November-December 2019
ISSN: 0193-4120 Page No. 733 - 740

An Investigational Research of Spray Pattern for Deflector Flat Spray Nozzle using Horizontal Patternator

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Abstract
Valuation of the spray patterns and spray angle is necessary for producing nozzle applications such as in combustion process, agriculture, which is the experiment result in less liquid usage, and increased spray distribution accuracy. Therefore, this study investigate to analyze the spray distribution nozzle and consider the water consumption and spray angle using several type of deflector flat spray. First, the result should assist with spray patternator construction to determine water consumption. Then, measure of spray angle using Digital Single Lens Reflex Camera (DSLR) and image J software. The results provided support two fluid flow in the nozzle with increase of air pressure can reduce water consumption compared with single fluid flow. Effect of relationship between air pressures with water pressure in the nozzle producing the large spray angle compared water pressure only in the nozzle. Thus, fluid pressure in the nozzle is main parameter in developing on spray distribution. Spray pattern and spray angle are also an important consideration in nozzle selection and application.

Keywords: Patternation, Nozzle, Spray Patternator, Spray angle, Pressure.

1. Introduction

Application of spray are used widely in the industries activities such as combustion application, cooling system, reduce gas emissions, painting, agriculture etc. So, spray pattern and distribution is depend on nozzle characteristics, nozzle design, fluid pressure, and design the spraying system. Patternator is device consist of test tubes with uniform distributed to collect of liquid spray. Therefore, it is give the data of liquid consumption, spray wide and spray pattern distribution and also to define the nozzle

position, nozzle spacing, and nozzle quantity.

The main objective of studied the spray pattern is to analyzing the uniform spray distribution and maintain the accurate fluid flow rates. Basically, nozzles are applied for three function. Firstly is to disperse a liquid over at the target area. After that, spray function is to increase the surface area of liquid, and finally is to make impact force of liquid on the solid surface. Benefit of spray pattern are investigate the relationship between the spray pattern and flame pattern as especially in combustion constancy. Liu, Liu, Yang, Mu, & Xu (2015) was deliberate the spray pattern with flame stabilization used the pressure-swirl atomizer. The finding in this studied is spray parameters such as spray pattern, droplet size, droplet size spreading, and flow in the combustor is control the combustion efficiency[1][2].

In agricultures sector, Khot et al. (2012) was investigate the water spray consumption by using the several type of axial fan nozzle. The researcher was used a vertical patternator to identify the spray pattern assessments. The finding from this research is liquid flow rates increased 60% to 100% and also increased the air-assistance in amount of spray liquid on the patternator compartments[3]. Pergher (2004) used vertical patternator to determine the largest deposit variability, both between single leaves and between sampling locations, due to dryness of spray deposits on the vertical patternator[4]. Luck, Schaardt, Forney, & Sharda (2016) mention that the patternator had develop data acquisition for spray system to collecting spray pattern data. Patternator can provide the evaluation of spray pattern with different type of nozzle design with determines whether acceptable or poor spray distribution[5].

Advantage of spray patternator are to define relationship between spray patterns with flame pattern in combustion process. Besides that, applications of spray patternation is important in various spray consumers include gas turbine, fuel injection, cooling spray, painting sprays, and spray drying processes. Spray patternator can determine the effectiveness of nozzle spray distribution include identify the nozzle design effective or not [5]–[7].

Against this background, the purpose of this research is to answer the liquid consumption in deflector flat spray nozzle used in kitchen hood ventilation system. More specifically, this research has two objectives:

1) To analyze the spray distribution base on width spray for several type of deflector flat spray nozzle.
2) To investigate the water consumption and spray angle of the deflector flat spray nozzle.

Information produced from this research should provide the knowledge the spray patternator measurement in evaluating the spray pattern using the deflector flat spray nozzle.

This article is structured as follow: First, an introduction of spray patternator and applications. Next description of the material and method for this study. The result and discussions of the study is presented. Lastly, the articles concludes of the study's research is described.

