

Performance and emissions of si engine with octane boosters

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Abstract. In today's world we see that the demand for gasoline and cars keep increasing and one problem which is significantly seen is that we either opt for a fuel which provides higher performance or for a fuel which provides lesser emissions. In this study we aim to provide higher performance and lower emissions by combining two chemicals or octane boosters, namely ethanol and toluene with gasoline and find out its performance and emission characteristics when compared with traditional gasoline and ethanol-gasoline blend. In this study we have made four blends which are PP, E10, E10T5 and E20T5 which are tested against two performance parameters which are Specific Fuel Consumption, Brake Thermal Efficiency with respect to brake power and emissions parameter which are Carbon Dioxide, Carbon Monoxide, Oxides of Nitrogen and Hydrocarbon with respect to brake power as well. In each of these performance and emissions parameters, the blends are compared and we find that E20T5 has the highest performance and E10T5 has the lowest emission.

1. Introduction

Since the inception of automobiles, spark ignited engines have been a boom in automotive industry and have been capable of converting chemical energy into useful mechanical energy. It is one of the most widely used form of engine in the world. The main issue arising from the spark ignited engine being the exhaust emissions which constitutes in the rise of global warming. Another point being that, to provide an increase in performance of the engine without modifying its parts, is to use octane boosters. Octane boosters are used for the purpose of increasing the octane rating of the fuel. These fluids prevent knocking by using anti-knock additives.

1.1 Toluene

Toluene is a clear and water insoluble liquid with the smell of paint thinners. It is a mono-substituted benzene derivative having a chemical formula of C_7H_8 .

Properties of Toluene:
Heating Value(MJ/kg): 40.528
Density(kg/m^3): 867
Octane Number: 112
Enthalpy of Vaporization(kJ/mol): 38.1

1.2 Ethanol

Ethanol is a clear colourless liquid having a chemical formula of C_2H_5OH . Ethanol is renewable energy source and it has good anti-knock characteristics when compared to gasoline. It is preferred due to its lower evaporative losses since it makes it easier to transport and store it.

Properties of Ethanol:
Heating Value(MJ/kg): 26.9
Density(kg/m^3): 785
Octane Number: 106-110
Enthalpy of Vaporization(kJ/mol): 40.65

1.3 Gasoline

Gasoline is a transparent, petroleum-derived liquid that is used as a fuel in spark-ignited internal combustion engines.

Properties of Gasoline:
Heating Value(MJ/kg): 44
Density(kg/m^3): 765
Octane Number: 95-98
Enthalpy of Vaporization(kJ/mol): 33.97

2. Literature Review

The reasons for choosing toluene over the traditional octane boosters is because it shows substantial increase in brake power, brake thermal efficiency, brake specific fuel

consumption and produced the highest level of air-fuel ratio according to the authors in [1] and had also mentioned that toluene has a sensitivity rating of 12. Authors of reference [2] chose toluene due to its low sensitivity rating which makes it an excellent choice for heavily loaded engines. Alcohols usually have a sensitivity rating of 20-30. From [2], we can understand that toluene is denser than gasoline and delivers more energy per unit volume. Henceforth, burning of toluene prompts more energy being released and more power being created. This is as opposed to oxygenated octane boosters like ethanol or Methyl Tertiary Butyl Ether (MTBE), which contain less energy per unit volume in comparison with gasoline. As the authors stated in [3], ethanol is a renewable energy source since it can be produced from corn, sugarcane, barley, and from many other materials. Since ethanol contains an oxygen atom, it is considered as a partially oxidized hydrocarbon. Hence, it has a lower heating value than petrol and the density of ethanol is observed to be slightly higher than petrol. Ethanol does produce higher octane number when compared to petrol due to which it can operate at higher compression ratios. Researchers in [1,3] stated that toluene is a better octane booster compared to ethanol, and it provides a substantial improvement in brake thermal efficiency and torque. It helps reduce the brake specific fuel consumption to a lower value than that of gasoline and ethanol. But where it lacks is in the emissions since it can only decrease the NO_x and HC emissions but it increases CO₂ and CO emissions but as mentioned in [1] ethanol reduces CO, CO₂ emissions and increases NO_x and HC emissions. It was stated in [4] that as the percentage of ethanol increases, the CO emission decreases and this was due to the presence of extra oxygenates within the cylinder and that ethanol has less carbon compared to gasoline. Hence, reduction in CO emission. It was also stated that increasing ethanol percentage in the blends would result in higher indicated mean pressure and higher in cylinder pressure. It would also result in more fuel-air charge being formed in the cylinder and higher amount of density of the charge being present within the cylinder. As stated in [4,5], increase in ethanol percentage causes an increase in NO_x emissions. But toluene reduces NO_x emissions. NO_x emissions are produced due to high temperatures during combustion and with enough heat nitrogen and oxygen present within the air combine to form NO_x as stated in [5]. From [6], we can understand that toluene, n-heptane and iso-octane have a much higher performance output than ethanol since they have a higher octane rating than ethanol. Researchers from [7] compared ethanol and isobutanol in terms of emissions and had found that using an ethanol-gasoline had brought a decrease in CO, HC and NO_x emissions but a slight increase in CO₂ emissions when compared to isobutanol-gasoline blend. The decrease noted in emissions was at least more than 8% in each case. Researchers in [8] were testing on unburnt HC emissions with five different fuels and had found that gaseous fuels such as methane and propane released lesser HC emissions when compared to liquid fuels such as toluene, benzene and isooctane due to oil layer adsorption/desorption. Researchers in [9] used E20 to test against performance, emissions and combustion of an engine in comparison to gasoline. They

