

Numerical Analysis on the Effect of Boom Sprayer Collecting Plate Angle to the Distribution of Granular Fertilizers

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Abstract. Optimization of boom sprayer collecting plate angle is a tedious procedure if it is done fully experimental. This paper demonstrates that the optimization process is more practical by simulation analysis validate through logical reflection of particles. This study is carrying out through simulating the distribution parts of the boom sprayer by using the commercial software, ANSYS. The multiphysics capabilities of ANSYS enable ANSYS to carrying out this simulation. The simulation is carrying out by manipulating the angle of the collecting plate, 32°, 60°, 90° and 120° of the boom sprayer to find the optimum range of angle that will produce a good distribution for different sizes of the granular fertilizers and air velocity of the blower. The constant variables in this simulation are the atmospheric pressure of 1 atm and the particles size of Potassium K is 1mm. There are 60 per cent of the images produce by ANSYS, through observing the number of stream lines and the angle of distribution show that the optimum angle is between 32° to 60°. For further study, in order to increase the accuracy, the simulation is further validate through experiment. It is preferred to carry up the experiment through scaled down model without causing any changes to the current design and in order to be carrying out in the lab.

1. Introduction

1.1. Current practice in boom sprayer collecting plate angle optimization

Optimization in this study is defined as finding the best parameters to produce the best distribution in distributing the fertilizers [1]. Optimization can be done both in experimental and simulation. However, carrying out full experiment is not preferable. First, the actual size of the boom sprayer is too bulky for lab scales. It requires a lot of space. Second, manipulating the parameters might interfere the actual geometry of the boom sprayer. Thirdly, if the experimental is carrying outdoor, the results might affect by a lot of others factors such as wind factors and the condition of the road, which makes the study complicated [2]. Forth, it is very costly because the usage of materials such as petrol must be consider and the usage of fertilizer will be in large scales. Firth, It took a longer time to finish one experiment whereby simulation can generate a lot of results at the same time by using all the available computer in the lab.

In these papers, the main focus is how the readjust of the angle of collecting plate to help to improve the distribution [3]. Further study can be made by validate the results through scaled down experiment and by manipulating more parameters such as the distance of the each blow head, the length of the collecting plate and even the sizes and shape of the boom. It depends on your modelling. Either simulation or scaled down experimental can be done in the lab, making the work of design



much more easier and comfortable compare to outdoor. The result of the simulation and conclusion produce in this paper help to contributing parts of ideas for researches to redesign boom sprayer for a better distribution under various condition.

Table 1.0 show the summary of previous study of researches which manipulating parameter of the boom sprayer. Some manipulated the air velocity of the blower and some the nozzles distance. So far manipulating the angle of the collecting plate still requires a lot of study. The function of the collecting plate is to direct the fertilizer from the boom to the field. Therefore, the distribution will change when the angle of the collecting plate is changed. This is a very tedious work which involved total of 40 experiments under two conditions. The first one is that the angle of the collecting plate from blow head 2 to 7 are the same. Another condition is the angle of the collecting plate of the blow head nearest to the inlet must not larger than the angle of the collecting plate further from the inlet. The reason is explained in Table 1.1. Conducting 40 experiments require a high cost and time consume. This can all be minimize by using simulation.

Table 1.0 : The summary of the previous study [4], [5], [6]

Author/year	Title	Findings
Dieter Foque, Pascal Braekman, Jan G. Pieters, David Nuyttens / 2012	A vertical spray boom application technique for conical bay laurel (<i>Laurus nobilis</i>) plants.	-The most efficient spray application technique was found to be an extended range flat fan, an air included flat fan or a hollow cone nozzle all at 4900 L ha ⁻¹ resulting in the highest relative spray deposits and the most uniform spray distribution in the canopy.
Dieter Foque, Jan G. Pieters, David Nuyttens / 2012	Spray deposition and distribution in a bay laurel crop as affected by nozzle type, air assistance and spray direction when using vertical spray booms	-Nozzle choice, spray boom setting, spray distance and the air speed of air assisted sprayers require careful consideration. -application made with an extended range standard flat fan nozzle without air support, directed straight toward the crop and used with a fixed spray distance of 30 cm to the stem generally produce the best spray results in the considered, conically pruned bay laurel crop.
D.Nuyttens, S.Windey, B. Sonck/2004	Optimisation of a Vertical Spray Boom	-Tests were conducted in greenhouses with two different spray systems both

