

Experimental Study of Emissions and Performance of Internal Combustion Engine Fuels

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Abstract

Experimental study of 8 different internal combustion fuels is conducted. The 8 fuels are: octane 90, octane 95, blend of 10% methanol & 90% octane 90, blend of 10% methanol & 90% octane 95, blend of 20% methanol & 80% octane 90, blend of 20% methanol & 80% octane 95, blend of 30% methanol & 70% octane 90 and blend of 30% methanol & 70% octane 95. A dynamometer setup is used to conduct the experiments and the emissions and torque at different speeds were measured. The efficiency, power and specific fuel consumption were calculated. The experimental results are represented graphically from which the advantages and disadvantages of each fuel relevant to environment and performance are extracted. The best fuels for internal combustion engines are recommended.

Keywords: Emissions, Fuel, Internal Combustion Engines

1. Introduction

At the end of the twentieth century human showed concern to the environment, especially after the industrial renaissance that destroyed many of the life forms. The problem settled after the negative effects that began to emerge largely on the level of each individual country or at the global level. Now it is everyone responsibility to work hard using all the knowledge we have to find different ways for protecting our earth and avoiding environmental disasters.

There are different environmental issues that became very important recently: 1) Global warming (green house effect) is an environmental issue that deals with the potential for global climate change due to increased levels of atmospheric greenhouse gases. 2) Smog and poor air quality is a pressing environmental problem, particularly for large metropolitan cities. 3) Acid rain is a broad term referring to a mixture of wet and dry deposited material from the atmosphere containing higher than normal amounts of nitric and sulfuric acids. 4) Gaseous compounds that are being produced from the chemical reactions in the internal combustion engines of automobiles. In this paper we are concerned with the last item, more specifically, we study the CO, CO₂, and HC emissions of various blends of octane and methanol fuels in internal combustion engines. The objective is to determine which fuels are more friendly to the environment.

Various internal combustion engine properties as functions of the fuel type have been studied in the literature. In [1] a method for both combustion irreversibility and working medium availability computations in a high-speed, naturally-aspirated, four-stroke, internal combustion engine cylinder is presented. The results of the second-law analysis of engine operation with n-dodecane (n-C₁₂H₂₆) fuel are compared with the results of a similar analysis for cases where a light, gaseous (CH₄) and an oxygenated (CH₃OH) fuel is used. In another research [2], reduced chemical kinetic mechanisms for the oxidation of representative surrogate components of a typical multi-component automotive fuel have been developed and applied to model internal combustion engines. The waste plastic oil was compared with the petroleum products and found that it can also be used as fuel in compression ignition engines [3]. The research in [4] evaluates and quantifies the environmental impact from the use of some renewable fuels and fossils fuels in internal combustion engines. The following fuels are evaluated: gasoline blended with anhydrous ethyl alcohol (anhydrous ethanol), conventional diesel fuel, biodiesel in pure form and blended with diesel fuel, and natural gas. A review of the production, characterization and current statuses of vegetable oil and biodiesel as well as the experimental research work carried out in various countries had been conducted [5]. This review touches upon well-to-wheel greenhouse gas emissions, well-to-wheel efficiencies, fuel versatility, infrastructure, availability, economics, engine performance and emissions, effect on wear, lubricating oil etc. Recent advances in research as demonstrated in [6] offer a comprehensive overview of hydrogen-fueled internal combustion engines.

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Topics therein that are discussed include fundamentals of the combustion of hydrogen, details on the different mixture formation strategies and their emissions characteristics, measures to convert existing vehicles, dedicated hydrogen engine features, a state of the art on increasing power output and efficiency while controlling emissions and modeling.

Alternative approaches have been pursued in the literature with the objective of maximizing power and minimizing fuel consumption and emissions in internal combustion engines. One of these techniques is the camless engine in which the intake and exhaust valves motion is regulated by electrohydraulic actuators instead of being connected to the engine rotation through the camshaft. Modeling and control of camless engines have been investigated in [7,8]. Furthermore due to the complexity of internal combustion engine dynamics neural networks were utilized to model the camless engine's breathing process [9]. The neural net based feedback control systems for the 4-cylinder and 8-cylinder camless internal combustion engines were demonstrated with the aid of simulation tools in [10] and [11], respectively.

