STUDY AND PERFORMANCE ANALYSIS OF BIOFUEL (LEMONGRASS OIL) BY VARYING INJECTION PRESSURE

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ABSTRACT:- With modernization and increase in the number of automobiles worldwide, the consumption of diesel and gasoline has enormously increased. As petroleum is non renewable source of energy and the petroleum reserves are scarce nowadays, there is a need to search for alternative fuels for automobiles. Work has been done in using a lot of bio-fuels, the fuels obtained from plant to be used in IC engines. In this point of view, lemon grass oil is used an alternative fuel for diesel. It is proposed to compare the lemongrass biodiesel blends with sole fuel and study the performance and emission characteristics of diesel engine. The biodiesel is extracted through transesterification process with methanol and KOH as catalyst. The lemon grass oil biodiesel was blended with sole fuel by various percentages such as 20, 40, 60, 80 and 100. The proposed work is carried out in a single cylinder, water cooled, four stroke Kirloskar TV 1 engine and coupled with an eddy current dynamometer as loading device.

In Phase -1, of the project work lemon grass oil biodiesel blends are tested for various load conditions and studied the performance and emission characteristics. The blend B20 (20%) has been taken as optimum blend because its performance and emission characteristics were nearer to diesel fuel. The properties of fuel blends were tested through ASTM standards and compared with conventional diesel fuel.

In Phase – II of the project work optimum blend of B20 is investigated with various injection pressures such as 210, 230 and 240 bar. The standard injection pressure is maintained as 220bar. From the experimental investigation it is observed that the brake thermal efficiency is increased by 1.2% for the B20 blend with 240 bar injection pressure and SFC is gradually decreased. The CO, HC and smoke density emission are decreased for blend B20 with 240 bar injection pressure by 12%, 17%, 6.3% respectively when compared to diesel fuel. The NOx emission for B20 blend with 240 bar injection pressure is slightly increased by 5.7% compared with diesel fuel.

INTRODUCTION

Considering the future energy security, sustainability and environmental damage, the study on various alternate, clean and renewable sources of fuel has grabbed the interest and attention of many researchers. As such, biofuels are being considered as potential alternate fuels for diesel engine applications over the past few decades. Generally, biofuel is the name given to the type of fuel derived from plant based sources and biomass, and are believed to gratify the demands of petroleum fuels in the near future. According to US Department of Agriculture and Energy, US can grow biomass feedstock to satisfy around 30% of its current gasoline needs by 2030 on a sustainable manner without converting any of its current croplands. The same study, through an extensive analysis, has estimated that 1.3 billion tons of biomass raw materials can be used to produce 3 billion gallons of ethanol by 2015. In the same note, each country has their own protocol in developing and utilizing various biofuels.

As an alternative fuel, biodiesel is becoming increasingly important due to diminishing petroleum reserves and adverse environmental consequences of exhaust gases from petroleum-fuelled engines. In contrast to conventional petrodiesel, it is environmental friendly and creates substantial reduction in emission, hence, these properties make Biodiesel a good alternative fuel to petroleum-based diesel oil.

Biodiesel has many other environmental benefits, such as it is biodegradable, non-toxic, and has low emission profile (including potential carcinogens). It can be used in today’s vehicle fleets worldwide and may also offer a viable path to sustainable transportation fuel. Moreover, it does not contribute to global warming due to its closed carbon cycle because the primary feedstock for biodiesel is a biologically-based material that can be grown season after season. And, since the carbon in the fuel was originally removed from the air by plants, there is no net increase in carbon dioxide levels.

Biodiesel is safer fuel as it has high flash point temperature of 154 °C. It is regarded as clean fuel since it does not contain carcinogenic substances and its sulphur content level is also lower than its content in petrodiesel. It is well known that biodiesel is non-toxic, contains no aromatics and is less pollutant to both water and soil. It is the most suitable fuel in environmentally sensitive areas (national parks, lakes, rivers) or in confined areas where environmental conditions and worker protection must meet high standards (underground mines, quarries). Moreover, it contains about 10% built in oxygen, which helps it to burn fully and also expected to reduce exhaust emissions. Its higher cetane number (CN) improves the ignition quality even when blended with petroleum diesel.

Nevertheless, diesel engines emit particulate matter, nitrogen oxides, greenhouse gases, and air toxics. Hence, the important property of Biodiesel is, then, its ability to reduce such pollutants as carbon monoxide, unburned hydrocarbons and particulate emission from engines. Studies also showed significantly lower levels of emissions of specific toxic compounds for Biodiesel and Biodiesel blends, including aldehydes, polyaromatic hydrocarbons (PAH), and nitro-polyaromatic hydrocarbons (nPAH).

