

23. Modeling of Electric Potential Distribution in EHD Flow Zone Utilizing Pin-Multi Ring Concentric Electrodes

by Muhlisin Zaenul

Submission date: 11-Feb-2020 02:01PM (UTC+0700)

Submission ID: 1255349333

File name: C.F.23_Power_consumption_analysis_DBD_plasma_ozon_generator.pdf (1.53M)

Word count: 2705

Character count: 13651

Power consumption analysis DBD plasma ozone generator

M. Nur^{1,2*}, M. Restiwijaya^{1*}, Z. Muchlisin¹, I. A. Susan², F. Arianto^{1,2},
S. A. Widyanto³

¹Physics Department, Faculty of Science and Mathematics, Diponegoro University

Jl. Prof. Soedarto, SH, Tembalang, Semarang. Central Java, Indonesia. 50275,

²Center for Plasma Research, Faculty of Science and Mathematics, Diponegoro University, Jl. Prof. Soedarto, SH, Tembalang, Semarang. Central Java, Indonesia. 50275,

³Faculty of Engineering, Diponegoro University. Jl. Prof. Soedarto, SH, Tembalang, Semarang. Central Java, Indonesia. 50275, INDONESIA

*E-mail: m.nur@undip.ac.id

Abstract.

Studies on the consumption of energy by an ozone generator with various constructions electrodes of dielectric barrier discharge plasma (DBDP) reactor has been carried out. This research was done to get the configuration of the reactor, that is capable to produce high ozone concentrations with low energy consumption. BDBP reactors were constructed by spiral-cylindrical configuration, plasma ozone was generated by high voltage AC voltage up to 25 kV and maximum frequency of 23 kHz. The reactor consists of an active electrode in the form of a spiral-shaped with variation diameter D_c , and it was made by using copper wire with diameter D_w . In this research, we varied number of loops coil windings N as well as D_c and D_w . Ozone concentrations greater when the wire's diameter D_w and the diameter of the coil windings applied was greater. We found that impedance greater will minimize the concentration of ozone, in contrary to the greater capacitance will increase the concentration of ozone. The ozone concentrations increase with augmenting of power. Maximum power is effective at DBD reactor spiral-cylinder is on the $D_c = 20$ mm, $D_w = 1.2$ mm, and the number of coil windings $N = 10$ loops with the resulting concentration is greater than 20 ppm and it consumes energy of 177.60 watts

1

1. Introduction

A dielectric barrier discharge (DBD) will appear in a gas gap when an ac or rf voltage is applied to an electrode system with one or both electrodes covered by a dielectric layer. The gas-filled gap is small. Typical materials used for the dielectric layer are glass, quartz, ceramics, and polymer coatings [1-4]. Ozone can be produced by using electrical discharge in pure oxygen gas or air that was in the between two electrodes in the DBD plasma system. The factors that can affect ozone formation in general are voltage, dielectric materials, the pressure, the system configuration of the plasma reactor and a gas insert in the plasma reactor [3-6]. The main mechanism of ozone formation are ionization, recombination, dissociation and association. The reaction of ozone formation can occur in a plasma reactor has been



explained for example by Fridman in his book [7]. Nur et al. produced ozone by using DBD plasma and it has been implemented in the rice storage for maintaining the quality of rice [8]. Experimental study on the current-voltage characteristics for atmospheric pressure DBD has been done by Pongsathon [9]. DBDP can be approximated by an equivalent electronic circuit. The equivalent circuit is based on the model proposed by F. Massines et al [10].

This paper tries to discuss the energy consumption of ozone generators and production capabilities. Several studies that have been done related to energy consumption and the concentration of ozone generated. The ozone chamber was developed using the RLC circuit base on RLC resonance tank circuit. This model was used to determine the resonance frequency for inverter as a power supply to ozone generator [11]. Research on quantification of capacitance and power consumption [12]. Influence of electrode configuration on ozone synthesis and micro-discharge property in dielectric barrier discharge reactor has been studied [13].

