Properties of a pre-heated Jatropha oil to be used in CI engine as a transportation fuel

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Abstract: *Diesel Engines have proved its utility in transportation, agriculture and power sector of India. These engines also help in developing decentralized systems energy for rural electrification. However, the concerns about long term availability of petroleum diesel and stringent environmental norms have mandated that renewable alternative to diesel fuel should be expeditely explored to overcome these problems. Vegetable oils have always been considered as a good alternative to diesel for last many years and oil derived from Jatropha curcas plant has been considered as a sustainable substitute to diesel. fuel. The present work aims at developing a dual fuel engine test rig with an appropriately designed shell and tube heat exchanger (with exhaust by-pass arrangement) for evaluation of potential suitability of preheated jatropha oil as a fuel.*

Index terms – Jatropha pre-heated oil, diesel engine, performance parameters

I. INTRODUCTION

Energy has always played an important role in development of a country. It is considered as an index of economic growth and social development. Per capita energy consumption is considered as measure of prosperity of a country besides GDP and per capita income. The world has witnessed industrial revolution in the past century, and it has also faced serious problems of indiscriminate utilization of the energy resources. The ideology was related to more energy consumption for higher industrial development and never considered

better and efficient use of energy. The US oil embargo and subsequent Gulf War were very crucial for both developed and developing countries. It was then the first time that crude petroleum importing nations felt the shock when the oil exporting countries bargained higher prices. This energy crisis forced the world to look for alternative sources of energy. This also resulted in efficient utilization of energy.

The focus of country planners changed to 'More efficiency, more productivity and reduced production cost'. This resulted in an immediate, long term and multi-facet solution to the problems immerging from increased energy demands against short supplies. Energy conservation and management has since become the buzz word in industrial circles and 'energy' is considered as a major component in the production cost.

II. ENERGY SCENARIO

Energy has undergone a major transition from a general field of study of technologies to an important issue in economic planning and international relations.

Energy is the building block for socio-economic development of any country. Although India is rich in coal and abundantly endowed with renewable energy in the form of solar, wind, hydro and bio-energy, its hydrocarbon reserve is 0.7 billion tonnes which are really very small (0.4 per cent of world's reserve). India accounted for 10.63 % of total primary energy consumption in Asia-Pacific region and 3.6 % of world primary consumption in 2007 [1]. Per capita energy consumption remains low as 491 KGOE (Kilogram of oil equivalent) compared with a world average of 1,796 KGOE in 2005 [2]**.** The distribution of primary energy in India vis a vis world in 2006 has been shown in Table 1.1.

TABLE 1.. DISTRIBUTION OF PRIMARY ENERGY IN INDIA AND WORLD (MTOE) [1]

	Oil	Natural Gas	Coal	Nuclear Energy	Hydro Electric	Total
India	128.5	38.6	208.0	4.0	27.7	404.4
World	3952.8	2637.7	3177.5	622.0	709.2	11099.3

India is fourth largest economy of world and has to extensively use energy to sustain its growth. Since India does not have huge reserves of petroleum products, it is heavily dependent upon the import of petroleum products to cater to its need for automobiles and other applications despite larger initiatives by government and exploration of new sources. Escalating prices, insufficient supply and limited reservesof petroleum have imposed an enormous burden on country's foreign exchange. In year 2006-07 the indigenous production of crude oil was 33.99 million tones where as consumption was 144.88 million tones forcing to import 110.89 million tones. The country is spending Rs.2199.91 billion [3] worth valuable foreign exchange towards import of crude petroleum which could otherwise be utilized for various other development works, that might ultimately prove to be more beneficial to Indian people. To improve the present energy crisis, future energy conversion in India should be sustainable which include increase share of renewable fuel, increase efficiency of fuel conversion, reduce environmental impacts, and increase knowledge. In this regard, the subsidy on traditional fossil fuels must be reduced in a phase manner and efforts must be put to develop and promote the use of renewable sources of energy to meet the energy requirement.

III.THE FUTURE OUTLOOK

OECD countries account for almost one-quarter and the transition economies for the remaining 6%. The increase in the share of the developing regions in world energy demand results from their more rapid economic and population growth. Industrialization and urbanization boost demand for modern commercial fuels.

