EXPERIMENTAL INVESTIGATION OF PERFORMANCE, EMISSION AND COMBUSTION CHARACTERISTICS OF KIRLOSKAR TVI DI DIESEL ENGINE USING DIESEL-ETHANOL-SURFACTANT AS FUEL

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ABSTRACT
An experimental investigation is carried out to analyze the effect of different diesel-ethanol blended fuels on the engine performance, combustion and emissions, such as Brake specific fuel consumption, Brake thermal efficiency cylinder pressure, Heat release rate, oxides of nitrogen, hydrocarbon and smoke density. The experiments were conducted on a single cylinder four stroke water-cooled naturally aspirated open chamber (DI) Kirloskar TVI diesel engine fuelled with neat diesel and diesel-ethanol-Tween80 (Surfactant) blends at an injection pressure of 220 kgf/cm^2 with constant speed of 1500 rpm at varying load condition. The results indicate that the emulsified fuel decrease the specific fuel consumption and increase the brake thermal efficiency. This is due lower heating value of blended fuel. Among the blends the D50 E40 concentrations shows the highest oxides of nitrogen, Hydrocarbon and lowest smoke density were obtained at maximum brake power of the engine. The cylinder pressure and heat release rate are higher and recorded as 76 bar and 152 kJ/m^{3}deg for D50 E40 blends than other blends and neat diesel fuel.

Keywords: diesel engine, ethanol, tween 80 performance, emission, combustion.

INTRODUCTION
In the last two decades of the 20th century major advances in engine technology have occurred, it has led to greater fuel economy in vehicles, the reduction of emission is in a desirable route as approved by environmental protection agency. A lot of money is being spent on impact of crude and other petroleum products. This expenditure is unavoidable become petrol and diesel is essential and vital and imperative for power generation hence elite scientists are forced to discover an alternative source of energy which should be environmentally friendly [1].

Conventional diesel fuels should be replaced by newly invented alternative fuels like ethanol and biodiesel. The ethanol can be produced from crops like corn vegetables, research continues on the development of high efficient, low cost process for producing ethanol from other feed stock such as waste from agricultural crops, food and beverage processing wood and paper processing, application of ethanol on diesel engines can reduce environmental pollution [2].

EMULSIFICATION

- Ethanol is immiscible in diesel over a wide range of temperatures and water content because of their difference in chemical structure and characteristics
- The addition of ethanol to diesel affects properties such as viscosity, lubricity, energy content and cetane number volatility and stability.
- The phase separation can be prevented in two ways, first is the addition of an emulsifier which acts by lowering the surface tension of two (or) more substances and second is the addition of a co-solvent that act as a bridging agent through molecular compatibility and bonding to produce a homogeneous blend [3].
- Diesel and ethanol fuels can be efficiently emulsified into a heterogeneous mixture of one micro-particle liquid phase dispersed into another liquid phase by mechanical with suitable emulsifier. The emulsifier would reduce the interfacial tension and increase the attaining b/w the two liquid phases leading to emulsion stability [4].

LITERATURE SURVEY
Alan *et al.*, [4] investigated the effects of ethanol-diesel fuel blends on the performance and exhaust emissions of six cylinder, turbocharged heavy duty, direct injection Mercedes-Benz engine. They observed that the ethanol addition reduces Smoke Density, Oxides of Nitrogen (NOx), Carbon Monoxide (CO), but increases Hydrocarbon (HC), it was also found that little higher specific fuel consumption and slight increase of brake thermal efficiency with increasing percentage of the ethanol in the blends.

De-gang *et al.*, [6] the experiments were conducted on a water-cooled single cylinder DI diesel engine using neat diesel fuel. E5 D, E10 D, E20 D, Ethanol - diesel blended fuels. They are indicated that the brake thermal efficiency increased and brake specific fuel consumption increased with an increase of ethanol contents in the blended fuel at overall operating conditions, also found that NOx emissions reduced, HC increased for ethanol-diesel when compared to neat diesel. Ajav *et al.*, [7] an experimental study was carried out to test the performance of a constant speed stationary diesel engine using ethanol-diesel blend, the content of ethanol is 5, 10, 15, and 20% by volume. They reported that the

VOL. 7, NO. 11, NOVEMBER 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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exhaust gas temperature, exhaust emissions (CO and NOx) were lower with operations on ethanol-diesel blend.