2. Materials and methods

2.1. Spray Patternator Construction

The spray patternator collection system was built following the standard AAMS Salvarani BVBA Company. Fig.1 as shown

November-December 2019
ISSN: 0193-4120 Page No. 733 - 740

as the picture of spray patternator construction. The surface of the spray patternator with dimension 0.7 m (length) X 0.3 m (width) X 0.025m (depth) and constructed from stainless steel The length of surface of spray patternator to allow for measurement from flat spray nozzles with wider of spray. The surface patternator with angle 15o degree is construct with test rig and nozzle holder. The nozzle position height is 20 cm from the surface patternator with distance each slot patternator is 17.5mm with test tube at the end of surface patternator as shown as in Fig.2. Test tube is allocate at test tube holder to collect amount of water spray from the nozzles[2][8][9].

2.2. Deflector Flat Spray Nozzle

The type of nozzle in this studied is deflector flat spray nozzles with four different type of design were measured to evaluate the spray pattern and spray angle. The detail drawing for each nozzles are given in Fig.3. Fig.3 (a) is deflector nozzle type single fluid flow, while Fig.3 (b), (c), and (d) is twin fluid flow nozzle. Single fluid flow is only one fluid whether liquid or air flow in the nozzle structure whereas twin fluid flow is mixing of liquid and air in the nozzle mixing chamber and through the nozzle orifice to produce atomization. In this study, use water as medium to investigate in the patternator system.

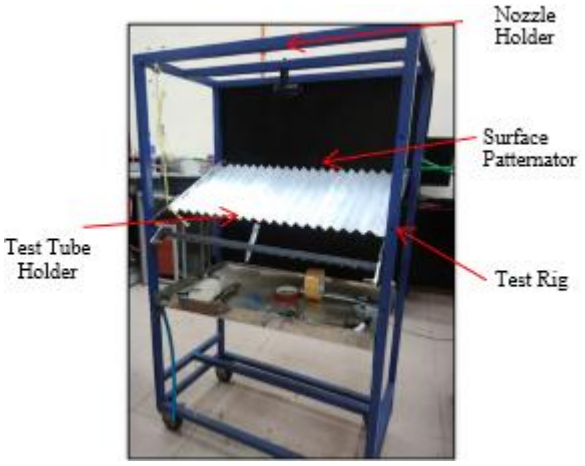


Figure 1. Picture of spray patternator construction.

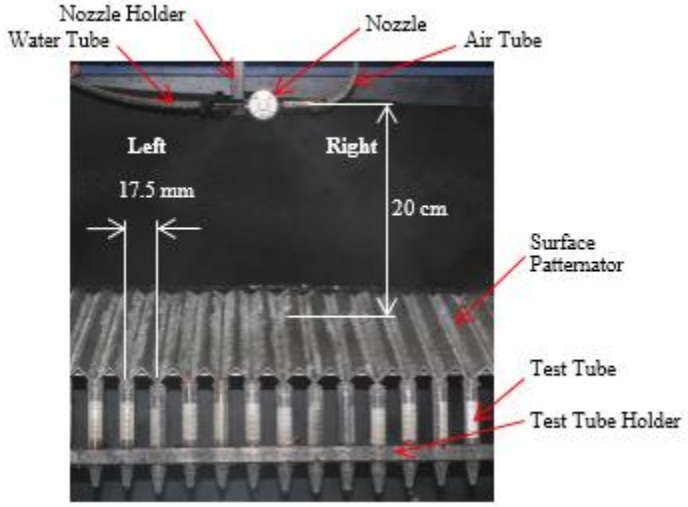


Figure 2. Nozzle mounted at spray test rig with surface patternator and test tube.

