Selection of suitable bio-fuel for diesel engine based on fuel properties

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***Abstract*- For travel and agricultural purposes, the diesel engine plays a major role in various developed economies. Due to serious environmental problem and rising cost of diesel, a lot of research is going on to replace traditional energy sources. Diesel engine cannot be replace because of its efficient performance at higher power and reliability with alternative engines. For this purpose, detailed experiments were conducted with different sets of diesel–diethyl ether–2–methoxy ethyl ether. Diethyl ether and 2–Methoxy ethyl ether were selected as additives on the basis of literature review, physical and chemical properties, availability in the market and cost. The experiments were performed with pure diesel and diesel–diethyl ether–2–methoxy ethyl ether blends with different blend ratio.**

Mixing of 5% DEE and 5% MXEE with 90% diesel on volume basis (D90–DEE5–MXEE5) showed optimum results of emission and performance. By comparison of mixture D90–DEE5–MXEE5 with diesel (at standard engine conditions), Low exhaust emissions (HC 63.15 %, CO 60.00 % and Smoke 18.29 %) found to be significant at peak loads and performance enhancement (decrement in BSFC 5.00 % and increment in BTE 3.00 %). However NOx increases (2.60%).

Keywords- Diesel engine; DEE; MXEE; BTE; NOx

1. INTRODUCTION

Energy is the cornerstone of the modern industrial economy, providing most human operations with a significant gradient. It provides lighting, transport services, water heating, manufacturing, and food production, etc. Our contemporary lives, both individual and social, are now dependent on their abundance, comfort and potential. IEA has developed different energy scenarios on the basis of worldwide data of energy production and consumption, policies, opportunities, and challenges. It is estimated that consumption of all recent fuels will see a rapid rise till 2040 under the new policies scenario. Oil demand is expected to increase to 103.5 million barrels/day (Mb/d) up to the year 2040; whereas gas consumption is projected to increase by approximately 50%. It is estimated that renewable energy will increase by 18% to 30% in power sector by 2050 [1].

For the travelling, automobile is a major way of various developed economies. According to the current study, It is experiential that approximately 1,000,000,000 (one thousand million) automobile vehicles go on the road nowadays with the prospect that the global fleet will grow to 1,300,000,000 (one thousand three hundred million) by 2020 [2].

The annual production pace of automotive in our country is one of the leading production countries in the world, which has led to a simultaneous raise in petroleum and crude oil consumption in our country as well as in over the world [3].

Developing clean alternative fuel for engine and control the emissions (i.e., NOx, smoke, etc.) by the engine, many research work going by the various researchers of worldwide to resolve the problems simultaneously. A small improvement in CI engine design can reduce emissions levels. However it is very difficult to regulate emission standards required by engine design modifications. Mixing of various additives (chemicals) in diesel has better alternative to attain the low exhaust emissions and high performance of engine as compared to diesel. From the last two decades this has been the main research topic for most of researchers [4].

Diesel engines have also play a very important role in agriculture sector, such that in tractors, threshers, pump sets and other agricultural equipment. CI engines dominate our agriculture and transportation sector due to some special features of diesel engines such as low specific fuel consumption, high power generation, durability and reliability [5-7].

1.1 Use of additives

Many additives are readily available at low cost to produce a mixture of diesel and additives in proportional quantities for the use in diesel engines. Among all available additives, oxygenated additives are more eminent due to more amount of oxygen is present in their molecular structures that help to better combustion. It was discovered that 10–20% of oxygenated additives can be mixed with diesel fuel to reduce exhaust emission. The combustion properties of blends, such as: viscosity, boiling point, cetane amount, volatility, and density will be improved by the mixing of additives in diesel with sufficient amounts. Nitroparaphene compounds have also high oxygen content available in their molecular structure and may improve the combustion quality of diesel engines [8].

1.2 Advantages of additives [8,9]

Following are the advantages of additives:

- Large amount of oxygen available in their molecular structure.
- It can be very simply mixed with diesel without any reagent.
- It can be used in engine without any alteration.
- Normally it does not harm any components of engine.
- There are no health and safety problems during the preparation of blends.
- It may improve the cetane number of blends.
- It may improve the combustion properties of a blend, due to high availability of oxygen.

