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Use of Jatropha Biodiesel in C.I. Engines- A review

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ABSTRACT
Petroleum based fuels play a vital role in rapid depletion of conventional energy sources. Along with their increasing demands, these are also major contributors of air pollution which is contributing to greenhouse effect and consequently to ozone layer depletion.
Major portion of today's energy demand in India is being met with fossil fuels. Hence, it is high time that alternative fuels for engines should be derived from different indigenous sources. As India is an agricultural country, there is a wide scope for the production of vegetable oils (both edible and non-edible) from different oil seeds.
This paper is based on recommending an alternate fuel for diesel engines. Expectations have been high for the production of biodiesel from the Jatropha oil-crop. Jatropha is promoted as a drought and pest resistant crop, with the potential to grow on degraded soils with a low amount of inputs. These characteristics encourage hope for positive environmental and socio-economic impacts from Jatropha biodiesel.
Key words: biodiesel, bio fuels, blending, Jatropha, renewable energy sources.

I. INTRODUCTION

The presented work here is aimed to explore the technical feasibility of Jatropha biodiesel in compression ignition engines.

Jatropha carcus is non-edible oil being singled out for large-scale for plantation on wastelands. Jatropha curcas plant can thrive under adverse conditions. It is a drought-resistant, perennial plant, living up to fifty years and has capability to grow on marginal soils. It requires very little irrigation and grows in all types of soils (from coastline to hill slopes).

The production of Jatropha seeds is about 0.8 kg per square meter per year. The oil content of Jatropha seed ranges from 30% to 40% by weight and the kernel itself ranges from 45% to 60%.Fresh Jatropha oil is slow-drying, odourless and colourless oil, but it turns yellow after aging. The only limitation of this crop is that the seeds are toxic and the press cake cannot be used as animal folder. The press cake can only be used as organic manure. The fact that Jatropha oil cannot be used for nutritional purposes without detoxification makes its use as an energy/fuel source is very attractive. [2]

II. BIODIESEL AS AN ALTERNATIVE FUEL

Growing concern regarding energy resources and the environment has increased interest in the study of alternative sources of energy. To meet increasing energy requirements, there has been growing interest in alternative fuels like biodiesel to provide a suitable diesel oil substitute for internal combustion engines. Biodiesels offer a very promising alternative to diesel oil since they are renewable and have similar properties.

Biodiesel is defined as a Trans-esterified renewable fuel derived from vegetable oils or animal fats with properties similar or better than diesel fuel. Extensive research and demonstration projects have shown that it can be used pure or in blends with conventional diesel fuel in unmodified diesel engine. Bio-diesel commands crucial advantages such as technical feasibility of blending in any ratio with petroleum diesel fuel, use of existing storage facility and infrastructure, superiority from the environment, emission reduction angle, capacity to provide energy security to remote and rural areas and employment generation. There are more than 350 oil bearing crops identified, among which only Sunflower, Karanja, Soybean, Cottonseed, Rapeseed, Jatropha curcas and Peanut oils are considered as potential alternative fuels for Diesel engines. So a particular crop which is available in surplus within the country should be used to produce Bio-diesel. [13]

Biodiesel is biodegradable and nontoxic and has low emission profiles as compared to petroleum diesel. Usage of biodiesel will allow a balance to be sought between agriculture, economic development and the environment. Of the various alternate fuels under consideration, biodiesel, derived from vegetable oils, is the most promising alternative fuel to diesel due to the following reasons:

- Biodiesel is made entirely from vegetable sources; it does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues.
- Biodiesel is an oxygenated fuel; emissions of carbon monoxide and soot tend to reduce.
- Unlike fossil fuels, the use of biodiesel does not contribute to global warming as CO_2 emitted is once again absorbed by the plants grown for vegetable oil/biodiesel production. Thus CO_2 balance is maintained.
- The occupational safety and health administration classifies biodiesel as a non-flammable liquid.
- The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel.
- Biodiesel is produced from renewable vegetable oils/animal fats and hence improves the fuel or energy security and economy independence. [11]

III. METHODOLOGIES OF PRODUCING JATROPHA BIODIESEL

A lot of research works have been carried out to use vegetable oil both in its neat and modified form. Studies have shown that the usage of vegetable oils in neat form is possible but not preferable. The high viscosity of vegetable oils and the low volatility affects the atomization and spray pattern of fuel, leading to incomplete combustion and severe carbon deposits, injector choking and piston ring sticking.

