# Studies on Emission Control in S.I. Engine Using Organic Fuel Additives

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***Abstract:*** **Alternative fuels provide huge rural employment, and reduce the dependency on fossil fuels, which are renewable, eco-friendly and help to preserve the atmosphere. The gaseous forms of alternative fuels are LPG, CNG, $H_2$, biogas and producer gas. The solid fuels are not used in IC engines due to their handling and storage difficulties. This paper aims to reduce the exhaust emissions from spark ignited engines by in-cylinder treatment. Two organic fuel additives, namely substituted formamide (Addt.-I) and substituted ketone with six carbon atoms (Addt.-II) were used in this work. The various percentages of concentration of additives i.e. 0.5%, 1.0%, 1.5%, 2.0% by volume were used in both additives. The experimental work was carried out in a 197CC, single cylinder, four stroke petrol engine of GENSET-HONDA. Carbon monoxide (CO), hydrocarbon (HC) and oxides of nitrogen (NOx) in the exhaust gas have been measured using "KANE" make exhaust gas analyzer. The experimental results show that an appreciable amount of reduction in CO and HC were obtained for all the concentrations of additive-I and additive-II. But in case of NOx emission, additive-I shown an adverse effect and incase of additive-II, during higher loads for additive concentrations of 1.0% & 2.0% by volume, the NOx level was marginally increased compared to neat gasoline.**

***Keywords:*** **Gasoline Engine, Fuel additives, In-cylinder treatment, Emission Control.**

## I. INTRODUCTION

In recent years, the major source of environmental pollution contributes by automobile exhaust emissions. The rise in civilization is closely related to improvements in transportation. Apart from other pollutants like industrial waste, electric power generating stations which mainly emit sulphur oxides, the main pollutants from automobile exhaust are carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NOx), Carbon dioxide (CO2), aldehydes, particulate, sulphur and lead. Air pollutants emitted by motor vehicles have a number of adverse effects on human health. Inhalation is the main route of air polluting originating from motor vehicle emissions. Other exposure routes-drinking water contamination, food contamination and absorption through skin are also possible. Exposure by inhalation directly affects respiratory, nervous and cardiovascular system of humans resulting in impaired pulmonary functions, sickness and even death. Addition of MTBE and ETBE to fuels can improve combustion and leads to decreased toxicity and BTEX content of the exhaust. Reduction of mutagenicity in the PM-extracts is most probably caused by a lower content of polycyclic aromatic hydrocarbons (Westphal et al. 2010). The addition of oxygenates such as ethanol, ETBE and MTBE and non oxygenates such as isooctane and toluene on the Reid vapor pressure (RVP) and octane number of two types

of gasoline with different chemical compositions. Locally produced gasoline was blended with five different percentages (v/v) of the additives, i.e. 5, 10, 15, 20 and

25%. Ethanol and MTBE increased significantly the RVP of the mixtures, but ETBE, and particularly toluene and isooctane, decreased the RVP of the original fractions when mixed with gasoline (Silva et al. 2005). Siwale et al. (2014) compared the effects of dual alcohols (n-butanol and methanol) with single alcohol (methanol) blended in gasoline fuel (GF) against performance, combustion and emission characteristics. The experiments were conducted on a naturally-aspirated, spark ignition engine. The brake thermal efficiency (BTE) improved whereas the exhaust gas temperature (EGT) of the blends reduced, which is a benefit that reduces compression work. The blend M53b17 was recommended in preference to M70 because the former had shortened combustion duration, high-energy content and its VP was selectively matched to that of GF's. The addition of renewable fuels, such as ethanol (EtOH) or ethyl tert-butyl ether (ETBE), to standard gasoline, may be necessary to comply with some environmental directives but could also prevent compliance with some fuel regulations and could also seriously change engine performance (Roddrguez-Anton et al.2013).

## II. POLLUTANT FORMATION IN S.I ENGINES

There are four possible sources of atmospheric pollution from a gasoline powered vehicle ie. fuel tank, carburetor, the crankcase and exhaust pipe. The complete combustion of hydrocarbon fuel is characterized by the chemical reaction

$$C_nH_m + \text{Oxygen} \longrightarrow nCO_2 + (M/2)\, H_2O$$

The products of complete combustion are carbon monoxide, water vapour and also nitrogen which is present in air (Heywood 1988). But by the nature of combustion process itself and other physical factors, combustion is never complete and carbon monoxide and hydrocarbons appear in the exhaust. Mixture strength is one of the factors which is to be considered in the control of emissions. Rich mixtures rises CO and HC and lowers NOx because of air deficiency and low combustion temperature. Also fuel consumption is higher in the case of rich mixtures. Lean mixture results in lower CO and HC as most of the carbon and hydrogen are oxidized and greatest amount of NOx due to higher combustion temperatures and also the availability of oxygen. The concentration of the gases in the exhaust depends on the mode of operation ie. idling, acceleration, cruising and deceleration.

