

Design of Backpack Sprayer with Electrical Pumping System Using Quality Function Development Approach to Optimize the Agricultural Facility

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Abstract - This paper presents an electric back sprayer based on the attributes required by sprayer users with the Quality Function Deployment (QFD) methodology by optimizing sprayers owned by farmers. In agriculture, the process of crop management and care and pest control is carried out routinely to obtain optimal results. The technical implementation of these efforts is carried out through soil and air media by spraying the plant organs. To keep the pressure and spray results stable, continuous pumping is required. This resulted in certainly more energy needed. Based on the results of research on farmers using a sprayer, the type that is widely used is the type of back sprayer. However, in the use of back type sprayers, farmers still experience problems. Problems encountered in using a back sprayer will be reviewed and overcome by developing a sprayer based on the wishes of the farmer. The design of the back sprayer using the Quality Function Deployment (QFD) method is more appropriate to be used in determining the attributes of the development of a back sprayer following the wishes of the fertilizer sprayer user. The resulting sprayer design is expected to be able to overcome the weaknesses in the back sprayer without having to procure a new sprayer, where the problem of the non-constant pressure level in pumping can be overcome.

Keywords: Electric back sprayer, Quality Function Deployment (QFD), Optimization

I. Introduction

Indonesia is an agrarian country and most of its population earns a living as farmers. In agriculture, the process of crop management and care and pest control is carried out routinely to obtain optimal results. The technical implementation of these efforts is carried out through soil and air media by spraying the plant organs. To spray the crops farmers usually use agricultural equipment, namely sprayers.

Sprayers that are commonly used by farmers in Indonesia are of three types, namely back sprayers, motor sprayers, and electric sprayers. The back

sprayer is widely used by farmers because the price is still affordable and the lightest weight, but the spray produced is not effective and the sprayer component is easily damaged. Besides, because pumping is done manually this causes the resulting spray pressure cannot be constant.

To keep the pressure and spray results stable, continuous pumping is required. This resulted in certainly more energy needed. The other type of sprayer is a motor sprayer that uses a 2 stroke engine as a pump drive [1]. This type of sprayer can work in a broad scope in a relatively short time. However, the price and maintenance is relatively expensive, heavier and is not suitable for young plants. Besides, there is also an electric sprayer that

is driven by a DC pump with a power source in the form of a battery. Judging from the price of this type of sprayer is lighter than a motor sprayer.

Based on the results of research on farmers using a sprayer, the type that is widely used is the type of back sprayer [2]. However, in the use of back type sprayers, farmers still experience problems. Problems encountered in using a back sprayer will be reviewed and overcome by developing a sprayer based on the wishes of the farmer. The design of the back sprayer using the Quality Function Deployment (QFD) method is more appropriate to be used in determining the attributes of the development of a back sprayer following the wishes of the fertilizer sprayer user (farmer) [3]. The resulting sprayer design is expected to be able to overcome the weaknesses in the back sprayer without having to procure a new sprayer, where the problem of the non-constant pressure level in pumping can be overcome.

The use of a back sprayer is evenly distributed among farmers, but the instability of the resulting pressure value causes the spraying results to be suboptimal. The existence of an electric sprayer can be a solution to these problems, but the device was previously abandoned. Therefore we need a design of a sprayer with an electric pumping system while still using a sprayer that is owned by the farmers so that the existing equipment can still be used [4].

The purpose of this research is to design and build an electric back sprayer based on the attributes required by sprayer users with the Quality Function Deployment (QFD) methodology by optimizing sprayers owned by farmers. With the design of an electric back sprayer, it is expected to be able to maximize the use of a back sprayer owned by farmers, as well as minimize the workload in the spraying process. Therefore, the procurement of spraying equipment can only be diverted for other purposes.

II. Literature Study

II.1 Study in Designing of Sprayers

Utomo (2013) in his thesis entitled "Design and Manufacture of Electric Fertilizer Sprayers" make auxiliary equipment in agriculture by producing tools in the form of electric sprayers. The design methodology used is the Theory of Resheniya Izobretatelskikh Zadatch (TRIZ) method. The results of the study were sprayers that were pumped with power sources derived from electrical energy.

