EVALUATION OF EMISSION CHARACTERISTICS OF MAHUA OIL ON VCR DIESEL ENGINE

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Abstract—*The world is getting modernized and industrialized day by day. As a result vehicles and engines are increasing. But energy sources used in these engines are limited and decreasing gradually. This situation leads to seek an alternative fuel for diesel engine. Vegetable oils offer an advantage of comparable fuel properties with diesel. Due to considerable pressure on edible oils in India, short term performance of diesel engine was evaluated using Mahua oil as a fuel and its blends with diesel. It was found that Mahua oil could be easily substituted up to 20% in diesel without any significant difference in power output, brake specific fuel consumption and brake thermal efficiency. The performance of engine with Mahua oil blends improved with the increasing compression ratio from 12:1 to 18:1.*

As crude oil price reach a new high, the need for developing alternate fuels has become acute. Alternate fuels should be economically attractive in order to compete with currently used fossil fuels. In this work, biodiesel (Ethyl ester) was prepared from Mahua oil. Ethyl alcohol with potassium hydroxide as a catalyst as used for the trans-esterification process. The biodiesel was characterized by its physical and fuel properties including density, viscosity, flash point according to ASTM standards. Production of biodiesel from Mahua oil for diesel substitute is particularly important because of the decreasing trend of economical oil reserves, environmental problems caused due to the use of fossil fuels and the high price of petroleum products in the international market.

The Emission characteristics evaluation on a single cylinder four stroke VCR diesel engine has been done when fuelled with different blends of diesel and biodiesel made of Mahua oil. It was found that with the use of biodiesel in VCR engine, the percentage of CO and CO_2 decreases which is a good sign as far as ecological conservation is considered.

Keywords: *Biodiesel, Transesterification, MahuaOil, Compression ratio, VCR engine.*

1. INTRODUCTION

Rise in the cost of petroleum products growing environmental hazards, Ozone layer depletion of global warming etc., is made substitute the use of alternate fuel in the present day. RudolfDiesel (1858-1913), creator of diesel cycle engines, used peanut vegetable oil to demonstrate his invention in Paris with main motto is to reduce the NOx, CO, HC emissions and decrease the pollutants in the atmosphere.

During recent years high activities can be observed in the field of alternative fuels, due to supply of petroleum fuels strongly depends on a small number of oil exporting countries. Hence, government of India has taken necessary steps to fulfill future diesel and gasoline demand and to meet the stringent emission norms. Biodiesel and alcohol are being considered to be supplementary fuels to the petroleum fuels.. These biofuels are being looked to provide employment generation to rural people through plantation of vegetable oils. Biodiesels are derived from edible oils and non edible oils such as Jatropha, Pongamia, Mahua, Cottonseed, Soy bean, Neem, Sunflower, Rapeseed, Palm etc. Cotton Seed Oil (CSO) was the first commercial cooking oil in many countries but it has progressively lost its market to other vegetable oils that have larger production and less cost. With the active researches on biodiesel production from vegetable oils, there is a promising prospective for the cottonseed oil as a feedstock for biodiesel production, which may enhance the viability of the cottonseed industry. India is one of the top five countries in production of cotton seed. The Neem grows on almost all types of soils including clay, saline and alkaline conditions and is also available in low cost. Mahua oil is obtained from the seeds of Madhuca Indica, a deciduous tree which can grow in semi-arid, tropical and sub-tropical areas. It grows even on rocky, sandy, dry shallow soils and tolerates water logging conditions.

Direct use of vegetable oils or animal fats as fuel can cause numerous engine problems like poor fuel atomization, incomplete combustion and carbon deposition formation, engine fouling and lubrication oil contamination, which is due to higher viscosity. Hence the viscosity of vegetable oils can be reduced by several methods which include blending of oils, micro emulsification, cracking / pyrolysis and trans-esterification. Among this trans-esterification is widely used for industrial biodiesel production. Biodiesel is produced through a chemical reaction known as trans-esterification. For trans-esterification process methanol was commonly used because methanol is cheaper than ethanol and the recovery of un reacted methanol is easier. In the case of base catalyst potassium hydroxide (KOH) or sodium hydroxide (NaOH) are used, because it is less expensive and easy to handle in storage and transport. High free fatty acid (FFA) content of oil samples needs two stages esterification and trans-esterification. These two steps approach is also known as acid catalysis followed by alkali catalysis. In the present investigation biodiesel from vegetable oils was produced by trans-esterification method by finding FFA value which is used to calculate catalyst content for each batch of biodiesel production and by adding alcohol. Properties analysis for trans-esterification is also made. Properties like viscosity, density, flash point, fire point, and calorific value are also determined.

