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THE STUDY ON THE PLASMA GENERATOR THEORY FOR THIN DISC AND THIN RING CONFIGURATION

Asep Yoyo Wardaya
Department of Physics, Diponegoro University
Master Program of Energy, School of Postgraduate Studies, Diponegoro University, Indonesia
asepyoyo@yahoo.co.id

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Abstract— Various corona discharges plasma generators equipment have been composed with significant ability to produce saturation current effect. The effect was generated by the potential difference of the capacitive system where two electrodes are set with opposite charges to each other. The saturation current occurring in this capacitive electrode system can be generated by a small voltage source (about 12 volts). A sufficiently large electric field and a saturation current, can be obtained from a configuration of sharp electrodes. An example of the electrode shape is a configuration of a very thin and sharp disc surrounded by a ring electrode in a two-dimensional space. The value of the electric field and the saturation current will be calculated in mentioned electrode configuration.

Keywords— plasma generator, disc configuration, ring configuration, electric field, saturation current.

I. INTRODUCTION

The corona discharges plasma generator equipment has been widely used to assist humanity in many areas of life, for they can generate saturation currents [1] by merely dc currents [2]. The utilization include, improving the quality of food storage [3], liquid waste treatment [4], microbial inactivation in rice [5], accelerator of nursery mangroves [6], et cetera. The calculation of electrical field and saturation currents are important part within the characteristic of various electrode plasma models, since each characteristic will produce different electrical current. Usually, the calculated characteristic comprises of a diagram of current related to voltage, where the results of the experiment often indicate that the induced current will be proportional to the quadratic function of the potential difference [7]. Coelho and Debeau in 1971, were carried out the calculation of electric field and induced current of electrode capacitive characteristics using a hyperbolic-shaped electrode model [8]. This paper will use their works as a basis for calculation.

II. THEORY

This paper will convey the calculation of the electric field and the saturation current generated by the plasma generator, with a configuration of the thin disc and ring which is depicted in the following tool model,

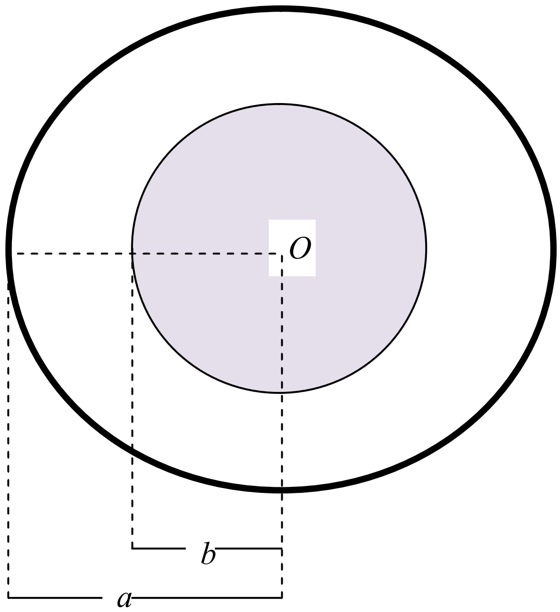

Fig. 1. Plasma generator device with the configuration of a thin disc and a thin ring in a two-dimensional space

The plasma generating device in Figure 1. is depicted within two-dimensional space and comprise of an outer ring with radius of ***a***, around a very thin disc with radius of *b* with the thickness of $\Delta l \rightarrow 0$. The capacitance characteristic of a plasma electrode generator can occur for the thin disk electrode is set with a positive charge while the thin ring with negative charge. The induced current will emerge due to the difference of potentials between the disc and the ring. The saturation current of the capacitor system is a measurable plasma current flow. In various experiments [7], the electric current is usually a function of the quadratic potentials difference of potential at the end of a positive charged electrode.

