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INVESTIGATION ON THE PERFORMANCE, COMBUSTION & EMISSION CHARACTERISTICS OF SINGLE CYLINDER FOUR STROKE CI DIESEL ENGINE OPERATED WITH DAIRY SCRUM OIL METHYL ESTER

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ABSTRACT

Diesel engines have the prominent role in our day to day life as they have more thermal efficiency and low fuel consumption. The biodiesel is derived from waste dairy scum is suitable as an alternative to diesel as the properties are similar to the diesel. This new approach for using dairy waste scum reduces the cost of production of bio-diesel and the problem associated to the disposal of waste dairy scum. The experimental work has be done on single cylinder four stroke diesel engine operated with Dairy Scum Oil Methyl Ester (DSOME) and studied the performance, combustion and emission characteristics for different blends B10, B20, B30 and B100 of DSOME. From the study it is revealed that the there is significance improvement of brake thermal (BTE) and reduced Brake specific fuel consumption (BSFC) operated with B20 blend (20% biodiesel +80% diesel). And this operation dose not requires the engine modification. From emission analysis, it shown that at the higher loads UBHC (Unburnt Hydrocarbon) and Carbon Monoxide (CO) are decreased while the Nitrogen Oxide (NOx) is increased for blend B20. As the density and viscosity of the pure biodiesel is higher there will be lower BTE and increase in NOx emission because of problems in pumping spray characteristics of the fuel.

***Keywords**: Dairy scum oil methyl ester, Diesel engine, Performance, Biodiesel, Combustion, Emissions.*

1. INTRODUCTION

The world is presently confronted with the twin crisis of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish utilization of petroleum fuels have led to reduction in underground based carbon resources [10, 11]. The search for an alternative fuel, which promises a harmonious correlation with sustainable development, energy conservation, management, efficiency, and environmental preservation, has become highly pronounced in the present context. For the developing countries of the world, fuels of bio-origin can provide a feasible solution to the crisis. The fuels of bio-origin may be alcohol, vegetable oils, bio mass, and biogas. Some of these fuels can be used directly while others need to be formulated to bring the relevant properties close to conventional fuels. The power used in the agricultural and transportation sector is essentially based on diesel fuels and it is, therefore, essential that alternatives to diesel fuels be developed. Biodiesel production Technology is a key factor to enhance both food and bio-energy production and increase the output without adverse economic and environmental implications. One of the main goals of developing the biofuels sector is sustainability.

The inventor of the diesel engine, Rudolf diesel, in 1885, used vegetable oil (peanut oil) as a Diesel fuel for demonstration at the 1900 world exhibition in Paris [8].Emissions are of the primary motivations for biofuels research. Furthermore, the growing concern on environmental pollution caused by the extensive use of conventional fossil fuels has led to search for more environment friendly and renewable fuels. Biofuels such as alcohols and biodiesel have been proposed as alternatives for internal combustion engines. Biodiesel is a clean burning fuel that is renewable and biodegradable and the engine performance with the biodiesel and the vegetable oil blends of various origins was similar to that of the neat diesel fuel with nearly the same brake thermal efficiency, showing higher specific fuel consumption [6, 7, 9]. In particular, biodiesel has received wide attention as a replacement for diesel fuel because it emits less GHG and other pollutants. Biodiesel can reduce net carbon-dioxide emissions when compared to conventional diesel fuel. Interest in and expansion of the production of the renewable fuel have been fostered by mandates and financial incentives offered by governments. This interest can be mostly attributed to the

