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Effect of Diethyl Ether on Combustion and Emission Characteristics of Biodiesel Blend B20 Algae Oil

Sanjay Singh, M Prabhahar

Abstract: ***Emission of carbon dioxide gases and damages occurring to the protective layers of the atmosphere due to the presence of pollutants like methane, chlorofluoro carbons etc. are the reasons for the Governments to adopt stricter emission norms. In the present situation where global warming is at an alarming level, there is a need to have alternate fuel which can reduce harmful emissions to a considerably low and acceptable level. Blends of B20, B40 and B100 algae oil are tested in variable compression ratio diesel engine and compared with diesel for its combustion, mechanical properties and emission performance. The performances of B20 blend are found closer to the performance of fossil fuel diesel and the blend is found suitable as one of the choice for the alternate fuel. Blend of B20 is further tested by adding 10% diethyl ether and an improvement in mechanical and emission characteristic is observed.***

Key words —Biodiesel, Blend, Brake Power, Carbon Dioxide, Diethyl Ether, Global Warming etc.

I. INTRODUCTION

In addition to emissions from industries, automotive emissions have also become a major contributor for the present day burning problem of global warming which has made all countries worried to a great extent and produced a question mark on the survival of life on earth. Emission of carbon dioxide gases and damages occurring to the ozone layer of the atmosphere due to presence of other pollutants like methane, chlorofluoro carbons etc. have forced Governments to adopt stricter emission norms. The heat reaching to the earth's surface during day time is not escaping to the outer space at the same rate and getting trapped in the inner atmosphere leading to increase in temperature of the earth day by day. Production of biodiesels and blends of algae oil, jatropha oil, fish oil, cooking oil etc. are tested for its mechanical performance, combustion and emission characteristics and found to be suitable for replacement of fossil fuel by using additives and properties improvers [1,2,3,4,5, 11,]. Environmentalists and technologists are morally obliged to design and produce engines running with clean and green fuels which can bring the alarming situation of global warming to acceptable level. Availability and level of conventional fossil fuels like petrol, diesel etc. is in dangerously alarming condition and the price of the same is also increasing with the pace of a rocket.

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* Correspondence Author
Mr. Sanjay Singh, Research Scholar, Department of Mechanical Engineering, Vinayaka Mission's Kirupananda Variyar Engineering College, Salem, Tamil Nadu, India.
Professor Dr. M. Prabhahar, Teaching Faculty, Department of Mechanical Engineering, Aarupadai Veedu Institute of Technology, Paiyanoor, Chennai, India.

There is a need to have some alternate fuels which can address global warming issues and also can become an effective replacement of fossil fuels in future [12,13,14,15]. Several blends of biodiesels have been tested by using different methods like by changing injection pressures, mixing with some percentage of exhaust gases in order to reduce combustion temperature etc. to reduce mainly NOx emissions [6,7, 8,9,10]. The blend B20 of Chlorella algae oil is tested for its performance for combustion and emission characteristics and a comparative analysis is done with addition of diethyl ether as additive. [16,17,18]. The algae oil is chosen for testing because of its abundance availability and suitability as an alternate fuel. It is observed that mechanical properties, combustion and emission characteristics have considerably improved.

II. ABOUT CHLORELLA MICROALGAE

Chlorella microalgae are available in abundance and can be grown easily in moist places. These algae are generally used as a food supplement due to its rich protein content especially in Japan, Germany, Taiwan etc. It also contains a rich content of lipids and starch. The biomass can be grown faster due to its high productivity. The lipids and starch present in this biomass can be easily converted into methyl and becomes a good source of bio diesel. Due to its pungent smell like fish, it is used less in food products.

III. PHYSICAL AND CHEMICAL PROPERTIES OF DIETHYL ETHER

Diethyl ether is a colorless liquid. Its odor is pungent and ethereal. Its taste is sweet and burning. Diethyl ether has a molecular weight of 74.1216 g/mol and a mass of 74.073165 g/mol. The boiling point of diethyl ether is 34°C or 94°F, and its melting point is - 116°C or - 177°F. Its flash point is - 45°C or - 49°F. Diethyl ether is soluble with ethanol, acetone, concentrated hydrochloric acid, naphtha, lower aliphatic alcohols, benzene, chloroform, petroleum ether, fat solvents, and many oils. It is also slightly soluble in water and solubility can be increased by adding hydrochloric acid. Diethyl ether has a density of 0.71in comparison to Water for which density is 1 and a viscosity of 0.2448 centipoise at 20°C. The heat of combustion of Diethyl ether is -8.807 kcal/g, and its heat of vaporization is 89.80 cal/g at 30°C. It burns with a smoky greenish flame and its heat of formation is - 907 cal/g. It is highly volatile and highly flammable at low ignition temperature. It can create fire hazards if not handled properly under controlled conditions. It can produce explosive peroxides when stored in contact with air.