Limited resources of diesel fuel and ecological concerns promote research in the field of emission control technologies and alternative fuels. Various types of additives/alternative fuels i.e., alcohol [10-16], biodiesel [17-19] and vegetable oils [20-22] may be used in diesel engines with sufficient performance and low exhaust emissions. Improved fuel can also be obtained by adding the appropriate percentage of these options to diesel. Among these, oxygen–rich additives have gained more attention due to their ability to reduce emissions without greatly affecting engine performance [23,24]. Oxygen–rich additives are renewable in nature and support the local agriculture industry as well. Various research in the field of alternative fuels for CI engines showed that fuels having oxygen in their molecular structure are capable of reducing emissions of smoke, NOx, CO and HC with unaltered or even improved performance (in some cases).

Many notable developments have taken place in the area of use of alternative fuels and additives in CI engines. Still, the use of oxygenated additives in CI engines has more or less been limited to some pilot studies or lab experiments only. Many studies have been done on diesel– additives blends and testing of performance and emission characteristics of the engines. However, there is a lack of detailed study with multiple additives.

In view of these aspects, research on the simultaneous use of diesel and oxygenated additives to form ternary blends is proposed. Guided by the literature survey, it was decided to select diethyl ether and 2–methoxyethyl ether as the experimental additives. Also, in order to make the results of research more impactful, it was decided to use a CI engine. Current study thus aims to present an experimental investigation using selective combinations of "diesel–diethylether–2–methoxyethyl ether" ternary blends to determine the optimum blend for performance and emissions of a diesel engine having widespread applicability.

Diethyl ether is basically developed from ethanol with reaction of isobutene and isoamylenes [25] or via a dehydration process [26]. Diethyl ether is an organic compound which is a volatile, colorless, and highly flammable liquid. Diethyl ether works as solvent for variety of organic compounds. DEE is having the high cetane number, low auto ignition temperature, high volatility and high oxygen content [27]. Smoke, NOx and PM can reduce by adding DEE with diesel in CI engine [28]. BTE 7.2% increased and BSFC 6.7% decreased, when diesel engines were given to diethyl ether with diesel [29]. HC and CO can be minimize by DEE and diesel blend.

2–Methoxyethyl ether is a organic additive and the chemical formula C6H14O3. It contents the high cetane number, boiling point and oxygen content in their physico–chemical and combustion properties. It is famous by the name of "diglyme". It is a 99% pure, colorless liquid with a just like ether odor. It is fully miscible with diethyl ether, diesel, alcohols, water, and hydrocarbon solvents.

The various combustion and physico–chemical properties of diesel, DEE and MXEE are compared in Table 1.

Table 1 Various properties of diesel, DEE and MXEE [8,25]

Particulars	Diesel	DEE	MXEE
Chemical Formula	$C_{10}H_{20}$–$C_{15}H_{28}$	$C_4H_{10}O$	$C_6H_{14}O_3$
Molecular Weight (g/mol)	170	74	135
Cetane Number	50	125	124
Density (kg/m^3) (25°C)	845	713	950
Boiling Point (°C)	190	35	162
Viscosity (40°C) cSt	2.54	1.20	1.08
Auto–ignition temperature (°C)	315	180	190
Lower heating value (MJ/kg)	45	34	24.5
Specific Gravity (g/cm^3)	0.827	0.713	0.945
Latent heat of vaporization (kJ/kg)	245	355	322
Oxygen Content (wt %)	0	22	36

Diethyl ether and 2–methoxyethyl ether have high oxygen content. The viscosity of both additives is close to that of diesel. Combustion efficiency is increased due to the higher cetane number available in DEE and MXEE. Therefore, DEE and MXEE can be used as additives with diesel for C.I. engines due to superior physico–chemical and combustion properties.

2. EXPERIMENTAL SETUP

2.1 Blend preparation

The first assignment of the experiments was mixture preparation. Three combinations (D92.5–DEE5–MXEE2.5, D90–DEE5–MXEE5, D87.5–DEE5–MXEE7.5) of diesel, diethyl ether and 2–methoxyethyl ether were prepared on a volume basis. Initially, the pure diesel fuel was taken in glass containers according to the blending ratio, after which diethyl ether (fixed amount–5 percent) was mixed drop by drop in pure diesel and stirred continuously with the aid of a magnetic stirrer. 2–methoxyethyl ether was similarly poured according to the mixing ratio in the diesel–diethyl ether blend following the mixing of diethyl ether in pure diesel. For various fuel blends, all the measures above were repeated.

