Effects of DMC Additive on Efficiency and Emission of Biodiesel-Fuelled in a Direct Injection Compression Ignition Engine

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Abstract - Biodiesel is one of the most well-known and widely used alternative fuels. Biodiesel is biodegradable, environmentally sustainable, and a suitable source to meet future energy problems. In this experiment the efficiency and emissions of the direct ignition compression ignition engine using Argemone Mexicana Methyl Ester with oxygenated additives as Di-methyl Carbonate (DMC) were analyzed and compared with the results of diesel. Argemone Mexicana Methyl Ester was prepared by trans-esterification process followed by esterification process. Brake thermal efficiency (BTE), Brake specific fuel consumption (BSFC) and Exhaust gas temperature (EGT) were determined by using B25, B45, B65 experimentally. At the same time emissions like carbon monoxide (CO), unburned hydrocarbons (HC) and nitrogen oxides (NO_x) were obtained by using exhaust gas analyser at the time of experiments. Then 2.5 ml DMC additive was added with the above fuel blends and efficiencies, emissions were determined and compared with diesel fuel at a fixed engine speed of 1500 rpm with varying load conditions. It was found that the Brake Thermal Efficiency of B65+2.5ml DMC blend was higher at constant speed of engine, BSFC decreased with load and increased with biodiesel concentration (B65+2.5ml DMC additive) and even the EGT increased for both increased in load and with increased in biodiesel concentration. Also the result is with some additives (B65+2.5ml DMC) shows the reduction of the exhaust emissions (CO, HC) including NO_x. Among the fuel blends and B-65 with 2.5ml DMC additive serves better purpose than the other fuel blend. As a result, Argemone Mexicana biodiesel is better for the environment than diesel and has a bright future.

Keywords: Biodegradable, Argemone Mexicana Methyl Ester, Oxygenated Additives, Trans-esterification, Emissions.

1. INTRODUCTION

Energy is a necessary and supreme supply of economic activities. A stable energy resource foundation is a prerequisite for country's long-term economic and social development. The goal of the present work is to analysis the use of Argemone Mexicana biodiesel blend as an replacement of diesel in a direct injection compression ignition engine (DICI). An oxygenated additive such as Di-methyl Carbonate (DMC) has played a major role in lowering exhaust emissions. Several researchers have tried using DMC additive with pure diesel and in the long run have discovered some advantages and also some drawbacks. Biodiesel's other key drawbacks are high viscosity, high density, cold starting problem, the need for preheating and greater pour point etc. [1]. Plant products such as sugarcane, corn, jatropha, canola, neemseeds, and karanja are used to make biodiesels. Initially, the United States and Brazil supplied 70% of global biodiesel, with corn-based ethanol and sugarcane-based ethanol being the most common [2]. According to the research, adding alcohols and small amount of additives with biodiesel can reduce exhaust gases while overcoming some of the above given drawbacks [3]. M. K. Parida et.al. had used response surface methodology and analyzed the data of BTE, BSFC, EGT in a VCR engine by taking Argemone Mexicana biodiesel with diesel. The CO and HC emissions found less by using these fuel blends [4]. Yuvarajan Devarajan was investigated the effects of DMC (10% and 20%) as an additive with pure Almond biodiesel (B100) to evaluate the engine emission, efficiency and combustion characteristics. Overall 20% of DMC addition found better result compared with 10% DMC addition [5]. Mei et. al. had used the Di-methyl-carbonate as oxygenated additive with diesel, as a result remarkable reduction in NOx exhaust emission and in break specific fuel consumptions also [6]. By using Mahua oil methyl ester (MOME), the efficiency and combustion characteristics were studied and compared to clean diesel. When compared to MOME with 15% DMC, and with 6% DMC, the HC emissions and smoke levels at 6% DMC were significantly reduced [7]. Rakesh Kumar and Manindar Singh had studied by using biodiesel blends of Argemone Mexicana (20%) and Mahua (20%) with diesel, as a results slight increase in brake power, nearly 0.06kg/kWhr increase in specific fuel consumption at 100% load case. The values emissions such as CO and HC found less by using the biodiesel blended fuel, while NOx exhaust gases was found higher compared with diesel fuel [8]. According to Mandeep Singh, Sarbjot Singh Sandhu studied, using biodiesel blends in engine the values of BTE were improved maximum 5.58% by taking 20% biodiesel blend at 100% load case. Values of brake specific fuel consumptions also increased by 7.88% by taking same fuel sample at 100% load case. There was reduction in exhaust gas emissions (except NO_x) at full load and part load when Argemone biodiesel concentration was 30% with diesel. But in case of low load the value of NO_x emissions was less and HC and CO exhaust gases found more for all biodiesel-diesel blends [9]. From the above survey it was observed that there was increased in exhaust gas temperature which reflects increase in NOx emissions using only Argemone Mexicana biodiesel. To overcome these problems an oxygenated additive, DMC was blended with the biodiesel fuel and observed the efficiency and emission parameters.