Fuel injection system

The fuel injection equipment is the essential component for the proper working of the diesel engine. The function of the fuel injector is to disperse the fuel through compressed charge of air in the engine cylinder. Proper functioning of injector should be ensured for proper functioning of engine as fuel injector has to spray fuel uniformly. The injector tester consists of a small tank, pump, pressure gauge and handle. There is a separate bowl for receiving the fuel sprayed from the nozzle. The injector to be tested is fitted in the injection testing equipment. A valve which is used to control the fuel is first opened, and then the handle is pressed downward.

The downward movement of the handle causes the fuel to be sprayed through the injector. The reading in the pressure gauge shows the atmospheric pressure. If this pressure is equal to the pressure specified by the manufacturer, then the injector is a good one. If the pressure is either more or less, the spring in the injector should be accordingly adjusted.

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LITERATURE REVIEW

Koula *et al.,* **(2004)** developed kinetic model has been developed for steam distillation of lemongrass (Cymbopogon spp.). This rate model was tested on pilot scale, steam distillation units, with lemon grass batches of 70 to 1000 kg. For intimate contact of lemongrass and steam, two improved direct steam spargers were provided in these units. Mustafa Balat and Havva Balat., **(2008)** stated that the use of vegetable oils as alternative fuels has been around for one hundred years when the inventor of the diesel engine Rudolph Diesel first tested peanut oil, in his compression-ignition engine. Bio-diesel is an alternative to petroleum-based fuels derived from vegetable oils, animal fats, and used waste cooking oil including triglycerides. Bio-diesel production is a very modern and technological area for researchers due to the relevance that it is winning everyday because of the increase in the petroleum price and the environmental advantages.

Tajidin *et al.,* (**2012)** reported that the effects of three maturity stages at harvest of lemongrass on essential oil, chemical composition and citral contents. The lemongrass plant was planted using a randomized complete block design with four replications, at the University Agriculture Park, Universiti Putra Malaysia. The plants were harvested at 5.5, 6.5, and 7.5 months after planting. After harvest, the essential oil, chemical composition and citral contents were analysed using gas chromatography-mass spectrometry (GC-MS) analysis. Sanjay Patil and Akarte., **(2012)** presented that biodiesel as an alternative to diesel could reduce the dependency on petroleum products and the pollution problem. The physical properties of the fuel such as viscosity, volatility and flash point also affect the combustion process, thereby engine performance. Specifically atomization of the fuel during the injection is attributed to higher viscosity of biodiesel. Injected fuel droplets get smaller as the injection pressure increases which contributes to better atomization of the fuel. Meyyappan Venkatesan., **(2013)** stated that investigation test were carried out to examine the performance and emissions of a direct injection diesel engine blended with Jatropa bio-diesel prepared with methanol to get jatropa oil methyl ester (JOME). Venugopal *et al.,* **(2014)** found that plant species, like lemon grass (cymbopogen citratusis) is discussed as source of oil for bio-diesel production. The bio-diesel that is produced from lemon grass through Transesterification process is used as a fuel. Performance test was conducted and compared with diesel.

Avinash Alagumalai., **(2015)** stated that the development of alternate fuels for use in internal combustion engines has traditionally been an evolutionary process in which fuel-related problems are met and critical fuel properties are identified and their specific limits defined to resolve the problem. Murat Kadir Yesilyurt., **(2019)** found that the effect of fuel injection pressure on the performance and emission characteristics of a diesel engine fuelled with waste cooking oil biodiesel (WCOB) and its 5-30% (v/v) blends with diesel fuel were investigated and compared with diesel fuel.

Materials and methods

To select the suitable non edible oil for the experimental investigation. To select the suitable method for convert the biodiesel from lemon grass oil. To select the suitable mixing proportion of lemon grass oil blends with diesel fuel. The physical properties of the lemongrass oil biodiesel blends are shown. To select the suitable injection pressure for enhance the diesel engine performance and emission.

The biodiesel was extracted through transesterification process. The physical and chemical properties of the lemon grass oil bio-diesel were tested through ASTM standards and compared with diesel fuel. The lemongrass oil biodiesel was blended with diesel by various proportions such as B20, B40, B60, B80 and B100. The injection pressure was changed with 200, 210, 230, 240 bar and experimentally investigated the performance and emission characteristics. The experimental investigation were conducted on a single cylinder, water cooled, four stroke, Kirloskar TV-I diesel engine. In phase I, the investigations were conducted with various blends of lemon grass biodiesel and found that optimum blend for further investigations. In Phase II the optimum blend of lemon grass oil biodiesel (B20) was investigated with changing injection pressure and studied the performance, emission characteristics of test engine. The investigations were conducted with different loads and maintained 1500 rpm constant speed of the engine.

