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Computation model of electrostatic spraying in Agriculture Industry

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ABSTRACT

Electrostatic spraying (ESS) has been used to improve plant coverage with treatment fluids. An Induction charging nozzle has been used to investigate the role of electrostatic forces on target coverage with spray fluid. Five metal targets were examined, conical, flat, cylindrical, ellipsoid and spherical. Theoretical and experimental studies were conducted under some common operational conditions. COMSOL software simulation was used to investigate the role of electrostatic forces on the different targets. Especial Faraday cage was constructed to isolate the experimentation zone from outside random fields in order to measure the current and charge mass ratio accurately. These values were measured at seven levels of air pressures (5psi, 10psi, 15psi, 20psi, 25psi, 30psi, 35psi). The results obtained from this study indicated that there are direct relationships between water flow rate with both current and charge mass ratio. The maximum current and charge mass ratio measured was for the conical target and followed by flat, cylindrical, ellipsoid and spherical targets respectively. These results will be used to design a smart spraying system with sensors to increase the efficiency of pesticide application.

Key words: *Electrostatic, Faraday pail, Induction nozzle, Targets.*

Introduction

Agricultural chemicals such as pesticides are used to protect plants against insects and diseases. A significant amount of the chemical applied is wasted in this approach. Electrostatic spraying can provide a solution for these problems. The idea had been examined as early as in the 1940's. The reasons for using electrostatic spraying are as follows

Electrostatic spraying achieves more complete coverage of difficult targets than uncharged spraying in addition to minimizing wastage and environmental impact from over spray and spray drift (Bayat,). Moreover, electric field lines from the approaching charged spray cloud will terminate on top and underside of leaves. In addition, the electrostatic forces help overcome other forces, such as droplet momentum and air flow that can cause the atomized materials to miss the intended target.

Electrostatic spraying can be used for efficient application of pesticide (Bentouati, 2006; Bentouati *et al.,* 2005). In this paper, electrostatic spraying is investigated for efficient application of pesticides on target plants. As a part of this project, COMSOL model was developed to understand spray properties, in terms of electric field distribution. In particular, FEM model was developed to investigate electric field distribution for charged droplet and grounded targets. Five different shapes of targets (conical, spherical, cylindrical, flat and ellipsoid) were investigated. To achieve highly charged droplet, there are various means (Sasaki *et al.*, 2013). The first one is the ***corona charging method*** which utilizes a pointed or sharply curved electrode that is raised to a high electrical potential. The intense electric field at the electrode breaks down the surrounding air and creates ions, which are then free to attach themselves to the atomized droplets. The second is ***contact charging (or conduction) method*** which utilizes a direct charge transfer, rather than ionization. In this method, an electric charge flows from a source of high potential (voltage) to the droplets that have come into contact with the source. The third is ***induction charging method***. It uses an electric field to induce charges onto the droplets. In this the atomization is achieved conventionally by forcing pressurized liquid through a nozzle and charging the resultant spray by induction, thus avoiding direct contact of the spray liquid with potentially hazardous high voltage and providing a spray whose charged droplets disperse effectively as a result of Coulombic repulsion, and which are in turn attracted to grounded targets[1]. The objective of this study is to identify the effect of induction charged spray deposition on different on targets.

COMSOL Multiphysics

COMSOL model: Electric static model (*es*) in the COMSOL software was used to simulate our FEM model. The figure below shows the COMSOL model developed; showing charged droplet, grounded target and grounded boundary box. Size of charge droplet size is 33 µm and surface charge density is 137.5×10^{-12} C/m^2. These parameters were

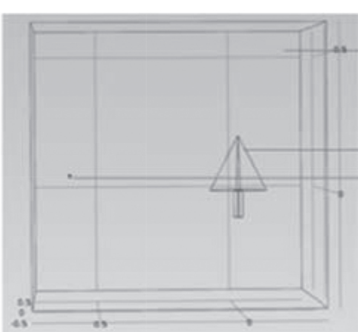

Fig. 1. COMOL Model of charged droplet and grounded target

obtained from our experimental work carried out in Brunel University, UK. The height of targets used is 20 cm and the volume of the boundary box is one cubic meter due representing the Faraday cage.

COMSOL finite element model (FEM) was solved for the following equations:

$$E = -\nabla V \text{ ....(1)}$$

$$\text{.............(2)}$$

Where: E= Electric field (V/m), V= Electric potential (V), [ε_0=Permittivity of free space = 8.854 X 10^{-12}(F/m), [ε_r=Relative permittivity of the air 1.0005, and ρ_i= Density of droplets 10^3(kg/m^3).

Methodology

Laboratory, experiments were carried out to observe and explain the effect of induction charging on different targets deposition by using electrostatic agriculture spray nozzle. This nozzle is manufactured by Electrostatic spraying company (ESS). Figure 2 explained nozzle components.