Mahua seeds contain about 40% pale yellow semi-solid fat. The seed oil is commercially known as ‘Mahua Butter’. The oil content of the seed varies from 33 to 43% of the weight of the kernel. Fresh Mahua oil from properly stored seeds is yellow in colour with an unpleasant taste. At temperatures prevailing in most parts of India during the major part of the year, the oil is fluid, often throwing out a deposit of stearine in cold weather.

1.1 Reasons For Choosing Mahua Oil As An Alternate Fuel

Wood of Mahua tree is hard and heavy, good fuel wood, calorific value of sapwood is 4890-4978Kcal/kg and heart wood 5005-5224Kcal/kg. Flowers yield alcohol which can be used as engine fuel. Mahua flower yields alcohol 340 litre/tone flower. Fruit pulp may also be used for alcohol production. Seed cake with cattle dung yields biogas and fertilizers. Bio diesel from Mahua seed is important because most of the states of India are tribal where it is found abundantly. Mahua seed contain 30-40 percent fatty oil called Mahua oil. The Mahua tree starts bearing seeds from seventh year of planting. Mahua seed oil is a common ingredient of hydrogenated fat in India. It is obtained from the seed kernels and is a pale yellow, semi-solid fat at room temperature. It is also used in the manufacture of various products such as soap and glycerin.

The properties of the Mahua Oil were found to be within the biodiesel limits of various countries. Hence the Mahua Oil can be used as a substitute for diesel, for sustainable development of rural areas and as a renewable fuel.

1.2 Composition Of Mahua Oil

Table 1

Palmitic Acid	24.5%
Stearic Acid	22.7%
Oleic Acid	37.0%
Lionolic Acid	14.3%
Unsaponifiable matter	1.5%

1.3 Fuel Properties Of Mahua Oil

Table 2

Property	Diesel	Esterified Mahua Oil
Kinematic Viscocity(cst)	3.8	2
Flash Point (0C)	72	75
Fire Point (0C)	75	78
Density (kg/m3)	830	901
Calorific Value (kJ/kg)	42500	38900

2. LITERATURE REVIEW

The flash point of Vegetable oils is much higher than that of diesel, indicating that they are much safer to store than diesel oil. They are about 10% denser than diesel [1]. Their cold point is higher, indicating problems of thickening or even freezing at low ambient temperatures. It is evident that vegetable oils are much less volatile than diesel. This makes their slow evaporation when injected into the engine. Vegetable oils have cetane numbers of about 35 to 50 depending on their composition [2]. It is seen that the value is very close to diesel. The compression process effectively starts only after the intake valve closes and also depends on the momentum of the flow into the cylinder, and thus, the actual realized amount of compression ratio is known as the effective compression ratio (ECR). ECR is a more suitable indicator of the compression process, and it also influences the engine operation. One of the very promising and interesting fields of study involves the use of alternative fuels including biodiesel and diesel fuels to provide effective solutions [3]. The development of treatment devices has also mitigated the emission problem to a large extent while allowing the combustion process to be optimized for maximum fuel efficiency [4]. Lehman et al. [5] obtained high ester conversion with a 6:1 M ratio of methanol to vegetable oil. In the process of peanut oil esterification, the 6:1 M ratio liberated significantly more glycerol than the 3:1 M ratio. These investigators also found that glycerol yields increased from 77% to 95% as the sodium hydroxide catalyst increased from 0.2% to 0.8% at the 6:1 M ratio. Fatty ester is the major product, and glycerol is the by-product. Barsic and Humke [6] have found that transesterification is one of the methods by which viscosity could be drastically reduced and the fuel could be adopted for use in diesel engine. The transesterification process involves reacting vegetable oils with alcohols such as methanol or ethanol in the presence of a catalyst (usually sodium hydroxide) at about 70°C to give the ester and the by-product glycerin. This esterified vegetable oil is popularly known as biodiesel which is commercially available in developed countries due to its distinct advantage over the conventional diesel. Free fatty acids (FFAs) present in the pongamia oil have got the greater influence in the process of converting it into biodiesel. This has been observed during the biodiesel preparation process in the laboratory level. However, their high viscosity and poor volatility lead to reduced thermal efficiency and increased hydrocarbon, carbon monoxide, and smoke emissions

