An assessment of combustion products of spark ignition engines supplied by ethanol – gasoline blends

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Abstract The causes of environmental pollution by internal combustion engines arise from the use of fuels containing bounded carbon, from the fact that combustion takes place on a cyclic basis and at high temperature. The first and the last causes are directly related to the fuel and therefore there is in principle a possibility to reduce pollution by acting upon the fuel used. The present paper deals with the comparison of the level of combustion products of a spark ignition engine supplied by gasoline and by a mixture of 10% ethanol - 90% gasoline.

1. Introduction
The effects of environmental pollution by internal combustion engines arise from the use of fuels containing bounded carbon, from the fact that combustion takes place on a cyclic basis and at high temperature. The first and the last effects are directly related to the fuel and therefore there is in principle a possibility to reduce pollution by acting upon the fuel used [1].

The researches carried out on the internal combustion engines in terms of conventional or non-conventional (gasoline and diesel oil mixtures) fuels considerably accelerated at the beginning of the 70’s with the world petroleum crisis. The higher prices for crude oil pointed out to the limits of crude oil deposits and also to its strategic importance.

Replacing conventional fuels by non-conventional ones (one fuel or a mixture of more) basically takes into account:
- the resources available
- the impact of the new fuel on the engine
- the price of the conventional/non-conventional fuels
- the influence on the environment protection

The European Union set some targets about renewable energy in short, middle and long terms. Thus, José Manuel Durão Barroso, former president of European Commission unveiled to the European Parliament the Commission’s plans to tackle climate change and to ensure Europe has more secure energy supplies in future. At the heart of the proposed legislation is the principle of “20 / 20 / 20 till 2020”, which means the target:
- 20% increase in energy efficiency,
- 20% cut in greenhouse gases
- 20% share of renewables in total EU energy consumption, all by the year 2020.
The use of biofuels is one of the main actions promoted by the European Union and member states in an effort to tackle global warming, enhance energy security and contribute to regional development.

In the second half of the ’80 the researches were focused on environment protection. The increasing demand for thermal energy by using fossil fuels almost exclusively have caused the greenhouse effect and a highly inadmissible contamination putting the planet’s future at risk.

To limit the negative effects of the environment pollution various international (such as the Rio Agreement) and local initiatives have emerged.

The substituting fuels of fossils origin (synthetic gasoline, methane gas, butane) have less polluting emissions but they are available only in small amounts therefore they fail to provide long-term solutions [2], [3].

Muchmore interest is attached to the fuels obtained from agricultural raw materials. Here again there is a limited possibility of obtaining alcohols (ethanol and methanol) and vegetal oils. Only a small part of the plowing soil can be dedicated to those cultures able to further provide fuels. That is why the vegetal oil fuels cannot be world - wide spread but only locally or regionally developed.

In America vegetal alcohols (ethanol) are experimented while West Europe is focused on vegetal oils.

2. Gasoline – ethanol mixtures

An important group of alternative fuels are the alcohols. Among these, the ethanol is used as alternative fuel for the internal combustion engines where there are raw materials rich in sugar.

A thorough study of the chemical and physical properties of the oxygen organic products highlights both advantages and disadvantages of these fuels as compared with gasoline as regards a spark - ignition engine requirements.

Blending gasoline and alcohols (ethanol, methanol) may result in a class of fuel favorable to the engine [11]. Up to now only two such fuels have been marketed:

- fuel M15 (mixture of gasoline and 15% methanol), in Germany, China, New Zealand
- gasohol E 10 (mixture of gasoline and 10% ethanol), in USA and South America

The methanol is a noxious substance. Ethanol produced from biomass is examined as large - scale transportation fuel. Desirable features include ethanol fuel properties as well as benefits with respect to urban air quality, global climate change, balance of trade and energy security.

The experiments conducted in laboratory have mainly used a mixture of gasoline and ethanol to supply an unmodified spark ignition engine.

When blended with gasoline, the ethanol tendency to separate is much lower than the methanol. The high volatility of the gasoline alcohol mixtures is a significant inconvenient because they cause fuel losses by evaporation [12]. Thus, the temperature of the fuel constant level chamber reaches 50 to 55 degrees during operation and in summer even 80 - 85 degrees. The losses by evaporation of an engine supplied with 10% vol. alcohol and gasoline increases by 90%.

The gasoline - ethanol mixtures behave normally relative to the abnormal detonation combustion also revealed by the increase in their self - ignition temperature. The generally high anti - detonation qualities of the gasoline - alcohol mixtures can be turned into a good account by optimizing the fuel or the engine.As far as the fuel is concerned, the basic gasoline composition (and therefore the fabrication technology) can be maintained. This is extremely important for prevention of the polluting exhaust gases. Using pure ethanol to fuel engines is limited by the need to make significant changes to the fuel supply systems. Since the ethanol caloric power is twice lower than that of the gasoline, a double quantity of alcohol is necessary to reach the same output. Pure ethanol supplying calls for specially designed and manufactured engines.

