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Scaled-down Model Design of Granular Fertilizer Boom Sprayer

E. P. Ying[*,1,a], *M. Z. Ngali*[1,b] *and N. H. Zakaria*[2,c]

[1]Faculty of Mechanical and Manufacturing Engineering, University Tun Hussein Onn Malaysia,P.O Box 101, Parit Raja, 86400, Johor, Malaysia.
[2]Facutly of Mechanical Engineering, University Teknikal Malaysia Melaka,Durian Tunggal, 76100,Melaka, Malaysia
[a,*]*gd140091@siswa.uthm.edu.my*, [b]*zamani@uthm.edu.my*, [c]*nazrihuzaimi@utem.edu.my*

Abstract – *Lately, harvesters and farmers are craving for any possibility to apply boom sprayer concept for granular fertilizers due to its simplicity and easy to repair features. Granular fertilizer Boom sprayer allows the fertilizers to distribute in a larger scale with a shorter time taken as compared to traditional application methods. However, the performance optimization of this bulky machinery is complicated due to all the parameters involved especially on the fertilizers, crops, boom arrangements and the feeding environment characteristics. This paper explains the process of modeling the whole scenario in order to facilitate the study of fertilizer distribution in laboratory scale. The actual granular fertilizer Boom Sprayer which is being used by MARDI is properly scaled down by the scale of 1:2 geometrically while the air flow Reynolds number is maintained at 51832 for both actual and the scale down model. The developed scaled-down experimental rig is essential in the process of fertilizer distribution optimization, boom sprayer design improvement as well as current design performance evaluation.*

Keywords: Granular fertilizer Boom Sprayer, Scaled-Down, Reynolds number.

1.0 INTRODUCTION

Rice is Malaysian preference food and the need has being increasing annually due to our growing population. In the year 2013, rice had provides the livelihood to 300,000 paddy farmers in Malaysia. Land utilization for paddy production is currently at 674,928 hectares which is 76 percent in Peninsular Malaysia (515,657 ha) while Sarawak and Sabah accounted for 18 percent (118,919 ha) and 6 percent (40,352 ha) of the total hectare age respectively [1].

Increasing crop yield is the main agenda for most local paddy growers through measures such as the introduction of new cultivars, reviewing existing planting practices such as fertilizing and pesticide cycle, type and amount of fertilizer and pesticide used and the intensity and frequency of such cycle. The main agriculture institute in Malaysia that directly deals with these issues is Malaysian Agricultural Research and Development Institute (MARDI). Fertilizer application issues that embrace the distribution rate and uniformity have always be their main concern.

There are basically two types of commonly used granular applicators which are drop spreaders (gravity flow) and centrifugal spreaders (rotating disk). These types of applicator

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usually in small model and are not effective for big paddy field under MARDI. Due to the advance of technology, Boom sprayer which commonly used with liquid fertilizer is now developed to meet the need in distributing the granular fertilizer in a bigger scale. There are a lot of advantages in using granular fertilizer, such as easy for maintenance, less drift and minimum off-target exposure from boom sprayer.

The applications of granular fertilizers are also very wide and significant. One of the most common use is as a soil preparation prior to planting, in which the fertilizer is worked into the soil to provide nutrients to the plants which will be established there. A good example is NPK fertilizer which is a chemical component used in growing paddy by MARDI. N represents nitrogen, P represents phosphorous and K represents potassium. N is more in promoting leaf grow, P contributes to root, flower and fruit development and K contributes to stem and root growth. However, the negative impact of this type of fertilizer is when excessive usage will causes residue toxicity and environment pollution because about 40–70% of nitrogen, 80–90% of phosphorus, and 50–70% of potassium of the applied normal fertilizers is lost to the environment and cannot be absorbed by plants [4,5]. The granular applicators stand a very important role in controlling the distribution the fertilizers.

The actual size of the granular boom sprayer is too bulky to be carried out in lab while the optimization of the fertilizer distribution needs proper analyses on parameter combinations. Fertilizer density and size, boom diameter and length, reflector plate angle, blower flow rate, boom height, wind direction and mover speed are among the factors to be considered during the optimization procedure. In order to facilitate the evaluation process, a scaled-down facility that capable of emulating the whole environment is a practical alternative. This work explains the preliminary process in realizing this agenda where physical dimensions are scaled-down while the flow parameters are calculated so that the characteristics of the actual air and fertilizer distributions are properly emulated. The developed setup will allow researchers to evaluate and improvise the granular fertilizer boom sprayer performances without any intervention on the actual machinery.

