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Research Paper

Automation of a Prototype of a Hydroponic System with Technologies

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ABSTRACT: *In Colima, agriculture is one of the most important economic activities, being an area of 30.72% of the total surface of the state used for this activity. With the purpose of favoring the development of agricultural technologies, a hydroponic system capable of implementing crops in spaces where the land is not appropriate is proposed, due to factors such as low soil fertility, hardness, temperature, among other environmental conditions, using a system for temperature, pH and salinity control, implementing IoT technology for remote system monitoring. In the first stage of the project, the design and validation of the system elements, the selection of sensors, radio frequency protocol and design of mechanical elements of the system were carried out using CAD/CAE software and finite element simulations. Both in the selection and in the manufacture of components, an optimal and efficient design was sought.*

KEYWORDS: *IoT, hydroponics, Nutrient Film Technique, agriculture, CAD/CAE, automation.*

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I. INTRODUCTION

Agriculture plays an important role in Mexico, providing economic support for approximately one seventh of the population. Due to the facilities provided by information technology, the agricultural sector faces the need to become an "intelligent" agriculture through knowledge management. [eleven].

Currently, there are a wide variety of hydroponic systems (ebb and flow, deep flow, nutritive film, floating root and drip) presenting specific characteristics to meet a particular application taking into consideration the space and type of crop [12]. However, this work will focus on hydroponic systems type NFT (Nutrient Film Technique), which is made up of a motor, mechanical structure, pipe, culture medium. The system is characterized by be a recirculating nutrient solution technique (nutrients dissolved in water), made up of which are brought into direct contact with the roots through a pumping system that works through work cycles, consequently presenting an optimization of energy at the time of cultivation a greater number of plants, in addition to allowing greater ease when monitoring, enabling the possibility of installing census test tubes in the tank as at the beginning and end of the system [14], for these reasons this model was selected to be used in this work..

Hydroponic crops have a large number of advantages over conventional crops. One of the most important is the viability of the hydroponic system without taking into account the characteristics of the soil, in addition to being able to carry out the cultivation vertically, a greater number of plants can be grown in a smaller space. Another of the most attractive advantages is that when growing the plant in an ideal space, there is no need to use pesticides and remove undesirable plants. It is worth mentioning that hydroponic systems also have certain disadvantages that can make the implementation of these cultivation systems difficult. Some of the main disadvantages are the initial cost, they require more equipment, in addition to needing a maintenance and control process that is commonly carried out by personnel with technical training due to the need to control variables in the system such as pH and nutrient level [16]. However, this issue is debatable since the process for making a hydroponic system is simple and methods are being developed to make it a viable practice for the whole community [17]. Additionally, it is projected that if an automation of these variables is carried out, it would allow a faster integration of the system to the community.

On the other hand, agriculture within the state of Colima is one of the most important economic activities, being the economic activity that uses the most space with an area of 158,335 hectares that correspond to 30.72% of the total surface of the state, however, also there is a percentage of 65.2% which is not used in human activities that currently corresponds to areas of jungles, forests and grasslands [8]. Many of these areas are not used due to environmental factors related to the hardness of the soil, land inclination or fertility that do not favor crops. Also, within the state there is a variety of climates and altitudes that favor carrying out a variety of different crops in each region, depending on whether you are in the tropical zone corresponding to the coast or if you are in the high forested areas.

In this way, with the objective of promoting new agricultural technologies in the state, an automated hydroponic system will be developed that allows the implementation of crops in spaces where environmental conditions are not optimal. One of the main characteristics of the system is the need to monitor and control variables that allow the cultivation of plants efficiently, allowing their development in ideal conditions, the main variables are temperature, conductivity and pH of the water [15]. Taking into consideration that the hydroponic system can be implemented in crops in the region with a greater extension and on some occasions in surfaces that are not so accessible, the decision was made to use IoT technology, allowing the monitoring of each of the variables of the system. remotely, in addition to backing up the information over time, which enables the user to have greater comfort in the system. Carrying out a research approach, wireless monitoring allows obtaining information on hydroponic crops in a central system, which allows an investigation of the behavior of hydroponics plants interacting with state conditions, seeking the tuning of the variables. to its optimal conditions, which is one of the main advantages of implementing IoT technology today [13] [10] [4].