The methods used to reduce the viscosity are:

3.1 Blending with diesel
3.2 Emulsification
3.3 Pyrolysis
3.4 Transesterification

Among these, the transesterification is the commonly used commercial process to produce clean and environmental friendly fuel. However, this adds extra cost of processing, because of the transesterification reaction involving chemical and process heat inputs.

3.1 Blending: Vegetable oil can be directly mixed with diesel fuel and may be used for running an engine. The blending of vegetable oil with diesel fuel in different proportion were experimented successfully by various researchers. Blend of 20% oil and 80% diesel have shown same results as diesel and also properties of the blend is almost close to diesel. The blend with more than 40% has shown appreciable reduction in flash point due to increase in viscosity. Some researchers suggested for heating of the fuel lines to reduce the viscosity. Although short term tests using neat vegetable oil showed promising results, longer tests led to injector coking, more engine deposits, ring sticking and thickening of the engine lubricant. [12]

Micro-emulsification, pyrolysis and transesterification are the remedies used to solve the problems encountered due to high fuel viscosity. Although there are many ways and procedures to convert vegetable oil into a Diesel like fuel, the trans-esterification process was found to be the most viable oil modification process. [13]

3.2 Emulsification: To solve the problem of high viscosity of vegetable oil, micro emulsions with solvents such as methanol, ethanol and butanol have been used. A micro emulsion is defined as the colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the range of 1–150 nm formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles. These can improve spray characteristics by explosive vaporization of the low boiling constituents in the micelles. All micro emulsions with butanol, hexanol and octanol will meet the maximum viscosity limitation for diesel engines. [13]

3.3 Pyrolysis: Pyrolysis is the process of conversion of one substance into another by means of heat or with the aid of catalyst. It involves heating in the absence of air or oxygen and cleavage of chemical bonds to yield small molecules. The pyrolyzed material can be vegetable oils, animal fats, natural fatty acids and methyl esters of fatty acids.

The pyrolysis of fats has been investigated for more than 100 years, especially in those areas of the world that lack deposits of petroleum. Since World War I, many investigators have studied the pyrolysis of vegetable oil to obtain products suitable for engine fuel application. Tung oil was saponified with lime and then thermally cracked to yield crude oil, which was refined to produce diesel fuel and small amounts of gasoline and kerosene. [13]

3.4 Transesterification Process: The conversion of Jatropha oil into its methyl ester can be accomplished by the transesterification process. Transesterification involves reaction of the triglycerides of Jatropha oil with methyl alcohol in the presence of a catalyst Sodium Hydroxide (NaOH) to produce glycerol and fatty acid ester.

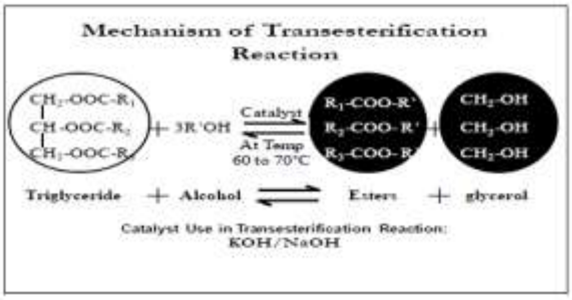

Fig.1 Mechanism of Transesterification reaction.[2]

The production of biodiesel by transesterification of the oil generally occurs using the following steps:

3.4.1 Mixing of alcohol and catalyst

For this process, a specified amount of 450 ml methanol and 10 gr Sodium Hydroxide (NaOH) was mixed in a round bottom flask.

3.4.2 Reaction:

The alcohol/catalyst mix is then charged into a closed reaction vessel and 1000 ml Jatropha oil is added. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters.

3.4.3 Separation of glycerine and biodiesel

Once the reaction is complete, two major products exist: glycerine and biodiesel. The quantity of produced glycerine varies according the oil used, the process used, the amount of excess alcohol used. Both the glycerine and biodiesel products have a substantial amount of the excess alcohol that was used in the reaction. The reacted mixture is sometimes neutralized at this step if needed.

3.4.4 Alcohol Removal.

3.4.5 Glycerine Neutralization

The glycerine by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerine. In some cases the salt formed during this phase is recovered for use as fertilizer. In most cases the salt is left in the glycerine.