2.0 METHODOLOGY

The overall framework to downscale the boom sprayer includes three steps. Firstly to determine the scaled-down parameters of the boom sprayer with respect to the actual flow Reynolds number. Secondly to fabricate the scaled down granular fertilizer together with the hopper and run the scaled-down boom sprayer. The third step is to compare the fertilizer distributions of the scaled-down model with the actual boom sprayer. The fabrication flow chart is as shown in Figure 1.

The flow pattern of the fertilizer particles via the scale-down boom sprayer must be comparable to the actual boom sprayer in order to assure the success of this project. Therefore, the formulae used for scaling down the boom sprayer were derived from Reynolds number formulae as in equation (1). The cross sectional area of the boom sprayer is as equation (2)

$$\mathrm{Re} = \frac{\rho V A}{\mu} \qquad (1)$$

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$$A = \pi r^2 \quad (2)$$

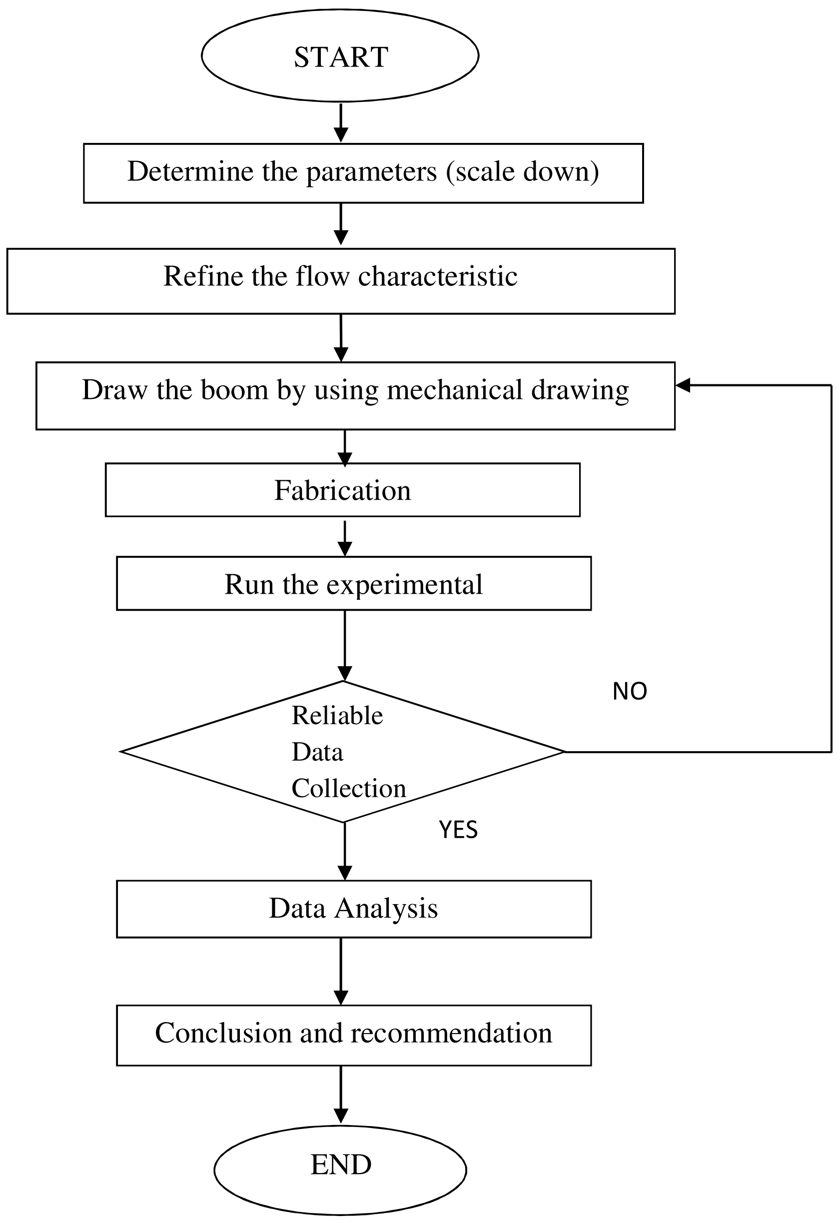

Figure 1: fabrication flow chart

where the Re is the Reynolds Number of the particles in the boom sprayer, ρ is the density of the air, V_1 is the velocity of the fan of the actual boom sprayer, r_1 is the radius of the actual boom, μ is the dynamic viscosity of the air, V_2 is the velocity of the fan of the scale down boom sprayer and r_2 is radius of the scale down boom. The scaled-down radius is half of the actual radius.

