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Evaluation of a Twin-Fluid Nozzle for Precision Air-Assisted Agro-Chemical Application

Adewunmi Taiwo

Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

Abstract-- *The purpose of agrochemical application is to provide nutrients for plant growth and to control weeds, insects and other crop pests as well as plant and animal disease pathogens. The objective of this study was to fabricate a twin fluid nozzle (TFN) and evaluate its distribution pattern for on-the-go precision air-assisted agricultural chemical application. The fabricated nozzle prototype was mounted on a test rig in the laboratory with a view to determine its distribution pattern at various liquid pressures and flow rates while the air pressure was kept constant in the first instance.Thereafter, the distribution pattern was also determined for varying air pressure while keeping the liquid flow rate and pressure constant.It was concluded that independent control of liquid flow rates and spray distribution pattern was achieved by a combination of controlling liquid and air pressure. In addition, a flow turndown ratio of 1.414:1 corresponding to 35.34 to 49.98 L/min, at a fixed air pressure was achieved by the TFN and that even spray distribution pattern were observed for 35.34 L/min liquid flow rate and 200 kPa liquid pressure for air pressures below 500 kPa. Although the pattern width was independent of variation in air pressure it decreased by 40 percent as the flow rate decreased from 49.98 to 35.34 L/min.*

Keywords— Distribution pattern, Pressurized air stream, Spraying, Turndown ratio, Twin fluid nozzle.

I. INTRODUCTION

It has been observed by specialists in the field of crop protection that the level of crop protection inthe West African sub-region is generally insufficient to effectively protect the crops against the number one constraint to increased production (i.e. pests). While on one hand they found out that an increased availability and affordability of both sprayers and pesticides would improve the situation, on the other hand, it is the ensuing and unbridled malpractices in chemical pesticide application and the bad state of the equipment used that hinders an effective application (FAO, 1998). The commonest specific equipment-related problems usually observed among farmers and applicators are leaks in containers and hoses as well as faulty locking caps that directly contaminate the users. Secondly, it is the damaged or purposely enlarged nozzles that seriously hamper effective pest control and undesirably increase the use of costly pesticides. Thirdly it is the problem of calibration. In their farming practices, this is not even thought of and, therefore, generally not carried out resulting in incorrect dosage hundred percent of the time. The obvious solution to the afore-listed problems is to create an environment that actively supports the end user with both ‘software’ i.e. the knowledge that a user needs, and the ‘hardware’, i.e. the physical inputs that a user needs (Zhu, *et.al*,2005). The development and evaluation of twin-fluid nozzle for use on an agro-chemical spraying apparatus will be a step in the right direction.

The use of sprayers equipped with twin-fluid nozzles for the application of liquid agro-chemicals in form of pesticides, surfactants, pheromones and nutrients may improve crop production efficiency and environmental stewardship. On-the-go breaking of liquid stream discharged from the nozzle into droplets with the air stream simultaneously discharged from the same nozzle results in uniform distribution pattern, as long as the air and liquid pressures and flow rates are carefully adjusted (Barreras*et.al*, 2006).The air supply required to operate this type of nozzle design is usually provided by a compressor mounted on the sprayer. An important feature of this system is the ability to vary nozzle output and spray quality independently for a given nozzle tip by varying the input pressures of both air and liquid. The nozzles can operate effectively at relatively low volumes with sprays whose droplets also have pressurized air-inclusion(Watanawanyoo, *et.al, 2012*).Trials carried out by numerousresearchers have been used to demonstrate that more effective drift control could be achieved with the use of twin- fluid nozzle than what was obtainable with the use of conventional nozzles operated at the same flow rates and liquid supply pressures. The remarkable reduction in drift with the use of the nozzle has been achieved as a result of:

the relatively larger inter droplet air inclusion in the spray generated with appropriate settings; co-axial flow of air current simultaneously discharged from the nozzle with the liquid spray; complex mechanism of spray formation within the nozzle body (Moore, 2003).

The objective of this study was to fabricate a twin-fluid nozzle (TFN) and evaluate its distribution pattern for on-the-go precision air-assisted agricultural chemical application.