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commonly cited advantages of biofuels, especially that they can reduce the emission of gases responsible for global warming, promote rural development, contribute toward the goal of energy security, are renewable, and reduce pollution. Another feature that proponents of biodiesel put forward is that the fuel can be used without modification in engines currently in use. [1]. the use of vegetable oil and its derivative as diesel fuel substitutes has almost similar cost as that of mineral diesel [2]. The important advantages of vegetable oils as fuel are that they are renewable, cheap, can be produced locally, and there is less pollutant emissions for the environment as compared to diesel fuel. According to the literature, the use of vegetable oils as fuel in diesel engines causes several problems, namely, poor fuel atomization and low volatility originating from their high viscosity, high molecular weight, and density. Transesterification is the processes of reacting a triglyceride with an alcohol in the presence of a catalyst to produce glycerol and fatty acid esters [3]. Production of milk in India is 150 million tones per year. Ther are large dairies are engaged in processing this milk across the nation. Scum can be produced while making milk products such as Butter, Ghee, Cream, Peda, Panner, Cheese, Yoghurt, Ice cream and other products. Enormous quantities of water are used for milk processing and effluent is get collected in treatment plant as a scum. Scum is a less dense floating solid mass usually formed by a mixture fat, lipids, proteins, packing materials etc as shown in fig.1. A large dairy, which processes 5 lakh liters of milk per day, will produce approximately 200–350 kgs of effluent scum per day, which makes it difficult to dispose. As the Most of the dairies dispose this scum in solid waste disposal are or by incinerating, it’s create direct effect on environment cause pollutants and is economically wasteful. Scum is direct use and blending, micro emulsification, pyrolysis and transesterification. Transesterification is the most commonly used and well established process among four different methods to improve the fuel property of oils and it is used for the current study [4, 5].

2. MATERIALS AND METHODOLOGY

2.1 Biodiesel and Its Properties

For the present investigation, dairy scum was obtained from a Milk Dairy. The properties of DSOME such as viscosity, specific gravity, flash point and calorific value were determined by using standards. Biodiesel is prepared from dairy waste scum oil using the transesterification process. Prepared biodiesel is mixed with neat diesel in differnt concentrations (10, 20, 30 and 100%) by volume termed as B10, B20, B30 and B100 respectively and are used as fuel to run the single cylinder direct injection diesel engine.

Table.1 Properties of Dairy Scum Biodiesel

Properties	Diesel	B100	B30	B20	B10
Density (kg/m^3)	830	870	840	840	830
Viscosity at 40^0 C (cSt)	2.9	4.36	3.15	2.93	2.85
Calorific Value (kJ/kg)	43000	38012	40402	40385	42935
Flash Point (^{0}C)	50	130	62	58	55
Fire point (^{0}C)	60	142	75	68	65

Fig.1 Photographic view of dairy scum and dairy scum biodiesel.

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Fig.2 Biodiesel production plant.

Fig.3 DSOME blends.

2.2 Experimental Setup

Kirloskar Company made single cylinder, 4 stroke, water cooled diesel engine of 3.7 kw (TV1) as shown in fig.4 is used to conduct the experimental work. Development of an experimental set up is done with using a single cylinder; water cooled four stroke diesel engines with necessary instrumentation to measure performance, emission and cylinder-pressure-crank-angle data. Instruments used for the defined work are- diesel engine-test rig, ECU, Exhaust gas analyzer, burette and stopwatch, digital manometer, Chromel Alumel (K-Type) thermocouples. The test engine is directly coupled to an electric dynamometer to digital control of loading and a piezoelectric pressure sensor (Fig.6) was flush mounted on the engine's cylinder head for capturing the in-cylinder pressure data. The fuel is injected with 3 hole injector into the centrally positioned Hemispherical Combustion Chamber (HCC) made in the piston crown. The engine operates at a constant speed of 1500 rpm. The cylinder pressure was measured by a piezoelectric pressure transducer fitted on the engine cylinder head and a crank angle encoder fitted on the flywheel. It is provided with temperature sensors for the measurement of temperatures of jacket water, calorimeter water, and calorimeter exhaust gas inlet and outlet temperature. Automotive Emission Analyzer HG-540 (Fig.7) is used to measure the five emission gases, such as Hydrocarbons (HC), Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2) and Oxides of Nitrogen (NOx).

Fig.4 Computerized experimental setup.

