Parametric Study and Determination of Spark Advancement Angle Required for Different Blends of Petrol and Ethanol for SI Engine

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Abstract: ***Environmental concerns as well as limited oil reserves have developed the interest of Indian Government in renewable energy sources. An increasing number of spark ignition, 4-stroke internal combustion engines calls for the use of ethanol blends at larger scale. Today the majority of the engines that are using low percentage ethanol blends are designed to run on petrol only. Researchers have time and over proved the fact that ethanol only up-to 10% can be used in existing vehicles via experimentations and analysis of performance parameters and emission characteristics. Studies have also been implied that using ethanol blends above 10% in your existing petrol vehicles without any modification will affect vehicle's performance and life considerably over time. The objective of this paper is to come up with the exact advancement angle for different blends of ethanol making the existing petrol engines compatible to run on ethanol blends above 10%. Tests were performed on four stroke, air cooled single cylinder engine with 3600 as rated RPM with different electrical loading conditions for five different blends (E0, E20, E40, E60 and E80). After analyzing the fuel consumption, AFR, HC and CO emissions for different blends, it has been found that there is a requirement of spark advance of 5° for every 20% increase of ethanol in blend with petrol.***

Keywords: Petrol engine, ethanol, blends, fuel properties, spark advance, performance parameters and emission characteristics

1. Introduction

The extent of air pollution with exhaust gases and continuously increasing number of automobiles running on conventional combustion engines have shown a negative effect not only on the environment but also on human health. For that reason the government in India has taken a strong step towards alternative sources of fuel and at the same time has accepted various norms and standards defining the maximum acceptable levels of noxious gases in exhaust gases for manufacturers of motor vehicles. These new legislative regulations force engine manufacturers to look for such technical solutions that would enable them to observe the defined limit values. Individual technical measures involve use of catalysers, filters of solid particles, high-pressure injection devices, and/or modified combustion chambers with turbochargers of aspirated air. Another way to achieve the aim of the regulations is to reduce the production of noxious emissions which is associated with a possible change of fuel. Internal combustion engines function mostly on petrol or diesel fuel, i.e. fuels made from crude oil. Crude oil, however, is one of the non-renewable sources of energy and this is associated with the fact that the availability w.r.t the consumption of fossil fuels has a worsening situation to cover future needs of the world population growing @ 1.2% every year. For that reason an increased attention has been paid in recent decades to the so-called green fuel, i.e. ethanol, a fuel made from any sources of cellulose.

The first attempts to use ethanol as a fuel in piston combustion engines can be dated back to the end of the 19th century. In Czechoslovakia, a compulsory addition of 20 % of ethanol into petrol was ordered by law already in the decade of 1926−1936. Before the World War II, the engine fuel called DYNAKOL (50 % of ethanol, 30 % of benzene and 20 % of petrol) was available in the domestic market, mainly because of shortage of petrol. An increasing efficiency of crude oil extraction (that took place at the beginning of the 20th century) enabled a gradual replacement of ethanol by petrol. The use of ethanol-petrol mixtures ceased in 1950s, mainly due to cheaper production of petrol. At the beginning of the 21st century, however, the launch of the EU bio-fuel program resulted in a comeback of ethanol-petrol mixtures. Pure ethanol (or fuel mixtures containing predominantly this light alcohol) is now-a-days used. Developed countries are using E85 on a much broader scale covering more than 50% of their total fuel usage. But still some countries are striving hard to overcome the availability issues to reduce their crude oil dependency.

The extent of use of ethanol as a fuel in automobiles has been restricted by the manufacturers. Time and again they have warned the users regarding the use of alcohol fuels, additives and lubricants. Companies limit the use of alcohol fuel differently but none of them hold the guarantee of engines' life and performance over 10% blending. Higher blends lean the running conditions because of the different chemical properties of ethanol. Although all the automotive rubbers, elastomers and other metals like Zamac showed resistance to corrosion up-to 20 years with blends up-to E20, nothing can be said certain about the link between ethanol, component corrosion and wear related engine malfunctions. Therefore, only blend up-to E10 is considered non-corrosive for engines made after 1995.