Furthermore Priyatmoko et al (2015) in the article entitled "Semi-Automatic Sprayer: Innovation Carry Free and Energy Saving Sprayer" designed a sprayer with a push model, where farmers stayed pushing the sprayer without having to be burdened carrying a sprayer. The method used in the form of field observations. The results of this study in the form of a two-wheel thrust sprayer following the embankment character of vegetable crops.

II.2 Components of a Sprayers

Sprayers for agricultural purposes are known as 3 types of sprayers, namely back sprayers, machine sprayers, and electric sprayers. Back sprayer or also known as knapsack sprayer. This sprayer is widely used by rice farmers, farmer farmers and plantation farmers.

The working principle of the back sprayer is the liquid in the storage tank will be removed as a result of the process of air pressure that comes from pumping movements on the pump lever. Then the liquid will be released through the valve to the nozzle, then from the nozzle will spray into the target area of the spray. To keep the pressure in the tank stable, pumping must be done often.

The following are the specifications of one of the sprayers commonly used by farmers.

- Tank capacity: 15 liters
- Spray pressure: 2-6 kg / cm²
- Tank length: 350 mm
- Tank width: 235 mm
- Tank height: 530 mm
- Sprayer empty weight: 4.2 Kg
- Sprayer full weight: 18.2 kg



Fig. 1. Back sprayer type

The back type sprayer consists of three main parts namely the tank, pump unit, and pulverizer unit, as can be seen in Figure 1. The tank serves to collect the liquid to be applied. Most of these

sprayers have a tank capacity of 14-15 liters. In general, there are two kinds of pump units namely the type of suction pump and pump type press. The pulverizer unit consists of three parts, namely the hose, the spraying barrel, and the nozzle. The length of the spray hose is an average of 1 meter, it depends on the manufacturer's brand that produces it. At the other end attached to the handle complete with spray taps. The length of the throwing barrel is 45-50 cm. The spray barrel is usually made of mixed metal, although some are given a layer of the crank on the outside. Society, in general, refers to this section as a sprayer or nozzle. There are two types of nozzle types namely single nozzle and double nozzle.

The motor type sprayer uses a 2 stroke engine as the pump driving force, as seen in Figure 2. The specifications are as follows,

- Tank capacity: 20 liters
- Fuel capacity: 0.75 liters
- Fuel: 2T oil mixed gasoline
- Brand: Tosca
- Cylinder: 26 cc
- The engine capacity of 1.8 HP
- Pressure produced: 5 - 30 kg / cm²
- Output Volume 1.5 - 7.4 liters per minute
- Dimensions: 450 x 330 x 600 mm
- Stater: recoil (pulled)



Fig. 2. Motor sprayer type

In electric type sprayers, spraying is done by an electric pump. The machine can be operated with an electric power source that has been stored in the accumulator (battery). The mechanism of using an electric sprayer does not require the pumping process as does the semi-automatic manual sprayer, so the user only needs to activate a switch that disconnects and connects the electric current from the battery to the pump, as seen in Figure 3. Part of the electric sprayer consists of a water pump equipped with an electric motor and a battery. The electric sprayer has a pumping unit that functions to drain the liquid automatically. This pump is a type of centrifugal pump with a power of 24.8 Watt with

a maximum pressure of 4.8 bar, the pump display can be seen in Figure 4.



Fig. 3. Electric sprayer type



Fig. 4. Water pump of electric sprayer type

The working mechanism of the pump is connected to a battery that allows an energy supply that can move the water pump. The specifications of the battery used have a voltage of 12 V, DC current, the weight of 1 kg and 4 Ah.

III. Methodology

III.1 Quality Function Deployment Method

The Quality Function Deployment (QFD) method was created by a Japanese professor named Yoji Akao in the late 1980s. QFD was created to design the process of making a product or service based on customer needs, as seen in Figure 5. The QFD method according to Lou Cohen has staged in the planning and development of the matrix namely:

- 1) House of Quality Planning Matrix: consists of customer needs, technical requirements, correlations, relationships, customer competitive evaluations, competitive technical assessments, and targets.
- 2) Part Deployment Matrix: commonly called a second home.
- 3) Matrix Process Design (Process Planing): commonly referred to as the third house.
- 4) Manufacturing Planning Matrix: commonly called the fourth house.