This work was carried out by taking Argemone Mexicana Methyl Ester, oxygenated additive and diesel blend. The preparation of biodiesel followed the esterification process and transterification process. Only 2.5% of oxygenated additive (DMC) blended with biodiesel and diesel fuel had used to run the direct injection compression ignition engine. The experiment was carried out by taking B25, B45 and B65 fuel blend at 2kg load to 10kg load with constant rpm initially. The values of BTE, BSFC and EGT were measured experimentally. Values of carbon monoxide emissions, unburned hydrocarbons and nitrous oxides were measured by using exhaust gas analyser. Then 2.5 ml of DMC added with the above fuel blend and compared the efficiencies and emissions with diesel.

2. MATERIALS USED

2.1 Argemone Mexicana Methyl Ester preparation and properties

Argemone Mexicana Methyl Ester is one of the important ingredients in this experiment. Argemone Mexicana plants are found in rocky field and road side area, whose seeds are small, black and round shaped. Argemone oils are not edible. For this experiment Argemone Mexicana crude oil was extracted mechanically from seeds. The value of free fatty acid (FFA) of Argemone crude oil is generally 19.5. 250 ml of acid (phosphoric) was added in one litre Argemone oil and heated at 60^{o}C for near about one hour placed in a magnetic stirrer. After that process, 0.1% aqueous NaOH solution was mixed and waits for settles down for one day. That process is known as degumming process [10]. Then the preheated Argemone oil was prepared for next processes where 200ml methanol and 20ml sulphuric acid was mixed at 65^{o}C for 3 hours. This process is called esterification process. After this process the FFA value was measured, if FFA value was measured not greater than two, the oil was ready for next process. The next process was transterification process, in which 200ml methanol and 8gm potassium hydroxide blended in heated oil to remove alcohol from the oil [11]. Continuous water washing methods were taken and finally Argemone Mexicana Methyl Ester was ready for the experimental work. The schematic layout of biodiesel preparation is shown on Figure-1.