## III. ABOUT ORGANIC ADDITIVES

Additives are compounds or mixtures which are added to gasoline fuel to produce some desirable effect on combustion process as well as engine performance and reduction in emission levels. Fuel additives can improve combustion and knock resistance of gasoline engines. Common additives in commercial fuels are “short-chain, oxygen containing hydrocarbons” such as methyl *tert*-butyl ether (MTBE) and ethyl *tert*-butyl ether (ETBE). Since these additives change the combustion characteristics, this may as well influence toxic effects of the resulting emissions. The most common additive used in gasoline is anti knock additive. The anti knock quality of gasoline is represented by its octane number. Oxygenates are added to gasoline to increase its oxygen content and therefore enhance cleaner combustion in motor vehicles. Combustion of oxygenated gasoline produces lower CO and HC emissions than straight gasoline. NOx emissions however may increase. Oxygenates also have higher blending octane number than most other gasoline components except for aromatic hydrocarbons. Oxygenates however can potentially reduce fuel economy because of the lower volumetric energy content than conventional gasoline. Oxygenates are either alcohol based or ether based. Alcohol based oxygenates include MTBE, ETBE and TAME. The most commonly used oxygenates are MTBE and ethanol. Of the two groups ether based oxygenates are preferred for processing and environment reasons.

## IV. EXPERIMENTAL SET-UP

In this paper, fuel modification method is adopted by adding organic fuel additives with gasoline. The experimental work was carried out in a four stroke HONDA gasoline operated engine (Genset application) with 2kW DUI alternator as shown in Fig.1. The concentration of additive strength with gasoline is 0.5%, 1.0%, 1.5%, and 2% by volume. Two additives substituted formamide (Addt-I) and substituted ketone with six carbon atoms (Addt-II) were tested. The engine was loaded with electrical rheostat assembly along with bulb loads. In the exhaust pipe line, a provision was made to pass the exhaust gas through an exhaust gas analyzer (KANE make) and the CO, HC and NOx are measured.

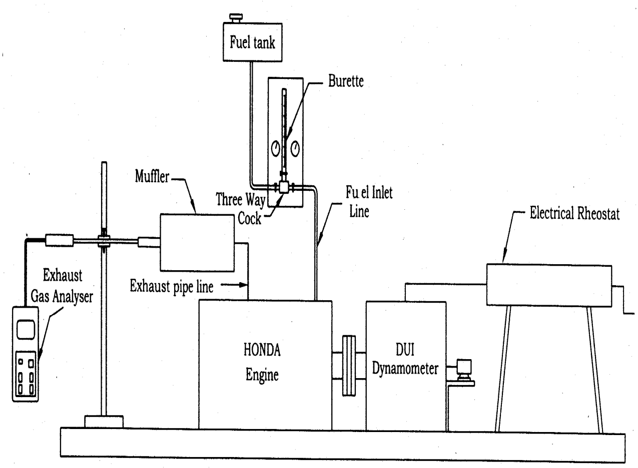


Fig.1 Experimental Set-up

## V. RESULTS AND DISCUSSIONS

From the experimental work and readings, the additive-I (Substituted formamide) which contains organic nitrogen, as expected produce more NOx emission when compared to neat gasoline. This is due to the formation of fuel bound NO during the combustion process. During pyrolysis additive-I gives various free radical according to the following reaction,

O
!!
H-C -<⟶ R,R',H,HCO,NCO,N,NH,CO,etc

The NCO radical can react with NO according to the following reaction and there by reduce at least part of NO formed during combustion.