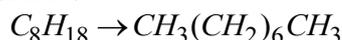
In this paper we conduct an experimental study of 8 different internal combustion fuels. The 8 fuels are: octane 90, octane 95, blend of 10% methanol & 90% octane 90, blend of 10% methanol & 90% octane 95, blend of 20% methanol & 80% octane 90, blend of 20% methanol & 80% octane 95, blend of 30% methanol & 70% octane 90 and blend of 30% methanol & 70% octane 95. A dynamometer setup is used to conduct the experiments and the emissions and torque at different speeds were measured. The efficiency, power and specific fuel consumption were calculated. The experimental results are represented graphically from which the advantages and disadvantages of each fuel relevant to environment and performance were extracted. The best fuels for internal combustion engines are recommended.

2. Octane 90, 95 & Methanol Fuels

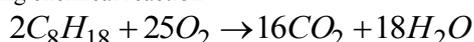
The emissions and performance of internal combustion engines using 8 different fuels consisting of octane 90, 95 and methanol are studied experimentally. Therefore we give in the following subsections a brief description of the above fuels.

2.1. Octane

Octane is a hydrocarbon which is made out of only carbon and hydrogen atoms, as the name suggests. The family of hydrocarbons to which octane belong is called the "alkane" series. Octane is the eighth molecule in the family. It has eight carbon atoms all single bonded to each other with the 18 hydrogen surrounding the carbon chain occupying all the unused bonding sites on the carbon atoms. The chemical composition of octane is



When octane burns CO₂ and steam are produced as in the following chemical reaction

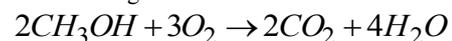


The main fuels for spark ignition engines used in Jordan are Octane 90 and Octane 95. The octane number (90 or 95) is a measure of a fuel's resistance to self ignition, hence a measure as well of the antiknock properties of the fuel. In another explanation, the octane number is equal to the numerical value

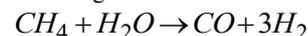
of the percentage by volume of iso-octane in a mixture of iso-octane and n-heptane having the same knock characteristics as the fuel being tested.

2.2. Methanol

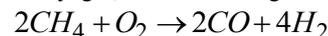
Methanol and Ethanol are organic compounds that are distinguished from hydrocarbons by the inclusion of a hydroxyl (-OH) group and they are the two simplest alcohols. Methanol also known as methyl alcohol, wood alcohol, wood naphtha or wood spirits, is a chemical with formula (often abbreviated MeOH). It is toxic; it is the simplest alcohol and is a light, volatile, colorless, flammable, and liquid with a distinctive odor that is very similar to but slightly sweeter than ethanol. At room temperature it is a polar liquid and is used as an antifreeze, solvent, fuel, and as a denaturant for ethanol, it is also used for producing biodiesel via transesterification reaction. Methanol burns in air forming carbon dioxide and water as in the following chemical reaction



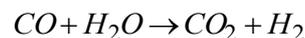
At moderate pressures of 4 MPa and high temperatures around 850 °C, methane reacts with steam on a nickel catalyst to produce syngas according to the chemical reaction



This reaction, commonly called steam-methane reforming or SMR is endothermic and the heat transfer limitations place limit or the size of and pressure in the catalytic reactors used. Methane can also undergo partial oxidation with molecular oxygen to produce syngas, as the following reaction shows



This reaction is exothermic and the heat given off can be used in-situ to drive the steam-methane reforming reaction, when the two processes are combined it is referred to as auto thermal reforming, the ratio CO and H₂ can be adjusted to some extent by the water-gas shift reaction



Methanol is used in a limited basis to fuel internal combustion engines, mainly by the virtue of the fact that it is not nearly as flammable as gasoline, methanol is harder to ignite than gasoline and produces just one-eighth of the heat upon burning. One of the drawbacks of methanol as a fuel is its corrosivity to some materials, including aluminum. Methanol, although a weak acid, attacks the oxide coating that normally protects the aluminum from corrosion.