Ethanol being an effective solvent has a problem of clogging of deposits from fuel system in fuel filters and small passageways causing problems in engine running performance. The most critical issue is ethanol being hydroscopic in nature. Fuel; an E10 blend cannot absorb enough moisture out of the air to cause the phase separation. However, if condensation is allowed to occur, or water is directly splashed in the tank, water phase separation can occur. It should be pointed out that this water separation is more likely to occur in straight petrol than in an ethanol blend, moreover many small engine gas tanks are already vented so the fuel can continue to flow into the carburettor. This makes it important to store these engines away from damp or wet conditions. As compared with petrol, alcohols themselves have some distinct and indisputable properties that contain in their high octane number and better evaporability. A major disadvantage of light alcohol consists in the fact that (at lower temperatures) they are not sufficiently volatile and this significantly influences the starting properties of internal combustion engines. Basic characteristics of petrol and pure ethanol are tabulated below:

Property	Petrol	Ethanol
Density (Kg/m^3)	719.7	789
Calorific value (KJ/Kg)	45800	29700
Octane Number	90	108.6
Flash Point (^{0}C)	-42.78	13
Ignition Temperature (^{0}C)	277 - 456	422
Specific Gravity	0.72	0.79
Vapour density (mm Hg)	38	44
Boiling Point (^{0}C)	95	79

When using pure ethanol, the problem of cold start comes only at temperatures below 7 °C. To improve the cold-start capability to the zone of temperatures below 0^{0}C it is mixed with light hydrocarbons or with petrol. In some countries, fuel mixture containing 85 % of ethanol and 15 % of petrol is used. To mix it with petrol, the bio-ethanol must be either water-free or may contain only small amount of it. Low fuel efficiency is another disadvantage of lower alcohols. As compared with petrol, the fuel value of bio-ethanol is low by approximately 30 % and this is the reason why it is necessary to change (i.e. increase) the amount of injected E85 blend into the engine cylinder if we want to preserve a proper course of combustion process in engines optimized for combustion of petroleum derived fuels. According to Park *et al*. (2009), the stoichiometric ratio of E85 is 1:10 (i.e. 10 kg of air per 1 kg of fuel); this means that the overall need of air is by 4.7 kg lower than in the case of petrol combustion.

The main objective of this experiment was to analyse and evaluate the effect of spark advance for different blending ratios in spark-ignition engines. And after the parametric study of power and emission characteristics approximate spark advance angle is to be identified for five different blends .i.e., E0, E20, E40, E60 and E80.

2. Experimental Setup and Procedure

This study was conducted on a single cylinder four stroke Transistorized magneto ignition petrol engine of Honda make. Single cylinder 0.5 KVA gen-set engine was chosen as it was light and easy to maintain and had sufficient space to examine spark advancement from a retrofit to the existing system. This 76 cc engine had forced air cooling system with a standard compression ratio of 9:1. It was fitted with a Hartnell governor to maintain the rated speed of 3600 rpm.

Maker	Honda
Engine type	4-stroke, side valve, single cylinder
Displacement	76 cc
Bore * Stroke	46*46 mm
Compression ratio	9:1
Engine speed	3600 RPM
Cooling system	Forced air cooling
Ignition system	Transistorized magneto

The objective of the whole experimentation was to find the approximate advance in spark angle for different blending ratios without affecting the performance and targeting lower emission values. The engine was outfitted with a DC output port; to which we connected an electrical load of 400W (100% loading) to measure the power output. Readings were taken with 0% load, 25% load and 50% load conditions. Digital tachometer was used to ensure the speed within a specific range at different loading conditions. Calibrated burette and a stop watch were used to measure the volume flow rate of fuel. AFR was measured using air box with orifice diameter of 25.4mm, coefficient of discharge of 0.65 and had a volume of 100 times the swept volume of the engine. U-tube manometer of 50 ml was used to measure pressure difference. Considering five different blends and four different provisions of spark angle advancement (0^0 advance, 5^0 advance 10^0 advance and 15^0 advance), there were 20 cases in all. For each case, five different parameters were calculated; power, brake specific fuel consumption, air-fuel ratio volumetric efficiency and HC and CO emissions.