LEMONGRASS

Lemongrass (Cymbopogon Citratus), is a tropical perennial plant which yields aromatic oil. The name lemongrass is derived from the typical lemon-like odour of the essential oil present in the shoot. The herb originated in Asia and Australia. Lemongrass was one of the herbs to travel along the spice route from Asia to Europe. Lemongrass oil of commerce is popularly known as Cochin oil in the world trade, since 90% of it is shipped from Cochin port. The state of Kerala in India had the monopoly in the production and export of lemongrass oil. The annual world production of lemongrass oil is around 1000t from an area of 16000 ha. In India, it is cultivated in an area of 4000 ha and the annual production is around 250t. The crop is extensively cultivated in the poor, marginal and waste lands and also along the bunds as live mulch. The well ramified root system of the plant helps in soil and water conservation.

Fig. 1. Photographic view of lemongrass

EXTRACTION OF LEMONGRASS OIL

Lemongrass (Cymbopogon Citratus) leaves were collected from garden. The plant sample was freshly cut, 10cm from the root, in the morning of the day they were collected. Lemongrass (Cymbopogon Citratus), the percentage essential oil yield for the partially dried leaves was found to be higher than that of the fresh leaves. Thus, once collected, the plant material was dried at room temperature for maximum 4 days, then kept in a sealed plastic bag at ambient temperature and protected from the light. Extraction yield increase by decreasing the particle size due to the higher amount of oil released as the leave cells are destroyed by milling. In order to improve the collection efficiency, the plant material was soaked in its distilled water for 30min before the extraction performed (M.A.Suryawanshi et al, 2016).

Solvent extraction method

150g of the dry sample of lemongrass were weighed from the sliced lemon grass sample and placed in a 1 lit clean flat bottom flask. 500ml of N- hexane solvent were poured into the flask. The flask and content were allowed to stand for 36 hrs. This was done to extract all the oil content in the lemongrass and for complete extraction. After which the extract was decanted into another 1 lit beaker.200ml of ethanol were added to extract the essential oil since essential oil is soluble in ethanol. The mixture was then transferred to 500ml separating funnel and separated by a process called liquid/liquid separation process. The content of the separating funnel was and allowed to come to equilibrium, which separated into two layers (depending on their different density).The lower ethanol extract and the upper hexane layer were collected into two separate 250ml beaker and were placed in a water bath at 78°C. This was done to remove the ethanol leaving only the natural essential oil. The yield of oil was determined by weighing the extract on an electronic weighing balance. The difference between the final weight of the beaker with extract and the initial weight of the empty beaker gave the weight of essential oil.

LEMONGRASS OIL BIODIESEL

The procedure done is given below: 1000 ml of Lemongrass oil is taken in a container. 14 grams of Potassium hydroxide alkaline catalyst (KOH) is weighed. 250 ml of methanol is taken is beaker. KOH is mixed with the alcohol and it is stirred until they are properly dissolved. Lemongrass oil is taken in a container and is stirred with a mechanical stirrer and simultaneously heated with the help of a heating coil. The speed of the stirrer should be minimum and when the temperature of the raw Lemongrass oil reaches 60 °C the KOH-alcohol solution is poured into the raw oil container and the container is closed with an air tightly. Now the solution is stirred at high speeds (720 rpm). Care should be taken that the temperature does not exceed 60 °C as methanol evaporates at temperatures higher than 60 °C. Also the KOH-alcohol solution is mixed with the raw oil only at 60 °C because heat is generated when KOH and alcohol are mixed together and the temperature of the raw oil should be more than this when mixing is done if the reactions have to take place properly. After stirring the oil-KOH-alcohol solution at 60 °C for two hour the solution is transferred to a glass container. Now separation takes place and biodiesel gets collected in the upper portion of the glass container whereas glycerin gets collected in the bottom portion. This glycerin is removed from the container. Then the biodiesel is washed with water. Again glycerin gets separated from the biodiesel and is removed. The biodiesel is washed with water repeatedly until no glycerin is there in the biodiesel. Now this biodiesel is heated to 100 °C to vaporize the water content in it. The resulting product is the biodiesel which is ready for use.