III. METHODOLOGY

The depiction of thin ring and thin disc electrode models with a thickness of $\Delta t \rightarrow 0$, can be seen in Figure 2. The capacitor area in Figure. 2.a, is the area of the plane between the two electrodes, which can be written as

$$A = 2\pi\left(\Delta l\right)\rho,. \quad (1)$$

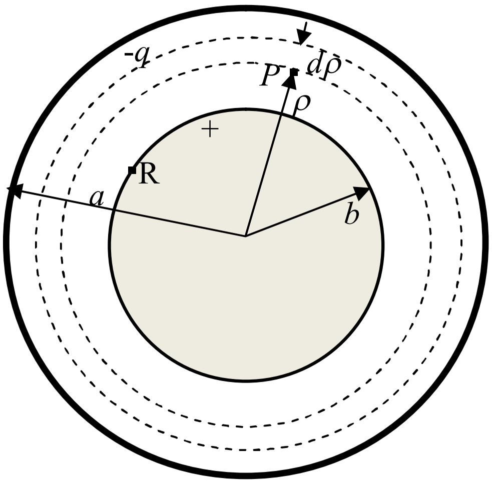

Figure2.a

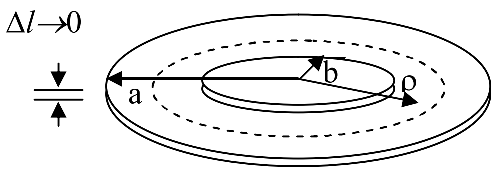

Figure2.b

Fig. 2. The model of thin disc electrode with $\Delta l \rightarrow 0$ thickness and *b* radius encircled by an axial ring with *a* radius and the Gauss surface with ρ radius, from above (a) and the side (b) perspective

where ρ is the distance between the two electrodes which is the radius of the Gauss surface. The magnitude of the electric field in distance of ρ (e.g. to the point P) that leads from the thin disc to the thin ring, can be obtained as [9],

$$E_P = \frac{q}{\varepsilon_0 A} = \frac{q}{2\varepsilon_0 \pi (\Delta l) \rho}, \qquad \Delta l \to 0,. \tag{2}$$

where the value $+q$ is the amount of electrical charge located at the end of the disc electrode, while at the end of the ring electrode has a $-q$ charge. To obtain the general formulation of the induced current against the potential difference of V which is at the end of the disk electrode, the electric charge of q can be converted to voltage magnitude. In this paper, the calculation of the electric field produced by thin disc using the calculation models of Coelho and Debeau [8], using the hyperbolic coordinates as illustrated in Fig. 3, which the x and y coordinates are formulated as

$$x = a \sin\zeta \cosh\eta, \qquad y = a\cos\zeta \sinh\eta,. \tag{3}$$

Let us assume that the hyperbolic coordinates of equation (3) can be used as an approach to calculate electric field of thin discs in polar coordinates as well. According to the calculations of Coelho and Debeau [8], the magnitude of the electric field in distance of ρ (e.g. to the point P) can be written as

$$E_P = \frac{V}{\ln\left\{2(a/b)^{1/2}\right\}} \frac{a}{(\rho-b)\left[2a-(\rho-b)\right]+\left[a-(\rho-b)\right]b}. \tag{4}$$

where a is the distance from the center of the disc to the ring electrode (ring radius) and b is the radius of the thin disc as illustrated in Figure 2. The V notation is the potential difference at the end of the electrode or around the tip of the thin disk. Since equations (2) and (4) are identical, the magnitude of the electric charge around the thin disc can be obtained as,

$$q = \frac{V}{\ln\left\{2(a/b)^{1/2}\right\}} \frac{2\varepsilon_0 \pi (\Delta l) \rho a}{(\rho-b)(2a-\rho+b)+(a-\rho+b)b},. \tag{5}$$

