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Wind Tunnel Measurements on the Effect of Sprayer Speed on the Droplet Size Spectra

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Nasir Salim Hassen[1,*], Nor Azwadi Che Sidik[1,2]

[1] Department of Thermofluid, Faculty of Mechanical Engineering Universiti Teknologi Malaysia, 81310 Skudai Johor, Malaysia
[2] Malaysia – Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia Kuala Lumpur, Jalan Sultan Yahya Petra (Jalan Semarak), 54100 Kuala Lumpur, Malaysia

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ABSTRACT

The quality of agrochemical spraying depends on speed of the sprayer and cross wind. Dynamic spray mechanism was designed and installed in the wind tunnel for simulating the effect of speed of the sprayer and cross wind combinations on droplet spectra classifications (DSC). It is able to generate two dimensional spraying (2D) at uniform sprayer speeds under wind tunnel conditions. Droplet spectra classifications were studied using water sensitive papers (WSPs). The effect of cross wind and sprayer speed on dynamic spray was analysed and compared with reference spraying. The result of the tests showed that there were differences in the DSC when speed of the sprayer and wind speed increased. This spray mechanism was suitable for the assessment of the dynamic spray.

Keywords:
Spray mechanism, nozzle, DSC, wind tunnel

1. Introduction

Several researchers have been working recently in development and improvement of new tools and corresponding methodology that is able to assess performance of the spraying distribution systems technology. According to Hofman and Solseng [1], engineers in the fields need to know suitable spraying combinations to do their very best in handling them to achieve optimum spraying parameters. Sprayers have not been well examined under combinations of a high speed of the sprayer and cross wind, and the majority of the tests were at low speed compared to the high speed of the conventional spraying.

The use of wind tunnel simulation to investigate agricultural spraying process is important to clarify some of the spray problems. The number of variables involved in the field studies makes their interpretation difficult; hence, wind tunnel studies have been advocated to characterize the effect of operating variables on the spray distribution with a high degree of reliability since all the parameters can be controlled and changed freely [2-7]. The objective of this paper was design test

[*] *Corresponding author.*
E-mail address: nasirsalimhassen@gmail.com (Nasir Salim Hassen)

method to determine the influence of speed of the sprayer and wind speed variations that occurred continuously during field spraying operations on the droplet spectra classifications (DSC).

2. Materials and Methods

2.1 Wind Tunnel

The subsonic wind tunnel built by aeronautical laboratory of the faculty of mechanical engineering at university technology Malaysia was used to determine the effect of wind speed on spray distribution from spray nozzle. The test section of the wind tunnel has a cross-sectional area of 1.36m by 1.36m and an overall length of 5m with a honeycomb and porous fabric to produce the required air turbulence intensity and uniform velocity as shown in Figure 1.

Fig. 1. Subsonic wind tunnel

2.2 Spraying Mechanism

A multi speed spraying mechanism was designed and tested in the wind tunnel to investigate the effect of speed of the sprayer and wind speed on the DSC. The spray mechanism consists of two systems: a linear motion system and a spraying system.

2.2.1 Linear motion system

The linear motion system consists of a linear motion platform (SIMO series, PBC linear, A pacific Bearing Company, 6402 East Rokton Road, Roscoe, IL61073, USA), a servo motor (GYS - 751 D5 - HC 2, Japan) and a servo amplifier (RYT - 751 D5 - VV 2 Japan). The specifications of the linear motion system are shown in Table 1.

Figure 2 shows connecting diagram of the servo amplifier and servo motor interfaced with a PC laptop of the linear motion system. A set of tests was carried out in the laboratory with the aim to assess the accuracy of the linear motion system to work at different speeds and positions as shown in Figure 3.

The speed of servomotor of the linear motion system was adjusted and controlled from a laptop depending on the software programmed. Push buttons board was connected to the servo amplifier to move the servomotor at different speeds easily.