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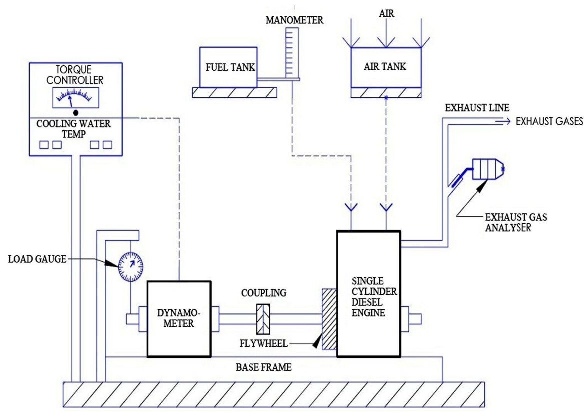

Fig.5 Schematic diagram of the experimental set up.

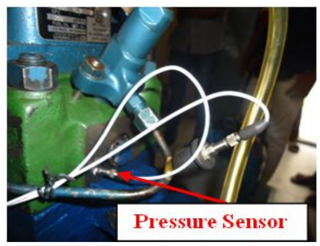

Fig.6 Piezoelectric Pressure Transducer

Fig.7 Exhaust gas analyszer.

Table 2.1 Engine Specifications.

Sl. No	Parameters	Specifications
1	Machine suppliers	Apex innovations Pvt. Ltd Sangli, Maharashtra, India
2	Type	TV1 (Kirloskar made) VCR
3	Software used	Engine soft
4	Nozzle opening pressure	200-205 bar
5	Governor type	Mechanical centrifugle
6	No. of cylinder	Single cylinder
7	No. of strokes	Four stroke
8	Fuel	H.S Diesel
9	Rated power	3.7 kw (5HP)
10	Cylinder diameter (bore dia)	87.5 mm
11	Stroke length	110 mm
12	Compression ratio	17.5
13	Speed	1500 rpm

3. RESULTS AND DISCUSSION

3.1 Performance Analysis

3.1.1 Brake Thermal Efficiency (BTE)

Figure 3.1 shows the variation of BTE with brake power for Dairy scum Oil Methyl Ester (DSOME) fueled engines with different blends. It is observed that BTE for biodiesel engine operation was lower than diesel operation over the entire load range. This is mainly due to lower calorific value of Dairy scum Oil Methyl Ester. The study with different blends show that the DSOME operation with B20 results in better performance compared to other fuel blend. This could be attributed to the presence of an increased amount of oxygen which might have resulted in its improved combustion as compared to other blends; hence, the brake thermal efficiencies come very near to that of HS diesel. The BTE values for Dairy scum Oil Methyl Ester with Diesel, B10, B20, B30 and B100 Diesel were found to be 31.32, 28.62, 30.55, 28.77 and 28.84 respectively for Dairy scum Oil Methyl Ester compared at 100% load for diesel operation with respectively Diesel fuels. The percentage increase in the value of brake thermal efficiency is higher at high load conditions. This is due to the better combustion of the blends and the additional lubricity provided by the biodiesel content in the blends. The BTE for B30 and B100 are lower compare to B20 as they have higher biodiesel content leads to reduced calorific value and increased viscosity.

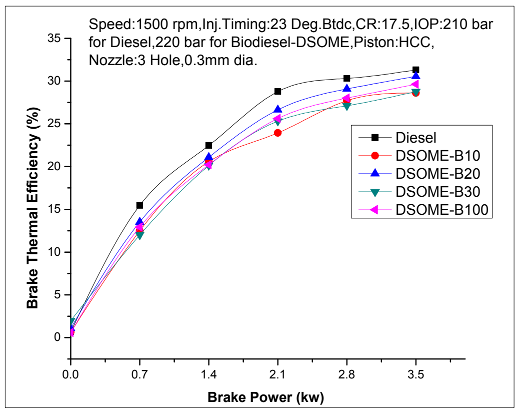

Fig. 3.1 Variation of BTE with BP for various blends.