It is not highly toxic and can be absorbed into the human body through ingestion or inhalation of its vapor.
Its inhalation can result in sedation, unconsciousness and exposure can lead to cough, sore throat, labored breathing, dizziness, drowsiness, headache, nausea, or vomiting. It can cause irritation to the eyes and skin. In earlier days it was used as an anesthetic.

IV. EXPERIMENTAL SET UP

Variable Compression Ratio (VCR) Kirloskar TV1 Engine as shown in Figure 1 is used for the test. It is a Single cylinder four stroke, constant speed and water cooled diesel engine. The experimental test set up is shown in figure 2. Specifications and other parameters of the engine are as mentioned in table 1.

Figure 1: Variable Compression Ratio Kirloskar Engine.

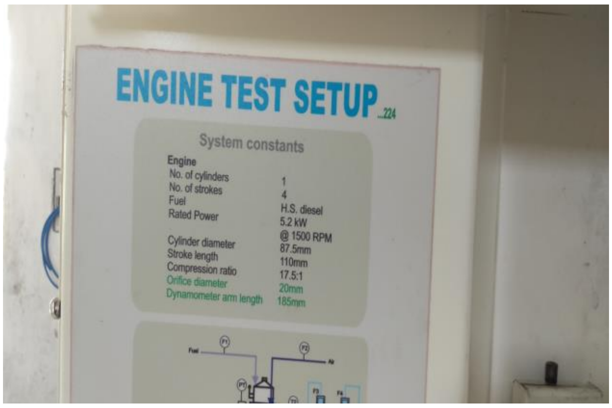

Figure 2: Engine test Set up of Kirloskar VCR Engine.

Table 1: Kirloskar Engine Specifications

Sl. No.	Description	Values
1.	Cylinder Bore in mm	87.50
2.	Stroke Length in mm	110.00
3.	Connecting Rod length in mm	234.00
4.	Swept volume (cubic centimeter)	661.45
5.	Compression Ratio	17.50
6.	Power in kW @ 1500 RPM	5.20

V. COMBUSTION PERFORMANCE AND MECHANICAL PROPERTIES - BLEND B20 OF ALGAE BIO DIESEL ONLY AND WITH 10% DIETHYL ETHER AS ADDITIVE AT 200 BAR INJECTION PRESSURE

The biodiesel B20 of chlorella microalgae is tested at 200 bar injection pressure for its performance characteristics. Engine load varied from 0% to 100% with an increment of 25% each time. The results obtained are compared with the performances of B20 plus 10% diethyl ether under the same climatic and laboratory conditions.

A. Brake Thermal Efficiency

The input heat energy in the form of fuel generated power at crankshaft. The efficient conversion of the input energy into useful work is called brake thermal efficiency. It is expressed in %. The total efficiency of the engine which is generally theoretical value and is calculated using algebraical formula is called indicated thermal efficiency. Some power is compulsorily lost due to friction and is termed as friction thermal efficiency. The test results obtained for the pure blend B20 and with 10 % diethyl ether at 200 bar injection pressure at different loading conditions are mentioned in table 2 and the graph is shown in figure 3.

Table 2: Test results of Brake Thermal Efficiency.

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	B20 + 10% DEE
0	0.4	0.83
25	18.67	19.58
50	25.7	26.82
75	29.03	29.93
100	31.09	31.97

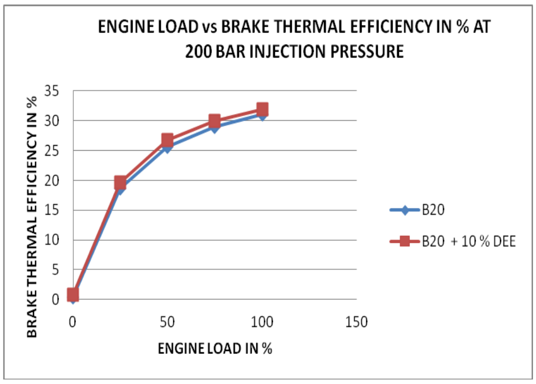

Figure 3: Engine Load vs Brake Thermal Efficiency

Addition of diethyl ether has resulted in improvement in performance of pure blend B20 biodiesel. This is due to high volatility and high flammability of diethyl ether leading to pre - mixing of mixture and complete combustion at low temperature.