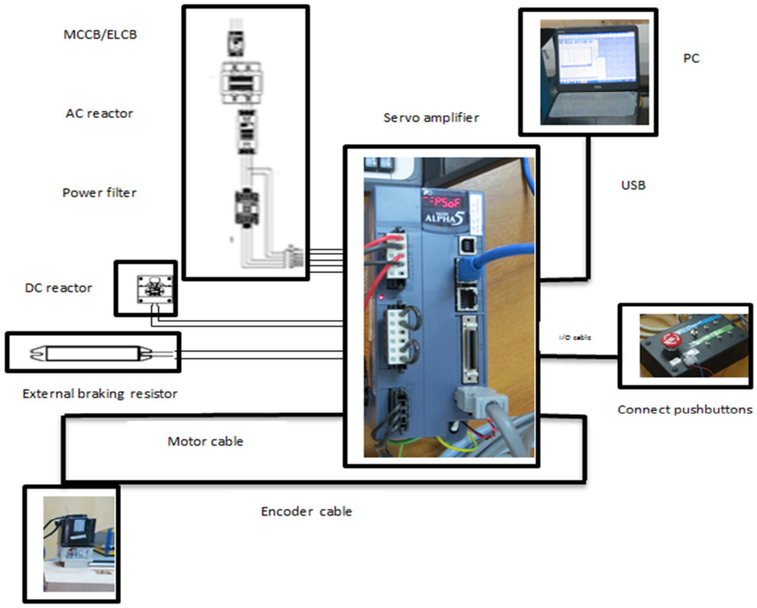

Fig. 2. Connecting diagram of the linear motion system

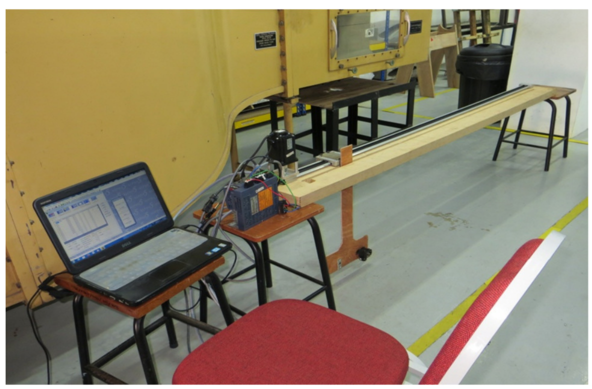

Fig. 3. Experimental set up for testing the speed of the linear motion system

Table 1
Specifications of the linear motion system

Parameter	Value
Linear motion platform	
Model	SIMO series, PBC linear
Length	2 m
Maximum speed	6.2 m/s
Resolution	0.375 mm/step in half-step mode
Motor and amplifier	
Servo motor	GYS - 751 D5 - HC 2
Servo amplifier	RYT - 751 D5 - VV 2
Motor mounting	Right-hand side
Related speed	3000 rpm
Maximum speed	6000 rpm

2.2.2 Spraying system

The spraying system consists of an external pressurized water tank, a filter, a water pressure gauge, and a single spray nozzle. The spray liquid was tap water. Table 2 shows specifications of the spray nozzle.

Table 2
Specifications of the spray nozzle

Parameter	Value
Model	AA250AUH automatic spray nozzle
Valve type	Electrically-actuated hydraulic atomizing valve
Cycle duration	From12 ms to continuous spray
Maximum cycles per minute	5,000
Power	24 VDC, 0.375 AMP
Nozzle tip sizes	Up to - 03 capacity
Maximum operating pressure	7 bar
Maximum flow rate	1.8 L/min
Flow control	Pulse width modulated (PWM)
Maximum fluid operating temperature	66°C
Weight	0.14 kg
Certificate	CE certified

2.2.3 *Measuring protocol*

The spray mechanism was installed above the wind tunnel as shown in Figure 4. The spray nozzle was mounted on a linear motion system at 0.50 m above the wind tunnel ground to move horizontally inside the wind tunnel; perpendicular to the airflow [8] to generate two-dimensional spray pattern as shown in Figure 5. Several wind tunnel tests were carried out to evaluate the effect of wind speed on performance of the spraying system. The spray tests were carried out using standard TeeJet flat fan nozzleTP11003 moving at three speeds of 2.2, 3.3 and 4.4 m/s and under effect three wind speeds of 1, 2, and 3 m/s at spray pressure of 3 bar.

