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EXPERIMENTAL RESEARCH CONCERNING THE INFLUENCE OF THE ON-BOARD HYDROGEN SUPPLY EQUIPMENT ON THE ENGINES COMBUSTION

Marius Nicolae MOLDOVEANU*, Cornel ARAMĂ**

*Sunrise Technology Co. Ltd, Jiaxing, Zhejiang, China,
** "Henri Coandă" Air Force Academy, Brasov, Romania

Abstract: *The rational use of fuels and the decreasing of IC (Internal Combustion) engines pollution are fundamental requirements which were globally emphasized by the traffic authorities. As a transition solution to the propulsion system which is nowadays named "unconventional" but, at the same time, as a viable possibility to improve the IC engines performances of the future HV's (Hybrid Vehicles), some researchers suggest the solution of Semy-Hybrid hydrogen fuelling system. This study is included in the same activity area but it has to be mentioned that the researchers have begun from a different idea: the hydrogen is not "the real culprit" for the positive results which were sometimes reported. The key of problem is a substance which is fully presented but it was neglected by the majority: the nitrogen.*

Keywords: *Semy-Hybrid vehicle, nitrogen, nitro-hydrogen additivation, Pre-Combustion Treatment Technology (PCTT)*

1. INTRODUCTION

The rational use of fuels and the decreasing of IC (Internal Combustion) engines pollution are fundamental requirements which were globally emphasized by the traffic authorities. Due to these, the OEM's invest more and more resources. The HV's (Hybrid Vehicles) and first of all the EV's (Electric Vehicles) are remarkable developing in the last years. Unfortunately the global economic crisis influenced this process negatively and partly stopped it before some aspects (which had decreased the costumer's interests: the acquisition price, the limited range, the technological constructive difficulties etc.) to be solved.

As a transition solution to the propulsion system which is nowadays named "unconventional" but, at the same time, as a viable possibility to improve the IC engines performances of the future HV's, some researchers suggest the solution of Semy-Hybrid fuelling system. These fuelling systems are based on the on board hydrogen supply equipment. All of them insist on the unquestionable positive effects of the hydrogen use together with conventional fuels (first of all, gasoline and diesel fuel).

Unfortunately, the researchers who were interested in the scientific study of these kinds of fuelling systems (which are sometimes named Semi-Hybrid) have noticed that the results from the tests were contradictory in too many situations and in the end, the energy balance was a negative one.

The aim of this paper is to explain why this phenomenon is happening and to try to explain how it is possible that the use of hydrogen does not have a positive effect on the fuel consumption and on the IC engines pollution for all the working conditions…

2. GENERAL RESEARCHES TRENDS IN THIS DOMAIN

Hydrogen as a fuel for automotive IC engines has had a long history of study in the academic and industry area. The properties that contribute to its use as a combustible fuel are well known: wide range of flammability, low ignition energy, small quenching distance, high auto ignition temperature, high flame speed at stoichiometric ratios, high diffusivity and very low density. Nowadays, the main researches are focused on using it as independent fuel or in developing the fuel cells. In this paper it is going to be discussed the situation of the IC engines which are using the conventional fuel enriched with hydrogen.

The use of hydrogen as an additional fuel to gasoline has been considered since the early '70, the alternative to the full hydrogen powered engine. Relying on its characteristics, all the producers or commercial firms advertise for their on-board hydrogen system gadgets because, from their points of view the Oxy-Hydrogen gas (the mixture called HHO, Aguygen gas, Brown gas, Hydroxy or EEW-Electrically Expanded Water) obtained from water electrolysis may improve the combustion's chemicals reaction and also increase the water formation as by product of combustion.

This work, which was performed at JIAXING SUNRISE TECHNOLOGY CO. LTD is included in the same activity area but it has to be mentioned that the researchers have begun from a different idea: the hydrogen is not "the real culprit" for the positive results which were sometimes reported. **The key of problem is a substance which is fully presented but it was neglected by the majority: the nitrogen**.

3. EXPERIMENTAL DETAILS/ NITRO-HYDROGEN ADDITIVATION

For our situation, the IC Engine seen as a thermodynamic and thermochemistry system looks as in figure 3.1.