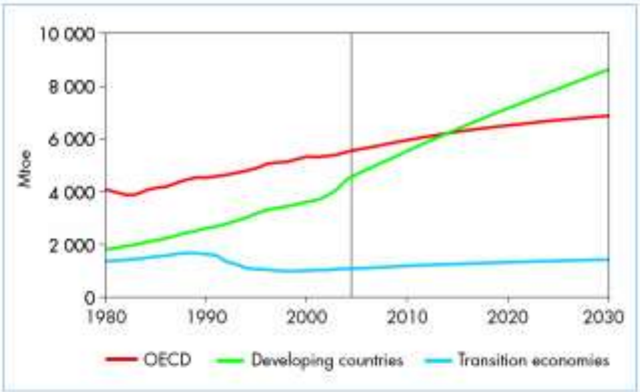

Figure 1.: Region wise Primary Energy Demand

Global Oil demand is expected to continue to grow steadily at an average annual rate of 1.3%. It reaches 99 mb/d in 2015 and 116 mb/d in 2030, up from 84 mb/d in 2005

IV.ALTERNATIVE FUELS FOR COMPRESSION IGNITION ENGINE

With the indispensable position gained by diesel engine in recent years, the demand for conventional fuel and environmental degradation caused by fossil diesel combustion can not be underestimated. As already elaborated, alternative fuels are immediately needed to deal the dual problem of fast depletion of fossil fuel reserves and environmental pollution. Such fuels should be renewable, should be suitable for use in existing engines and associated systems (such as fuel tank, pumps and hoses) as well other existing fuel storage, transportation and retail infrastructure. Since diesel engine plays an important and indispensable role in Indian economy and various sector of the country, fuels of bio-origin can provide a feasible solution to the problem.

Some of these fuels can be used directly while others need to be transformed to bring the relative properties close to the conventional fuels. Ethanol is an attractive alternate liquid source for I.C engines since it can be produced from renewable sources such as grains [15]. Given the widespread use of diesel fuels, in various sectors, the study on the performance of vegetable oils when used as a fuel in the neat or blended form is desirable [16]. Since the viscosity of vegetable oils, hence of the fuel is of prime concern, the reduction in the viscosity is required which can be carried out by transesterification process [17].

The history of using Jatropha oil instead of diesel goes back to the Second World War when Madagascar, Cape Verde and Benin used Jatropha oil as a diesel substitute. The recent tests of unmodified and modified Jatropha oil for diesel engines in Mali, Nicaragua and India make Jatropha oil a potential renewable fuel for road transport as a replacement or an extender of diesel fuels. Jatropha oil could also be used as cooking fuel or lighting fuel in rural areas. The focus of this study is for using Jatropha oil as a fuel for decentralized energy production. Jatropha oil is a very promising fuel for this application due to several advantages: Jatropha oil is a renewable fuel that could last for many years without any problem. Jatropha oil is environmentally friendly fuel and could be produced easily in rural areas. The major disadvantage of Jatropha oil as a fuel for road transport is the high viscosity of Jatropha oil that is due to the large molecular mass and chemical structure of Jatropha oil. Previous studies show that the high viscosity causes problems in pumping, combustion and atomization in injector systems of diesel engines. The literature further notes that in the long term the high viscosity may develop gumming, the formation of injector deposits, and ring sticking. Therefore, the reduction of viscosity in order for Jatropha oil to be used for road transport is paramount.

VI. DEVELOPMENT OF AN EXPERIMENTAL TEST RIG

A Kirloskar make, single cylinder, air cooled, direct injection, DAF 8 model diesel engine was selected for the present research work, which is primarily used for agricultural activities and household electricity generations as shown in fig.2.

It is a single cylinder, naturally aspirated, four stroke, vertical, air-cooled engine. It has a provision of loading electrically since it is coupled with single phase alternator through flexible coupling. The engine can be hand started using decompression lever and is provided with centrifugal speed governor. The cylinder is made of cast iron and fitted with a hardened high-phosphorus cast iron liner. The lubrication system used in this engine is of wet sump type, and oil is delivered to the crankshaft and the big end by means of a pump mounted on the front cover of the engine and driven from the crankshaft. The inlet and exhaust valves are operated by an overhead camshaft driven from the crankshaft through two pairs of bevel gears. The fuel pump is driven from the end of camshaft.

Fig.2. Test Engine

For conducting the desired set of experiments and together required data from the engine, it is essential to get the various instruments mounted at the appropriate location on the experimental setup. Apart from this, a dual fuel system has been developed for diesel and jatropha oil.

VII. EXPERIMENTAL PROCEDURE

The engine was started at no load by pressing the exhaust valve with decompression lever and it was released suddenly when the engine was hand cranked at sufficient speed. After feed control was adjusted so that engine attains rated speed and was allowed to run (about 30 minutes) till the steady state condition was reached. With the fuel measuring unit and stop watch, the time elapsed for the consumption of 10, 20 and 30cc of fuel was measured and average of them was taken. Fuel Consumption, RPM, exhaust temperature, smoke density, CO, NO_x, HC , CO_2 and power output were also measured. Fuel leakages from the injector were measured with small measuring cylinder. The engine was loaded gradually keeping the speed with in the permissible range and the observations of different parameters were evaluated. Short term performance tests were carried out on the engine with diesel to generate the base line data and subsequently neat Jatropha oil was used to evaluate its suitability as a fuel. The performance and emission characteristics of neat jatropha oil were evaluated and compared with diesel fuel. When the dual mode fuel engine was to run with preheated jatropha oil, a heat exchanger was used and is connected with the help of a bypass line of exhaust gases. The jatropha oil was heated to the different desired fuel inlet temperature and their performance and their performance and emission characteristics were evaluated. These data were than compared with both the diesel fuel and the unheated jatropha oil. The engine was always started with diesel as a fuel and after it was run for 20-25 minutes, it was switches over to jatropha oil. Before turning the engine off, the jatropha oil was replaced with diesel oil and it was run on diesel oil till all jatropha oil in fuel filter and pipe line is consumed.