2. Research Methods.

Figure 1 shows a series of experiments in this study. Ozone has been produced by using Dielectric Barrier Discharge Plasma (DBDP) with spiral-cylindrical reactor configured. DBDP generated by high voltage AC voltage up to 25 kV and maximum frequency of 23 kHz. Electrical parameters of DBPP determined through a voltage divider (HV Probe DC Voltage DC max 40 kV; 28 kV AC EC code number 1010, En G1010). Electrical signal from the probe detected by an Oscilloscope GOS-653, 50 MHz. The electric current, that was generated in the reactor was measured by using a multimeter (Sunwa TRXn 360). Photo taken from experiments using a CCD camera (Creative, DV Cam).

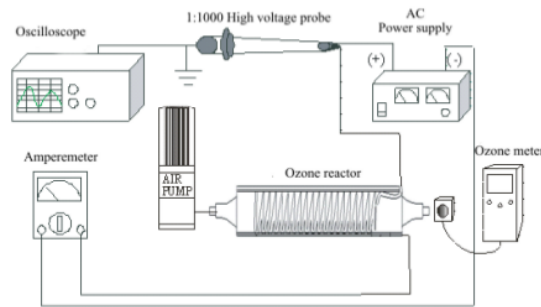


Figure 1. Experimental set up

The concentration of ozone generated DBDP reactor with spiral-cylindrical configuration measured using an ozone monitor (Quant Ozone "2"). Measurements were taken at applied voltage variations and multiple electrode diameter cylinders/Pyrex tube.

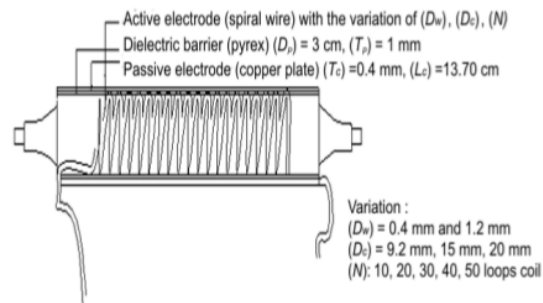


Figure 2. Dielectric Barrier Discharge Plasma Reaktor

The reactor used in this study was Dielectric Barrier Discharge Plasma reactor (DBDP) reactor, with wire spiral - cylinder configuration (Figure 2). The reactor consists of an active electrode in the form of a spiral-shaped copper wire (wire diameters variation (D_w) are 0.4 mm and 1.2 mm), the diameters of the wire coil windings (D_c) are 9.2 mm, 15 mm, 20 mm, number of loops coil windings (N) are 10, 20, 30, 40, 50 loops. Wire spiral was inserted in a dielectric barrier was shaped pyrex tube pyrex diameter ($D_p = 30$ mm) and pyrex thickness ($T_p = 1$ mm) and pyrexlength ($L_p = 15$ cm). the outer part of the dielectric barrier will be veiled with a copper plate that serves as a passive electrode, with copper thickness ($T_c = 0.4$ mm) and copper length ($L_c = 13.70$ cm).

3. Results and Discussion

We used air as source of ozone generator. The air most constituent is nitrogen and oxygen. The air introduced into the reactor with a pump and with certain flow rate. According to Lofthus and Krupenie [14], O_2 molecules have ionization and dissociation energies lower than N_2 molecules. So the O_2 molecule more susceptible to ionize and dissociate of than nitrogen molecules. Energy levels of molecules O_2 and N_2 molecules that can be found in [15] and the ionization energy of O_2 molecule is 12 eV. If the O_2 molecules gain energy 12 eV can ionize the O_2 . Because the conditions of ionized molecules in an unstable state and tends to return to its normal state (recombination), O_2^+ ions can capture electrons and emit an energy of 12 eV. How the same is true of N_2 molecules having ionization energy of 15 eV can ionize and go back to the normal state (recombination) to emit an energy of 15 kV.

Effect of Impedance and Capacitance Against Ozone Concentration

The influence of impedance to ozone production was investigated to get the best value of the parameters for an ozone generator that constructed base on DBDP. In this study, the impedance value was obtained by calculation using equation (9).