3.4.6 Methyl Ester Wash

The most important aspects of biodiesel production to ensure trouble free operation in diesel engines are complete reaction, removal of glycerine, removal of catalyst, removal of alcohol and absence of free fatty acids. [2]

IV. WHY JATROPHA BIODIESEL?

Jatropha has numerous advantages over the other non-edible vegetable oil sources, which supports the notion that Jatropha could be used as the primary feedstock for Indian biodiesel. The Jatropha plant species grows on wastelands with minimal water or nutrients, and has a relatively high oil yield per plant. It has a life expectancy of up to 50 years, maturing after four to five years, and grows into different shapes, with one stem with no or few branches, or with branches growing from below.

According to estimates, one hectare of Jatropha could yield about 1,892 litres of oil. Additionally, the plants produce seeds for a predicted 30 years. Jatropha contributes negligibly to the “Fuel vs. Food” debate because it is not edible for humans or other animals. Thus growing Jatropha for biofuel production neither pulls away nutrients from the food market nor requires valuable due to its preference for arid soils. [14]

Fig.4 Examples of Jatropha plant and stem in Southern India. [14, 15]

Fig.3 Example of Jatropha leaves and flower. [14, 15]

Jatropha curcas is unusual among tree crops is a renewable non-edible plant. From Jatropha seeds Jatropha oil can be extracted which have similar properties as diesel but some properties such as kinematic viscosity, solidifying point, flash point and ignition point is very high in Jatropha oil. By some chemical reactions, Jatropha oil can be converted into biodiesel. Jatropha oil can also be used directly by blending with diesel. Some other benefits of Jatropha oil are as follows:

1. The oil is being extensively used for making soap in some countries because it has a very high saponification value.
2. The oil is used an illuminants as it burns without emitting smoke.
3. The latex of Jatropha curcas contains an alkaloid known as “jatrophine” which is believed to have anti cancerous properties.
4. From the bark of Jatropha curcas a dark blue dye is produced which is used for colouring cloth, fishing nets etc.

5. The by-product of Jatropha seeds contain high nitrogen, phosphorous and potassium which is used for fish foods, domestic animals food and in lands as fertilizer.

Now a day it has found that Jatropha may display certain anti tumer and anti-malarial properties and research is advancing related to HIV/ AIDS. It also serves to decrease the net production of carbon dioxide (CO_2), oxides of nitrogen (NOx), particulate matter etc. from combustion sources. [1]

V. Use Of Jatropha In Diesel Engine: A Potential Future Prospect For India

Indian scientists, economists, and politicians have become increasingly interested in Jatropha, a plant that grows in arid or semi-arid tropical regions, and produces seeds containing anywhere between 21% to 48% oil. It is speculated that Jatropha could be the answer to the food-versus-fuel debate because it grows on marginal land or around crops as a protective barriers without competing with them for natural resources. [14]

Fig.4 Examples of fresh fruits and seeds.[14, 15]

Biofuel development in India centers mainly around the cultivation and processing of Jatropha plant seeds which are very rich in oil (40%). The drivers for this are historic, functional, economic, environmental, moral and political. Jatropha oil has been used in India for several decades as biodiesel for the diesel fuel requirements of remote rural and forest communities; Jatropha oil can be used directly after extraction (i.e. without refining) in diesel generators and engines.

Jatropha has the potential to provide economic benefits at the local level since under suitable management it has the potential to grow in dry marginal non-agricultural lands, thereby allowing villagers and farmers to leverage non-farm land for income generation. As well, increased Jatropha oil production delivers economic benefits to India on the macroeconomic or national level as it reduces the nation's fossil fuel import bill for diesel production (the main transportation fuel used in the country. And since Jatropha oil is carbon-neutral, large-scale production will improve the country's carbon emissions profile. [15]

Large plots of waste land have been selected for Jatropha cultivation and will provide much needed employment to the rural poor of India. Businesses are also seeing the planting of Jatropha as a good business opportunity. The Government of India has identified 400,000 square kilometres (98 million acres) of land where Jatropha can be grown, hoping it will replace 20% of India's diesel consumption by 2020. [14]

The production of biodiesel is limited by land area but Jatropha curcas trees can be cultivated in any kinds of land. Jatropha is a wildly growing hardy plant, in arid and semiarid regions of the country on degraded soils having low fertility and moisture. It can be cultivated successfully in the regions having scanty to heavy rainfall even it can be cultivated even on fallow and barren lands. There is huge unused area in southern part of Bangladesh, where Jatropha can be cultivated with profitable income. The seeds of Jatropha contain 50-60% oil. So India can produce a huge amount of biodiesel from Jatropha curcas and can save a large amount of importing of petroleum products from foreign countries. [1] A Jatropha incentive in India is a part of India's goal to achieve energy independence by the year 2012.