$$r_1 = 2\, r_2 \quad (3)$$

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Therefore,

$$A_2 = \pi \frac{1}{4} r_1^2 \quad (4)$$

Substitute it into equation (1), therefore it is

$$V_1 = 4\ V_2 \quad (5)$$

Figure 2 shows the boom sprayer system from the hopper to the boom sprayer. The hopper stores all the granular fertilizers before it enters the boom sprayer. When the shutter changeover lever is turned on, the metering mechanism conveys the granular to the boom inlet. The fertilizers then distributed throughout the boom by the blower.

Figure 3 shows the blow head of the boom sprayer. The collecting plate angle must be optimized in order to control the fertilizer distribution on each blow head. The collecting plate of each blow head is set uniquely since the number of granular fertilizers that flow through each blow head from the hopper is vary in concentration. The number of granular fertilizers that enter into the first blow head is always higher followed by the second, third, and forth because it is closer to the hopper. Therefore the angle of the collecting plate of first blow head must be lower than the other three. The design will be further discussed in the next section.

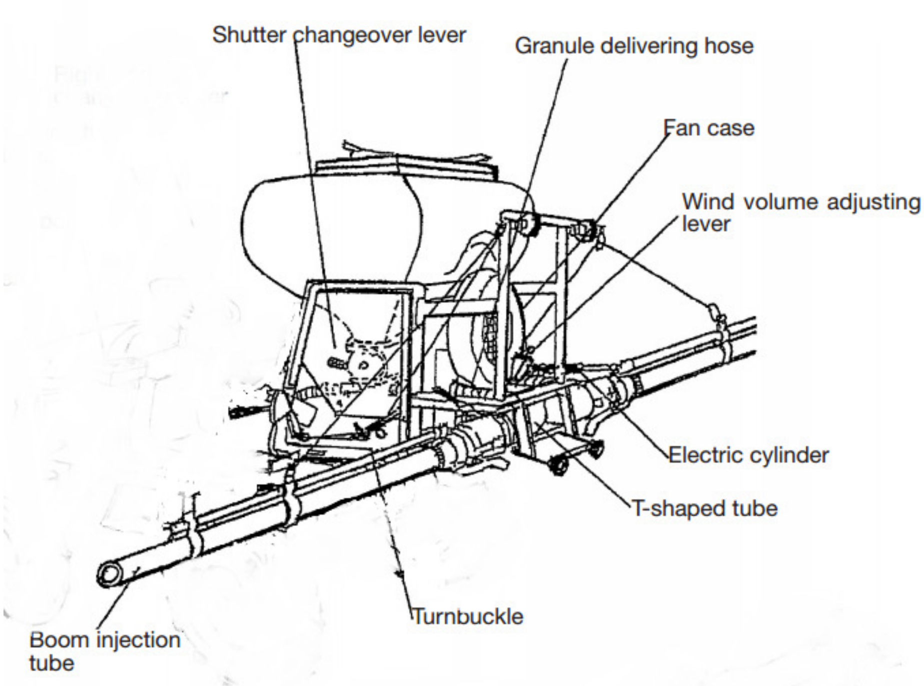

Figure 2: Parts of fabricate of the scale-down boom sprayer [3]

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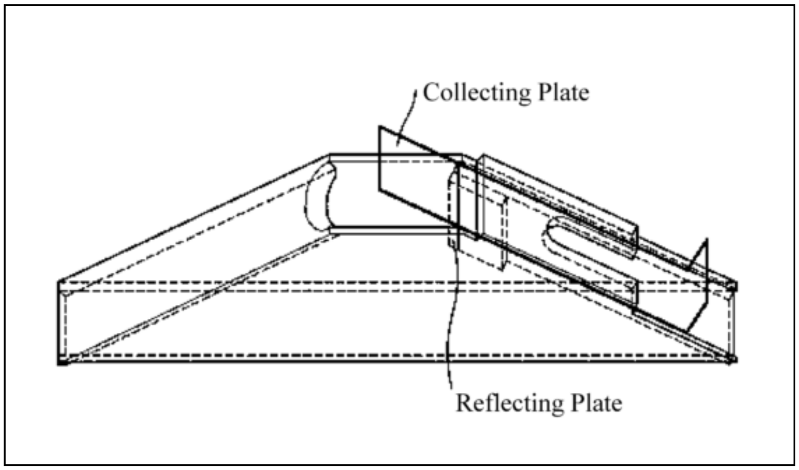