Fuel	Calorific Value (KJ/Kg)	Density (Kg/m^3)
Pure Petrol (E0)	45800	719.7
20% ethanol +80% petrol (E20)	42580	733.56
40% ethanol +60% petrol (E40)	39360	747.42
60% ethanol +40% petrol (E60)	36140	761.28
80% ethanol +40% petrol (E80)	32920	775.14
Pure Ethanol (E100)	29700	789

Counting on the petrol-ethanol blend properties, it was found that a spark advance of near about 5^0 will be required for every 20% increase in ethanol content in the blend; accordingly readings were taken. Before taking readings, proper care was taken; engine was allowed to achieve a stable running condition every time we tested it and also sufficient time-gap was taken before subsequent emission readings. Values were taken when the speed achieves its approximate range with every loading condition and then it was tested for all five different blends. By the comparative study of each of the 20 cases, we aimed to establish the best admitted advancement angles required for each of the 5 blends.

3. Modification

This experiment was mainly concentrated on changes in carburetor design to make it compatible to achieve desired AFR and spark position as per the requirements of different blends of petrol and ethanol. The setup contained a magnetic pickup coil responsible for spark along with wheels having magnet on periphery; mounted directly on engine crankshaft and following two ways could have been adopted for spark advancement :-

- Changing position of magnet on wheel or
- Changing position of coil

We opted the latter one as in this different position for various blends can be easily obtained. The experiment also focuses on zero water content in blends for which experimentation of filtration using molecular sieve of 3Å were carried out which are not mentioned in this paper. The existing carburetor was tuned in ways that it allows richer AFR using choke and idling circuit.

The complete experimental setup

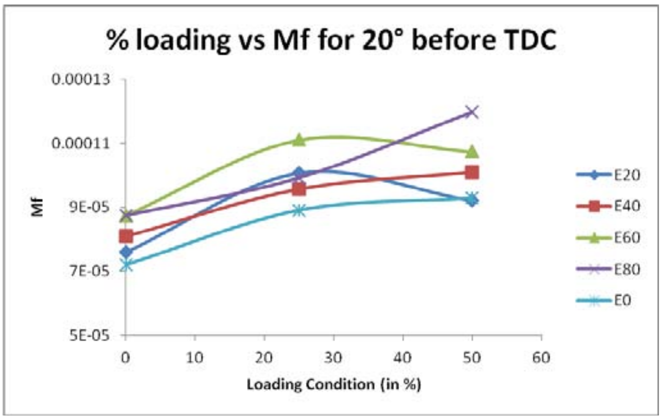
Load tester

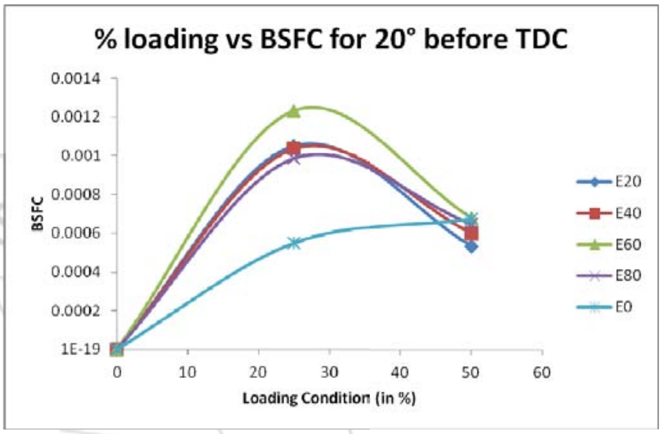
4. Result and Discussion

Results; engine performance based on crucial parameters such as brake specific fuel consumption (BSFC) , fuel consumption (M_f) and AFR were recorded at varying loading conditions (no load, 25% load and 50% load; as explained earlier). These tests were repeated for different blends of petrol and ethanol (E0, E20, E40, E60 and E80) individually first for spark at actual position (i.e.20^0 before TDC) and then for 5^0, 10^0 and 15^0 advance. All the results were plotted on graphs to have a comparative study of the performance of the engine at different spark angle with different fuels.