With the purpose of promoting the agro-industrial development of the state of Colima, for which it is projected that the system can efficiently produce a wide variety of crops, allowing its selection through market analysis and projections made by the user, To allow this, a cooling system will be implemented in the system with the objective of cultivating temperature-sensitive vegetables, such as lettuce, cabbage, tomato, etc. [5] which could not be cultivated in the conventional way in the state.

During stage 1 of the project, it will focus on the design and analysis of the elements that make up our hydroponic system through the use of CAD/CAE tools that allow us to carry out simulations of each of the elements that make up the system, such as the bases for the hydroponics tubes, the greenhouse structure and bases for the nutrient tank, looking for an optimal design of the same, considering the aesthetics and accessibility in the construction.

II. METHODOLOGY

In this first stage, the conceptualization and design of the NFT-type hydroponic system was carried out, taking into account the temperature requirements, nutrient quality, as well as the space necessary for the optimal growth of the vegetables.

Design

The structural part of the hydroponic system consists of a base of 1.3m*0.7m with a slope in the longitudinal part of approximately 3%, this to comply with the recommendation of inclination of the FAO [5], so on the one hand the base measures 30 cm high and the other 26 cm. The hydraulic installation of the hydroponic system is commonly ABS (Acrylonitrile butadiene styrene), PVC (Polyvinyl chloride), PEBD (Low density polyethylene) and HDPE (high density polyethylene). PEBD is more flexible and less brittle than PVC, so it can better withstand blows and impacts. HDPE is a more rigid material, and has better resistance to chemical agents and extreme temperatures. However, since extreme working temperatures are not considered, PVC was chosen as the material for the irrigation pipes, being this more economical and accessible on the market than ABS [18].

The designed hydraulic system will consist of three 4" PVC pipes with a length of 1.5 m where 5 perforations of 7 cm in diameter will be made, used to place the culture medium. These perforations will be presented at 25 cm distances to allow the plants to develop properly, avoiding that the growth of the roots and the search for radiation is a problem [6]. The tubular sections will be spaced 10 cm apart, seeking in the same way that the distance between the plants allows the absorption of solar radiation.

The material used for the construction of the base will be a 2x1 PTR structural steel profile, due to its resistance characteristics: minimum yield stress of 36 KSI and a tensile breaking stress of 58 KSI, modulus of elasticity of 200 GPa, in addition to be accessible in the market and present an affordable price compared to other solutions in the market.

The storage of nutrients in the system will be carried out by means of a connection to a polyethylene tank used in hydroponic systems due to its long-term resistance in the nutrients used and being a material that lacks oxidation, reasons why this type of tambos are widely used in the agricultural sector. The dimensions of the tank will be 90 cm high and 60 cm in diameter, which is buried in the ground at a depth of 70 cm seeking to support the conservation of temperature, this being lower than on the surface.

The distribution of the nutrient solution will be carried out through a 1/2" PVC pipe, which will lead to three irrigation hoses, these will be inserted into the PVC pipe to administer the water with nutrients to the plants. The return to the tank occurs in the same way, but in the reverse order, that is, the irrigation hoses come out of the pipe, which end in a 1/2" CVPC tube, which discharges the water with nutrients to the tank. .

The circulation of the nutrient solution is the main characteristic of the NTF system, allowing its oxygenation and monitoring throughout the system. One of the main problems is the accumulation of salt residues, which cause obstructions in the hydraulic equipment in the system. Consequently, in the system developed, hydraulic recirculation will be carried out by means of a 1/2 hp submersible motor for dirty water. This solution has been used before in the Rainwall system in Colombia, where they even collect rainwater for irrigation of hydroponics [7].

The concentrated nutrient solution will be stored in a container 1 m above the ground, due to the height difference it will allow the use of only one solenoid valve, which will control the incorporation of the formula into the storage tank, allowing the use of a system of control and automation of the same, the selection considerations were that the operating voltage was 12V or 5V and the pipe not larger than 1", the first because the voltages that we can provide without adding more electronics are 12V and 5V, while the latter to have a better control of the nutrient that is poured. Finally, we selected a 1/2" solenoid valve with a 12V supply voltage and a working pressure of 0.02-0.8 MPa.

The following image (Figure 1) shows the greenhouse with all its components.