Figure 3: The blow head of the boom sprayer [3]

3.0 RESULTS AND DISCUSSION

Figure 4 shows the scaling down dimension of the right side of boom sprayer. There are 4 blow heads in each side of the boom. It serves as the entrance for the granular fertilizer to distribute out of the boom sprayer.

Table 1 shows the parameters of the actual and scaled-down boom sprayer. The actual boom sprayer radius is 0.054m which is more than half of the scaled-down boom sprayer radius taken from equation (3). The velocity of the boom sprayer blower is 4 times the velocity of the scaled-down boom sprayer blower model as in equation (4). The Reynolds number for both actual boom sprayer and scaled-down model is maintained to assure that the model is in fact emulate the actual flow of the fluid. Since both actual boom sprayer and scaled-down model boom sprayer are having the same fluid which is air, therefore ρ which represent the density of the fluid is also maintained.

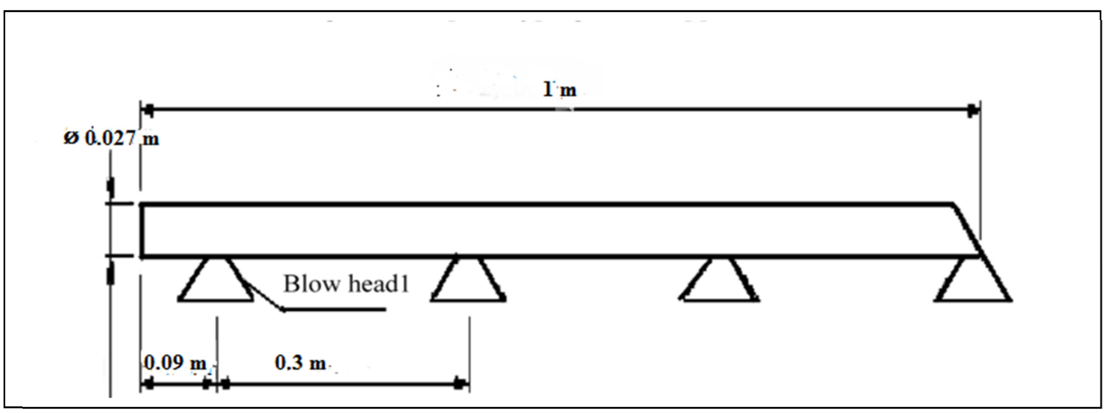

Figure 4: The scaling down dimension of the right side of boom sprayer

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Same analogy goes to the viscosity of the fluid. These leave only the velocity in equation (1) as the variable. This fact allows us to develop the whole scaled-down model with only the air blower to be optimized to get the same flow pattern with the one on the actual scenario. In this particular case, the air velocity on the scaled-down model is a quarter of the actual boom sprayer even though the diameter was only scaled down into half size. This is absolutely correct since the half diameter will reduce the cross sectional area of the model into one-fourth of the actual area.

Table 1: Parameters of the actual and scaled-down boom sprayer

Actual Boom Sprayer	Scaled-down Boom sprayer
Re 51832	Re 51832
ρ (kg/m)1.2754	ρ (kg/m)1.2754
V_1 (m/s) 8	V_2 (m/s) 2
μ $1x10^{-5}$	μ $1x10^{-5}$
r_1(m) 0.054	r_2 (m) 0.027

4.0 CONCLUSSION

The actual granular fertilizer Boom Sprayer being used by MARDI is properly scaled down by the scale of 1:2 geometrically. The air flow Reynolds number however is maintained at 51832 for both actual and the scale down model. The model parameters are all determined and the fully functioning scaled-down model is ready for fabrication. The fertilizer distribution pattern of the scaled-down model of boom sprayer is expected to be identical since the characteristic of the air flow is having the same Reynolds number. The developed scaled-down experimental rig can be implemented in the process of fertilizer distribution optimization, boom sprayer design improvement and current design performance evaluation.

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