	for Greenhouse Spray Application	equipped with vertical spray boom. - spray with 0.35 m nozzle spacing provided a much better spray distribution than that with 0.50 m nozzle spacing. -The optimal spray distance for 80° flat fan nozzles with the 0.35 m nozzle spacing was about 0.30 m.
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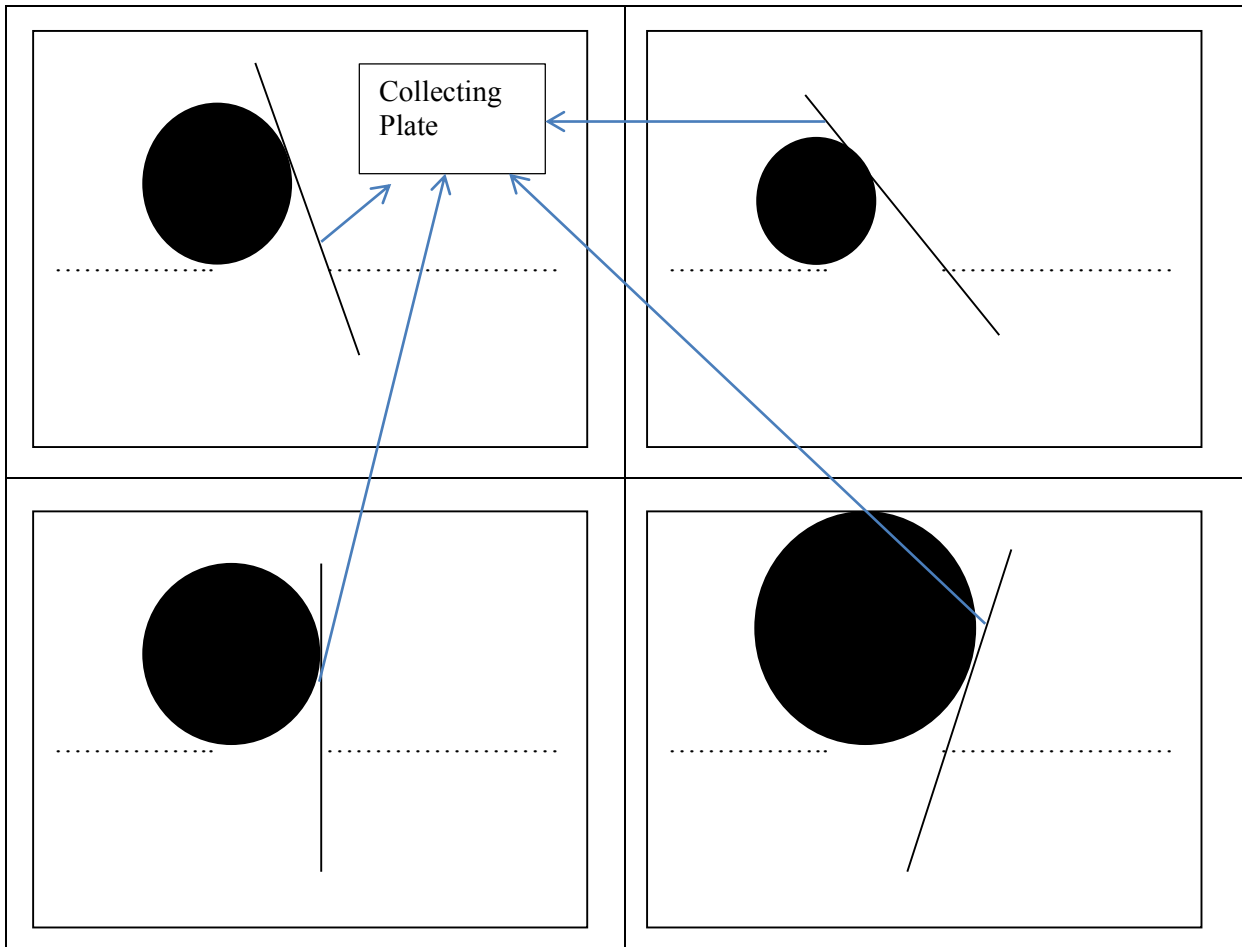
1.2. Proposed procedure in boom sprayer collecting plate angle optimization

By using orthogonal array in arranging the parameters, there are total of 40 experiments. As mentioned earlier, the angle of all the blow head from 2 to 7 is the same and that the angle of the collecting plate of the blow head nearer to the inlet must not more than those that further away from the inlet.

Table 1.1 shows an explanation for the second consideration. The black circles of the four images had a fix position which is at the end of the left hand side of the dotted line in each of the images. It represent the area of particles flow before touching the collecting plate. The bigger the circle, the larger the possibility of the particles exit the blow head. Conclusion is the larger the angle of collecting plate, bigger the distribution area. The blow head nearer to the inlet require a smaller area of distribution because most of the particles will drop at the blow head which is nearer to the inlet.

