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Effects of Oxygenated Gasoline on Fuel and Air Mass Flow Rates and Air-Fuel Ratio

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Abstract: The effects of excess feeding oxygen to the fuel-air mixture on air and fuel mass flow rates and also on air-fuel ratio are investigated here experimentally. This study concerned with the effects of injecting pure oxygen quantity to the mixture of fuel and air before interring the combustion chambers. It is found that the mass flow rate of fuel with the oxygen feeding is less than that of with no oxygen feeding at some specific values of engine speeds and the same thing was found for air mass flow rate. The air-fuel ratio also is less with considerable values in the case with oxygen feeding than that with no oxygen samples. Also this technique can be used partially, in some conditions oxygen can be feed into the combustion chambers to increase engine performance.

Key words: Fuel-air mixture, fuel mass flow rate, excess oxygen feeding, air-fuel ratio

INTRODUCTION

Today, decreasing fuel consumptions and exhaust emissions become a considerable matters because if these things are done then cost of energy or fuel will be decreased and an environmental problem will be solved partially too. Feeding pure oxygen quantities to the mixture before entering the combustion chamber is studied here experimentally to find or investigate its effects on fuel mass flow rate, air mass flow rate and also air-fuel ratio. All tests were carried on a Honda 200, single cylinder-197 cc engine. Little studies have been discussed this issue, here are some of these studies, Charles and Martin[1] studied in detailed mechanisms by which oxygenated diesel fuels reduce engine-out soot emissions. Their experiments were conducted at a 1200-rpm, moderate-load operating condition using a modern-technology, 4-stroke, heavy duty DI diesel engine with optical access. Images of broadband natural luminosity (i.e., light emission without spectral filtering) from the combustion chamber, coupled with heat-release and efficiency analyses, were presented for three test-fuels. One test-fuel (denoted GE80) was oxygenated with tri-propylene glycol methyl ether; the second (denoted BM88) was oxygenated with di-butyl maleate. The overall oxygen contents of these two fuels were matched at 26% by weight. The third test-fuel (denoted CN80) was a non-oxygenated, 80-cetane blend of two $C_{16}H_{34}$ primary reference fuels. The compositions of the three test-fuels were tailored such that each fuel had the same ignition delay at the given operating condition. Oxygen content, combustion phasing and adiabatic flame temperature also were carefully matched to isolate (as much as possible) the effects of oxygenate molecular structure on combustion and soot-formation processes. Whereas no dramatic differences in the spatial development of ignition or combustion processes among the fuels are evident from the Natural Luminosity (NL) images, Spatially Integrated Natural Luminosity (SINL) data, used as a relative measure of the average in cylinder soot volume fraction, show differences among the fuels. The non-oxygenated CN80 produced 3 times and >7 times higher peak SINL than the oxygenated BM88 and GE80 fuels, respectively. The peak SINL measured for BM88 was twice as great as for GE80, indicating that overall oxygen content is not the only important parameter in determining the soot-reduction potential of an oxygenated fuel.

David *et al*.[3] discussed nonoxygenated and oxygenated gasoline from the standpoint of fuel economy and engine performance. The focus is on winter oxygenated gasoline (i.e., gasoline designed to meet the requirements of CO reduction programs). Issues that are not likely to be encountered during the winter months, such as summer volatility issues, are not discussed. The following fuel-related sources of potential engine performance problems were discussed: enleanment, fuel quality, antiknock quality, fuel handling and storage practices, water absorption/phase

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separation, materials compatibility and fuel mixtures. All of the fuel related potential engine performance problems can occur with either oxygenated or nonoxygenated gasoline. With regard to fuel economy, the theoretical change in fuel energy as a result of the addition of oxygenates to gasoline was in the range of a 2.3% reduction when compared to nonoxygenated gasoline. This corresponds to less than 1 mile per gallon (i.e., approximately 0.5-0.8 miles per gallon) for a car that averages 27 miles per gallon. The large body of research indicated that actual measurements of changes in fuel economy agree with the theoretical changes in fuel energy. However, some older vehicles experience slightly improved fuel economy with oxygenated gasoline because of the resulting enleanment of the air-fuel mixture. Any fuel economy loss actually experienced is the result of the slight decrease in energy content of the fuel. They were found that reductions in fuel economy were not supported by numerous laboratory and on-road studies. Existing research indicated that the largest fuel economy loss that could be attributed to the presence of oxygenates is 3%. Consumer estimates frequently fail to account for several critical factors that would explain their calculation error or provide the reason for lower fuel economy.

