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Design of Automated Vegetable Transplanter

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Abstract - The paper is about the design and evaluation of an automated vegetable transplanter aimed at improving the efficiency, precision, and scalability in modern agriculture. This system integrates a robotic arm, a crank-driven pickup mechanism and a 5-bar digging system to ensure accurate and damage-free planting of vegetable saplings. The transplanter is designed for variety of vegetable crops. The use of a mechanical arm and conveyor system enables smooth conveyance of saplings to the planting mechanism, where blades and digging arms facilitate precise soil penetration and optimal plant spacing. Analytical results demonstrate the system's ability to transplant a variety of vegetable species with high accuracy and efficiency, offering significant advantages over traditional methods in terms of speed and adaptability to diverse field conditions. By automating the transplantation process, the system reduces labor requirements, minimizes operational costs, and promotes sustainable farming practices. These findings suggest that the automated transplanter is a promising tool for increasing productivity, improving crop yield and supporting the modern agricultural industry.

Keywords: Modern agriculture, Automation, Vegetable transplanter, productivity, crop yield, saplings.

1.INTRODUCTION

The foundation of human civilization has been agriculture, and technological developments have constantly transformed farming methods. Transplanting vegetable crops is one crucial area of attention; this labor-intensive procedure requires accuracy and efficiency to guarantee the best possible crop growth. Manual labor is frequently used in traditional transplantation techniques, which can be labor-intensive, inconsistent, and error-prone. The creation of automated solutions has accelerated in response to these issues, offering increased agricultural sustainability and production. Because of its modular construction, it can be used with a variety of vegetable crops, which makes it extremely flexible and able to adjust to different field circumstances. The transplanter's main characteristics are a conveyor system that guarantees the saplings are delivered to the planting mechanism steadily and smoothly, as well as specialized digging arms and blades that enable accurate soil penetration and ideal plant spacing. Together, these elements reduce root damage and increase planting precision, two crucial elements for a successful crop establishment. The automated transplanter has many useful advantages in addition to its technical ones. It solves labor shortages and lowers operating expenses by lowering reliance on human labor. Its reliable performance also improves planting uniformity and efficiency, which raises agricultural yields. Since the transplanter's accuracy minimizes waste and encourages resource-efficient agriculture, it also supports sustainable agricultural methods. This study examines the automated vegetable transplanter's construction, operation, and performance assessment, emphasizing how revolutionary it could be for contemporary farming.

. 2. PROBLEM STATEMENT

In agriculture, transplanting vegetable seedlings is a crucial but time-consuming procedure that calls for extreme caution and precision to guarantee the best possible crop establishment and output. In addition to being irregular and time-consuming, traditional manual transplantation techniques are also prone to inefficiencies including uneven plant spacing, sapling damage, and changes in planting depth. These difficulties lead to lower crop yields and higher operating expenses, especially in large-scale farming operations when the problem is made worse by a lack of workers and growing wages. The precision and adaptability needed to manage the delicate nature of vegetable saplings under a variety of crop varieties and field circumstances are sometimes lacking in current robotic transplantation techniques. Additionally, many people may not be able to use these systems because to their complicated installations, excessive energy consumption, or limited adaptability.

A creative solution that blends effectiveness, accuracy, and scalability is desperately needed to address these problems.

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With its sophisticated mechanical and robotic integration, an automated vegetable transplanter has the potential to completely transform the transplantation procedure. In addition to decreasing labor reliance and operating costs, such a system must guarantee damage-free handling of saplings, regular spacing, and adaptation to different field conditions and crop types. In order to provide a dependable, effective, and sustainable response to contemporary agricultural demands, this project attempts to design and test an automated vegetable transplanter that tackles these important issues.

3. METHODOLOGY

This study presents a systematic approach to designing, developing, and evaluating an automated vegetable transplanter to address the inefficiencies of manual transplantation processes. The methodology involves several stages

