Automatic Potato Separation Device from a mixture of Soil and Potato

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***Abstract*—Several methods have been developed in an effort to improve harvest efficiency and optimize soil separation in automated potato separation operations. Unfortunately, during the separation process, several of these procedures cause damage to the potatoes. Addressing this concern, a novel method is presented using a structure comprising a sieve plate, three brushes, and two fans.According to research findings, this new method cleans potatoes more effectively while causing the least amount of damage. It has been identified through careful simulation that increasing the sieving plate's oscillation frequency and the brush system's revolutions per minute (rpm) greatly improves system efficiency as a whole. The careful selection of the number of brushes used and the oscillating speeds utilized in the system are important factors in attaining maximum efficiency.This technique not only shows positive results in reducing potato damage during separation, but it also highlights the possibility of significant gains in total process efficiency. The key to optimizing the effectiveness of this novel potato separation system is the methodical adjustment of operating parameters, such as oscillation frequency and brush system rpm.**

***Index Terms*—potato harvest, soil potato separation device, simulation analysis**

I. Introduction

Potatoes, a starchy staple originating from the Americas, have gained global prominence as a fundamental food source. Ranked as the world's third-most crucial food crop, following rice and wheat, potatoes offer a rich composition of carbohydrates, fiber, vitamins, and minerals. Given their widespread consumption, the demand for efficient potato harvesting methods has surged, particularly as potato farm sizes continue to expand.

The increase in potato farm dimensions has necessitated the development of more effective harvesting techniques, surpassing the limitations of human labor. Numerous methodologies exist for the extraction of potatoes from fields. However, owing to the intrinsic connection between potatoes and soil during harvesting, a subsequent need arises for an efficient separation process. The utilization of human labor for the meticulous removal of soil becomes impractical, particularly when confronted with extensive agricultural fields.

Harvesting potatoes in a large field is a very labor-intensive process. Potato harvesting in large fields is done in a few days, so the harvesting methods should be very efficient and the cost of the operation should be less. A small delay in the harvesting

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Fig. 1. Potatoes in a large farm

process can cause serious adverse effects, like crop damage. There are various types of soil in which potatoes are grown. Some are sandy, and some are clay-type. When developing a system, it should comply with all soil conditions. There are existing methods in the world that comply with only one type of soil.

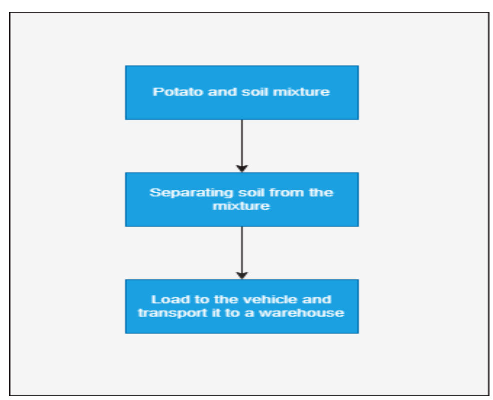

Fig. 2. Simple flowchart showing the process

II. Literature Review

Investigations of mechanisms including swing sieves [1], lifting chains [2], spinning discs [3], spiral soil separators [4], conveying systems [5], and several other processes for soil separation demonstrate the diversity of approaches used to separate potatoes from soil. The two main areas of focus for these research projects are equipment efficiency optimization and minimizing potato damage during the separation process. These factors highlight the need for separation mechanism development that simultaneously prioritizes the preservation of potato integrity and improves overall operational effectiveness.

Swing sieves are easy to use and reliable, but they can damage potatoes if not operated correctly, leading to their exclusion from consideration. A current industry trend involves the adoption of air flotation systems [6] for waste removal during crop harvesting. While effective in removing soil and dust from potatoes, this method requires significant water and time, making it impractical for large farms where a quick separation process is crucial. The need for quick separation is also complicated by the challenge of storing heavy soil and potatoes, emphasizing the importance of energy-efficient solutions for vehicular motion.

Another method discussed in research papers is lifting chains. In this approach, the potato and soil mix is placed on a conveyor belt and lifted upward.This approach proves highly effective in expelling substantial quantities of soil from the mixture. However, the higher speeds of this method can damage potatoes.With the increasing prevalence of artificial intelligence (AI), there's a method that utilizes AI [7] for potato and soil separation. This method employs image recognition to accurately identify potatoes from stones. While highly accurate, especially in identification, it's less efficient for large farms as it requires preliminary cleaning of potatoes and operates at a slower pace.

