Syngas Makes any Vehicle Green

Hydrogen vehicle without hydrogen

Objective:

The commercial introduction of simple, cost effective technology for the improvement of air quality in urban areas and reduction of greenhouse emissions caused by automobiles with engines equipped with spark ignition system.

Background:

At the present, motor transportation reminds one of the main sources of air pollution in cities despite strict regulations that limit toxic emission introduced in many countries and significant technical advances in engine technologies. The present level of fuel consumption and engine emission index remains very high. The traditional method for reducing toxic emissions from engines involves the use of expensive catalytic neutralizer, providing CO afterburning and reduction of nitrogen oxides (NO_x) in car exhaust system. Expensive three-component, containing platinum-group metal catalysts, increases the price of a car and reduces the engine efficiency. Besides, a catalytic neutralizer cannot help lowering the carbon dioxide emission level. In other words, today's methods to reduce toxic emissions are aimed at combating the consequences of the main shortcoming of fuel combustion in the engine – its inability operating on lean air – fuel mixture. The mixture of air – fuel leaner than 1.3 to stoichiometric value is not ignited by a spark. Simultaneously burning leaner mixtures increases the formation of NO_x.
It is well known that the addition of a small fraction of hydrogen to a main fuel of Internal Combustion Engine (ICE) leads to its even operation on lean mixtures. The presence of hydrogen also reduces the formation of NO_x. The problem is how to get hydrogen on board of a vehicle. Certainly it is possible to store hydrogen in high-pressure gas-cylinder but there is no infrastructure for hydrogen refills and a car using two fuels is not convenient for user. Another possibility open to natural gas fueling cars is the so called hythane, a mixture of methane and hydrogen, also has a disadvantage – hydrogen methane proportion fixed in fueling station and cannot be changed for optimization of engine operation in different load.

Solution:

The most promising area is to use hydrogen generated on-board of the car as an additive to the prime fuel in internal-combustion engines. This approach significantly improves both the economic and environmental characteristics available for transportation. For this purpose some units for generating hydrogen-containing gas from almost any source fuel have been developed. The application of novel nano-structured catalytic systems and innovative structural concepts made it possible to design a simple and small-sized device for on-board hydrogen generation from the fuel consumed by a vehicle's own engine.

To date, the time it takes for the catalyst to start has been a delaying factor, but significant improvements have been developed by the Russian scientists. The catalyst can be warmed up from room to operating temperature level (600^{o} C) in 10 seconds as opposed to 30 plus seconds with previous devices. When hydrogen containing gas is added, an automobile primarily designed to meet Euro-2 Standard becomes superior to Euro-4 Standard parameters without catalytic neutralizer and enables a saving of more than 20% of fuel in town drive. Further projects expect to examine methods to neutralize the toxicity of powerful diesel engine emissions and to improve the ecological properties of gas turbines.

This approach represents a good alternative to fuel cells technology before it became cost competitive, due to very simple and inexpensive technical solution, and to use of hythane fuel because there is no need for development of hydrogen supplying infrastructure.

The most appropriate method for onboard synthesis gas generation is using catalytic reactions of partial oxidation of natural gas or autothermal reforming of liquid hydrocarbon fuels. In the last five years, considerable amount of R&D works on this problem has been performed by a number of partnering Russian institutes: BIC (Novosibirsk), VNIIEF (Sarov), OAO "ZMZ" (Zavolzh'e), OOO "Gazomotor-R" (Rybinsk). The partners developed catalysts, tested a number of pilot on-board syngas generators and a computerized control system adapted for "Gazel" minivan (Fig. 1).

