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Pulsed Power Technology for Pollution Control

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Recently, the pulsed power technology led us to generate discharge plasma in high-pressure gas, liquid and solid environment. The discharge plasmas have a lot of functions such as an intense electric field, a large current flow, a chemically active radical formation, a shockwave generation, and an ultraviolet irradiation. Using the functions, the pollution control technologies, including exhaust gases treatment, ozone generation, water treatment, and material destruction or separation, were developed in laboratory. In the paper, the NO removal by ns pulsed discharge plasma and the aggregate recycling by the discharge inside of concrete would be introduced.

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1. Introduction

The development of the pulsed power technology allows us to generate discharge plasmas in atmospheric gases, liquids and solids environment. As a result of the development, many industrial applications using pulsed power have been proposed in laboratories and its researches have been going. For practical applications, the improvement of the energy efficiency of the processing is the paramount work.

Previously, it is reported in the literature [1, 2] that the discharge plasma produced by the shorter duration pulsed power could remove nitric oxide (NO) in the exhaust gases and generate efficiently ozone (O_3) from air. In addition, it is also reported in the literature [3] that the pulsed discharge inside solids, such as the concretes and the rocks, could be new fragmentation technology. In the paper, the removal of NO by the nanoseconds pulsed plasma, which is produced by ns pulsed discharge, and the recycling of the aggregates using the pulsed discharge inside of the concrete scrap would be introduced and the both technologies have higher energy efficiency of the processing.

2. Nanoseconds pulsed plasma for NO removal

Figure 1 shows the streak image of the general pulsed discharge observed in the coaxial electrode filled with dry air [4]. In this case, the pulsed power having 60 kV of the peak voltage, 40 ns of the rise time and 100 ns of the duration time applied to the coaxial electrode. The diameters of the central wire and the outer cylinder were 0.5 mm and 76 mm, respectively. It is clear from Fig. 1 that the discharge mode started from the streamer discharge (= streamer heads propagation between electrodes) and

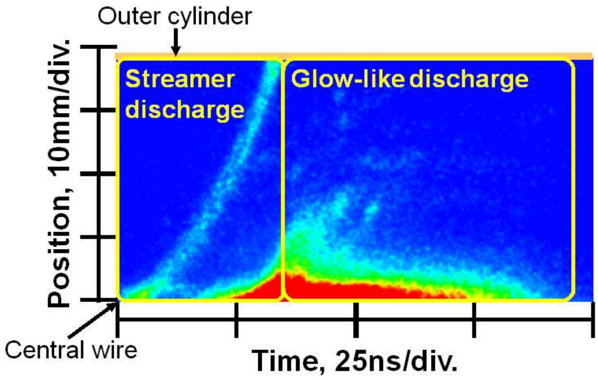

Fig. 1. The streak image of typical pulsed discharge.

then transitioned to the glow-like discharge during the pulsed discharge. The discharge mode would finally become the arc discharge if the pulse duration is longer. Until now, for the reduction of the thermal energy loss and the achievement of the efficient plasma chemical reaction, the pulsed power technology has controlled the duration of the discharge and protected the transition into arc discharge. However, it is found recently that the plasma temperature increased during the glow-like discharge [5]. It results that there is the generation of the thermal loss in the glow-like discharge. Therefore, the ns pulsed plasma, resulting in the streamer discharge only, would be introduced below.

Figure 2 shows the streak image of the ns pulsed discharge observed in the coaxial electrode filled with dry air [6, 7]. In this case, the applied pulsed power into the discharge chamber had +100 kV of the peak voltage, 2 ns of rise time, and 5 ns of the duration time, and the gap separation between the central wire and the grounded cylinder electrodes was 38 mm. It is confirmed from Fig. 1 that the ns pulsed discharge disappeared just

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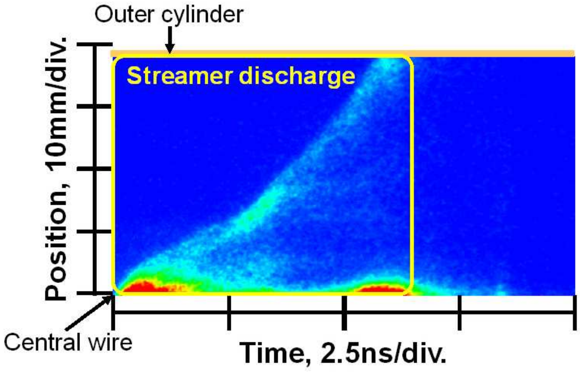

Fig. 2. The streak image of the ns pulsed discharge.

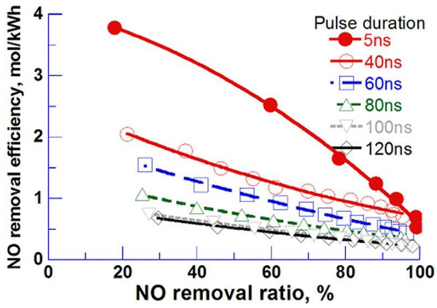

Fig. 3. The NO removal energy efficiency on NO removal ratio for the different pulsed durations.

after the full development of the streamer heads between the central wire and the grounded cylinder electrodes.

This means that the ns pulsed discharge has no transition into glow-like and arc discharges.

