that the blend B20 is suitable to run the engine at medium and higher loads.

CONFLICT OF INTEREST

The author confirms that there is no conflict of interest to declare for this publication.

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