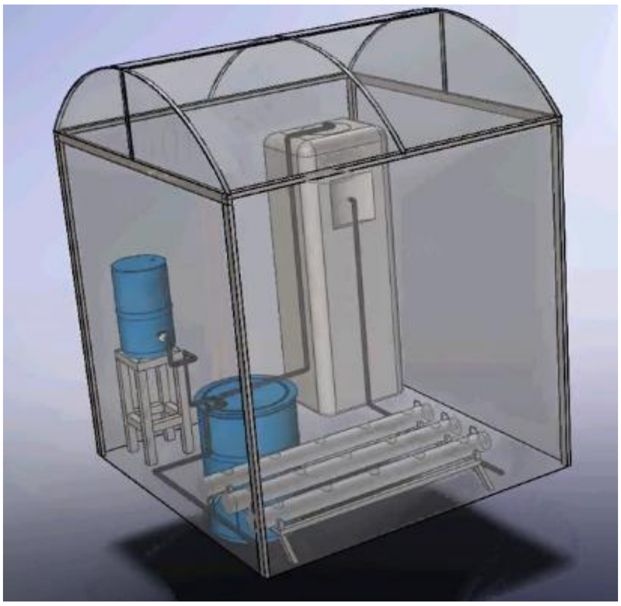

Figure 1: Design of the hydroponic system.

The stress support of the base for the pipe, the base for the nutrient container and the greenhouse structure were validated using the CAE ANSYS software.

Control system

The temperature and nutrient control part will take place in the tank, in which the water temperature, PH and total dissolved solids will be measured and then with this information take the corresponding control actions. The ranges of these variables for cultivation in hydroponics according to the FAO are 5.5-7 for PH, 1500-2000 us/cm [5], and since the temperature depends on each crop, 18°C was chosen as the minimum. The Table 1 shows the selected sensors.

It was sought that all the sensors could be powered at 5V, to avoid adding extra electronics to adjust the voltages, it was also sought that the sensors were easy to acquire for their replacement. In the case of the temperature sensors and the ultrasonic sensor, they were sought to be waterproof, to prevent them from being damaged.

The microcontroller to be used will be an STM32F108C3, presenting the characteristics of: 24 Kbytes of SRAM, 64-byte flash memory, I2C connection, SPI connection, 2 USART ports, 2 12-bit ADCs, CRC calculation unit, 37 GPIO, etc., which are sufficient in the implementation of the monitoring and control system of the system, in addition an LCD will be used to create a user interface, from where the values of the variables can be adjusted, as well as monitor them.

The system variables will be transmitted to a specialized database, which will allow the monitoring of the implemented systems such as data collection, the options for wireless communication are currently extensive (Xbee, Zigbee, Lora, RF, Bluetooth), each one presents special characteristics, such as range, latency, available channels, price and accessibility, in this project two wireless communications will be carried out, the first for monitoring at short distances which allows communication between different hydroponic systems within the same terrain, the second is a long-distance communication and Gateway which allows a coverage of km of distance in addition to sending the information to the internet. For communication over short distances, the Xbee S2C module will be used, presenting a working frequency of 2.4 GHz, an output power of 2mW, a data rate of up to 250,000 bauds, a sensitivity of 102 dBm, allowing communication between systems within a radius. approximately 1.2 km. As a solution for long distances, Sigfox technology will be used with a frequency of 902 MHz, which allows communication with a range of 86 km, sending the information directly to the Internet as a Gateway.

Table 1: Sensors

Sensor	Model	Features	Selection Rationale
pH	pH-4502C	Response time of 5 seconds, detection range of 0-14 pH, power supply 5V, current 10 mA, working temperature 10-50 °C.	The response time, the detection range and the working temperature guarantee its proper functioning within the system, as well as being of low consumption and that it can be powered with 5V.
TDS o CE	TDS meter v1.0	Power supply 3.3 to 5V, working current 3-6 mA, detection range 0-2000 us/cm.	It was chosen for the measurement range, the 5V power supply and the low consumption.
Temperature	dsb1820	Temperature range -55° to 125° C, working current 4 mA, power supply 3 to 5.5 V.	The temperature range that it handles is suitable for use in the system, in addition to the supply voltage and low current consumption.
Tank level	Sensor Ultrasonic Jsn-sr04t Ip67	Measurement range of 25-450, working current 30 mA, power supply 5V.	The height of the tank to be used is 1 m, so its range is more than enough for its use in the system.