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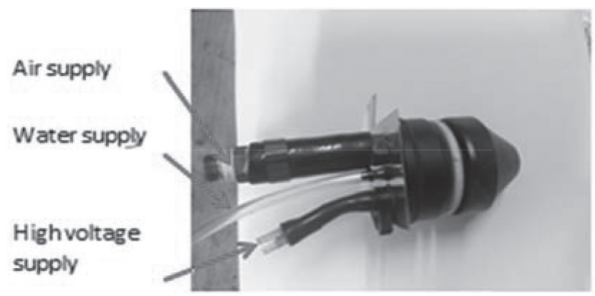

Fig. 2. Explained the components of nozzle

The air move at high speed through the nozzle and disintegrates liquid into droplets. The droplets are charged by induction charging at the nozzle. High speed air flow through the annular area assures that the droplets are swept away from by the electrode and propelled outward from the orifice of the nozzle. Five metal targets were examined, conical, flat, cylindrical, ellipsoid and spherical. The experimental set-up is shown Figure 3.

In the laboratory experiment a grounded Faraday cage (140 cm x 90cm x 90cm) was used in order to isolate the experiments from external electric field interference. Faraday cage was constructed using aluminum frames and stainless steel mesh. Polyethylene plastic sheets were hanged around Faraday cage in order to contain the sprayed water. The droplets from the nozzle were charged by applying

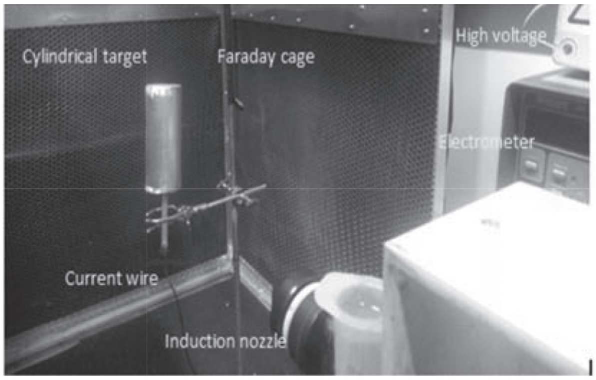

Fig. 3. The experiment set up

high voltage to the induction electrode at the nozzle using the high voltage supply source (Emco model 7200). A range of high voltages (0.3kV, 0.42kV, 0.51 kV, 0.72 kV, 0.85kV, 1.07kV) were applied to the nozzle in conducted experiments. An electrostatic spray atomizer supplied with tap water by using a compressor model (JUN-AIR). The spray current was measured with a Keithley programmable Electrometer Model 617 connected to the target. The flow rate of water was measured at seven air pressure settings from 5 psi to 35 psi.

Results

The electric filed distribution of the charged droplet-target model for an Ellipsoid target is shown in the Figures (1, 2, 3, 4 and 5). The maximum electric filed achieved, charged-to-mass ratio and induced current in the targets are summarized in the Table 1. Conical shaped target generates highest electric field and a rounded target generates the least electric field. These results will be used in our intelligent sprays so that amount of pesticides can be controlled based on the shape and size of targets. From the laboratory experiments, the relationships between the water flow rate and spray current (μA)

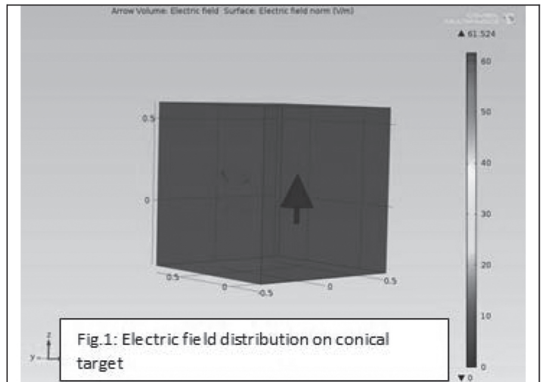

Fig.1: Electric field distribution on conical target

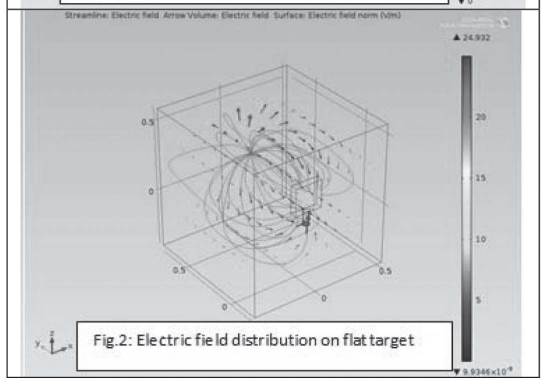

Fig.2: Electric field distribution on flat target

and the relationship between the water flow rate and charge mass ratio (CMR) are explained in Fig. 6 and 7.

