Experimental Investigation of Performance on Diesel Engine with Different Blends of Castor Oil at 100% EGR

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Abstract— Biodiesel has been used as a renewable and potential fuel in diesel engines. Biodiesel and its blends with diesel is a better substitute on the basis of single fuel concept for diesel engine. Many researchers have tried different proportions of the blends with diesel. Difficulty with biodiesel run engine is that it emits higher NOx emission. In order to overcome this limitation researchers have adopted various techniques. The present work is to study the effect of Exhaust Gas Recirculation (EGR) on the performance and emissions of a single cylinder diesel engine. Exhaust Gas Recirculation (EGR) System means to use the Exhaust Gas coming from Exhaust Manifold to inlet manifold in order to reduce the emission of NOX, which is particularly very harmful. This paper reports the experimental investigation carried out on the direct injection diesel engine when pure diesel, B25% castor oil, B75% castor oil at 100 % EGR. This research paper illustrates the thermal performance on diesel engine including brake power, total fuel consumption, brake mean effective pressure, brake specific fuel consumption, brake thermal efficiency. Using Exhaust Gas Recirculation (EGR) Technique in engines, the emissions are very much controlled. This method is very reliable in terms of fuel consumption.

Key words: Diesel, Castor Oil, Diesel Engine, Turbocharger, EGR

I. INTRODUCTION

Diesel engine is used in reliable power source for light, medium and heavy duty applications and these cannot be replaced for it in agriculture and transportation sectors. The DI Diesel's high fuel conversion efficiency and cheaper diesel fuel cost are the main driving factors for its wide popularity. However, fluctuating petroleum-fuel prices in the international market and associated environmental degradation have stimulated the researchers to develop various ways of developing clean diesel engines. Nature of Diesel engine combustion process is unsteady, turbulent, diffusion and heterogeneous and due to these effects the understanding makes more complex [1].

With increasing power consumption and an increase in number of transport vehicles the coal pits are going to empty within short period. The world at present heavily depends upon petroleum fuels for transportation and for operating agriculture machinery. Diesel engines dominate the field of transportation and agriculture machinery on account of its superior fuel efficiency. The consumption of diesel in India is several times higher than that of petrol consumption. Roughly estimate of petrol and diesel consumption is 30% and 70%, respectively. Reserves appear to grow arithmetically while consumption is growing geometrically. Under this situation world will be leading to an industrial disaster [2].

Diesel engines are widely used for their low fuel consumption and better efficiency. Ever increasing diesel consumption, large outflow of foreign exchange and concern for environment have prompted developing countries like Bangladesh to search for a suitable environmental friendly alternative to diesel fuel. But the rapid depletion of petroleum fuels and their ever increasing costs have led to an intensive search for alternative fuels. This research has been accelerated after the 1973 oil embargo. As per one of the study within 40 years, the present reservation of the petroleum fuel including diesel will deplete at an increased consumption rate estimated to be order of 3% per annum [3]. Increasing number of automobiles in recent years has resulted in great demand for petroleum products. Vegetable oils may provide a viable alternative to diesel as they are renewable in nature and environmentally friendly. The use of vegetable oil in engines without any modifications results in poor performance and emissions. Transesterification method is used to reduce the viscosity of the vegetable oil which has higher viscosity and solves the most of the problems of raw vegetable oil. Transesterification is the reaction wherein the vegetable oil is transesterified with alcohol and the process of removal of glycerol from fatty acids. This esterified vegetable oil is called biodiesel [4].