$NCO + NO \longrightarrow N_2O + CON$ ---- (1)

$N_2O \longrightarrow N_2 + O$ ------ (2)

Since the reaction (2) normally takes place in high temperature region (1100°C), the NO reduction takes place more predominantly at higher load conditions. This may be the reason for comparatively lower emission of NOx during higher loads when additive-I is used. The $N_2O$ produced by reaction (2) may be responsible for the observed CO and HC reductions as it can oxidize (burn) both of them involving the reaction

The additive-II (Substituted ketone) during pyrolysis gives hydroxyl free radicals, because it is an oxygenated additive. These hydroxyl radicals can react with both CO and N radical according to the reactions,

$CO + OH \longrightarrow CO_2 + H$ ----- (1)

$N + OH \longrightarrow NO + H$ ------ (2)

Because of reaction (1) the CO reduction takes place and therefore the CO emissions are less when additive-II is used. Because of reaction (2) more NO is easily formed and hence NO emissions are higher with this additive. The measured and calculated values of CO, HC, NOx and Brake thermal efficiency (B.T.E) are tabulated and respective graphs shows performance characteristics.

Table 1: Measured Parameters for Neat Gasoline

| BP in KW | CO %vol | HC ppm | NOx ppm | λ |
|---|---|---|---|---|
| 0.2 | 2.23 | 80 | 50 | 1.2 |
| 0.6 | 3.33 | 119 | 69 | 1.1 |
| 1.1 | 4.36 | 145 | 103 | 1.1 |
| 1.6 | 6.19 | 206 | 156 | 1.0 |
| 2.1 | 7.74 | 208 | 168 | .94 |

Table 2: Measured parameters for different Additive-I Concentrations

| Additive Concentration (%) | BP in KW | CO %vol | HC ppm | NOx ppm | λ |
|---|---|---|---|---|---|
| 0.5 | 0.2 | 1.85 | 75 | 116 | 1.33 |
| | 0.6 | 2.85 | 108 | 181 | 1.20 |
| | 1.1 | 3.49 | 119 | 192 | 1.14 |
| | 1.6 | 5.75 | 168 | 256 | 1.05 |
| | 2.1 | 6.48 | 150 | 198 | .997 |
| 1.0 | 0.2 | 1.65 | 62 | 185 | 1.25 |
| | 0.6 | 2.5 | 98 | 240 | 1.16 |
| | 1.1 | 3.01 | 112 | 253 | 1.10 |
| | 1.6 | 5.40 | 152 | 313 | 1.04 |
| | 2.1 | 6.05 | 138 | 261 | .992 |
| 1.5 | 0.2 | 1.45 | 51 | 248 | 1.37 |
| | 0.6 | 2.20 | 89 | 300 | 1.22 |
| | 1.1 | 2.70 | 104 | 315 | 1.17 |
| | 1.6 | 5.05 | 138 | 375 | 1.07 |
| | 2.1 | 5.65 | 128 | 320 | .987 |
| 2.0 | 0.2 | 1.24 | 38 | 314 | 1.34 |
| | 0.6 | 1.9 | 80 | 360 | 1.22 |
| | 1.1 | 2.3 | 97 | 378 | 1.16 |
| | 1.6 | 4.75 | 124 | 435 | 1.10 |
| | 2.1 | 5.24 | 118 | 382 | .981 |

Table 3: Measured parameters for different Additive-II Concentrations

| Addt Conc. %vol | B.P KW | Exhaust gas readings | | | |
|---|---|---|---|---|---|
| | | CO %vol | HC ppm | NOx ppm | λ |
| 0.5 | 0.2 | 1.84 | 35 | 31 | 1.485 |
| | 0.6 | 2.99 | 50 | 43 | 1.349 |
| | 1.1 | 4.10 | 79 | 63 | 1.304 |
| | 1.6 | 5.05 | 95 | 112 | 1.297 |
| | 2.1 | 5.45 | 106 | 129 | 1.216 |
| 1.0 | 0.2 | 1.75 | 49 | 40 | 1.379 |
| | 0.6 | 2.8 | 60 | 49 | 1.333 |
| | 1.1 | 3.85 | 84 | 72 | 1.265 |
| | 1.6 | 4.9 | 101 | 126 | 1.085 |
| | 2.1 | 5.23 | 111 | 147 | 1.062 |
| 1.5 | 0.2 | 1.71 | 58 | 34 | 1.562 |
| | 0.6 | 2.62 | 67 | 47 | 1.456 |
| | 1.1 | 3.6 | 86 | 67 | 1.321 |
| | 1.6 | 4.75 | 104 | 116 | 1.181 |
| | 2.1 | 5.05 | 115 | 132 | 1.166 |
| 2.0 | 0.2 | 1.65 | 59 | 28 | 1.500 |
| | 0.6 | 2.5 | 70 | 39 | 1.373 |
| | 1.1 | 3.4 | 86 | 72 | 1.314 |
| | 1.6 | 4.6 | 102 | 135 | 1.197 |
| | 2.1 | 4.85 | 112 | 143 | 1.174 |

