Pak. Jour. Agri. Sci.
23 (3-4) 235, 1986

USE OF FLUID DYNAMICS IN PREDICTING SPRAYING PARAMETERS

Ghulam Sarwar Sheikh and M. Shafi Sabir

Faculty of Agricultural Engineering and Technology,
University of Agriculture, Faisalabad.

Sprayers have played and will continue to play a vital role in the advancement of Agricultural production. The major problem in their development and safe application, however, is the lack of information on the optimum values of spraying parameters under different operating conditions. The principles of fluid dynamics were used for obtaining necessary information on spraying parameters like pressure, velocity of flow, nozzle orifice diameter, droplet size etc. On the basis of such an information, the final equipment was evolved and suitable recommendations for the application of insecticides and herbicides were made.

INTRODUCTION

Sprayers have played a vital role in the advancement of agricultural production by increasing crop quality and yields and reducing labour requirements for weed control. Spraying operations are also becoming increasingly important in modern agricultural practices, like Zero and minimum tillage, where eradication of weeds during pre-emergence of crop seedlings is important for direct drilling operations. Nevertheless, the extensive use of pesticide may create serious hazards, particularly, due to drifting phenomenon. Such problems are of great concern to the farmer and the design engineer.

The major problem in the development of spraying equipment is lack of information on the optimum size of droplet, pressure, velocity of flow and necessary relationships existing between the associated variables, like nozzle orifice dimensions, properties of chemical liquids, and the rate of application for herbicide and insecticide applications. In this study, efforts were made with the help of fluid dynamics to generate necessary information on the optimum values of droplet size, pressure, delivery rate etc., for insecticide and herebicide applications. Important relationships between nozzle dimensions, fluid properties and operating variables like pressure and discharge were also established. Dimensional analysis and Buckingham Pi thearem were used to evolve necessary relationships required for design engineers in order to predict the droplet size under different operating conditions. Based upon the above information and tests, a tractor mounted sprayer was evolved and necessary recommendations were made for its use in order to control insects and weeds.

PREDICTION EQUATION

The droplet size may be considered a function of the following variables :

$d = f(D, v, p, u, s, e,)$ — Dimension

When : d = droplet size = ———— L

D = dia of orifice (size of nozzle) = L

p = density of fluid — $ML^{-3} = FL^{-4}T^2$

u = visoosity of fluid ——— $F\,T\,L^{-2}$

s = surface tension ——— $F\,L^{-1}$

e = compressibility ——— $F\,L^{-2}$

The four Pi or dimensionless parameters have the following functional relationship :-

$$\frac{d}{D} = f\left(\frac{pvd}{u}, \frac{pv^2d}{s}, \frac{pv^2}{e}\right)$$

Where : $\frac{pvD}{u}$ = Reynold's Number (Viscosity effect)

$\frac{pv^2D}{s}$ = Weber Number (Surface tension effect)

$\frac{pv^2}{e}$ = Mach Number (Compressibility effect)

For the operating conditions of sprayers, surface tension and compressibility have least effects on the droplet size and consequently, they may be deleted from the original list of variables. The functional relationship is thus as follows:

$$\therefore \frac{d}{D} = f\left(\frac{pvD}{u}\right)$$

tions. Important relationships between nozzle dimensions, fluid properties and operating variables like pressure and discharge were also established. Dimensional analysis and Buckingham Pi thearem were used to evolve necessary relationships required for design engineers in order to predict the droplet size under different operating conditions. Based upon the above information and tests, a tractor mounted sprayer was evolved and necessary recommendations were made for its use in order to control insects and weeds.

PREDICTION EQUATION

The droplet size may be considered a function of the following variables :

$d = f(D, v, p, u, s, e,)$ — Dimension

Wherp : d = droplet size = —————— L

D = dia of orifice (size of nozzle) = L

p = density of fluid — $ML^{-3} = FL^{-4}T^{2}$

u = visoosity of fluid ——— FTL^{-2}

s = surface tension ——— FL^{-1}

e = compressibility ——— FL^{-2}

The four Pi or dimensionless parameters have the following functional relationship :-

$$\frac{d}{D} = f \left(\frac{pvd}{u}, \frac{pv^{2}d}{s}, \frac{pv^{2}}{e} \right)$$

Where : $\frac{pvD}{u}$ = Reynold's Number (Viscosity effect)

$\frac{pv^{2}D}{s}$ = Weber Number (Surface tension effect)

$\frac{pv^{2}}{e}$ = Mach Number (Compressibility effect)

For the operating conditions of sprayers, surface tension and compressibility have least effects on the droplet size and consequently, they may be deleted from the original list of variables. The functional relationship is thus as follows:

$$\therefore \frac{d}{D} = f \left(\frac{pvD}{u} \right)$$

It shows that the relation of the droplet size (d) to orifice dia (D) of the nozzle is a function of Reynold's number (which is the ratio of inertia force to viscous force). In case of steady flow, a small value of Reynold's number means that viscous forces predominate. A large value means that inertia forces predominate. A small value of Reydold's number may arise either from a large viscosity, small velosity or small dia of nozzle orifice.