found that E20 had reduced CO emission by 65% and HC emission by 38% while doubling in NO_x emissions. It was found that combustion duration increases while using E20 and it had also increased the performance of the engine marginally. Researchers in [10] have stated that particulate emissions from vehicles are harmful due to the release of ultrafine particles. It was also said that the variability in these particles increases with the change in the composition of the blends. When toluene was added to gasoline, it confirmed the hypothesis and increased particle number concentration. This was also observed with the addition of ethanol in gasoline.

3. Methodology

Four samples were prepared to be tested. These samples were 100% Petrol, 10% Ethanol blended with 90% petrol, 10% Ethanol and 5% Toluene blended with 85% petrol and 20% Ethanol and 5% Toluene blended with 75% petrol. These four samples were labeled as Pure Petrol (PP), E10, E10T5 and E20T5 respectively and subjected to standard performance and emissions test. The performance tests were conducted under a constant speed of 1500 RPM with varying loads of 10kg, 20kg and 30kg. Emission tests were conducted using the exhaust gas analyzer to obtain the various emissions from the exhaust gas constituents. The experimental setup consists of four cylinders, four stroke, Ambassador 1800 ISZ carbureted SI Engine connected to an Eddy current dynamometer arrangement. It consists of a panel board arrangement which displays the RPM of the engine and a throttle valve to adjust the RPM of the engine and a fuel input measuring arrangement which consists of 10 liters capacity fuel tank mounted on a stand and a burette which facilitates the measurement of the fuel consumption for a definite period of time. An AVL DiTEST MDS 215 exhaust gas analyzer was used to measure the exhaust gas constituents from the engine using a probe during the experiment. The readings were recorded on its proprietary application on a smartphone.

4. Results and Discussion

The results were obtained from the experimental setup which was run at 1500 RPM. All the four blends were tested and the following results were obtained.

4.1 Specific Fuel Consumption

Specific Fuel Consumption or SFC is a measure of the amount of fuel consumed in one hour to produce 1 kilowatt of energy. As we can observe from figure 1, the trend signifies that SFC decreases with increase in BP. We can notice that pure petrol (PP) has the highest SFC followed by 10% Ethanol (E10) and 10% Ethanol with 5% Toluene (E10T5) and finally see that 20% Ethanol with 5% Toluene (E20T5) has the lowest specific fuel consumption compared to the rest of the blends. SFC reduces for increase in brake power, since brake power increases more rapidly than the fuel consumption. The gain of brake

power is due to the increase of indicated mean pressure and the in-cylinder pressure due to the higher ethanol and toluene content in the mixture.