Caro *et al*., [8] injection improver and other additives are required to improve the durability and ignition of diesel engines when ethanol blended diesel fuels are used. Bang *et al*., [9] the addition of ethanol to diesel fuel simultaneously decreases cetane number, high heating, aromatic fractions and kinematic viscosity of ethanol blended diesel fuel, with the aid of additive and ignition improver the blends reduce smoke, CO and NOx.

Jincheng *et al*., [10] studied the performance and emissions of a diesel engine using ethanol-diesel blends. They found that the thermal efficiency increased with some increases of fuel consumption they also showed that reduced smoke emissions, CO emissions and increase HC emissions with the blends comparing with neat diesel fuel. Ozer Can *et al*., [11] investigated the effects of ethanol addition on performance and emission characteristics of a turbocharged indirect injection diesel engine running at different injection pressure. They found that the addition of ethanol reduces carbon monoxide, Sulphur dioxide (SO_2), and increases of oxides of nitrogen emissions.

EXPERIMENTAL SETUP AND PROCEDURE

In the present investigation the performance combustion and emission characteristics of single cylinder four stroke water cooled direct injection compression ignition diesel engine were studied by using 10% Tween 80 (Surfactant) was added to the ethanol-diesel blend fuels to prevent phase separation of ethanol from diesel and compared with that of neat diesel fuel.

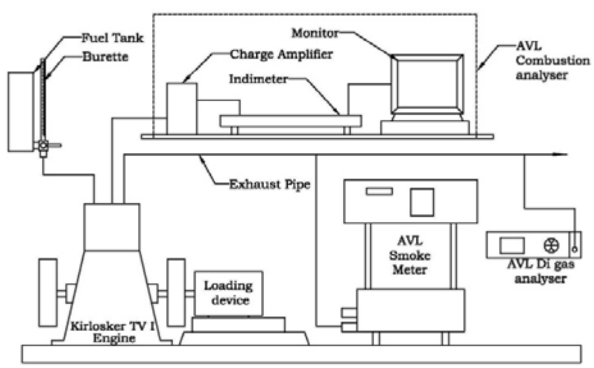

Figure-1. Experimental setup.

Experiments were conducted on a computerized, 5.2 kW, single cylinder vertical naturally aspirated four stroke, water cooled, open chamber (Direct injection) constant speed (1500 rpm), Kirloskar TVI diesel engine Figure-1 shows the schematic experimental setup and eddy current dynamometer was used for loading the engine. The fuel flow rate is measured on the volumetric basis using a burette and stop watch arrangements. The engine exhaust gas temperature was obtained using Chromel-alumel (K type) thermocouples. An AVL 444 die gas analyzer was used to measure the NOx (ppm), CO (% by volume) CO2 (% by volume) and HC (ppm) emissions in the exhaust gas. The smoke density was measured by an AVL 413 Smoke meter. The combustion chamber pressure was measured by a sensitivity of 16.11 pc/bar water cooled Piezo electric pressure transducer mounted on the engine cylinder head. The engine was started on neat diesel fuel and allowed to warm up for about 30 min, to attain a normal working temperature. Initially engine test were performed using diesel fuel and the results were recorded.

The above procedure is also repeated at the same operating conditions for all the blends. Steady state performance, combustion and emission readings were taken for three times, when the engine was operated at constant speed (1500 rpm) and the average of the measured data was used for further calculation. The specifications of the engine are given in Table-1.

Table-1. Specification of the engine.

Type	**Vertical, water cooled, four stroke**
Number of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Maximum power	5.2 kw
Compression ratio	17.5:1
Speed	1500 rev/min
Dynamometer	Eddy current
Injection timing	23^0 before TDC
Injection pressure	220 kgf/cm^2

In this study, four kinds of fuels were prepared, such as neat diesel as the base line fuel 10% Tween 80 (surfactant) blending with 80% Diesel and 10% ethanol (identified as D80 E10), 10% Tween 80 blending with 70% diesel and 20% ethanol (D70 E20), 10% Tween 80 blending with 60% diesel and 30% ethanol (D60 E30) 10% Tween 80 blending with 50% diesel and 40% ethanol (D50 E40) Physico-Chemical properties of diesel, ethanol and emulsified fuels (D50 E40) are listed in Table-2.