Table 1. Properties of diesel and lemon grass biodiesel blends

Properties	Diesel	B20	B40	B60	B80	B100
Specific gravity @ 15/15°C	0.8235	0.8366	0.8490	0.8620	0.8720	0.8877
Kinematics viscosity (40°C) cSt	3.06	3.11	3.34	3.66	4.05	4.45
Flash point, °C	44	56	63	76	106	134
Fire point °C	48	61	69	86	118	146
Pour point °C	-22	-20	-17	-15	-12	-8
Calorific values kJ/kg	44000	43942	43281	42636	41987	41338
Density (15°C) kg/m^3	0.8381	0.8358	0.8481	0.8613	0.8709	0.8865
Cetane number	52	50.3	50.6	50.8	51.1	51.4

EXPERIMENTAL SETUP

An experimental set up was configured with necessary instruments to evaluate the emission and combustion parameters of the compression ignition engine at different operating conditions. Single cylinder water-cooled four-stroke direct injection diesel engine Kirloskar TV, injection pressure 220 kg/cm^2, compression ratio of 17.5:1, developing 3.7 kW at 1500 rpm was used for this work. The eddy current dynamometer is coupled with the engine and is used to load the same. AVL smoke meter and AVL Di - gas analyzer are connected with the engine suitably

Table 2 Specification of the test engine

Type	Single cylinder, vertical, water Cooled, 4-stroke diesel VCR engine
Bore	80 mm
Stroke	110 mm
Compression ratio	17.5:1
Orifice diameter	20 mm

Dynamometer arm length	195 mm
Maximum power	3.7 kW
Speed	1500 rpm
Loading device	Eddy current dynamometer
Mode of starting	Manually cranking
Injection timing	23°C before TDC

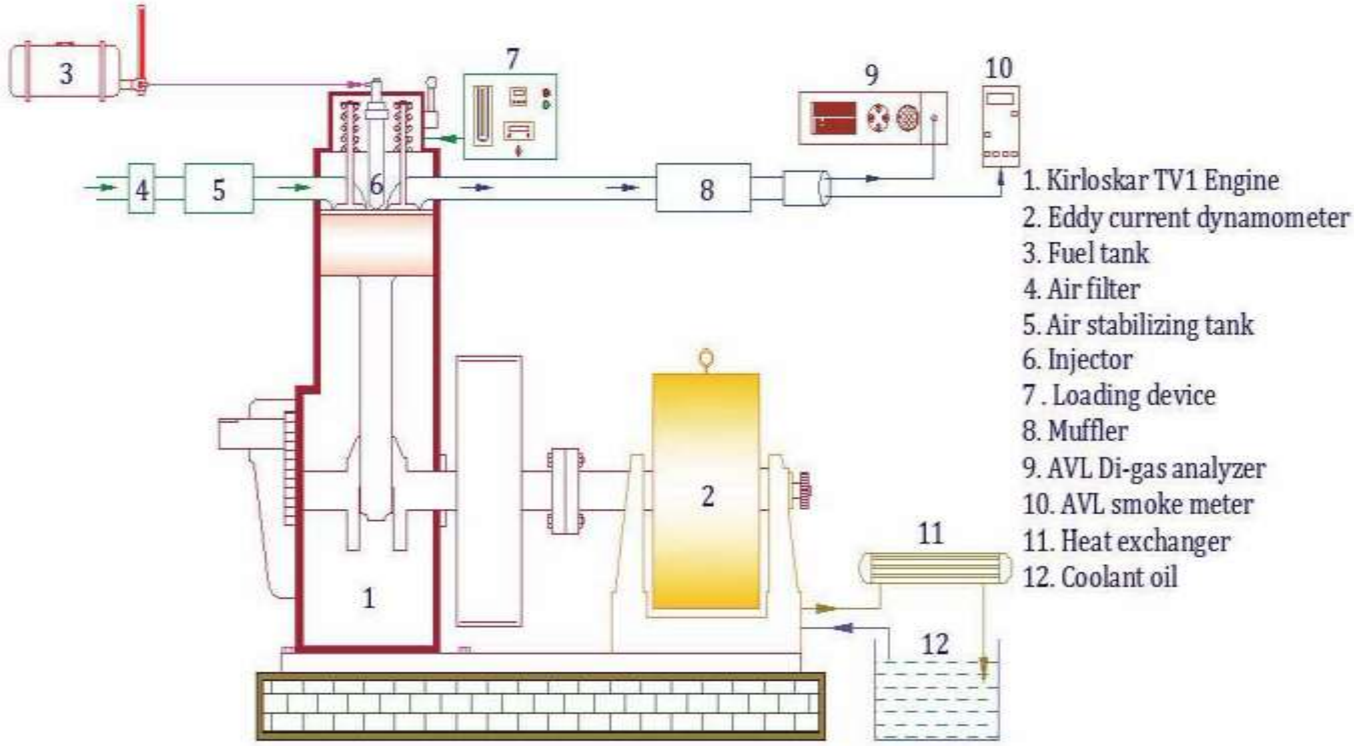

Fig. 2 Experimental setup (Kirloskar TV-1 Engine)

RESULT AND DISCUSSION

The experimental investigations were conducted by lemon grass oil biodiesel blend (B20) with various injection pressures (210 bar, 220 bar (standard), 230 bar, 240 bar). The experiment investigations were conducted with lemon grass oil biodiesel blend and analyzed the performance, and emission characteristics. The various parameters such as smoke density, oxides of nitrogen, hydrocarbon, carbon monoxide and brake thermal efficiency against the brake power of the engine were discussed and reported.

