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Design and simulation of Solar Powered Automated Dual Rotor Mechanism for Sugarcane Harvesting

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Abstract - ***Sugarcane being the vast cultivated cash crop of India's agricultural economy has undoubtedly one of the most difficult harvesting processes. The existing mechanisms to harvest sugarcane are costly and are not affordable by rural based farmers. In this project a novel design mechanism is suggested that would serve the purpose of harvesting with least manpower, being cost effective and serving the purpose of cutting, stripping, sorting and loading of the harvested sugarcane. The machine consists of a dual stage rotary conveyor belt mechanism built on a sturdy box-frame consisting of a dual wire-cut mechanism setup. One on the top to chop the shoot of the crop and other at the bottom for the root removal. The DC motors for powering the wire cut mechanism are run by a 9 v 9 amp battery powered through a monocrystalline solar panel while the conveyor belts run with the power sourced from the tractor. The bottom belt is responsible for the sugarcane stem and the top rack conveyor roller transports the chopped shoot leaves to discard. An output of 3 acres per day of harvest is expected from the machines efficiency which can be attached to the normal tractor in a common farmers farmland. Mechatronic devices such as a load cell to monitor the overall load capacity of the harvested sugarcane, steel brushes to wear away the stems from leaves and blowers to discard excess leaves are placed in sequence of the loader design. This projects works on a***

prototype design and focuses on simulation of the mechanical components using solidworks software. The automatic sugarcane loading conveyor belt system is an innovative agricultural solution designed to streamline the post-harvest handling process by automating the transfer of cut sugarcane into transport vehicles or storage units. This system eliminates the need for manual loading, significantly reducing labor, time, and physical effort while improving operational efficiency and safety.

Keywords- Simulation, Automated sugarcane harvester, Solar powered, Twin roller mechanism, wire cut

I. INTRODUCTION

II.

Sugarcane is an essential cash crop predominantly grown in tropical and subtropical regions for the production of sugar and biofuels [1]. Traditionally, the processes of harvesting and seed preparation have relied heavily on manual labor, which is not only time-consuming and physically demanding but also prone to inefficiencies such as inconsistent cutting, higher rates of bud damage, and reduced operational productivity [2, 3]. A simple wire cut mechanism with a 0.5 mm steel wire that is ideal for precision cutting of semi hard materials is used. The system works on the principle of a steel wire being moved to slice through the material with minimal resistance and high accuracy [4, 5]. The mechanism sits on a sturdy frame to hold the wire in tension. A high rpm DC motor for controlled movement and a simple control circuit for power regulation is used. A mechanical setup with 0.5 mm dia steel wire is tightly fixed between two reels of the frame. The wire is motor-driven across the sugarcane [6]. The wire slices through the plant, providing a smooth and precise cut [7]. The system is cost-effective, portable, and suitable for farming or prototyping applications [8]. A summary of the various components implemented in past research is presented in Table 1. A double decker conveyor system is a compact design to streamline sugarcane harvesting by separating and transporting sugarcane and plant leaves simultaneously. The lower belt is constructed using a heavy-duty rubber capable of handling the weight and volume of sugarcane stalks. It is powered by a 0.75–1 HP electric motor with steel rollers ensuring smooth and continuous movement. The upper belt is designed a but lighter but with durable material, handles lighter waste material and is powered by a separate 0.5 HP motor. The belts operate independently, allowing flexible speed control for varying loads.

Table 1 Summary of component specifications.

Sl. No.	Component	Description	References
1	Solar panel	Solar power concentration using LFR, Angular error correction and performance, varying width reflector.	[9-11]
2	Frame design	Thermal aanalysis barrier, modified frame system, barrier coatings,	[12-14]
3	Sheet metal body work	Explicit dynamics on sheet metal simulatory strength analysis.	[15]
4	Motor	Slow stirrer motor with high torque	[26]
5	Energy sources to move the device	Wireless method, power plant using magnets	[17, 18]
6	Microprocessor and IoT	Cloud monitoring, sensor and arduino usage	[19]

A blower used to direct plant hus removal from the cutter mechanism in the lower belt is placed above the steel rollers that surface clean the sugarcane. This dual-purpose conveyor system reduces manual labor, increases harvesting efficiency, and supports cleaner field operations by automatically sorting and transferring sugarcane and its waste in real-time.