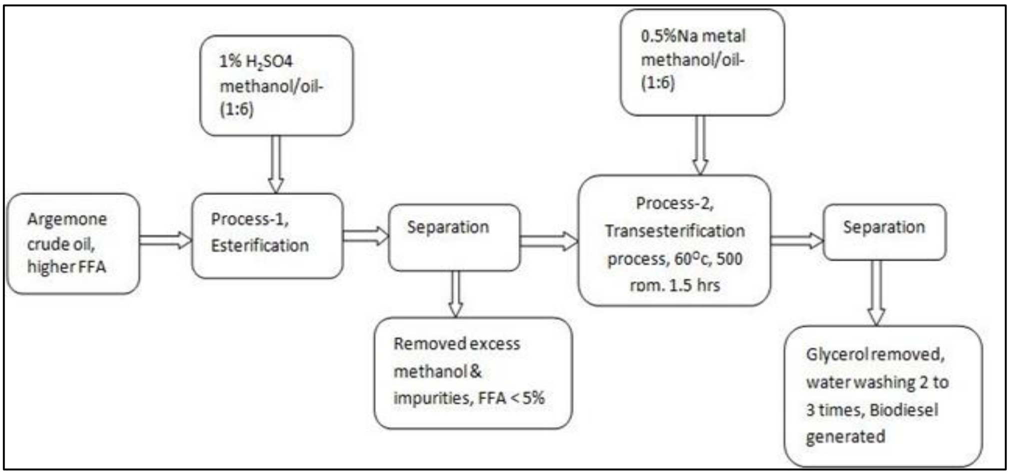

Fig-1 Stepwise processes for preparation of biodiesel from crude oil

2.2 Oxygenated additives Di-methyl Carbonate (DMC)

Di-methyl carbonate, an oxygenated additive, that's physical and chemical properties are best as an additive to run the engine. Many studies found that adding of oxygenated additives in fuel blends are fund as the best alternative fossil fuels. Using Argemone Mexicana biodiesel blend were found drastically improve in engine efficiencies and exhaust emissions. The properties of blended fuel are very equal to the characteristics of diesel [12]. In the present experiment DMC was used as oxygenated additive in Argemone Mexicana bio-fuel mixed with diesel and engine efficiencies and emissions were evaluated. DMC is colourless, flammable organic liquid composing formula $C_3H_6O_3$. By mixing DMC as an additive in biodiesel with diesel, the physical and chemical characteristics of fuel like density, viscosity, cetane number were changed. There were also changed in density, volatility of the fuel, flash point and calorific value. Due to changes in properties, engine efficiencies and exhaust emissions were also found change in a positive way [13]. In the present experiment only 2.5ml DMC was mixed in biodiesel fuel blends which did not affect the fuel economy in a large extent.

2.3 Working fuel sample preparation

The requirement fuel to run the engine for this experiment were prepared by adding biodiesel with diesel in different percentages like 25% biodiesel, 45% biodiesel and 65% biodiesel and checked physical and chemical properties of these fuels. Again, next set of fuel samples were prepared those were B25+2.5mlDMC, B45+2.5mlDMC, and B65+2.5mlDMC and experiments were conducted to determine engine efficiencies and emissions. Physical and chemical properties of biodiesel were measured by normal ASTM test procedures and comparison with diesel fuel which are shown in Table 1.

Table.1. Properties of fuel blends

Properties of fuel blend/ unit	Neat Diesel	Argemone Maxicana Methyl Ester	DMC additive	B-25	B-45	B-65
Flash point (°C)	55	168	66	87	115	132
Kinematic viscosity at 40°C (Cst)	2.51	5.05	0.61	4.2	4.34	4.63
Density (Kg/m^3)	824	869	1065	845	852	861
Calorific value (KJ/kg)	42600	41450	1578	42503	42240	41910
Cetane number	47	52	35	53	57	59
Oxygen content (Wt. %)	0	10	54.27	6	7	8

Blended fuel with biodiesel and additive

Fuel-1: Diesel

Fuel-2: B25 (75% Diesel + 25% Biodiesel)

Fuel-3: B45 (55% Diesel + 45% Biodiesel)

Fuel-4: B65 (35% Diesel + 65% Biodiesel)

Fuel-5: B25+2.5ml DMC (75% Diesel + 25% Biodiesel +2.5ml DMC)

Fuel-6: B45 + 2.5ml DMC (50% Diesel + 45% Biodiesel + 2.5ml DMC)

Fuel-7: B65 + 2.5ml DMC (35% Diesel + 65% Biodiesel +2.5ml DMC)

3.Experimental work

3. 1 Setup for experiment

The experiments were done in four strokes, one cylinder and water-cooled engine utilizing diesel, biodiesel and additive blends fuel. The direct injection compression ignition engine was attached with an eddy current dynamometer and a load controller. Typical air tank with a manometer device was used to measure input rate of air flow. Engine performance, combustion performance values were measured by considering constant engine speed using a computer and Engine Soft LV under various load circumstances. The data of engine speed, temperature and cylinder pressure were displayed on the computer screen. Manometer readings were also taken and compared with the manual readings of the engine. Average values for all fuel samples were taken after examined four times. Table.2 contains the engine specifications. Using an AVL 444N gas analyzer, exhaust emissions like carbon monoxide, hydrocarbon and nitrogen oxides were measured. Temperatures of the exhaust gases were measured using a thermocouple.