Larry Wagner et al. [7] studied the effect of soybean oil esters on the performance and emissions of a four-cylinder direct-injection turbocharged diesel engine. They found that the engine performance with soybean oil esters is the same with diesel.The work done by Gumus et al. [8] deals with the performance and emissions of a compression-ignition diesel engine without any modification using neat apricot seed kernel oil methyl ester and its blends. They found that a lower concentration of apricot seed kernel oil methyl ester in blends gives better improvement in engine performance and exhaust emissions. Jindal et al. [9] studied about the comparison of performance and emission characteristics for different compression ratios along with injection pressure, and the best possible combination for operating engine with Jatropha methyl ester has been found. It is found that the combined increase in compression ratio and injection pressure results in an increased brake thermal efficiency and reduced brake specific fuel consumption while emissions were lowered.. Murata et al. [10] reported a 60% reduction in both NOx and PM with a very minute increase in fuel consumption in a single-cylinder engine. They used early fuel injection with high EGR rates and reduced ECR by intake valve closing (IVC) modulation. The model was validated against different operating points using engine data from Cummins. In addition, the model was also validated with data from a second engine of similar make at Purdue University's Herrick Laboratories. This model will be used here for the simulation study. Combustion homogenization is accomplished by early injection of fuel, allowing more time for the fuel to get thoroughly mixed with the charge inside the cylinder [11]

After reviewing the above listed papers, Mahua oil is also most prominent for improving performance as well as emission characteristics of diesel engine. Experimental evaluation was carried out and analyzed the emission characteristics Mahua oil on VCR Engine is done and presented.

3. EXPERIMENTATION

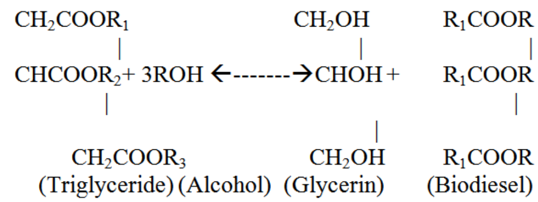
3.1 Preparation Of Biodiesel

Bio-diesel is prepared to reduce the viscosity of oil and ready usage in diesel engine for performance evaluation. The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and poly unsaturated character. These can be changed in at least four ways: Pyrolysis, Micro-emulsification, Dilution and Trans-esterification

3.2 Trans-esterification

The most common way of producing biodiesel is the trans-esterification of vegetable oils and animal fats [6, 8-11]. Oil or fat reacts with alcohol (methanol or ethanol). This reaction is called trans-esterification. The reaction requires heat and a strong catalyst (alkalis, acids, or enzymes) to achieve complete conversion of the vegetable oil into the separated esters and glycerin.

3.2.1 Chemistry Of Trans-Esterification Process:



3.3 Transesterification Mixture

The following Proportions used for the preparation of Bio-diesel: Mahua oil (1 litre), Methanol (200 ml) and Lye (KOH or NaOH) (5gms).

3.4 Manufacturing Process

Mahua oil is filtered to remove solid particles. Mahua oil is then heated up to 100˚C to remove moisture content. Exact quantity of Potassium Hydroxide (KOH) also known as Lye, is then thoroughly mixed in methanol till it dissolves completely to get potassium methoxide. Now this mixture is stirred for about 50-60 minutes and simultaneously heated below the flash point temperature. It is then allowed to settle for 24 hours. Bio-diesel will be formed at the top of the container and all the high denser particles will be formed as the by-product (glycerin) is removed from bottom. Bio-diesel fraction is then washed and dried, and then checked for quality. In trans-esterification, KOH and Methanol are mixed to create potassium methoxide (K^+ CH_3O). When mixed in with the oil this strong polar bonded chemical breaks the trans-fatty acid into glycerine and ester chains (bio-diesel), along will some soap if you are not careful. The esters become methyl esters. They would be ethyl esters if reacted with ethanol instead of methanol.

3.5 Processes In Detail

Pre-treatment (removing of moisture), Trans-esterification, Settling and separation

Fig. 3.1: Pre-treatment

3.5.1 Pre-Treatment: Oil is first heated to remove moisture content, since waste oil will probably contain moisture, which can slow down the reaction and cause saponification (soap formation). Temperature is raised to 100 degrees centigrade to allow any water to boil off.