II. MATERIALS AND METHODS

1. Design and fabrication of the twin fluid nozzle prototype

Twin fluid nozzles make use of spray liquid and air simultaneously fed into the nozzle body under pressure to create a spray. The air supply needed to operate this type of nozzle design is usually provided by a compressor mounted on the sprayer. A very important feature of this system is the ability to vary nozzle discharge and spray quality independently for a given nozzle tip just by varying the input pressures of both air and liquid(Rahman, *etal.*, 2009). The nozzles can operate effectively at low volumes because sprays have droplets with air-inclusions. The presence of air-included droplets in the spray discharged from twin fluid nozzles means that they differ in behaviour after leaving the nozzle compared with the same size of conventional droplet.In this study, a 7.5 mm diameter, and 110 mm long gas injector with a 4.5 mm diameter hole throughout its length was machined from a 25 mm diameter and 110 mm long brass stock. Six 2 mm diameter equally spaced orifices were drilled on its tapered lower end while 45 mm of its upper length was machined into an M14x 2.6g thread with 6 mm length, 14 mm length of hexagonal shape of 12.5 mm width and 25 mm length of M18x2.5-6g thread consisting of a 4.5 mm diameter as shown in Figure 1.

In view of this, the established spray classification system does not apply directly to sprays discharged from this type of nozzle design. Trials by numerous researchers have shown that good control of drift can be achieved when compared with conventional nozzles operating at the same flow rates(Watanawanyoo, *etal.*, 2012).

2. Description of the Twin Fluid Nozzle (TFN)

In the twin-fluid atomizer, the liquid is broken into droplets and ligaments by the interaction between the pressurized gas and liquid to lead to spray. This process will proceed more easily if the liquid is introduced as liquid sheets which have higher surface energies or higher instabilities,and thus are more susceptible to disintegration(Moore, 2003). Aerodynamic forces promote the disruption by exerting external distorting forces to the bulk liquid (Barreras*etal.*, 2006). A breakup occurs when the magnitude of the disruptive force exceeds the consolidating surface tension force (Watanawanyoo, *et al.*, 2012).

The fabricated nozzle, originally designed by Moore, (2003), has an internal mixing chamber where air and fuel separatelyintroduced through specified inlet ports are mixed. It is the mixing of the air and fuel that causes a primary breakup within the chamber, leading to the production of fine droplets at the exit of the nozzle.

3. Fabrication of the twin fluid nozzle

3.1 The gas injector

The gas injector is a very essential component of the twin fluid nozzle because it is the device that introduces high velocity and pressurized air into the mixing chamber where it interacts with a relatively low velocity pressurized liquid stream introduced into the nozzle body through the two water inlets.

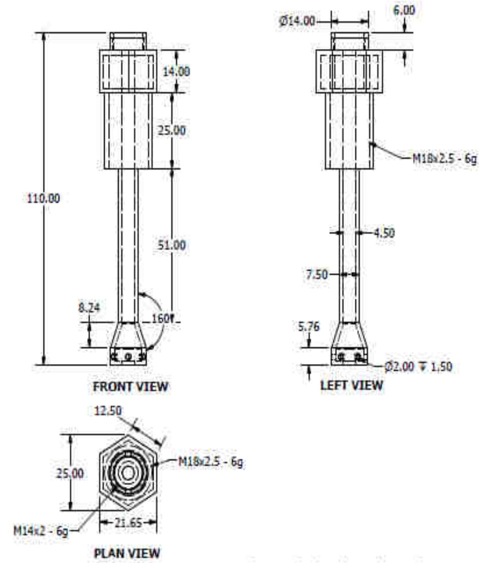

Fig 1: Sectional views of the gas injector of the fabricatedtwin fluid nozzle (all dimensions are in millimeter

3.2 The mixing chamber

The mixing chamber is that part of the nozzle where the high pressure gas introduced into the nozzle body by the gas injector interacts with the pressurized liquid introduced into it through the two water inlets (Figure 2). The sudden reduction in its internal diameter from 16 to 13 mm causes a large drop in local pressure which triggers the acceleration of the two-phase flow in this region which were in the annular flow regime. Operating in this regime promotes instability which led to atomization.

The mixing chamber was fabricated by drilling a 16 mm ϕ hole, 84.5 mm deep at one end of a 95 mm long, 22 mm ϕ brass stock. A hole of 13 mmϕ was drilled 49 mm deep at its other end. Two M22x1.5-6g threads were machined on the two ends of the 85 mm long mixing chamber as shown in Figure 2.