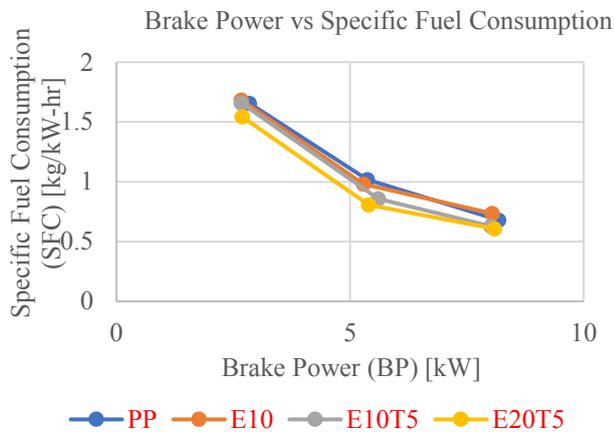


Figure 1. BP Vs SFC

4.2 Brake Thermal Efficiency

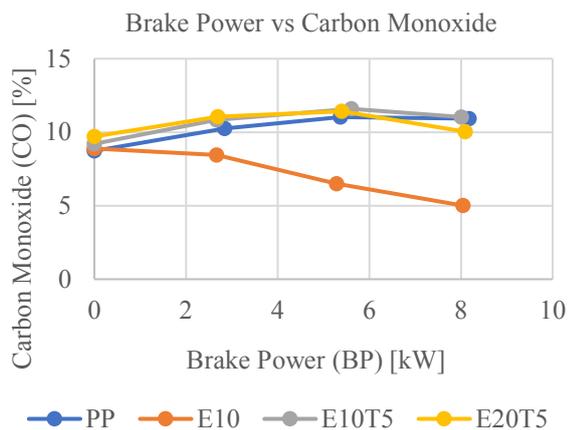


Figure 2. BP Vs Brake Thermal Efficiency

We can infer from figure 2 that the trend shows that brake thermal efficiency increases with increase in brake power. We can also see that PP has the lowest brake thermal efficiency, followed by E10, E10T5 and E20T5. E20T5 produces the highest brake thermal efficiency compared to the other mixtures as seen from figure 2. We can infer from the properties of toluene that it has the highest density of 867 kg/m³ followed by ethanol having a density of 785 kg/m³ and gasoline having a density of 765 kg/m³. Due to higher density of toluene and ethanol, it produces the substantial increase in power which leads to the rise in brake thermal efficiency.

4.3 Carbon Monoxide

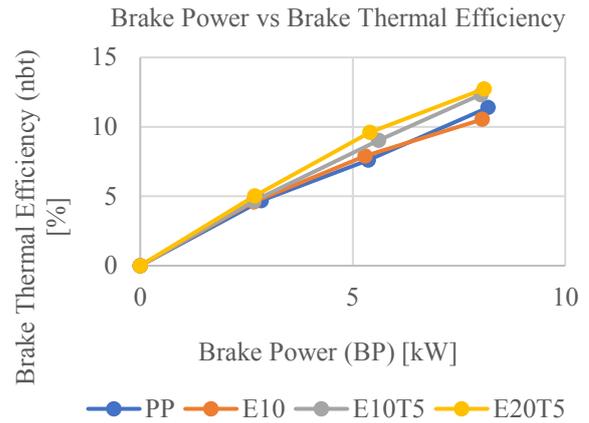


Figure 3. BP Vs CO

We can infer from figure 3 that there are three trends, the first being when comparing between PP and E10, it is noticed that there is significant reduction in CO emission. The second trend shows that when comparison between E10T5 and E20T5 is made, it can be noticed that CO emission for E20T5 initially increases but it starts to decrease at high loads. Also, a third trend can be noticed when comparing E10T5 and E20T5 between PP, there is a rise in CO emission release. The first trend occurs because ethanol has fewer carbon compared to gasoline and more oxygenates are present in the cylinder. Due to this, carbon and oxygen combine to form CO₂, which shows that complete combustion is occurring within the cylinder. For the second trend, we can see that CO emissions initially increases but at higher loads emissions decreases. The increase is due to the presence of toluene within E10T5 and E20T5. Since toluene is present within the mixture, the carbon content within the mixture is more compared to gasoline, and due to which there are more carbon atoms compared to oxygen atoms. The decrease in the trend is because the fuel mixture becomes leaner for increasing blends and increasing loads, due to which more oxygen is present within the cylinder. For the third trend, since toluene is present within the mixtures of E10T5 and E20T5, it causes an increase in CO emissions due to the presence of excess carbon content within the mixture.

4.4 Carbon Dioxide

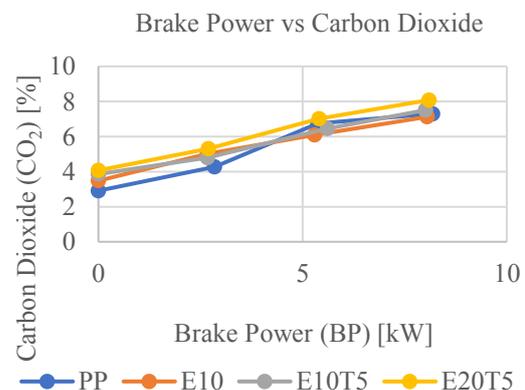


Figure 4. BP Vs CO₂

We can infer from figure 4 that there is an increasing trend. While comparing E10 with PP, it can be noticed that initially E10 has higher CO₂ emission compared to PP but at higher loads E10 has lower CO₂ emissions compared to PP. E10T5 also has a similar trend when compared with PP. E10T5 when compared to E10 has an overall higher CO₂ emission release. While comparing E20T5 with the rest of the mixtures, it can be noticed that it has the highest CO₂ emission release. According to [4], CO₂ emissions decreases with increase in CO emissions. From figure 4, we can observe that the trend obtained is quite different. Since, E20T5 has the highest emission of CO₂ and because of which it can be said that complete combustion occurs when E20T5 is compared with the other mixtures.