3.5.2 Trans-esterification

During transesterification process the required revolution of the stirrer stirring rpm was to be maintained within the range of 550-700 rpm. It was observed that the required temperature range of water at 60 ^{0}C was achieved within 10-15 min and then reaction temperature is remained constant throughout the trans-esterification process. Increase in process temperature beyond 65 ^{0}C will cause formation of vapors of methyl alcohol, because it boils above 70 ^{0}C temperature and therefore reaction would be altered. Further increase in the speed of stirring would disturb the process by excessive splashing in the trans-esterification process. Therefore, the process parameters, such as constant heating at 60 ^{0}C and 550-700 rpm were recommended.

Settling and Separation: Allow the solution to settle and cool for at least eight hours, preferably longer. The methyl esters (bio-diesel) will be floating on top while the denser glycerin will have congealed on the bottom. Then carefully decant the bio-diesel.

Fig. 3.2: Transesterification Process

3.6 Properties Of Mahua Oil Methyl Ester

Viscosity	2 cst
Calorific value	38900 kJ/kg
Flash point	75°c
Fire point	78°c
Density	901 kg/m3

3.7 Experimental Test Rig

The setup consists of single cylinder, four stroke, Multi-fuel, VCR research engine connected to Eddy current type dynamometer for loading. The operation mode of the engine can be changed from Diesel to Petrol or from Petrol to Diesel with some necessary changes. In both modes the compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The basic principle of the tilting cylinder block assembly is ued for experimentation. When the CR is to be reduced the block is tilted so that the clearance volume increases and swept volume remains a constant.

Fig. 3.3: Variable Compression Ratio (VCR) Engine Test Rig

3.7.1 Engine Specifications

TABLE III

Type	Research engine test set up single cylinder, 4-stroke, VCR engine
Configuration	Naturally aspirated, water cooled, Direct injection.
Rated power	3.5 kW @ 1500 rpm
Fuel used	Diesel
Bore	87.5mm
Stroke length	110mm
Compression ratio range	12:1 to 18:1
Dynamometer	Eddy current, water cooled, with loading unit.

3.8 Experimental Procedure

Before starting the engine we must ensure that the engine should be in no load condition.

1. Check the fuel level, lubrication oil and water, fuel supply of the engine**.**
2. Start the engine by self ignition.
3. Check the compression ratio of the engine by compression ratio indicator.
4. By gradually increasing loads (0 to 12 kgs) at various compression ratios (18-12) note the values of speed, time to consume 10ml of fuel.

5. From the above valves we will noted down the emission parameters of the exhaust using exhaust gas analyzer..
6. Repeat the steps 5 and 6 with various blends of bio-diesel.

3.9 Compression Ratio Adjustment

It is the ratio of total cylinder volume when the piston is at the bottom dead centre to the clearance volume.

The tilting cylinder block arrangement consists of a tilting block with six Allen bolts, a compression ratio adjuster with lock nut and compression ratio indicator. For setting a chosen compression ratio, the Allen bolts are to be slightly loosened. Then, the lock nut on the adjuster is to be loosened and the adjuster is to be rotated to set a chosen compression ratio by referring to the compression ratio indicator and to be locked using lock nut. The Compression Ratio can be identified by the threads on the Compression Ratio indicator. Finally all the Allen bolts are to be tightened gently. The compression ratios considered for conducting the experiments are 12, 14, 16 and 18.