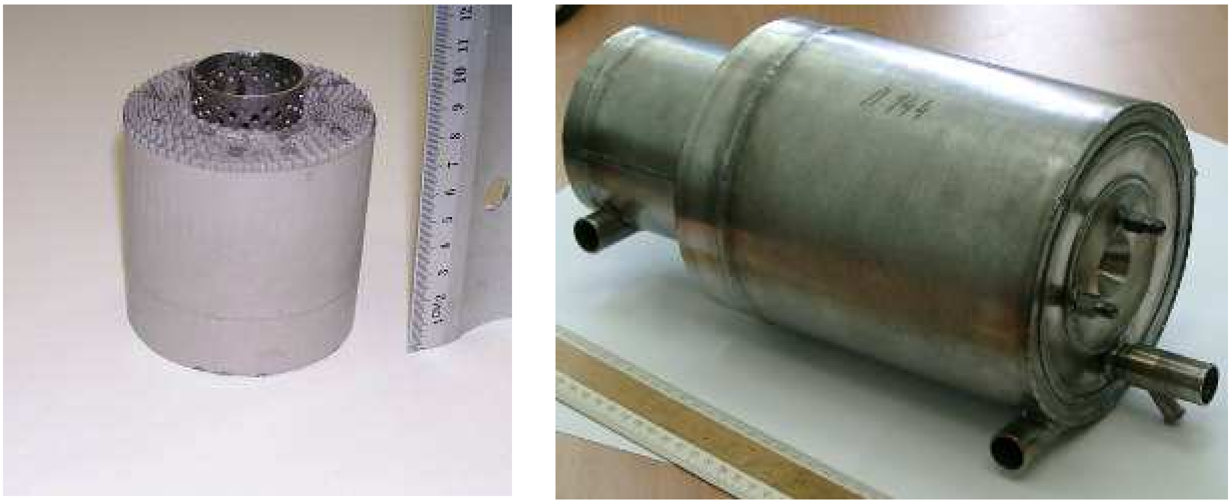

Fig. 1. General view of catalyst (left) and on-board synthesis gas generator (right)

In 2001-2004 bench tests of Russian cars VAZ-2111, -2114, and M406(Volga) engines fuelled by gasoline with the additives of synthesis gas generated by the reaction of partial oxidation of natural gas in experimental catalytic reactor were performed. The tests proved feasible the stable operation of the engines fed by lean gasoline-air mixture enriched with synthesis gas additives. The tests show gasoline saving of 42% in idle and up to 24% in partial load regime. Considerable decrease (by a factor of 10-15 in idle mode) of CH and NOx emissions was observed in these experiments.
In 2007-2008 BIC, VNIIEF and OOO "Gazomotor-R" equipped a pilot minivan "Gazel" with on-board syngas generator (Fig. 2 a,b,c) and tested its performance where data of engine tests was confirmed.
The data of 1800 km road tests –rally Moscow – St. Petersburg – Moscow, organized by Gazprom, presented in Table 1.

