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- FISITA WORLD AUTOMOTIVE CONGRESS, BARCELONA 2004 -

TITLE:

EXPERIMENTAL STUDY OF PLASMA REFORMER FOR DIESEL EMISSION CONTROL

Topic:

- ○ FUTURE AUTOMOTIVE TECHNOLOGY
- ○ INTELLIGENT TRANSPORTATION SYSTEMS
- ○ USER FRIENDLY AUTOMOBILE
- ○ ADVANCED PRODUCTION AND LOGISTICS
- ● VEHICLES & THE ENVIRONMENT

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National Society: ● YES ○ NO

Name of the National Society: KSAE

Abstract:

In this paper, a new plasma system is introduced to generate hydrogen-rich gas for decreasing pollutants from diesel engine and for other applications. Plasma boosts partial oxidation reaction that reforms hydrocarbon fuels into hydrogen-rich gas.
As a source of non-equilibrium plasma, we used a low current plasma reformer with convective cooling of electrodes. We gauged the gas composition in reforming gas by GC-TCD, concentration change of hydrogen as a variable functions. This plasma reformer could be on-board system with diesel engine.
Potential applications: NOx absorber catalyst regeneration, HC SCR aftertreatment, and operation of diesel engine on air-fuel mixture with hydrogen admixtures.

Place / Date:

Incheon, 11/02/2004

INTRODUCTION

The motivation of many modern researches in the development of advanced engines lies primarily in the field of lowering exhaust emissions. For diesel engine, the main problem is strong emission of NOx and PM(Particulate Matter). The problem of lowering the pollutants in diesel engine exhaust is very important for the city traffic conditions. These pollutants, especially PM, influence badly on the ecological environment and very harmful for inhabitants and surrounding nature.

During the last decade, there was an abundance of various efforts to utilize some alternative fuels for diesel engine(1). Many studies were also developed to use hydrogen for vehicle systems. The development of the plasmatron system of lowering exhaust emissions is proposed in this project, namely by starting and operation of diesel engine on air-fuel mixture with hydrogen admixtures. In additional it helps to heat the catalytic converter by ecologically pure combustion products at cold start. These products are generated due to the partial substitution of diesel fuel by hydrogen.

The advantages of hydrogen as a fuel for diesel engine are quite evident, in the view of the elimination of PM, CO, NO_x and HC emissions in the exhaust. The necessary modifications on the diesel engine seem not to be too difficult. However, the efficient and ecologically compatible production and the on-board storage problems prevent from the development of the hydrogen fuelled car in the nearest future. The utilization of hydrogen admixtures to the commercially available fuels would allow to increase the thermal efficiency of engine, reduce the cyclic variability and therefore to utilize the lean mixtures(2). The excessive oxygen in the combustion products will contribute to the complete combustion up to CO_2 and H_2O and eliminate PM, CO and unburned HC in the exhaust. Decreasing combustion temperature will significantly reduce the NO_x formation.

Compact plasmatron fuel converter has the features that are suitable for on-board production of hydrogen for both fuel pretreatment and for exhaust aftertreatment applications. Compact plasmatron fuel converter has shown the efficient reformation of natural gas, gasoline, diesel and hard-to-reform biofuels into hydrogen rich gas (H_2 + CO). Recent developments in compact plasmatron reformer designed at PSFC, MIT(USA) have resulted in substantial decreases in the value of the electrical power requirements. These new developments also increase the lifetime of the electrodes(3).

THE AIM OF THE RESEARCH AND THE EXPECTED RESULTS

This project is intended to develop the hydrogen assisted system for reduction of diesel exhaust pollutions, especially NOx and PM. Special plasma device, plasmatron, would decrease the need for catalytic converters or would be used with DPF(Diesel Particulate Filter) – absorber catalytic reactor for controlling and reducing emission from diesel engines, and for increasing working life of a catalytic reactor.

