Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2015, 7(2):332-339

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Improving the performance and emission parameters of a single cylinder spark ignition engine with Ethanol-Gasoline blends

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ABSTRACT

Environmental pollution through emissions from internal combustion engine leads to greater global impact. Usage of alcohols and its blends with gasoline in spark ignition engine has contributed to a large extent in improving the engine's exhaust emission. This article deals with the experimental investigation of using gasoline-ethanol blends in a four stroke single cylinder overhead cam spark ignition engine for performance and emission characteristics. The performance parameters like brake specific energy consumption, brake thermal efficiency, mechanical efficiency and emission parameters like unburned hydrocarbons, carbon-monoxide and oxides of nitrogen were analyzed in detail. The BSEC was found to decrease with increase in ethanol blends at all loads where as BTE and mechanical efficiency showed a significant increase with addition of ethanol blends. The UBHC and CO emission was noticed to be higher initially during starting and found to decrease with addition of ethanol. NO_x emission showed an increasing trend for the entire load condition with increase in ethanol blends.

Keywords: Ethanol, Performance, emission, Brake thermal efficiency, Carbon-monoxide

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INTRODUCTION

As a result of continuously increasing population and tremendous change in human's lifestyle, the transportation and industrial sector has witnessed a progressive change. Due to this, the petroleum derivatives have been found to deplete at a rate faster than expected. The adverse effect of greenhouse gases on the earth's atmosphere is an increasing threat to the life on the planet. Also the reduction in the layers of petroleum derivatives from the earth surface forces us to find a suitable alternate fuel. Continuous research is being done to find the best alternatives and some of the fuels with satisfactory results are natural gas, hydrogen, alcohols, vegetable oils, bio fuels and nuclear fuels. The alcohols like methanol, ethanol and Butanol have identified a prominent place in the fuels of transportation sector [2]. Due to better thermal efficiency and higher octane number, ethanol has found a suitable berth as an automobile fuel. Ethanol contains oxygen, which contributes during the combustion process and thereby results in lesser or cleaner emissions from the engine [6]. It is estimated that the global ethanol production was around 91.562 billion liters in 2013-14, which was mainly through fermentation process of starch and molasses. Experimental investigation of ethanol-gasoline blends with oxygenated additives were performed in a two state process. The blending was carried out using gasoline, ethanol, cyclooctanol and cycloheptanol at various ratios [8, 18]. The performance and emission tests on a multicylinder spark ignition engine resulted in a significant increase in brake thermal efficiency. The emission analysis revealed a significant increase in CO and HC with a notable decrease in NO_x and CO_2.Masum et al. [5] has discussed the use of gasoline ethanol blend in a SI engine mainly to reduce NO_x emission. The primary analysis revealed the physio-chemical properties of gasoline-ethanol blend and a mathematical model approach involving the variation in engine parameters and fuel properties on NO_x formation.

Hakan [10] studied the comparison of experimental and theoretical investigation of ethanol-gasoline blends in SI engine in a quasi-dimensional SI engine cycle model. The blending ratios were between 1.5 to 12 volume percentage of ethanol and with mathematical model, upto 21 volume percentage of ethanol. It was concluded that that the experiment with 7.5% of ethanol was optimal blend ratio on analyzing the engine performance and emissions, but the mathematical model revealed 16.5% ethanol proved to be an optimal blend ratio, which required further enhanced studies. A four stroke multi-cylinder Toyota Tercel 3A engine was used to analyze the performance and emission characteristics of unleaded gasoline and ethanol blend by Al-Hasan [3]. The performance parameters include brake thermal efficiency, volumetric efficiency, brake specific fuel consumption, equivalence A/F ratio and brake power. The parameters were analyzed with variation in ethanol blend ratios. The results showed the performance parameters were better with notable decrease in BSFC and equivalence A/F ratio. It was also identified that CO and HC emissions decreased with a marginal increase in CO_2, when 20% ethanol-gasoline blend ratio was used. Simona et al. [23] investigated the effect of Butanol-Gasoline blend on the combustion process in a SI engine. The blending ratios were 20 and 40 percentage and testing was carried out for low, part and full load conditions. It was observed that on advancing the spark timing, Butanol blend showed reduced knocking. Gasohol (Gasoline with alcohol) blends were investigated in four-stroke multicylinder MPFI engine, due to its higher octane number. The gasohol blends were containing 5-15% ethanol. The performance and emission parameters were recorded and found that there was a marginal increase in BHP, BTE and BSFC with a little reduction in CO, HC and NO_x[13].