II. COMPONENTS OF SET-UP

A. Exhaust Gas Recirculation (EGR):

Different methods that are widely used to reduce NOx from diesel engines are exhaust gas recirculation, retarded injection timing, fuel denitrogenation, staged injection of fuel, water injection, exhaust catalysts and reduction of pre-mixed burn fraction by reducing ignition delay. Among the above methods, exhaust gas recirculation is one of the most effective techniques currently being adopted for reducing NOx emission from I.C. engines. The thermal effect is related to EGR the increase in inlet charge temperature that affects volumetric efficiency (thermal throttling) and increase in charge specific heat capacity due to the presence of CO_2 and H_2O. EGR involves diverting a fraction of the exhaust gas into the intake manifold where the recirculate exhaust gas mixes with the incoming air before being inducted into the combustion chamber. The recirculation of exhaust gases increases the total heat capacity of the working gases in the engine cylinder and thus lowers the peak gas temperature. Introducing exhaust gas recirculation and is an effective approach to decrease, the nitrogen oxide emissions. Introduction of EGR can significantly reduce the engine-out NOx emissions and can increase the ignition delay time; both of these are beneficial but a high rate of EGR causes a reduction in the in cylinder oxygen content therefore resulting in reduced combustion and increased

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formation of soot, carbon mono-oxide and un burnt hydrocarbons [5].

B. Characteristics of Castor Oil:

Castor oil is one of hard oils, where the oil content in the seed is relatively high. In the case of castor seed, the oil content is close to 50% of the total by weight - the castor bean contains 50-55% oil. Castor oil is non-volatile fatty oil taken from beans of the plants. It ranges in color from colorless to greenish. It has two derivatives such as blown castor and hydrogenated oil. The oil itself contains a number of fatty acids similar to those in cooking oils, such as oleic acid, linoleic acid, stearic acid and palmitic acid. However, among vegetable oils, castor oil is distinguished by its high content (over 85%) of ricinoleic acid. No other vegetable oil contains so high a proportion of fatty hydroxyacids. Castor oils unsaturated bond, high molecular weight (298), low melting point (5ºC) and very low solidification point (-12ºC to -18ºC) make it industrially useful, most of all for the highest and most stable viscosity of any vegetable oil. The basic composition of any vegetable oil is triglyceride, which is the ester of three fatty acids and one glycerol. Castor oil used in textiles, paints, varnishes, plastics, cosmetics, fibers, hair oils and drying oils. It is also used for traditional and medical treatment purposes [6].

C. Turbocharger:

Turbocharger is a unique machine that uses the exhaust of an engine to provide an extra charge of air to the engine cylinders. A turbocharger is basically a combination of a compressor and a turbine, both mounted on a common shaft. Turbocharger uses the exhaust gases of the engine itself, to rotate the turbine which in turn moves the compressor.

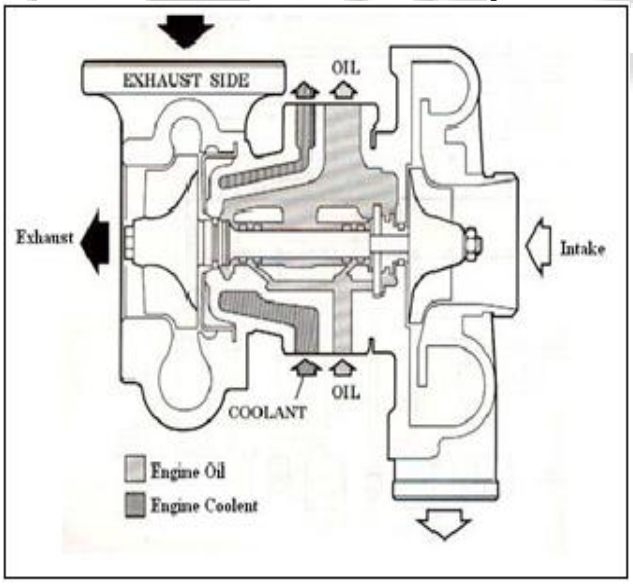

Fig. 1: Sectional view of Turbocharger

By turbo charging an engine, the following advantages are obtained:

- Increased power for an engine of the same size or reduction in size for an engine with the same power output.
- Reduced specific fuel oil consumption-mechanical, thermal and scavenge efficiencies are improved due to less cylinders, greater air supply and use of exhaust gasses.
- Thermal loading is reduced due to shorter more efficient burning period for the fuel leading to less exacting cylinder conditions.