Table-2. Physico-chemical properties.

Properties	**Diesel**	**Ethanol**	**(D50E40)**
Densityat 15°C (gm/cc)	0.8289	0.789	0.8314
Sp. Gravity at 15°C	0.81	0.796	0.8349
Kinematic viscosity (CSst) at 40°C	4	1.20	3.08
Flash Point °C	74	13	14
Cetane number	45	5-8	47
Calorific value kJ/kg	44600	26600	39450

VOL. 7, NO. 11, NOVEMBER 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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RESULTS AND DISCUSSIONS

Figure-2 Illustrate the variation of specific fuel consumption (SFC) with brake power of the engine using emulsified fuel and neat diesel. It is observed that the brake specific fuel consumption is found to decrease with increase in load. The specific fuel consumption in the case of emulsified fuel was lower as compared to neat diesel.

Among the blends B80 E10 concentration shows the minimum specific fuel consumption than other blends and neat diesel. The minimum SFC is observed as on 28 kg/kW-hr for the D80 E10 blend whereas for neat diesel it was 0.296 kg/kW-hr at full load of the engine. This may be due to better combustion and an increase in the energy content of the blend. This is also due to high specific gravity and lower calorific value of the blended fuel as compared with diesel fuel.

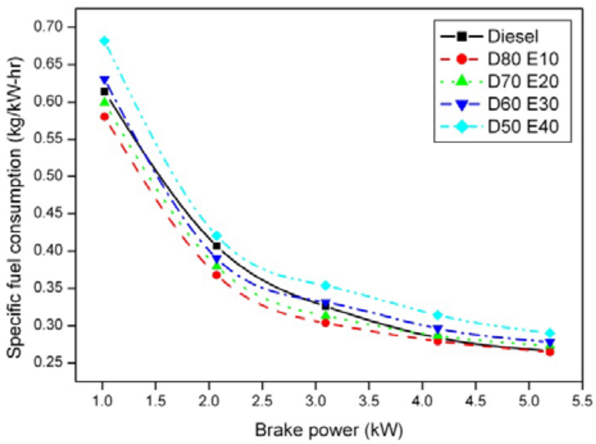

Figure-2. Specific fuel consumption against brake power.

Figure-3 depicts the variation of brake thermal efficiency with brake power of the engine for neat diesel and diesel-ethanol-surfactant blends. It can be seen that in the beginning with increasing brake power of the engine the brake thermal efficiency of various concentration of blends and neat diesel were increased. From the test results, D80 E10 blends have yielded higher brake thermal efficiency than other blends and neat diesel at full load condition. The maximum thermal efficiency is observed as 35.8% for the D80 E10 blend at full load whereas it is 29.8% for neat diesel.

This is due to the increase in cylinder pressure and low heat rejection that increase the brake thermal efficiency. It may also be due to improved atomization fuel vaporization, better spray characteristics and improved combustion through mixture.

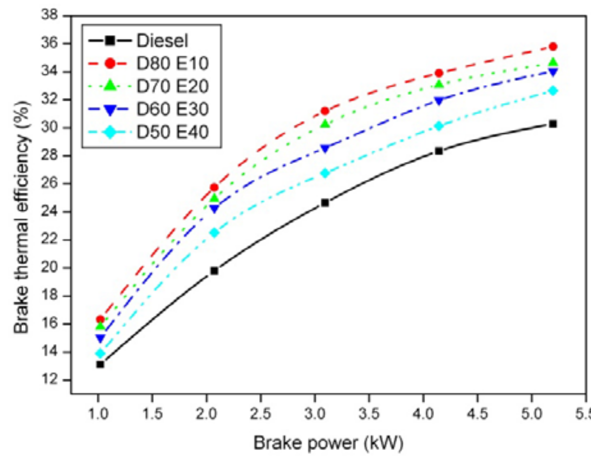

Figure-3. Brake thermal efficiency against brake power.

