Study of Ozone Generator with Electric Fields Distribution on Water Surface

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Abstract: This paper proposes a study of an Ozone generator. The generator under the study is designed using the electrode with uniform field. The electrode is constructed in the plane shape with positive potential. The transformer oil is used as insulating materials to prevent discharges around the electrode discharges in the air void depends on the size, the types of dielectrics and level of applied voltage. Between the electrode and the air void, there is acyclic dielectric. The stainless electrode with water is used as a ground potential. The breakdown depends on the electric field intensity. It is found that there is sufficient amount of ozone due to the ionization, Development and design ozone generator this research electric field intensity on the water type and this can be used as a principle to construct a new type of ozone generator.

Keyword: electrode, electric field, dielectric, ozone generator

1 INTRODUCTION

The ozone is an active modification of the oxygen. It has clear blue color and spicy odor, it is more soluble in water and much more active than the oxygen, it is considered the more powerful oxidant over the earth and it has a lot of applications mainly in sanitation, salubrity and contamination. Due to its chemical properties, it is used as a disinfectant and germicidal. It is employed in air and residual water treatment, deodorization, oxidation process, dental medicine, etc. An important property of the ozone is the absence of toxic substances as a result of its application to disinfect water or other substances, by this reason is commonly used by purification and deodorization industry. The principle of operation of OG consists to apply a high voltage between two parallel plaques with air inside, the high voltage produces the phenomenon know as silent discharge or corona effect. The silent discharge produces ultraviolet radiations that break the oxygen molecule producing ozone. It is important to avoid the arc discharge to maintain the silent discharge, which is obtained adding a dielectric between the air gap and one of the electrodes.

This paper presents the behavior of ozone generation by using discharge scheme between electrode and air gap in the tube. The shape of electrode is like the ground of electrical system that using Taylor theory. A breakdown with Taylor theory depends on the electric field. Whenever the electrode discharges to the water surface, the ozone gas is generated due to the ionization.

The organization of this paper is classified as follows. Section 2 presents the theory and operation principle of ozone generation. Design and Analysis are shown in Section 3. Section 4 shows the simulation results by using finite element. Experiment results are given in Section 5 that testing- bench at RMUTT high voltage laboratory, Thailand. Section 6 discusses the conclusion.

2 INTRODUCTION

A. Ozone Formation and Decomposition

The formation of ozone from molecular oxygen can be represented by the equation

$$3O_2 \rightarrow 2O_3 \qquad (1)$$

which, if the O2 and O3 molecules are in their fundamental energy states, requires an energy input of 142.3 kJ per mole of ozone produced [2]. Given that one mole of ozone has a mass of 48 g, the theoretical energy requirement for complete ozone formation from oxygen is 0.82 Wh per gram of ozone, or 1220 g of ozone per kilowatthour. The process most widely used for ozone generation is the passage of an oxygen-bearing gas through an electrical discharge. In this process, the major reactions that result in the formation of ozone are

$$e^- + O_2 \rightarrow 2O + e^- \qquad (2)$$

$$O + O_2 + M \rightarrow O_3 + M \qquad (3)$$

where the third body M is needed to absorb the excess energy of the reaction. The initial dissociation reaction requires an energy of 5.1 eV per molecule of oxygen, which is supplied by the bombarding electron [3].

Several mechanisms result in the decomposition of one. Ozone's half-life decreases significantly as temperature increases. Bombardment by electrons can break ozone molecules apart, and ozone molecules can combine with each other, as well as with oxygen molecules and oxygen atoms. Water vapor can cause a substantial decrease in net ozone production by absorbing electronic energy that could otherwise be used in the ozone formation process. Hydrogen and hydroxyl radicals can be formed from water vapor and, consequently, permit reactions that destroy ozone molecules [3]. In addition, oxygen atoms can combine with water vapor and its products, preventing ozone formation.