Researchers are exploring a vertical circular device for potato combine harvesters [8]. This method stands out for its higher efficiency in separating potatoes and causing less damage to them. However, finding the right speeds for smooth operation poses some challenges, especially regarding linear and rotational speeds.Another method involves using a series of brush rollers [9] to separate soil. This approach effectively removes fine and large soil particles from potatoes. However, because it uses nylon fibers on the rollers at higher speeds, there's a risk of damaging the potatoes. To address this, it's crucial to find the right rotational speed for the rollers to balance efficiency and damage caused to potato.

Leading potato harvester manufacturing companies like AFC and AGCO use conveyor belt systems to separate soil from potatoes. There are many types of conveyors used for this process, like roller conveyor systems, chain conveyor systems, etc. These conveyors are very efficient in removing large amounts of soil and main stem from the mixture.

III. System Overview

In pursuit of a balance between efficiency and minimizing potato damage, a model incorporating a reciprocating horizontal sieving screen, a brush system, and two fans was employed. The horizontal sieving screen functions akin to a chain conveyor, elevating potatoes while concurrently expelling soil. Notably, the conventional lifting mechanism poses a risk of

Fig. 3. Conveyor system for separation

potato damage due to the force exerted between the potatoes and the conveyor.

To mitigate this concern, a horizontal sieving screen was introduced into the system. The reciprocating motion essential for the screen's operation was achieved through the integration of a scotch yoke mechanism. This mechanism, influencing acceleration, induces a lateral movement of the potato and soil mixture within the screen. Consequently, loose soil is detached from the mixture due to the frictional interaction between the mesh and the amalgam, contributing to the overall efficacy of the separation process.

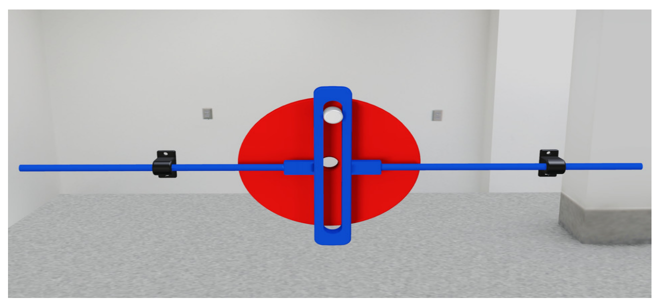

Fig. 4. Scotch York Mechanism

According to the researchers, farmers remove large stones from the fields [10] before planting potatoes to facilitate mechanical harvesting. It is assumed that the stem of the potato plant is cut with a haulm topper so that only the tube part remains in the field. Due to that, only loose and muddy soil will come to the sieving plate. So, most of the mud and soil attached to the potato will be removed when it moves through the sieving plate.

In addressing the need for the removal of fine soil particles attached to potatoes, a system incorporating brushes has been implemented [11]. This configuration has proven highly effective in eliminating dust from the potatoes. While alternative methods, such as water cleaning, exist for the removal of fine soil particles, the choice of brushes is particularly advantageous when considering both efficiency and the preservation of potato skin purity.Within this system, three brushes facilitate

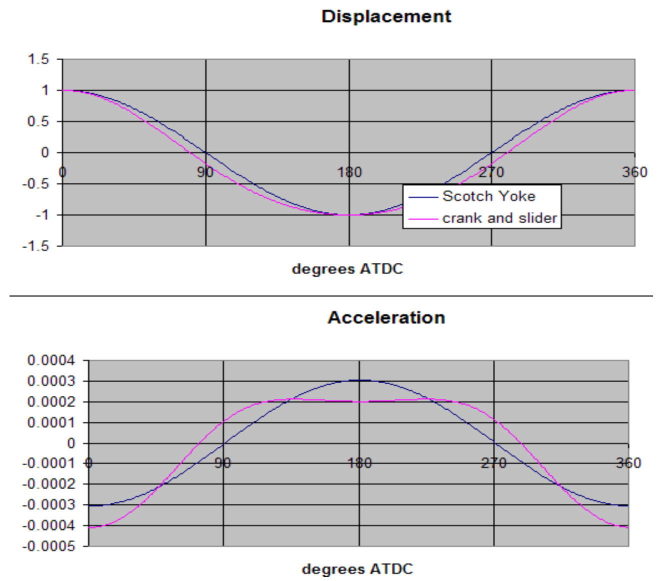

Fig. 5. Side crank displacement and acceleration of Scotch York Mechanism

Fig. 7. Blow fan

the passage of potatoes through them. Notably, two of these brushes rotate in one direction, while the remaining brush rotates in the opposite direction, ensuring that no potatoes get displaced from the machine during operation. The brushes, designed for ease of replacement and maintenance, contribute to minimizing operational costs associated with them.