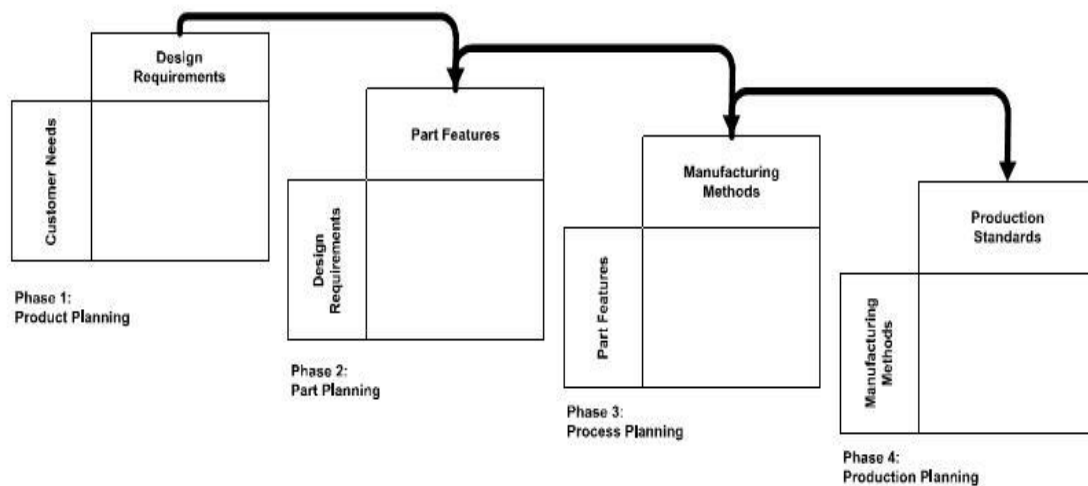


Fig. 5. Quality Function Deployment (QFD) method

III.2 Product Planning Matrix

The steps are taken in the process of making a product planning matrix are as follows:

1. Consumer Ratings

User satisfaction cannot be measured directly through subjective measurements but must be assessed as something abstract in the form of certain indicators.

2. Making Questionnaire

With the design of a back sprayer design with an electric pumping system, we can find out the user's opinion in this case farmers in terms of weaknesses and strengths of the products produced.

3. Survey

An effective way to do a survey is through direct interviews. The tool used is the same as a questionnaire only filled by field officers who ask respondents in this case farmers using a sprayer.

4. Making a Checklist

Checklists are a common way of determining category assessment methods that can be modified so that different weights can be applied to sentences or words.

5. Making the House of Quality Matrix.

House of Quality (HOQ) is the first house from QFD development. At the House of Quality, there is information about WHATs in the form of customer requirements or the voice of customers, HOWs in the form of technical requirements, competitive assessment relationship matrix.

6. Filling in the House of Quality Matrix

The stage before completing the House of Quality matrix is the making of a planning matrix consisting of the level of consumer interest and the level of customer satisfaction.

IV. Results and Discussion

The general description of the electrical sprayer system block diagram in this study is shown in Figure 6. Next in Figure 7 is shown the DC pump switching diagram block in the disconnected switch condition. The DC pump switching diagram of the connected switch condition is shown in Figure 8.

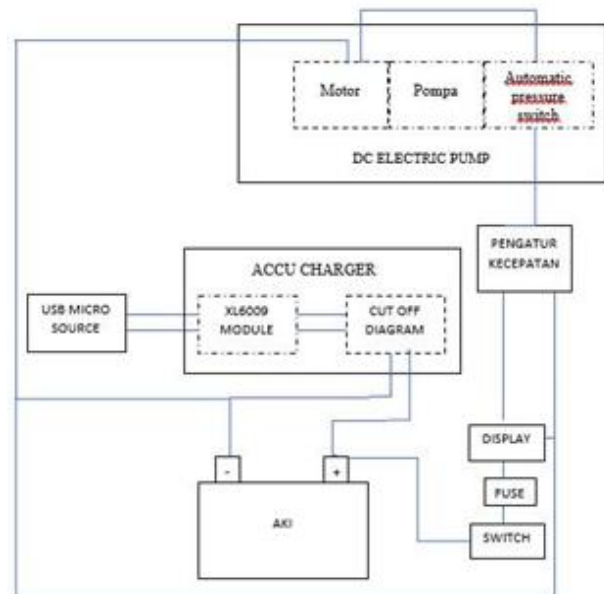


Fig. 6. The complete electrical sprayer system block diagram

The process of recharging the battery in this study uses the XL6009 module which functions to change the voltage from the micro USB input both from the cell phone charger, power bank or other resources.