Jatropha oil is produced from the seeds of the Jatropha curcas, a plant that can grow in wastelands across India and the oil is considered to be an excellent source of bio-diesel. India is keen on reducing its dependence on coal and petroleum to meet its increasing energy demand and encouraging Jatropha cultivation is a crucial component of its energy policy. [14]

VI. Properties Of Jatropha Biodiesel And Diesel Fuel And Their Comparison

The fuels (Mineral diesel and Jatropha biodiesel) were tested for several physical, chemical and thermal properties in Indian Biodiesel Corporation, Baramati, Maharashtra state, India. The test results are listed in following table:

Test Description	**Ref. Std. (ASTM 6751)**	**Diesel**	**Jatropha Biodiesel (JB 100)**
Density (kg/m^3)	D 1448-1972	830	875
Kinematic viscosity (cst)	D 445	2.72	5.72
Calorific value (kj/kg)	D 6751	42500	39500
Cetane no.	D 613	51	53
Cloud point (Deg. Celsius)	D 2500	-6	14
Flash point (Deg. Celsius)	D 93	64	138
Fire point (Deg. Celsius)	D 93	70	142

Table 1: Comparison of Diesel fuel and Jatropha biodiesel for various physical, chemical and thermal properties

It was found that Jatropha biodiesel is slightly heavier than the mineral diesel fuel. Density of Jatropha diesel was found to be 875 (kg/m^3) while that of Diesel was 830 (kg/m^3). This allows use of splash blending by adding bio-diesel on top of diesel fuel for making Jatropha bio-diesel blends. While blending bio-diesel should always be blended at top of diesel fuel. If bio-diesel is first put at the bottom and then diesel. It was seen that for lower blends like JB 10 and JB 20 the results of densities of Jatropha biodiesel are quiet comparable with diesel fuel.

Viscosity of Jatropha biodiesel was found to be 5.72 cst at 40 ^oC against that of 2.72 cst of diesel fuel. It was observed that viscosity of Jatropha oil decreases remarkably with increasing temperature and it becomes close to diesel at temperature above 90 ^oC.

It was seen that the calorific value of Jatropha biodiesel approximately 90% that of the diesel fuel, which makes its use to be more viable in diesel engines. The most distinguished property that observed was related to cetane number. The cetane number of Jatropha biodiesel was found higher than diesel fuel which adds to notion that Jatropha biodiesel could be used in diesel engines.

The flash and fire points of Jatropha oil was found quite high compared to diesel fuel. Hence, Jatropha oil is extremely safe to handle. Flashpoint of bio-diesel blends is dependent on the flashpoint of the base diesel fuel used, and increase with percentage of bio-diesel in the blend. Thus in storage, biodiesel and its blends are safer than conventional diesel.

Cloud point is the temperature at which a cloud or haze of crystals appear in the fuel under test conditions and thus becomes important for low temperature operations. Cloud point of Jatropha biodiesel was found higher than diesel and it has been seen from previous literature that Cloud point of Jatropha biodiesel too was generally found higher than diesel.

Higher cloud and pour point reflect unsuitability of Jatropha oil as diesel fuel in cold climatic conditions. It has been Preheating of Jatropha biodiesel is advisable in such cases.

VII. EXPERIMENTATIONS

A large no. of experiments and studies were carried out for checking the feasibility of Jatropha biodiesel in Diesel engines. A summary of some of these works is listed below:

Kazi Mostafijur Rahman et al. (2007) [1] investigated the prospect of making of biodiesel from Jatropha oil. In this study the oil was converted to biodiesel by the well-known transesterification process and used it to diesel engine for performance evaluation. Experiments were conducted on single cylinder, 4 stroke, in-line, vertical, air cooled diesel engine cycle. The team used JB-50 and JB-100 blends for trial and found that the performance of biodiesel (JB-100), mixture of 50% biodiesel & 50% diesel (JB-50) when compared; the brake power, brake thermal efficiency was greater than diesel fuel. Also from the analysis of exhaust gas it was observed that % of CO_2 gas in biodiesel and from the mixture of 50% biodiesel & 50% diesel was found to be lower than the diesel. The % of O_2 in biodiesel was found to be higher than the diesel and nearly with mixture of 50% biodiesel & 50% diesel.