3. The properties of gasoline and of the gasoline – ethanol blends

We consider the case of a spark ignition engine supplied by gasoline and by a mixture gasoline – ethanol. The quantity of ethanol is maximum 10%, so the construction of the engine should not be modified [6].
Properties of mixtures:

- **Molecular mass:**
  - gasoline: \( \mu_G = 110 \text{ [kg/kmol]} \)
  - ethanol (\( \text{C}_2\text{H}_5\text{OH} \)): \( \mu_E = 46 \text{ [kg/kmol]} \)

Molecular mass of ethanol – gasoline blends:

\[
\mu_{E-G} = z \cdot 46 + (1-z) \cdot 110 \text{ [kg/kmol]}
\]  
(1)

- **Composition:**
  - gasoline:
    \[
    c = 0.855 \begin{bmatrix}
    \text{kg C} \\
    \text{kg fuel}
    \end{bmatrix} \quad h = 0.145 \begin{bmatrix}
    \text{kg H} \\
    \text{kg fuel}
    \end{bmatrix}
    \]  
(2)

  - ethanol:
    \[
    c = \frac{2 \cdot 12}{46} \begin{bmatrix}
    \text{kg C} \\
    \text{kg fuel}
    \end{bmatrix} \quad h = \frac{6 \cdot 1}{46} \begin{bmatrix}
    \text{kg H} \\
    \text{kg fuel}
    \end{bmatrix} \quad o = \frac{1 \cdot 16}{46} \begin{bmatrix}
    \text{kg O} \\
    \text{kg fuel}
    \end{bmatrix}
    \]  
(3)

- **Mixtures composition:**

\[
\begin{align*}
    c &= \frac{z \cdot 24 + (1-z) \cdot 0.855 \cdot 110}{z \cdot 46 + (1-z) \cdot 110} \text{ [kgC/kgfuel]} \\
    h &= \frac{z \cdot 6 + (1-z) \cdot 0.145 \cdot 110}{z \cdot 46 + (1-z) \cdot 110} \text{ [kgH/kgfuel]} \\
    o &= \frac{z \cdot 16}{z \cdot 46 + (1-z) \cdot 110} \text{ [kgO/kgfuel]}
\end{align*}
\]  
(4)

where \( z \) is the percentage of ethanol blended with gasoline: \( z = 0 \div 100\% \)

\( z = 0 \) - fuel: gasoline

\( z = 100\% \) - fuel: ethanol

The use of pure ethanol causes problems, so we consider it can be mixed maximum 10% ethanol with gasoline, named E 10.

4. **The calculus of the chemical combustion products of a spark ignition engine supplied by gasoline – ethanol blends**

The composition of fluid at the last part of burning in spark ignition engine depends on fuel/air ratio, \( \lambda = 0.95 – 1.03 \).

Considering \( \lambda < 1 \) the burn products are: \( \text{CO}_2, \text{CO}, \text{H}_2\text{O}, \text{H}_2, \text{N}_2 \).

The stoichiometric air for 1 kg fuel is:

\[
L_0 = \frac{1}{0.21} \left( \frac{c}{12} + \frac{h}{4} - \frac{o}{32} \right) \begin{bmatrix}
    \text{kmol air} \\
    \text{kg fuel}
    \end{bmatrix}
\]  
(5)

The actual (real) air:

\[
L_r = \lambda \cdot L \begin{bmatrix}
    \text{kmol air} \\
    \text{kg fuel}
    \end{bmatrix}
\]  
(6)

We consider \( M_1 \) [kmol/kg fuel] the mass of reactants and \( M_2 \) the mass of combustion products:

\[
M_1 = \lambda \cdot L_0 + 1/\mu_{E-G} \text{ [kmol/kg fuel]} \]  
(7)

\[
M_2 = M_{\text{CO}_2} + M_{\text{CO}} + M_{\text{H}_2} + M_{\text{H}_2\text{O}} + M_{\text{N}_2} \text{ [kmol/kg fuel]} \]  
(8)
The mass of each product is:

\[
M_{CO_2} = \frac{c}{12} - 0.42 \cdot \frac{1-\lambda}{1+k} \cdot L_o \quad [kmol \ CO_2 / kg \ fuel]
\]

\[
M_{CO} = 0.42 \cdot \frac{1-\lambda}{1+k} \cdot L_o \quad [kmol \ CO / kg \ fuel]
\]

\[
M_{H_2} = 0.42 \cdot k \cdot \frac{1-\lambda}{1+k} \cdot L_o \quad [kmol \ H_2 / kg \ fuel]
\]

\[
M_{H_2O} = \frac{\bar{h}}{2} - 0.42 \cdot k \cdot \frac{1-\lambda}{1+k} \cdot L_o \quad [kmol \ H_2O / kg \ fuel]
\]

\[
M_{N_2} = 0.79 \cdot \lambda \cdot L_o \quad [kmol \ N_2 / kg \ fuel]
\]

(9)

The figures 1, 2, 3 and 4 represent the variation of combustion products according to percentage of ethanol blended with gasoline.

We consider \( \lambda = 0.95 \) and \( k = 0.45 \) for the ratio: \( h/c = 0.17 - 0.19 \)

![Figure 1. Mass of CO2](image1.png)

![Figure 2. Mass of CO](image2.png)
The molar variation of the products and reactants is:

$$\Delta \text{M} = \text{M}_2 - \text{M}_1 \quad (10)$$

According of the percentage $z$ of ethanol in gasoline and of the coefficient fuel/air, we can notice the variation of burning products.

5. Conclusions
The physical and chemical properties of the ethanol are significantly different from those of the conventional liquid oil fuels. An efficient use of alcohols as fuels calls for construction modifications and adjustments to the engine in order to diminish the negative influences and turn into good account the good properties.

That is why, to avoid modifications to the spark ignition engine, the use of the mixture E10 (10 % ethanol - 90% gasoline) is worth being considered.
Using a mixture ethanol – gasoline to fuel the spark ignition engine, a number of positive results are obtained, such as:
- the extent to which heat is saved by using ethanol- gasoline shows that, although the engine efficiency does not increase, supplying two types of fuels to the same engine represents an important research trend;
- the tendency to reduce the effective power at a constant fuel rate as a consequence of the combustion value which is much lower than that of the gasoline;
- the decrease of level of combustion products when using ethanol - gasoline indicates that the future belongs to those engines able to operate while protecting the environment, the atmosphere, i.e. life.

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