III. RESULTS

For the irrigation base (Figure 2), the finite element analysis of the cultivation base was carried out considering the irrigation tubes with nutrient water at 75% of their capacity, equivalent to a weight of 120 N, distributed in two point loads. per tube at the ends of the base.

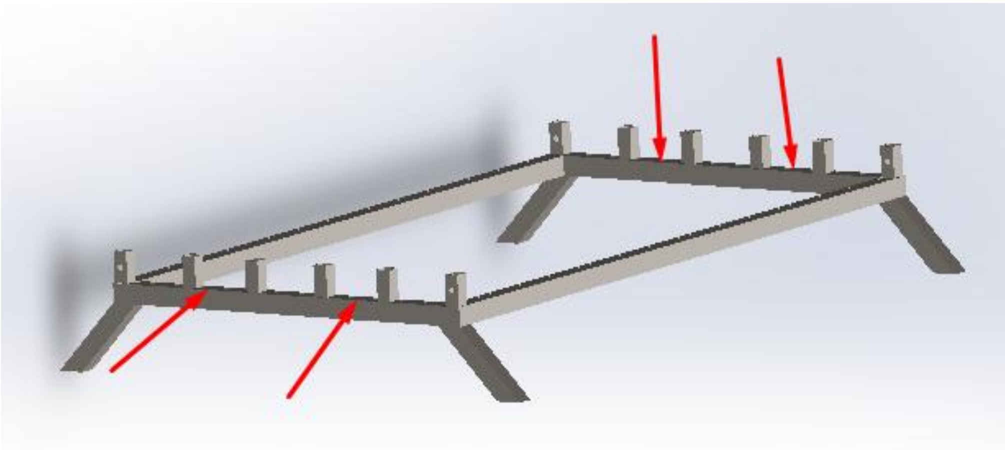

Figure 2: Design of the base for cultivation.

From these boundary conditions, a maximum total deformation of 0.3 mm was produced in the structure, present in the center of the support points where the culture tubes are supported. From this analysis, a safety factor of 15 was obtained with respect to deformation, for which the mechanical design of the base was validated.

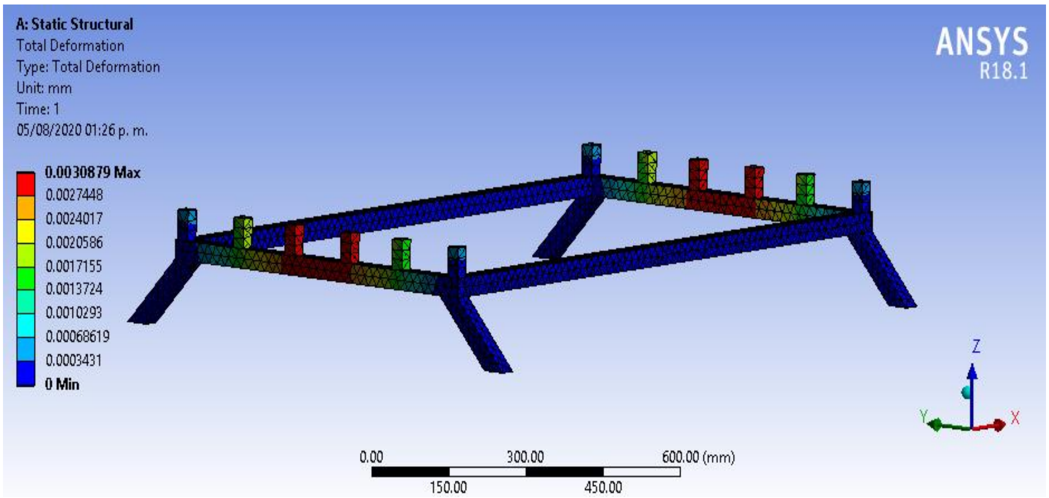

Figure 3: Graph of total deformation of the culture base.

For the analysis of the base for the nutrient storage tank, a force of 503.6 N was considered, which corresponds to the maximum weight of the nutrient solution tank, as a load distributed on the upper face of the structure, while the legs were fixed as fixed supports. A maximum total deformation of 0.1 mm occurred at the top of the tank base, which is where it is in contact with the nutrient tank, as shown in Figure 4.