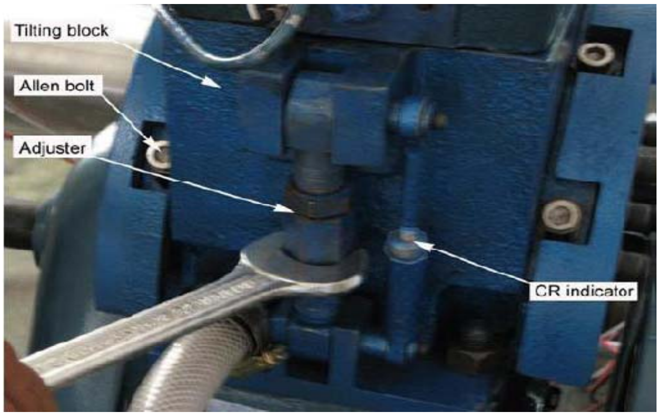


Fig 3.4: Adjusting of CR using Double open ended spanner

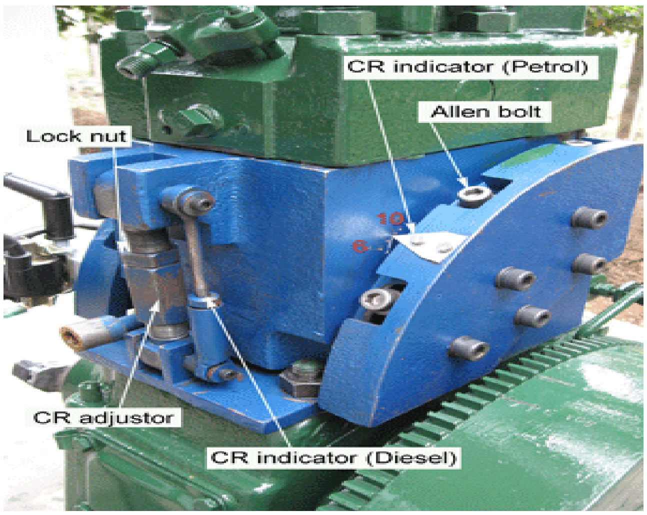
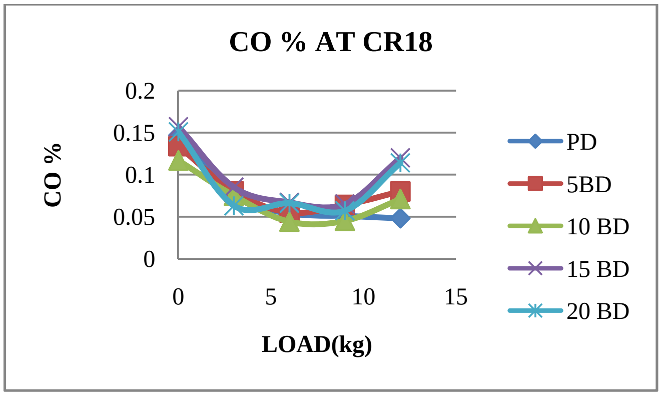
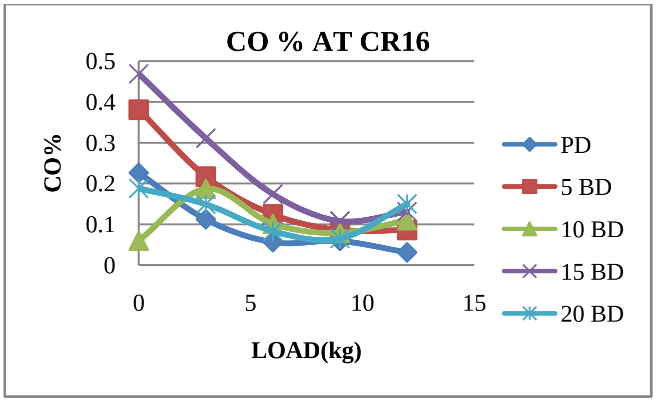


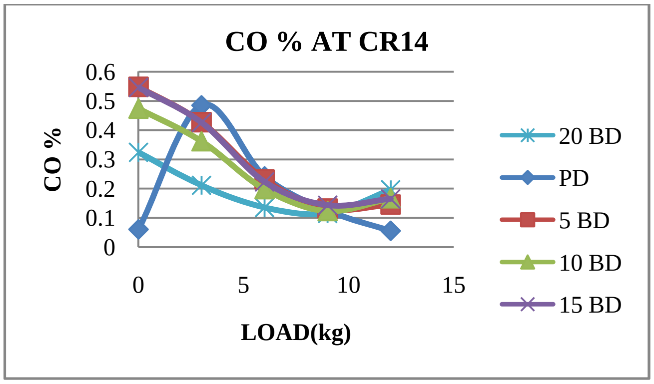
Fig. 3.5: Detailed position after adjusting the CR

