Design of Semi-automatic Plant Media Bagging Machine for Container Plant Nursery

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Abstract—Plant nursery is a prosperous business in Indonesia, high demand of ornamental plant leads this business to keep expanding. As another agricultural business, a plant nursery is labor intensive business. Labor problem such as increasing minimum wage, labor scarcity, and low productivity becomes main issue in recent years. Automation has been known as suitable solution for solving labor problems in manufacturing sector. Therefore, implementing automation to assist nursery production might solve nursery labor problem. In this research a semi-automatic bagging machine is designed to reduce the labor required and production lead time during re-planting process. Observation and interview is conducted at one plant nursery for collecting user requirements. Collected user requirements, then transformed to engineering specification using house of quality matrix. Machine conceptual design is created by analyzing the current practice of re-planting and identify the function with function structure diagram. Identified function, then inserted into the morphological matrix in order to generate possible solutions for automating the function. One concept is selected to further develop into detail design. Selected machine concept is using compressed air to fill plant container with media and compress the media. This machine is capable to reduce production lead time up to half of current production process by utilizing one operator. Moreover, to sustain in today’s market competition, nursery is forced to produce plants in larger quantity and better quality with shorter lead time.

On the other hand, mechanization and automation have widely applied in agriculture sector, especially in developed countries which human labor is scarce and expensive. A survey of automation usage in 127 nurseries at southern United States reveals that almost 70% of respondents are implementing automation in their production process [5]. Another research in automation implementation in nursery production process [6]-[8] reported successfully improved the production process. Automation is widely used because it offers many advantages such as increase productivity, reduce labor cost, reduce manufacturing lead time, improve product quality, and mitigate labor shortages [9]. Because of these advantages, implementing automation considered as a feasible solution for solving the nursery labor problems.

Implementing automation only can’t solve all nursery problems, it needs to integrate with the whole production system. Moreover, several scholars consider that automation is a complicate issue and requires large investment to develop and maintain [10]. In order to successfully implement automation the designer should able to find, select, acquire, and properly implement the right type and level of automation in relation to the company needs and goals [11].

In general, nursery production process can be separated to four different process, namely propagation, re-planting, growing and display. In this research, automation will implemented to re-planting process of container plant nursery in Indonesia. Re-planting is selected to be automated because it requires lots of energy if done manually, and similar approach can be applied for all nursery plants re-planting process.

II. Method
The design process is following product development approach and considering the appropriate level of automation. Design procedure is explained as follows:

A. Identify User Requirements
User requirements are the foundation of any machine design, good machine design cannot be made without understanding the requirement. User requirements are obtained from observing the present process and interviewing the nursery owner. Good requirement should represent the objective or requirement for a solution that
technically achievable and unambiguous [12]. Identified requirement, then transformed into engineering specifications by utilizing house of quality matrix. This matrix can define product specifications to meet the user requirement with at the same time paying attention to the competitor, and transform the user need into measurable characteristics of product [13].

B. Generate Conceptual Design

Conceptual design generation begins with identifying function by using function structure diagram. This method is used because it can break the problem into smaller function that need to perform by specific component and extend the possibility of a feasible design solution [14]. Identified task then inserted to a morphological matrix to generate a conceptual design solution. Morphological matrix is a very useful tool for generating solution, it can generate numerous possible solution by combining alternatives of performing each task. Although this method is highly depends on designer knowledge and creativity, this technique is very useful for generating out of the box solutions [15]. The best concept will chose from generated solution by considering the user requirements, manufacturability, cost and engineering feasibility [16].

C. Generate Detail Design

A selected concept, then developed into detail design that provide information about shapes, forms, and dimension of each individual component [17]. Finite element analysis and failure mode and effect analysis are used to evaluate the design. Finite element analysis is used for calculating deformation, stress, and structural dynamic using approximated geometries from cad model [18]. Detail design development and evaluation are conducted concurrently, design refinement is done for multiple times until it fulfil the engineering specification and safety.

III. RESULT AND DISCUSSION

A. Present Re-planting Practice

In the present process, two employees are assigned to do re-planting with daily productivity up to 350 trees. The re-planting process (Fig. 1) begin with preparing the plastic bag (a) and fill it with rice husk (b), then it must be compressed until dense by using wooden stick (c) before the employee insert the plant seedling (d). Once the seedling is inserted, the employee continues to fill the bag with rice husk until it’s full (e) and compress it again until dense (f). Potted plant then placed in a cart for transport to growing area, where the nursery grows the plants until it reach saleable size.