The commercial simulation software used is ANSYS. The ANSYS software is use as the analysis software computing fluid dynamics to simulate the flow in the boom pipe and collecting plate [7]. ANSYS license provided by the University of Tun Hussein Onn, CFD lab able to mesh up to 510000 and above number of nodes. CFX is one of the simulation tool used in ANSYS to provides facility to simulate particles flow in fluid through computer modeling. The result is produce by the software through the displays of images and data to predict the performance of the design.

Table 1.1: The area of distribution versus the angle of collecting plate



2. Methodology via Engineering software manipulations

2.1. Boom sprayer and the ambient modelling and the preliminary setup

Figure 2.0 show the overall process of the methodology. ANSYS software procedure is necessary to make the mesh before carrying out an analysis. Meshing can help to get the results on the surface or in geometry. Mesh size is very important because it plays an important role for obtaining a more accurate and effective. Detail of solid works that have been stored in IGES format (*.igs) will be imported into ANSYS software [8]. Figure 2.1 show the model of the boom sprayer by using solid work.

After meshing, the domain is established for the geometry. The domain of air and fertilizer parts of the input and output [9]. Fluid type and its properties have been added in the domain. Parameter set to air as a continuous fluid while the boom has been designated as a solid spread as fertilizer to be discharged from the hopper. Because this study is a multi-phase fluid, homogeneous model should be selected. Figure 2.2 show the pre-processor. This is how it display after setting up all boundaries.

After all properties completed inserted domain, boundary conditions are added to the domain. Four different boundary conditions created in that part of the air intake, part of the product and the

wall. At the exit pressure is only relatively fixed. In addition, the characteristics of air and fertilizer in certain areas [10]. Table 2.0 show the modeling properties of the boom sprayer and its boundaries

Turbulence model is used to increase the accuracy of the result by combining with Navier–Stokes equations. In this simulation, model K-Epsilon is been used. K-Epsilon is the most common turbulence model and it involved on two equations. The first transported variable is turbulent kinetic energy. The second transported variable in this case is the turbulent dissipation. Good result is provided that the pressure gradient is small [11]. In this case study, it has a low pressure gradient because there is only one pump that provide constant flow rate. The involvement equation is lesser, therefore the running time of the simulation is been reduce.

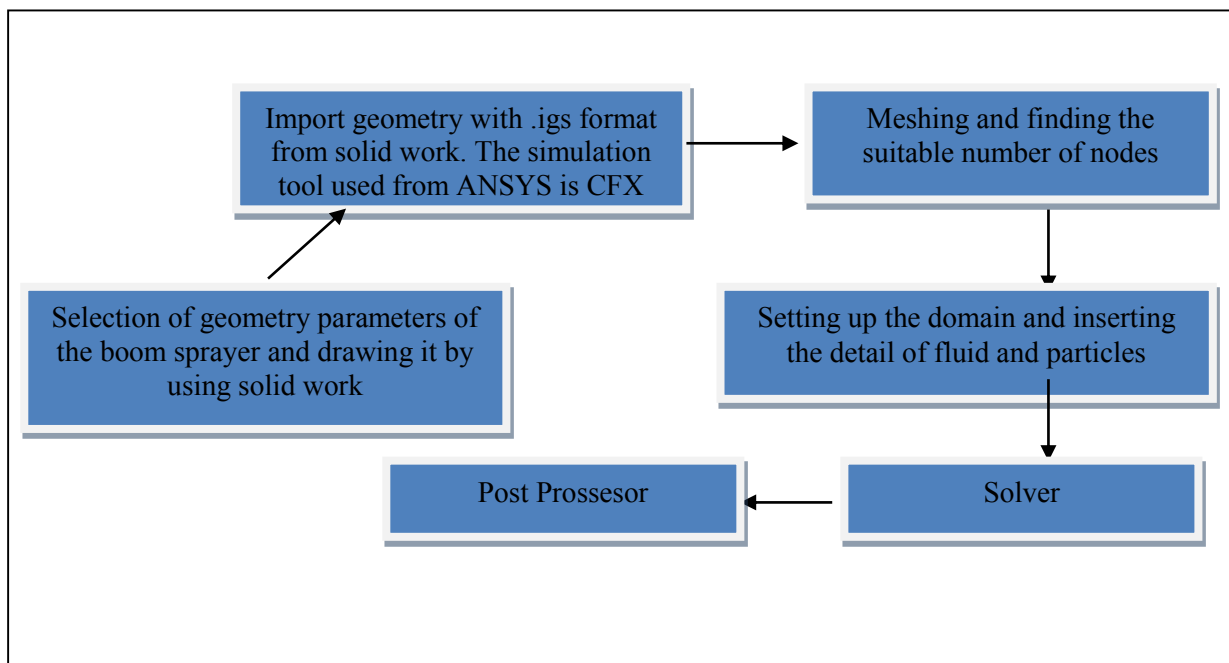


Figure 2.0: the overall process of the methodology [12]