Figure 3 indicates the dependences of NO removal energy efficiency on NO removal ratio for the different pulsed duration [1, 8]. The simulated gas of the exhaust gas consisted of 200 ppm NO, 5% O_2, 2% H_2O and balance N_2. The gas flow rate was fixed at 2.0 l/min using mass flow controller. ¿From Fig. 3 it is found that the energy efficiency for NO removal decreased with NO removal ratio. This is because the reaction ratio between NO and the radicals generated in discharge plasma decreased with the reduction of NO for all pulse durations. On the other hand, the energy efficiency improved with the shorter duration of pulsed power. This result shows the thermal loss during the glow-like discharge mode reduced with decreasing the pulse duration. In the case of 5 ns pulsed discharge, the energy efficiency for NO removal might reach maximum.

3. Aggregate recycling by pulsed power discharge inside concrete

Figure 4 shows the discharge pass in the concrete formed by the application of pulsed power to the concrete placed in the point to hemisphere electrodes immersed in water [9]. In this case, the pulsed power from 0.04 μF

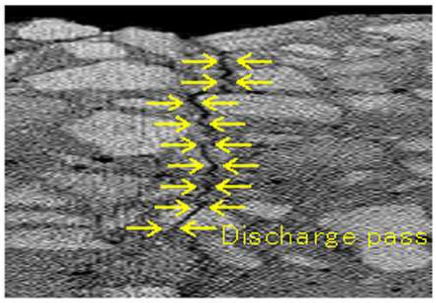

Fig. 4. The discharge pass in the concrete.

of capacitor charged up to 200 kV was applied to the concrete.

It is clear that the discharge propagated in the part of the cement paste. This is because that the breakdown voltage of the aggregate is higher than that of the cement paste. The discharge pass could make the cement paste fragile.

After the breakdown between the electrodes, the discharge pass became thermalized and had the thermal expansion. At that time, the shockwave due to the expansion is generated near the discharge pass. When the shockwave propagates in the concrete, the tensile stress is produced at the boundary between the aggregate and the cement paste by the transmitted and the reflected shockwaves, shown in Fig. 5. The tensile stress could separate the cement paste from the aggregate.

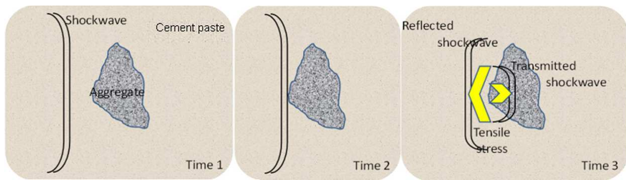

Fig. 5. The production of the tensile stress by the shockwave due to the discharge.

The destruction of the cement paste and the separation of the cement paste from the aggregate by the discharge phenomena inside the concrete could be suitable for the recycling of the aggregate. Here, the qualities of the discharge treated aggregate and the recycled concrete would be introduced.

Figure 6 shows the appearances of the recycled aggregates after discharge treatments [9]. It is clear that the recycled aggregates become small with increasing the number of the discharge treatments. After 100 discharge treatments, the most of the recycled aggregates has the same appearance to the original aggregates. As a result of the quality test under the Japan Industrial Standard (JIS) regulation, the bone-dry density and the water absorption ratio of the discharge treated aggregates were 3.0 g/cc and 0.9%, respectively. The both values satisfied class H of the JIS 5021 regulated the recycled ag-

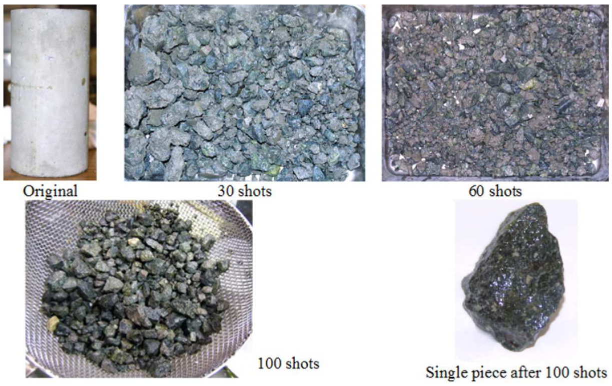

Fig. 6. The appearance of the recycled aggregates after the discharge treatments.

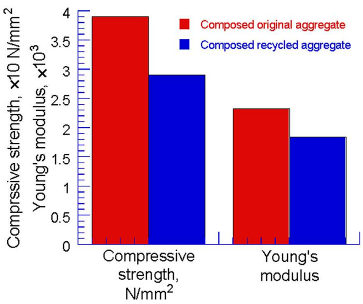

Fig. 7. The qualities of the original and the recycled concretes.

gregate. The qualities of the recycled concrete produced with the discharge treated aggregates are shown in Fig. 7. In Fig. 7, the compressive strength and the Young modulus of the original concrete are indicated for the comparison with the recycled concrete. It is clear from Fig. 7 that the both values of the compressive strength and the Young modulus for the recycled concrete become lower than that for the original one. However, the both values are enough to use for buildings.

4. Summary

In the present situation, the NO removal using ns pulsed discharge and the aggregate recycling by the pulsed power discharge inside concrete reach the practical applications.

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