3.1.2 Brake Specific Fuel Consumption (BSFC)

Fig.3.2 shows the variations of BSFC with different blends of dairy scum biodiesel and also it shows that the BSFC increases with the increase in percentage of biodiesel in the blend. This may be due to the lower calorific values of biodiesel and short delay period. It observed that the BSFC for B20 is lower compared to other blends. The higher specific fuel consumption for B100, B30 and B10 may be attributed to poor air fuel mixing which lead to poor combustion**.** The BSFC at 100 % load for Diesel, B100, B30, B20 and B10 are 0.29, 0.32 0.31, 0.29, and 0.29 kg/kw.hr.

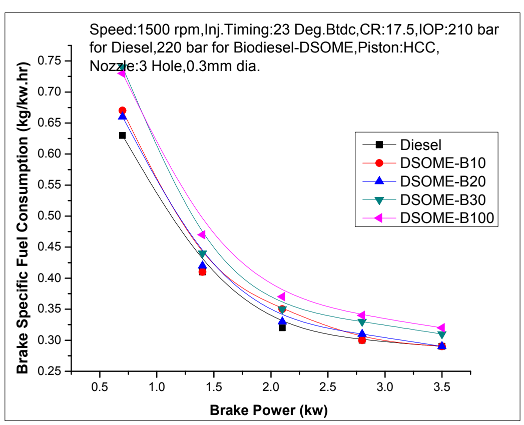

Fig. 3.2 Variation of BSFC with BP for various blends.

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3.1.3 Volumetric Efficiency

The volumetric efficiency significantly influences engine output. Both design and dimensions of an intake and exhaust system have large impact on volumetric efficiency. The volumetric efficiency is the parameter describing the effectiveness of the induction process. The induction process is defined as all events taking place between the inlet-valve opening (IVO) and the inlet-valve closing (IVC). Fig 3.3 shows the volumetric efficiency for the Diesel, B100, B30, B20 and B10 among these B20 results in greater volumetric efficiency than the other Blends of dairy scum biodiesel.

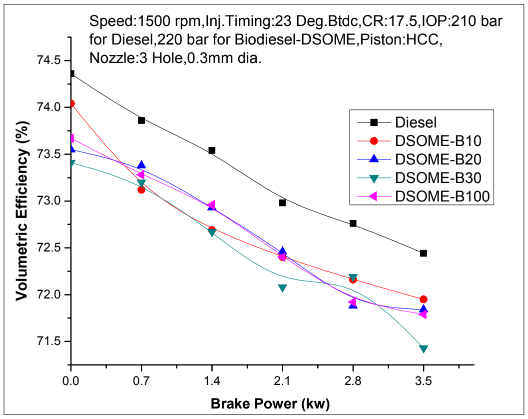

Fig. 3.3 Variation of Volumetric efficiency with BP for various blends.

3.2 Combustion Analysis

3.2.1 Heat Release Rate (HRR)

Figure 3.4 shows rate of heat release versus crank angle for different Dairy scum Oil Methyl Ester with different Blends. Dairy scum Oil Methyl Ester operation for B100, B30 results in lower heat release rate compared to the operation with B10 and B20. The heat release rate of blend B10 and B20 is higher than the other blendsB30 and B100. This is due to the result of higher second peak obtained B100, B30 and B20 in the diffusion combustion phase compared to the dual fuel operation with B10 operation.

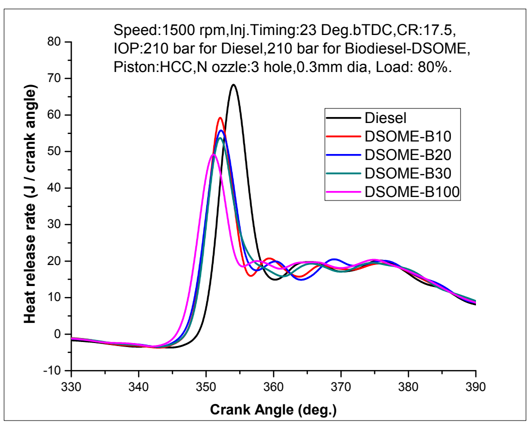

Fig. 3.4 Net heat-release rate for different fuel blends at 80% load.