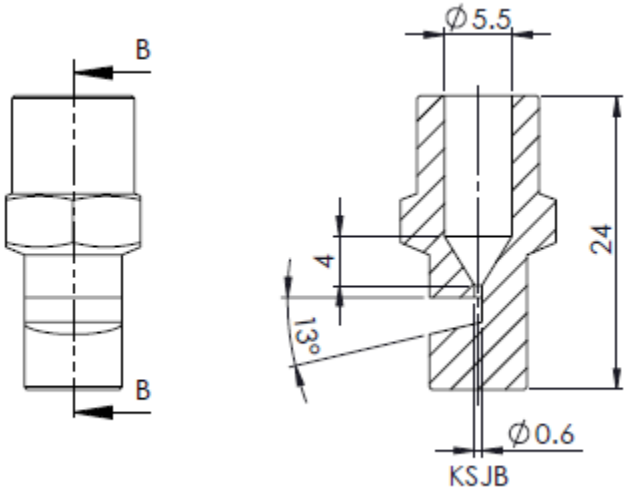
The detail description of deflector flat spray nozzles as bellows:

a. Fig. 3(a) shows single fluid flow nozzle which is only water flow. This KSJB nozzle (KSJB is nozzle's name) is conversional nozzle where it is install in kitchen hood system produce by Halton Company. This nozzle has diameter orifice 0.6 mm with length 24 mm and angle 13^{o} of deflector. Deflector is break up of bulk liquid to small particle or droplets and spreading the water spray.
b. Fig. 3(b) indicate twin fluid flow nozzle. It is also conversional nozzle and the

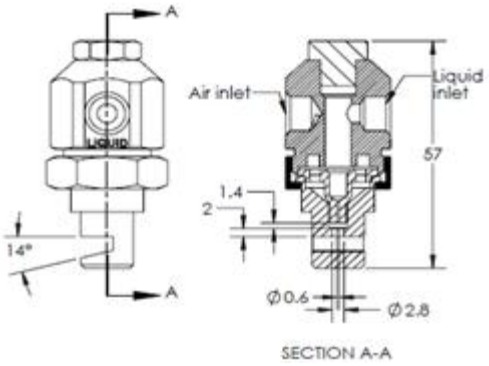
November-December 2019
ISSN: 0193-4120 Page No. 733 - 740

model name AL 75 produce by Delevan Company. The diameter of nozzle orifice is 2.8 mm with size of mixing chamber is 13.3 mm^2.

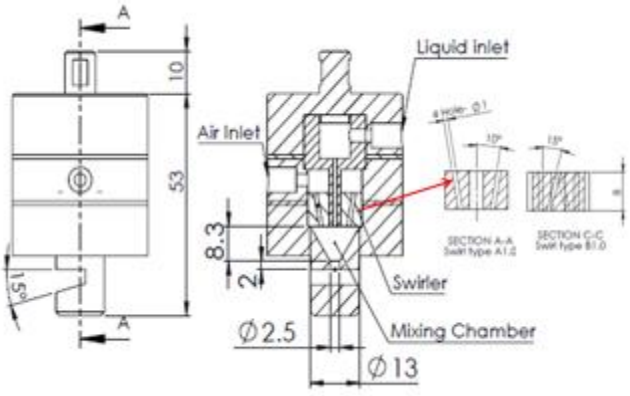
c. Refer fig.3 (c), this is new deflector nozzle (ND 2.5). The nozzle orifice is 2.5 mm with cone mixing chamber with sizes is 64.95mm^2. It has two type of swirl as shown as in fig. 3 (d). Type 1 is A1.0 where the orifice diameter 1 mm with angle 10^o, while type 2 is B1.0 with orifice diameter 1 mm and angle 15^o. So, new deflector nozzle have two type, there are ND 2.5 A1.0 and ND 2.5 B1.0.



(a)



(b)



(c) (d)

Figure 3. Types of deflector nozzles used in this study (a) KSJB (b) AL75 (c) ND 2.5 (d) Type of swirl A1.0 and B1.0 (all dimension in mm).

2.3. Experiment setup

2.3.1 General information

Inspired by previous work on pressure fluid sprays for KSJB, AL75, ND 2.5 A1.0, and ND 2.5 B1.0 deflector nozzle as shown as in Table 1[10].