The variations of brake thermal efficiency against brake power for lemon grass oil biodiesel blend with various injection pressures are shown in the Figure 3. From the graph it is clearly observed that the lemon grass oil biodiesel blend (B20) is investigated with various injection pressures with constant speed of 1500 rpm. The blend B20 with 240 bar injection pressure shows maximum brake thermal efficiency when compare to standard (220 bar) injection pressure at full load condition. The advanced injection pressures (210bar) show the lower brake thermal efficiency. The brake thermal efficiency of diesel and blend B20 with 240, 230, 220 bar is 27.2 %, 28.3%, 27.5%, 26.1% respectively. The blend B20 at 240 bar injection pressure shows 1.2% of brake thermal efficiency increases when compared to that standard injection pressure. The reason is due to better atomization, and fine spraying of biodiesel blend with maximum injection pressure.

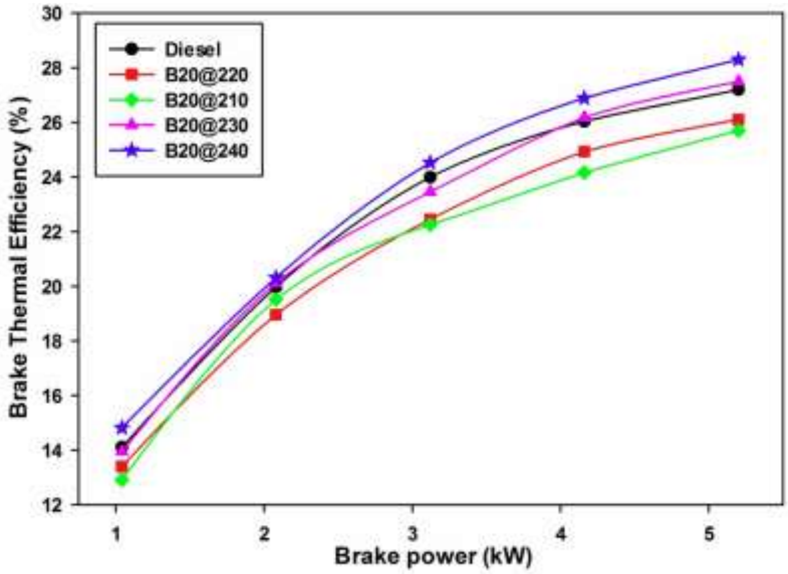

Fig. 3 Variations of brake thermal efficiency with brake power

The variations of specific fuel consumption against brake power for lemon grass oil biodiesel blend (B20) with various injection pressures are shown in the Figure 4. The specific fuel consumption when using biofuel is expected to increase, corresponding to the increase in heating value in mass basis. As seen in the figure, when fuelling with the biodiesel blend B20, the SFC was increased when compared with the diesel fuel. From the figure, it is also clear that the increase in injection pressure drastically reduced the specific fuel consumption. This is due to, increase of injection pressure reduces the fuel particle diameter and because of this, atomization occurs properly and causes better combustion. The SFC of B20 blend at 240 bar fuel injection pressure shows a considerable decrease of about 8.2% in comparison with diesel fuel injection pressure. The SFC of diesel, B20@220 bar, B20@240 bar is 0.286 kg/kW-hr, 0.297 kg/kW-hr, 0.262 kg/kW-hr respectively. From the figures it is clear that the B20 blend at 240bar having less fuel consumption when compared with other fuel injection pressures.