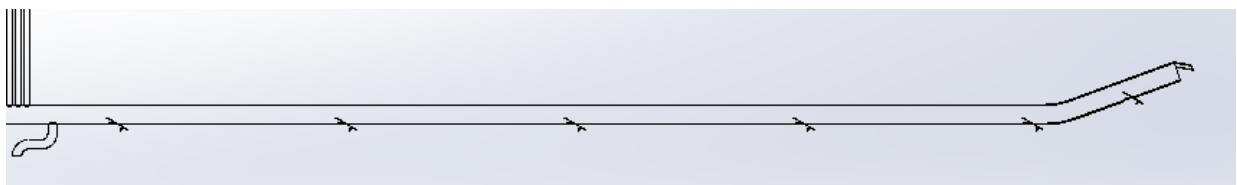


Figure 2.1: The model of the boom sprayer

Table 2.0: Modeling properties of the boom sprayer and its boundaries.

Fluid and particle definition	Air at 25°C	Continuous fluid
Domain model	Particle	Particle transport solid
	Reference pressure	1 atm
Fluid specific models	Air	Non buoyant
	Particle	Density difference
Urea	Specific diameter	2 mm, 4mm
	Gravity X and Z Dirn.	0 m/s ²
Buoyancy model	Gravity Y Dirn.	- 9.81 m/s ²
	Bouy. Ref. Density	1.226 kg/m ³
Boundary condition		
Air inlet	Flow regime	Subsonic
	Normal speed	8 ms ⁻¹ , 24 ms ⁻¹
	Flow regime	Subsonic
Particle inlet	Normal speed	0.2 ms ⁻¹
	Fluid value	0.2 ms ⁻¹
	Number of position	10000
	Flow regime	Subsonic
Outlet (opening)	Mass & momentum	Normal speed
	Pressure	0 Pa