For spray data, water sensitive papers (WSPs) (Novartis Corp., Basel, Switzerland) [9, 10] were used as collections and placed horizontally at one row in the centre of the wind tunnel at five positions under the swath width of the spray nozzle. The distance between two samples was 25cm [11, 12]. All samples were placed at a height of 0.07 m above the wind tunnel floor to avoid boundary layer effects, and the corresponding long axis parallel to the wind direction. After each spray run, WSPs were allowed to dry and then collected. For the validation testing protocol, three test runs were conducted. Each piece of the WSPs was put in a small plastic box and took to the laboratory for calculating the DSC.

For an appropriate magnification of the WSPs pictures, a digital camera (resolution: 2260 dpi) with a stereo microscope inserted (type: Leica Microsystems Cambridge Ltd United Kingdom, zoom range 20X), with a software was used to take the pictures. The pictures of the samples were recorded electronically. To determine the real droplet diameter, the spot diameter was inserted to the following calibration equation [13, 14]:

$$D_r = 1.033 \times D_s^{0.879} \quad (1)$$

where D_r = actual droplet diameter (µm) and D_s = spot diameter (µm). A program was written to calculate the DSC. Analyses of the DSC were made within 28 different diameter class ranges. In the software, the diameter values corresponding to 10, 25, 50, 75 and 90% in volumetric distributions ($DV_{0.10}$, $DV_{0.25}$, $DV_{0.50}$, $DV_{0.75}$ and $DV_{0.90}$), the percentage ratio of the droplets in diameter smaller than 200 µm was calculated [13, 15]. To validate the spraying results, the reference spraying was carried out for comparison.

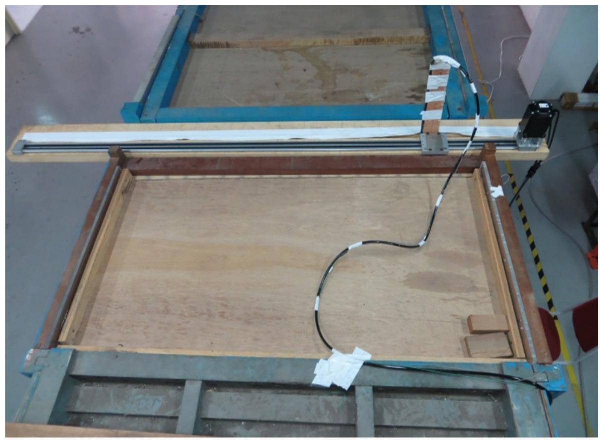

Fig. 4. Installation of the spray mechanism (linear motion system) above the wind tunnel

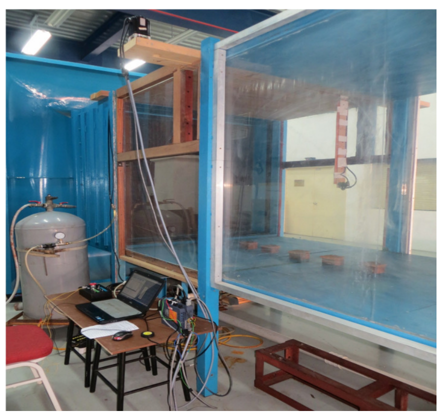

Fig. 5. Experimental set up for testing the spray nozzle in the wind tunnel

3. Results and Discussion

A ground speed of the sprayer is an important factor that affects DSC [16, 17]. A greater portion of smaller spray droplet volumes is subject to entrainment in the air [12]. As shown in Figure 6, the higher speed of the sprayer decreased the droplet size spectra of the spray nozzle [18].

All droplet size classes are capable of off-target movement under effect wind speed, but the smallest droplets would move the farthest distance before depositing on the ground [19]. In Figure 7, droplet sizes parameters of the spray pattern of the nozzle generally tended to be large at higher wind speeds because of drifting small droplets by the action of air flow[12].