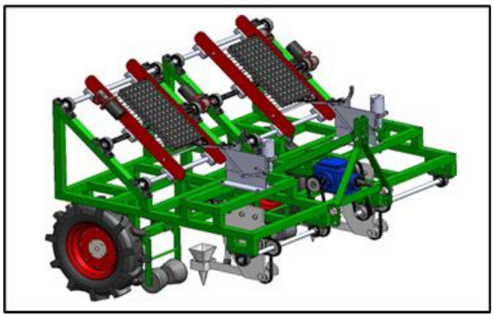

FIGURE.1 *3D MODEL OF THE AUTOMATED VEGETABLE TRANSPLANTER*

Designing and fabricating the transplanter requires careful selection of materials and components to meet durability, performance, and cost-effectiveness. The chassis is fabricated using AISI 4130, a low alloy steel with high tensile strength, toughness, and weldability, making it suitable for handling heavy loads and stresses. Chain sprockets and gears are made using EN 24, an alloy steel of high strength with excellent fatigue strength, wear resistance, and impact toughness; thus, the components are long-lasting under cyclic loads and allow for efficient transmission of power. The casing of the gearbox is fabricated using Aluminum 6063, a lightweight but strong alloy having excellent corrosion resistance and machinability, which reduces the overall weight while still providing the structure's integrity. The motor has characteristics of 8.782 Nm of torque, 80W of output power, and 100 RPM of torque speed using a 12V input voltage, thus able to deliver the required power to operate the mechanism smoothly. Control and automation are achieved using an Arduino Uno R3 microcontroller programmed using C++ via Arduino IDE 2.2.1 for precise operation and adaptability. The materials and components used were selected based on the transplanter operational requirements, allowing for an optimum strength-to-weight ratio, wear and corrosion resistance, efficient power transmission, and precise control, all within the dimensional and weight limitations specified in the rulebook. All this combines to ensure that the transplanter is economically and practically viable for use in agricultural applications

4. WORKING OF PROPOSED MODEL

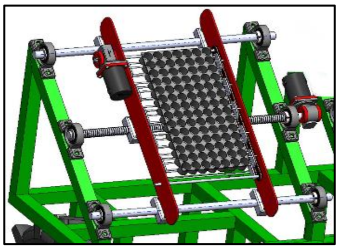

FIGURE.4.(A) *CONVEYING SYSTEM*

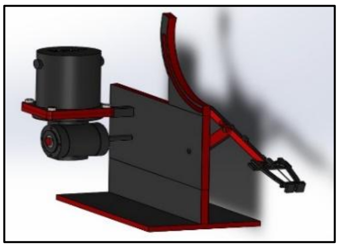

FIGURE.4.(B) *PICKUP & DROP SYSTEM*

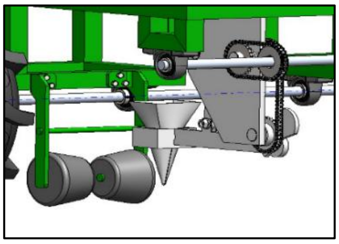

FIGURE.4.(C) *DIGGING AND CLOSURE SYSTEM*

The machine is totally divided into 3 modules, which is mentioned below:

- Conveying System
- Pick up and drop system
- Digging and closure system

An innovative design is incorporated into the automated vegetable transplanter to guarantee effective and damage-free sapling transplantation. To minimize the chance of sapling injury, rubber grippers are employed for delicate sapling plucking and transfer. Through a static mechanical arm that moves saplings to the digging mechanism, the system has a total conveyance capacity of 196 saplings, with a tray capacity of 98 saplings per pair of conveying systems. Saplings are effectively retrieved by the crank-driven pickup mechanism, which then gently deposits them into the planting hopper. The system's 48V DC battery-operated motor guarantees dependable and long-lasting operation. For accurate sapling handling, the crank mechanism mechanically actuates the robotic arm.

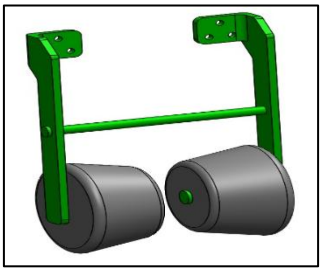

FIGURE.4.(D) CLOSURE SYSTEM

The planting mechanism uses a 5-bar principle and has key parts that help with accurate soil penetration and sapling placement, such as blades, digging arms, and cones. For actuation, chains, sprockets, and connecting rods are used, guaranteeing precise planting and synchronized operation without endangering the saplings. With a storage unit holding up to six trays, including two in the conveying system and four in storage, the system ensures continuous operation without frequent refilling. The trays are seamlessly integrated into the implement through the conveying system, ensuring smooth sapling transfer throughout the process. The result is a very effective planting mechanism that encourages scalable and sustainable farming methods while drastically lowering labor needs.