The offered plasma device doesn't have existing analog. The basic construction difference of new generation plasmatron is the followings: a) in absence of the water cooling system, or using a combined cooling system, b) using of special thermal protection of the cathode for increase electrode life, c) in absence of constructive changes in an existing design of internal combustion engine. This project implies to develop the new type plasma devices (plasma fuel converters and source of the electrical power supplies) and investigate the characteristics of plasmatron on the stand with diesel engine. The regimes of ignition and combustion of mixtures of hydrocarbon fuels with different amount of hydrogen admixtures will be studied. The composition of combustion products as a function of hydrogen amount will be determined. The optimal regimes for the reduction of concentrations of NOx, PM, CO, and unburnt hydrocarbons formation in the exhaust gas will be determined. On the base of obtained results the next items will be developed by the recommendation for the future design of more effective construction of the hydrogen assisted system for commercial diesel engine used in common practice in Republic of Korea for reducing NOx, PM and other pollutants to the applicable standard. It is expected that the concentration of NOx and of PM in the diesel engine exhaust will be reduced up to 10-30 times than the normal diesel engine.

APPLICATION EXAMPLES OF PLASMATRON FUEL CONVERTER

Low emission engine concept

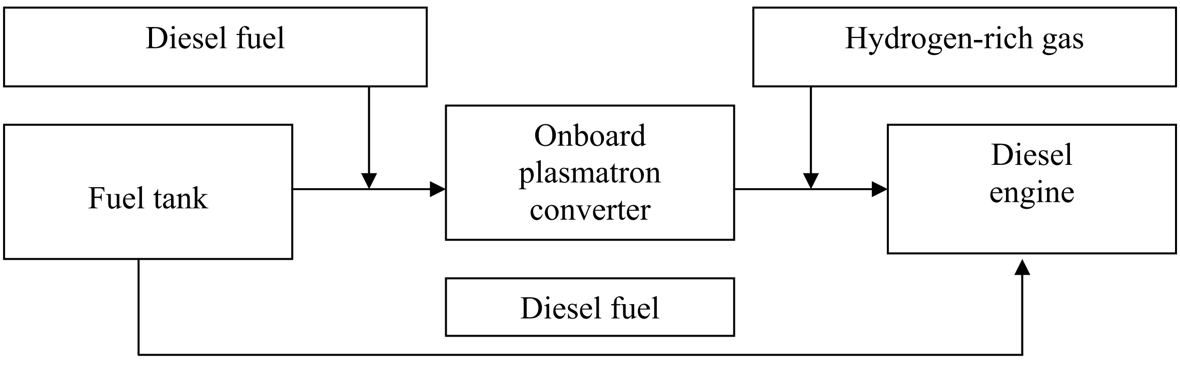
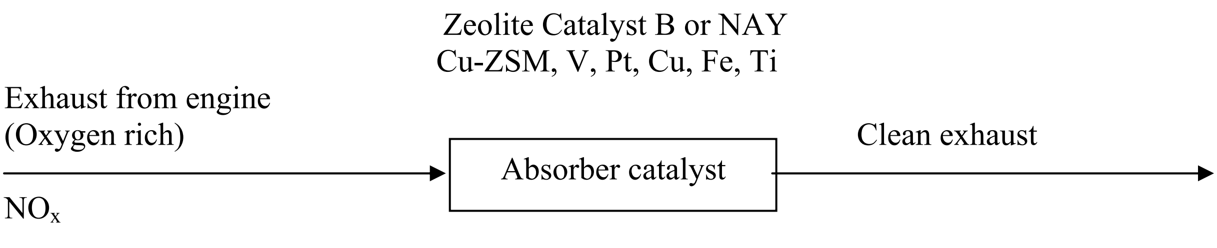
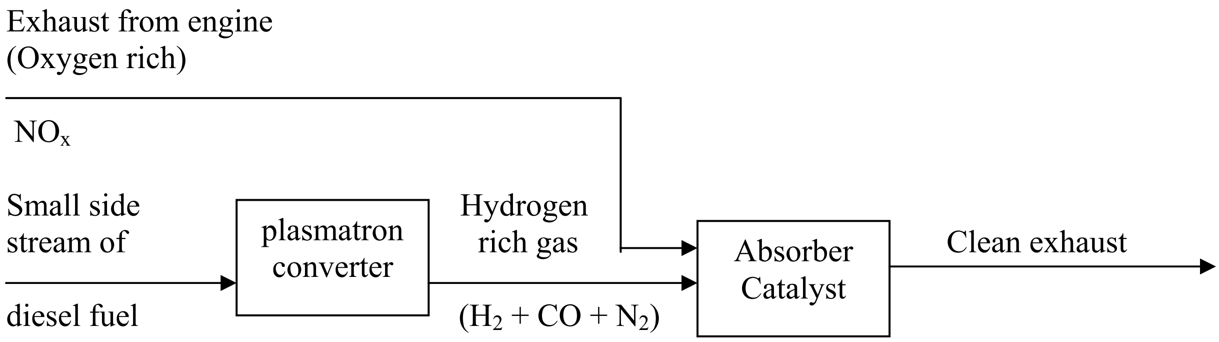