Table.2 Specifications of engine for this experiment

Name of the Model	Kirloskar
No of Stroke	4, 1 cylinder
Rated power	3.5 KWatt
Diameter of cylinder	88 mm
Stroke Length	110 mm
Connecting rod length	235
Diameter of orifice	20 mm
Arm length of Dynamometer	185 mm
Swept volume	66105 cc
Injection pressure	240 bar

Figure. 2 depict the experimental test rig of direct injection compression ignition engine, complete with labelling. Engine, fuel pipe connection, dynamometer and rota meter connections are displayed in this diagram. The connection of exhaust gas analyzer is displayed also in this diagram.

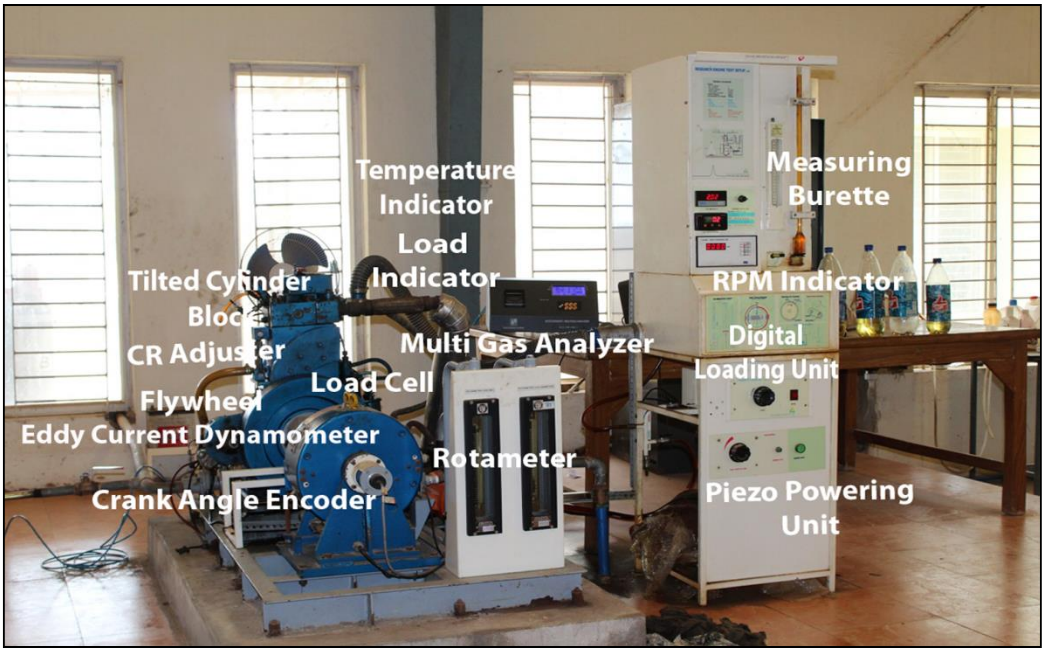

Figure. 2. Direct injection compression ignition engine

3.2 Experimental procedure

For this experiment first the engine ran on no load by adjusting speed 1500rpm using diesel fuel. Through eddy current dynamometer load were varied from 2kg to 10kg. Experiments had conducted by using the blended fuels, those fuel blends were diesel, B25, B25+2.5ml DMC, B45, B45+2.5ml DMC, B65 and B65+2.5ml DMC. The engine was driven for at least 3 minutes for each load situation before data was gathered. The engine's efficiencies were determined in BTE and BSFC at different loads at fixed compression ratio of 17.5. The temperature of exhaust gas was monitored using a thermocouple. Exhaust gas temperature were measured by thermocouple. The engine's exhaust emissions were routed through a lengthy pipe with minimal back pressure. A portable multi gas analyzer (AVL 444N) was used to measure exhaust emissions, those were carbon monoxide, carbon dioxide, hydrocarbon and nitrogen oxide.