Fig. 6. Different types of debirs cleaning brushes

As the brushes detach the fine soil particles, the potatoes and finer soil particles fall to the collecting box at the bottom. To avoid dust and fine soil particles entering the collecting box, two fans are fixed to the side of the frame [12]. These fans rotate at a high rpm so that the dust and fine particles will be pushed away from the machine. Since this method is mostly employed in paddy cultivation, a performance graph showing results is shown below. We can assume the fine soil particles and dust are empty grains.

A model of this system was developed in SolidWorks and MATLAB Simulink. All the motions were simulated in the SolidWorks environment and exported to the Simulink environment. Separate sub-systems for the fans, brushes, and sieving plate were developed.

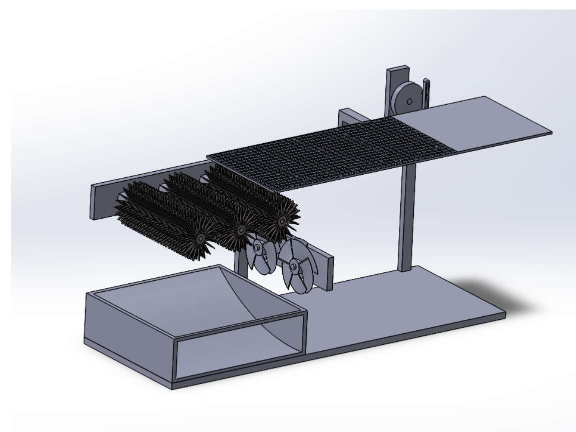

Fig. 8. The developed model in solidworks

Following represents the block diagrams of each sub-systems and the whole system in Simulink environment.

All the graphic files were created in the solid works environment. The motion of all the rotating devices is connected to the main frame through cylindrical joints. The motion to those rotating parts is given through the cylindrical joints. Scops and displays are used to get the output from the models.

IV. System Design

To physically create the system, the following items are needed:

A. Frame

To hold all the parts, a frame is needed. Since this system consists of moving parts, the frame should not become overly stressed. Since this system works with dry as well as wet soil, so that the frame tends to corrode over time. If it corrodes,

