Experimental analysis of electrode parameter effect on spray charge

H R Cui and C Z Yang
Ningbo University of Technology, Ningbo, Zhejiang, China

Abstract. In this paper, the influence of the diameter of the annular electrode and the arrangement of the nozzle on the droplet in electrostatic spray was studied by experiment and analysis. On the conical spray nozzle, five different diameters of ring electrodes and five mounting positions were used to carry out the jet charged spray test. The net current method was used to measure the charged current, total mass and test time of the droplets. The charge to mass ratio was used to evaluate the inductive charge performance of the droplet. The test results show that the charge increases with the increase of the charge voltage on the electrode. When electrode ring diameter increases, the droplet charge decreases. While the installation position of the electrode moves forward along the direction of the spray, the charge of the droplet increases. There is a linear relationship between the charge and the electrode ring diameter and installation location.

1. Introduction
Electrostatic spray can increase the deposition of droplets on the plants and reduce the drift, waste and pollution [1-3]. In recent years, electrostatic spraying as a new technology has been applied in plant protection machinery. The research of electrostatic spraying and development of equipment has also risen [4-6]. Induction charge is the main way to make the droplets charged in electrostatic spray technology, and most of the electrode structures are ring electrodes. The diameter of the ring electrode and the installation position and spray the charge voltage, droplet size and dielectric constant of the charged droplets have complex effect on the induction charge. There are many theoretical research and experimental study on mechanism of induction charge [7-12], but little study on the electrode parameters effect on the charge and equipment developed [13-17].

This paper focuses on the influence of electrode ring structure parameters and layout form on the charging effect of jet spray, which is used to guide the design of electrode and electrostatic nozzle structure.

2. Charge load test
2.1. Test device
The induction charged spray test device consists of three parts: spray system that produces pressure atomization, variable voltage supply [13], and data acquisition system for measuring load and quality. The device used is shown in Figure 1.
Pressure is pumped from the pump to the liquid spray system. Working pressure is regulated and stabilised by valve to control medicine spraying from the nozzle in forming a uniform refinement of the droplet through air impact rupture. High voltage is generated by HVDC. Electrode is connected with negative power electrode, its position is arranged at ahead of the nozzle of the spray system. When the electric field produced by the electrode acts on the conical mist ejected through the nozzle, the nebulized droplet is charged. The output voltage from HVDC is adjustable within 0~30kv. Charged droplets in front of the nozzle are collected by net receiving device. The micro current relative to the ground loop is measured by precision ammeter. The total mass of the droplet population and the time of the test experience are collected and measured by the foggy sample bailer, which is used to calculate the droplet charge mass ratio.

2.2. Test design
The electrode size and installation position are changed in the test. The influence of electrode diameter and installation location on the power and influence of droplet charge is investigated. The test design is as follows:

- Five sizes of diameter of electrode ring respectively are 50mm, 60mm, 70mm, 80mm, 90mm. The electrode rings are made of stainless steel wire with a diameter of 0.8mm.
- Installation position: the electrode is installed in front of the nozzle, and the distance between the electrode and the nozzle is divided into 5 sizes, such as 0mm, 5mm, 10mm, 15mm, 20mm.
- Nozzle: the angle of spray nozzle is 90 degrees and the flow rate of hollow cone nozzle is 4.92mL/s. The droplet sprayed from the nozzle shapes a cone. The electrode is located outside the conical surface of the fog, and the electrode is near the conical surface of the fog with the diameter of 50mm. The contact charge is easily formed by the close of the electrode to the fogging cone.
- Target acquisition distance: the distance between the mesh target and the nozzle is 200mm. The net target is measured with the mesh target method.
- Jet pressure: the test pressure is 0.2MPa.
- Electrode voltage: the charge voltage can be changed steplessly between 5kV and 15kV.

2.3. Test index
The charge characteristics of the droplets are expressed by the ratio of the charge of the droplets to the total mass of the droplets (the ratio of charge to the mass).

The net target method is used to measure the charge current and the total liquid mass of the droplet group. The charge is the product of the charge current and time, and the relationship between the measurement results and the charge to mass ratio is:

$$\lambda = q / M = \frac{It}{\rho L} = V / p L$$
where $\lambda$ is the ratio of charge to mass (mC/Kg); $q$ and $M$ are the charge volume (mC) and mass (Kg) of droplet group in $t$ seconds interval respectively; $I$ and $L$ are respectively the steady current (A) of group droplet and the liquid flow rate (mL/s) of sprinkler head.

3. Results and analysis

3.1. The influence of charged voltage

During the test, the output voltage of HVDC is changed to affect the charging voltage on the electrode. One group of charged data are measured every 1000V. The test is repeated three times, and the arithmetic mean is taken as the effective data for calculating the charge.

Figure 2 shows the relationship between the charge of different diameter electrodes and the charge voltage when the electrode is in the front of the nozzle 20mm. The test results show that there is a linear relationship between charge and charge voltage, and the charge increases with the increase of charge voltage. It can be seen from physics that the electric field intensity is directly proportional to the voltage. The higher the voltage on the electrode is, the stronger the electric field intensity is, and the higher the electric charge is. The higher voltage is beneficial to obtain better charging effect.