The maximum von-Mises stress produced by the load was 1.64 MPa. Being 250 MPa the elastic limit of the PTR, this does not suppose a problem in the design. The resulting safety factor with respect to deformation is 15, for which the design was validated.

Sensors, actuators and selected sensors.

Microcontroller: Bluepill board with integrated STM32F103CT8, Ultrasonic Sensor: JSN-SR04T Sensor, Temperature Sensor: DSB1820 Sensor, Solenoid valve: 1/2" NC 12V solenoid valve, Electrical conductivity sensor: TDS Meter V1.0 Sensor, pH sensor: Solenoid valve 1/2" NC 12V, Submersible pump: Submersible pump for dirty water 1/2 HP.

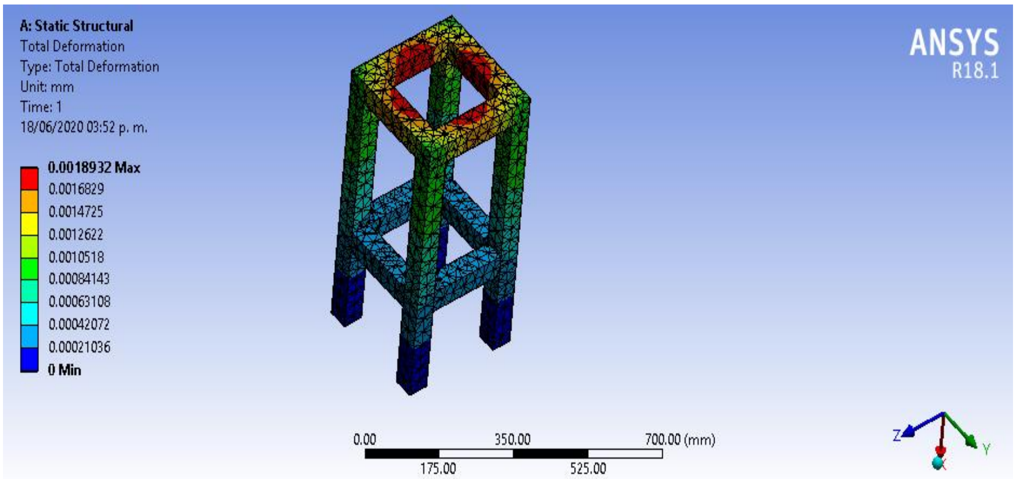

Figure 4: Graph of total deformation of the culture base.

IV. DISCUSSION

Currently there are a wide variety of hydroponic systems which are increasingly used in more spaces and which year after year acquire greater value due to the advantages of implementing this type of crop [2]. Although in recent years various hydroponic crops have been created to which new technologies have been implemented with the aim of improving the production of these systems and making crop management easier, currently there are practically no hydroponic systems that adapt to the needs of crops that occur within the state of Colima.

An example of the aforementioned is the hydroponic system developed at the Faculty of Biological and Agricultural Sciences of the University of Colima, where it was possible to carry out a lettuce crop, however, the study focused on finding optimal concentration values. of nutrients in the nutrient solution [3]. Although it was possible to cultivate lettuce, the environmental conditions of the coastal area where the faculty is located constantly raised the temperature of the water, causing the vegetables to enter a reproductive state in an accelerated manner, causing a more bitter taste to be produced in the plant. [1], which is not ideal if the production is intended to be used for human consumption. Thus, through the implementation of the water cooling system, this problem is sought to be solved by applying a control system that allows optimizing crop production by controlling the variables of pH and conductivity with the aim of ensuring the proportion of nutrients necessary for the correct growth of the plants and that in turn avoids the need for human supervision on a recurring basis.

V. CONCLUSION

The simulations applied to the system turned out to be satisfactory, the mechanical simulation of the main structure and the bases obtained a wide margin of safety, which guarantees that it will not fail under the stress of weight and wind.

The experimentation of the thermal system provided the necessary information on the temperature parameters so that it could be verified that the system is functional for the proposed objectives.

The analysis of this stage, the necessary information is available that indicates that the project is technically viable and easy to adapt to produce on a larger scale.

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