Table 4: Calculated values of brake thermalefficiency (B.T.E) for Neat Petrol

| Addt Conc. %vol | B.P kW | FC | FP | BP | B.T.E |
|---|---|---|---|---|---|
| | | Kg/hr | kW | kW | % |
| Neat Petrol | 0.2 | 0.489 | 6.027 | 0.201 | 3.33 |
| | 0.6 | 0.572 | 7.050 | 0.602 | 8.54 |
| | 1.1 | 0.674 | 8.307 | 1.104 | 13.29 |
| | 1.6 | 0.893 | 11.006 | 1.606 | 14.59 |
| | 2.1 | 1.141 | 14.063 | 2.108 | 14.99 |

Table 5: Calculated values of brake thermal efficiency (B.T.E) for Additive – I

| Addt Conc. %vol | B.P kW | FC | FP | BP | B.T.E |
|---|---|---|---|---|---|
| | | Kg/hr | kW | kW | % |
| 0.5 | 0.2 | 0.495 | 6.101 | 0.201 | 3.3 |
| | 0.6 | 0.539 | 6.643 | 0.602 | 9.06 |
| | 1.1 | 0.650 | 8.011 | 1.104 | 13.78 |
| | 1.6 | 0.933 | 11.500 | 1.606 | 13.97 |
| | 2.1 | 1.128 | 13.903 | 2.108 | 15.16 |
| 1.0 | 0.2 | 0.484 | 5.965 | 0.201 | 3.37 |
| | 0.6 | 0.561 | 6.914 | 0.602 | 8.71 |
| | 1.1 | 0.709 | 8.738 | 1.104 | 12.63 |
| | 1.6 | 0.916 | 11.290 | 1.606 | 14.22 |
| | 2.1 | 1.134 | 13.977 | 2.108 | 15.08 |
| 1.5 | 0.2 | 0.493 | 6.076 | 0.201 | 3.3 |
| | 0.6 | 0.545 | 6.717 | 0.602 | 8.96 |
| | 1.1 | 0.626 | 7.715 | 1.104 | 14.31 |
| | 1.6 | 0.879 | 10.834 | 1.606 | 14.82 |
| | 2.1 | 1.109 | 13.668 | 2.108 | 15.42 |
| 2.0 | 0.2 | 0.489 | 6.027 | 0.201 | 3.33 |
| | 0.6 | 0.563 | 6.939 | 0.602 | 8.68 |
| | 1.1 | 0.677 | 8.344 | 1.104 | 13.23 |
| | 1.6 | 0.882 | 10.87 | 1.606 | 14.77 |
| | 2.1 | 1.158 | 13.9 | 2.108 | 15.16 |

Table 6: Calculated values of brake thermal efficiency (B.T.E) for Additive – II

| Addt Conc. %vol | B.P kW | FC | FP | BP | B.T.E |
|---|---|---|---|---|---|
| | | Kg/hr | kW | kW | % |
| 0.5 | 0.2 | 0.502 | 6.187 | 0.201 | 3.25 |
| | 0.6 | 0.572 | 7.050 | 0.602 | 8.54 |
| | 1.1 | 0.668 | 8.233 | 1.104 | 13.41 |
| | 1.6 | 0.892 | 10.994 | 1.606 | 14.61 |
| | 2.1 | 1.103 | 13.594 | 2.108 | 15.5 |
| 1.0 | 0.2 | 0.50 | 6.163 | 0.201 | 3.26 |
| | 0.6 | 0.577 | 7.112 | 0.602 | 8.46 |

| | | | | | |
|---|---|---|---|---|---|
| | 1.1 | 0.687 | 8.467 | 1.104 | 13.04 |
| | 1.6 | 0.908 | 11.191 | 1.606 | 14.35 |
| | 2.1 | 1.075 | 13.249 | 2.108 | 15.91 |
| 1.5 | 0.2 | 0.514 | 6.335 | 0.201 | 3.17 |
| | 0.6 | 0.594 | 7.321 | 0.602 | 8.22 |
| | 1.1 | 0.684 | 8.430 | 1.104 | 13.09 |
| | 1.6 | 0.864 | 10.649 | 1.606 | 15.08 |
| | 2.1 | 1.032 | 12.719 | 2.108 | 16.57 |
| 2.0 | 0.2 | 0.495 | 6.101 | 0.201 | 3.29 |
| | 0.6 | 0.569 | 7.013 | 0.602 | 8.58 |
| | 1.1 | 0.673 | 8.295 | 1.104 | 13.31 |
| | 1.6 | 0.860 | 10.603 | 1.606 | 15.15 |
| | 2.1 | 1.062 | 13.089 | 2.108 | 16.11 |