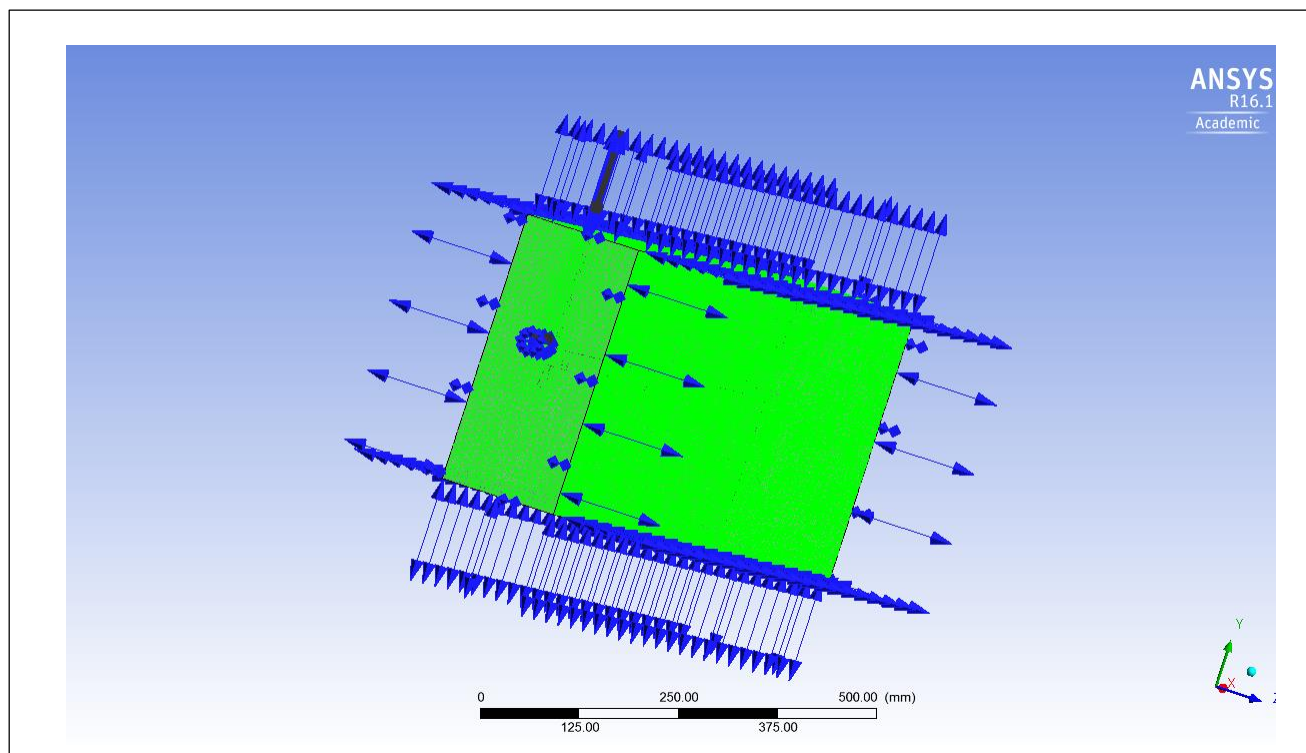


Figure 2.2: Pre-Processor

2.2 Solver, Post Processing procedure and Parameter selections

CFX solver will pre solutions and calculate the parameters set out above. Accuracy and time taken by CFX solver to calculate the mixture was largely dependent on the geometry of the mesh. Element and node value higher will result in a more accurate and also will take a longer time to complete [13].

The results of flow simulations obtained from CFX post. To see the flow behaviour, flow streamlines for air flow and the flow of steel. Airflow and steel will be incorporated into the flow streamlines different. This is because the flow streamlines have a different starting point. Although both fluid flows coupled with flow line is different but the behaviour of the mixture can be seen after the two current lines intersect each other. Contour plus in his decision to see the effect of these two current lines and contours. Distribution of velocity and pressure can be seen in the current line and contour.

The results of flow simulations obtained The results of flow simulations obtained from CFX post manipulating the parameters that will affect the distribution in order to find the optimum parameters to produce a good distribution. The parameters are the sizes of the granular fertilizers, air velocity of the blower and the angle of the collecting plate. Reference pressure is at atmospheric pressure of 1 atm and the particles size of Potassium K is 1mm. Table 2.1 show the parameters for the overall simulation.

The manipulation variables is angle of the collecting plate, the air velocity of the blower, granular fertilizers size for each Nitrogen, N and granular fertilizers size for Phosphorus, P. 2mm and 4mm are both the maximum and the minimum sizes of Nitrogen and Phosphorus. This is to study the effect of the granular size toward the flow. Same goes to air velocity of the blower whereby the minimum and maximum values had been selected. Each angle of the collecting plate is 30° different from one and another. This is because we want to find the range of the optimum angle that will affect the distribution. 32° is chosen instead of 30° because 32° is the minimum of the bending of the collecting plate which touches the other parts of the blow head as show in Figure 2.3. The blue line represent the collecting plate when it is at 30°.

Table 2.1: Parameters for overall simulation.

Factor	Level	1	2	3	4
Granular fertilizers size for each Nitrogen, N (mm)		2	4	-	-
Granular fertilizer size for each Phosphorus, P (mm)		2	4	-	-
Air velocity of the blower		8m/s	24m/s	-	-
Angel of the collecting plate 1 (°)		32	60	90	120
Angel of the collecting plate 2 (°)		32	60	90	120
Angel of the collecting plate 3 (°)		32	60	90	120
Angel of the collecting plate 4 (°)		32	60	90	120
Angel of the collecting plate 5 (°)		32	60	90	120
Angel of the collecting plate 6 (°)		32	60	90	120

2.5.1 Orthogonal Array

Based on the parameters that have been made, the Taguchi method was chosen to simplify and expedite the experimental method to be executed. From Table 2.3, there are 2-4 levels and 9 factors

controlled during the experiment. The Table 2.4 shows the collector array by each blow head with the combination of 4 different angle of collecting plate that has been introduced by Taguchi without the combination of the sizes of granular fertilizers and air velocity of the blower. A represents 32°, B represents 60°, C represents 90° and D represents 120°. This paper only cover having the angle of the collecting plate for each blow head the same. In order to see the effect of the each angle toward it distribution. The total number of experiment is 40.

The Table 2.3 : The number of experience taken by inserting the 3 types of fertilizers.