Note: the other components from the air were neglected because of lower percentage and the low influence on the combustion.

Nitrogen is essentially chemically neutral and does not react in the combustion process. Its presence, however, does affect the temperature and pressure in the combustion chamber. This is a general statement of the researchers in the IC engines. But, in case of On-board electrolyzers the situation could change radically.

The nowadays situation:

The lean-burning nature of diesel engines and the high temperatures and pressures of the combustion process result in significant production of Nitrogen oxides, and provide a unique challenge in reducing these compounds. Modern on-road diesel engines typically must use selective catalytic reduction to meet emissions laws, as other methods such as exhaust gas recirculation cannot adequately reduce NO_x to meet newer standards in many jurisdictions. However, the fine particulate matter (sometimes visible as opaque dark-colour smoke) has traditionally been of greater concern in the realm of diesel exhaust.

Actual pollution reduction technologies are sophisticated (and expensive): electronic injection systems correlated to various sensors and coordinated by ECU (Electronic Computer Unit) corroborated with EGR (Exhaust Gas Recirculation) systems, DPF (Diesel Particulate Filters), catalysts systems and DEF (Diesel Exhaust Fluid) (commonly referred to it as AdBlue).

A new approach of the emissions problem was highlighted by US Department of Transportation report from 2007: "*Onboard electrolyzers are used with hydrogen injection systems for diesel engines. In this case, only a small amount of hydrogen and oxygen is produced to supplement, not replace, the diesel fuel used in the engine. The electricity to operate the electrolyzer is typically supplied by the engine's alternator or 12/24-VDC electrical system*".