Pure methanol has been used in open wheel auto racing since the mid 1960s, unlike petroleum fires, methanol fires can be extinguished with plain water. A methanol-based fire burns invisibly, unlike gasoline, which burns with a visible flame. If a fire occurs on the truck, there is no flame or smoke to obstruct the view of fast approaching drivers, but this can also delay visual deflection of the fire and the initiation of fire suppression actions. Methanol is readily biodegradable in both aerobic (oxygen present) and anaerobic (oxygen absent) environments. Methanol will not persist in the environment. The "half-life" for methanol in ground water is just one to seven days, while many common gasoline components have half-lives in the hundred of days (such as benzene at 10-730 days), since methanol is miscible with water and biodegradable, methanol is unlikely to accumulate in ground water, surface water, air or soil.

3. Experimental Setup Description

Experiments were conducted with the following 8 different internal combustion fuels: octane 90, octane 95, blend of 10% methanol & 90% octane 90, blend of 10% methanol & 90% octane 95, blend of 20% methanol & 80% octane 90, blend of 20% methanol & 80% octane 95, blend of 30% methanol & 70% octane 90 and blend of 30% methanol & 70% octane 95. The objective of the experiments is to reduce the emissions produced by the internal combustion engines, especially the spark ignition ones, while having the same performance, power and efficiency.

The engine used in the experiments is a 4-stroke (Otto) single cylinder petrol engine with 3 interchangeable cylinder heads. The specifications of the engine are: bore diameter = 2.375 in, stroke = 1.75 in, swept volume = 7.75 in³, compression ratios = 5:1, 6:1, 7:1, 4:1 and 10:1, lubrication: wet sump/splash, recommended oil: SAE 30, recommended fuel: regular grade petrol (gasoline), ignition type: coil and contact breaker with manual ignition advance, contact set part no.: intermotor no. 284, condenser part no.: intermotor no. N376, coil part no.: wipac part no. SO810, sparking plug: champion Z-10, and torque setting – cylinder head nuts: 17 ft lb.

The dynamometer of the experiments is of the D.C. swinging field type and can be used for absorbing and motoring. When absorbing the power is dissipated in a resistance load bank mounted on the right hand side of the frame. A thyristor control unit is used to power the dynamometer for motoring and starting purposes.

Torque is measured is by a strain gauge load cell connected to the dynamometer torque arm (radius 0.2m). The output is displayed in Nm on an analogue meter mounted on the instrument panel whose picture is shown in Fig. 1. The meter reading is reversed automatically when going from load to motor conditions and vice versa. A remote reading multipoint temperature measuring system enables temperatures to be measured quickly and accurately on a dual scale analogue meter. Exhaust temperature is indicated on the upper scale automatically, until another temperature is selected by pressing the appropriate push button. The selected temperature is then indicated on the lower scale. Once the push button is released the meter again reads exhaust temperature.



Fig. 1. Photograph of the experimental instrument panel

The system is calibrated before shipment and should require no adjustment. Temperatures can be measured at the following engine air inlet, cooling air outlet, exhaust temperature at exhaust valve, calorimeter cooling water in, Calorimeter cooling water out and exhaust temperature at outlet of calorimeter. The fuel flow is measured through a burette connected into the fuel system is fitted on the instrument panel and is calibrated 0-10 ml. With the fuel valve in the 'ON' position the petrol bypasses the burette and is taken direct from the fuel tank into the carburetor. If the fuel valve is closed using a stopwatch.

Three cylinder heads of different compression ratios are supplied as standard. Optional heads are available to provide compression ratios in the range 4:1 to 10:1. Each head has two 10mm tapping, the front one being for the sparking plug and the other to allow the fitting of a pressure transducer.

Cooling is provided by an electrically driven centrifugal fan, which draws air over the engine and through a calibrated orifice. The exhaust gases are passed through a water-cooled calorimeter. A variable area flow meter is provided for water flow and the water inlet and outlet temperatures are measured thus enabling the heat extracted from the exhaust gas to be calculated. The exhaust gas is cooled to less than 100°C and the remaining energy can be ignored and still give good accuracy. A schematic diagram of the experimental apparatus is shown in Fig. 2.