2.2 Engine set up

For experimentation, a four stroke, water cooled, single cylinder, direct injection, diesel engine was used. The fuel was provided by feeding gravity via filters and fuel tanks to the fuel pump. Before the experimentation, new lubricating oil was applied to the engine. Splash types of lubrication system used to lubricate the various parts of the engine. 12 V and 45 Amp battery was used to start the engine. The various technological specification of the engine has given in the table 2.

Table 2 Specifications of experimental set up

Equipment	Specification
Engine	TVI Kriloskar, Constant rpm (1500), single cylinder, four stroke, 3750W, 0.556 litre, 8cm bore, 10.1cm stroke length, 14-21 CR, self/crank start
Dynamometer	Power mug, eddy current type, power rating 3750W, constant rpm (1500), air cooled, load sensor S type.
Exhaust Gas analyzer	AVL-DIGAS Modal- 444N NOx gas- Electrochemical, Range 0-5000 PPM , Resolution 1PPM
Fuel rate measurement	Range of fuel rate- 0-10kg/hr, resolution-0.06kg/hr The fuel rate is measured by two capacitive sensors with a glass burred and solenoid valve.
Air intake measurement	An orifice and differential pressure transmitter used for the measurement of air flow (m^3/s). range of air rate – 50m^3/hr, resolution – 0.1m^3/hr
Temperature measurement	K Type thermocouple , range 0-700^{0}C, Resolution -1^{0}C
Water flow measurement	Transducer- turbine flow type, range- 0-99.9cc/s, resolution-0.1 cc/s

3. RESULT AND DISCUSSION

A detailed experimental analysis of the CI engine has been completed in this chapter. Different CI engine performance and exhaust emission analyses have been conducted for different fuel blends (D–DEE–MXEE) and pure diesel. Experiments were performed without any stagnation and at the same time with different engine parameters with all sets of fuels, pure diesel and blends (D–DEE5–MXEE2.5, D–DEE5–MXEE5 D–DEE5–MXEE7.5). Results have been discussed in details with the help of the figures.

Standard (normal) engine parameters (CR–17.5, IP–200 bar and IT–23 before TDC) with pure diesel and various fuel blends were examined for the CI engine performance and exhaust emission characteristics, as shown in figures.

The engine's brake thermal efficiency is the portion of the heat that is directly transferred to the output of shaft power. Figure 1 illustrates the relationship between brake thermal efficiency (percent) and brake power (kW). It has also been observed that brake power is directly proportional to brake thermal efficiency.

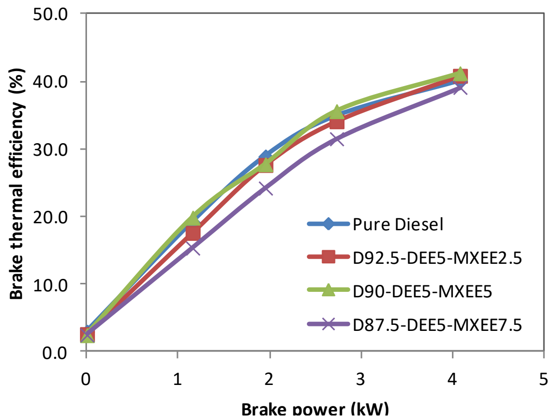

Fig.1 BTE v/s BP curve for various fuels

The BTE (percent) is highest for D90–DEE5–MXEE5 (41.2 percent) at the peak load as per the above curve, and as the amount of MXEE is increased, the efficiency decreases. The result above indicates that diesel's heating value is the highest. Due to the reduced heating value, the blended fuels emit less heat, which in turn reduces engine BTE [4].

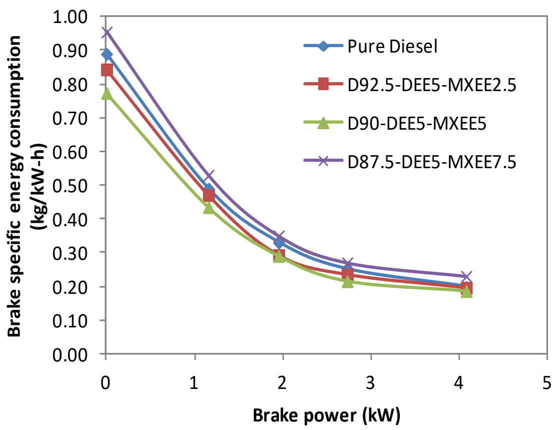

Fig.2 BSFC v/s BP curve for various fuels

As per the above fig. 2 the BSFC is lowest for D90–DEE5–MXEE5 (0.19 kg/kW–h) at the peak load and the BSFC raise as the additives quantity is increased. However, D87.5–DEE5–MXEE7.5 blend showed increment in BSFC as compared to D90–DEE5–MXEE5 due to decrement of lower calorific value.

