A METHOD FOR MEASURING AEROSOL PARTICLE CONCENTRATION BY DISCHARGE CURRENT VARIATION IN NEGATIVE CORONA

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Introduction

Although the discharge current of a negative corona in the air is continuously stable within a certain range of applied voltage, the current decreased and fluctuated when an aerosol passed through this discharge field¹⁾. In this report, the variation of electric current is considered in connection with aerosol concentration and a new method based on a stochastic model of current variation is proposed for measuring aerosol concentration.

1. A Stochastic Model

As a theoretical analysis of the new method, a linear time-invariant system may be considered.

Since the aerosol particles are, in general, randomly distributed in a certain space, the probability of coincidence of the particles in the discharge field can be estimated by using the Poisson distribution. Therefore, the input function, $\phi(t)$, of the particle coincidence at any time in this system is expressed by a series of Poisson impulses as follows:

$$\phi(t) = \sum_i q \delta(t - t_i) \quad (1)$$

where $\delta(t)$ is Dirac's delta function, q is impulse intensity, and t_i are random points in time.

When each particle has the same impulse intensity q and impulse response function $\xi(t)$, the output function of the linear system, $\phi(t)$, can be given by the equation:

$$\phi(t) = \sum_i q \xi(t - t_i) \quad (2)$$

where the output function is defined as a difference of discharge current shown in Fig. 1 in this experiment.

The mean value $E\{\phi(t)\}$ and the variance σ_ϕ^2 of the output function have been solved as follows²⁾:

$$E\{\phi(t)\} = \lambda q \int_{-\infty}^{\infty} \xi(t) dt \quad (3)$$

$$\sigma_\phi^2 = \lambda q^2 \int_{-\infty}^{\infty} \xi^2(t) dt \quad (4)$$

where λ is the mean value of the input function $\phi(t)$. Eliminating q from Eqs. (3) and (4), λ becomes

$$\lambda = \frac{E^2\{\phi(t)\}}{\sigma_\phi^2} \cdot \frac{1}{\alpha} \quad (5)$$

where α is defined as

$$\alpha \equiv \left[\int_{-\infty}^{\infty} \xi(t) dt \right]^2 / \int_{-\infty}^{\infty} \xi^2(t) dt \quad (6)$$

In this theory, it is assumed that each particle has the same impulse response function $\xi(t)$; thus α becomes constant in Eq. (6) even though the impulse response function is not given. Therefore, in Eq. (5) the input impulse density λ , which corresponds to the average concentration of the aerosol particles, is proportional to the term $E^2\{\phi(t)\}/\sigma_\phi^2$ alone.

2. Experimental Apparatus and Procedure

A schematic diagram of the experimental apparatus is shown in Fig. 2. Negative voltage up to 50 KV was applied to a titanium needle electrode having a 0.1 mm point radius, and the opposite brass plate electrode of the Rogowski type, 80 mm in diameter, was grounded. In this experiment, the distance between the electrodes was a constant 2.5 cm. The maximum output of DC electric current was 2.0 mA.

The mean value of discharge current was obtained by measuring the voltage at both sides of a resistor located between the plate electrode and the ground,

Fig. 1 A typical diagram of discharge current variation

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1. High voltage generator
2. Mist or fume generator
3. Fan
4. Recorder or oscilloscope
5. Cascade impactor
6. Vacuum pump

Fig. 2 Schematic diagram of experimental apparatus

and was registered by a pen recorder in this system. Similarly, the shape of current variation was directly observed by a synchronous oscilloscope and also recorded by photographs.

As for the sample aerosol, a water mist and an ammonium chloride fume were produced from the evaporation-condensation generator and introduced into the measuring system with a constant flow velocity of 4.1 m/sec. Concentration and size distribution of aerosol particles were measured by the cascade impactor.

3. Experimental Results and Discussion

Figure 3 shows the experimental result of current variation related with particle concentration. This indicates that the parameter $\alpha\lambda$ is proportional to particle concentration. As mentioned in the theory, α is a function of the impulse response function $\xi(t)$, which varies with type of electrodes, applied voltage, and diameter and dielectric constant of the aerosol particle. Hence, α becomes constant when these conditions are the same. However, as shown in Fig. 3, the parameter $\alpha\lambda$ is not proportional to particle concentration at higher concentrations. That is caused by other factors influencing impulse response function, such as the interaction of the electric charge between particles.

The effect of applied voltage on the parameter $\alpha\lambda$ is shown in Fig. 4. When the applied voltage is less than 23 KV, the parameter $\alpha\lambda$ is zero; however, it increases with a rise in applied voltage. This point where the parameter $\alpha\lambda$ starts to increase is the same as the starting point of the corona discharge in this experiment. Moreover, it is found that the parameter seems to be saturated in the region of higher

applied voltage 36 kV, particle diameters $\bar{D}_p = 2.4 \mu\text{m}$ ($\sigma_g = 1.76$) for water mist and $\bar{D}_p = 1.7 \mu\text{m}$ ($\sigma_g = 1.84$) for ammonium chloride fume

Fig. 3 Relation between particle concentration and parameter $\alpha\lambda$

particle concentration 1.59 g/m³ and particle diameter $\bar{D}_p = 3.4 \mu\text{m}$ ($\sigma_g = 1.30$) for water mist

Fig. 4 Relation between applied voltage and parameter $\alpha\lambda$

applied voltage over 35 KV.

Conclusion

It is experimentally clarified that the input impulse density λ , theoretically derived from the stochastic model of discharge current variation, is proportional to aerosol particle concentration. Consequently, based on the above experimental relationship, the method proposed in this paper should be applicable for measuring the particle concentration of aerosols.

Nomenclature

$\bar{D}_p$	= average diameter of aerosol particle (number)	$[\mu\text{m}]$
E	= mean of function	$[\text{A}]$
i	= number of points	$[-]$

n	= particle number concentration	[l/sec]	ϕ	= input function	[—]
q	= impulse intensity	[C]			
t	= time	[sec]			
α	= coefficient defined by Eq. (5)	[—]			
δ	= Dirac's delta function	[l/C]			
λ	= input impulse density	[—]			
ξ	= impulse response function	[l/sec]			
σ	= deviation of current	[A]			
σ_g	= geometric standard deviation of particle	[—]			
ϕ	= output function	[A]			

Literature Cited

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