B. User Requirements Identification

After observing current re-planting process and discuss with the nursery owner several requirements are identified, these are: minimize the number of worker, fast process, inexpensive, easy to use, low operation cost, simple maintenance and safe for use by the operator. These requirements then transformed into engineering specification and ranked by using quality function diagram. Three most important engineering specifications are used for representing the user requirements, those are: number of operators, filling speed and machine cost.

C. Conceptual Design Development

The function structure diagram of re-planting process is presented in Fig. 2, identified function then inserted to morphological matrix. Possible solutions for each function is identified and listed in the matrix, there are no limitation of possible solution to be listed in the matrix. Identified possible solution for each function (Table I ) then combined to create the machine concept. For example, the machine will use suction cups to open the plastic bag then, fill and compress the plant media by using screw conveyor. Because there are hundreds possible combination that can generated from the matrix, a time study is used to prioritize function that should be automate. Prioritizing function can reduce time required for developing conceptual design and effectively allocate available resources. Based on time study result, filling and compressing rice husk is the longest activity during re-planting process (Fig. 3). Therefore, by focusing to automate this activity, nursery can significantly reduce the process lead time.
Moreover, this activity doesn’t need a complex thinking process makes it affordable for the nursery to invest automation in it. After considering the feasibility and capability in fulfilling the user requirement, one concept is selected to perform re-planting process. The machine concept will use gravity to fill the bag with plant media and compress the media by using pneumatic piston rod. The rest of functions are still done manually because those processes requires complex automation system, but only contribute a small portion of time reduction.

**D. Detail Design Development**

Selected concept is developed into a detail machine design with machine specification as follows:

- **Dimension**: 1060 x 680 x 2280 mm
- **Capacity**: 100 bags/hour
- **Power**: 0.9 kW / 220 V
- **Working air pressure**: 6 bar
- **Air consumption**: 80 liter/minute
The machine is equipped with hopper for store plant media before it inserted to bag container. Designed hopper (Fig. 4) can hold up to 250 liter of plant media, which can be used for filling 100 bags. At the hopper also installed an air blower (Fig. 5) to assist material flow, this blower work by releasing high pressured air in form of pulse (± 0.5 sec/pulse) to reduce friction between hopper plate and plant media. Therefore, plant media can transferred to the press tube by using gravity force. The air pulse will repeated every 5 second until the press tube is filled with enough plant media.

After falling from hopper, plant media will enter a compression tube (Fig. 6) that used for compressing plant media up to certain density specified by the nursery. Besides increasing density, press tube also used to form a hole for insert the plant seedling. Two pneumatic cylinders are used for compress the plant media, one located below the tube for lock and hold plant media where another pneumatic cylinder compress the media from above. The bottom cylinder is equipped with weight sensor which used for weight plant media inside the bag during filling process and monitor the compression force by top cylinder.

During initial position, bottom cylinder is retracted allowing operator attach plastic bag to the press tube. Whereas the top cylinder is extruded, closing the plant media channel from hopper. When activated, bottom cylinder will extrude locking plastic bag with press tube then top cylinder will retracted allowing plant media to enter the press tube. Air blower then activated to assist the flow until weight sensor measure required weight and assign the top cylinder to extrude and compress the media inside the tube. After reaching ± 15 kg of compression force, bottom cylinder will slowly retracted and drive compressed media move from press tube to the plastic bag. Operator can remove the bag after it completely detach from the tube and attach new bag to fill again.

New workstation layout (Fig. 7) is proposed to fit with designed machine. Machine operator is required to fill the hopper with rice husk one sack at a time. After filling the rice husk, operator must open and attach the plastic bag to press tube then press the start button. While waiting the machine work, operator can insert plant seedling into a hole that prepared during compressing the rice husk. The plant seedling is propagated inside a tray to make it uniform size and easier when inserted into the hole. After plant seedling is planted, it placed on a larger container box that use for transport the plants to next station. By implementing this machine, the nursery can reduce re-planting process lead time up to 40 seconds per bags with employing one operator only.

![Figure 6. Compression tube](image1)

![Figure 7. Workstation design](image2)

### IV. CONCLUSION

Automation is considered as a suitable solution for solving labor problem in many industry. However, the use of automation also widely practiced in agriculture, especially in developed countries. In this research, semi-automatic plant media bagging machine is designed for assisting container plant nursery re-planting process. Designed machine is use compressed air to fill and compress plant media. Calculation result shows that designed machine is able to reduce re-planting lead time up to 50% of current practice with one employee to operate the machine.

**REFERENCES**


Soranat Raibhu is assistant professor at Industrial Engineering Department, Mahidol University, Thailand. He got his PhD in metallurgy and materials from University of Birmingham, United Kingdom in 2000. He has research interest in industrial metallurgy, surface coating, product and production design and development.

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