B. Specific Fuel Consumption (SFC)

Fuel consumed by the engine at various power ratings is known as specific fuel consumption and is expressed in kg / kWh. It is one of the important parameter showing the power developed in the engine per kg of the fuel consumed per unit time. An engine generating more power with less fuel consumption is preferred as it clearly reflects rate of combustion of fuel inside the cylinder. The test results of SFC obtained for pure blend B20 and with 10% diethyl ether are as mentioned in table 3 and the graph is plotted in figure 4.

Table 3: Test Results for Specific Fuel Consumption.

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	B20 + 10% DEE
0	0.95	0.93
25	0.46	0.42
50	0.33	0.31
75	0.3	0.29
100	0.28	0.27

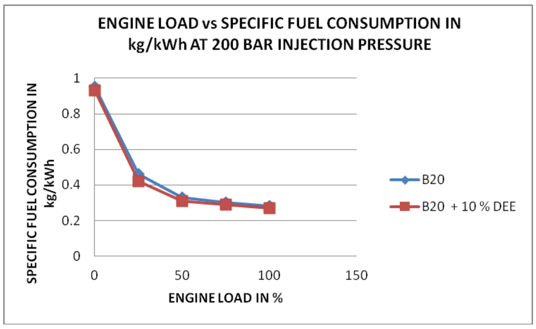

Figure 4: Engine Load vs Specific Fuel Consumption.

The decrease in specific fuel consumption is observed in case of diethyl ether mixed blend B20 biodiesel in comparison to pure B20 biodiesel. This is due to reduction in viscosity of biodiesel and high volatility of diethyl ether resulted in achieving proper atomization.

C. Mechanical Efficiency

Effective and efficient working of all components together in an engine for best output and power is expressed in terms of mechanical efficiency in %. Individual performances of components are calculated first and the same is compared with its performance in one unit as assembly of all components. The test data obtained are shown in table 4 and the graph is plotted in figure 5.

Table 4: Test Results of Mechanical Efficiency.

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	B20 + 10% DEE
0	0.81	1.09
25	34.51	36.31
50	53	55.45
75	64.41	66.25
100	71.78	74.18

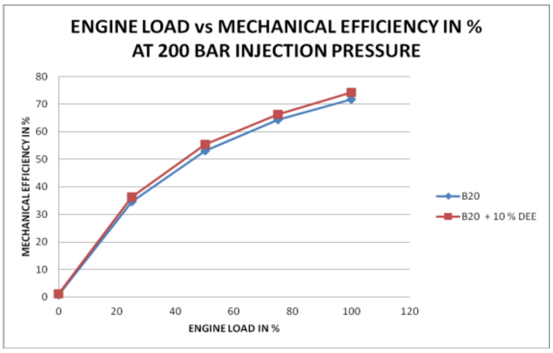

Figure 5: Engine Load vs Mechanical Efficiency.

A considerable increase in mechanical efficiency is observed in all loading conditions for B20 with diethyl ether. The increase is due to complete combustion of fuel achieved and lowering of viscosity resulting in good atomization.

D. Brake Power

The input chemical energy is first converted into heat energy and the same is converted into useful work. The theoretical amount of work or power the engine should produce is called indicated horse power (IHP). Some amount of work is lost in the form of friction and is called as friction horse power (FHP). The difference of IHP and FHP is called as Brake horse power (BHP) and is expressed in kilowatt (kW). It is the amount of power actually used for doing useful work. The test results obtained are mentioned in table 5 and the graph is plotted in figure 6.

Table 5: Test Results of Brake Power.