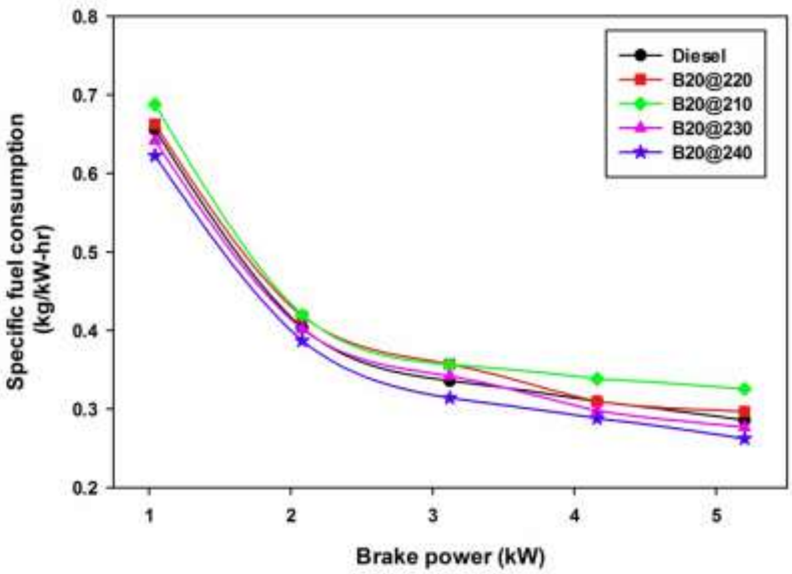

Fig. 4 Variations of specific fuel consumption with brake power

The variations of smoke density against brake power for lemon grass oil biodiesel blend (B20) with various injection pressures are shown in the Figure 5. From the graph it is noticed that the blend B20 with 240 bar injection pressure shows lower smoke density when compare to diesel and the same blend with standard injection pressure. The smoke density of blend B20 with 240, 230, 220, 210 bar, injection pressure is 74, 77, 80, 82 HSU respectively. The diesel fuel at standard injection pressure is 79 HSU at full load. The blend B20 with 240 bar injection pressure has 6.3% lower smoke density when compare to standard injection pressure with diesel fuel. The increasing smoke density for lower pressure due to attributed to the lengthening combustion duration. Decreasing smoke density is due to high pressure better atomized as a result of improvement of fuel evaporation and diffusion combustion.

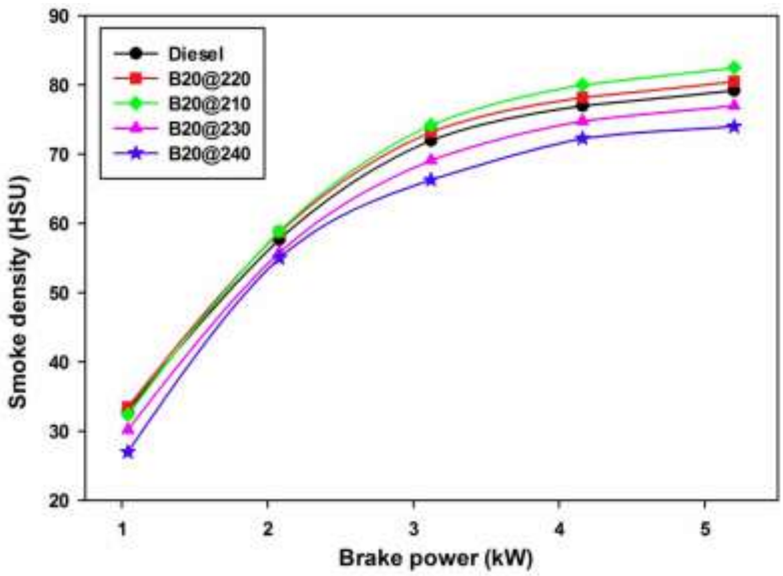

Fig. 5. Variations of smoke emission with brake power

The variations of NOx emission against brake power for lemon grass oil biodiesel blend (B20) with various injection pressures are shown in the Figure 6. The blend B20 with 210 bar injection pressure shows lower NOx emission when compare to other injection pressure. The NOx emission of the blend B20 with 240, 230, 220, 210 bar injection pressure is 1220, 1180, 1115, 1037 ppm respectively. The diesel fuel with standard injection is 1150 ppm. The blend B20 with 240 bar injection pressure has 5.73% higher NOx emission when compare to standard diesel with pressure. The reason is better atomization; shorten ignition delay period will enhancing constant temperature during the combustion. In high temperature nitrogen (N_2) is react with oxygen and increased more amount of oxides of nitrogen (NOx).