The amount of smoke is smaller for the D90–DEE5–MXEE5 blend as the additives have a low boiling point, lower combustion temperature and higher oxygen content compared to gasoline, as shown in Figure 3.

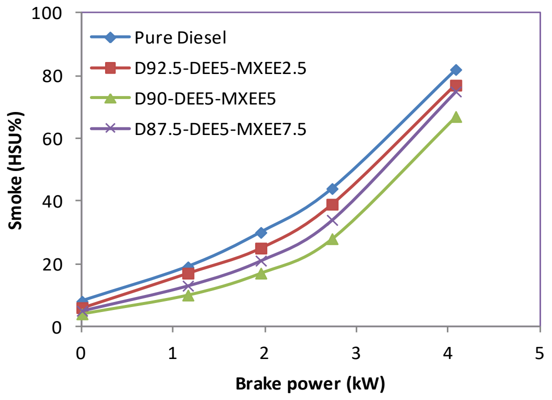

Fig.3 Smoke v/s BP curve for various fuels

The high cetane number (125 and 124) and good volatility (boiling temperature 35 °C and 162°C) characteristics of DEE and MXEE as compare to pure diesel (high boiling temperature 180–360 °C) are responsible to improving combustion quality. The high oxygen content of DEE and MXEE (22 and 36) is also responsible for the supply of ample oxygen to help minimize smoke in the fuel–rich region. At peak load conditions for all D–DEE–MXEE mixtures and pure diesel, a minimum value of 67 Hartridge Smoke Unit (HSU) percent smoke emission value was observed for the blend D90–DEE5–MXEE5.

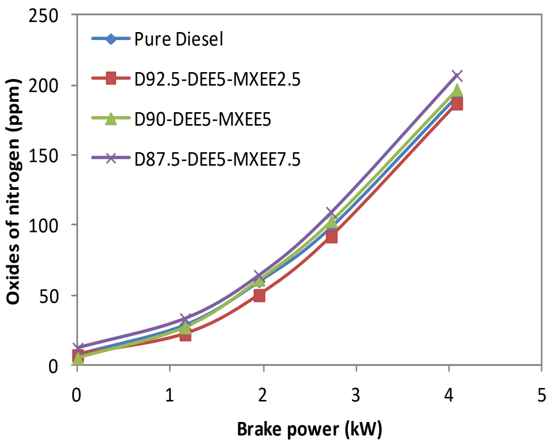

Fig.4 NOx v/s BP curve for various fuels

As per the above fig.4 the amount of NOx is the minimum for the blend D92.5–DEE5–MXEE2.5, as compared to pure diesel. Reason being additive have high cetane number and high oxygen content makes an early combustion. A least value of 187 ppm NOx emission value was found with blend D92.5–DEE5–MXEE2.5 at full load conditions between all D–DEE–MXEE mixtures and diesel. Though, increment in NOx observed at higher blends (i.e., D87.5–DEE5–MXEE7.5) could be result of superior combustion due to higher percentage of available oxygen and cetane number in the fuel.

4. CONCLUSION

In the current work, a diesel engine was operated at different loads with ternary fuel blends (diesel–diethyl ether–2–methoxyethyl ether) and its performance and emission characteristic were recorded. Initially, engine was operated at standard engine parameters using pure diesel and variable ternary blends (D92.5–DEE5–MXEE2.5, D90–DEE5–MXEE5, D87.5–DEE5–MXEE7.5), and result were also recorded. Then these results compared with the pure diesel to get the best blend. Base on the obtained results and analysis, following concluding remarks may be drawn:

- At standard conditions of engine i.e., IT 23° CA btdc, IP 200 bar and CR 17.5, D–DEE5–MXEE5 blend was found the most excellent fuel blend due to high cetane number, high oxygen content available in the blend.
- BTE was increased by 3.00 % and BSFC was decreased by 5.05 %.
- D90–DEE5–MXEE5 also controlled smoke emission (reduced by 18.29 % respectively) as compared to neat diesel at peak load.
- However slightly increment in NOx emission 2.60 %.

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