III. Experimental Methodology

A) Components

The mechanical system is composed of a sugarcane feeding platform, self-adjusting conveyor rollers, and a high-speed rotary wire-cutting mechanism. Sugarcane stalks are directed onto a guide rail with the help of spring-loaded rollers that automatically adapt to the varying diameters of the cane. A crank-slider assembly provides the necessary reciprocating motion for the cutting operation. Precision cuts are achieved using a pair of wires, with their spacing adjustable between 8 and 20 centimeters. The entire setup is constructed on a lightweight yet durable aluminum alloy frame to ensure structural integrity while keeping the overall weight low [20].

1) DC motor for wire cut mechanism

Figure 1 shows the drive system of the proposed design. Table 2 displays the specification of the DC motor used in the project.

Fig. 1 DC motor drive used in the project

Table 2 Specification of the DC motor proposed in the project.

Specification	**Typical Value**
Rated Voltage	12 Volts DC
Rated Current	1–10 Amps (varies by motor size/load)
No-Load Speed	1000–6000 RPM (depends on winding/gearing)
Rated Torque	0.2 – 1 Nm
Output Power	10 – 150 Watts
Efficiency	70% – 85%
Motor Type	Brushed

A 12V DC motor is widely used in mini projects because of its simplicity, reliability, and compact form. It runs on a 12-volt direct current supply and transforms electrical energy into mechanical motion, making it suitable for driving components like small wheels, blades, or lightweight systems. With typical speeds between 1000 to 6000 RPM, they offer enough torque for small-scale mechanical tasks. Power can be supplied through batteries or solar panels, allowing for portable or energy-efficient setups. This makes them ideal for educational projects such as basic robots, smart doors, or simple automation systems. Their ease of use and availability make them a great learning tool for students and hobbyists exploring electronics and mechanics. Overall, the 12V DC motor is a key component in hands-on learning and DIY innovation [21, 22].

2) Solar Power source and battery system

Fig. 2 Rechargable battery

Fig. 3 Solar panel

For a small solar power project, a typical setup includes a 100W solar panel, which generates energy from sunlight. The energy is regulated by a 12V charge controller to prevent overcharging and ensure battery longevity. Figure 2 and Figure 3 shows the battery and solar panel proposed for the project respectively.

Table 3 Specification of the Solar panel proposed in the project.

Specification	Typical Value

Power Output	150W or higher
Voltage at Max Power (Vmp)	17–18V (standard for "12V" panels)
Current at Max Power (Imp)	8.5A – 9A or higher
Open Circuit Voltage (Voc)	20–22V
Panel Type	Monocrystalline
Output Type	DC

A 12V deep cycle battery (100Ah) stores the energy for later use. The system also includes a 500W inverter to convert stored DC energy into AC power for running small appliances. The system can power lights, fans, or small devices in off-grid applications. With proper sizing, this system can provide a reliable, sustainable energy source for daily needs, particularly in remote or rural areas [23].

3) Wire Cut Drive for cutting

To minimize the overall weight associated with traditional heavy cutting blades and to enhance operational safety, a wire-cutting mechanism is employed. This approach also delivers more precise cuts and reduces sugarcane wastage. This mechanism is ideal for intricate, high-precision cutting tasks in small-scale harvesting or prototyping. Figure 4 and Figure 5 represents the model of a wire cut mechanism and steel wire used in the proposed project.

Fig. 4 Wire cut mechanism

Fig. 5 Steel wire ream for cutting mechanism

4) Steel brush husk remover

This project focuses on developing a steel brush mechanism to efficiently remove the outer husk or dirt from harvested sugarcane. The system is designed for use in small to medium-scale sugarcane processing operations where manual cleaning is labor-intensive and time-consuming. The core component is a rotating steel brush drum, which scrapes off the fibrous husk and surface impurities without damaging the inner cane. Figure 6 shows the stell brush used in the proposed project.

Fig. 6 Steel brush for sugarcane husk removal

The brush is made from high-carbon steel wire bristles, with a diameter of 0.3–0.5 mm, densely packed on a cylindrical roller. The roller is mounted on a shaft supported by bearings and powered by a 0.5–1 HP electric motor (single-phase or three-phase, depending on the setup). The brush rotates at 300–600 RPM, which provides optimal cleaning without cutting into the cane. The sugarcane is fed manually or via a small conveyor under the rotating brush. The frame of the machine is constructed from mild steel for strength and corrosion resistance. A protective casing and dust collector can be added to improve safety and cleanliness.

