

Exhaust Cleaning with Dielectric Barrier Discharge

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The regulations of diesel exhaust emissions become stricter, so intensive. The present work continues our investigations on engine emissions treatment with discharges assistance^{1,2}. We designed variations of greed shaped DBD plasma sources in order to reduce the NO_x content of a diesel engine exhaust, testing it on the different engine operation modes. Discharge frequency has a crucial impact on equipment performance and gas treatment. The plasma source supply frequency was varying from 400 Hz to 28.5 kHz. A 95 % decreasing of NO and 70 % reduction of NO_x was obtained. It was found that the discharge application increased efficiency of carbon particles removing 1.4 times.

Keywords: DBD, plasma, Exhaust gas.,

1. INTRODUCTION

The regulation of diesel exhaust emissions became strict, so investigations of exhaust treatment using plasma became more intensive [1,2].

In plasma treatment, typical discharge system [3] can be considered as long-life devices with low maintenance service necessary. Also it is finely controllable and it has possibility to efficiently use feedback. These features make using electrical discharge more attractive. But the insulation problems because of using of high frequency and special form of signal make it difficult to apply in vehicles.

In the present work we tested a direct DBD (dielectric barrier discharge) treatment of the diesel exhaust. We studied the discharge configuration, power and frequency effect on harmful content of diesel emissions.

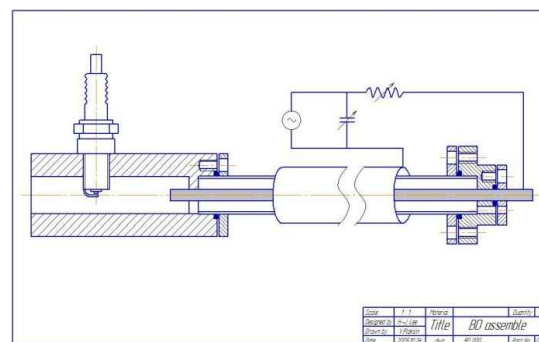


Fig. 1 DBD chamber with gas supplying system .

Among the kinds of discharge we selected for investigations the volume DBD with planar and cylindrical shapes.

2. EXPERIMENT

2.1. Treatment the model Gas using Axial DBD

We studied an influence of the DBD on the gas composition with several dischargers. The diagram of the first one is presented on the Fig.1. In this case, we used at frequency 28.5kHz and 1kHz. The principal part is the quartz pipe (inside diameter 17 mm) with adjoined to outer grounded electrode and internal electrode (6 mm in diameter). The width of the outer electrode was varied.

Initial experiments were made with model gas simulating the diesel exhaust. It consist mostly of N₂ with an addition of O₂ 0-15% and NO about hundreds of ppm.

2.2. Treatment of the model Gas Using Multilayer DBD

In this experiment we used another DBD configuration (Fig. 2). Electrodes with deposited ceramic insulation were disposed in parallel to each other. Ground and potential electrodes were alternated

The system on the Fig. 2 we used at frequencies 0.4, 1, 10 kHz. A half of electrodes were connected to the casing. For this experiment the function generator with sound amplifier (EUROPOWER EP2500) and self made transformer was used. At first, these experiments were made with the model gas. In all series of experiments described in this section the supplied gas composition was: oxygen – 20.3 %, NO – 200 ppm, NO₂ – 0, N₂ – balance gas.

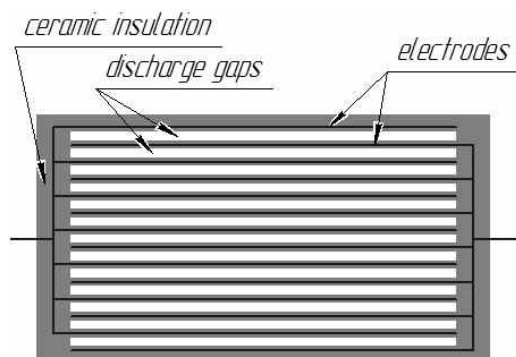


Fig. 2 DBD chamber with parallel electrodes (Multilayer discharge).

