

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 the least manpower, be cost-effective, and serve 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 another at the bottom for 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 be discarded. An output of 3 acres per day of harvest is expected from the machine's efficiency, which can be attached to the normal tractor on a common farmer's 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 in the loader design. This project works on a prototype design and focuses on simulation of 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

INTRODUCTION

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

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Received Date: January 13, 2026

Accepted Date: February 27, 2026

Published Date: March 16, 2026

Citation: Sachin S. Raj, R.A. Kapgate, Harshal Darekar, Krishna Darade, Nikita Dongare, Sarthak Narode. Design and simulation of Solar Powered Automated Dual Rotor Mechanism for Sugarcane Harvesting. International Journal of Robotics and Automation in Mechanics. 2026; 4(1): 18–26p.

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 are used. A mechanical setup with 0.5

mm diameter 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 to be 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. A blower used to direct the plant husks 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 waste in real time [9–19].

EXPERIMENTAL METHODOLOGY

Components

The mechanical system comprised 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 canes. The 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 cm. The entire setup was constructed on a lightweight yet durable aluminum alloy frame to ensure structural integrity while maintaining a low overall weight [20].

DC Motor for Wire-Cut Mechanism

Figure 1 shows the drive system of the proposed design. Table 2 displays the specifications of the DC motor used in this study.

Table 1. Summary of component specifications.

S.N.	Component	Description	References
1	Solar panel	Solar power concentration using LFR, Angular error correction and performance, and varying-width reflector.	[9–11]
2	Frame design	Thermal analysis barrier, modified frame system, barrier coatings.	[12–14]
3	Sheet metal bodywork	Explicit dynamics on sheet metal simulator strength analysis.	[15]
4	Motor	Slow stirrer motor with high torque.	[16]
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]

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

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

Specification	Typical value
Power output	150 W or higher
Voltage at max. power (V_{mp})	17–18 V (standard for “12 V” panels)
Current at max. power (I_{mp})	8.5 A–9 A or higher
Open circuit voltage (V_{oc})	20–22 V
Panel type	Monocrystalline
Output type	DC



Figure 1. DC motor drive used in the project.

A 12 V DC motor is widely used in mini projects because of its simplicity, reliability, and compact form. It operates on a 12-volt direct current supply and transforms electrical energy into mechanical motion, making it suitable for driving components such as small wheels, blades, or lightweight systems. With typical speeds between 1000 and 6000 RPM, they offer sufficient torque for small-scale mechanical tasks (Table 3).

Power can be supplied through batteries or solar panels, allowing portable or energy-efficient setups. This makes them ideal for educational projects, such as basic robots, smart doors, and simple automation systems. Their ease of use and availability make them excellent learning tools for students and hobbyists exploring electronics and mechanics. Overall, the 12 V DC motor is a key component in hands-on learning and DIY innovation [21, 22].

Solar Power Source and Battery System

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

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

Wire-Cut Drive for Cutting

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



Figure 2. Rechargeable battery



Figure 3. Solar panel.



Figure 4. Wire-cut mechanism.



Figure 5. Steel wire ream for cutting mechanism.

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 that scrapes off the fibrous husk and surface impurities without damaging the inner cane. Figure 6 shows the steel brush used in the proposed project.



Figure 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 was 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, providing optimal cleaning without cutting into the cane. Sugarcane is fed manually or via a small conveyor under the rotating brush. The machine frame was constructed from mild steel for strength and corrosion resistance. A protective casing and dust collector can be added to improve safety and cleanliness of the device.

Mechanisms

Conveyor Belt System

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

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

- *Belt material:* Rubber, with high-tensile strength (minimum 1500 MPa), designed for resistance to abrasion and moisture. The belt width ranges from 300 mm to 500 mm, depending on the volume of cane being transported.
- *Belt speed:* Typically operates at speeds of 0.5–2 m/s, adjustable depending on the load and distance to be covered. Motor: A 12 V or 24 V DC motor is commonly used, with power ratings between 100 W and 500 W, offering sufficient torque ($\geq 5 \text{ kg}\cdot\text{cm}$) to handle the weight of the harvested cane. The motor is usually coupled with a gear reducer to lower the speed and increase the torque.
- *Rollers/pulleys:* Galvanized steel rollers with a diameter of 100 mm to 150 mm, designed for smooth belt movement and minimal friction.
- *Frame material:* Mild steel providing durability and resistance to environmental conditions, with adjustable height for varying terrain (e.g., 500–1500 mm).
- *Capacity:* Can transport up to 200 kg of sugarcane per hour, depending on belt width, speed, and incline.



Figure 7. Pulley drive for conveyor.