Fig. 1. Application of plasamtron for hydrogen-premixed diesel engine

Converter-Exhaust Catalyst System



(a) Normal operation



(b) Regeneration

Fig. 2. Application of plasmatron as aftertreatment of diesel engine exhaust

EXPERIMENTAL RESEARCH OF DECOMPOSING OF DIESEL FUEL IN COLD NON-EQUILIBRIUM PLASMA OF A HIGH-VOLTAGE SPARK DISCHARGE

Description of the trial type

The general view of the trial type is shown in Fig. 3.

Fig. 3. A general view of the installation

The installation consists of plasmatron, extension reactor, cooling chamber, high-voltage discharge power supply, and flow meter for both fuel supply and air. Microplasmatron(Fig. 4) consists of an anode (steel, cone-shaped form), cathode (automobile suppository), chamber of submission of a fuel mixture.

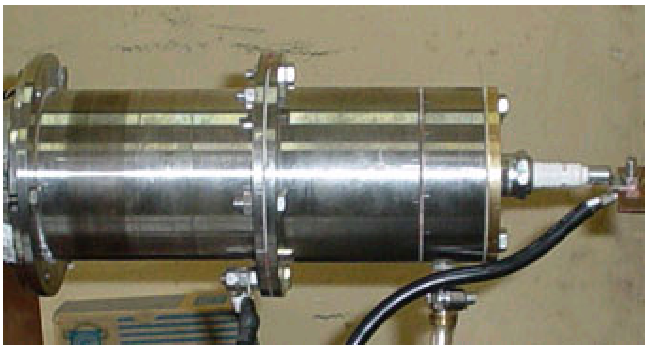


Fig. 4. A plasmatron with the extension reactor

The size of a plasmatron with the extension reactor - diameter of 114 mm, length of 275 mm. The central welding rod (cathode) was used of two kinds:
-The standard spark plug such as CHAMPION (RN9YC4) with the external electrode, cut off on 12 mm. Diameter of a central electrode -2,6 mm, length of -1,5 mm. The resource of activity of such welding rod at operating current 2-3 A has compounded ~ 30 minutes.
In Fig. 5, the central electrode before activity is shown, and in Fig. 6, the electrode after destruction.

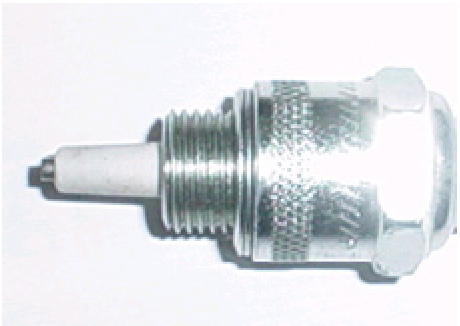


Fig. 5. A central electrode before activity

Fig. 6. A central electrode broken after activity

- The standard spark plug such as CHAMPION (RN9YC4) with the isolator, cut off on 6 mm, on a central electrode, on which one is wound a central electrode from copper. Diameter of central electrodes -10, 11, 12 mm, length of -35 mm.

In Fig. 7, the central electrode after 60 minutes of activity didn't have any problems. The tracks of spark discharges are visible.

Fig. 7. A central copper electrode after 60 minutes of activity

In Fig. 8, the central copper electrodes after 60 minutes of activity of each electrode with operating current 2-3 A. are shown.