III. EXPERIMENTAL SET-UP

A. Comparative Study of Diesel and Castor Oil:

Table I shows the comparison of properties of castor oil with diesel. Effect of dilution on viscosity of castor oil and diesel blends castor oil and diesel are blended in 0/100%, 25/75%, 75/25% on volume basis and the mixture is stirred well to get homogenous stable mixture.

Property	Diesel oil	Castor oil
Density (g/ml) at 30^0C	0.84	0.956
Calorific value (KJ/kg)	44000	36000
Viscosity at 30^0C	5.0	78
Flash point (^{0}C)	57	320
Fire point (^{0}C)	65	345

Table 1: Comparison of Properties of Castor Oil with Diesel Oil

Variation of density, viscosity, and percentage reduction in viscosity of blends at 30^0C are shown in Table 2. The density and viscosity of blends reduces with increases in percentage of diesel in blend. The blend containing 75% of diesel has density and viscosity close to that of diesel.

Castor oil (%)	Diesel oil (%)	Density (g/cc) at 30^0C	Viscosity at 30^0C	Viscosity in reduction (%)
75	25	0.925	62	20.5
25	75	0.862	25	67.9
0	100	0.840	5	93.58

Table 2: Properties of Castor Oil – Diesel Blends

Effect of Temperature on Viscosity of Castor Oil and Diesel Blends:

The viscosity of blends deceases with increase in temperature. Blend containing 75 % diesel have viscosity close to diesel at 30^0C and does not require heating. However blends containing 25%, 0% diesel requires heating up to 80, 95^0C respectively before firing into combustion chamber to attain viscosity equivalent to that of diesel at 30^0C.

B. Engine Test:

A single cylinder, water cooled, four stroke direct injection compression ignition developing 1.07 kW power at 1500 rpm was used for this work. The engine is coupled with rope brake dynamometer. Fuels used were diesel, its blends with castor oil at pre heated to different temperatures at 100% EGR. Load was applied in 6 levels namely, 4 Kg, 6 Kg, 8 Kg, 10 Kg, 12 Kg and 14 Kg at the rate of 100% EGR.

The easier way to study the effects of single parameter variation while maintaining all others constant is to perform the test on a single cylinder engine with separate systems for the control of EGR rate, inlet temperature, air and fuel flows. By the way, this hides some limits of an actual engine: for instance, the boost pressure depends on energy available at the exhaust when using a turbocharger.

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Engine parameter	Specification
Engine model	Single Cylinder Four Stroke Diesel Engine
Engine type	Four stroke, CI, air cooled, single cylinder, diesel engine
Bore (mm)	87
Stroke (mm)	80
Rated power@1500 rpm (kW)	4.4
Retarded injection timing (Deg CA)	17° BTDC
Dynamometer	Rope Brake Type

Table 3: Specification of the Test Engine

C. *Test Installation:*

The experiment is performed on a single cylinder four stroke diesel engine. In the experiment, the blends of diesel and castor oil are to be heated to reduce the viscosity for smooth running of engine and faster combustion rate. For this purpose, the special type of exhaust pipe is provided with the copper tube winding inside it which has high thermal conductivity. When the engine is started, due to the hot exhaust gases, the copper tube inside the pipe gets heated. After this, the mixture is passed through the tube. Due to this hot tube, the viscosity of the mixture gets reduced which enters in the combustion chamber of engine and engine can run smoothly.