3.2.2 Peak Pressure (P-ϴ)

The variations of peak pressure for diesel, Dairy scum Oil Methyl Ester operation with respect to various blends are presented in figure 3.5. Higher peak pressure was observed with B10 compared to B100, B30 and B20. This may be due to better burning of the fuel combination at rapid combustion phase and decreased diffusion combustion phase occurring at lower content of biodiesel with diesel. Peak pressure with Dairy scum Oil Methyl Ester operation was found to be lower compared to diesel operation. This may be due to combined effect of lower calorific value of Dairy Scum Oil Methyl Ester, lower flame velocity; higher viscosity and density of Dairy Scum Oil Methyl Ester leading to poor combustion at rapid combustion phase. The peak pressures obtained for Dairy scum Oil Methyl Ester for different blends are 53.82, 51.4, 52.18, 51.27 and 52.3 bar for Diesel,B10,B20,B30 and B100 respectively.

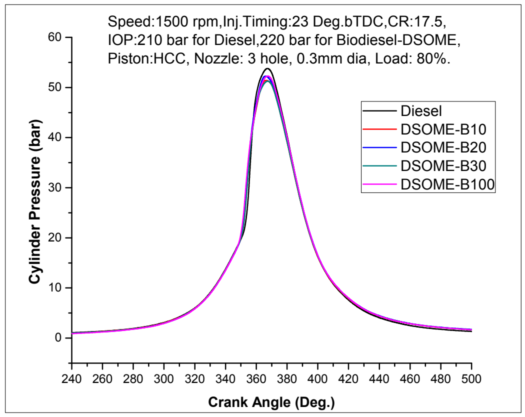

Fig.3.5 Pressure crank angle variation for different fuel blends at 80% load.

3.3 Emission Analysis
3.3.1 Unburnt Hydrocarbon Emission (UBHC)

Figure 3.6 shows the variation of hydrocarbon (HC) emission levels for diesel, dairy scum biodiesel operation with all loads. The UBHC and emission levels are higher for DSOME operation compared to diesel operation. It could be due to incomplete combustion of the Dairy Scum Oil Methyl Ester. The incomplete combustion resulted is due insufficient oxygen available for combustion, lower calorific value of DSOME, lower adiabatic flame temperature and higher viscosity of DSOME and lower mean effective pressures are also responsible for higher UBHC emission levels. The main sources of hydrocarbon emissions in diesel engine are wall quenching, lean mixing and the burning of lubricating oil. However, combustion with DSOME operation with B20 resulted in lower HC emission levels at higher load compared to other blends. It could be due to proper mixing of fuel and air leads better combustion as the higher oxygen present in the DSOME leads to better combustion with B20. However, other Blends may not contribute to the proper mixing fuel combinations; it may be due to improper mixing of fuel and air leads incomplete combustion. The HC levels for DSOME operation with Diese, B10, B20, B30 and B100 were found to be 23,18,20,20 and 18 ppm for Dairy Scum Oil Methyl Ester.

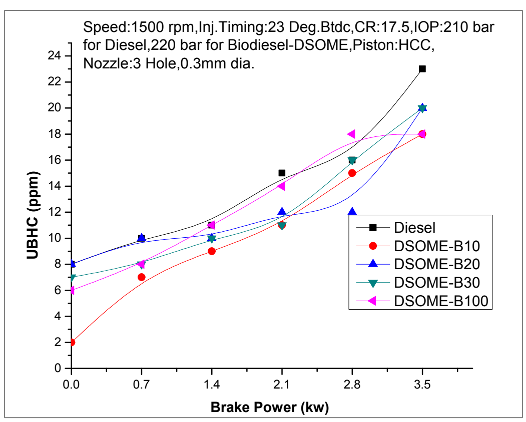

Fig.3.6. Variation of UBHC with BP for different blends.

