DESIGN, MANUFACTURING, AND TESTING AN A-SHAPE HYDROPONIC VEGETABLE GROWING SYSTEM USING SOLAR ENERGY

THIẾT KẾ, CHẾ TẠO VÀ THỬ NGHIỆM MÔ HÌNH TRỒNG RAU THUỶ CANH KIỂU CHỮ A SỬ DỤNG NĂNG LƯỢNG MẶT TRỜI

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ABSTRACT

Nowadays, the supply of green vegetables in some areas such as coastal islands and offshore islands is often transported from the mainland or grown in small foam pots and carefully covered frame houses. Vegetables supplied from the mainland are dependent on transport ships. Growing vegetables in foam pots and frame houses is also difficult because of the harsh marine climate and limited freshwater resources. From that practice, in this article, the authors calculate, design, manufacture, and test a hydroponic vegetable growing system model using solar energy. This model is effectively used for areas with limited land and limited electrical energy, such as coastal and offshore island areas.

Keywords: *Hydroponics system; Offshore islands; Solar energy.*

TÓM TẮT

Ngày nay, việc cung cấp rau xanh ở một số khu vực có diện tích chật hẹp như các đảo ven bờ, đảo xa bờ thường được vận chuyển từ đất liền hoặc được trồng ở các chậu xốp nhỏ, nhà khung được che chắn cẩn thận. Rau được cấp từ đất liền thì bị phụ thuộc vào tàu vận tải. Rau trồng trong chậu xốp và nhà khung cũng khó khăn vì điều kiện khí hậu biển khắc nghiệt, nguồn nước ngọt hạn chế. Xuất phát từ thực tiễn đó, trong bài báo này, các tác giả tính toán, thiết kế, chế tạo và thử nghiệm mô hình hệ thống trồng rau theo phương pháp thuỷ canh, sử dụng năng lượng mặt trời để vận hành. Mô hình này sử dụng hiệu quả cho những khu vực diện tích đất canh tác chật hẹp, điều kiện năng lượng điện hạn chế như các khu vực đảo ven bờ, đảo xa bờ.

Từ khóa: *Hệ thống thuỷ canh; Đảo xa bờ; Năng lượng mặt trời.*

1. INTRODUCTION

Vietnam is a maritime country with many coastal islands and offshore islands. Through the author's field surveys on offshore islands, it was found that growing vegetables on the islands faces many difficulties due to the harsh climate and water-absorbing coral soil. Meanwhile, fresh water sources for daily life are limited, so the amount of fresh water for watering vegetables is even more scarce. Especially in DKI rig areas, it is even more difficult because there is no arable land.

Vegetables are an essential food source in daily life. Vegetables not only provide a large amount of vitamins but also provide a part of the necessary multi-micronutrients in cell structure, ensuring human life and health. The supply of green vegetables in some areas with limited arable land such as coastal islands and offshore islands is often carried out in the following options: Option 1: green vegetables are provided from the mainland. Option 2: vegetables are grown in growing areas on the island or grown in small foam pots and carefully covered frame gardens. Vegetables supplied from the mainland depend on transport ships and are mainly tubers and fruits for long-term preservation. Vegetable growing in the growing area faces many difficulties due to the coral soil absorbing water and freshwater resources being scarce. Vegetables grown in foam pots and frame houses also face many difficulties because of harsh climatic conditions and limited fresh water sources for watering vegetables.

In 2014, the Project "Production and testing of some plant and animal varieties in the Truong Sa Islands" achieved some initial results, researched and tested, and found a number of suitable plant varieties. Adaptable to island climate conditions, but trees must be grown in carefully covered frame houses. Recently, scientists have applied the solution of growing organic vegetables on Sinh Ton Island. With this solution, vegetables are grown in plastic pots and organic matter is provided from organic waste and decomposed by earthworms.

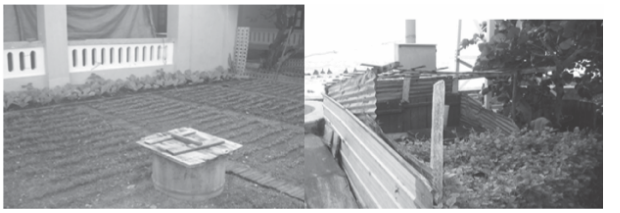

Fig. 1. Some pictures of vegetables growing on Truong Sa Islands.