Nomenclature

BSFC	Brake Specific Fuel Consumption
MPFI	Multi Point Fuel Injection
BHP	Brake Horse Power
BTE	Brake Thermal Efficiency
OHC	Over Head Cam
LHV	Lower Heating Value
E0	Gasoline
E5	95% Gasoline and 5% Ethanol
E10	90% Gasoline and 10% Ethanol
E15	85% Gasoline and 15% Ethanol
E20	80% Gasoline and 20% Ethanol
BSEC	Brake Specific Energy Consumption
UBHC	Unburned Hydrocarbons
NO_x	Oxides of Nitrogen
CO	Carbon Monoxide
CO_2	Carbon Dioxide

The present study aims at analyzing the effect of gasoline ethanol blends at 5, 10, 15 and 20% ethanol blend by volume in a TVS Victor OHC engine and the load was applied using D/C generator dynamometer. The physiochemical properties of gasoline, ethanol and its blends were found to be within the usable standards. The performance and emission parameters were analyzed in detail.

EXPERIMENTAL SECTION

Table (1) shows the comparison of physiochemical properties of gasoline and ethanol. The molecular weight of gasoline lies between 102-111 kg/kmol, whereas ethanol exhibited 46.17 kg/kmol. Density of ethanol was found to be 794 kg/m^3, which was 10-12% higher than gasoline. The octane number of ethanol was found to be very much higher. The lower heating value of ethanol was noticed to be 27.8 MJ/kg, whereas gasoline showed 45.4 MJ/kg which makes ethanol blend more suitable for spark ignition engine. The specific heat and the heat of vaporization of ethanol was found to be 1.8 KJ/kgK and 847 KJ/kg respectively. Blending of ethanol and gasoline was carried out at four different ratios. The density of blended fuel increases gradually with the increase in ethanol blends, whereas the gross calorific value gradually decreases with the increase in ethanol blend as shown in Table (2). The flash point and fire point were also found to be gradually increasing with increasing quantities of ethanol [20-22].

Table 1. Properties of Gasoline and Ethanol

Properties	Gasoline	Ethanol
Formula (liquid)	C_8H_{18}	C_2H_5OH
Molecular weight (kg/kmol)	102-111	46.17
Density (kg/m^3)	710-745	794
Octane number	90-97	107
LHV (MJ/kg)	44.5	27.8
Stoichiometric air/fuel ratio	15.12	9.1
Specific heat (kJ/kgK)	2.5	1.8
Heat of vaporization (kJ/kg)	313	847
Enthalpy of formation MJ/kmol	-253.24	-234.10

Table 2. Comparative Properties of different Ethanol blends

Parameters	E5	E10	E15	E20
Density @ 15^{o}C (gm/cm^3)	0.7521	0.7582	0.7618	0.7649
Kinematic viscosity @ 40^{o}C (cst)	1.21	1.23	1.25	1.25
Gross calorific value (Kcals/kg)	8486	8426	8392	8327
Flash point (^{o}C)	48.4	48.6	49.1	49.3
Fire point (^{o}C)	53.1	53.3	53.4	53.8
Ash content (%)	0.01	0.01	0.01	0.01
Conradson carbon residue (%)	0.01	0.01	0.01	0.01

A single cylinder four stroke air-cooled OHC TVS VICTOR engine with a cubic capacity of 109.3cc was used in this experimental investigation. The compression ratio of the engine was found to be 9.3:1 with a maximum rated RPM of 5000. The maximum power of the engine was noticed as 8.1 BHP @ 7250 rpm with a maximum torque of 8.1 Nm @ 5500 rpm.