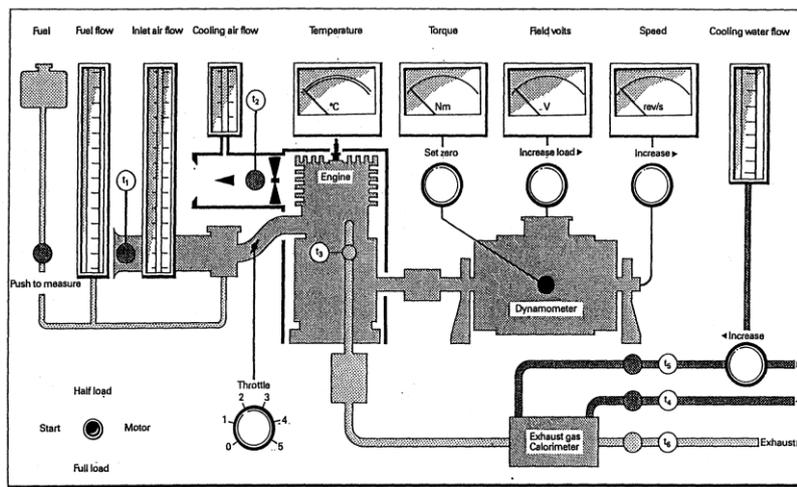


Fig. 2. Schematic diagram of the experimental apparatus

4. Experimental Results

The calorific value and density for each fuel tested were obtained experimentally and are listed in Table 1. The CO, CO₂, and HC emissions and torque were measured at various speeds (acceleration and deceleration) in the experiments for each of the 8 fuels used. The specific fuel consumption, A/F ratio and brake power are calculated from the collected data of the experiments.

Table 1. Fuel types along with their density and calorific values

No.	Fuel	Density (kg/m ³)	C.V(cal/g)
1	Octane 90	755	9822
2	Octane 95	765	9119
3	Blend 10%(90)	758.5	9194
4	Blend 10%(95)	767.5	8632
5	Blend 20%(90)	762	8818
6	Blend 20%(95)	770	8641
7	Blend 30%(90)	765.5	7236
8	Blend 30%(95)	772.5	8122

The results are represented graphically. The brake power versus speed is plotted in Fig. 3. The SFC versus speed is depicted in Fig 4. The emissions CO, CO₂ and HC versus speed are plotted in Figs. 5, 6 and 7, respectively.