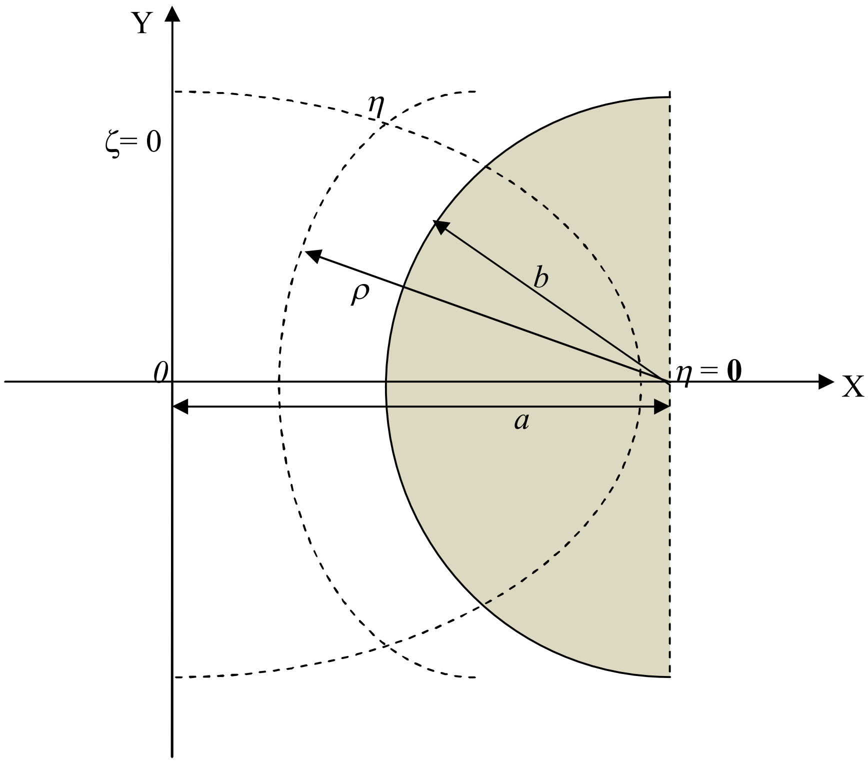

Figure 3.
Two-dimensional hyperbolic coordinate approach to calculate the electric field generated by the thin disc.

IV. RESULTS AND DISCUSSION

The expected result of this study was the discovery of the characteristics induced current *i* to the difference of voltage *V*. The basis of the calculation of the characteristic *i* vs *V* for each configuration of the two electrodes capacitor in current-induced system, is by using the formulation of the Q_1- induced charge [8], as

$$Q_1 = \frac{V(\xi)-V}{V} q, . \tag{6}$$

where *V* and *q* are the potential difference and the charge contained at the end of the electrode (in this paper is at the tip of the thin disc), thus generating induced currents as [8],

$$i = -\frac{dQ_1}{dt} = \mu \frac{q}{V} E_P{}^2, . \tag{7}$$

where E_P is the magnitude of the electric field at the end of the electrode (at the edge of the thin disc). Using equations (4) and (5), the value of induced current in equation (7) can be written as

$$i = \frac{1}{\ln^3\left\{2(a/b)^{1/2}\right\}} \frac{2\mu\varepsilon_0\pi(\Delta l)\rho a^3 V^2}{\left[(\rho-b)(2a-\rho+b)+(a-\rho+b)b\right]^3}, \quad \in << 1, \tag{8}$$

where *i* is the induced current and ρ is the radius of the Gauss surface between the two electrodes. In equation (8), we can see that the induced currents occurring from the capacitive electrode system between the electrodes in the configuration of thin discs and thin rings, are proportional to the square of the potential difference *V* at the tip of the thin disc disk, thus yielding the characteristic *i* vs *V* as a hyperbola function. The value of the induced current will be greater when the disc's radius is also greater and the ring radius remains because there is a $\left[(\rho-b)(2a-\rho+b)+(a-\rho+b)b\right]^3 > \rho a^3$ factor. The value of the induced current will also increase in the area adjacent to the disc and progressively smaller in areas far from disc. The significant value of electric induced current in equation (8) can be related to thickness factor of $\Delta l \rightarrow 0$ in the very thin disc as well as the ring. Although the best way to prove the diagram *i* vs *V* is, through experiments (which was not covered in this paper) as comparison of the formulation (8).

V. CONCLUSIONS

From the calculation of the electric field and the induced current magnitude generated by the plasma generator with the configuration of the thin disc and the thin ring in the two-dimensional space, it can be concluded that the resulting induced current will be proportional to the potential square at the tip of the thin disc disk. The resulting induced current value will be quite significant when the thickness of the disc and ring is very thin. The calculation of the induced current will be better than the actual experimental results.

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