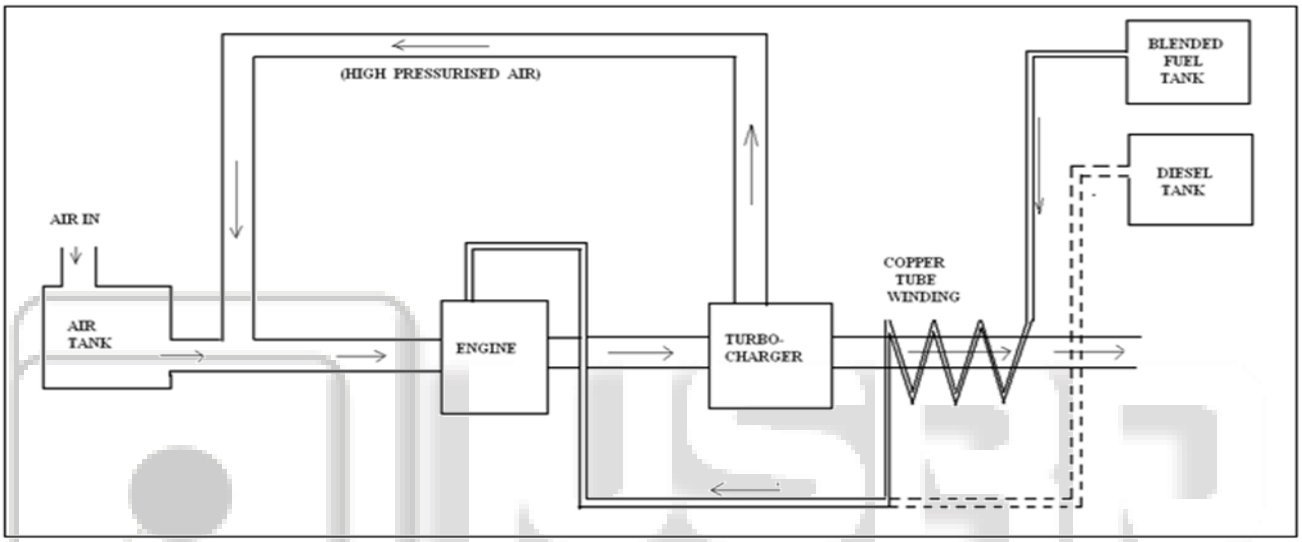

Fig. 2: Experimental Setup for testing.

IV. RESULTS AND DISCUSSIONS

A. *Total Fuel Consumption*

Figure 3 shows the variation of total fuel consumption with brake power. From above graph for constant BP, different values of TFC are plotted for three different fuels. From the graph, we can say that TFC is lower for only diesel as compared to both fuel i.e. 25% castor oil & 75% diesel and 75% castor oil & 25% diesel. This is attributed to more amount of fuel consumption for blends as compared to diesel.

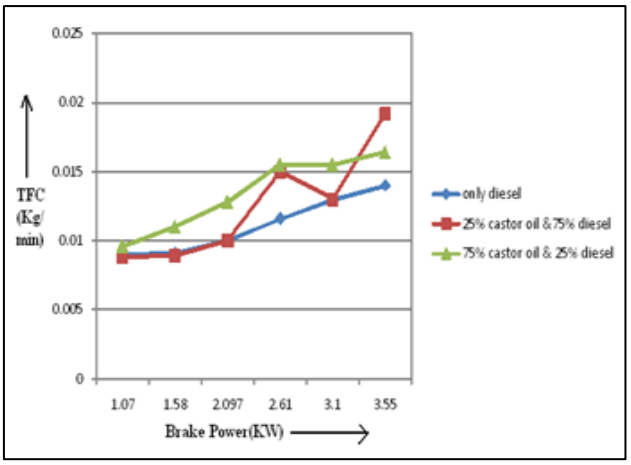

Fig. 3: TFC Vs BP at 100% EGR

B. *Brake Specific Fuel Consumption:*

Figure 4 shows the variation of brake specific fuel consumption with brake mean effective pressure. From the above graph, we can say that the brake specific fuel consumption is higher for blend of 75% castor oil & 25% diesel than that of other two fuels.