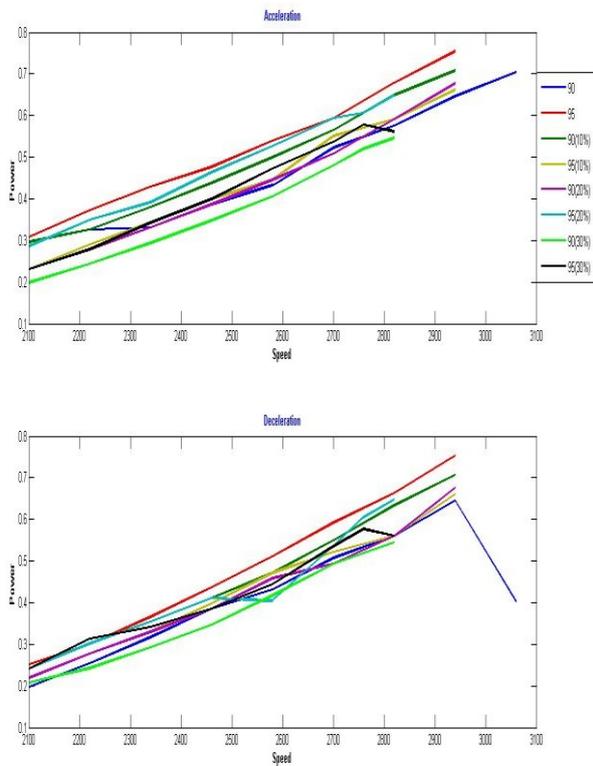


Fig. 3. Brake power versus speed

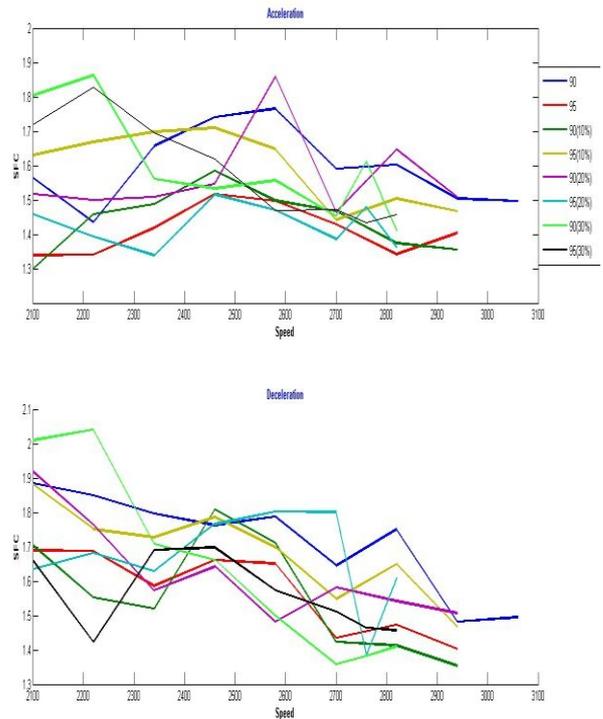


Fig. 4. SFC versus speed

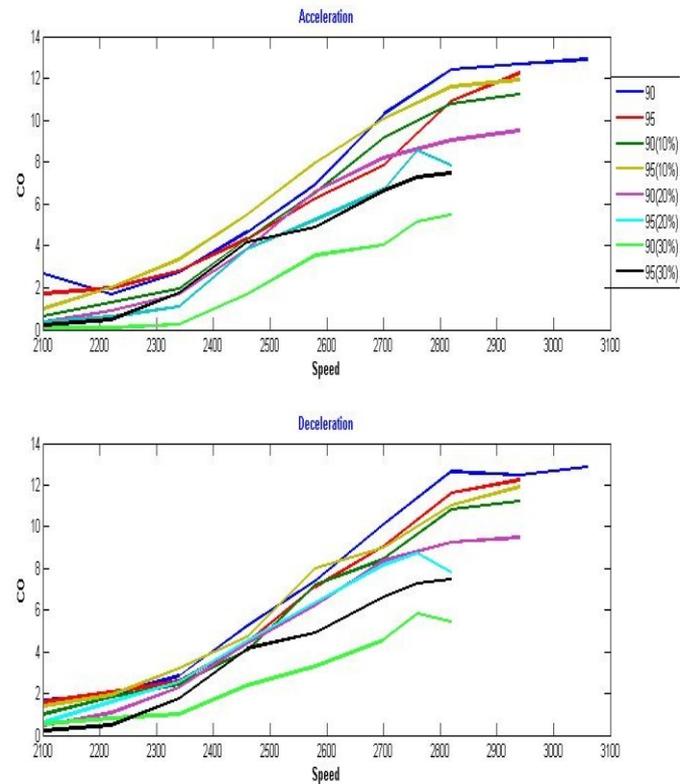


Fig. 5. CO emissions versus speed

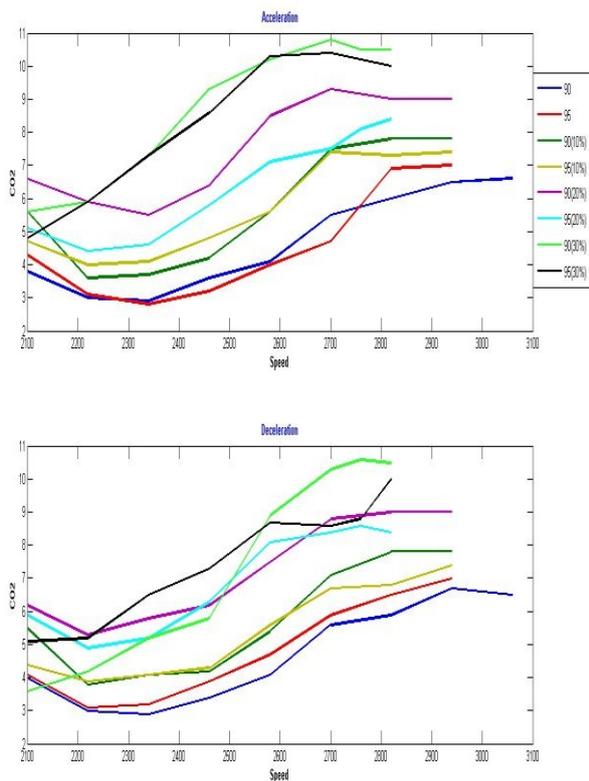


Fig. 6. CO2 emissions versus speed

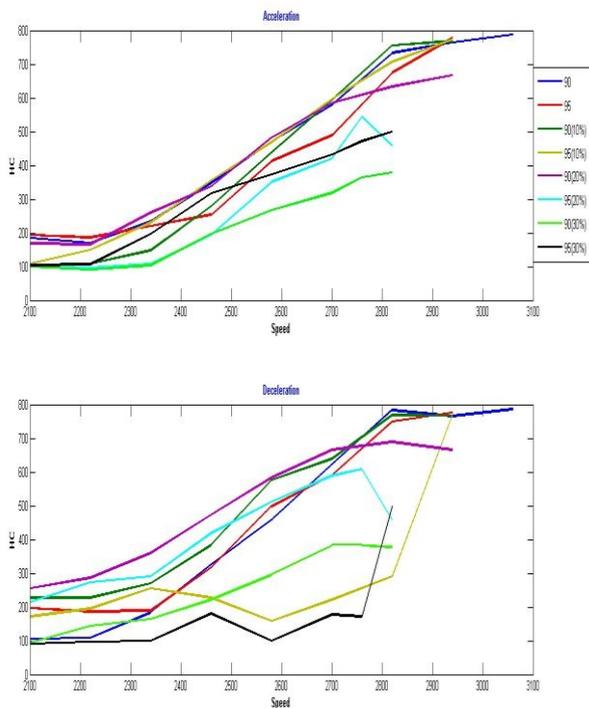


Fig. 7. HC emissions versus speed

We were wondering if using methanol as an additive to the fuels used here in Jordan (Octane 90, 95) would be effective or not. From the graphical representation of the results shown above we discovered that there is a big potential in using such an alternative fuel. The Figures have a lot of information and sometimes is conflicting. However we discuss below the important issues of the results.

The density of the alternative fuel (with methanol) is close to the densities of octane 90 or 95. Economically the prices of methanol and octane fuels are in a narrow range. During the experiments no problems were encountered with methanol on the engine that was designed to use octane 90 or 95. Adding the small percentage of methanol to the two octane fuels within an upper limit of 30% didn't affect the engine. Thus it is safe enough based on the experiments to use as this percent for the cars used in Jordan.

From the above figures and tables we extract some important outcomes keeping in mind that the most practical speed is around 2000 rpm. Blend of 10% methanol and 90% octane 90 and blend of 20% methanol and 80% octane 95 have brake power near to Octane 95 during acceleration. All the blends have less values of CO than octane 90 or 95. In addition the blend of 30% methanol has less values of HC than octane 90 or 95.

The study carried out in this paper shows the importance of adding methanol to the octane 90 or 95 fuels which are used in Jordan. It is apparent that the methanol addition produces more friendly fuels to the environment. Taking into account the threats to our atmosphere and globe it is very important to move on and replace the currently used fuels with healthier ones.

5. Conclusion

Eight types of internal combustion fuels are tested experimentally towards determining the best fuels for reducing CO, CO2 and HC emissions. The fuels are blends of octane 90, 95 and methanol. The results showed that the addition of methanol to octane 90 or 95 is beneficial. If a choice is to be made on the best fuel it was noticed that all the blends have less values of CO emissions than octane 90 or 95 without the addition of methanol. The blend of 30% methanol has also less values of HC than octane 90 or 95. The blends have good brake power and thus are efficient. It is worthwhile to start thinking about using methanol along with octane fuels in internal combustion engines.

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