4. Results and discussions

4.1. Break thermal efficiencies

The BTE of an internal combustion engine is defined as work of energy in terms of thermal, input from the combustion fuel. That efficiency is a metric that measures how successfully a fuel's chemical energy is transformed into mechanical energy in an engine. The mass of fuel used determines the BTE. The values of brake thermal efficiencies had measured for all sample fuels at constant engine speed and varying loads from 2kg to 10 kg. Figure.3 represents the results of the Brake Thermal Efficiencies with different loads for all fuel blends including 2.5ml DMC additive. From the experiment it was found that using di-methyl carbonate as additive the value of BTE was found maximum at 8kg weight in B25+2.5ml DMC fuel sample. At 10kg load the BTE value was minimum for B65+2.5ml DMC fuel compared with diesel. In B45+2.5ml DMC fuel the value of BTE was found maximum at 6kg. At high load case the value of BTE decreased after adding 2.5ml DMC in this experiment. In Fig.3 represents the values of Brake Thermal Efficiency of all blended fuel with varying loads are shown.

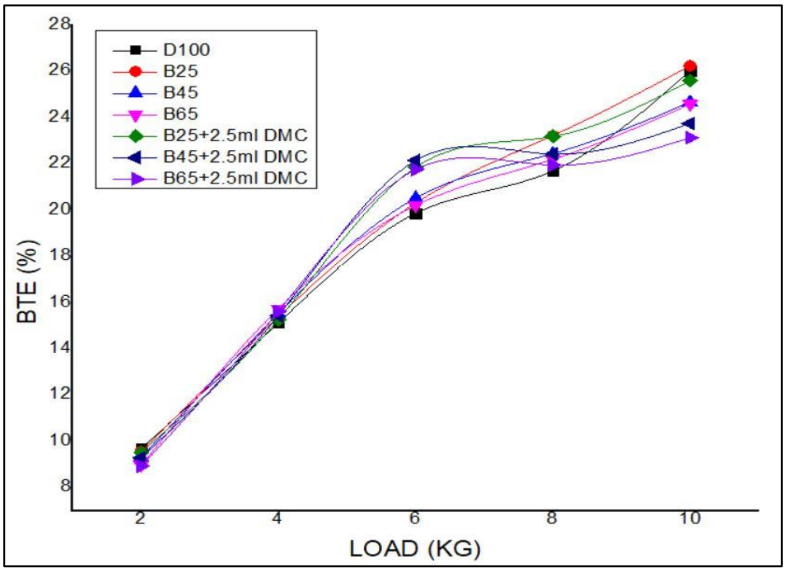

Figure.3 Values of BTE vs. various Loads

4.2 Brake Specific Fuel Consumptions

Brake specific fuel consumptions defined as the ratio of rate of fuel consumption and shaft power produced from the engine. The value BSFC indicates how efficiently the compression ignition engine converts fuel supplied into useful shaft work. The value of BSFC of the engine fuelled added with only bio-diesel was more than that of pure diesel as observed from different survey [14]. By adding of oxygenated additives as DMC the calorific value increases as a result there was a decreases in BSFC value. The BSFC value was maximum when more amount of biodiesel i.e. 65% biodiesel added with diesel at 8kg load. On the other hand if 2.5ml DMC was blended with B65, the BSFC value was minimum at 6kg load. The values of BSFC were less for B65+2.5ml DMC fuel at all load conditions. In case of B45 fuel the values of BSFC were more in all load case except 6kg load. In the present experiment the variations of BSFC vs. load of all fuel samples are shown in Figure 4.