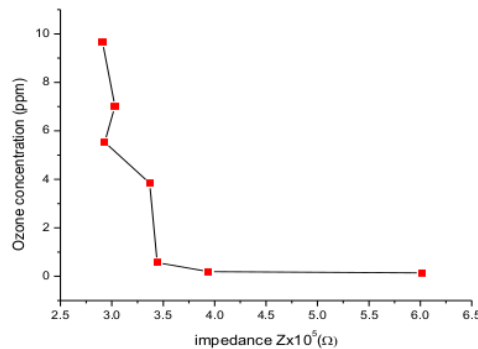


Figure 3. Ozone concentration as function of impedance for $N= 50$ coils $D_w=0.4$ mm, $D_c= 20$ mm, and $D_p = 30$ mm

The impedance value depends on voltage variation (V), the wire diameter (D_w), the diameter of the wire windings (D_c) and the number of wire windings (N). Graph ozone concentrations as a function of the impedance shown in Figure 3 for the number of wire windings ($N = 50$ coils), the diameter of the wire windings ($D_c = 20$ mm) and wire diameter ($D_w = 0.4$ mm). We found that the greater the value of the impedance then the concentration of ozone generated is getting smaller. This is because the electric field near the electrode active decline. So the process of ionization and recombination also decreased. Capacitance influence on ozone production also investigated in this study. In the DBD reactor, the electrical equivalent circuit consists of two capacitances, the capacitance of gas (C_g) and dielectric capacitance (C_d). Total capacitance can be obtained with equation $\frac{1}{C} = \frac{1}{C_d} + \frac{1}{C_g}$. The reactance value was

determined by the equation $Xc = 1/2\pi fC$. While the dielectric capacitance obtained from measurements using capacitance LCR meter. Graph of ozone concentrations as a function of gas capacitance shown in Figure 4.

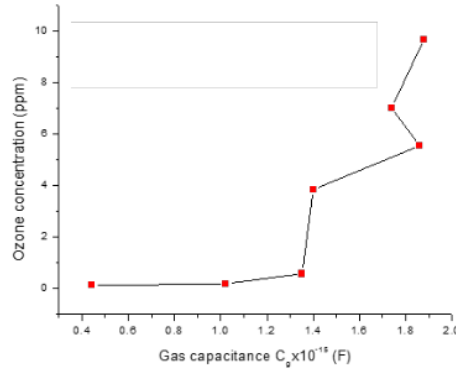


Figure 4. Ozone concentration as function of voltage with several number of winding coil $N = 50$ coil spools, for $D_w = 0.4$ mm, $D_c = 15$ mm, and $D_p = 30$ mm

From this figure, it can be seen that the concentration of ozone enlarges with the enlargement capacitance of gas discharge. It can be understood that the electric current had been enlarged with increasing capacitance of gas discharge. Already mentioned earlier that in the gas discharge, electric currents are capacitive current. That's mean, the greater the capacitance, the greater the charge in the discharge. The total electrical charge determined transformation to the electric current. Moreover, it was followed by greater of the electrical charge changes in change of time (dQ/dt). Electric current shows the occurrence of ionization, and other processes such as dissociation. Energetic electrons produced in the plasma that will be able to break up oxygen molecule (O_2) becomes oxygen atomic (O). These process are the main condition occurrence of free reaction bodies in the formation of ozone reaction such as: $O_2 + O + M \rightarrow O_3 + M$. In this reaction M is other molecules inside reactor such as, N_2 , O_2^- , etc.

The effect of power consumption to produce ozone

The influence of power by generator to the ozone concentration produced is shown in Figure 5.

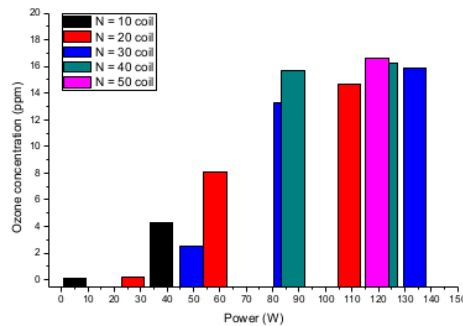


Figure 5. Ozone concentration as function of power for several number of coil spools (N), for $D_w = 1.2$ mm, $D_c = 20$ mm and $D_p = 30$ mm

From all the reactors that tested, we select on the DBD reactor with a construction which was capable to produce large ozone concentration. Construction selected is reactor that has components such as: $D_w = 1.2$ mm, $D_c = 20$ mm and $D_p = 30$ mm, $L_p = 150$ mm. Figure 6 shows that the change in the number of windings coil (N) affect the value concentration of ozone generated. It is closely related to the electric field distribution and decomposition of ozone.