Experiment	Granular sizes of each Nitrogen (mm)	Granular sizes of each Phosphorus (mm)	Granular sizes of each Potassium (mm)	Air velocity (m/s)	Blow head 1	Blow head 2	Blow head 3	Blow head 4	Blow head 5	Blow head 6
1	2	-	-	8	A	A	A	A	A	A
2	2	-	-	24	A	A	A	A	A	A
3	2	-	-	8	B	B	B	B	B	B
4	2	-	-	24	B	B	B	B	B	B
5	2	-	-	8	C	C	C	C	C	C
6	2	-	-	24	C	C	C	C	C	C
7	2	-	-	8	D	D	D	D	D	D
8	2	-	-	24	D	D	D	D	D	D
9	4	-	-	8	A	A	A	A	A	A
10	4	-	-	24	A	A	A	A	A	A
11	4	-	-	8	B	B	B	B	B	B
12	4	-	-	24	B	B	B	B	B	B
13	4	-	-	8	C	C	C	C	C	C
14	4	-	-	24	C	C	C	C	C	C
15	4	-	-	8	D	D	D	D	D	D
16	4	-	-	24	D	D	B	D	D	D
17	-	2	-	8	A	A	A	A	A	A
18	-	2	-	24	A	A	A	A	A	A
19	-	2	-	8	B	B	B	B	B	B
20	-	2	-	24	B	B	B	B	B	B
21	-	2	-	8	C	C	C	C	C	C
22	-	2	-	24	C	C	C	C	C	C
23	-	2	-	8	D	D	D	D	D	D
24	-	2	-	24	D	D	D	D	D	D
25	-	4	-	8	A	A	A	A	A	A
26	-	4	-	24	A	A	A	A	A	A
27	-	4	-	8	B	B	B	B	B	B
28	-	4	-	24	B	B	B	B	B	B
29	-	4	-	8	C	C	C	C	C	C
30	-	4	-	24	C	C	C	C	C	C
31	-	4	-	8	D	D	D	D	D	D
32	-	4	-	24	D	D	D	D	D	D
33	-	-	1	8	A	A	A	A	A	A
34	-	-	1	24	A	A	A	A	A	A
35	-	-	1	8	B	B	B	B	B	B
36	-	-	1	24	B	B	B	B	B	B
37	-	-	1	8	C	C	C	C	C	C
38	-	-	1	24	C	C	C	C	C	C
39	-	-	1	8	D	D	D	D	D	D
40	-	-	1	24	D	D	D	D	D	D

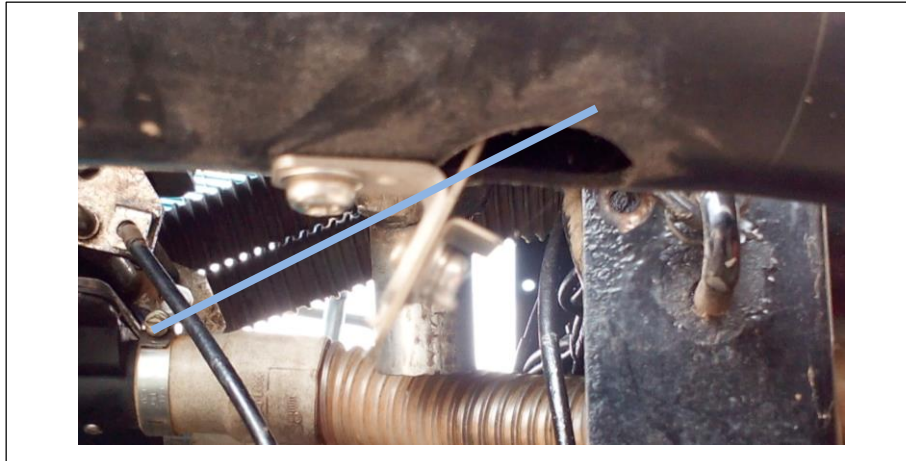


Figure 2.3: The angle of collecting plate of the actual blow head

3. Result and Discussion of the simulation

Table 3.1 show the good samples results of the various angle of collecting plates, particles sizes and air blower velocity which refer to Table 2.3. Whereby, Table 3.2 show the bad samples results of the various angle of collecting plates, particles sizes and air blower velocity which refer to Table 2.3. The nitrogen, N fertilizer is green color, the phosphorus, P is grey color and the potassium, K is orange color. These samples are the best result among the 40 experiments that is taken. Through analysis of the images, there is a big different between both Table 3.1 and Table 3.2. Table 3.2 shows the different between the result produce by Table 3.0 and Table 3.1.