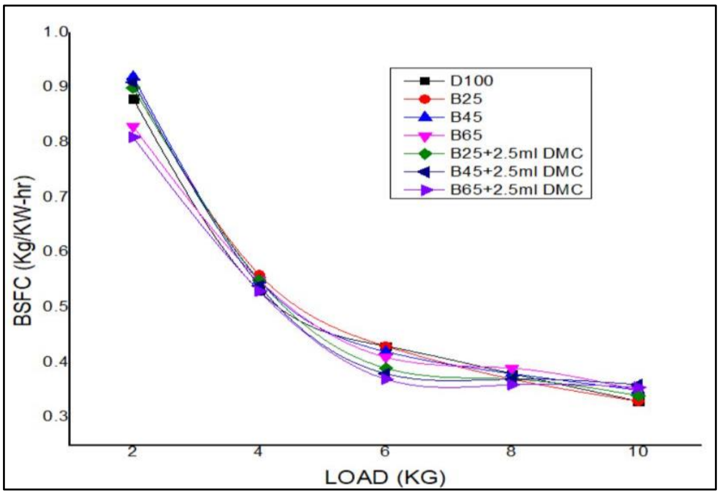

Figure.4 Values of BSFC vs. Loads

4.3 Exhaust gas temperature (EGT)

To monitor the exhaust gas temperature of an internal combustion engine a thermocouple type pyrometer is connected. The value of EGT either increases or decreases depend upon the fuel concentration and air-fuel ratio. For a longer life of engine cylinder the value of EGT is very important [15]. The exhaust emissions values are also related with the exhaust gas temperature. In this experiment the values of EGT by using B65 fuel were very nearer to the values by using diesel fuel. It means that higher percentage of biodiesel blend produced more exhaust gas temperature than using DMC in the fuel blend. In B45+2.5ml DMC fuel the values of EGT were less at all loads compare with the other fuel blends. The values of Exhaust Gas Temperature for all blended fuel with loads are presented in Figure 5.

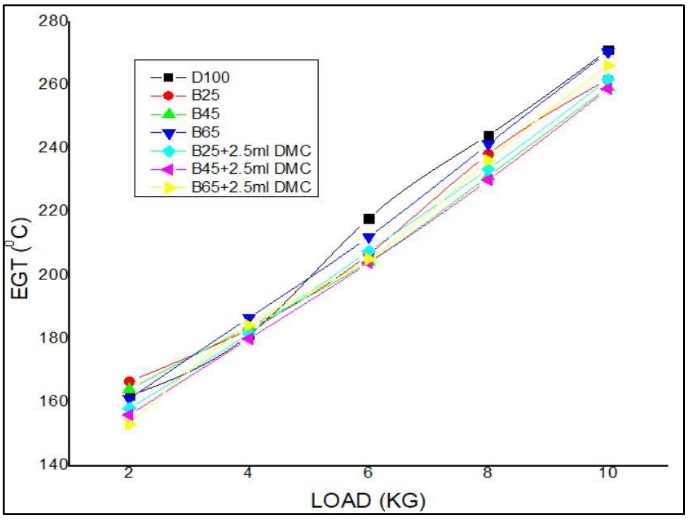

Figure.5 Values of EGT vs. various Loads

4.4 Carbon monoxide emission (CO)

Carbon monoxide gas produced during incomplete combustion of fuel in internal combustion engine. Insufficient of air supply in combustion process causes incomplete combustion, which is a important cause of producing CO emission. CO gas is odourless, colourless and a non irritating emission gas. CO emission is a very harmful exhaust gas. When CO gas binds with haemoglobin, it reduces the ability to carry oxygen in blood. In this experiment CO emission was measured by AVL Gas analyzer using all fuel blends mentioned above at all load conditions. By using 25% biodiesel with diesel the values of CO emission found not vary less than diesel fuel at all loads conditions. DMC additive blends in fuel found better result compared with the fuel of without DMC. At high load case when 2.5ml DMC blended with B45 fuel used in this experiment to run the engine the CO emissions found less compared with the other fuel blend. But in low load condition by using B65+2.5ml DMC fuel, it was found that there was less CO emissions produced compared with the other fuel blends. Figure.6 represents the values of carbon monoxide emissions with various loads.