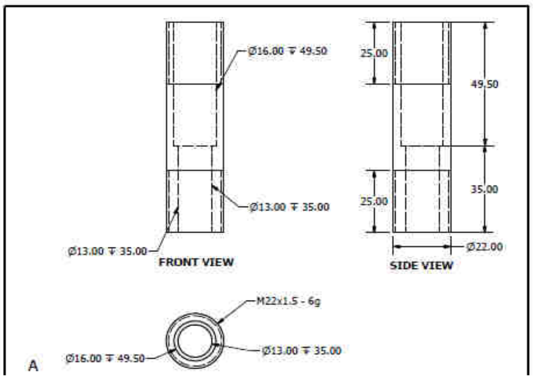

Fig. 2: Sectional views of the mixing chamber (all dimensions are in millimeters)

3.3 Nozzle tip

A single 2.5 mm diameter hole was drilled on the closed end of the hexagonal-shaped nozzle tip which was machined from a 50 mm long, 30 mm diameter brass stock. The lower 10 mm of the nozzle tip was machined into a taper shape that reduced its leftmost end to 9.50 mm diameter. An annulus containing two orifices with internal and external diameters of 0.94 and 2.50 mm respectively were drilled on its left end. The details of the milling of its remaining 25 mm length as well the drilling and threading of the internal holes are as shown in Figure 3.

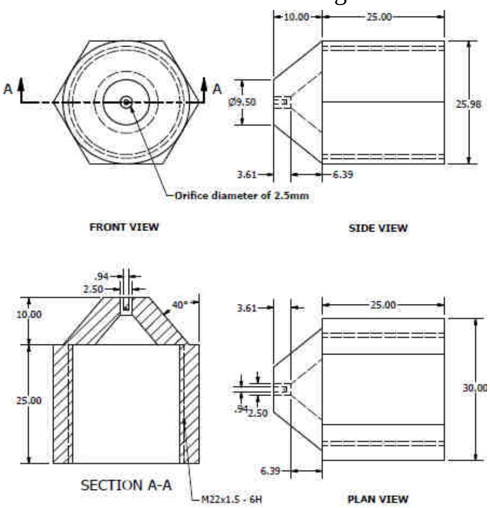

Fig.3: Sectional views of the nozzle tip(all dimensions are in millimeters)

3.4 Nozzle body

The nozzle body serves the purpose of a casing and point of attachment for all the other components of the twin fluid nozzle. It was machined from a 90 mm long cylindrical brass stock with 85 mm diameter. The last 20 mm length of the stock was reduced to a 32 mm diameter cylinder before milling the remaining 70 mm length into 75 mm x 70 mm flat surfaces on a milling machine. Thereafter internal holes were drilled and threaded. The fabricated water inlets, gas injector, mixing chamber and nozzle were assembled on it as shown in the sectional and exploded views shown in Figures 4 and 5.

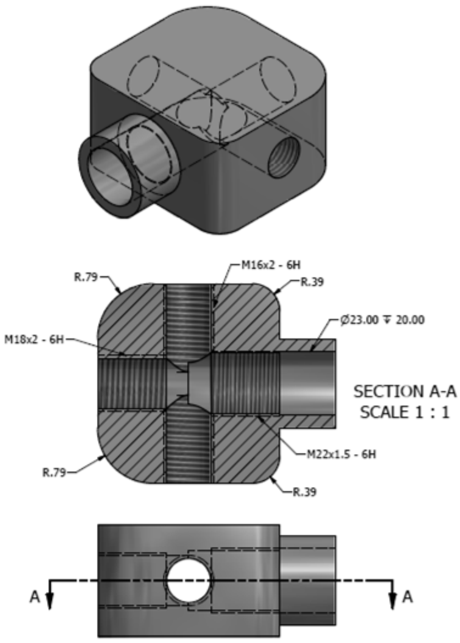

Fig. 4: Sectional views of the nozzle body (all dimensions are in millimeters)

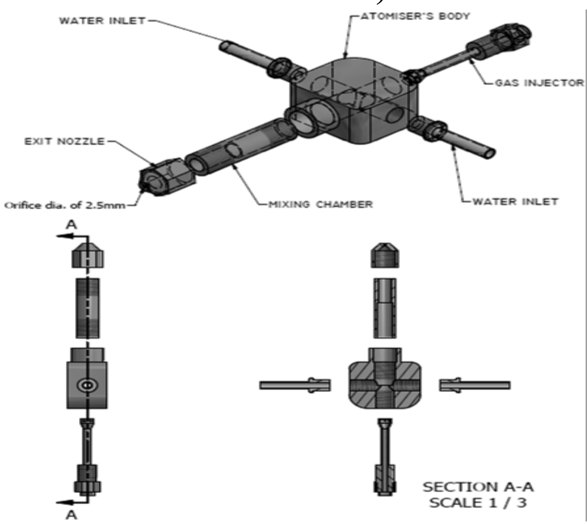

Fig. 5: Exploded view of the Assembled Fabricated twin fluid nozzle (all dimensions are in millimeters)

