

Study of the Effects of Ethanol Use on a Ford Escort Fitted with an Old Technology Engine

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ABSTRACT

The purpose of this study is to investigate the effects on the engine's efficiency and exhaust gas emissions by the use of ethanol/gasoline blends in conventional technology vehicles. The fuels E0, E10, E20 and E50 were tested in a 1300cc old technology vehicle without a catalytic converter. The measurements of the engine's brake torque, revolutions and fuel consumption were accomplished on a chassis dynamometer for different engine loads and with different gear ratios. Regarding the exhaust gas emissions, the concentrations of CO₂, CO, HC and NO_x were recorded. The results have shown that increasing the ethanol percentage in the blend has decreased the CO and HC emissions but increased the NO_x emissions. For fuels E10 and E20 an increase on the engine's brake torque and power along with a decrease in fuel consumption were observed. For E50, both brake torque and power were reduced. The CO₂ emissions were increased as the ethanol concentration increased. The best overall results were obtained by using the E20 blend.

INTRODUCTION

The use of alcohols, such as ethyl alcohol, as fuels is not something new. As a matter of fact, the majority of the early internal combustion engines used ethanol as a fuel [1]. In 1826 Samuel Morey received a patent for an internal combustion engine that burnt a mixture of ethanol and turpentine oil. Also, the Ford Model T of 1908 that can be regarded as the first Flexible Fuel Vehicle or FFV was capable of burning a mixture of gasoline and ethanol in any proportion [2]. In the following years of the 20th century the use of ethanol as a fuel was limited due to the low cost of crude oil and its refined products. However, in the 1970's the idea of using ethanol came back due to the first oil crisis. In 1975 Brazil enacted the "Proalcool" program in order to promote the use of ethanol fuel made from sugar cane. Until 2005 Brazil was the world's leader in ethanol production; in 2006 its sales of FFV's were 75 % of the total vehicles sold. As a result, Brazil has succeeded in producing very low emissions of CO₂ in the transport sector [3].

Today the main environmental reason for the use of ethanol as a fuel is to reduce the CO₂ emissions from vehicles. A second reason is the very high cost of crude oil and the reduction of its reserves. The European Union passed the Directive 2003/30 by which all member states have to mix some biofuels with the fossil fuels on sale in the market. The goal of 5.75 % of biofuels was set to be achieved by the year of 2010 [4]. However, in a 2006 report this goal is stated to be unattainable [5].

To study the effects of ethanol/gasoline mixtures on the performance of an internal combustion engine one has to consider some of ethanol's properties. The most important are the following:

The oxygen present in ethanol's molecule C₂H₅OH allows the use of a poorer air to fuel mixture, and as a result a better combustion is achieved. This fact further causes fewer emissions of CO and unburned HC. Ethanol has a higher octane rating (RON=107) than gasoline and because of its antiknock properties, engines with a higher compression ratio, and subsequently more power, can be designed. Ethanol has a smaller Lower Heating value (26750 kJ/kg) than gasoline (43000 kJ/kg). Practically this means fewer kilometers per liter of ethanol fuel and a larger fuel reservoir. Ethanol, in contrast with gasoline, is soluble in any proportion in water. This property is of particular importance because even a small quantity of water present in a mixture of ethanol/gasoline can cause a phase separation with adverse effects on the engine's performance [6]. The enthalpy of evaporation of ethanol is 842-930 kJ/kg that is higher than the value of 330-440 kJ/kg for gasoline. This property can contribute to the increase of engine power and efficiency because of the resulting higher density of the mixture, but this also causes ignition problems at low temperatures [7]. In mixtures of ethanol/gasoline it has been observed a small volume increase of the mixture in relation to the sum of the volumes of the two liquids [6]. The high volatility of the ethanol/gasoline mixtures enhances the creation of vapors in the fuel lines; this can cause decreased fuel flow to the engine. Then the engine's efficiency drops, even to the point of shutting down the engine. The flame temperature of ethanol is 1930 °C that

is very close to that of gasoline (1977 °C). The burning of alcohol causes a larger volume of exhaust gases than burning gasoline with an increase in the pressure inside the combustion chamber as a result [7]. Because of the higher electrical conductivity of ethanol there are corrosion problems with certain materials, especially when mixtures with high ethanol content are used [6].