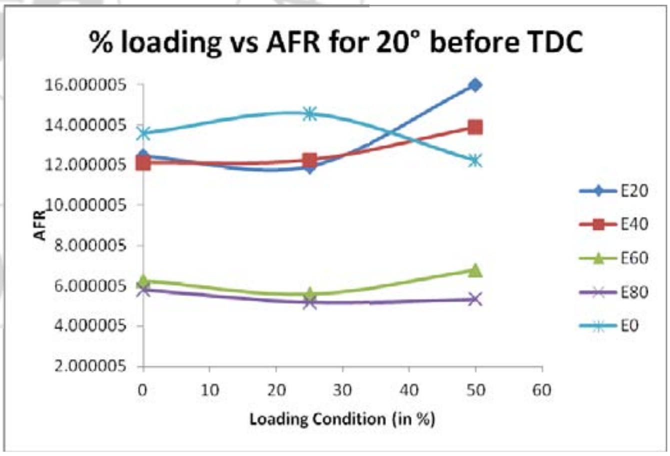
0^0 ADVANCE (20° before TDC)

20 degree before TDC is actual engine spark position and for different blends it is observed from loading vs mf graph that as percentage of ethanol in blends increases mass of fuel consumed also increases.



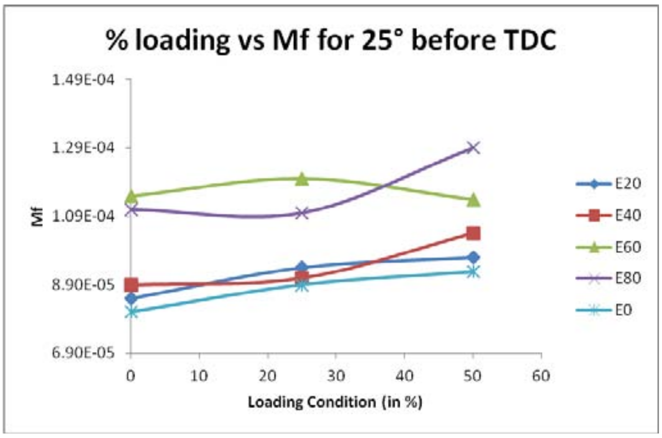


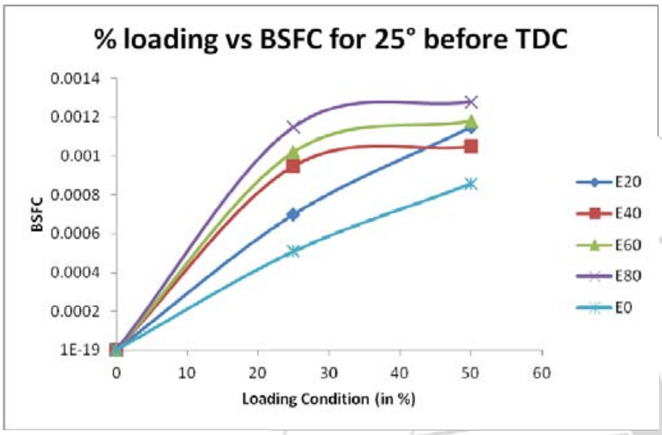
Also loading vs AFR graph shows that air requirement for higher blends reduces gradually. This data helps in accessing nature of ethanol as fuel and in requirement of carburetor design for fulfilling each blend requirement.

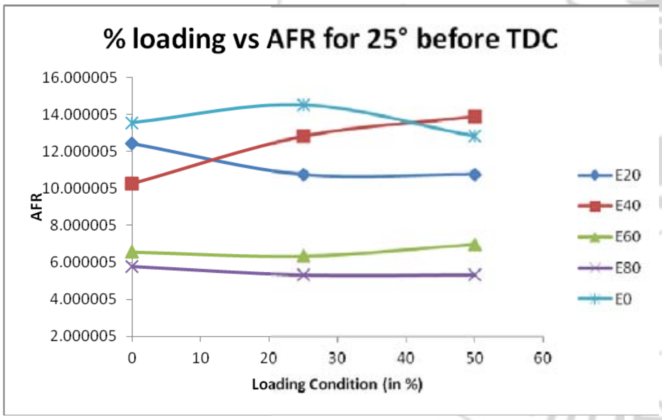


5^0 ADVANCE (25° before TDC)

After advancing 5^0 the graphs trends show that E20 blend data is much more similar to that of E0 blend with no advance but here mass of fuel consumption increases slightly in E20 blend which is a sign of ethanol being a fuel of low calorific value







10^0 ADVANCE (30° before TDC)

Trends similar to 5^0 advance are also found in 10^0 advance for E20 and E40 blend. But in this case, the trends for E0 show little deviation from earlier configurations indicating the inability of carburetor to fulfill desired AFR requirement.