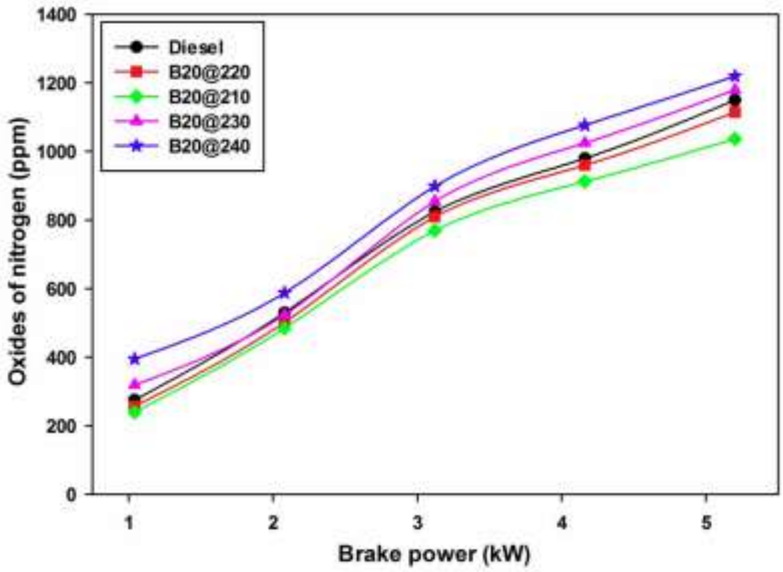

Fig. 6 **Variations of NOx emission with brake power**

The variations of CO emission against brake power for lemon grass oil biodiesel (B20) blend with various injection pressures are shown in the Figure 7. From the graph B20 blend with 240 bar injection pressure shows lower CO emission when compare to standard injection parameter. The CO emission of blend B20 with 240, 230, 220, 210 bar is 0.22, 0.24, 0.28, and 0.26% respectively with full load condition. The blend B20 with 240 bar injection pressure shows lowest CO emission when compare to sole fuel with standard injection pressure. It has show a decrease of 12% compared with standard fuel and injection pressure. The reason is biodiesel and its blends contain more oxygen content which increases conversion of CO into CO_2. The high injection pressure leads to better fuel mixer in combustion chamber. There by resolving the CO emissions.

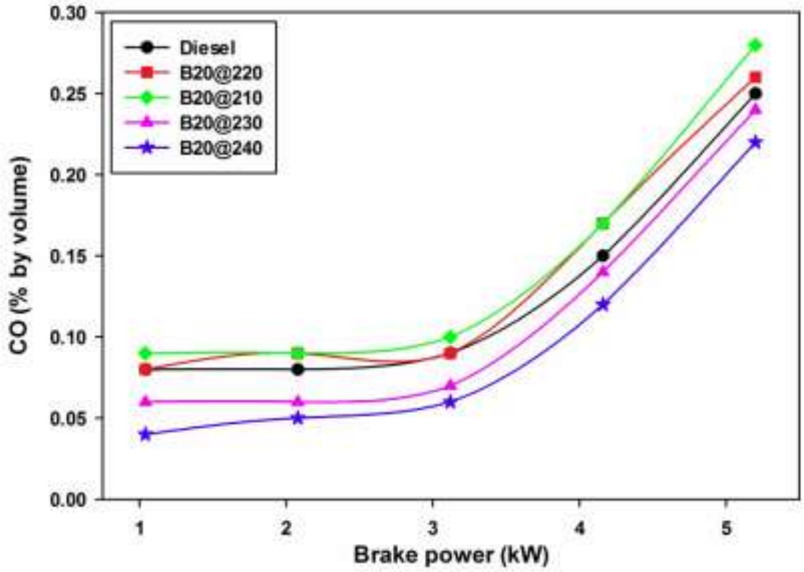

Fig. 7 Variations of CO emission with brake power

The variations of HC emission against brake power for lemon grass oil biodiesel blend (B20) with various injection pressures are shown in the Figure 8. The advanced injection pressure reflects high HC emission and a retarded injection pressure reflects lower HC emission for the biodiesel blend. The blend B20 with 240 bar injection shows lower HC emission when compare to all other injection pressure and sole fuel. The HC emission of B20 blend with 240, 230, 220, 210 bar is 110, 120, 137, 141 ppm respectively and standard pressure with diesel is 133 ppm. The HC emission of B20 with 240bar pressure has a decrease of 17% when compare to standard injection pressure with diesel fuel. The reason for decreased HC emission is the complete combustion of biodiesel and its blends due to rich oxygen content.