4.Spray Distribution Test

The nozzle spray pattern distribution was measured with the use of the test rig developed by Taiwo and Oje, (2011). The patternator table of the test rig was designed in such a way that the spray run-off was measured with the use of graduated cylinders positioned every 12.2 mm along the spray width (Figure 6). The twin-fluid nozzle was mounted at a height of 57.76 cm above the table top. The graduated cylinders were labeled from the left to the right hand side of the table to enhance their visual identification for ease of recording the volume data.

After each pattern test run of the TFN, the spray volumes collected in all cylinders were summed up. The volume in each cylinder was then divided by the total collection. The fraction of total nozzle flow in each cylinder was used to investigate the spray distribution at the different flow rates and pressures of liquid and gas. This method was similar to the one used by Womac, (2001).

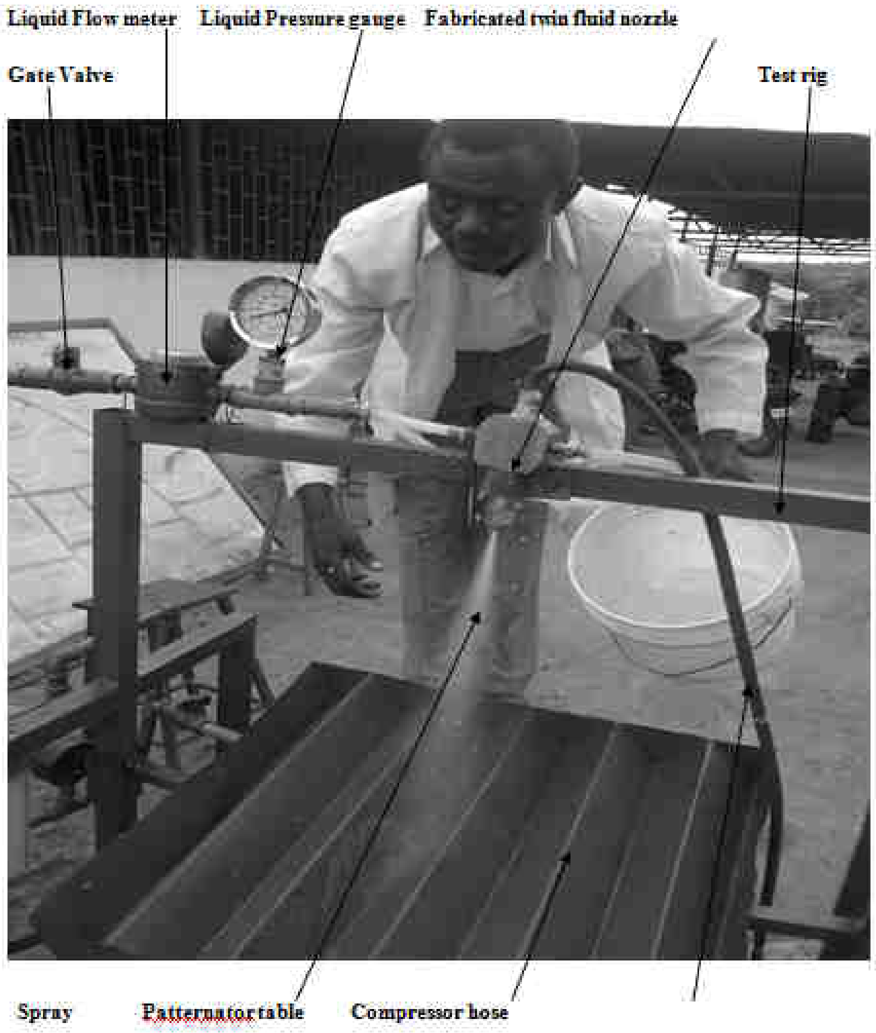

Fig. 6: Test setup for measuring the nozzle spray distribution pattern

III. RESULTS AND DISCUSSION

Observed spray pattern data for the flow rate in the range of 35.34 to 49.98 L/min at a constant air pressure of 700 kPa and liquid pressure in the range of 200 to 400 kPa are shown in Figure 7. The spray distribution pattern was slightly skewed to the left of the
nozzle axis.