Recently more scientists have devoted their attention to ethanol's effects on the performance of engines and on the environment.

Yücesu et al. [8] studied mixtures of E0, E10, E20, E40 and E60 in a four-stroke one-cylinder engine tested on a dynamometer. The average reductions of HC and CO emissions for E40 and E60 mixtures were 11 % and 19.8 % correspondingly. They also examined the effect of increasing the compression ratio from 8:1 to 11:1 with the E60 mixture and measured a reduction on the specific consumption by 14.5 % and 17 % at 3500 RPM and 5000 RPM correspondingly.

He et al. [9] used a multipoint injection engine with E0, E10 and E30. They reported that under normal operation the ethanol presence in the mixture reduces slightly the CO and NO_x emissions, and substantially the HC. When the engine is in idle they found that the E10 mixture causes a slight decrease in CO, HC and NO_x emissions, while the E30 mixture causes a larger decrease.

In 1999 Bonnema et al. [10] studied for one year the effects of E10 and E30 in old technology engines using a chassis dynamometer and under road conditions. They reported a reduction in fuel consumption for the E30 mixture but no conclusive results on emissions. No problem occurred in the engine operation in ambient temperatures of -18 °C to 32 °C.

F. Yüksel and B. Yüksel [11] used the E60 mixture in an old technology engine with a modified carburetor. They reported a small increase in torque and a substantial decrease at 80 % of CO and at 50 % of HC emissions due to a poor mixture of ethanol/gasoline. The CO₂ emissions increased 20 % because of a better combustion.

EXPERIMENTAL SET UP

Test vehicle

An old car Ford Escort 1.3, table 1, was used as a test car for this comparative evaluation. The curb weight of the car was 850 kg and was fitted with a spark ignition engine, 1.3 liter, (4 cylinders, 8 valves). The car was instrumented to measure engine RPM, engine coolant and lubricating oil and ambient air temperature. At the start of the evaluation trials the vehicle odometer reading was approximately 170000 km. Such an old vehicle was chosen, firstly, because of its relatively high emissions, compared to more modern vehicles and secondly, as they are still a significant proportion of the Greek vehicle fleet and hence major contributors to air pollution in cities. Future work will investigate more modern vehicles.

TABLE 1: Ford Escort Engine characteristics

Number of cylinders	4/OHV
Displacement	1297 cm ³
Diameter of cylinder	73.96 mm
Diameter of piston	75.48 mm
Compression ratio	9.3:1

Test fuels

The ethanol/gasoline mixtures that were used were E0, E10, E20 and E50. For the preparation of the mixtures the LRP (Lead Replacement Petrol) gasoline was used and ethyl alcohol of 99.8 % purity. Mixtures were prepared on a daily basis so that any possibility of content change due to evaporation or atmospheric humidity was minimized.

Test procedure

Before the first measurements were taken the vehicle was thoroughly checked out and underwent preventive maintenance. In addition, a new set of tires was put on. No conversion was made to the vehicle except for changing the fuel source; an external container filled up with the fuel mixture substituted the fuel reservoir. This container was placed on an electronic balance that recorded the fuel consumption during the test.

The CARTEC chassis dynamometer was used has already described elsewhere [12, 13] and will be briefly described here. Before the engine was started, the engine crankcase oil level and viscosity were checked. All instruments were turned on and checked as well as the condition of the tires. The engine was fully warmed up and then full load was applied on the dynamometer. Measurements were taken in WOT (Wide Open Throttle) test mode, at constant engine speeds and at specific gear settings; 30 km/h with a second gear selected in the gear box, 50 km/h in third gear and 90 km/h in fourth gear. For every single mixture and for each speed at least twenty measurements were taken; Chauvenet's criterion was applied to help eliminate wrong data.

Measurements were taken during a forty second time span; this was deemed adequate since the emission data stabilized in the gas analyzer. In comparison the time span of thirty seconds with the motor in idle is considered adequate for gas emission measurements in the Greek Vehicle Inspection Stations (MOT Stations) [14]. The software of the CARTEC dynamometer recorded the engine's RPM and torque, and thus, calculated the engine's power. Since the ambient pressure and temperature have an effect on the engine's power [15], the calculated power was corrected according to DIN 70020. This standard considers as