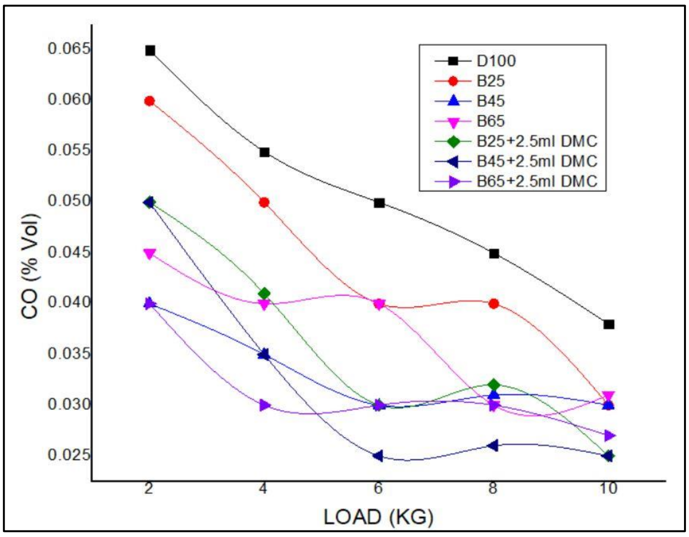

Figure.6 Variation of CO vs. various Loads

4.5 Unburned Hydrocarbon emission (HC)

Diesel engines normally emit low level of hydrocarbons. Unburned hydrocarbons are produced due to the incomplete combustion of fuel in engine. For formation of smog HC gas are the important parts [16]. In the present experiment HC emission was measured by AVL Gas analyzer using all fuel blends at all load conditions and analyzed with diesel fuel. Using B25 fuel blend the emissions of HC gas was nearly equal to the HC emission of using diesel fuel. Blending of DMC in the fuel blend, the value of HC emissions emitted drastically reduced compared with diesel and with biodiesel blend. More amount of biodiesel with 2.5ml DMC found less value of unburned HC gas in this experiment. Using B65+2.5ml DMC in engine the value of HC gas found less. The values of Hydro Carbon emissions for all blended fuel with loads are presented in Figure.7.