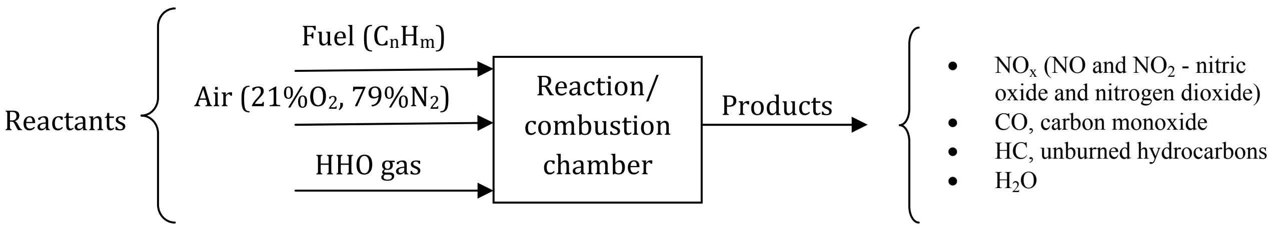

Fig. 3.1 The IC Engine seen as a thermodynamic and thermochemistry system

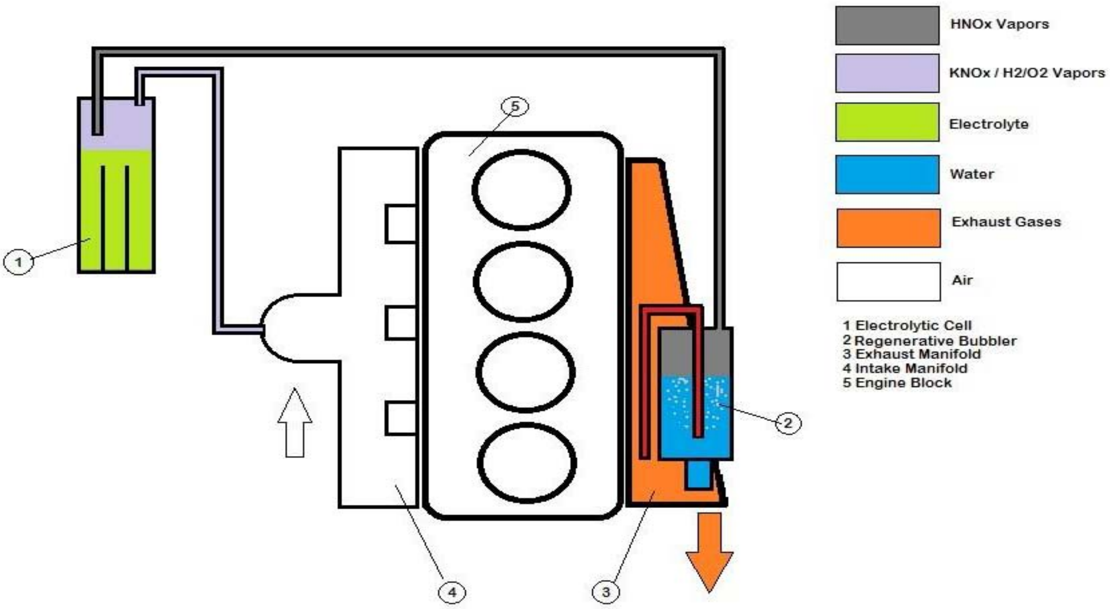

Fig. 3.2 The Pre-Combustion Treatment Technology (PCTT)

Oxy-Hydrogen (the mixture called HHO) obtained from water electrolysis may improve the combustion's chemicals reaction and also increase the water formation as by product of combustion. Water will be converted into steam and that act as carbon deposits cleaner and enhance the pressure on the explosion stroke. The addition of HHO is effective technology but is limited to efficiency of the system, the type of engine and operational parameters.

In conclusion, all the technologies in use are applied as a post combustion phase as passive methods or involve extra energy to operate (in case of HHO methods). Post combustion methods are expensive and resource consuming. NO_x and unburned particulates generation and reduction mechanisms are opposite and achieving both results require a complex system. None of them are designed to solve the main pollution problem: actual engines park!

The Pre-Combustion Treatment Technology (PCTT):

Considering the facts that diesel engines already produce Nitrogen Oxides and the addition of HHO increases the temperature and this fact creates conditions to produce NOx, an active method called **Pre-Combustion Treatment Technology** (PCTT) was developed in order to reduce both NO_x and soot – particulate matters - from exhaust gases. A combination between HHO generator and a regenerative bubbler (RB) were used as it can be seen in figure 3.2.

The RB is fixed to exhaust manifold and use the EG (Exhaust Gas) temperature to warm up the water content where a small amount of EG is bubbled then transferred to HHO cell. The alkaline type Oxy-Hydrogen generator (an electrolytic cell) produces the HHO gas and water vapors, contaminated with electrolyte (usually KOH).

The Regenerative Bubbler contains water which is bubbled a small amount of EG in order to produce HNO_3 (nitric acid). As it is well known, the nitric acid is one of the strongest inorganic (mineral) acids. It is, at the same time, in pure state or concentrated, a very powerful oxidant. The nitric acid is very toxic, very corrosive and it can destroy different materials which get in contact with it (from the weaves to the metals). The nitric acid is very used in explosive industry where it is one of the most important substances. An example: the nitro-glycerine and other explosive substances are obtained by nitration.

Combined, the oxidant KNO_2/HNO_3 and extra H_2 and, in some conditions, ammonia, NH_3, is generated in a Oxy-Hydrogen rich flow of mixed steam. In terms of energy conservation our technology is synergetic and regenerative since the use of the elevated exhaust gases temperature to increase water temperature, induces the conditions of NO_x reaction and produces supplemental steam, then using a chemical reaction to neutralize both KOH and HNO_x vapors to almost neutral pH salt KNO_x. Oxy-Hydrogen positive effect is enhanced by Nitrogen’s chemical reaction and the presence of extra volumes of water in the form of steam.

In short, for this situation, the chemical reactions are:

$$2H_2O = 2H_2 + O_2$$
$$2H_2O = H_3O + OH$$
$$3NO_2 + H_2O = 2HNO_3 + NO$$
$$4NO + 6H_2O = 4NH_3 + 5O_2$$
$$2NO + 2KOH = 2KNO_2 + H_2$$
$$HNO_3 + KOH = H_2O + KNO_3$$

The bubbler is shown in figure 3.3 and the electrolytic cell in figure 3.4.