Y. V. Hanumantha Rao et al. (2009) [2] evaluated the performance of single cylinder water-cooled diesel engine using Multi-DM-32 diesel additive and methyl-ester of Jatropha oil as the fuel. JB-25 and JB-100 blends were considered as the Jatropha biodiesel blends for the experimentation. JB-25 blend showed closer performance to diesel and JB-100 had lower brake thermal efficiency mainly due to its high viscosity compared to diesel. The brake thermal efficiency for biodiesel and its blends was found to be slightly higher than that of diesel fuel at tested load conditions and there was no difference between the biodiesel and its blended fuels efficiencies. For Jatropha biodiesel and its blended fuels, the exhaust gas temperature was found to be increased with increase in power and amount of biodiesel. However, its diesel blends showed reasonable efficiencies, lower smoke, CO_2 and CO emissions. It was observed that Multi-DM-32, Bio-additive possesses many attributes as Multi-Functional fuel additive. Its ability to reduce the surface tension between two or more interacting immiscible liquids helped the fuel to flow better through injector and better atomization of fuel, which improved the combustion and performance of the engine at all variable loads. Multi-DM-32 also improved the pollution control.

Pavanendra Kumar et al. (2013) [3] investigated the influence of compression ratio (CR) on the performance and emissions of a DI diesel engine using Jatropha biodiesel (50%) blended-diesel fuel, known as JB-50. Tests were carried out using three different CRs (14, 16 and 18:1) at 1500 rpm with varying load from 0 to 100%. The results showed that increasing compression ratio improves the burning characteristics of biodiesel. At higher compression ratio, brake specific fuel consumption (BSFC) increased while brake thermal efficiency decreased. However, slight increase in brake power was found especially at higher load. Steep decrease was recorded in smoke opacity (OP), carbon monoxide (CO), oxygen (O_2) and hydrocarbon (HC) emissions, while increase in CO_2 was also observed. The maximum brake power was obtained at compression ratio of 18:1 using JB-50 at full load. The maximum brake thermal efficiency was found using JB-50 at compression ratio of 18:1.So, it was found that that biodiesel blend (JB-50) could be used as alternative fuel for CI engine at compression ratio of 18:1, for better engine performance. It was observed that utilization of biodiesel as fuel in diesel engine required modifications in the input parameters but increase in CR will help in utilization of higher percentage of BD in diesel fuel.

Rachayya. Arakerimath et al. (2012) [4] used biodiesel from Jatropha oil is in a M&M Turbo Charged , four stroke, four cylinders, water cooled, diesel engine in pure and blended form without any modification in engine design or fuel system. The power, torque, and brake thermal efficiency using biodiesel were found higher at various load conditions compared to petro-diesel; however specific fuel consumption was found slightly more. The biodiesel blend JB-20 showed better performance than the diesel and other blends. According to the test, it was observed that at low load, mechanical efficiencies of diesel and all consider blends of biodiesel were same but the load increased, the mechanical efficiency was varied. At full load, JB-40 showed same efficiency as diesel.

Venkata Ramesh Mamilla et al. (2013) [5] detailed the analysis of the performance and emission characteristics of the Jatropha methyl esters and its comparison with petroleum diesel. The tests were carried out on a 3.7 KW single cylinder, direct injection water-cooled diesel engine. The fuels used were neat Jatropha methyl ester, diesel and different blends of the methyl ester with diesel.

The experimental result showed that JB-20 blend was better in performance with reduced pollution. The analysis showed that Jatropha methyl ester blended biodiesel was a good substitute for pure diesel. It was observed that smoke density increased with increasing load for all the blends of Jatropha methyl esters. It was found that smoke density decreased at higher blends of Jatropha methyl esters.

K. Pramanik (2013) [6] carried out investigation to reduce the viscosity of Jatropha curcas oil to make it comparable that of conventional fuel to make it suitable to use it in C.I. engines. Significant reduction in viscosity was achieved by dilution of vegetable oil with diesel in varying proportions. Among the various blends, the blends containing up to 30% (v/v) Jatropha oil showed viscosity values close to that of diesel fuel. The blend containing 40% (v/v) vegetable oil showed viscosity slightly higher than that of diesel. The viscosity was further reduced by heating the blends.