Based on real requirements, in this article, the authors calculate, design, manufacture, and test a model of a hydroponic vegetable growing system, using solar energy to operate. Hydroponic growing is a technique of growing plants without using soil but directly in a nutrient medium or substrate such as sand, mud, and so on. The basis of this technique is to provide the plant with enough water and mineral elements necessary for the plant to mature. In 1936, scientist W.F. Gericke was the first to use the term hydroponics to describe the practice of cultivating in water solutions where nutrients have been dissolved. Since the 1980s, hydroponic techniques have been applied to produce vegetables, fruits and flowers of significant commercial value. Summary of plant growing techniques based on hydroponic principles by the authors [1]-[5]. In Vietnam, there have also been a number of scientists researching hydroponics techniques [6].

2. DESIGN A HYDROPONIC VEGETABLE GROWING

The general structure of a hydroponic vegetable growing system includes the ☞

following main parts: racks, vegetable trays; nutrient storage tanks, mini motors for nutrient pumps and nutrient supply and recovery pipeline systems; solar panels provide power for the motor to operate (Fig. 2). There are many ways to arrange vegetable racks, such as arrangement in the style of in an A-shape, ladder-type truss, support-type truss, multi-storey style, etc. Among those layouts, the A-shape layout is the most optimal style. Depending on the terrain characteristics of each area, choose the appropriate layout type.

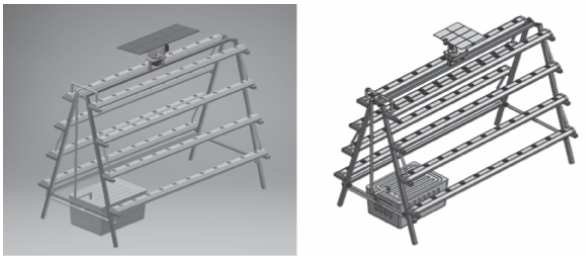

Fig. 2. 3D model of hydroponic vegetable growing using solar energy in Autodesk Inventor software.

To choose the support frame, the authors choose the size and preliminary materials, then simulate the stress field and, deformation field and check the structure's durability on Autodesk Inventor software (Figs. 4–5). The calculation result is to choose the size of the support frame as shown in Fig. 3. Support frame length: 1800 mm, length of vegetable trays: 2000 mm, frame height: 1600 mm, frame height including battery installation: 1828 mm , frame width: 900 mm to 1100 m. The two horizontal bars are designed with threaded connections to adjust the frame width to vary from 900 mm to 1100 mm, flexible according to the installation terrain. The main frame and connecting bars are made from CT3 steel TCVN 1766-75 standard, box steel 30 x 30 x1.5 mm TCVN 1656-75 standard. The welds ensure aesthetics, are durable, and do not retain slag, structure according to TCVN 1691-75 standard.

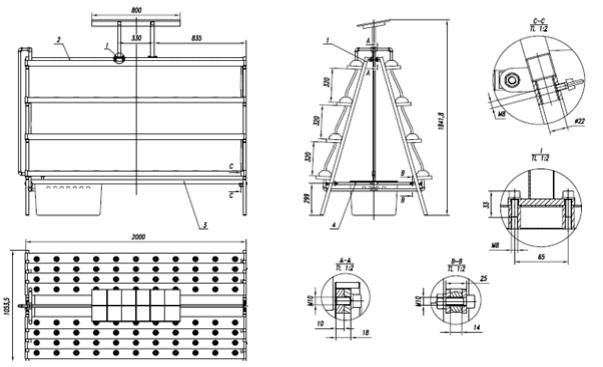

Fig. 3. The dimensions of the hydroponic system.

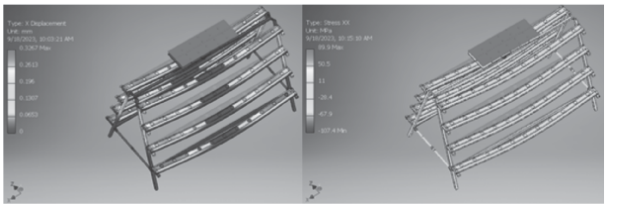

Fig. 4. The x-displacement field and the stress field σ_{xx} of the model.