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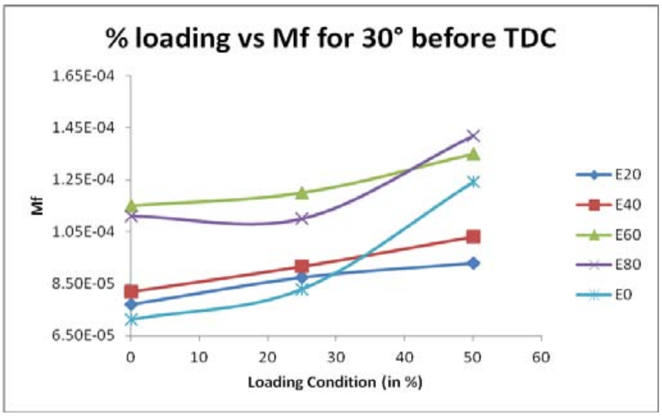

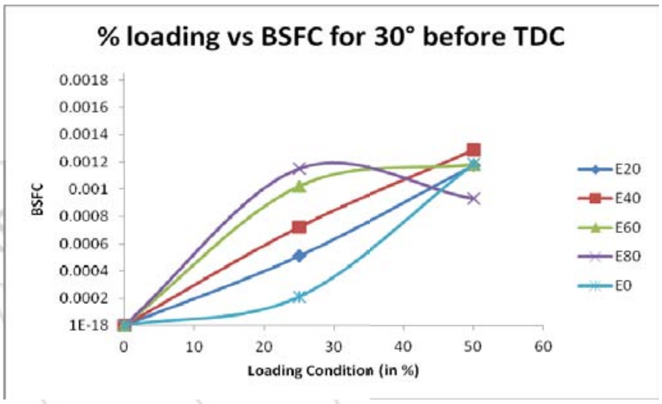

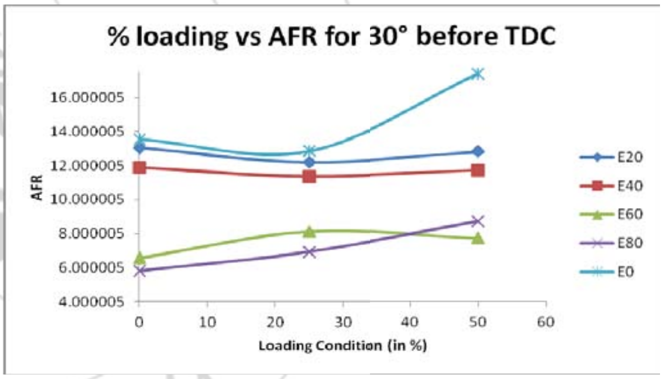

5. Conclusion

Considering the above trends following conclusions were drawn:

a) Ethanol as a blend in petrol up-to 10-15% can be conveniently used without any considerable loss in engine performance. [5]
b) Using ethanol above 20% in normal SI engine is not suited and causes decent loss to engine's performance which increases further with the increase in ethanol content in the fuel.
c) For each 20% increase of ethanol in the fuel; 5^0 advance in spark is required to adjust for the blend. As for our test engine; spark is done at 20^0 before TDC for running on pure petrol and if one wishes to use E20 as fuel, he/she has to advance the spark to 25^0 before TDC and for E40 30^0 before TDC.
d) Heavy deviations and unstable performance of the engine at higher blend (above E40) shows inability of existing carburetor to provide required AFR. Hereinafter if one wants to use higher blends in the same engine, he must

switch to a compatible carburetor. [Details of which can be found in our next paper, "Design of Flex fuel carburetor to support ethanol blending in SI engines" which is capable of achieving the required stoichiometric AFR for ethanol and gasoline blend in any proportion].

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