3.3.2 Carbon Monoxide (CO)

The variation of carbon monoxide (CO) emissions with engine loading for different fuels is compared in Figure 3.7. These lower CO emissions of biodiesel blends may be due to their more complete oxidation as compared to diesel. It can be observed from Graph.3.8 that the CO initially decreased with increasing load and later increased sharply up to maximum load. This may be due to the incomplete combustion of the fuel due to very short time available for combustion. The CO emission is found to decrease at initial load conditions and increases with corresponding increase in load. CO levels for Dairy Scum Oil Methyl Ester operation with Diesel, B10, B20, B30 and B100 were found to 0.089, 0.105, 0.117, 0.167 and 0.177% for Dairy Scum Oil Methyl Ester. The study noticed that the CO emissions from the engine with B20 are lower among different blends because of better air availability and proper mixing of air and fuel for better combustion.

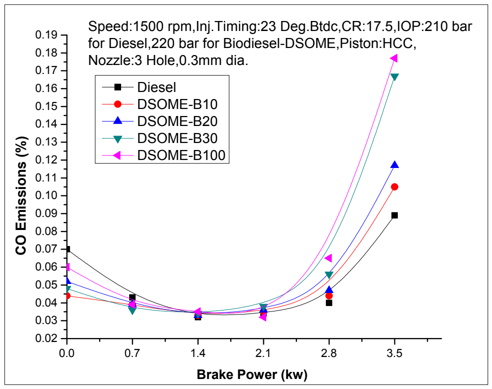

Fig.3.7. Variation CO with BP for different blends.

3.3.3 Nitrogen Oxide (NO_x)

Fig.3.8 shows the variations of oxides of nitrogen emissions for standard engine with Dairy Scum Oil Methyl Ester. In a DI diesel engine, the NO*x* emission is affected by oxygen content, adiabatic flame temperature, spray characteristics, and fuel properties like cetane number, etc. NOx emission levels were found to be higher Dairy scum Oil Methyl Ester fuel operation over the entire load range (Fig. 3.9). This is because of higher heat release rate during premixed combustion phase occurs with diesel compared to Dairy scum Oil Methyl Ester. Slightly higher NOx is resulted from Dairy scum Oil Methyl Ester operation with B20 compared to the operation with other blends. This could be due to slightly better combustion occurs due to more homogeneous mixing and larger part of combustion occurs just before top dead center. The reason for the increase in NOx may be attributed to higher combustion temperatures arising from improved combustion due to better mixture formation and availability of oxygen in Dairy scum Oil Methyl Ester. However NOx can be controlled by application of Exhaust Gas Recirculation (EGR).

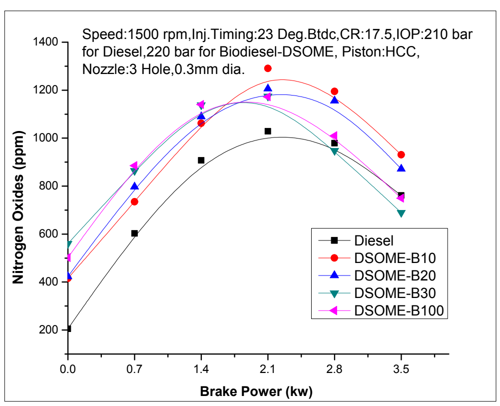

Fig.3.8. Variation of NOx with BP for different blends.

3.3.4 Carbon Dioxide (CO_2)

Figure 3.9 depicts the CO_2 emission of different fuels blends used for the work. The tendency of CO_2 emission for all fuel blends increase with increase in output power. Biodiesel produce a higher level of CO_2 emissions in exhaust emission is an indication of the complete combustion of fuel, supplying the necessary oxygen to convert CO (Carbon Monoxide) to CO_2 (Carbon Dioxide), thus the CO_2 emission increases. Blend B20 emits very low emission levels at maximum loads. This is due to the fact that the biodiesel in general is a low carbon fuel and has lower elemental carbon to hydrogen ratio than diesel. However, with use of higher content DSOME blends beyond 30%, an increase in CO_2 emission is noticed at higher load which is due to the more complete combustion of the fuel. The higher level of biodiesel content in diesel will indicate the complete combustion of fuel in the cylinder.