In the exhaust cleaning experiments, the grid was placed inside of metal housing imitated a part of Diesel Oxidation Catalyst (DOC) or Diesel Particulate Filter (DPF). A half of electrodes were connected to the housing.

In this experiments, we used diesel engine (KDE16 T3) that is water cooled 4cycle 3sylinder, 993cc of displacement and 15.3kVA

3. RESULTS AND DICUSSION

3.1. Treatments of Model Gas

In a cylindrical shape DBD, change of NO content at the exit of quartz reformer with 12 cm width electrode when the 28.5 kHz 10 kV discharge was applied is shown on the Fig.3. No discharge case is left bar, right bar is NO content with discharge. The decrease of NO is more than 90 % (from 570 to 41 ppm) in case of absence of O₂. When oxygen is supplied (4% in our case), it is also affected by the discharge, and it forms the NO as it can be seen on the Fig. 3.

The discharge devices worked with 28.5 kHz had a significant problem.

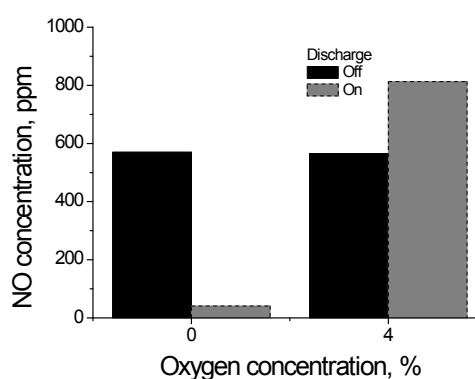


Fig. 3 Change of NO concentration with discharge at the presence of 0 and 4 % of O₂. Axial DBD

They could be overheated easily, and this phenomenon caused the breakdown of insulation, so the lifetime of devices were not sufficient for applications. The cooling system is necessary to increase the workability at 28.5 kHz operation

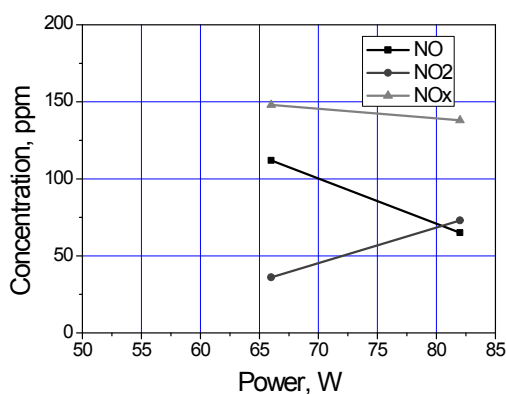


Fig. 5 Power effect of 400 Hz discharge on 100 l/min of model gas flow.

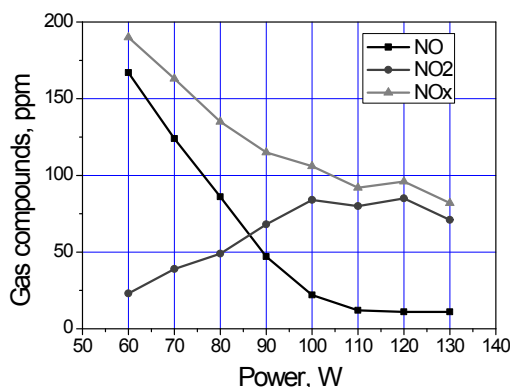


Fig. 6 Power effect of 1 kHz discharge on 100 l/min of model gas flow.

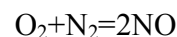
To prevent overheating and breakdown of insulation we decreased the frequency to 400 Hz in a multilayer DBD. In this experiment the model gas contains 200 ppm of NO at first. Good cleaning was obtained – see Fig. 5, where the power effect of 400 Hz

discharge on 100 l/min of model gas flow is shown.

Changing the frequency to 1000 Hz improves the treatment at increased gas flow rates (see Fig. 6). It is noticeable better on the example of NO_x – about 60 % decreasing comparing to 30 % at 400 Hz at same flow rate.