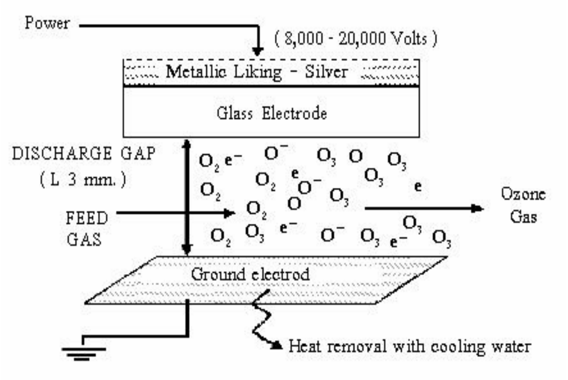

Fig. 1: principle generation of ozone gas

Fig. 1 presents a principle generation of ozone gas on the silent discharge. The most commonly employed type of electrical discharge in commercial ozone generators is the silent, or dielectricbarrier, discharge. This type of discharge is often also referred to as a form of corona discharge. The silent discharge occurs in a gas-filled gap between two electrodes separated by a dielectric. When an alternating voltage, high enough to cause electrical breakdown of the gas in the gap, is applied to the electrodes, a series of discrete discharges, termed microdischarge, occurs in the gap. The dielectric accumulates charge that limits the growth of the individual discharges and causes the discharges to occur at many locations throughout the gap [5]. Alternating voltage is required to prevent quenching of the electric field in the discharge gap due to charge accumulation on the dielectric. Microdischarges are current filaments consisting of thin cylindrical conducting plasma columns. They can be started by a succession of Townsend avalanches, or by a streamer that can achieve breakdown in a single transit, depending on conditions. A weakly ionized channel of fairly homogeneous charge density and field strength is formed across the gap, and a surface discharge spreads out on the dielectric. The fading of the discharge is similar, in many respects, to a glow discharge. The microdischarge is interrupted long before leader formation or spark transition can occur [6], [7]. Water vapor can affect the functioning of the dielectric and, in addition, can cause extremely strong microdischarge.

B. High voltage generation for generating the ozone gas

The high voltage supply cab be the direct current and alternative current of voltage as shown in Fig. 1. A high AC exciting voltage generated by high voltage transformer is applied to ozone generation tube in this paper. This is composed of discharge gap and the dielectrically material of glass inserted into the electrodes [4]. The process of ozone generation can represent in Fig. 2. The high voltage source is supplied into the ozone generator. Next the ionization on the water surface occurs in the silent discharge. The ozone gas is produced in the process. We have to control the volume of ozone gas for user applications by control the input voltage source. In commercial ozone generators, glass and ceramic are commonly used as the dielectric material. Water, oil, and air are used as cooling fluids. Either flat parallel-plate or concentric-cylinder electrodes are employed [4].

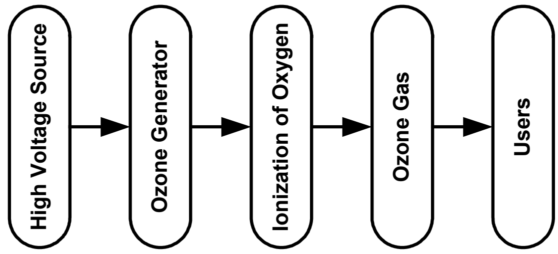

Fig. 2: Process of Ozone gas generation

3 DESIGN PROCEDURE

A design of ozone generation that uses high voltage source is important to find the optimal electrode. This electrode is to generate the electric field stress. This section presents the analysis and simulation by using FEMLAB version 3.1.

To find the electric field in the three layers insulator(oil, acyclic and air), this paper presents the emission of electric field and voltage by using FENLAB program as shown in Fig 3 to Fig. 5 at 40 kV high voltage source. The electrode is placed as insulator in the tube. The equivalent capacitances are like the serried connection as shown in the equation (3)

$$Q = C_1U_1 = C_2U_2 = C_3U_3 \qquad (3)$$

Where C1, C2 and C3 are the capacitances of the three types insulator with ε_1 , ε_2 and ε_3 , respectively. But each capacitance can be found in the following equation.

$$C_1 = \frac{\varepsilon_1 A}{d_1} \qquad (4)$$

$$C_2 = \frac{\varepsilon_2 A}{d_2} \qquad (5)$$

$$C_3 = \frac{\varepsilon_3 A}{d_3} \qquad (6)$$

Therefore the electric stresses of insulator are:

$$E_1 = \frac{U_1}{d_1} = \frac{U}{d} \times \frac{\varepsilon_2 / \varepsilon_1}{\frac{d_1}{d} \times \left(\frac{\varepsilon_2}{\varepsilon_1} - 1 \right) + 1} \qquad (7)$$

$$E_2 = \frac{U_2}{d_2} = \frac{U}{d} \times \frac{1}{\frac{d_1}{d} \times \left(\frac{\varepsilon_2}{\varepsilon_1} - 1 \right) + 1} \qquad (8)$$

$$E_3 = \frac{U_3}{d_3} = \frac{U}{d} \times \frac{1}{\frac{d_3}{d} \times \left(\frac{\varepsilon_3}{\varepsilon_2} - 1 \right) + 1} \qquad (9)$$