B) Mechanisms

1) Conveyor belt system

A small conveyor belt system typically consists of a motor (0.5-1 HP) driving a belt made from durable material like rubber or PVC. The system may include rollers (made of stainless steel or plastic) to support the belt and ensure smooth operation. Figure 7 and figure 8 shows the drive mechanism and conveyor belt system proposed for the design. For the project, the conveyor belt could be around 2-3 meters in length and 0.5 meters in width. It is powered by an electric motor with a speed control mechanism to adjust the belt speed according to needs. This type of conveyor system is ideal for material handling in small-scale industries, warehouses, or assembly lines for efficient operations.

Fig. 7 Pulley drive for conveyor

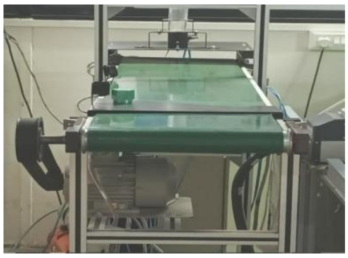

Fig. 8 Conveyor system

The system consists of several key components, each with specific technical data to ensure optimal performance.

1.1) Belt Material: Rubber, with high tensile strength (minimum 1500 MPa), designed for resistance to abrasion and moisture. Belt width ranges from 300 mm to 500 mm, depending on the volume of cane being transported.

1.2) Belt Speed: Typically operates at speeds of 0.5 to 2 m/s, adjustable depending on the load and distance to be covered. Motor: A 12V or 24V DC motor is commonly used, with power ratings between 100W and 500W, offering enough torque (≥5 kg·cm) to handle the weight of the harvested cane. The motor is usually coupled with a gear reducer to lower the speed and increase torque.

1.3) Rollers/Pulleys: Galvanized steel rollers with a diameter of 100 mm to 150 mm, designed for smooth belt movement and minimal friction.

1.4) Frame Material: Mild steel providing durability and resistance to environmental conditions, with adjustable height for varying terrain (e.g., 500 mm to 1500 mm).

1.5) Capacity: Can transport up to 200 kg of sugar cane per hour, depending on belt width, speed, and incline.

2) Wire cut mechanism

Figure 9 shows the animated wire cuting mechanism. A wire-based mechanism designed to cut a 30 mm diameter tree branch efficiently. The system uses a high-tensile steel wire operated manually or via a motorized setup.

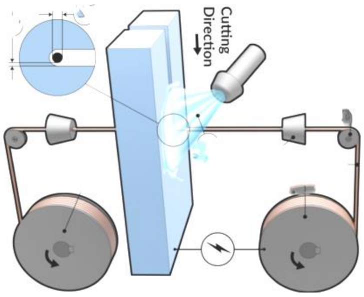

Fig. 9 Wire cut Mechanism animation

The recommended wire is a 0.5–0.8 mm diameter stainless or carbon steel wire with a tensile strength of at least 1000 MPa. A serrated or abrasive-coated wire is preferred for improved cutting performance. The wire should be approximately 500–700 mm in length to allow full wraparound and movement. The wire operates in a sawing motion—either manual (by pulling alternately from both ends) or motorized using a low-RPM (60–100), high-torque DC gear motor (≥ 5 kg·cm torque, 12V power supply). Cutting time varies depending on the method: manual sawing may take 30–60 seconds, while motorized cutting can reduce this to 15–30 seconds. The setup is portable, lightweight, and ideal for pruning or cutting small branches. Safety gloves and wire guides are recommended to avoid injury and ensure smooth operation.

IV. PROJECT SIMULATORY DESIGNING

Figure 10 shows the simulatory design of the proposed project through solidworks software. The major components like solar panel power source, wire cut machanism and the conveyor belt system having a motor drive are designed and successfully simulated [24, 25].