4.5 Hydrocarbon

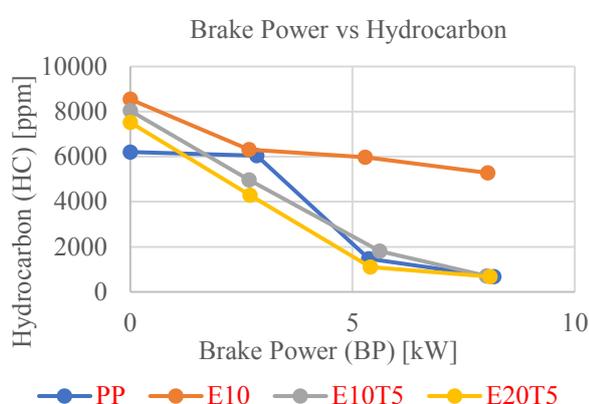


Figure 5. BP Vs HC

Hydrocarbons emissions are released due to incomplete combustion or due to releasing unburnt fuel into the atmosphere. From figure 5 we can infer that there are two trends present. The first trend being the comparison of HC emission between PP and E10. The second trend being the comparison of HC emission between E20T5 and the rest of the mixtures. For the first trend, we can notice that E10 has higher HC emission than PP. This is because ethanol has less carbon when compared to gasoline. For the second trend, we can see that E20T5 has the lowest HC emission when compared to the rest of the mixtures. This is because E20T5 has higher carbon content within the mixture due to the presence of toluene and also due to the presence of ethanol, more oxygenates are present within the cylinder.

4.6 Oxides of Nitrogen

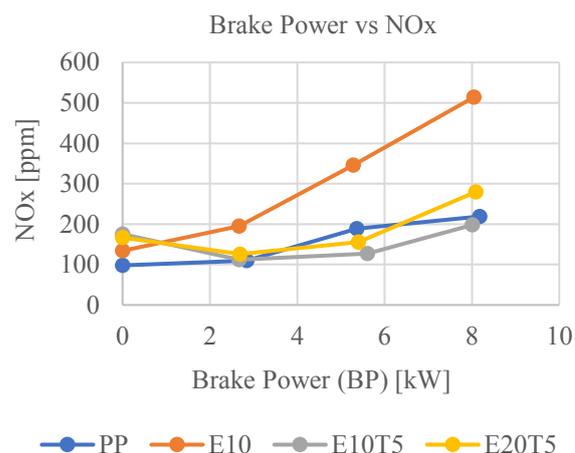


Figure 6. BP Vs NO_x

NO_x emissions in an SI engine occurs due to the combination of nitrogen and oxygen under high temperature conditions, which is above 1370°C. We can infer from figure 6 that three trends are present. First trend being the comparison between E10 and the rest of the mixtures. The second trend being the comparison between E10T5 and E20T5. The third trend being the comparison of E10T5 with the rest of the mixtures. From the first trend, we can notice that E10 has the highest NO_x emission. The reason as to E10 having the highest NO_x emissions is that due to the presence of ethanol, more oxygenates are present within the cylinder which causes NO_x emissions to increase. From the second trend, we can notice that E20T5 has a higher NO_x emission when compared to E10T5. This is due to the presence of more ethanol in E20T5, as said earlier, it contains more oxygenates, hence would increase NO_x emissions. From the third trend, we can notice that E10T5 has the lowest NO_x emissions when compared to the rest of the mixtures. This is due to the fact that, E10T5 has less time to reach above 1370°C and due to the presence of toluene, more carbon is available and it combines with oxygen to produce CO₂ and CO emissions at lower temperatures, hence lesser oxygen available at higher temperatures for the formation of NO_x.

5. Conclusion

The effect of using ethanol-toluene-gasoline blends in an SI Engine has been researched and studied upon. This study consists of comparing the ethanol-toluene-gasoline blends with gasoline and ethanol-gasoline blends using the performance and emission parameters and determining which has the best performance and emission characteristics. Figure 1 showed that E20T5 had the lowest specific fuel consumption and figure 2 showed that E20T5 had the highest brake thermal efficiency. In emissions, figures 3 and 4 respectively showed that E20T5 and E10T5 have higher CO and CO₂ emissions compared to E10. But E20T5 and E10T5 show much lower HC and NO_x emission when compared to E10 in figures 5 and 6 respectively, which is good for the environment. Complete combustion occurs when this ethanol-toluene-gasoline

blend is used due to the high CO₂ emission release and also due to the decrease in CO emission noticed in figure 3 for E20T5. From this study it can be concluded that E20T5 indicates the best performance and E10T5 indicates the best emission characteristics when compared to traditional gasoline and ethanol-gasoline blend. Perhaps further tests can be conducted in order to find the optimum blending ratio for toluene and ethanol in order to achieve better emissions without the loss in performance.

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