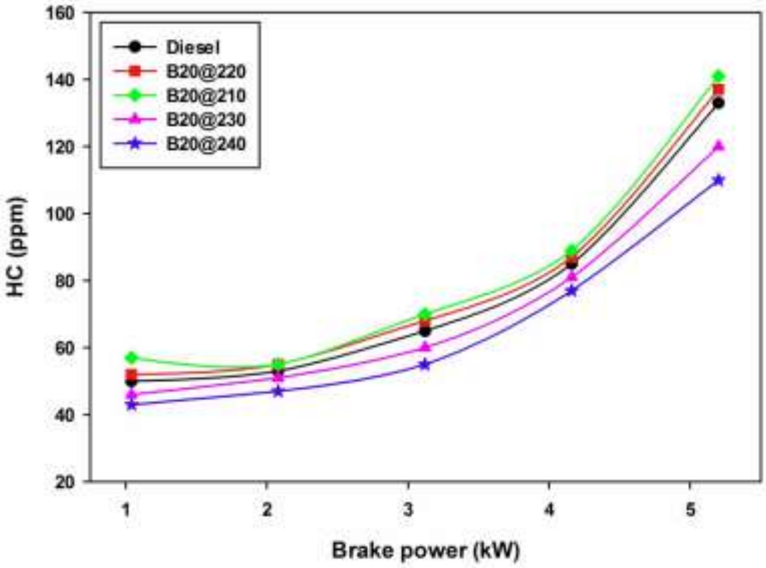

Fig. 8 **Variations of HC emission with brake power**

Combined CO, HC and NOx emission

Figure 9 shows comparison of CO, HC and NOx emission with brake power for 240 bar injection pressure of diesel and B20 blend. From the figure CO, HC and NOx emission represent there is no much more difference between diesel and B20 blend. The CO, HC and NOx emission for diesel with 240 bar injection pressure is reported by 0.20 % by vol, 104ppm, 1250 ppm respectively. The same emission are reflected for B20 blend with 240 bar injection pressure is reported by 0.22 % by vol, 110 ppm, 1220 ppm respectively.

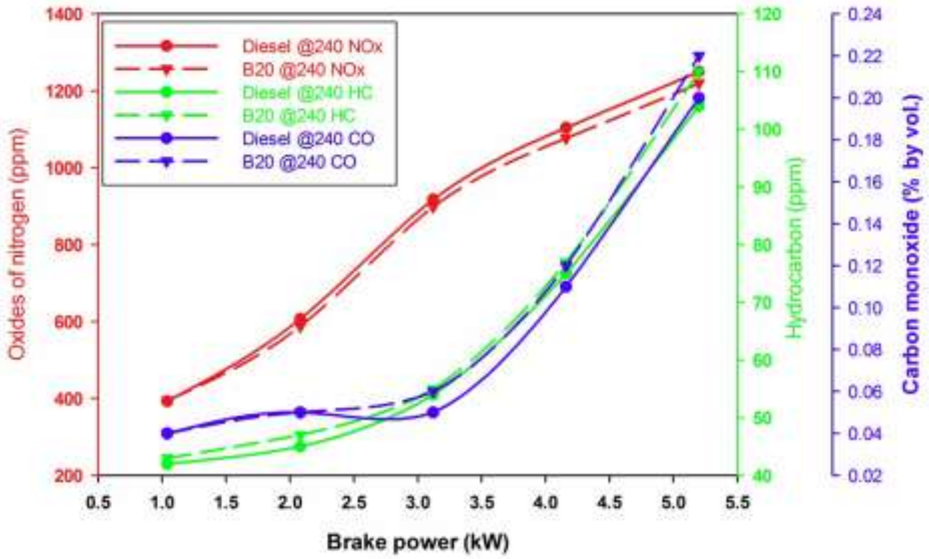

Fig. 9 **Comparison of CO, HC and NOx emission**

CONCLUSIONS

This chapter summarizes the results obtained by the experiments conducted and presents the salient features as conclusion.

1. The biodiesel was extracted from lemon grass oil through transesterification process by using methanol and KOH as catalyst.
2. The physical properties of the biodiesel is measured by ASTM standard and compared to that of diesel fuel.
3. The extracted biodiesel was blended with diesel by varying percentage B20, B40, B60, B80 and B100.
4. In Phase-1, the blend B20 has been taken as optimum blend because its performance and emission characteristics were nearer to diesel fuel.
5. In Phase – II the optimum blend of B20 was investigated with various injection pressure such as 210, 230 and 240 bar.
6. From the investigations brake thermal efficiency of blend B20 with 240bar injection pressure shows 1.2% higher than diesel fuel. The SFC was gradually decreased for the biodiesel blend B20 with 240 bar injection pressure compared with diesel.
7. The emission of CO, HC and smoke density are decreased for blend B20 with 240 bar injection pressure by 12%, 17%, 6.3% respectively compared to diesel fuel.
8. The NOx emission for B20 with 240 bar injection pressure is slightly increases by 5.7% compared with diesel fuel.
9. From the above results lemongrass oil blend B20 with 240 bar injection pressure shows best performance and emission characteristics.

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