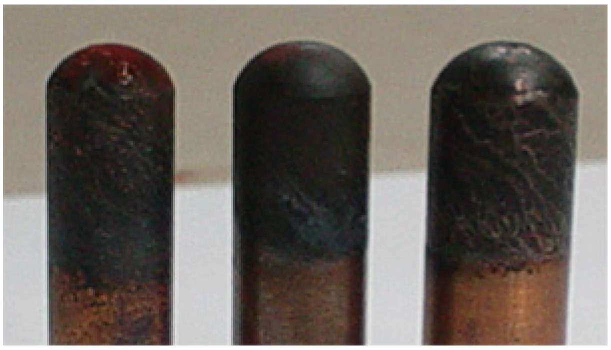


Fig. 8. Central copper electrodes(From left to right, diameter 10, 11 and 12 mm)

As it is visible, all welding rods uniformly are coated with products of decomposing of diesel fuel, that speaks about an enough good center-of-gravity position of welding rods despite of a rather small interelectrode gap (diameter of mouth of an anode - 14 mm).

Power supply consists of a voltage regulator 220/220 V, high-voltage transformer 220/1000 V, high-voltage rectifier with the ballast condenser $20*10^{-6}$ F (2000 V), magnetic throttle, system of pulse high-voltage initiation of discharge (~ 3000 V), the control equipment's and are provided with working constant voltage up to 1000 V at a current up to 5 A.

In Fig. 9, the representative oscilloscope waveform of voltage on a discharge gap of a plasmatron is shown.

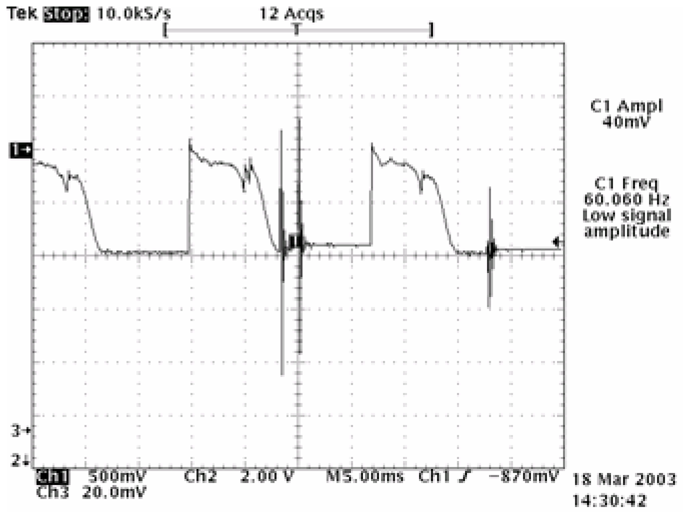


Fig. 9. The representative oscilloscope waveform of voltage

The test of a plasmatron with different electrodes are proceeded. The copper electrodes a diameter 12, 11 and 10 mm were used. Most stable operation the plasmatron demonstrates with electrode a diameter of 12 mm and constant fuel flow ~ 1-2 ml/s.

Table 1 shows the concentration of several gas reformed by plasmatron. For analyzing the concentration of hydrogen, GC-TCD(HP6890) was used. In this table, hydrogen increases according to the increase of applied current.

Table 1. Gas concentration reformed by plasmatron in different applied current
(air: 100 l/m, fuel: 1 ml/sec, 2A, 800V)

	Concentration (%)							
Current(A)	H_2	CO_2	C_2H_6	C_2H_4	O_2	N_2	CO	CH_4
2	8,55	7,50	2,87	0,09	1,30	69,84	7.62	1.52
3	9,51	6,78	3,21	0,10	1,34	67,63	8,57	1,79
4	10,29	7,02	3,37	0,12	0,89	67,01	8,25	1,87

CONCLUSION

Plasma-assisted fuel reforming could be a promising way to control diesel engine emission in the future. For developing on-board plasmatron system, the basic characteristics of plasmatron were studied. In reformed gas, there are H_2, CO_2, C_2H_6, CH_4, O_2, N_2, CO, etc. Hydrogen generation by plasmatron is due to partial oxidation process. We could utilize this reformed gas into diesel engine as on-board system.

Appendices

None

References

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(3) Bromberg L, Cohn DR, Rabinovich A, Heywood J, "Emissions reductions using hydrogen from plasmatron fuel converters", J,Int.Hydrogen Energy 26, 1115-1121, 2001