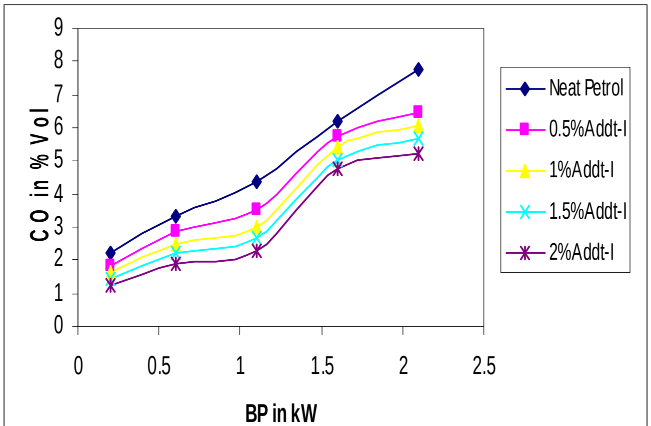

Fig.2:CO Vs Brake Power

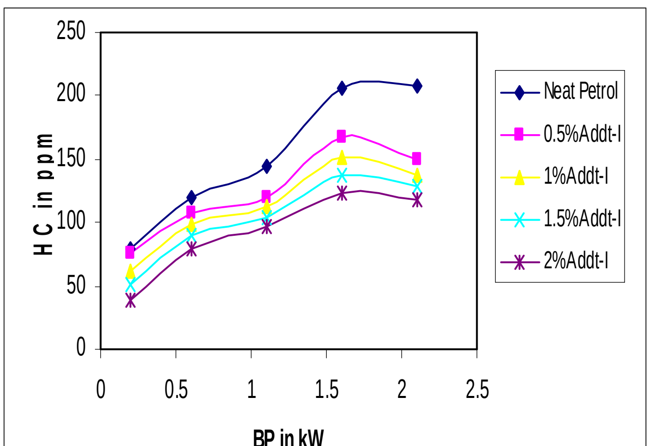

Fig.3: HC Vs Brake Power

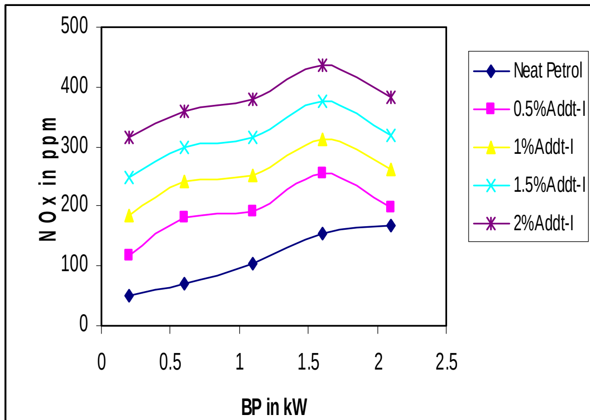

Fig.4:NOx Vs Brake Power

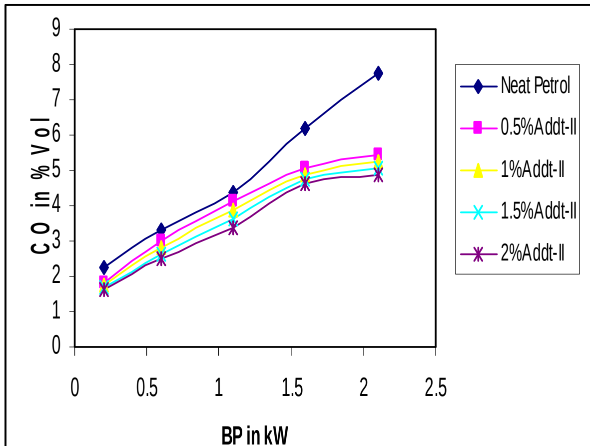

Fig.5: CO Vs Brake Power

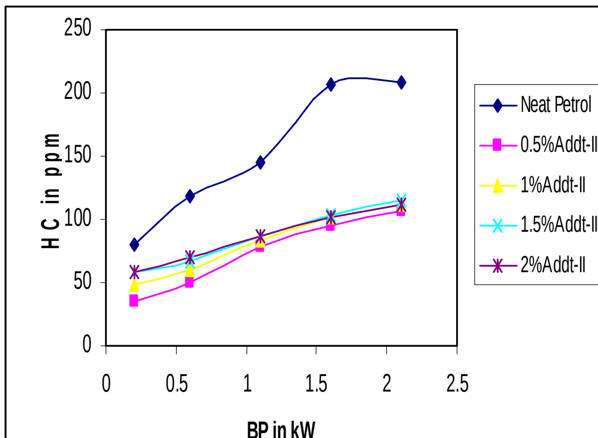

Fig.6: HC Vs Brake Power

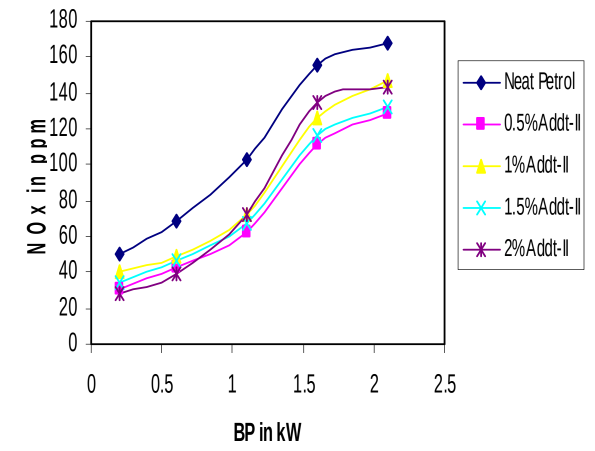


Fig.7: NOx Vs Brake Power

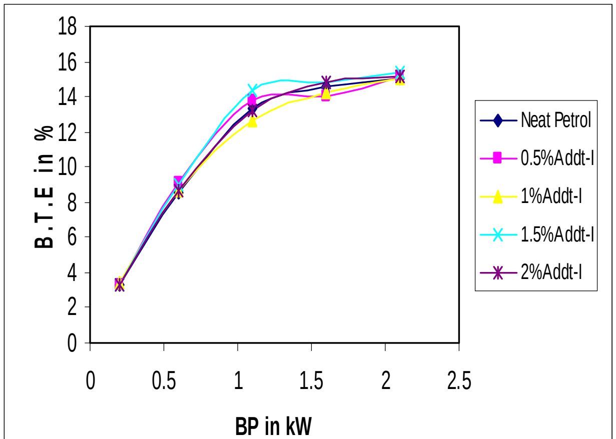


Fig.8:B.T.E. Vs Brake Power

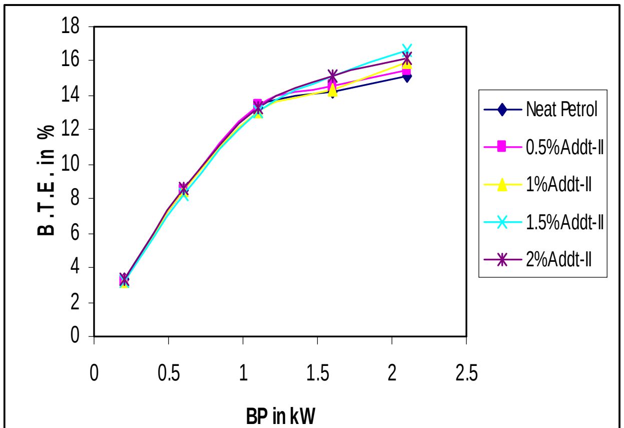


Fig.9: B.T.E. Vs Brake Power

## VI. CONCLUSION

From the experimental results, it is found that when the concentration of additive increases for both Additive-I and Additive-II, the CO and HC emission levels decrease significantly and linearly, with respect to brake power but NOx emission level is increased marginally. It is also found that the carbon monoxide reduction and hydrocarbon reduction increases from 20% to 32% and 21% to 39% respectively. The NOx emission level increases from 18% to 460% and there is no difference in brake thermal efficiency.

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