PHYSICO-CHEMICAL PROPERTIES

A. Density

Density is the mass per unit volume. The measurement was made at room temperature. The density was measured with the help of a U-Tube Oscillating True Density meter. The density of jatropha oil was measured and then compared with that of diesel fuel. The equipment used for density determination is shown in fig. 2.

Fig. 2. U-Tube Oscillating True Density Meter

B. Viscosity

When a fluid is subjected to external forces, it resists flow due to internal friction. Viscosity is a measure of internal friction. The viscosity of the fuel affects atomization and fuel delivery rates. It is an important property because if it is too low and too high then atomization and mixing of air and fuel in combustion chamber gets affected. Viscosity studies were conducted for different test fuels. Absolute viscosity sometimes called dynamic or simple viscosity is the product of Kinematic viscosity and fluid density. Kinematic viscosity of liquid fuel samples were measured using Kinematic viscometer shown in plate 3.2 at 40^0 C as per the specification given in ASTM D445. A suitable capillary tube was selected, and then a measured quantity of sample was allowed to flow through the capillary. Efflux time was measured for calculating Kinematic viscosity using the formula given below:

$$\nu = c^* t \ldots (3.1)$$

Where,

ν = Kinematic viscosity, cSt or mm^2/sec

c = constant; mm^2/sec^2

t = time, second.

Fig. 3. Kinematic Viscometer

C. Flash and Fire point

Flash point is the minimum temperature at which the oil vapour, which when mixed with air forms an ignitable mixture and gives a momentary flash on application of a small pilot flame. The flash and fire point of the test fuels were measured as per the standard of ASTM D 93. The sample was heated in a test cup at a slow and constant rate of stirring for proper and uniform heating. A small pilot flame was directed into the cup through the opening provided at the top cover at the regular intervals. The temperature at which these vapour catches flash is observed and called as the flash point of that liquid. Fire point is an extension of flash point in a way that it reflects the condition at which vapour burns continuously for at least for 5 seconds. Fire point is generally higher than the flash point by 5-8 ^{o}C.

Fig. 4. Pensky Marten Flash Point Apparatus

D. Calorific Value

The calorific value is defined in terms of the number of heat units liberated when unit mass of fuel is completely burnt in a calorimeter under specified conditions. Higher calorific value of fuel is the total heat liberated in kJ per kg or m^3. All fuels containing hydrogen in the available form will combine with oxygen and form steam during the process of combustion. If the products of combustion are cooled to it initial temperature, the steam formed as a result will condense. Thus maximum heat is abstracted. This heat value is called the higher calorific value.

The calorific value of the fuel was determined with the Isothermal Bomb Calorimeter as per the specification given in ASTM D240. The combustion of fuel takes place at constant volume in a totally enclosed vessel in the presence of oxygen. The sample of fuel was ignited electrically. The water equivalent of bomb calorimeter was determined by burning a known quantity of benzoic acid and heat liberated is absorbed by a known mass of water. Then the fuel samples were burnt in bomb calorimeter and the calorific value of all samples were calculated. The Bomb Calorimeter used for determination of Calorific value is shown in fig.5

Fig.5. Bomb Calorimter

The heat of combustion of the fuel samples was calculated with the help of equation given below:

$$H_c = W_c T / M_s$$

Where,

H_c = Heat of combustion of the fuel sample, kJ/kg

W_c = Water equivalent of the calorimeter assembly, kJ/ ^oC

T = Rise in temperature, ^oC

M_s = Mass of sample burnt, kg

VIII. CONCLUSION

The experimental results show that the engine performance with unheated jatropha oil is slightly inferior to the performance with diesel fuel. As the fuel inlet temperature of jatropha oil is increased, the engine performance was improved. The thermal efficiency of the engine was lower and the brake specific energy consumption of the engine was higher when the engine was fueled with unheated jatropha oil compared to diesel fuel. However, in case of preheated jatropha oil, these parameters were superior to unheated jatropha oil.

The long term assessment of engine durability and effect on lubricating oil with preheated jatropha oil need to be examined by the future researchers.

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