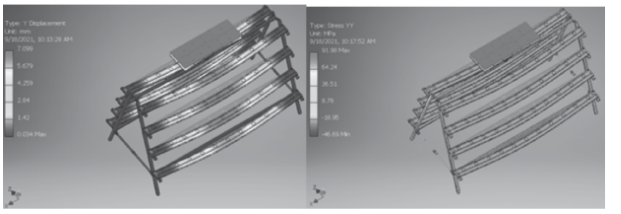

Figure 5. The y-displacement field and the stress field σ_{yy} of the model.

The pump capacity is calculated according to the following formula [7]-[9]:

$$P = K\frac{\gamma gQH}{1000\eta} \quad (1)$$

Where: Q – Pump flow (m^3/s); g – Gravitational acceleration (m^2/s); H – Pump height (m); γ – Specific weight of the liquid (kG/m^3); η – Pump performance; K – Power reserve factor.

Calculate the pump capacity as follows:

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$$P = K\frac{\gamma gQH}{1000\eta} = 1.5\frac{1000\times 9.81\times 3.6.10^{-4}\times 1.8}{1000\times 0.8} = 0.012\,kW \quad (2)$$

In addition, the pump capacity can be calculated using the Pipe flow wizard software. From the pump capacity, select the pump and solar panel capacity. Referring to the available engines, the Lifetech AP3100 motor is suitable. The specifications of the AP3100 motor are as follows: pump capacity 28W, pump flow 1.35 m^3/h, maximum pump height 2.8 m.

3. FABRICATE, ASSEMBLE AND TEST MODEL

Based on the design drawings in part 2, in this part, the authors proceed to manufacture, assemble and test the model. Steps to assemble the model include: assembling the frame, assembling trays and vegetable baskets, and assembling the transport and nutrient recovery system. The authors experimented with two types of vegetables, spinach and bok choy, with two ways of creating seedlings: seedlings were nursed in foam trays and seedlings were nursed in soil. The testing process showed that the vegetable plants grew well and evenly. The testing process revealed a number of issues that need to be improved, such as the need to use a mechanical or electronic timer to adjust the pumping time to avoid root rotting of the vegetables. It is necessary to fix the base to the ground to increase the system's rigidity, especially when it rains or wind can cause it to fall. When it rains, rainwater flows into the holes containing the vegetable plants, following the system to the tank, spilling nutrients out. Therefore, the hole containing the vegetable plants must have a suitable cross section.

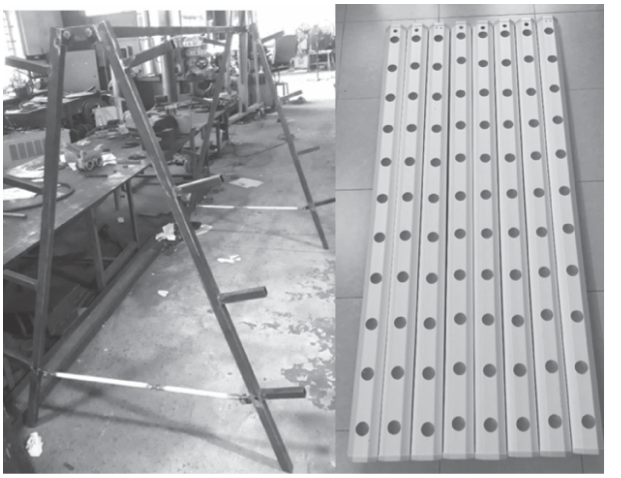

Fig. 6. Manufacturing frames and vegetable trays.

Fig. 7. Assemble and test model.

4. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDIES

In this article, the authors present the urgency of the research problem. Designed, manufactured, and tested a model of an A-shape hydroponic vegetable growing system, using solar energy to operate. Preliminary operational testing was conducted to evaluate the effectiveness of the model. Test results show that the model works well. The testing process revealed a number of issues that need to be improved, such as the need to use a mechanical or electronic timer to adjust the pumping time to avoid root rotting of the vegetables. It is necessary to fix the base to the ground to increase the system's rigidity, especially when it rains or wind can cause it to fall. When it rains, rainwater flows into the holes containing the vegetable plants, following the system to ☞

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From this model, it can be developed in the direction of designing and manufacturing hydroponic vegetable growing models, using wave energy and wind energy to suit the terrain of different areas such as floating islands, submerged islands, DKI rig, and so on. Research into replacing metal materials with composite materials to both ensure the system's operation and avoid corrosion by salt vapor.❖

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