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	B20 + 10% DEE
0	0.02	0.05
25	1.31	1.78
50	2.56	2.87
75	3.76	4.13
100	4.92	5.35

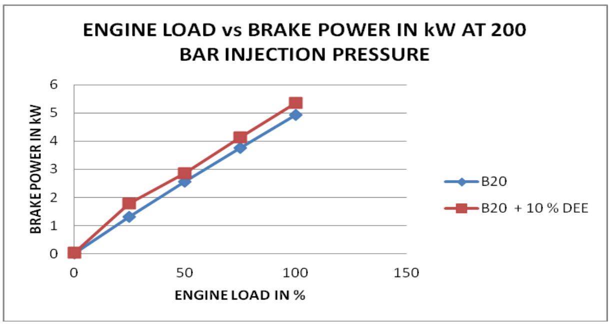

Figure 6: Engine Load vs Brake Power.

The increase in brake power clearly reflects reduction in power loss. This increase in brake power is due to thorough mixing of diethyl ether with B20 bio diesel and proper combustion. This is due to higher solubility with oils resulting in lowering of viscosity and good atomization leading to complete combustion.

E. Torque

Torque is an indication of the power developed in the engine. It is produced on the crankshaft by the cylinder pressure making the piston to move in power stroke. The torque on the piston in the cylinder is called indicated torque whereas the actual torque available at the crankshaft for useful work is called brake torque. The torque is measured in newton metre (Nm). The brake torque values obtained in the test are mentioned in table 6 and the graph is plotted in figure 7.

Table 6: Torque values.

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	B20 + 10% DEE
0	0.15	0.2
25	8.36	8.97
50	16.53	16.85
75	24.69	25.15
100	32.99	33.82

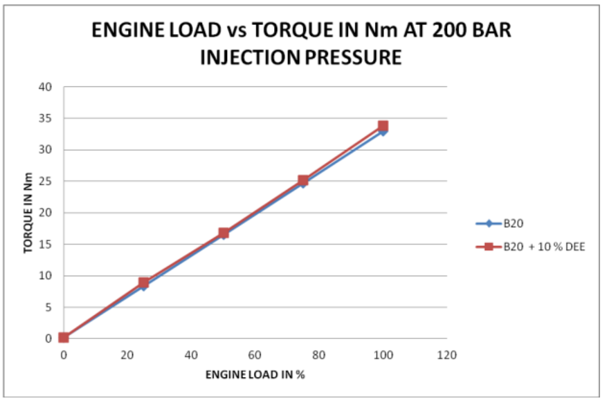

Figure 7: Engine Load vs Torque

On comparison of the values obtained it is observed that torque has increased in case of biodiesel with diethyl ether. This increase in performance is due to better atomization at high pressure and pre-mixing of fuel air mixture and complete combustion in the engine cylinder.

VI. EXHAUST GAS EMISSIONS - BLEND B20 OF ALGAE BIO DIESEL ONLY AND WITH 10% DIETHYL ETHER AS ADDITIVE AT 200 BAR INJECTION PRESSURE

Biodiesel blend B20 and blend B20 with 10% diethyl ether are also tested for their exhaust gas emissions. The emission characteristics of the biodiesels for Carbon Monoxide (CO), Carbon Dioxide (CO_2), Oxygen (O_2), Hydro Carbon (HC) and Nitrogen Oxides (NO_X) are measured using 5 gas analyzer.

A. Emission of Carbon Monoxide (Co)

The main reason of emission of carbon monoxide is incomplete combustion of fuel. The test results obtained are shown in table 8 and the graph plotted is shown in Figure 8. It is expressed in %.

Table 7: Carbon monoxide emission in %.

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	B20 + 10% DEE
0	0.049	0.035
25	0.044	0.028
50	0.04	0.014
75	0.037	0.011
100	0.185	0.134

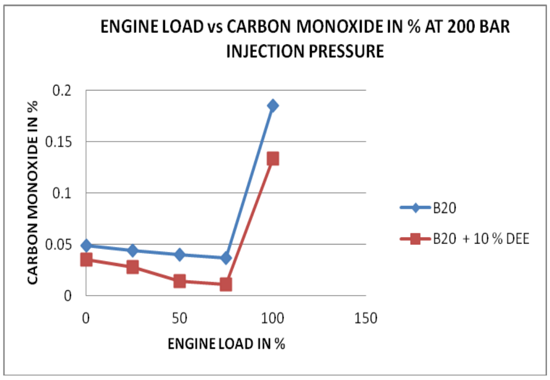

Figure 8: Engine Load vs Carbon Monoxide (CO) emission.