The variation of oxides of nitrogen with brake power of the engine is shown in Figure-4. It can be observed that oxide of nitrogen emission increases with addition of ethanol in the blends

Also seen that the NOx emission behavior for all the blends was found to be decreased at lower load with a marginally increase at higher load. The NOx emission is higher for the D50 E40 blends, when comparing to all the fuel blends and neat diesel. The higher NOx emission is recorded as 720 ppm for D50 E40 blend, where as for neat diesel, it was 510 ppm at the full load of the engine. Due to the ethanol addition results in faster premixed combustion is the cause for higher combustion temperature which results in higher NOx form De-gang Li *et al*., [6] found that same observation.

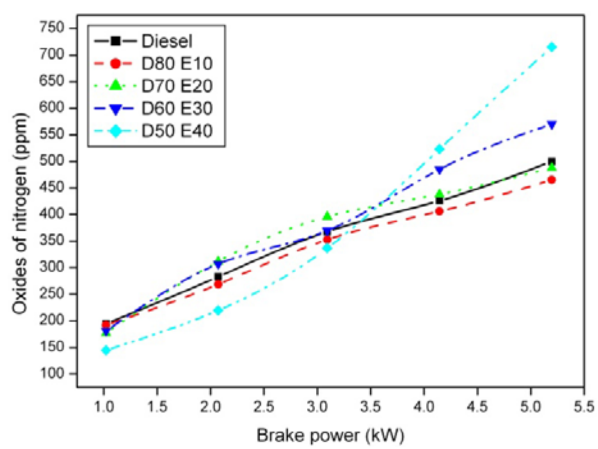

Figure-4. Oxides of nitrogen against brake power.

Figure-5 represents the variation of hydrocarbon with brake power of the engine for neat diesel and various concentrations of blended fuels. Among the blends the D50 E40 shows higher hydrocarbon emission than other blends and neat diesel. This is due to the fact that cetane number of blended fuel is higher than that of neat diesel fuel and also reasons that higher heat of evaporation, ethanol that caused slower evaporating it leads to increase the hydrocarbon emission.

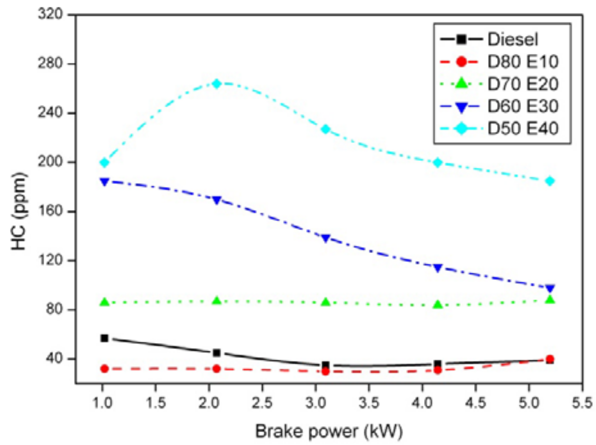

Figure-5. Hydrocarbon against brake power.

The variation of smoke emission in different loads for neat diesel and diesel-ethanol blends is shown in Figure-6. It was also observed that smoke opacity values decreased as the percentage of ethanol in the fuel increased. The smoke density is lower for the blend D50 E40 compared to other concentration of blended fuel and neat diesel.

The minimum smoke density is observed as 38.2 HSU for the D50 E40 blend at maximum brake power of the engine. It may be due to the oxygen content in the fuel increase there would be complete combustion high combustion temperature and therefore the smoke content in the exhaust is reduced.

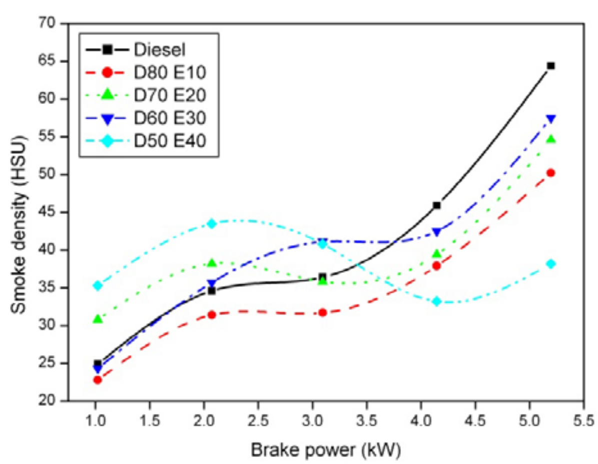

Figure-6. Smoke density against brake power.