Table 3.0: The good samples result of various angle of collecting plates, particles sizes and air blower velocity which refer to Table 2.3

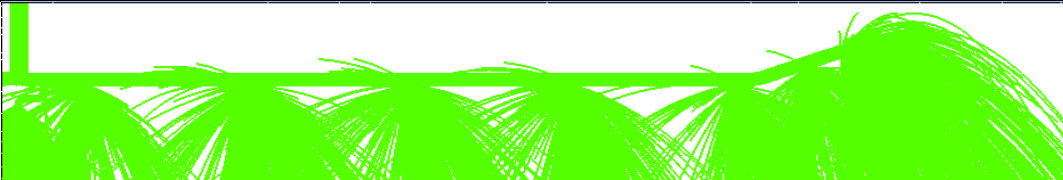
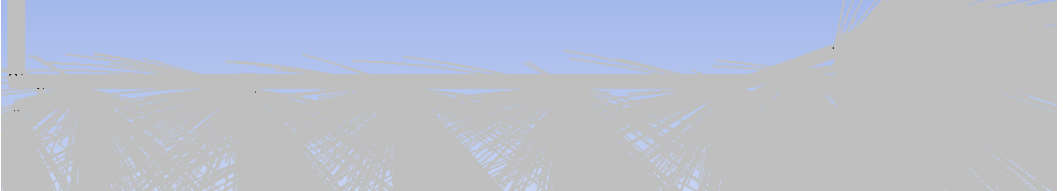
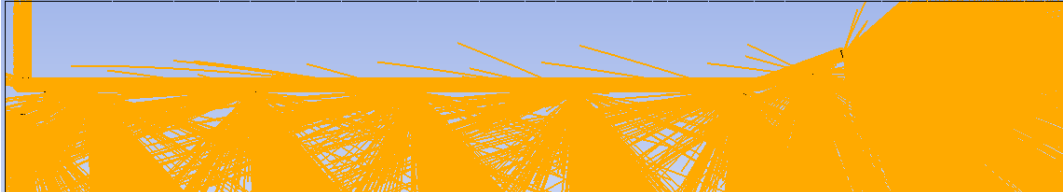
Experiment	Good result
1	
18	
34	

Table 3.1 : The bad samples result of various angle of collecting plates, particles sizes and air blower velocity which refer to Table 2.3

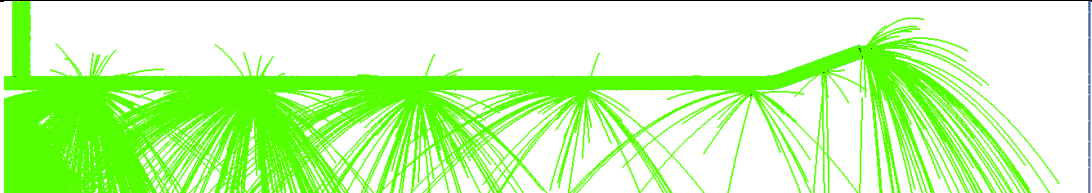
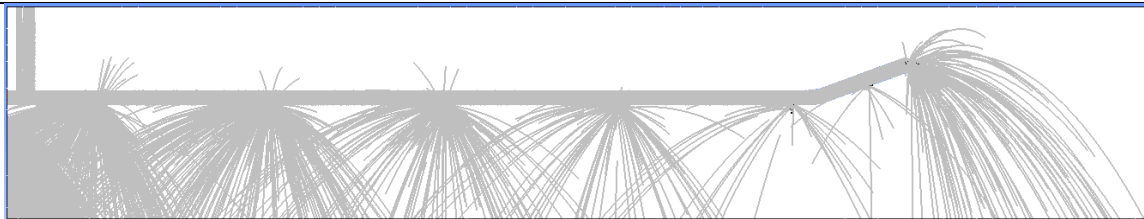
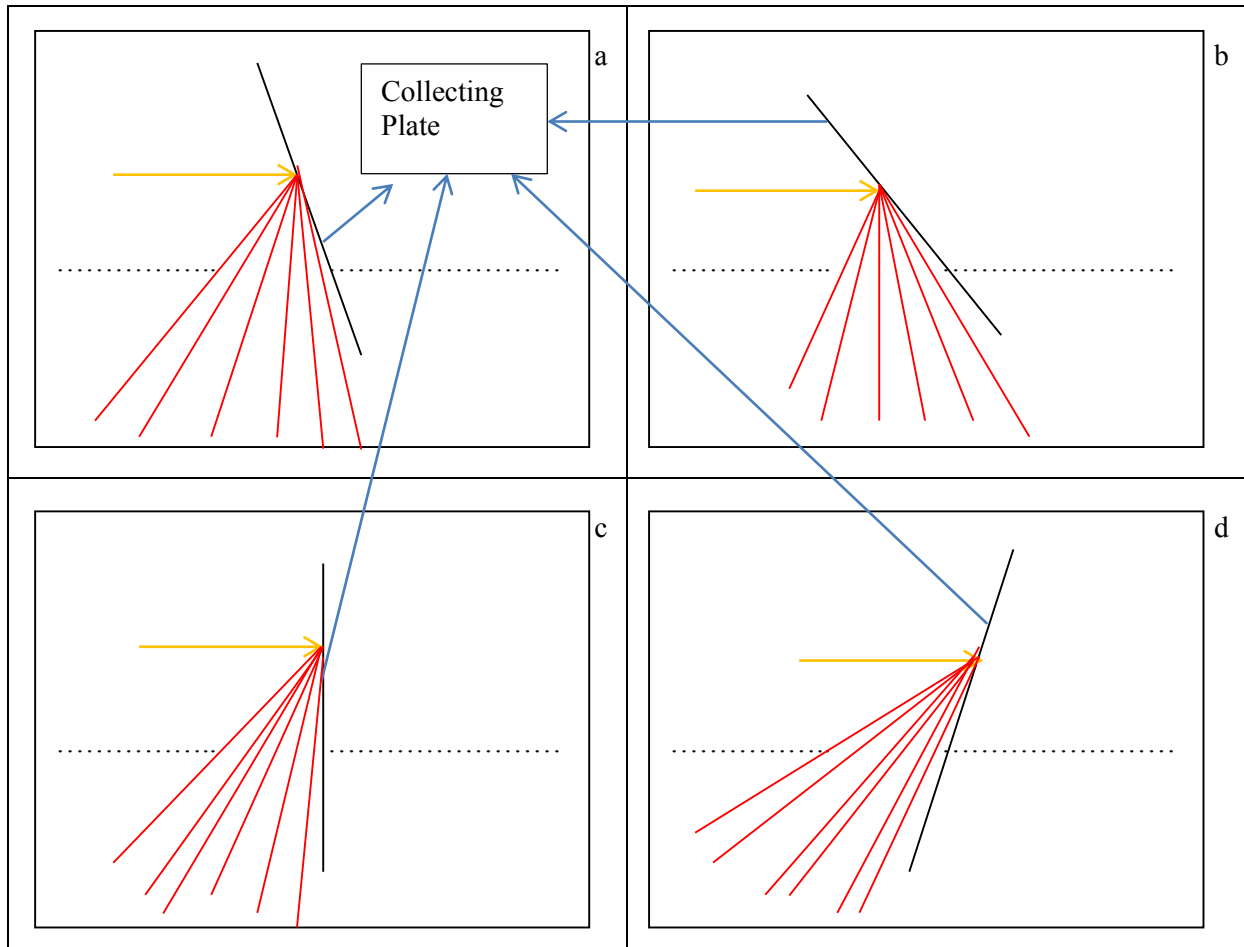
Experiment	Bad result
15	
23	
37	