When the number of windings coil on the more active electrode electric field between the electrodes is much more uniform and almost complete in the area so that the ionization electrode is also much more intense and uniform. The concentration of ozone produced is also higher. In the figure 6, we can see that windings coil N = 50 coil spools produce ozone concentration is more high than N= 30 and 40 coil spools, with less power consumption.

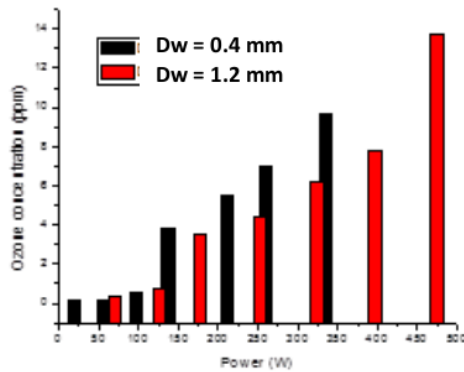


Figure 6. Ozone concentration as function of power for coil spools N = 50, for $D_w = 0.4$ mm, $D_w = 1.2$ mm, $D_c = 15$ mm, and $D_p = 30$ mm. The graph shown in Figure 7 is ozone concentration as a function of power. From the figure it can be seen that no ozone is generated for all input power. It is very influential here is the distance between the active electrode with Pyrex tube. This graph is for diameter spiral made of copper wire of 9.2 mm or 4.8 mm from the axis (radius).

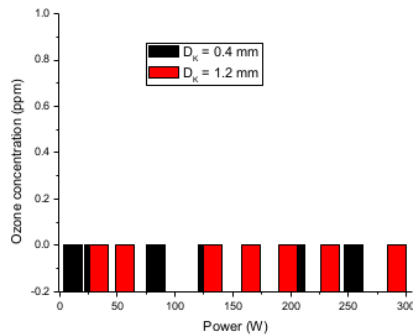


Figure 7. Ozone concentration as function of power for $D_w = 0.4$ mm, $D_w = 1.2$ mm, $D_c = 9.2$ mm, N = 50 coil spools and $D_p = 30$ mm

So that the edge of the active electrode to a distance of 11.2 mm tube (tube radius = 15 mm). The distance is so large that the electron energy is not enough to dissociate the oxygen molecules. Furthermore, tree bodies reaction does not take place so that ozone is not formed.

Results are shown in Figure 7 corresponds with previous research that has been reported [16]. Differences in diameter spiral-shaped of the active electrode give effect to the concentration of ozone generated. The larger the diameter spiral-shaped of the active electrode closer to the Pyrex, it can generate the greater the concentration of ozone.

4. Conclusions

Ozone concentrations greater when the wire's diameter D_w and the diameter of the coil windings applied was greater. We found that impedance greater will minimize the concentration of ozone, in contrary to the greater capacitance will increase the concentration of ozone. The ozone concentrations increase with augmenting of power. Maximum power is effective at DBD reactor spiral-cylinder is on the diameter of coil winding ($D_c = 20$ mm), diameter of wire ($D_w = 1.2$ mm), and the number of coil windings ($N = 10$ loops) with the ozone concentration produced is greater than 20 ppm and it consumes energy of 177.60 watts. Differences in diameter spiral-shaped of the active electrode give effect to the concentration of ozone generated. The larger the diameter spiral-shaped of the active electrode closer to the Pyrex, it can generate the greater the ozone concentration.

5. Acknowledgment

All members of group of research thanks to Ministry of Research, Technology and High Education for financial support of this research in the schema Flagship Research for High Education (PUPT Program) of the year 2016 with contract number 176-09/UN7.5.1/PG/2016.