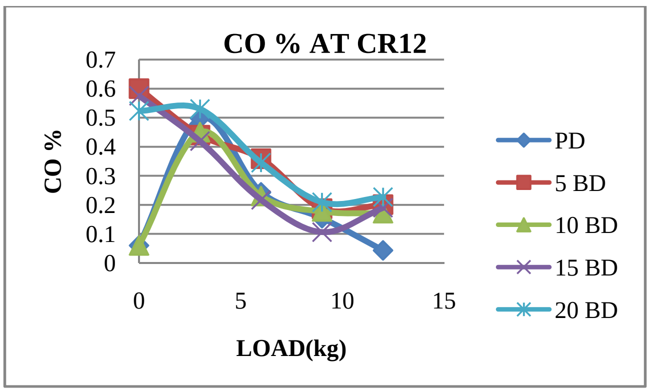
4. RESULTS

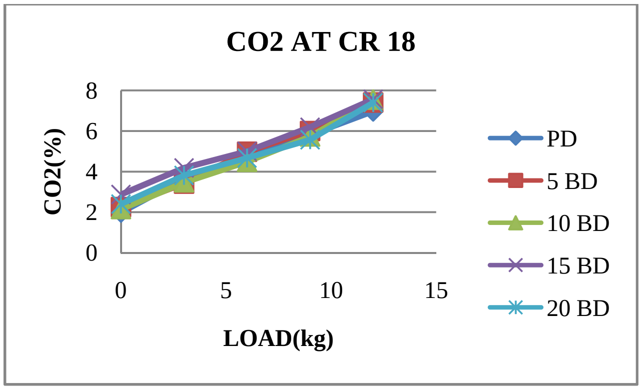
4.1 Emission Characteristics Graphs

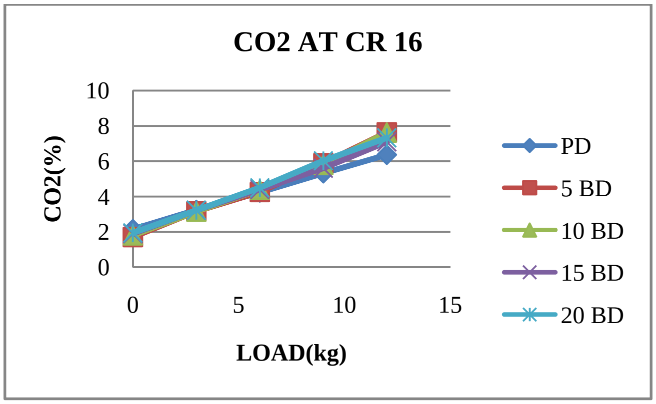


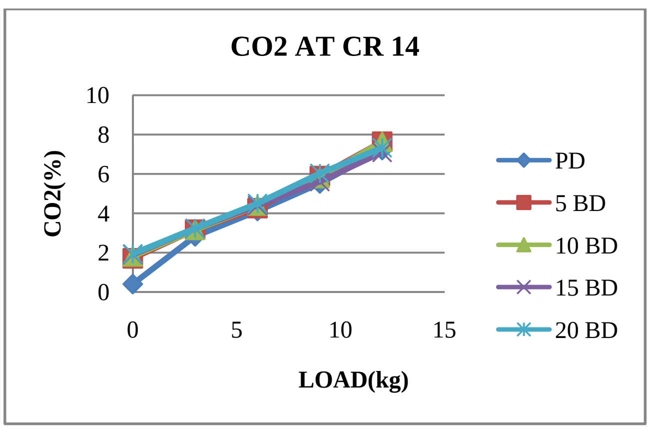


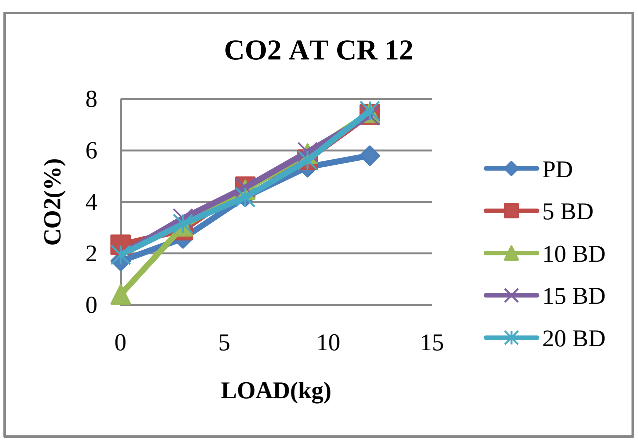












5. CONCLUSIONS

The study aims to evaluate the suitability of using Mahua oil (biodiesel) as an alternative fuel in VCR engine. Experimental investigations were carried out on the emission characteristics of the engines are improved in VCR engines. The following conclusions are drawn from the investigations:

The percentage of CO emission for low compression ratio increases due to the rising temperature in the combustion chamber. The CO emission of the esterfied Mahua oil is found to be lower for high compression ratio of 18 and it is 0.15% at no load and in proportion to maximum load. The esterfied Mahua oil emits higher percentage of CO_2 at high compression ratio, less at the lower compression ratios, and vice-versa .More amount of CO_2 is an indication of complete combustion of fuel in the combustion chamber. The CO_2 emission is 7.4% at the compression ratio of 18 and 7.33% at the compression ratio of 12 for maximum load. From the above conclusions, it is proved that the Mahua oil could be used as an alternative fuel in VCR engine in without any engine modifications.

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