Table 1. Fluid flow rate and working pressure for each nozzles.

Type of Nozzle	WFR cm^3/min	W P (bar)	AFR L/min	A P (bar)
KSJB	350	3	none	0
AL75	140	3	40	3
AL75	130	3	60	6
ND2.5-A1.0	460	3	25	3
ND2.5-A1.0	330	3	40	6
ND2.5-B1.0	440	3	25	3
ND2.5-B1.0	300	3	40	6

Remarks: WFR = Water flow rate
WP = Water pressure
AFR = Air flow rate
AP = Air pressure
1 cm^3/min = 0.001 L/min

November-December 2019
ISSN: 0193-4120 Page No. 733 - 740

In order to determine the spray patternation the experimental setup as presented below:

Method 1: Spraying System (Patternator)

The operation the experiment apparatus as shown in Fig.2 and schematic diagram of the spraying system as presented in Fig.4. The spraying system needed water pump and air compressor to produce atomization for nozzle AL75, ND 2.5 A1.0 and ND 2.5 B1.0, however for KSJB nozzle used water pump to produce water spray. First step is make sure piping system in good condition included water pump and air compressor. Next step is make sure gate valve for water and air system in fully open and then switch on the air compressor and water pump. Control volume of the air gate valve and water gate valve base on pressure required refer Table 1 until spray constant. Switch off the piping system. Clean the surface patternator include test tube without water. Then, switch on air compressor and water pump until constant spray distribution around 20 seconds. Switch off the piping system and collect the data on the test tubes. Clean the surface patternator and test tubes before run the next experiments. Repeat this experiment for three times and get the average.

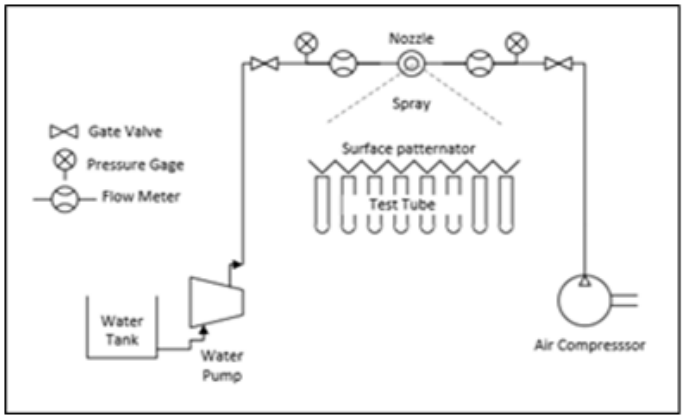
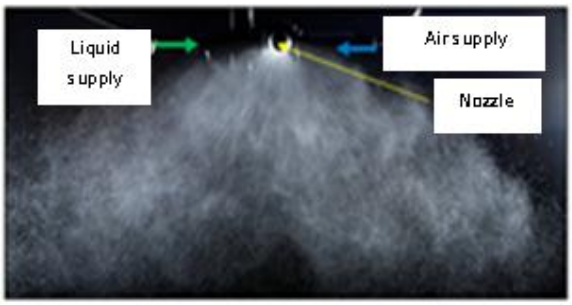


Figure 4. Diagram of spraying system

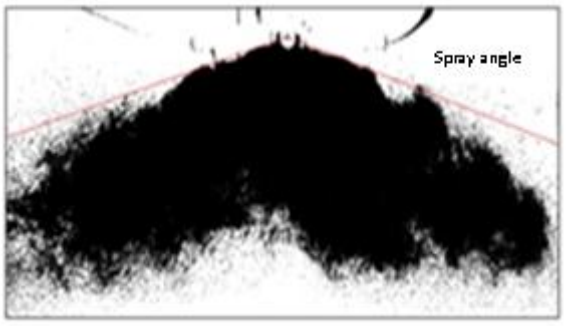
Method 2: Spray Angle measurement technique.