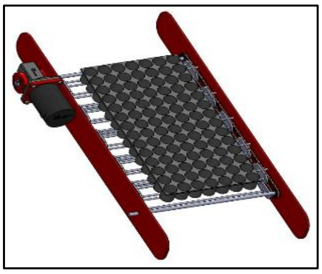

FIGURE.4.(E) CONVEYING SYSTEM TRAY

The conveying system employs a belt-pulley type mechanism with a 45-degree elevated angle. It consumes 0.704 kW of power and achieves a linear speed of 0.052 m/s. The conveyor belts, with a diameter and spacing of 370 mm, efficiently transfer saplings at a flow rate of 12 saplings per minute. The closure system ensures proper covering of saplings after planting to protect them and promote healthy growth. It uses a combination of blades and soil-compacting mechanisms to cover the sapling roots efficiently. The system operates smoothly, minimizing damage while maintaining soil firmness for optimal support and moisture retention.

5. CALCULATIONS

Bending Stress:

Outer diameter(D_o) = 50mm

Thickness = 25mm

$D_i = D_o - 2t$

$= 50 - (2 \times 2.5)$

$= 50 - 5$

$D_i = 45$ mm

$I = \pi/64\ [D_o^4 - D_i^4]$

$= 3.14/64\ [50^4 - 45^4] \times 10^{-12}$

$= 3.14/64\ [6250000 - 4100625] \times 10^{-12}$

$= 0.0490625\ [2149375] \times 10^{-12}$

$I = 105453.7109 \times 10^{-12}$

Bending Stiffness:

$k_b = E \times I$

E = Modulus of elasticity = 205apa

$= 205 \times 10^9$ N/m^2

$k_b = 205 \times 10^9 \times 105453.7109 \times 10^{-12}$

$k_b = 21618.01073$ N/m^2

Bending strength:

$S_b = S_y\ I / C$

S_y = yield strength = 365 mpa

$= 365 \times 10^6$ N/m^2

C = 50 / 2 = 25mm = 0.025 m

$S_b = (365 \times 10^6 \times 105453.7109 \times 10^{-12}) / 0.025$

$= 38.49060448 / 0.025$

$S_b = 1539.624179$ N/m^2

Longitudinal Torsional Stress:

Factor of safety (N/mm^2) = Tensile strength / Von mises

= 440 / 216.5

FOS = 2.03

Vertical Bending Stress:

Factor of safety (N/mm^2) = Tensile strength / Von mises

= 440 / 211.7

FOS = 2.07

Transverse Bending Stress:

Factor of safety (N/mm^2) = Tensile strength / Von mises

= 440 / 183.6

FOS = 2.39

6. DESIGN AND FEA OF CHASSIS

The longitudinal torsional stress analysis evaluates the ability of the transplanter's frame to withstand twisting forces along its length. The results indicate a maximum stress of 464.72 MPa, concentrated at critical joints, but well within the material's safety limits, ensuring structural reliability. ***FIGURE.6.(A)***

The longitudinal torsional displacement analysis evaluates the deformation of the transplanter's frame under twisting forces. The maximum displacement observed is 16.83 mm, occurring at the top sections, indicating acceptable flexibility while maintaining structural stability. ***FIGURE.6.(B)***

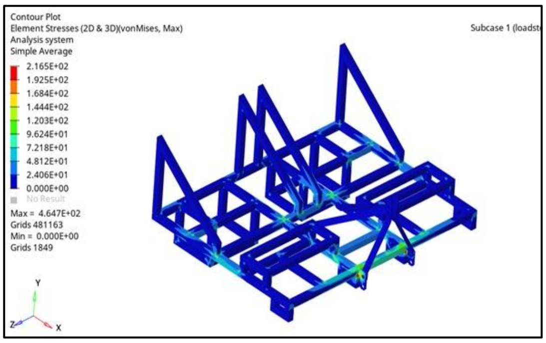

FIGURE.6.(A) *LONGITUDINAL TORSIONAL STRESS*

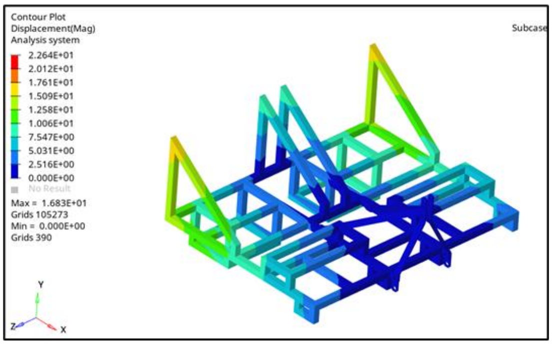

FIGURE.6.(B) *LONGITUDINAL TORSIONAL DISPLACEMENT*

The vertical bending stress analysis examines the structural response of the transplanter's frame under vertical loading conditions. A maximum stress of 320.8 MPa is observed at load concentration points, ensuring the frame's design effectively distributes stresses within safe limits. ***FIGURE.6.(C)***