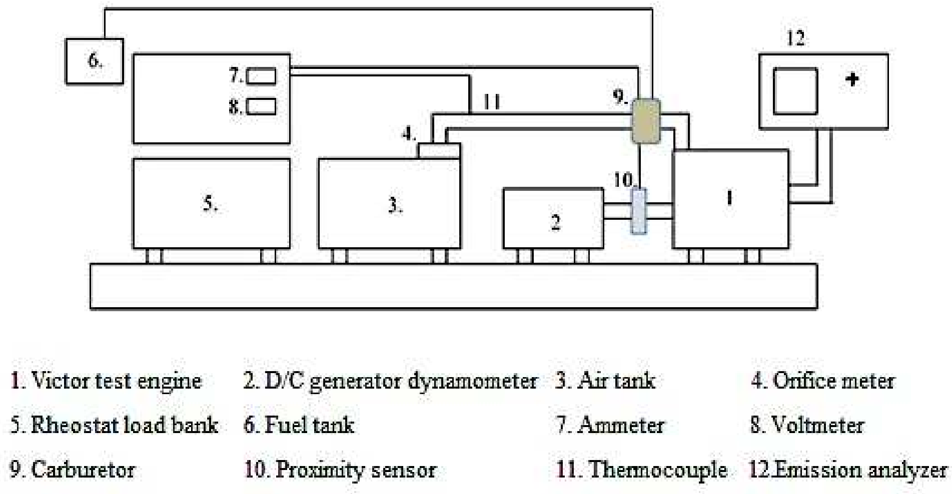

Figure 1. Schematic diagram of experimental Setup

The engine was loaded with a D/C generator dynamometer with a loading capacity of 4 KW@ 3000 rpm. The schematic diagram of the experimental setup and the pictorial view of the test engine is shown in Figure (1) and Figure (2) respectively. The test engine is equipped with a burette-manometer setup to analyze the fuel consumption with the help of a stopwatch. The air intake through the air box filter is measured with the help of orifice meter, before entering the carburetor. A proximity sensor is placed on the dynamometer shaft to measure the speed of the engine. The loading is accomplished with a D/C generator dynamometer coupled to the engine shaft and the output is received through the ammeter and voltmeter arrangement as shown in the Figure (2).

Figure 2. Pictorial view of the engine setup

Table 3. Engine and Dynamometer specifications

Engine model	TVS Victor
Type	4 Stroke air cooled OHC
Cubic capacity	109.3cc
Compression Ratio	9.3:1
Rated speed	1000-5000
Max Power	8.1 bhp@7250rpm
Max Torque	8.1Nm@5500
Bore	51mm
Stroke	53.5mm
Loading Device	D/C generator dynamometer loading with rheostat load bank
Capacity of D/C dynamometer	6KW at 3000 RPM
Rheostat load bank capacity	AMP = 30 A, VOLT = 230

RESULTS AND DISCUSSION

Variation of Performance Parameters

The effect of ethanol and gasoline blends with respect to performance parameters like brake specific energy consumption, brake thermal efficiency and mechanical efficiency are discussed below.

Figure (3) shows the variation of BSEC with brake mean effective pressure for gasoline, E5, E10, E15 and E20 blend. From Figure (3), it was noticed that the BSEC for all blends showed a decreasing trend with increase in load. At low load condition, the BSEC of gasoline was found to be 12.1 MJ/KWh and E5, E10, E15 and E20blend showed 11.69 MJ/KWh. 11.12 MJ/KWh, 10.64 MJ/KWh and 9.24 MJ/KWh respectively. At part load conditions, E20 blend showed a gradual decrease in BSEC of 6.17 MJ/KWh, which was 22% lower than low load conditions. At full load operations the BSEC was found to be very minimal which varies between 3.71 MJ/KWh for E20 blend and 4.55 MJ/KWh for E5 blend. During this period, gasoline showed 4.667 MJ/KWh of brake specific energy consumption, which may be due to consistent increase in octane number and decrease in heat of combustion value with the increase in ethanol gasoline blends [1,10-12].

The variation in BTE and BMEP with gasoline and blends of ethanol is shown in Figure (4). Generally the BTE curve shows an increasing trend as the load increases. Gasoline exhibits 7.57% to 18.27% of brake thermal efficiency from low load to full load operation, whereas the higher blend of ethanol (E20) exhibits 11.21% to 21.28% of BTE.