Second experiment is measure spray angle used the Digital Single Lens Reflex Camera (DSLR) and image J software. This technique used DSLR type Nikon D7000 with a resolution of 1920×1080 pixels and shutter speed 1/8000 fps with Aperture F22. The Lens brand is Nikon EF 17 - 40 mm F41. Distance of the Lens to the nozzle is about 0.6 m. Capture the spray distribution for each nozzles and measured the angle use the Image J software. Fig. 5(a) Spray image captured by DSLR camera and Fig. 5(b) image convert to binary process in Image J software. After that, make line in button Angle tool. Then, Select Analyze tool and then click Measure to determine Spray angle.



(a)

November-December 2019
ISSN: 0193-4120 Page No. 733 - 740



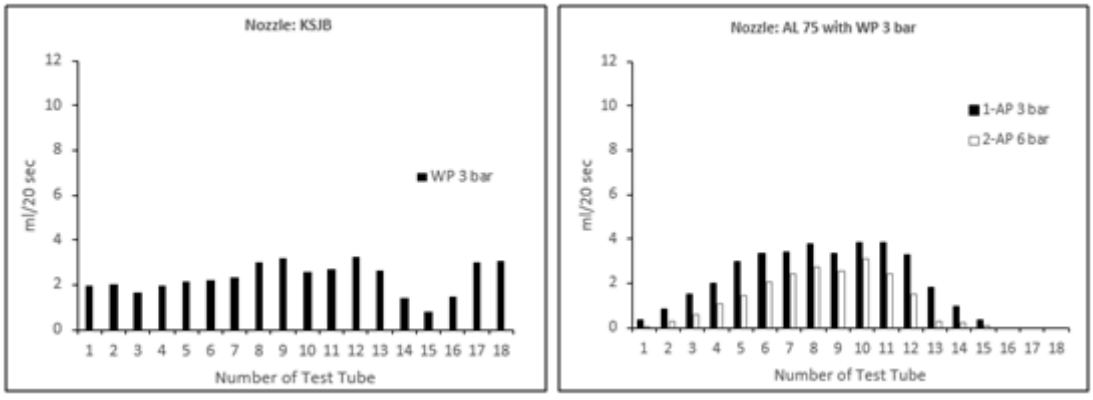
(b)

Figure 5. (a) An example of spray image for Nozzle AL-75 with water Pressure 3 bar and air pressure 6 bar using DSLR camera (b) Draw two intersecting line for measure spray angle using Image J

3. Results and Discussion

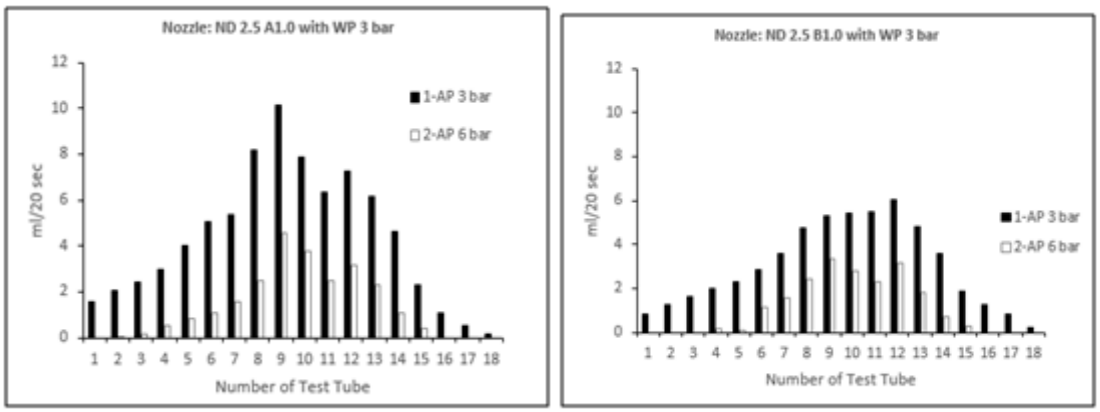
Fig. 6(a) until 6(d) shows the spray distribution patterns of the deflector flat nozzles with specific fluids pressure. Details explanation as shown as in Table 1. For KSJB nozzle only water pressure at 3 bar while for AL75, ND 2.5 A1.0 and ND 2.5 B1.0 needs 3 bar water pressure and air pressure 3 and 6 bar. Fig. 6 (a) provided the spray pattern for KSJB nozzle. The results indicate that water fills in every test tube from number 1 until 18 but the graph pattern is fluctuations. This nozzle is not contribute atomization process because of single fluid flow and low fluid pressure.