It is clearly observed that the emission of carbon monoxide has greatly reduced in case of biodiesel with diethyl ether. This is due to the addition of diethyl ether which has increased volatility of mixture resulting in complete combustion of fuel.

B. Emission of Carbon Dioxide (Co2)

Incomplete combustion of fuel in an engine also leads to emission of carbon dioxide in presence of excess oxygen. It is expressed in %. The test results obtained are shown in table 8 and the graph plotted is shown in figure 9.

Table 8: Carbon monoxide emission in %

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	B20 + 10% DEE
0	2.01	1.81
25	4.14	3.99
50	5.89	5.57
75	7.76	7.47
100	10	9.62

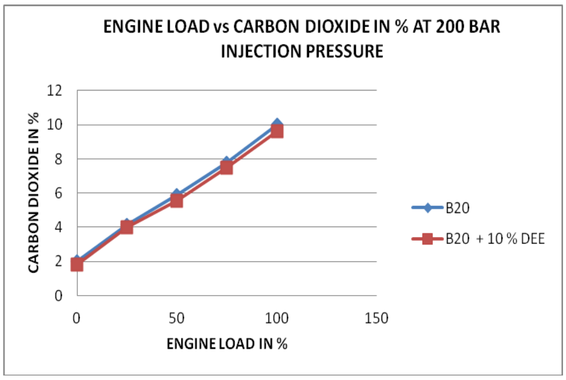

Figure 9: Engine Load vs Carbon dioxide Emission in %.

Discussion: The emission of Carbon Dioxide (CO_2) gas is found to be lower in case of biodiesel B20 with diethyl ether in comparison to pure biodiesel B20 and is expressed in %. This is due to complete combustion achieved and thorough mixing of diethyl ether with biodiesel resulting in enhancement in combustion properties.

C. Emission of oxygen (O2)

The biodiesel is rich in oxygen content as algae are having good amount of oxygen in it. The emission of oxygen takes place in an engine due to improper mixing of fuel and air mixture. The available oxygen is not utilized completely for combustion resulting in oxygen emission. The test results obtained are shown in table 9 and the graph plotted is shown in Figures 10.

Table 9: Oxygen emission in %.

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	B20 + 10% DEE
0	18.31	18.05
25	15.18	15.03
50	13.02	12.55
75	10.04	9.89
100	7.14	6.89

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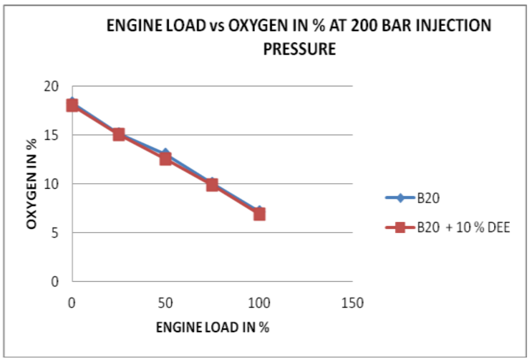

Figure 10: Engine Load vs Oxygen Emission in %.

The presence of oxygen in exhaust gas emissions is found to be lower in case of biodiesel B20 with diethyl ether in comparison to pure biodiesel B20. Complete utilization of available oxygen in combustion process of the biodiesel reduces its emission in exhaust gases.

D. Emission of Hydrocarbons (HC)

All petroleum products consist of hydrocarbons. Emission of the hydrocarbons from an engine through exhaust gases clearly reflects absence of utilization of 100 % fuel for combustion. The emission of hydrocarbon is due to unburned fuel and is the major cause for photochemical smog in various climatic conditions. The test results obtained for hydrocarbon emission in ppm (particles per million) are shown in table 10 and the graph plotted in figure 11.

Table 10: Hydrocarbons (HC) emission in ppm.

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	**B20 + 10% DEE**
0	12	9
25	22	17
50	28	22
75	30	23
100	50	34

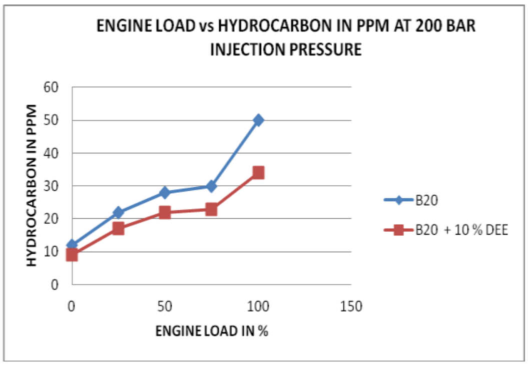

Figure 11: Engine Load vs Hydrocarbons (HC) emission in ppm.