3.2. Treatment of Exhaust Gas

The 1 kHz DBD had no overheating problem. We tested the cylindrical discharge (Fig. 1) with real engine exhaust. The amount of oxygen doesn't change with power at 1 kHz frequency, that eliminates the below oxidation reaction which happened at 28.5 kHz



An application of the axial discharge decreases NO_x about 2 times – 45 % reduction, and NO has 85 % reduction, as shown on the Fig. 7

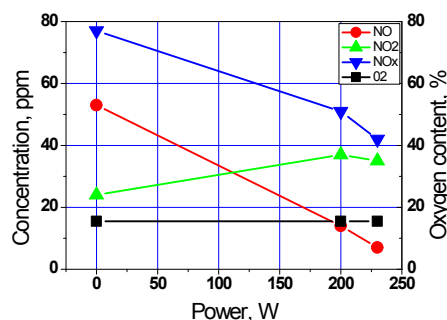


Fig. 7 Effect of discharge on the exhaust gas compounds. Axial DBD. Electrode width is 2 cm.

We tested multilayer discharge for reduction of NO_x from the engine exhaust. The most suitable frequency was close to 10 kHz for the multilayer discharger performance. We checked the effect of frequency from 10 kHz to 16 kHz.

The entire stream of an engine exhaust passed through the DBD structure. The concentrations of the NO, NO₂ and NO_x after treatment for the idle mode are shown on Fig. 8.

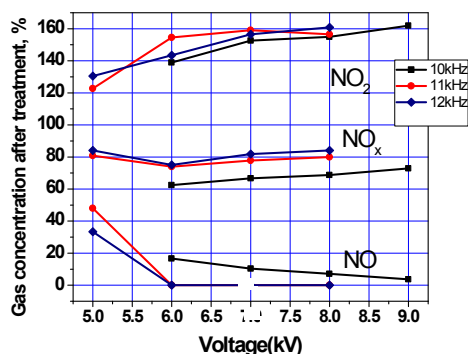


Fig.

8. Gas concentration according to the voltage, Engine on the idle mode (no load)

The effect of voltage (power) for several frequencies around 10 kHz on the concentration of NO and NO_x are presented on the Fig. 9 and Fig. 10, respectively. These data were taken on the condition of 7.3 kW load. NO concentration decreases with voltage while NO_x concentration does not change a lot with voltage.

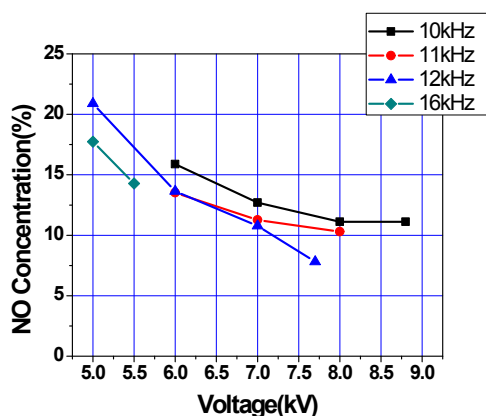


Fig.9. NO contents depend on the voltage and frequency

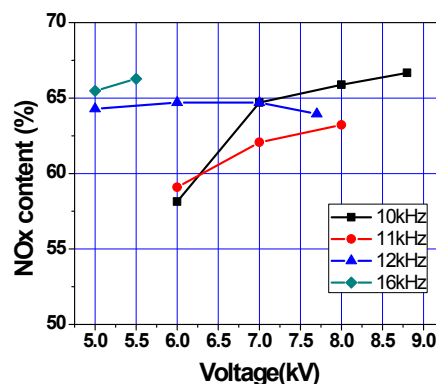


Fig.10. NO_x contents depend on the voltage and frequency

4. CONCLUSION

The DBD plasma sources with frequencies from 400 Hz to 28.5 kHz were used to reduce the NO_x content of a diesel engine exhaust. A 85 % decreasing of NO and 55 % of NO_x were obtained in axial geometry of discharge. The multilayer DBD shows 95 % removal of NO and 55 % of NO_x at 1 kHz frequency. The deepest degree of NO_x and especially NO reduction was achieved on multilayer barrier discharge (55% and 95% respectively). In multilayer discharge, and 10kHz and 12 kHz has the widest range. But in reduction rate 10kHz more suitable to decrease NO_x.

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