The vertical bending displacement analysis assesses the deformation of the transplanter's frame under vertical loads. The maximum displacement recorded is 6.735 mm, occurring at the upper sections, indicating adequate rigidity and structural performance. ***FIGURE.6.(D)***

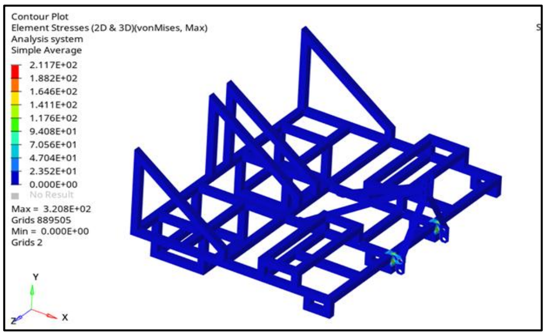

FIGURE.6.(C) *VERTICAL BENDING STRESS*

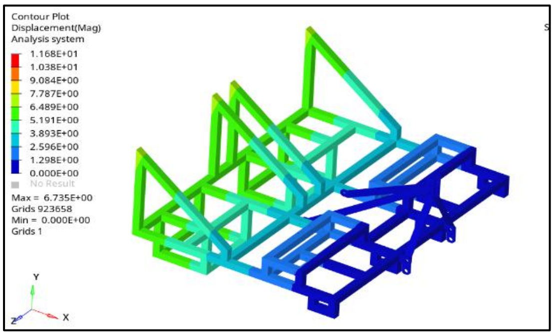

FIGURE.6.(D) *VERTICAL BENDING DISPLACEMENT*

The transverse bending stress analysis evaluates the frame's resistance to lateral loading conditions. A maximum of 183.6Mpa is observed well within the material's yield strength, ensuring structural stability under transverse forces. ***FIGURE.6.(E)***

The transverse bending displacement analysis examines the lateral deformation of the transplanter's frame under transverse loads. The maximum displacement recorded is 1.836mm, occurring at the upper sections, indicating adequate rigidity and structural performance. ***FIGURE.6.(F)***

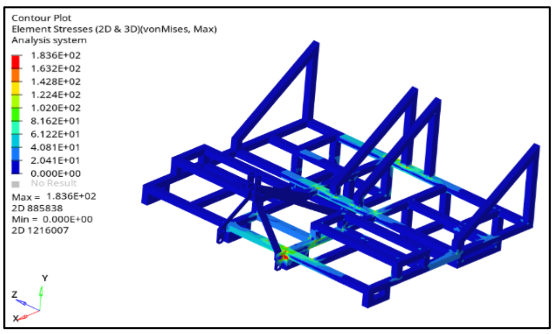

FIGURE.6.(E) *TRANSVERSE BENDING STRESS*

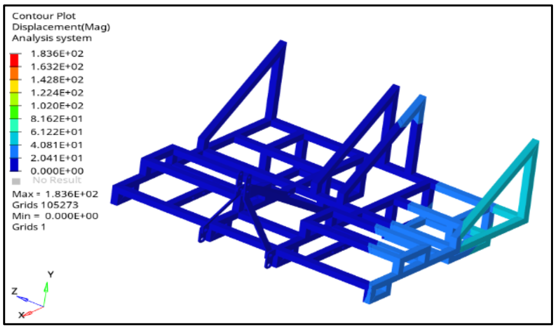

FIGURE6.(F) *TRANSVERSE BENDING DISPLACEMENT*

7. CONCLUSION

The automated vegetable transplanter effectively addresses challenges in traditional manual transplanting by integrating advanced mechanisms for precise and gentle sapling handling. Equipped with rubber grippers, a crank-based pickup system, and a robust conveying mechanism, the transplanter ensures efficiency and damage-free operations. Structural analysis under various stress and displacement conditions confirmed the machine's reliability and durability, with all parameters within safe limits. Compatible with all variety of vegetable saplings, the transplanter improves productivity, reduces labour dependency, and supports sustainable farming practices. This innovation signifies a step forward in agricultural mechanization, promoting efficiency and enhancing modern farming techniques

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