6. References

- [1] Changquan Wang, Guixin Zhang, and Xinxin Wang 2012 *Journal fo Vacuum* 86 960-964.
- [2] S. Jodpimai, S. Boonduang, and P. Limsuwan, 2015 *Journal of Electrostatics* 74, 108-114
- [3] Bogaerts, A., Neyts, E., Gijbels, R., and van der Mullen, J 2002 *Spectrochimica Acta Part B: Atomic Spectroscopy* 57 609-658.
- [4] Nur, M. Supriati, A. Setyaningrum, D.H. Gunawan, Munir, M., and Sumariyah 2009 *Journal of Berkala Fisika* 12 69-76.
- [5] R.G. Rice, 1999 *Ozone. Sci. Eng.* 21 99-118.
- [6] A. Bohme 1999, *Ozone. Sci. Eng.* 21 163-176.
- [7] Fridman, A. 2012 *Cambridge University Press*, Cambridge
- [8] Muhammad Nur, Aribat Solichin, Endang Kusdiyantini, Tri A. Winarni, Susilo, Dian Arif Rahman, Resti Maryam, Sosiowati Teke, Wuryanti, and Harjum Muharam 2013 *The IEEE, Conference Publications, ICICI-BME*, 221-225.
- [9] Pongsathon Jitsomboonmit, Mudtorleb Nisoa, and Somsak Dangtip 2012 *Journal of Physics Procedia* 32 723-731.
- [10] F. Massines, N. Gherardi, N. Naudé, and P. Ségur 2005 *IOP Science, Plasma Physics and Controlled Fusion* 47 577-588.
- [11] Mochammad Facta, Zainal bin Salam and Zolkafle Bin Buntat, 2009 *IEEE Conference Publications, CITISIA* 2009 pp 440 - 445
- [12] Jochen Kriegseis, Benjamin Möller, Sven Grundmann, and Cameron Tropea 2011 *Journal of Electrostatics* 69 302-312.
- [13] Jae-Duk Moon and Jae-Seung Jung 2007 *Journal of Electrostatics* 65 660-666.
- [14] A. Lolthus and P. H. Krupenie 1977 *Journal of Physical and Chemical Reference Data* 6.
- [15] Terrell, C.A., Hansen, D.L., Ajello, J.M., 2004, *Journal Of Physics B: Atomic, Molecular And Optical Physics* 37 1931-1949.
- [16] Muhammad Nur, Maryam Restiwijaya, Tri Agustina Winarni 2014 *IEEE Conference Publications, ISTMET* 2014, pp. 129 - 132

23. Modeling of Electric Potential Distribution in EHD Flow Zone Utilizing Pin-Multi Ring Concentric Electrodes

ORIGINALITY REPORT

8%

SIMILARITY INDEX

2%

INTERNET SOURCES

5%

PUBLICATIONS

2%

STUDENT PAPERS

PRIMARY SOURCES

- 1** Changquan Wang, Guixin Zhang, Xinxin Wang. "Comparisons of discharge characteristics of a dielectric barrier discharge with different electrode structures", Vacuum, 2012 2%
Publication

- 2** Mochammad Facta, Zainal bin Salam, Zolkafle Bin Buntat. "The development of ozone generation with low power consumption", 2009 Innovative Technologies in Intelligent Systems and Industrial Applications, 2009 1%
Publication

- 3** eprints.undip.ac.id 1%
Internet Source

- 4** S. Jodpimai, S. Boonduang, P. Limsuwan. "Dielectric barrier discharge ozone generator using aluminum granules electrodes", Journal of Electrostatics, 2015 1%
Publication

- 5** Submitted to Western Governors University 1%
Student Paper

1%

6

ejournal.undip.ac.id

Internet Source

1%

7

Shao, T.. "Discharge characteristic of nanosecond-pulse DBD in atmospheric air using magnetic compression pulsed power generator", *Vacuum*, 20120208

Publication

1%

8

Petr Lukes. "Generation of ozone by pulsed corona discharge over water surface in hybrid gas–liquid electrical discharge reactor", *Journal of Physics D Applied Physics*, 02/07/2005

Publication

<1%

9

A.M. McCance, J.P. Moss, D.R. James. "Le Fort I maxillary osteotomy: is it possible to accurately produce planned pre-operative movements?", *British Journal of Oral and Maxillofacial Surgery*, 1992

Publication

<1%

10

Submitted to Universiti Malaysia Sabah

Student Paper

<1%

Exclude quotes Off

Exclude matches Off

Exclude bibliography On

23. Modeling of Electric Potential Distribution in EHD Flow Zone Utilizing Pin-Multi Ring Concentric Electrodes

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6