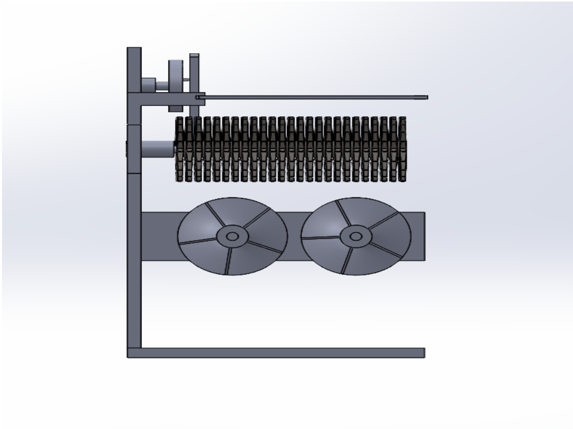

Fig. 9. Side view of the system

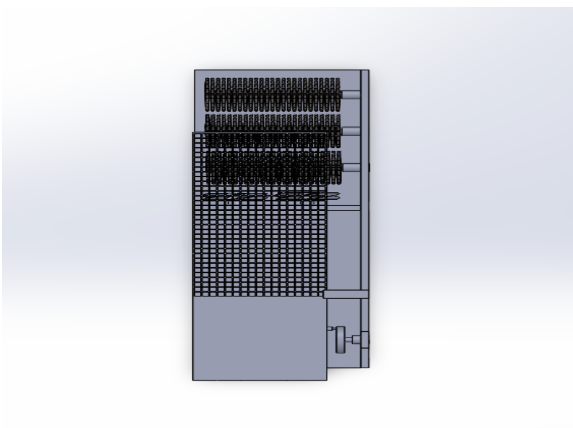

Fig. 10. Top view of the system

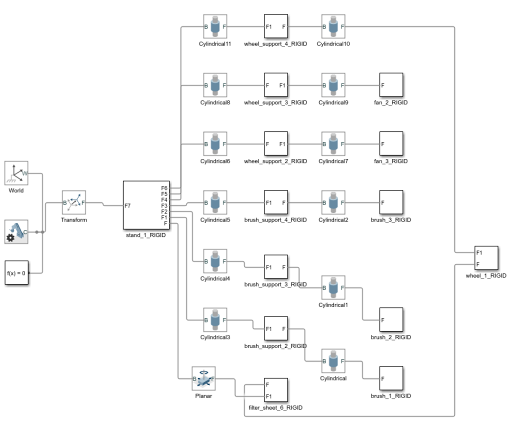

Fig. 11. Exported simulink model of the system

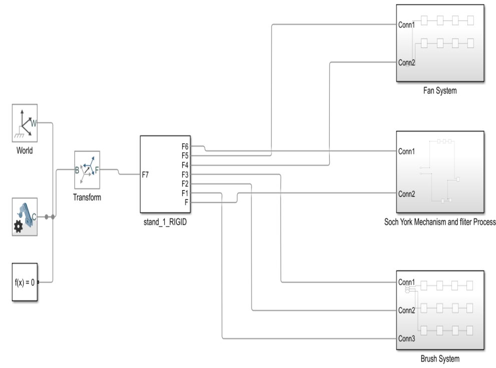

Fig. 12. Sub systems of the main system

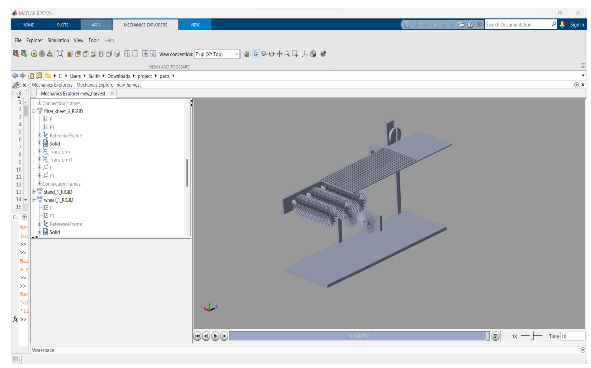

Fig. 13. Model compiled in the simulink environment

the entire system collapses. so that the frame is made up of stainless steel, which is a non-corroding, high-strength material.

This frame is attached to the harvester assembly, which is connected to the tractor or which is in the main vehicle. To allow the potato and soil mixture to easily move through the sieving plate, the frame is set at an angle of 3 to 5 degrees relative to the horizontal axis. Otherwise, potatoes will remain on the sieving plate for a long time, which reduces the efficiency of the system.

B. Sieving sheet

The potato and soil mixture harvested from the digger comes to this plate. As discussed above, due to the scotch York mechanism, this plate moves in a simple harmonic motion. The sheet is made of mesh and a frame. The size of the mesh is determined by the average size of potatoes. According to studies, the average size of a potato is between 1.2-2.25 inches, so a square mesh with a length of 1 inch can be used for the system. As it is assumed that there are no large rocks available on the farm, only potatoes will remain on the screen when the mixture arrives at the end of the sieving sheet. As the soil is removed from potatoes using friction, this also needs to be made up of a high-strength material like stainless steel and should be regularly maintained.

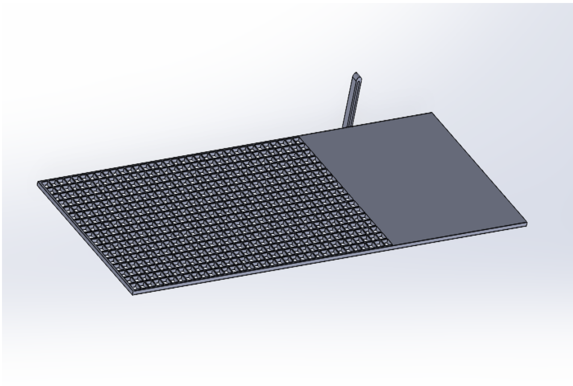

Fig. 14. Sieving sheet

C. Brushes

As discussed above, brushes are used to remove fine soil particles from potatoes. The fibers of these brushes should be flexible enough to let potatoes pass through them. Since these brushes rub the surface of the potatoes, they should not scratch the skin of the potato. But the brush should be made of a material that has a low wear coefficient. Nylon 6, which has a good balance of strength, toughness, and flexibility, can be used for this process. Motion to the brushes is given by a motor through the brush connector.