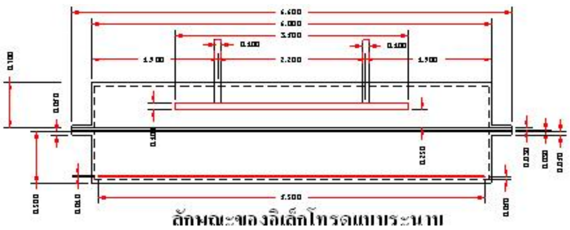

Fig. 3: Model of electrode in FEMLAB

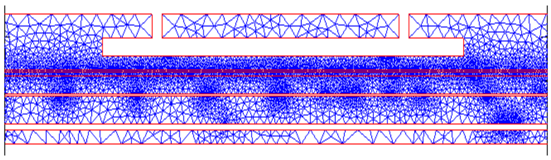

Fig. 4: Node elements of electrode

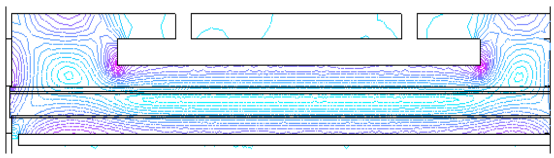

Fig. 5: Electric fields of electrode

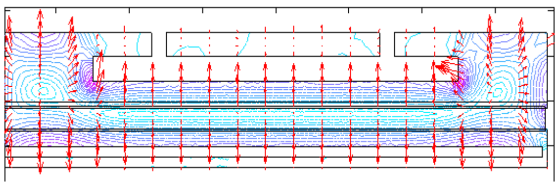

Fig. 6: Electric fields emission of electrode

Table 1 presents the electric fields of insulator for different high voltage source (10 kV to 40 kV) where d_{oil} is a air length in cm. of electrode when oil is used to be the insulator, d_{PE} is a air length in cm. of electrode when acyclic is used to be the insulator, d_{AIR} s a air length in cm. of electrode when air is used to be the insulator, E_{oi}l is maximum electric field that occurred at oil dielectric (kV/cm). E_{PE} is maximum electric field that occurred at acyclic dielectric (kV/cm). E_{AIR} is maximum electric field that occurred at air dielectric (kV/cm).

Table 1: The electric field for different voltage source

U	d_{OIL}	d_{PE}	d_{AIR}	E_{OI}	E_{PE}	E_{AIR}
10	1.5	0.5	1	5.61	2.80	2.54
20	1.5	0.5	1	11.22	5.60	5.08
30	1.5	0.5	1	16.84	8.40	7.63
40	1.5	0.5	1	22.45	11.2	10.1

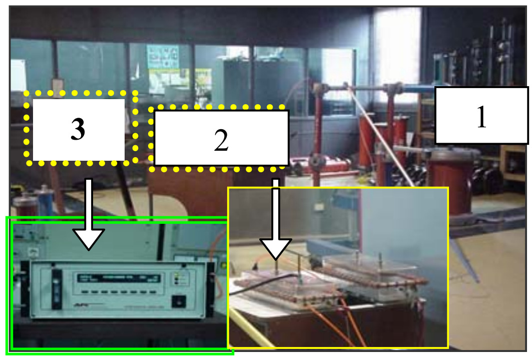

Fig. 7: The prototype of ozone generator

Fig. 7 shows the prototype of ozone generator and instrument for ozone gas measurement. The equipment No. 1 is high voltage source that can vary the high voltage up to 40 kV. The electrode is shown in No. 2 and No.3 is the ozone meter that can measure the ozone gas in part per million (PPM).

4 EXPERIMENTAL RESULTS

The testing of electrode by using the electric emission on water surface is to measure the ozone gas by Teledyne API Model 450H O2 monitor. The result is shown in Table 2.

Table 2: The ozone gas at electrode

U	Ozone gas (PPM)						`ime
	AC Voltage			DC Voltage			
	Gap length (CM)			Gap length (CM)			
	0.5	1.0	1.5	0.5	1.0	1.5	
20	28	18	9	10	7	5	5
25	32	19	12	12	9	8	5
30	36	20	14	14	10	10	5
35	49	32	19	22	18	14	5
40	59	39	20	25	20	15	5

Fig. 8: Display panel of ozone gas meter Teledyne API Model 450H O_3 Monitor

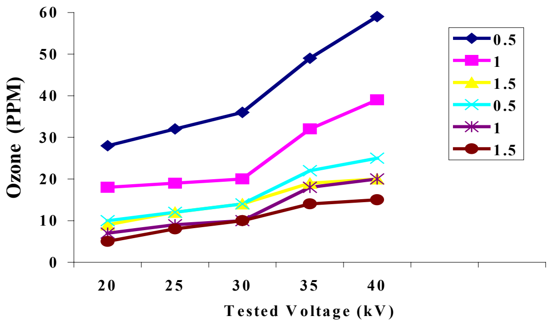

Fig. 9: Comparison of ozone gas and tested voltage

Fig. 9 shows the comparison of ozone gas and tested voltage with two different voltages (AC and DC source). The gap length at 0.5 cm when used AC high voltage source, it can get the highest ozone gas volume.

5 CONCLUSION

Design and analysis is investigated in this paper for ozone generation. The electrode is constructed in the plane shape with positive potential. The transformer oil is used as insulating materials to prevent discharges around the electrode discharges in the air void depends on the size, the types of dielectrics and level of applied voltage. The breakdown depends on the electric field intensity. It is found that there is sufficient amount of ozone due to the ionization, Development and design ozone generator this research electric field intensity on the water type and this can be used as a principle to construct a new type of ozone generator.

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7 BIOGRAPHY

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