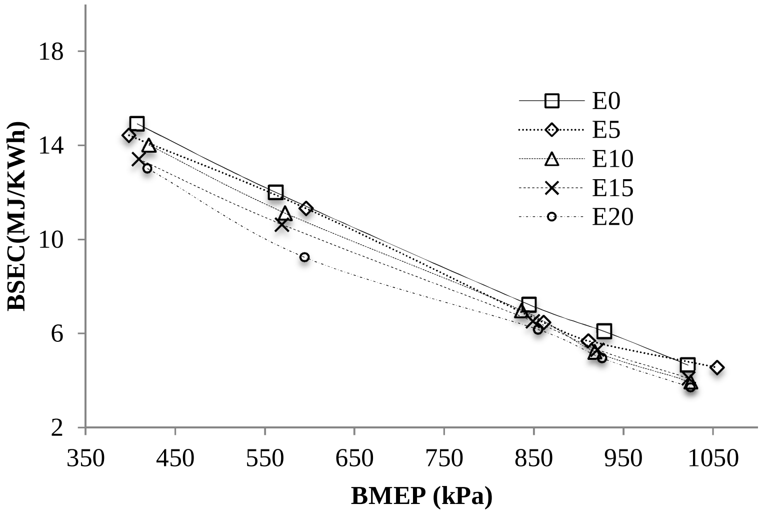

Figure 3. Variation in Brake Specific Energy Consumption and Brake mean effective pressure

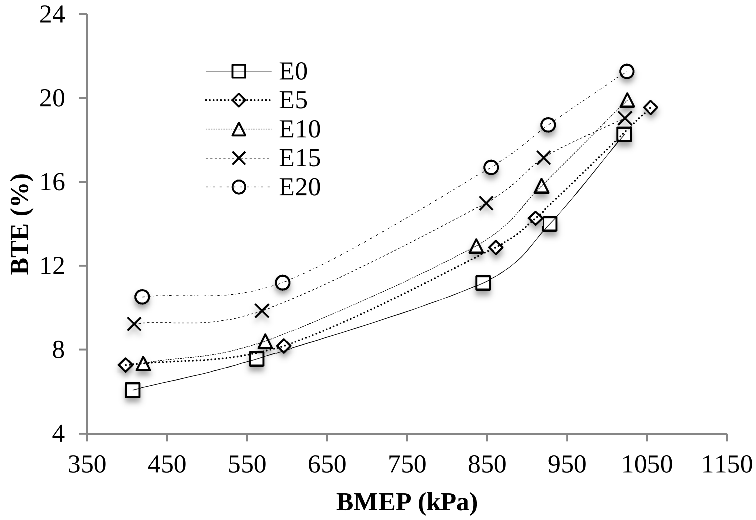

Figure 4. Variation in Brake Thermal Efficiency and Brake mean effective pressure

At low load conditions, E5, E10, E15 and E20 gasoline-ethanol blend shows 8.19%, 8.42%, 9.87% and 11.22% of BTE respectively. At part load conditions, there was a significant variation in brake thermal efficiency between gasoline and blends of ethanol, where E20 blend exhibited 16.71% efficiency. At full load operations, gasoline showed 18.27% of BTE and E20 blend showed a highest of 21.28% of BTE. This increasing trend of brake thermal efficiency may be due to increase in heat of vaporization with the increase in ethanol blends [14,15].

The Figure (5) shows the variation of mechanical efficiency at low load, part load and full load conditions for gasoline, E5, E10, E15 and E20 blends. From the figure (5) it was noticed that the mechanical efficiency continuously increases with load across all blends of fuel, which may be due to reduction in frictional losses between moving parts. At low load conditions, the mechanical efficiency of gasoline was found to be 24.01%, whereas E5, E10, E15 and E20 showed 26.43%, 27.74%, 29.78% and 32.34% respectively. At part load operations, the mechanical efficiency varied between 38% and 45% as the ethanol blend was increased. At full load conditions E20 blend exhibited a maximum mechanical efficiency of 58.18%, whereas gasoline showed 51.61%. This considerable increase in mechanical efficiency may also be due to conversion of waste heat into useful work and increase in the octane value [4,7].