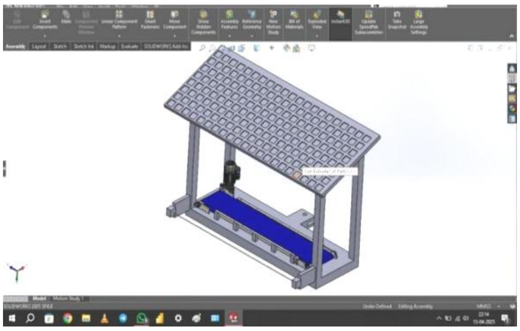

Fig. 10 Design silmulation in solid works software

Design simulation in SolidWorks for a small project involves creating a 3D model of the system or part to analyze its functionality. The process includes selecting materials, applying boundary conditions, and running simulations such as stress, thermal, or motion analysis. For example, in a small mechanical project, SolidWorks can simulate the performance of a conveyor belt, or a mini sugarcane cutter, by testing factors like load, speed, and material wear. The software provides detailed results that help optimize design choices, ensuring reliability and efficiency before physical production. This simulation process saves time and reduces errors in the final product.

SolidWorks provides powerful tools within its Motion Study environment to simulate servo motor behavior accurately. To simulate a servo motor, you use SolidWorks Motion (part of the SolidWorks Motion Analysis add-in), which allows time-based, motion-based, or force-based simulations. Figure 11 and figure 12 shows the double decker design of conveyor belt and transportation deck assembly. This helps analyze how the motor influences motion in assemblies. First activated the Motion Study tab at the bottom of the screen. Select Motion Analysis as the study type to access advanced motion simulation features. Then, use the Motor feature from the Motion Manager toolbar. Choose Rotary Motor if your servo is rotational or Linear Motor for linear movement. Apply it to a selected face, edge, or axis where the servo interacts with the model.

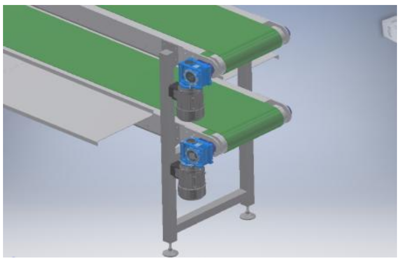

Fig. 11 Dual conveyor design

Fig. 12 Conveyor Deck assemble

A double-decker conveyor belt system is a compact, vertically-stacked material handling solution designed to increase throughput while saving floor space. In design software like SolidWorks, the system is modeled in 3D to visualize component layout, simulate motion, and analyze structural integrity. The design features two independent conveyor belts—upper and lower—mounted on a common support frame. Each deck can transport different materials simultaneously or function as an input-output flow system. Key components include rollers or pulleys, belt material (typically rubber or PVC), drive motors, support frames, guide rails, and tensioning systems.

IV. CONCLUSION

The sugarcane harvesting machine project, integrating a conveyor belt system, wire cutting mechanism, and solar power, presents an innovative, efficient, and eco-friendly solution for modern agricultural needs. This multi-functional design addresses the challenges faced by small to medium-scale farmers, such as labor shortages, time-consuming manual harvesting, and high fuel costs. By combining mechanical automation with sustainable energy, the project significantly enhances productivity while promoting environmental sustainability. The conveyor belt system ensures smooth and continuous transfer of harvested sugarcane from the cutting point to the collection unit. Its compact, lightweight design makes it suitable for mounting on a tractor or a mobile platform. Constructed from durable materials like PVC or rubber, the belts are powered by low-voltage DC motors, making them energy-efficient and capable of handling heavy loads without interruption.

The wire cutting mechanism, utilizing high-tensile steel wire, offers a precise, low-maintenance alternative to traditional blades. It effectively cuts through sugarcane stalks with minimal damage, ensuring clean cuts that are important for further processing and maintaining crop health in ration farming. Most notably, the integration of solar panels provides a renewable power source, reducing dependency on fossil fuels and operational costs. The solar system powers the conveyor and wire cutting motors, ensuring the machine can function in remote fields without access to electricity. In conclusion, this sugarcane harvesting machine is a practical step toward mechanized, sustainable farming. It not only reduces manual effort and harvesting time but also supports green technology by leveraging solar energy. The modular design allows for easy assembly, repair, and scalability. This project exemplifies how innovative engineering, when combined with renewable energy, can transform traditional agricultural practices and benefit both farmers and the environment. It sets a foundation for future development in smart and sustainable agro-machinery.

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