D. Collecting box

This is a temporary storage unit for potatoes until they are transferred to the tractor. As the cleaned potatoes fall freely under the gravity from the brushes, those should be grabbed accordingly so no damage is done to the potato. For that, the bottom plate of the box is made of rubber so that no damage will be caused to the potato.

E. Motor

One of the main parts of the system. These are used to provide motion to all the parts. For this assembly, a total of six motors are needed. There are three motors for the brush system, two motors for the fans, and one for the scotch and York mechanism. All the motors should have a high torque as the motion of inertia in the system is high. For that purpose, brush less DC motors can be used, as they have good power efficiency as well as high torque.

Results and Discussion

To further study the motion of the brushes, fans, and sieving plate, they were separately simulated in a Matalb Simulink environment. The scotch York mechanism provides a simple harmonic motion to the sieving plate. That motion causes the mixture of potato and soil to slide through the plate. The simple harmonic motion of the plate with different powers of the motor was simulated to study the velocity and acceleration of the sieving plate.

The velocity and acceleration of simple harmonic motion is given by the equations,

$$v(t) = A\omega sin(\omega t + \varphi)$$
$$a(t) = A\omega^2 cos(\omega t + \varphi)$$

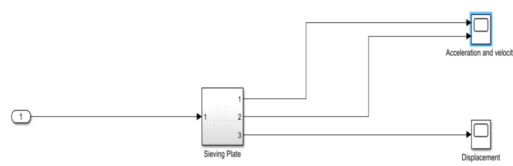

Fig. 15. Simulink model of sieving sheet

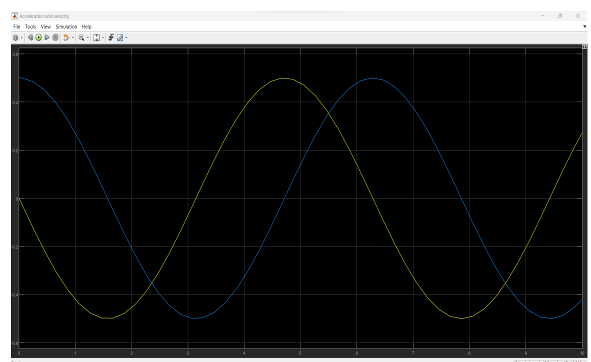

Fig. 16. Acceleration and velocity in the sieving sheet for low power motor Acceleration in yellow and velocity in Blue

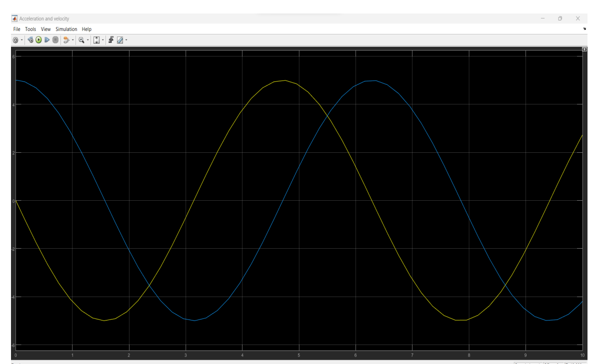

Fig. 17. Acceleration and velocity in the sieving sheet for high power motor Acceleration in yellow and velocity in Blue

It is evident that when the power of the motor increases, the acceleration and velocity of the plate increase. so that the process will be more efficient. But, it is needed to find out the optimum speed for the sieving plate, as higher oscillating speeds can cause damage to the equipment as well as cause the mixture of potato and soil to slide away to the brush system without getting separated.

The motor systems for the fan and the brush were also simulated in the Simulink environment to get better plots of the speed and torque graphs. More fan speed will cause more energy consumption, so the optimum fan speed should be determined to get the maximum economic advantage from the system.

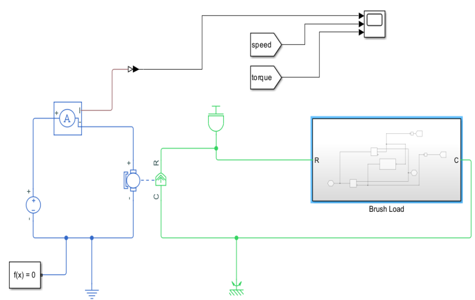

Fig. 18. Simulink model of motor

When the harvester's moving speed varies, the rate at which potatoes are fed into the system also varies. If the harvester moves at a high speed, a lot of potatoes come into the system, so the cleaning process should be able to adapt to such a speed. If the cleaning system works at a high speed when the harvester moves at a slow speed, then there is no need for that much speed. So, it will be a waste of energy. To overcome this problem, there is a sensor mounted on the tractor to sense the speed of the potato harvester. Then the sensed speed will be fed into the motor controller system. Then the speed of the sieving plate, brushes, and fans will vary accordingly.