P.K. Sahoo et al. (2009) [7] produced the methyl esters of non-edible Jatropha (Jatropha curcas), Karanja (Pongamia pinnata) and Polanga (Calophyllum inophyllum) oil for experimentation and blended with conventional diesel having sulphur content less than 10 mg/kg. Ten fuel blends (Diesel, B-20, B-50 and B-100) were tested for their use as substitute fuel for a water-cooled three cylinder tractor engine. Test data were generated under full/part throttle position for different engine speeds (1200, 1800 and 2200 rev/min). Change in exhaust emissions (Smoke, CO, HC, NOx, and PM) were also analysed for determining the optimum test fuel at various operating conditions. The maximum increase in power was observed for 50% Jatropha biodiesel and diesel blend at rated speed. Brake specific fuel consumptions for all the biodiesel blends with diesel increases with blends and decreased with speed. There was a reduction in smoke for all the biodiesel and their blends when compared with diesel. Smoke emission reduced with blends and speeds during full throttle performance test.

T. Elango et al. (2011) [8] investigated the performance and emission characteristics of a diesel engine which is fuelled with different blends of Jatropha oil and diesel (10-50%). A single cylinder four stroke diesel engine was used for the experimentation at various loads and speed of 1500 rpm. An AVL 5 gas analyser and a smoke meter were used for the measurements of exhaust gas emissions. Engine performance (specific fuel consumption SFC, brake thermal efficiency, and exhaust gas temperature) and emissions (HC, CO, CO_2, NOx and Smoke Opacity) were measured to evaluate and compute the behaviour of the diesel engine running on biodiesel. The results showed that the brake thermal efficiency of diesel was higher at all loads. Among the blends, maximum brake thermal efficiency and minimum specific fuel consumption were found for blends up to 20% Jatropha oil. The specific fuel consumption of the blend having 20% Jatropha oil and 80% diesel (B-20) was found to be comparable with the conventional diesel. The optimum blend was found to be B-20 as the CO_2 emissions were lesser than diesel while decrease in brake thermal efficiency was marginal.

K. Srinivasa Rao et al. (2013) [9] carried out experimental investigations on a single cylinder, direct injection, diesel engine using diesel-biodiesel blends with cetane improver Ethyl Hexyl Nitrate as an additive under different Exhaust Gas Recirculation conditions. The combined effect of EGR and Ethyl Hexyl Nitrate on Exhaust emissions was studied. With increase in EGR percentage CO_2, CO emissions were found to be increased while HC, NO_X emissions were decreased.

M. Loganathan et al. (2012)[10] tested the Jatropha Biodiesel -Dimethyl Ether (JBDE) blend in a 4-cylinder, direct-injection, diesel engine to investigate the performance and emission characteristics of the engine under five engine loads at the maximum torque. The engine speed was maintained at 1500 rpm. Jatropha oil was used as a non-edible oil to produce the biodiesel. The dimethyl ether was used as an additive to enhance the engine combustion. The BDE-5 (biodiesel 95% and dimethyl ether 5%), BDE-10 (biodiesel 90% and dimethyl ether 10%) and BDE-15(biodiesel 85% and dimethyl ether 15%) were tested in the engine. The results indicated that when compared with neat Jatropha, the engine performance increased and emission level decreased with adding the dimethyl ether with methyl ester of Jatropha oil. In comparison with neat Jatropha, the BDE-10 blends were shown 10% higher brake thermal efficiency (BTE). The experimental results showed that the CO, HC and NOx emission was decreased for all BDE blends. The brakes specific fuel consumption (BSFC) decreased for all BDE blends compared to neat Jatropha oil.

VIII. CONCLUSION

From the above literature review and discussions, it is concluded that:

- ♣ Jatropha biodiesel can be used as an alternative fuel in C.I. engines without any substantial hardware modifications in the engine.
- ♣ The physical, chemical and thermal properties of Jatropha biodiesel is improved by the process of transesterification.
- ♣ The oil bearing capacity of Jatropha plant is higher than the other plants from which vegetable oils are extracted.
- ♣ As Jatropha oil is non-edible, it is cheaply and abundantly available.
- ♣ Lower blends of Jatropha biodiesel shows low BSFC, high BTE and reduced emissions compared to the diesel fuel.
- ♣ Poor results are seen for higher blends of Jatropha and it is not suitable to use for long run in C.I. Engines.
- ♣ With increase in compression ratio of the engine, the performance of the Jatropha blends is improved, moreover higher blends too showed a satisfactory performance with increase in compression ratio.
- ♣ Decrease in CO, HC and smoke opacity and increase in CO_2 and NOx emissions are seen with Jatropha biodiesel.
- ♣ Jatropha biodiesel with oxygenated additives improved the overall performance of the engines and reduced emissions which are comparable with diesel fuel.

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