The values obtained for emissions of Hydrocarbon (HC) in ppm are lower in case of biodiesel B20 with diethyl ether. Enhancement in combustion properties and utilization of maximum amount of available fuel for generating power leads to lowering of the HC emissions.

E. Emission of Oxides Of Nitrogen (Nox)

Atmospheric air normally consist of higher percentages of oxygen and nitrogen gases and 1% other gases. Nitrogen being a major constituent in air and at when heated at high temperature produces Nitrogen oxides (NO_X). NO_X is also one of the main cause for photochemical smog and acid rain. The test results obtained for NO_X emission in ppm (particles per million) are shown in table 11 and the graph plotted in figure 12.

Table 12: Nitrogen Oxides in ppm.

Engine Load	AT 200 BAR INJECTION PRESSURE	
	B20	**B20 + 10% DEE**
0	98	67
25	458	428
50	833	825
75	1184	1125
100	1394	1325

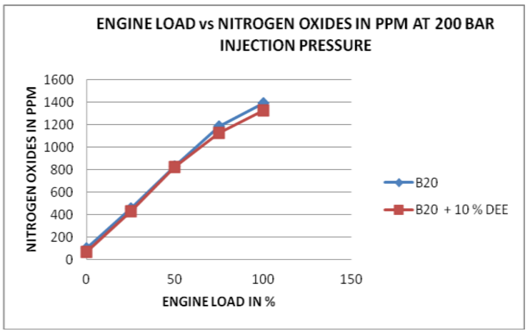

Figure 31: Engine Load vs Nitrogen Oxides.

On analysis of the test results obtained and from the graph, the emission of NO_X is found to be lower in case of biodiesel B20 with diethyl ether in comparison to pure biodiesel B20. High volatility of diethyl ether leads to pre-mixing of fuel and air and further combustion at lower temperature.

VII. CONCLUSION AND FUTURE SCOPE

Global warming is emerging as a serious issue and all countries are worried due to its dangerous effect on the survival and existence of human being. There is an urgent need for environmentalists and technologists to work together for curbing the menace of global warming. Automobile sectors are also responsible in contributing green house gases like carbon dioxide which do not allow heat to escape in outer atmosphere. Technologists have to devise or invent alternate fuels as day by day the reservoir levels of fossil fuels like petrol, diesel etc. have reached to an alarming level. Algae oil can become as one of the source to develop an alternate fuel due to high lipid content and abundance availability. The algae can be grown easily under controlled climatic conditions. The biodiesel blends B20 pure and B20 with 10% diethyl ether of chlorella microalgae oil are used in a variable compression ratio diesel engine to measure their combustion properties and exhaust emissions. The test results obtained are compared and analyzed. Biodiesel blend B20 with 10% diethyl ether is found to have better performance, combustion and exhaust emissions characteristics. In future, the combustion properties can also be enhanced by addition of additives to the level of performance, combustion and exhaust emissions characteristics obtained with fossil fuel diesel.

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AUTHOR PROFILE

Mr. Sanjay Singh is a research scholar and teaching faculty in Department of Mechanical Engineering, Vinayaka Mission's Kirupananda Variyar Engineering College, Salem. His qualification is AMIE and M.E and currently pursuing Ph.D. from Vinayaka Mission's research Foundation, Deemed to be University, Salem. His area of interest is Alternate fuel.

Professor Dr. M. Prabhahar is a teaching faculty in the Department of Mechanical Engineering, Aarupadai Veedu Institute of Technology, Paiyanoor, Chennai. His qualification is B.E. and did his his Post Graduation from Mepco Schlenk Engineering College, Sivakasi. Subsequently he acquired Ph.D. Degree from St. Peters University, Chennai. He has published 15 papers in National and International Journals. His area of interest is biodiesels. Having 85 citations in the International Journals including Springer, Taylor and Francis and IEEE proceedings and 40 publications in reputed journals and has h-index as 5, he has become a member of technical executive committees on National and International conferences and potential reviewer of several journals and is reviewing at least four papers per month. He is also working referee of many reputed journals. "Modeling and construction of bio diesel processor", is selected for the cover note article for the Global Journal of Research in Engineering, USA.