The old technical calculation of the battery with 12 Volt voltage specifications and 4Ah capacity,

can backup the load is as follows:

Pump power = 24.8 Watt
 Electric current on the battery (24.8 Watt / 12 Volt) = 2.066 Amperes
 Usage Time (12 Ah / 2,066 Ampere) = 5.808 hours - Battery deficiency value = 0.5 hours
 Estimated battery timeout (5.808 Hours - 0.5 Hours) = 5.308 hours

The optimal charging voltage on the 12 Volt battery ranges from 110% to 115% of the nominal battery voltage. So we get the optimal range of charging voltage values:

110% x 12 Volts = 13.2 Volts
 115% x 12 Volts = 13.8 Volts

In testing the equipment made in this study, the value of the charging voltage is ± 13.52 V, as seen in Figure 9.



Fig. 9. Voltage measurement of charging process

The results of the sprayer test are completely summarized in a table as shown in Table 1.

TABLE I
 THE RESULTS OF THE SPRAYER TEST

Examination criterion	The results of the sprayer test
Weight less than 10 kg	8.5 kg
Costs less than IDR 550,000	IDR 536,000
Spray range of more than 2 m	3 meters
The duration of use is more than 1 hour	5 hours 18 minutes and 48 seconds
Power source from 12 volt battery	12 volt 4 Ah
The spray rate is stable	1.5 liters per minute

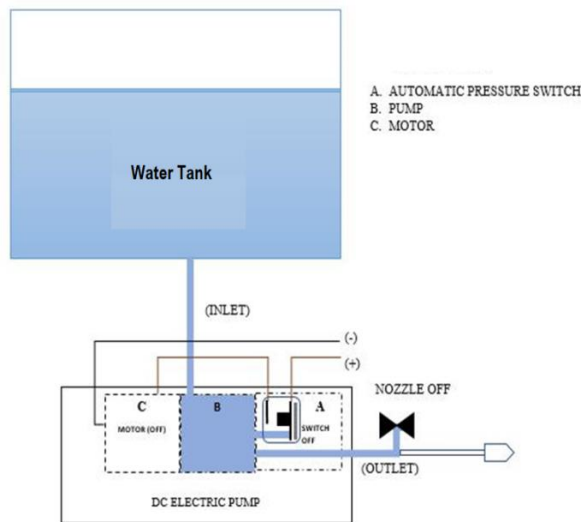


Fig. 7. DC pump switching diagram block in the disconnected switch condition

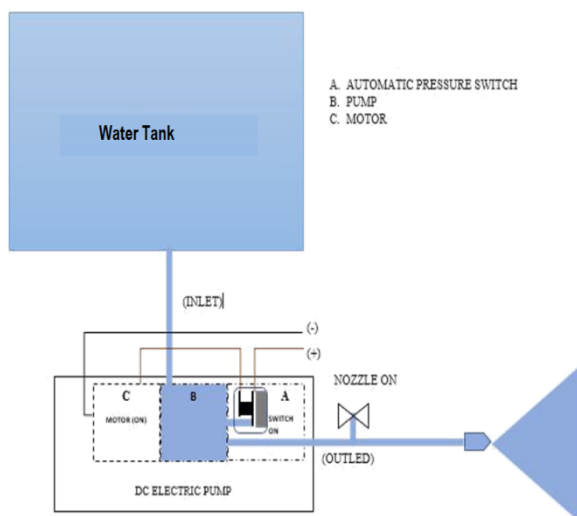


Fig. 8. DC pump switching diagram block in the connected switch condition

V. Conclusion

Based on the research results of the electrical sprayer design the conclusion is in the form of an electrical sprayer design that can work optimally with a 12-volt battery, 4 Ah, producing a constant spray of 1.5 Liters per minute for 5 hours 18 minutes and 48 seconds. This design tool can reach a distance of 3 meters and can be operated both electrically and manually. The test results also showed that the sprayer results of this study were able to show stable performance for long-term use.

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