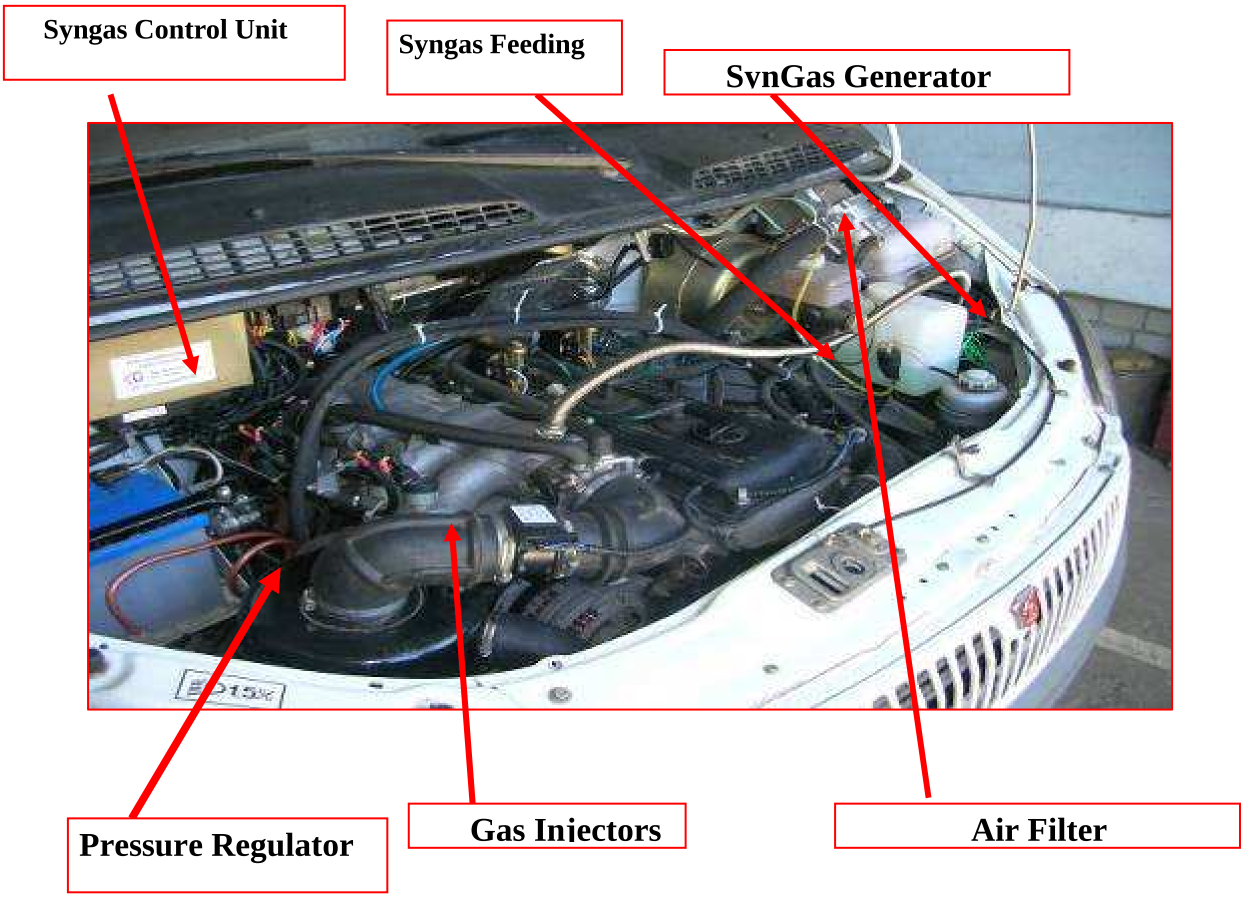

Fig 3a. Arrangement of on-board syngas generator and engine operating components under engine cowling

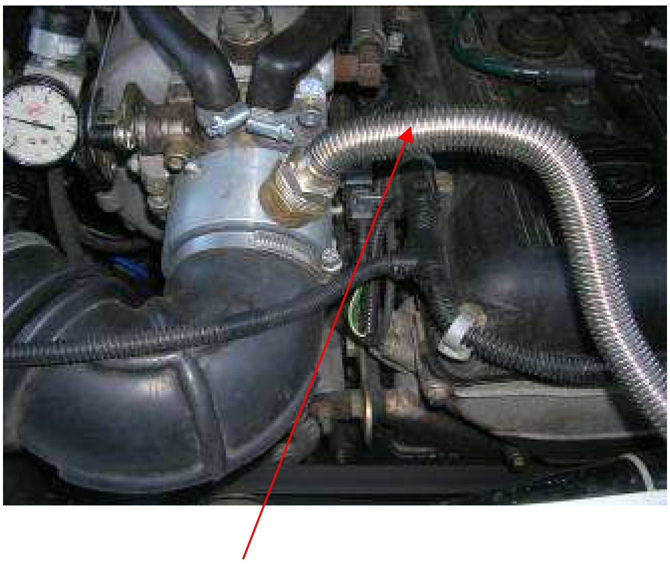

Fig.3b Synthesis gas supply into engine

Fig. 3c. Synthesis gas control unit

Table 1. Road Testing Results of Vehicle with on-Board Syngas Generator

Emission	Gasoline	Natural Gas	Natural Gas +Synthesis Gas	Euro-3 Standard (max)	Euro-4 Standard (max)
CO, g/km	1.56	1.92	0.81	5.22	2.27
CH, g/km	0.16	0.16	0.045	0.29	0.16
NOx, g/km	0.97	0.47	0.107	0.21	0.11
CO2, g/km	308.0	232.7	200.4	-	-
Fuel consumption, per 100 km	11.5 litre	10.5 m3	8-9 m3	-	-

The test results clearly show fuel saving and emission decrease when singas is used as an additive to the main fuel.
So, the bench and road tests proved reliably that syngas additives to liquid and gaseous feeding fuels for spark ignition ICE facilitate considerable decrease of carbon and nitrogen oxides emissions.

Conclusion

Simple and inexpensive technology that makes any car with spark ignition engine green was developed.
To equip the car with this system you need:

1. Singas generator (fuel reformer), this is a device that produced hydrogen reach gas from hydrocarbon fuel. The composition of syngas can be different, depends on fuel and method of conversion. For methane converted by partial oxidation syngas contains 34% of H_2, 16% of CO, and N_2 + CO_2 – balance. The size of reformer varies on engine volume and typically is from 1 to 3 liters. Estimated cost of production is not exceed $500;
2. Fittings to connect generator to fuel line, car cooling system, and air line to engine for syngas injection;
3. Additional air filter and blower for air supply of generator;
4. Controller of syngas generator linked to main engine controller and corresponding software;
5. No other changes are needed.

The complete set of above listed equipment exists at the moment only for Russian made car “GAZEL” but could be developed for any other type of car.
There is also a number of laboratory proved solutions that could further increase a value of this technology for user. There is a list of most developed one.

1. Universal catalyst that can be used for any of existing fuel. Next step is development of a system that automatically recognizes the fuel or their mixture and adjusted to optimal regime control system
2. Use of biofuels for syngas generation as a secondary fuel of comprehensive car, that will lead to oil based fuel saving and optimal use of biofuel.

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