The variation of cylinder pressure with crank angle is shown in Figure-7. It is found that D50 E40 concentrations provide higher cylinder pressure compared to that of neat diesel and other blended fuels. The maximum cylinder pressure is observed as 76 bar for D50 E40 blneds, at maximum brake power of the engine. This trend may be attributed to higher cetane number, increase in ignition delay and better vaporization of blended fuel.

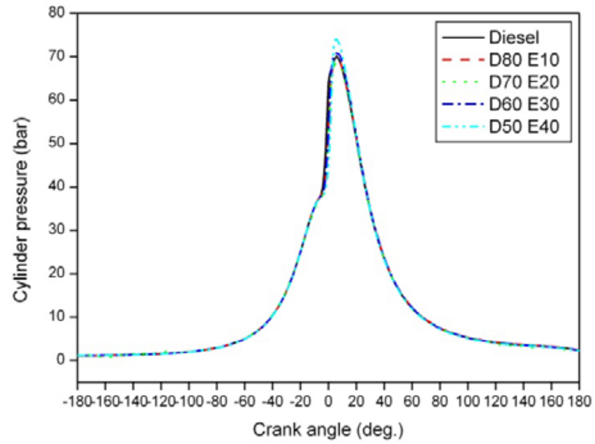

Figure-7. Cylinder pressure against crank angle.

Figure-8 shows the variation of heat release rate with crank angle for neat diesel and blended fuel. The heat release rates are higher for D50 E40 blend than neat diesel and other blends. The higher heat release rate is observed as 152 kJ/m^{3}deg for D50 E40 blend whereas for neat diesel it was 124.3 kJ/m^{3}deg at maximum brake power of the engine. This attributed to decreases its viscosity higher cetane number and improves its volatility which leads to better atomization, the ignition delay period increases and hence a higher heat release is produced.

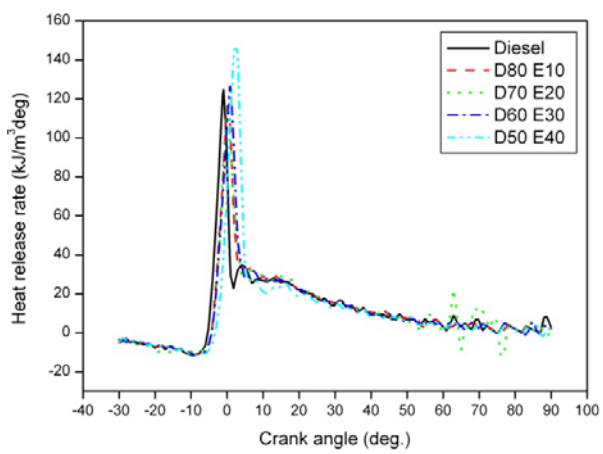

Figure-8. Heat release rate against crank angle.

CONCLUSIONS

The performance, combustion and emission characteristics of diesel and emulsified fuel (Diesel-ethanol - Tween 80) were investigated on single cylinder four stroke naturally aspirated water cooled direct injection diesel engine. The conclusions of this investigating at are also follows.

- The specific fuel consumption of 0.28 kg/kW-hr was observed with the blend D80 E10 the SFC is lower for above blend than that of other blends and neat diesel.
- The maximum brake thermal of 35.8% was observed with the blend D80 E10 as compared to neat diesel and other blend at maximum brake power of the engine.
- The HC emissions increased with the increase of ethanol percentage in diesel-ethanol-surfactant blends. The blend D50 E40 was slightly higher than that of diesel fuel.
- The NOx emission of the blend D50 E40 was higher, when comparing to other blends and neat diesel.
- The smoke density emissions of the blend D50 E40 was lower than that of diesel fuel.
- In the combustion analysis, the maximum cylinder pressure and higher heat release rate occurred for D50 E40 blends with a value of 76 bar and 152 kJ/m^3deg with crank angle.

The experimental investigations concluded that D50 E40 blend can be effectively used as an alternative fur for DI diesel engine.

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