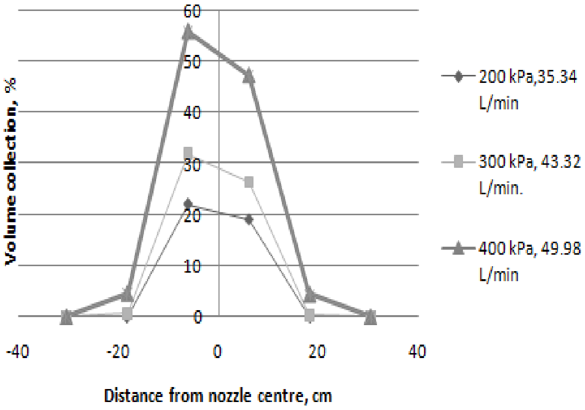

Fig. 7: Spray distribution pattern for various liquid pressures and flow rates at a constant air pressure of 700 kPa

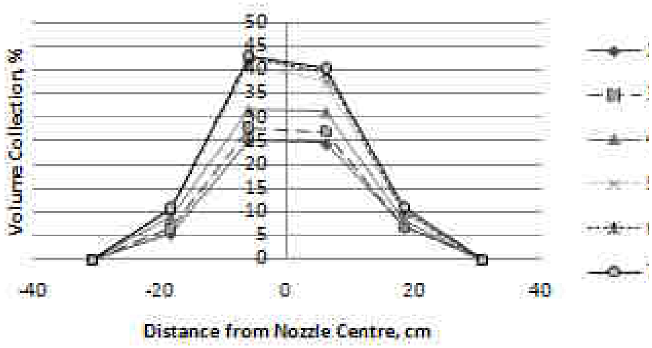

Fig. 8: Spray distribution pattern for various gas pressures at a constant liquid flow rate of 35.34 L/min and liquid pressure of 200 kPa

Although the spray distribution pattern remained symmetrical as the air pressure was varied from 200 to 400 kPa, it skewed towards the left side of the nozzle axis as the air pressure varied from 500 to 700 kPa. While the maximumvolume collection on the left side of the nozzle axis was 43% when the air pressure was 700 kPa, the maximum volume collection on the right of the axis at the same air pressure was 40.4 %. This pattern was maintained down to air pressure of 500 kPa. Conversely, the volume collection on both the left and right side of the nozzle axis was 31.6 % when the air pressure was 400 kPa. This pattern was maintained for the two lower air pressures. Although the spray distribution increased as the air pressure increased, the width of the distribution pattern did not vary with variation in air pressure. The width of the distribution pattern was maintained at 70 cm for all the six levels of air pressure.

The maximum volume collection on the left of the nozzle axis at the maximum liquid pressure and flow rate was 56 % while that of the right was 47.4 %. This pattern was maintained for the two other combinations of liquid pressures and flow rates. Generally, volume collection increased with increase in combination of liquid pressure and flow rate. This implies the spray was not distributed uniformly along the pattern width and that it tapered at the pattern edges as the combination of liquid flow rate and pressure varied. At a nozzle height of 55.76 cm, the pattern width decreased from 70 cm to 36.6 cm as the liquid flow rate and pressure decreased from 49.98 L/min and 400 kPa to 34.34 L/min and 200 kPa respectively.

The observed spray distribution pattern data when the air pressure was varied from 200 to 700 kPa while the liquid flow rate and pressure were kept constant at 35.34 L/min and 200 kPa respectively are shown in Figure 8.

IV. CONCLUSIONS

A twin-fluid nozzle (TFN) using liquid and air pressure to achieve independent liquid flow rate and various spray distribution patterns was fabricated and tested. Specific conclusions were drawn as follows:

1. Independent control of liquid flow rates and spray distribution pattern was achieved by a combination of controlling liquid and air pressure.
2. A 1.414:1 flow turndown ratio corresponding to 35.34 to 49.98 L/min, at a fixed air pressure was achieved by the TFN.
3. Even spray distribution pattern were observed for 35.34 L/min liquid flow rate and 200 kPa liquid pressure for air pressures below 500 kPa. Although the pattern width was independent of variation in air pressure it decreased by 40 percent as the flow rate decreased from 49.98 to 35.34 L/min.

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