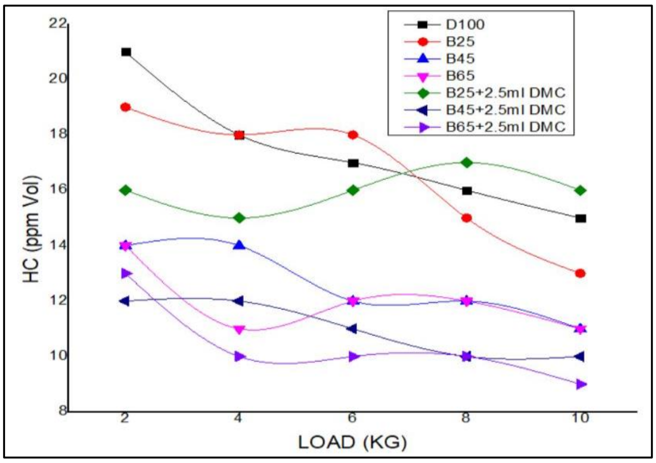

Figure.7 Values of unburned HC vs. Load

4.6 Nitrous oxide emission (NO_x)

When nitrogen in the air combines with oxygen at high pressure and temperature inside the engine chamber, nitrous oxide is created. NO_x is an important component for acid rain and smog. When the engine runs at high temperature NO_x emission produces more and more. From so many literature surveys it was found that using biodiesel with diesel blend fuel the NO_x emissions are produced more compare with the diesel fuel [17]. In this experiment AVL gas analyzer are used to measure NO_x emissions at all load conditions. In the present work also it was found that by using B25 fuel blend the value of NO_x emissions are more compared with diesel fuel. By blending 2.5ml DMC additive in the fuel the temperature of the fuel decreased as a result the NO_x gas production reduced. From the experimental result it was found that by using B65+2.5ml DMC the NO_x gas emits less at all load conditions except 8kg compared with all fuel blends. Figure.8 presents the values of NO_x emission with load for all fuels.

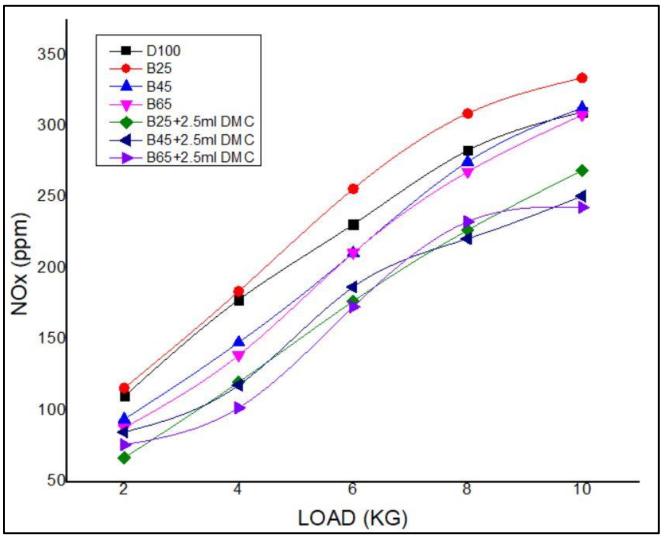

Figure.8 Values of NO_x emission vs. Load

5. Conclusion

In this work 2.5ml DMC as an additive had blended with B25, B45 and B65 fuel and checked the physical and chemical properties. BTE, BSFC and EGT values were determined by taking all fuel blends at varying load conditions and analysed the results by plotting graphs. Argemone Mexicana biodiesel was the main components of this experiment, which was prepared by different processes. Initially 25%, 45% and 65% biodiesel added with diesel and the physical and chemical stability was checked. The engine run by taking the above fuel blends and analysed BTE, BSFC and EGT. Later on 2.5ml DMC was added with the fuel blends and also determined the efficiencies. Using additive the values of BTE were maximum at 8kg weight in B25+2.5ml DMC fuel. At 10kg load the values of BTE were minimum for B65+2.5ml DMC fuel compared with diesel. The values of BSFC were less for B65+2.5ml DMC fuel at all load conditions where as BSFC value was maximum by using B65 blended fuel at 8kg load. Using B45+2.5ml DMC fuel the values of EGT were less at varying load case compare with other fuel blends.

AVL exhaust analyzer was used for this experiment using the above fuel blends and measured the emissions of CO, HC and NO_x at all load conditions. By using B45+2.5ml DMC at high load case CO emissions found less compared with the other fuel blend. DMC added fuel blends produced less CO emissions compared with the fuel of without DMC. By using B65+2.5ml DMC in engine the value of HC gas found less compared with the other fuels. Without DMC in the fuels there were not remarkable reductions in HC emissions shown in the graph. Using 25% biodiesel in fuel blend the emission value of NO_x was more compared with diesel fuel. By using B65+2.5ml DMC the NO_x gas emits less compared with other blended fuels.

From this experiment, it was found that the fuel samples such as diesel-Argemone biodiesel with DMC are treated as best suitable fossil fuels for internal combustion engine. There were also considerable reductions in exhaust emissions, better efficiencies in engine compared with diesel. B65+2.5ml DMC fuel blend performed better result compared with the other fuels.

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