Kunte *et al*.[4] studied the soot reduction potential of oxygenated fuels. The influence of oxygen containing fuels on the soot forming tendency within a laminar diffusion flame had been investigated. The promising results show a strong decrease in soot content at higher admixtures whereas at small quantities the soot production rises slightly under highly diluted conditions. The addition of oxygenated compounds to diesel fuel can result in a sizable decrease of particulate matter in the exhaust gases. Of special interest are acetals as an admixture agent because they are compatible with the technical restraints of commonly used engines. Our investigations have been carried out on a wolfhard-parker burner. DME, methylal (dimethoxymethane (DMM)) and butylal (dibutoxy-methane) were admixed to a basic fuel and burnt in an over ventilated diffusion flame. Laser Induced Incandescence (LII) was used to measure soot volume fractions within the flame. To separate as much as possible the effects due to the specific reaction kinetics of the added compound from those due to a change in temperature, ethylene, well matching the adiabatic flame temperatures of the investigated additives, was used as a base fuel. Another comparison is possible with an addition of CH_4 instead of oxygenates. CH_4, having a soot reducing effect due to its very low sooting propensity, does not change the combustion chemistry by the introduction of oxygen in the fuel stream.

Craig *et al*.[2] made an optimization of synthetic oxygenated fuels for diesel engines. The results from the experimental study were correlated using a novel application of structural group additivity. From the screening data and analysis, several oxygenated fuels with significant potential for particulate emissions reduction from diesel engines-ether and a ketone-were selected for detailed study in shock tube and flow reactor experiments. The experimental studies provide data on ignition delay, soot yields and soot induction times and detailed species evolution profiles for the fuel and major intermediate and product species. Studies using dimethyl ether and dimethyl ether/n-heptane blends had been completed. The results from the experimental studies had been compared with predictions from a detailed reaction mechanism and areas where mechanism improvements are required were identified.

To assess the effectiveness of oxygenated fuels in reducing pollutant emissions in diesel engines and to optimize the diesel engine process for the particular fuel characteristics, they were performing a limited set of engine experiments as well as three-dimensional numerical simulations of diesel engine combustion. The simulations permit a more extensive investigation of effects of engine design and operating conditions on performance and emissions. For the simulations, they were developing a state-of-the-art computational tool which was capable of performing Large Eddy Simulation (LES) of turbulent combustion in diesel engines. Over the past year, significant progress had been made in the development and implementation of a structured grid solver and a method to model piston motion. The code had been validated by comparison of code predictions with available experimental data on unsteady flows, including a reacting jet in cross flow and a square piston compression machine.

Theory: It is known that the mass flow rate of fuel can be calculated as:

$$M_{fuel} = 3600 * Q_{fuel}\rho \quad (1)$$

Where:

- ρ = The density of fuel (879 kg m^{-3})
- Q fuel = The volumetric flow rate of fuel ($Q = V/t*10^6$ $m^3 sec^{-1}$)
- V = The swept volume(25 cm^3)
- t = The time (sec)

The mass flow rate of air can be measured by using a special device contain an orifice and the pressure difference is measured between two points: before the orifice and after it. This pressure difference is appeared as a head difference in the u-tube manometer filled with water. To calculate mass flow rate of air the following equations are used:

$$Q_{air} = c D^2 \sqrt{H} \quad (2)$$

Where:
Q_{air} = The volumetric flow rate of air [L min^{-1}]
c = The orifice constant (0.11233)
D The orifice diameter
H = The head difference

Also the mass flow rate of air can be calculated as:

$$M_{air} = Q_{air} * \rho / 60 * 10^3 \quad (3)$$

Where:
M_{air} = The mass flow rate of air [kg sec^{-1}]
ρ = The air density given as:

((ρ = P/RT)

Where:
P = The ambient pressure
R = The gas constant of air [KJ kg^{-1}.K]
T = The ambient temperature [K])

The air-fuel ratio should be calculated because this value affects the state of mixture(lean or rich), the combustion reaction and the power produced To calculate the air fuel ratio (without oxygen feeding) the following equations will be used:

$$A/F = 2.66 * C + 7.94 * H_2 + 0.998 * S - O_2 / 0.232 \quad (4)$$

Where:
A/F = The air fuel ratio [kg air kg^{-1} fuel]
C = Percentage of carbon in fuel
H_2 = Percentage of hydrogen in fuel
S = The percentage of sulfur in fuel
O_2 = The percentage of oxygen in the fuel

Also the air fuel ratio with the oxygen feeding can be calculated as follows:

- The first step is to calculate the total mass flow rate of oxygen which enters the combustion chamber:

$$M_{O_2 total} = M_{O_2 air} + M_{O_2 injected} \quad (5)$$

- The mass fraction of oxygen form air enters the system can be written as:

$$M_{O_2 air} = 0.232 * M_{air} \quad (6)$$

- The mass flow rate of the oxygen injected to the system:

$$M_{O_2 injected} = Q_{O_2, injected} * \rho_{O_2} \quad (7)$$

- The volumetric flow rate of the oxygen injected is given as:
-

$$Q_{O_2 injected} = c_d * (\pi D^2 / 4) * \sqrt{2g * \Delta H} \quad (8)$$

Where:
c_d = The discharge coefficient of the orifice
D = The orifice diameter
ΔH = The head orifice
G = The acceleration of gravity [m sec^{-2}]

Now, the oxygen percentage (after injection of oxygen) can be calculated as:

$$\%O_2 = M_{O_2 total} / M_{air} \quad (9)$$

CONCLUSION

Using last equations the mass flow rates for both fuel and air and A/F ratios can be calculated for the two cases with and without oxygen feedings. Figure 1 shows the fuel mass flow rate against the engine speed and it's obvious from Fig. 1 that the fuel mass flow rate with oxygen feeding is at some engine speed is less than that without oxygen feeding but its values make some fluctuation, but in general it is sure that fuel mass flow rate will be less in the case of excess oxygen. In Fig. 2 it is very clear and expected that the mass flow rate in the case of oxygen feeding is more than that of without oxygen feeding. Figure 3 makes a comparison of A/F ratios between the two cases: With and without oxygen feeding, it is clear that the A/F at the case without oxygen feeding is nearly constant at 14.7, but at the case of "with" oxygen feeding is less than that of without oxygen and it is no constant but it fluctuates.

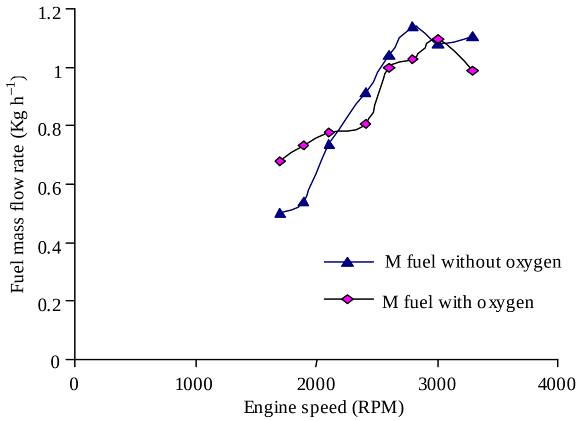

Fig. 1: Fuel mass flow rate vs. engine speed

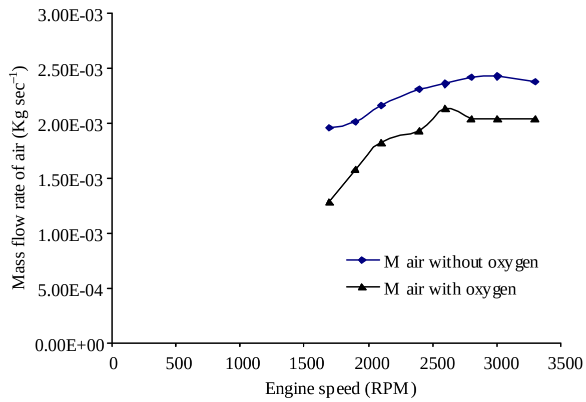

Fig. 2: Mass flow rate of air vs. engine speed

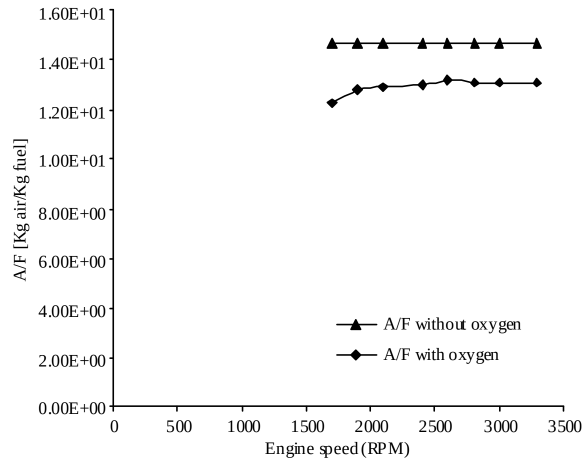

Fig. 3: Air-fuel ratio vs. engine speed

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