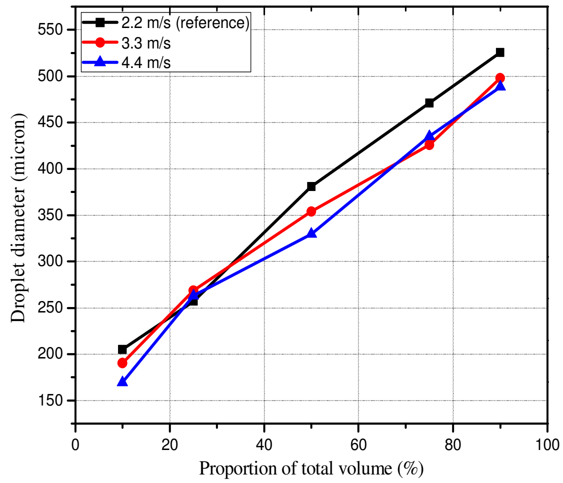

Fig. 6. Graph of droplet diameters vs proportion of the total volume for the spray nozzle at three sprayer speeds under effect wind speed of 2 m/s

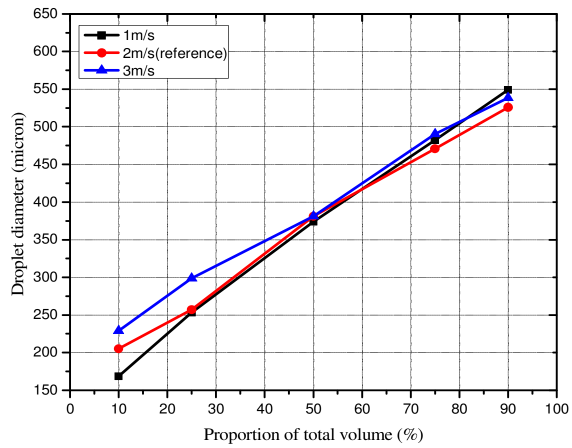

Fig. 7. Graph of droplet diameters vs proportion of total volume for spray nozzle at driving speed of 2.2 m/s under effect three wind speeds

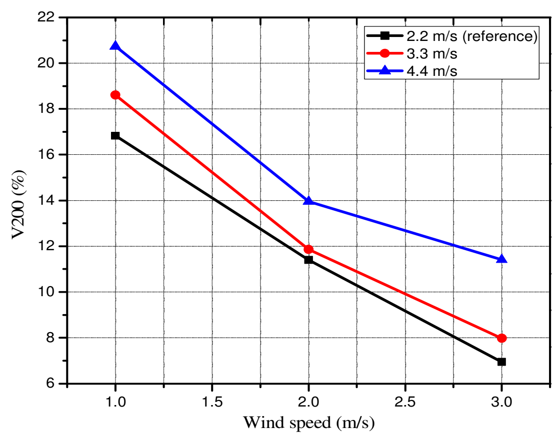

Fig. 8. Graph of V200 vs wind speed for the spray nozzle at three sprayer speeds

A proportion of droplets in diameter smaller than 200 μm in total spray volume of the nozzle was evaluated at different sprayer speed and wind speed combinations. From the results in Figure 8, the speed of the sprayer and wind speed clearly affect on DSC. The percentage of droplets smaller than 200 μm increases with increasing the speed of the sprayer [20].

4. Conclusion

The data typically showed important variations in droplet sizes under effect of the sprayer and wind speed combinations. Increasing speed of the sprayer reduces the droplet size spectra whereas increasing wind speed increases the droplet size spectra of the spray pattern. The methodology used in this study presents not only viable method for generating practical data, but also represents an easy way in which that a single user can quickly perform a large number data with minimal specialized equipment in a small laboratory. The designed spray mechanism model in the wind tunnel proved mean can be used to quickly and inexpensively simulate a large number of spraying scenarios to select the most promising spraying application combinations for field measurements. This method reduced high time and man power consumption, difficult and expensive procedure.

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