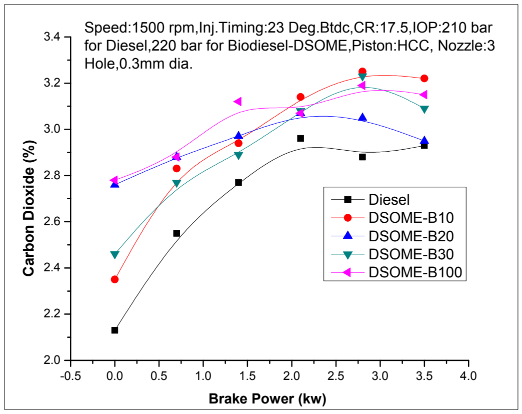

Fig.3.9. Variation of CO_2 with BP for different blends.

3.3.5 Oxides of Oxygen (O_2)

Fig.3.10 shows the variations of Oxygen dioxide emissions for standard engine with Dairy Scum Oil Methyl Ester. From the graph its shows that there is greater O_2 for diesel operation. Whereas the blend B10 has higher O_2 emission levels compare to other blends of DSOME.

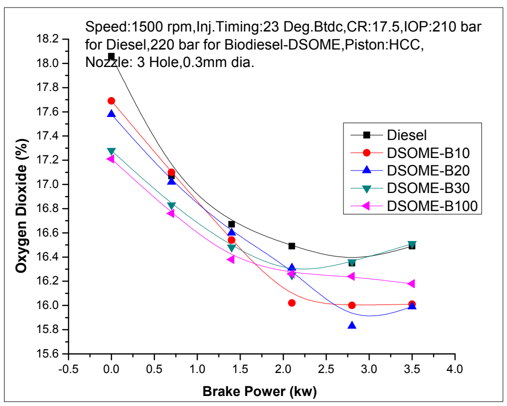

Fig.3.10. Variation of O_2 with BP for different blends.

4. CONCLUSIONS

In the present study, dairy scum oil methyl ester was produced by transesterification method. Different blends of DSOME were prepared and used as fuel for diesel engine. The properties of dairy scum biodiesel closely match with diesel and hence it can be used directly in diesel engines. The experimental investigation made on the single cylinder four stroke diesel operated with different blends of DSOME B10, B20, B30 and B100 to study the performance, combustion and emission characteristics. Following Conclusions are drawn based on the experimental work.

- The 20% blends of Dairy scum biodiesel with diesel was found to be the best, since optimum values of BTE, BSFC are obtained for all loads and also there is increased volumetric efficiency at higher loads.
- From emission analysis, it shown that the HC and CO emissions with pure DSOME (B100), is found to be greater than the mineral diesel operation. There will be reduction in HC and CO emissions for blend B20 compare B30 and B100 but whereas NOx is increased. And also it is found that CO_2 emissions are more for B20 biodiesel blend than that of diesel hence higher CO_2 emissions reduce harmful CO emissions.
- The engine operated with DSOME B20 shown slightly higher in cylinder pressure and net heat release rate as compared to B30, and B100 at a 80% load when engine run at a speed of 1500 rpm.
- The best blending ratio is 20% DSOME which gives the best performance and less increment in the NOx emissions as compared with other DSOME blends.

On whole, the addition of higher oxygen content and high volatility characterized fuel can be a promising method for use of biodiesel efficiently in conventional diesel engines without any modifications in the engine. Hence it is concluded that the dairy scum biodiesel blended with diesel can be successfully used in CI engines without any major engine modification in the engine, since these results in best performance, combustion and emission characteristics. The use of neat dairy scum oil in engines need long term observations of engine performance, may be in due course of time with necessary engine modifications and minimum fuel modifications the straight oils can be directly used in CI engine. Replacement of diesel fuel can be done by direct use of B20 with diesel without any alteration of the engine. Results also indicate that the use DSOME and its blends with HS diesel help in air pollution to a greater extent.

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