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Design of a DBD System for On-Board Treatment of the Exhaust Gas

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1. Introduction

This study is a part of the investigation of the diesel engine exhaust cleaning processes concerning a design of a compact, low power dielectric barrier discharge (DBD) system for on-board treatment of the exhaust gas in combination with a catalyst. The activated gas molecules and reduction agents which are produced by the discharge make the operation of the catalyst more efficient [1]. The effect of the discharge frequency, power and geometry on the gas composition is described in our previous publication [2].

2. Results and Discussion

2.1 Prototype Model

As a prototype of the discharger for the exhaust gas treatment we took the multilayer discharger containing parallel 0.1x100x18 mm electrodes covered with 0.8 mm ceramic, forming a grid structure with 18 air gaps of 2 mm height and 100 mm wide. The diagram of the discharger is shown on the Fig. 1. This structure has shown a good performance at frequency close to 10 kHz [2]. We fed the discharge with AP Plasma Power Supply which has a frequency range of 10-20 kHz, and a relatively high current limitation. The gas path in the active area in-between electrodes was 18 mm thought.

In the same time we knew that an increasing of the distance which the treating gas is passing in the discharge is important for soot agglomeration [2]. We decided to make a discharger with the planar configuration, but having a bigger longitudinal dimension.

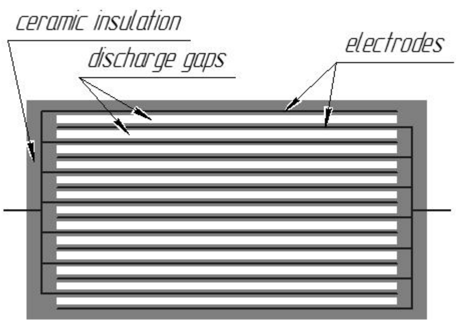

Fig. 1 Schematic diagram of the DBD chamber with the parallel electrodes (Multilayer discharge).

2.2 Initiation of the Discharge

The discharger consists of a number of flat parallel gaps between a grid of cupper sheet electrodes of alternative polarity adjoined with ceramic insulation of 1 mm thickness. It has 80 mm wide, and the lengths 280, 70 and 15 mm in different variants.

When the discharger containing 10 air gaps with 3 mm height was connected to the AP Plasma Power Supply, the frequencies were high. See the Fig.2. The discharge appeared at approximately 5 – 5.5 kV, and disappeared at 5.5 – 9.3 kV.

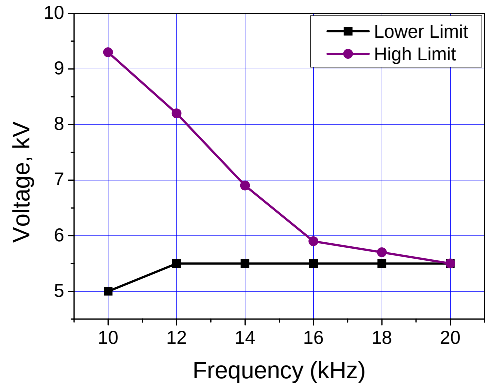

Fig. 2 Discharge with a power source without a current limitations.

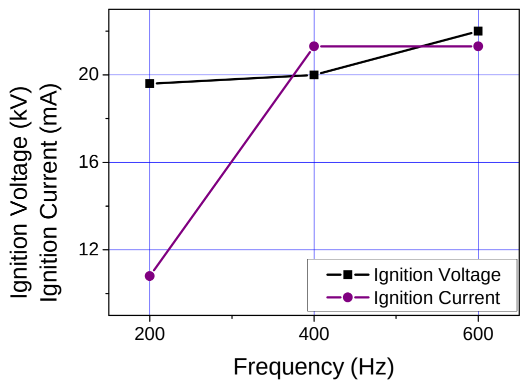

Fig. 3 Ignition of the discharge at frequencies 200, 400, and 600 Hz.

The lower frequencies seemed to be preferable for the device performance, so we closed another power source, which is consisting of a function generator and an amplifier (TREK 20/20C). Due to the amplifier's characteristics the discharge current is limited by 20 mA. Before the breakdown of the inter-electrode space the voltage and current has a sine shape. The current is reactive. After the discharge reach the current limit the voltage starts to be distorted. The maximum current limitations make the discharge to maintain itself at the significantly lower frequencies, as it shown on the Fig. 3. The gap electrical breakdown happens at approximately 20-22 kV.

2.3 Structure of the Discharge

Experiments with different numbers of the inter-electrode air gaps revealed different structures of the discharge. In some cases in the inter-electrode space many bright slowly migrating streamers are observable, in other cases the discharge appears uniform (see Table 1.) The electrode's length was 28 cm. The observation was made at frequencies supplying maximum power to discharge.

Table 1. Discharge shape at maximum input power.

Gap height / Gaps number	2	3	4	5
10	S	S	M	-
8	S	S	M	-
6	M	U	U	S
4	M	U	U	U

S – Streamer type discharge; U – Uniform; M – Mixed.

The electrodes with 7 or 1.5 cm length show the similar discharge behavior.

The frequency has its effect on the discharge form as it shown in the Table 2 for 1.5 length electrodes forming 10 air gaps with 2-mm height. The power was calculated by averaging of the current and voltage product by the oscilloscope.

Table 2. Frequency effect on the discharge shape.

Frequency, kHz	Shape	Power, W
3.1	S	43.4
2.7	S	50.4
2.0	M	55.4
1.7	U	60.0
1.26	U	62.4
0.88	U	65.6

The uniformity of the discharge plays a positive role, supplying lower electron temperature and more uniform gas treatment. So, the better performance with the 20 mA current limitation the device will show at proper air gaps number at maximum power (lower possible frequency).

For the production of the exhaust in-line discharger were selected the next parameters. Electrodes has the surface about 200 cm^2, the number of inter-electrode discharge gaps is 6, the air gaps height is 4 mm. The power frequency must be as low as possible, but not lower than 200 Hz, because at lower frequency the discharge has a tendency to breakdown connections outside the discharger and to form the surface discharge, which causes the overheating and system cracking.

The pictures of the discharger are shown on the Fig. 4.

Fig. 4 Pictures of the dielectric barrier discharger components.

3. Conclusions

Systematic studies of discharge configurations gave a possibility to design, optimize and produce the low power discharger for using in the light vehicles to support the catalyst for diesel exhaust cleaning. We revealed two different discharge modes: uniform and streamer types. We studied the frequency and power effect on the discharge performance.

REFERENCES

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