Fig. 3.3 The bubbler

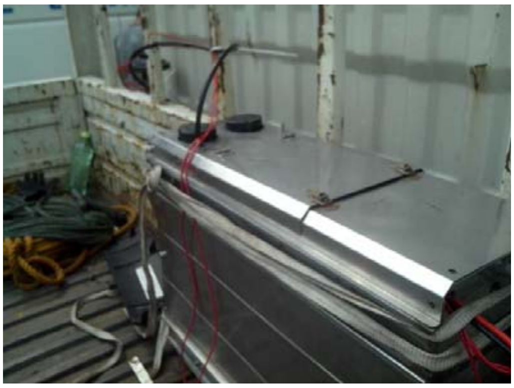

Fig. 3.4 The electrolytic cell

Preliminary results/conclusions:

The equipment based on the water ionization/electrolysing in order to produce the HHO gas and which has been made so far for decreasing the fuel consumption and pollution are not the final solution. The effects sometimes positive are due to some complicated chemical reactions which are produced (or they should be produced) in the combustion chamber as a result of captive fire gases (which resulted from the former combustion cycle or captured with the support of EGR) and mainly due to the different forms of water which followed the electrolyse gas. This is the reason why the dry electrolyse gas does not have significant effects.

The oxy-hydrogen which was produced by the used generator provides steam and gases with ammonia smell due to some volumes of the reactive nitrogen which are in the exhaust gases. When salt water (NaCl) was introduced in equation, powerful explosions appeared into bubbler despite of lack of ignition source which could explain the phenomenon (note: into the bubbler is a mixture of oxygen and hydrogen which is flammable but with the condition of existence of ignition source). These explosions destroyed the bubbler. A possible explanation: it is known that the gaseous ammonia has sometimes a violent reaction with the chlorine. In this situation, the gaseous ammonia inflames and the result is a fog consisting of ammonium chloride as it can be seen in the next chemical equations:

$$2NH_3 + 3Cl_2 = N_2 + 6HCl$$
$$6NH_3 + 6HCl = 6NH_4Cl$$

Another possibility to create a supplementary engine torque is forming ANFO mixtures (*ammonium nitrate-fuel oil* - blasting agents representing the largest industrial explosive manufactured, in terms of quantity, in the United States) by nitration of engine lube oil and the ANFO detonation with the support of hydrogen produced by the electrolysing on-board equipment.

4. CONCLUSIONS: POSSIBILITIES TO DEVELOPE THE ON-BOARD HYDROGEN SUPPLY EQUIPMENT TOGETHER WITH SOME ORIGINAL AUXILIARY INSTALLATIONS

Briefly, the main developing directions for this area are shown in Table 4.1.

The situations 2, 3, 4 and 8 are the current on-board hydrogen supply equipment. In this case A, B, E and G are obtained. The former HHO supply plants are shown in 1, 3 and 8 cases. These had a lower efficiency to produce hydrogen but they had high water volumes. In these situations A, B, C, E, F and G can be obtained. Nowadays, the situations 2, 3, 6 and 8 are tested. The water injection system (situation 9) has good results and it can work with the possibilities 2 ,3 and 6.

The hydrogen cannot be used as a simple engine fuel only if it is in high volumes which are impossible to be produced on-board. Moreover, it is not more efficient than classic hydrocarbons (because of generation difficulties) and it is very dangerous in exploitation. It is unlikely for a distribution network to be realised soon in order to solve the problem of "hydrogen economy".

As a final conclusion, the fundamental paradigm (general conception) changing, the use of nitrogen from the environment air, of the water and some chemical substances cheap and abundant as ingredients in the combustion chamber in order to obtain explosive substances could ensure a slower and more efficient transition to "electrical economy".

Table 4.1

Possibilities:		It could be obtained:	
1	The water electrolysing with acid electrolyte	A	Ionized water
2	The water electrolysing with alkaline electrolyte	B	Oxygenated water
3	The combustion chamber residual EG use	C	Nitrogen acids
4	The EGR (if it exists) exhaust gas use – without bubbling	D	Ammonia
5	The EG use by building of EGR type route – without bubbling	E	Nitrogen salts
6	Using of a bubbler for the recovered EG	F	Hydrocarbon nitrates
7	The using of additives or fuel mixtures or/and lube oil which could be nitrated	G	Gas hydrogen, gas oxygen – HHO (the name adopted in this situation)
8	The water injection into combustion chamber		
9	The water and different additives injection		

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