Table 3.2: The different between the result produce by Table 3.0 and Table 3.1

No	Table 3.1	Table 3.2
1.	The streamline of every blow head is nearly the same	The streamline at the first half of the boom and the second half of the boom is very much different
2.	The streamline of every blow head is a lot	The streamline at the last blow head is very little
3.	The angle of distribution is very even	The angle of distribution is not even

Table 3.3 show the logical explanation of having the range angle of collecting plate of 32° to 60° that will produce a better distribution. Orange color line represents the direction of flow of fertilizers from the inlet to it touches the collecting plate. Red color lines represent the possibilities of the direction of the fertilizer after it bound from the collecting plate to the nozzle. By comparing the 4 images, the angle which is less than 90° has a better shape of distribution. The image (a) and (b) show that the red lines producing a shape of a triangle with the left and right spread in much event compare to image (c) and (d). Therefore, it is logical to say that the angle of range 32° to 60° will produce a better distribution compare to angle 90° and above.

Table 3.2: The different between the result produce by Table 3.0 and Table 3.1



4. Conclusion

4.1. With the invention of commercial simulation software, optimization of boom sprayer collecting plate angle is much easier compare to fully be done by experimental. Simulation is more practical for this paper because the number of experiment that needed to be carried out is a lot, 40 experiments. Through using the simulation, one time can generate a lot of results by utilized all the computer that is available in the lab.

4.2. The commercial software as mentioned is actually ANSYS. ANSYS has multiphysics capabilities and it is user friendly. The manipulate variables for the simulation are the angle of the collecting plate, 32° , 60° , 90° and 120° of the boom sprayer, different sizes of the granular fertilizers and air velocity of the blower. Whereby, the constant variables in this simulation are the atmospheric pressure of 1 atm and the particles size of Potassium K is 1mm. 60 per cent of the images produce by ANSYS, show that the optimum angle is between 32° to 60° . The way of analyse is through observing the number of stream lines and the angle of distribution. By using simple reflection of particles as explained in Table 3.2 prove that the optimum range of angle is logical.

Further study can be done by validating the result through experiment. It is preferred to carry up the experiment through scaled down model without causing any changes to the current design and in order to be carrying out in the lab.

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