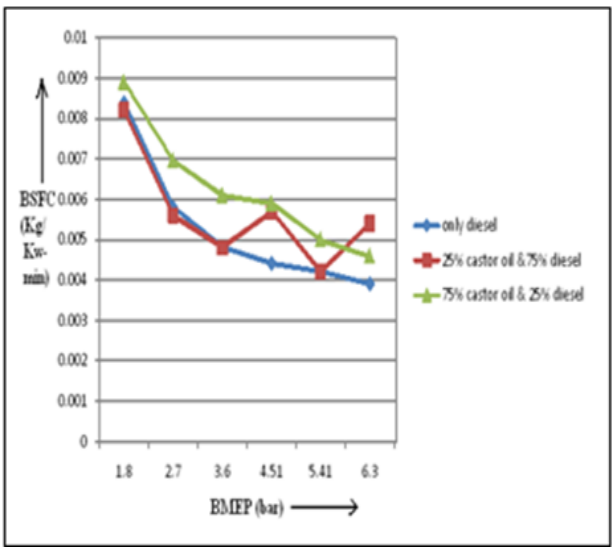

Fig. 4: BSFC Vs BMEP at 100% EGR

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C. Brake Thermal Efficiency:

Figure 5 represents the variation of brake thermal efficiency with brake power developed. Thermal efficiencies of all the blends are lower than that of diesel except for blend of 25% castor oil & 75% diesel, it is higher than diesel. This is attributed to more amount of fuel consumption for blends as compared to diesel whereas the blend of 75% castor oil & 25% diesel, the brake thermal efficiency is lowest as compared to other two fuels.

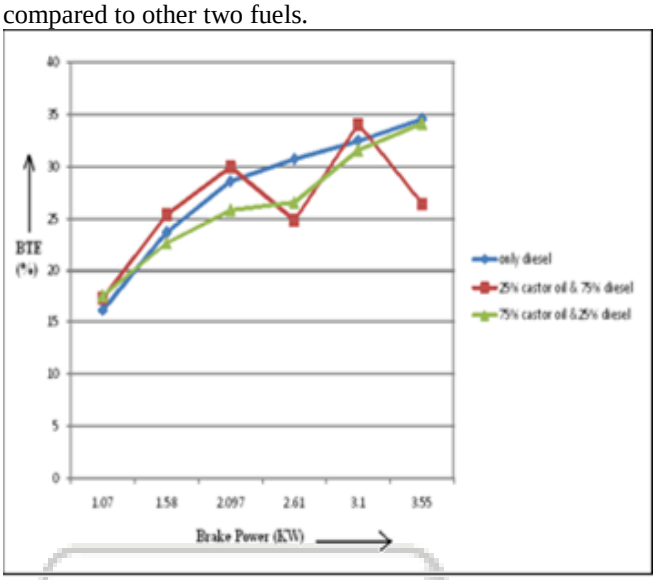

Fig. 5: BTE Vs BP at 100% EGR

V. CONCLUSION

Based on the experimental results for the base line engine with different configuration at rate of 100% EGR, the following conclusions are drawn:

- The DI compression ignition engine may be able to operate with different proportional blends of castor oil and diesel.
- Adding EGR to the air flow rate to the Diesel engine, rather than displacing some of the inlet air, appears to be a more beneficial way of utilizing EGR in Diesel engines.
- At 100% EGR, the brake thermal efficiency of diesel is less than 25 % castor oil and 75% diesel blend for diesel but mostly less than 75 % castor oil and 25% diesel blend.
- The specific fuel consumption is slightly higher for 75 B than diesel and 25 B for 4 Kg to 12 Kg but for 14 Kg, it is more than diesel and less than 25 B.
- Total fuel consumption is higher for 75 B than diesel and 25 B for 4 Kg to 12 Kg but, it is more than diesel and less than 25 B for 14 Kg.
- It can be concluded that Blend containing 75 % diesel have viscosity close to diesel at 30^0C and does not require heating. However blends containing 25% and 0% diesel require heating up to 80^0C and 95^0C respectively before firing into combustion chamber to attain viscosity equivalent to that of diesel at 30^0C so to bring physical and chemical properties of neat castor oil close to diesel for safe operation of fuel without any engine modification.

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