3.2. The influence of the electrode ring diameter

In Figure 2, the measured data of the different diameter of the electrode rings and the fitting curves are also given. At the same location, the increase of the diameter of the electrode ring means that the distance between the fog cone surface and the droplet formed is also increased. The electric field intensity is weakened, and the induction effect becomes worse, and the power charge of the droplet decreases. In the range of test, the result of the test is described with linear relation, which has high correlation.

3.3. The influence of the electrodes arrangement

The different arrangement of the electrodes is represented by the position which is distanced to the nozzle. Figure 3 shows the measured value of the charge of the droplet and the fitting curve with an electrode ring with a diameter of 70mm under the different installation distances. Under the same load condition, the smaller the location of the electrode to the nozzle is, the smaller the charged capacity of

\[
y_{50} = 0.0451x \quad R_{50}^2 = 0.9572
\]
\[
y_{60} = 0.0435x \quad R_{60}^2 = 0.9735
\]
\[
y_{70} = 0.0421x \quad R_{70}^2 = 0.9723
\]
\[
y_{80} = 0.0384x \quad R_{80}^2 = 0.9973
\]
\[
y_{90} = 0.0363x \quad R_{90}^2 = 0.9937
\]
the droplet is. In the same word, the closer it moves to the front, that is the closer it is to the fog cone surface, the larger the power charge is.

![Figure 3](image)

**Figure 3.** Effect on the charge-mass ratio by charging voltage and installation position of ring electrode.

From effect of electrode diameter and electrode configuration on the droplet charge properties, electrode diameter decides electric field strength and distribution formed within the ring, on the other hand it decides the affecting distance to the change of fog cone. The arrangement position of electrode is mainly to change the role of fog cone distance. It is known from the experimental results that the diameter of the electrode ring is smaller and the electrode ring is closer to the fog cone, and the better the charge effect is.

4. Conclusions

Through the experimental study and analysis of the influence of the diameter of the electrode ring and the position of the electrode installation on the charge, the following conclusions are obtained.

(1) The charged charge (charge to mass ratio) of induction charged droplet is directly proportional to the charged voltage. The effect of increasing the voltage on the electrode can effectively improve the charging effect.

(2) The charge of the droplet increases with the shift of the electrode position, and decreases with the increase of the electrode diameter. In the premise of ensuring the insulation of the electrode and the spray cone surface, the smaller diameter of the ring electrode and the electrode is as close as possible to the spray cone, are the preferred solution for high load capacity, and can be used as a basic principle for electrostatic nozzle design.

Acknowledgement

This work was financially supported by the Ningbo Natural Science Foundation (No. 2016A610106).

References

[1] Han S M 2011 *Agricultural Mechanization Study* vol 12 p 249-252 (in Chinese)
[2] Huang G, Wang S X and Wang J C 2008 *China Plant Protection* vol 28 p 20-21 (in Chinese)
[3] Sun Y and Qin L 2018 *Journal of Ordnance Equipment Engineering* vol 2 p 172-176 (in Chinese)
[4] Wang J F, Zhang J J, Wang Z T, Huo Y P and Wang Z 2012 *Transactions of the CSAE* vol 43 p 61-65 (in Chinese)
[5] Wang C H, Jiang S W and Gao Q J 2013 *Transactions of the CSAE* vol 44 p 84-89 (in Chinese)
[6] Okamoto T, Takahashi T and Miyzaki S 2012 *Transactions on Fundamentals and Materials* vol 132 p 108-113
[7] Wang J, Guo H Z and Xie S Y 2014 *Agricultural Mechanization Study* vol 3 p 159-166 (in Chinese)
[8] Yang C Z, Wu C D and Chen C Y 2007 *Transactions of the CSAE* vol 38 p 72-75 (in Chinese)
[9] Wang J F, Wang S C and Zuo Z W 2017 *High Voltage Engineering* vol 43 p 514-519 (in Chinese)
[10] Wu C D, Wang L G and Yang C Z 2011 *Agricultural Mechanization Study* vol 10 p 147-149 (in Chinese)
[11] Ru Y, Zheng J Q, Zhou H P and Shu C R 2008 *Transactions of the CSAE* vol 24 p 119-122 (in Chinese)
[12] Xu X J, Wu C D and Yang C Z 2011 *Agricultural Mechanization Study* vol 11 p 138-142 (in Chinese)
[13] Yang C Z 2008 *Drainage and Irrigation Machinery* vol 26 p 64-67 (in Chinese)
[14] Yang C Z, Ye W M and Zhao W M 2009 *Agricultural Mechanization Study* vol 11 p 178-181 (in Chinese)
[15] Chen Z G, Zhou J M, Wu C D and Chu J Y 2007 *High Voltage Engineering* vol 33 p 128-131 (in Chinese)
[16] Gao X, Wang A T, Liu Y Z and Zhang X H 2012 *Agricultural Mechanization Study* vol 9 p 180-186 (in Chinese)
[17] Zhang R and Zhou Y J 2013 *Agricultural Mechanization Study* vol 1 p 181-183 (in Chinese)