The following Matlab code is used for the motor control system. For simulating purposes, federate was assumed to be varying according to a sinusoidal pattern. The maximum and minimum values for the speed of the brush, sieving plate and the motor are selected such that they don't damage the potatoes.The mean rpm values of the system are calculated and shown in the terminal.

The equation for total potato harvest is as follows,

$$harvestedPotatoes(i) = feedRate(i) * timeStep;$$

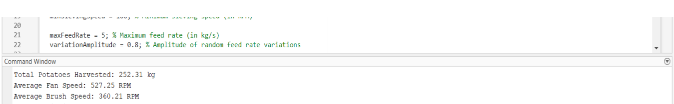

Fig. 19. Matlab code for fan speed variations

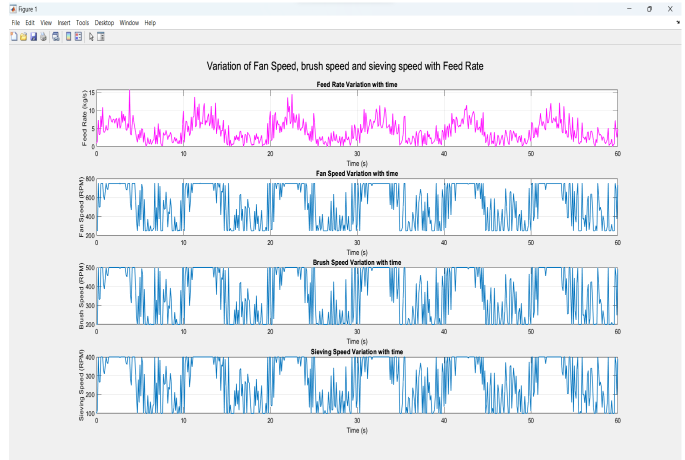

Fig. 20. Speeds of the respective motors

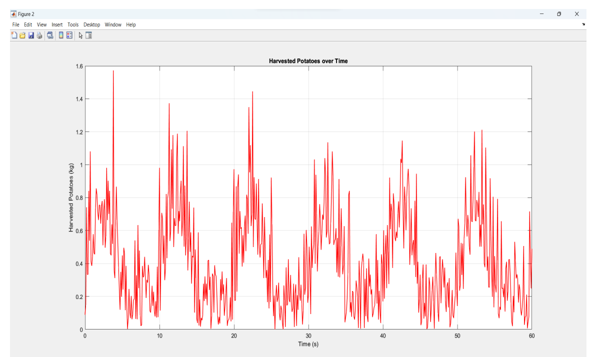

Fig. 21. Potato harvest variation with the speed of the machine

CONCLUSION

More research can be conducted to find the most appropriate number of brushes and brush speed. The AI method for harvesting potatoes can be integrated into this system, but there should be a separate way to remove the identified potatoes from the mixture. Using robot arms is not ideal for that process. The optimum oscillating speed for the sieving plate should be selected such that it has the maximum efficiency while the damage done to the potatoes will be at a minimum level. Developing a method to vary the oscillating speed of the sieving plate and the rpm of the brushes based on the type of soil may be useful when dealing with the efficiency of the system. By designing the system in such a way that the motor speeds of the system can vary according to the speed of the harvester, the energy consumed by the system can be reduced. There are areas in which this model can be improved, such as using green energy to run the system, using an efficient water separation method to remove dust from the potatoes, and using new light-weight materials so that the weight of the assembly will be less. To energize the system using green energy, we can mount solar panels on the top of this assembly. As this system works outdoors, the energy required to run it can be harvested from the solar panels. By making the assembly lightweight, the inertia of the system becomes less, so less energy is required for the motion of the system.

INDIVIDUAL CONTRIBUTION

Pathmila K.K.Y.(210453D)- Matlab codes for fan speeds, simulink model for fan and brushes

Perera A.S.D(210456N) - Designing the assembly in solidworks and exporting it to simulink

Perera P.S.R.(210470C) - Report preparation, adding motion in simulink, matlab coding for brushes and sieving plate.

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