Discussion

A direct relation was found between water flow rate and electrical current of cloud spray as show in Fig. 7. The reason behind this is the increase in flow rate which means larger surface area of liquid resulting in increased number of charged droplets (Roten *et al.,* 2013). The largest value of the charge mass ratio appears to be achieved at a fraction of the Rayleigh limit. Fig.8. illustrates the effect of flow rate on the charge mass ration. This figure shows that they are

Table 1. Various targets and their parameters

Type of target	Maximum electric field (V/m)	Charged mass ratio (mc/kg)	Current in the target (μA)
Conical	61.524	14.6	14.892
Flat	24.932	14.2	13.206
Cylindrical	19.928	13.700	11.645
Ellipsoid	17.662	11.8	8.968
Spherical	17.255	8.3	5.694

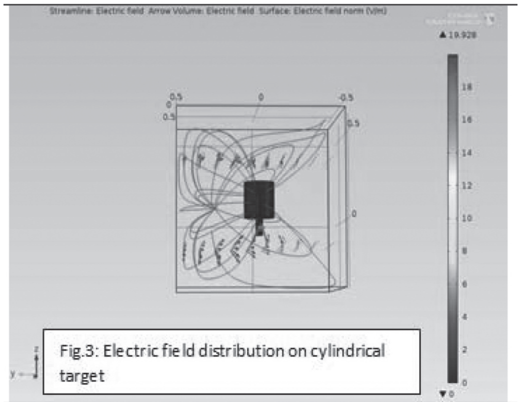

Fig.3: Electric field distribution on cylindrical target

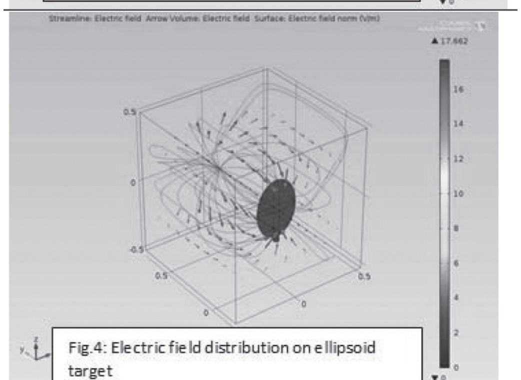

Fig.4: Electric field distribution on ellipsoid target

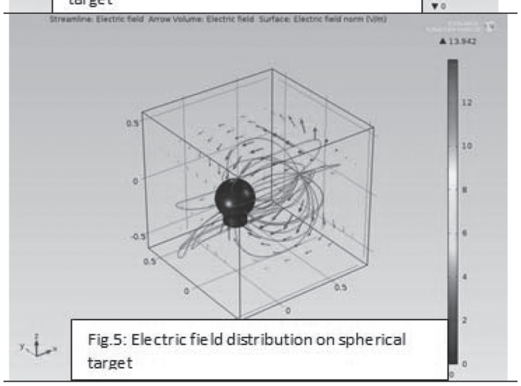

Fig.5: Electric field distribution on spherical target

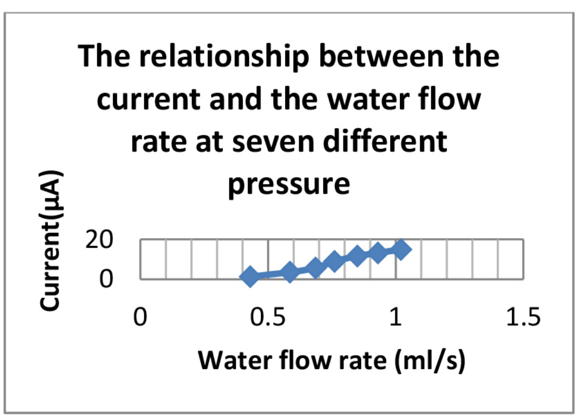

Fig. 7. Relationship between the water flow rate and current.

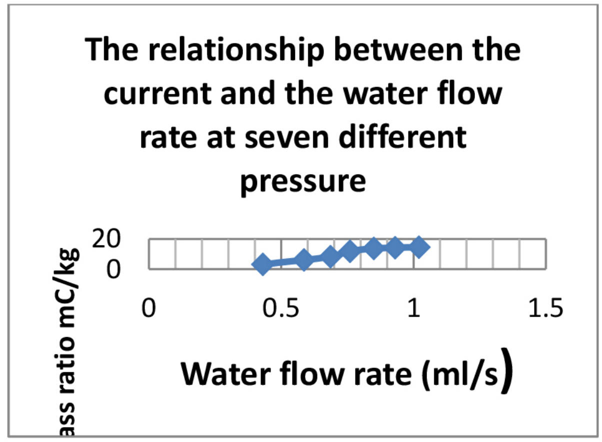

Fig. 8. Relationship between the water flow rate and current.

directly proportional. Plausibly, the reason lies in the large flow rate which resulted in larger current and larger charge mass ratio CMR. Another reason is the change in the break length by different flow rates causing a rapid change in charging ability (Mamidi *et al.*, 2003; Zhu *et al.*, 2011). Current and charge mass ration are increased with the increasing of water flow rate. The experimentally obtained results are found to be in good agreement with the COMSOL simulation results.

Conclusion

COMSOL FEM model was developed and simulation was conducted to identify electric field distribution and induced current on different five grounded targets with different shapes (conical, spherical, cylindrical, flat and ellipsoid) for a fixed charged water droplet. Direct relationships have been observed between the water flow rate and both current and charge mass ratio. There is good conformity between the theoretical and practical results. The results obtained in this work will be used to design and implement a smart spraying system equipped with sensors to improve the efficiency of pesticide application and consumption.

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