Refer Fig. 6(b) and 6(d) shows that the graph patterns clearly verified non-symmetric spray distribution on the right and left side of the sprayer for nozzle AL75, ND 2.5 A1.0 and ND 2.5 B1.0. Test tube number 16, 17 and 18 is no water enter in the test tube because of right side is air tube supply and this region more air supply compared with water especially for air pressure 6 bar. Increase of air pressure in atomization process will increase spray angle and droplet sizes. All these figure shows the spray pattern of adapted from nozzles for 3 bar water pressure (refer Table 1-water flow rate) and air flow rates (25, 40 and 60 L/min). At any increasing of air-assistance setting on 6 bar, decreasing of nozzle flow rates from water collection by 18 test tubes. Generally, the spray patterns proven that with increasing air-assistance (Fig. 6b, 6c and 6d), the amount of water reduce 41% for AL75, 69% for ND 2.5 A1.0 and 63% for ND 2.5 B1.0 (refer Table 2).



(a) (b)

November-December 2019
ISSN: 0193-4120 Page No. 733 - 740



(b) (d)

Figure 6. Spray pattern from each type of deflector nozzles with 3 bar Water pressure, air assistance in 3 bar and 6 bar air pressure (a) KSJB (b) AL 75 (c) ND 2.5 A1.0 (d) ND 2.5 B1.0.

A summary of the experiment results for spray patternator using four type of deflector flat nozzles are shown in Table 2. Table 2 is illustrated from Fig. 6 (a) until 6 (d). The limitation might be related to collecting data and interpreting the results. the limitation is four different type of deflector nozzles always operate at 3 bar water pressure and minimum air pressure is 3 bar and maximum air pressure at 6 bar, were used in the tests in order to measure the effect of spray angle. An increase of air pressure, the spray angle increase depends on the nozzles design. KSJB nozzle has a smaller angle compared to the other nozzle because of the single fluid flow and small design. Air assistance of spraying nozzle to supports for increase the spray angle but depending on the nozzle design. If the air pressure over in the nozzle, it cannot produce the spray distribution and it's called over flow or back flow. Refer Table 2 indicate that ND2.5 B1.0-2 has larger spray angle (157.9 ^{o}) compared the other deflector nozzle because of bigger size of nozzle mixing chamber compared AL75 and larger of swirler angle compared ND 2.5 A1.0 (refer Fig. 3d). However, influence of decrease air pressure (3 bar) in the nozzle system give effect to increase the water consumption[8][9][11].

Table 2 Summary of the result for four (4) type of deflector flat nozzles

Nozzle	Average water consumption for each test tube (ml/20sec)	Total water consumption (ml/20sec)	Spray angle (^{o})
KSJB	2.30	41.31	108.1
AL75-1	1.98	35.55	143.5
AL75-2	1.15	20.73	145.8
ND2.5 A1.0-1	4.34	78.08	149.4
ND2.5 A1.0-2	1.35	24.32	157.1

ND2.5 B1.0-1	2.99	53.88	148.4
ND2.5 B1.0-2	1.10	19.74	157.9

4. Conclusion

The effect of fluid pressure on spray pattern and spray angle constantly depends on nozzle design and fluid flow rates. The water consumptions is greatly reduced with water/air pressure ratio at spray distribution. Meanwhile, spray angle is related with water/air ratio and a nozzles design. Air assist in spray distribution also contribute objectives achievement in this study. The spray behaviors include spray pattern and spray angle can be explained the spray applications.

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