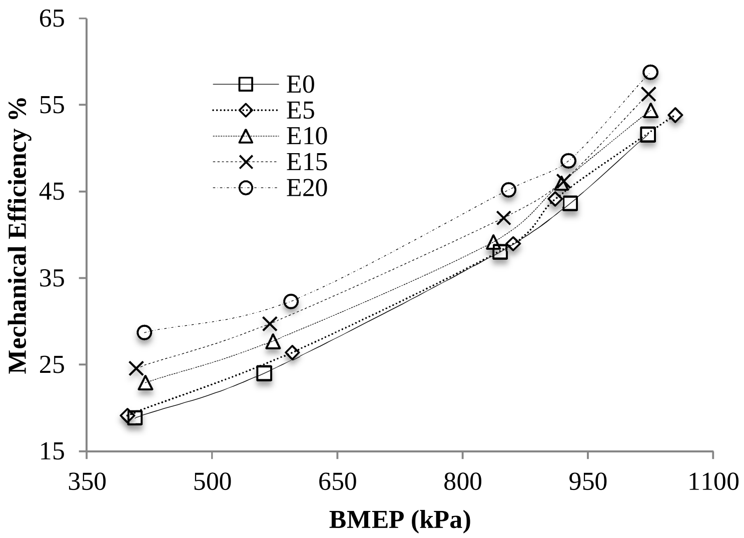

Figure 5. Variation in Mechanical Efficiency and Brake mean effective pressure

Variation of emission parameters

The formation of UBHC mainly depends on lack of oxygen contribution during the combustion process. The Figure (6) exhibits the variation of UBHC emission with gasoline and various blends of ethanol at low load, part load and full load operations. From the Figure (6), it is evident that during starting conditions, UBHC emissions were found to be very much higher up to 84 ppm for gasoline, due to reduce in-cylinder temperature. E5, E10, E15 and E20 blends exhibited 82 ppm, 81 ppm, 79 ppm and 78 ppm of hydrocarbon emissions. This decreasing trend of hydrocarbon emission during low load conditions was due to the presence of oxygen in the fuel blends [3,4].

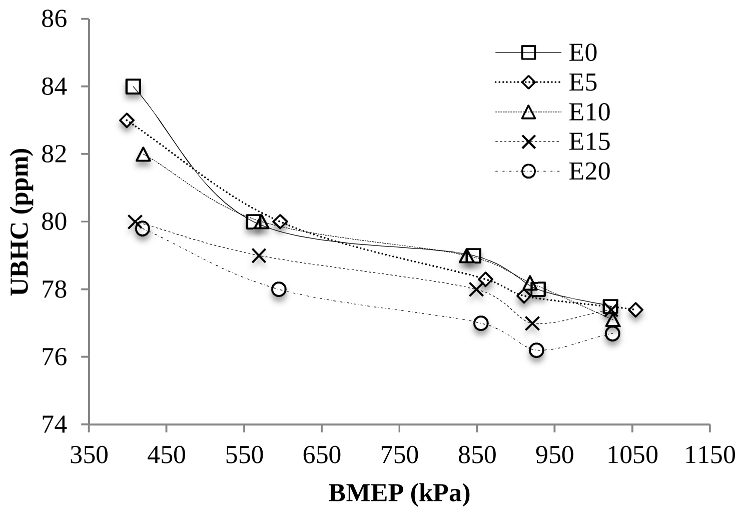

Figure 6. Variation in Unburned Hydrocarbon and Brake mean effective pressure

As the load is increased, the UBHC emissions of all the blends was seen to reduce gradually, which may be due to reduced flame quenching effect in the cylinder wall and increased combustion efficiency. At full load conditions, the variation of UBHC emission between gasoline and ethanol blends showed minimal variation, i.e. 77.5 ppm for gasoline, 77.4 ppm for E5, 77.1 ppm for E10, 77 ppm for E15 and 76.7 ppm for E20 blend which may be due to availability of surplus oxygen in ethanol blends [15-19].