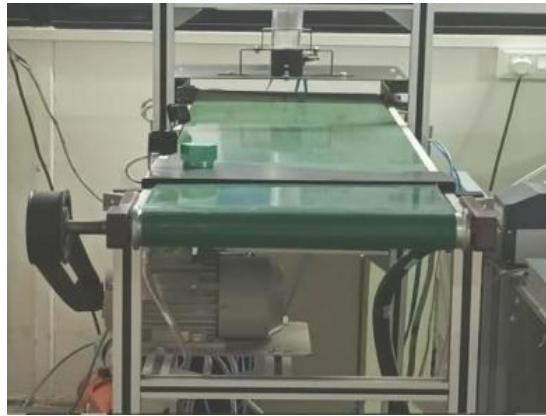


Figure 8. Conveyor system.

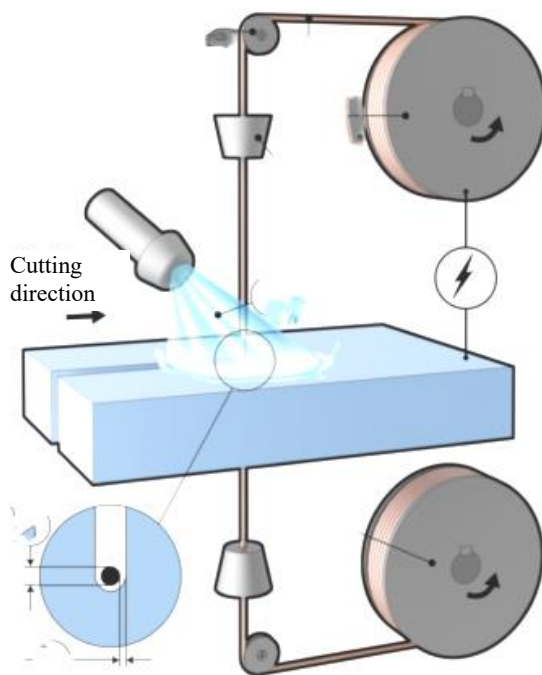


Figure 9. Wire-cut mechanism animation.

Wire-Cut Mechanism

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

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 ($\geq 5 \text{ kg}\cdot\text{cm}$ torque, 12 V 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 was portable, lightweight, and ideal for pruning or cutting small branches. Safety gloves and wire guides are recommended to avoid injuries and ensure smooth operations.

PROJECT SIMULATED DESIGN

Figure 10 shows the simulation design of the proposed project using SolidWorks software. The major components, such as the solar panel power source, wire-cut mechanism, and conveyor belt system with a motor drive, were designed and successfully simulated [24, 25].

The 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 mini sugarcane cutter by testing factors such as load, speed, and material wear. The software provides detailed results that help optimize design choices, ensuring reliability and efficiency prior to physical production. This simulation process saves time and reduces errors in the final product.

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

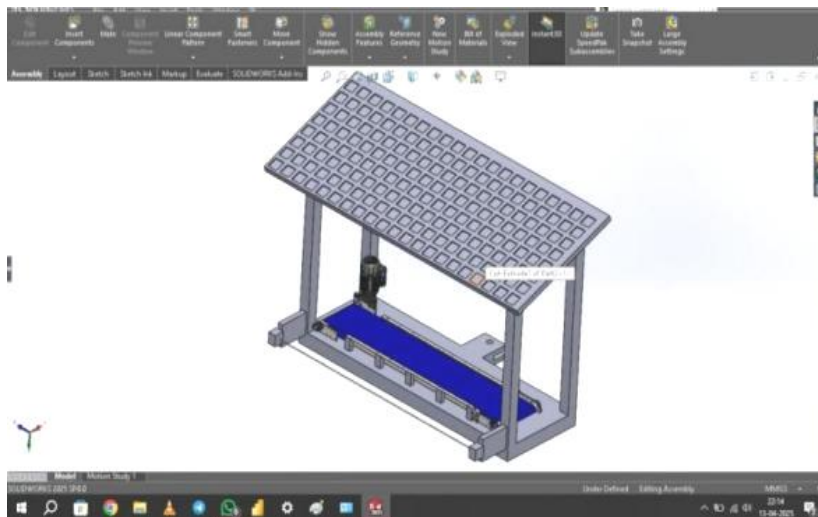


Figure 10. Design simulation in SolidWorks software.

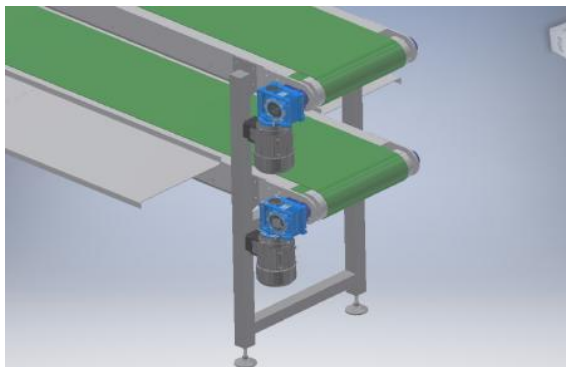


Figure 11. Dual conveyor design.



Figure 12. Conveyor deck assembly.

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 such as SolidWorks, the system is modeled in 3D to visualize the 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. The key components of belt conveyors include rollers or pulleys, belt material (typically rubber or PVC), drive motors, support frames, guide rails, and tensioning systems.

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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