SPRAYER DEVELOPMENT AND TESTING

A small scale model of the sprayer fitted with electric motor as a prime mover was developed in the laboratory for carrying out initial investigations. Locally made available nozzles, pumps and other parts were procured for assessing their performance. Allman's type nozzles (imported and locally fabricated) were also procured for comparative study. The equipment was initially tested and evaluated for its efficiency in the laboratory. The spray boom was installed on tripods on either side. The pressure gage recorded the pressure of the nozzles. The discharge from each nozzle was first collected on a currugated sheet metal, with large surface area and of length greater than the leegth of the spray boom from where it was allowed to pass on to the graduated cylinders. Due to loss of discharge by evaporation and impact, producing atomization of the liquid, the corrugated sheet was replaced with individual trays held opposite to each nozzle. The amount of liquid thus collected was measured with the help of the graduated cylinders. The experiment was repeated at different pressures by chenging the speed of the pump with the help of pulleys. From the trajectory and geometry of the spray pattern of the nozzle, the appropriate height and spacing of the nozzle required for different crops with at least 50 percent overlap was worked out.

Subsequent to laboratory tests, the sprayer was iustalled on the tractor through its power take off shaft (P. T. O.). The diaphragm pump had a provision for direct coupling with the P. T. O. shaft of the tractor. The operating pressure at the nozzles was registered with the help of a pressure gage. Plastic nozzle body, fibre glass tank, stainless steel spray boom and rubber hoses were used to avoid clogging of nozzles due to corrosion and abrasion.

RESULTS AND DISCUSSION

a) *Effect of Pressure on Discharge*

The following relation showing the effect of pressure on discharge was established by using tfie data, experimentally obtainted from the Sprayer developed in the laboratory :

$$Q = 45 + 31\ p - 0.104\ p'^2$$

Where : Q = discharge in C.C./minute

p' = pressure in psi

It will be observed from the above relation that the discharge increases with pressure. The locally made diaphragm type pump and Allman's type nozzles were found to fanction satisfactorily within the pressure range of 10 to 40 psi. (69 to 276 KN/m^2).

b) *Effect of Pressure on Droplet size*

In order to determine the effect of pressure on the droplet size, the following equation developed by Fraser (1956) wag used :

$$d = 437 \left(\frac{FN}{P'} \right)^{\frac{1}{2}}$$

Where : d = Surface mean dia (microns)

$$FN = \text{Flow Number} = \frac{\text{flow rate (gallons/hour)}}{\sqrt{\text{pressure in psi}}}$$

p' = Pressure of fluid in psi

(1000 cc/min = 13.2 imperial gallons per hour)

The following functional relationship was obtained from the experimental data :

$$d = 329 - 9.43\ p' + 0.1378\ p'^2$$

Where : d = mean droplet size in microns

p' = pressure in psi.

The above relation indicates that the droplet size decreases linearly with pressure from 12 to 30 psi and then remains almost constant from 30 to 40 psi. The range from 30 to 40 psi may be considered optimum beyond which the system may be rendered uneconomical, since greater pressures beyond 40 psi require study equipment and accessories to withstand high pressures. Further, it may be noted that the minimum droplet size for the pressure range of 30 to 40 psi is around 170 microns, which supports the recommendations given by many workers for insecticides applications.

c) *Effect of Reynold's Number on droplet size* :

The following relationship was developed from the experimental data :

$$\frac{d}{D} = 1415 - 0.1307\ R + 6.391 \times 10^{-6}\ R^2$$

It will be concluded from the aqove equation that there is no appreciable decrease in the droplet size beyond Reynold's Number of about 8000. It shows therefore that for the values of Reynold's Number greater than 8000, the droplet size is stable for the type of flow involved.

CONCLULIONS

The following conclusions were drawn from such investigations :

i) The Nozzle with 0.02754 cm. orifice dia gives suitable results for low volume spraying applications.

ii) Lower pressures of 12 to 15 psi (35 to 105 KN/m^2) which produce droplet sizes upto 250 microns with the above nozzle are appropriate for weedicide and herbicide applications in different crops.

iii) Medium pressures from 30 to 40 psi (210 to 280 KN/m^2) which produce droplet sizes upto 170 microns are appropriate for insecticide application in different crops.

iv) Reynold's Number from 5000 to 6000 with a velocity of flow of 2.5m/Sec., which produces droplet sizes upto 250 microns is suitable for weedicide and herbicide applications for different crops.

v) Reynold's Number from 8000 to 13000 with a velocity of flow from 3m/Sec to 6m/Sec produces a stable and uniform droplet size of 170 microns suitable for insecticide applications in different crops.

REFERENCES

Fraser, R.P. 1956. Proceedings of the Second International Conference on Plan Protection. Published by Butterworth Scientific Publications, 88 Kingsway London, W. C. 2.

Murphy, Glenn. 1950. Similitude in Engineering. The Ronald Press Co., New York.

Rouse, Hunter. 1967. Engineering Hydraulics. John Wiley and Sons, New York.