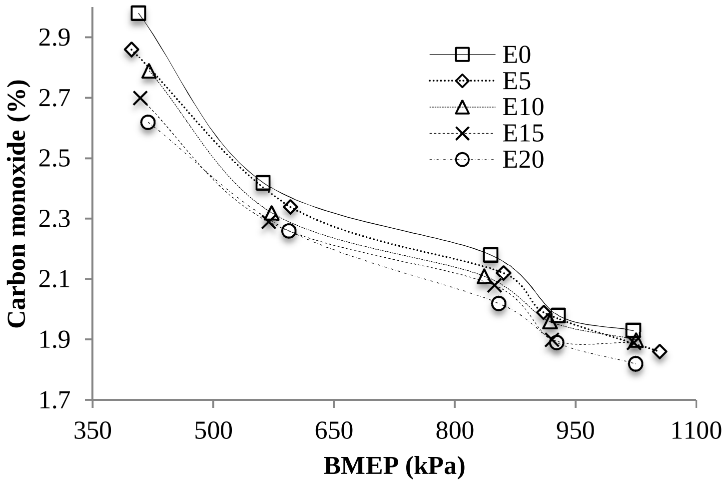

Figure 7. Variation in Carbon Monoxide and Brake mean effective pressure

The variation in carbon monoxide emission with gasoline and ethanol blends at low load, part load and full load is shown in Figure (7). It can be noticed that the carbon monoxide emissions shows a decreasing trend with increase in load. During initial conditions, carbon monoxide emission was found to be 2.42% for gasoline, 2.34% for E5, 2.32% for E10, 2.29% for E15 and 2.26% for E20, which may be due to unavailability of monoatomic oxygen, which combines with carbon monoxide, and thereby carbon dioxide emission increases [9]. At full load conditions, the carbon monoxide emissions were found to be varying between 1.92% and 1.83% for blends of gasoline and ethanol as shown in Figure (7).

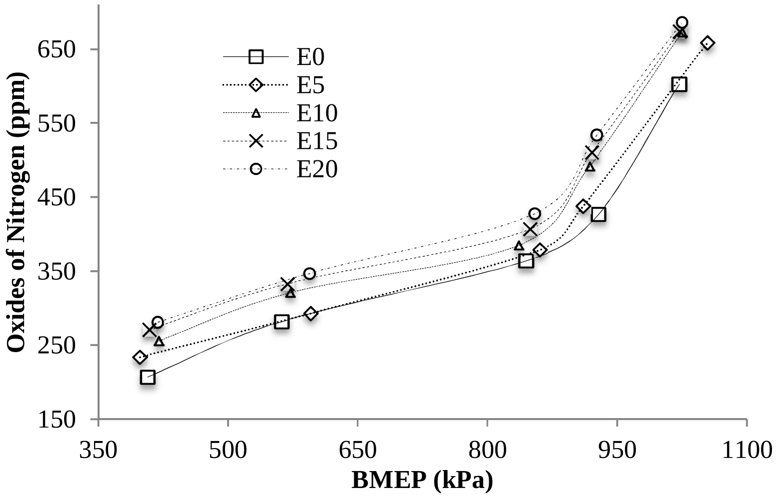

Figure 8. Variation in Oxides of Nitrogen and Brake mean effective pressure

From the Figure (8), the variation of oxides of nitrogen emission with gasoline, E5, E10, E15 and E20 blends are shown with respect brake mean effective pressure for low load, part load and full load. Generally NO_x emission shows an increasing trend for the entire operation. At low load conditions, NO_x emission for E0, E5, E10, E15 and E20 was found to be 282 ppm, 293 ppm, 321 ppm, 333 ppm and 347 ppm respectively. As the load is increased, NO_x emission is found to increase and vary between 364 ppm and 428 ppm for gasoline and blends of ethanol. During full load conditions, NO_x emissions were found to increase rapidly due to higher in-cylinder temperature where diatomic oxygen atom disintegrates into monoatomic oxygen and combines with inert nitrogen [5,24]. At this operation, the NO_x emission was found to be 603 ppm for gasoline, 659 ppm for E5, 673 ppm for E10, 678 ppm for E15 and 686 ppm for E20 as shown in the Figure (8).

CONCLUSION

The feasibility of ethanol-gasoline blends on improved performance and reduced emission characteristics on a single cylinder spark ignition engine was investigated thoroughly in this study and following conclusions were arrived,

- ❖ The physio-chemical property of ethanol was found to be very much suited for its use in spark ignition engine. With the increase in percentage of ethanol in the blends, density and kinematic viscosity was found to increase marginally. The calorific value of ethanol blend was found to vary between 0.5% and 0.8% throughout its blend. The flash and fire point was noticed to be almost similar for the entire blends of ethanol.
- ❖ The BSEC was found to decrease from 15.5 MJ/kWhr to 13.8 MJ/kWhr when ethanol blends were increased at low load condition and it also exhibited a decreasing trend for the entire operating condition.
- ❖ The BTE was found to increase with addition of ethanol blends which showed 21% at full load condition for E20 blend. The mechanical efficiency also showed a similar trend of BTE which consistently increased by 6% to 7% with increase in ethanol blends.
- ❖ The UBHC and CO emissions were found to decrease by 6% and 11% respectively and NO_x increased marginally at full load condition.

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