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Design and Development of EV-Based Sugarcane Harvester

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A B S T R A C T

The agriculture sector faces significant challenges, including labor shortages, environmental impacts, and inefficiencies in traditional sugarcane harvesting methods. This paper presents the design and development of a lightweight, Electric Vehicle (EV)-based sugarcane harvester aimed at addressing these issues. The proposed harvester incorporates a BLDC motor, a ladder frame chassis, a gear ratio gearbox, and an efficient cutting mechanism to improve operational efficiency and reduce environmental impact. Key findings demonstrate the harvester's potential to significantly lower carbon emissions, operational costs, and soil compaction compared to conventional harvesters. This research contributes to the ongoing evolution of sustainable agricultural practices, promoting a greener and more efficient future for the sugarcane industry.

Keywords: Electric Vehicle (EV), Sugarcane Harvester, Sustainable Agriculture, Electric Propulsion, Lightweight Design, Environmental Impact

1. Introduction

The Design and Development of EV Based sugarcane Harvester is a aim of the project to reduce the dependency of farmers from Heavy oil burning machinery and human labor shortage problems like compaction of soil, air pollution and unaffordable prices of expensive harvesters. The Harvester design is made to overcome the sugarcane harvesting problems. Focus on simple and robust design which can sustain agriculture requirements and used renewable energy to power the electric motors of the harvester.

The Harvester is combination of mechanical, electrical and electronics parts to increase the efficiency and controllability. focus on use of renewable energy and high efficiency mechanisms to reduce carbon footprints. Mechanisms are deigned to cut the sugarcane from bottom and transfer it to out of harvester pathway which can later piked-up.

In the dynamic landscape of agricultural practices, the integration of sustainable technologies has become imperative to address the challenges posed by climate change and environmental concerns. The agricultural sector, particularly in the realm of crop harvesting, is witnessing a transformative shift towards cleaner and more efficient solutions. This project report explores the innovative application of Electric Vehicle (EV) technology in the context of sugarcane harvesting—a crucial facet of the agro-industry.

The conventional methods of sugarcane harvesting often involve the utilization of fossil fuel-powered machinery, contributing to greenhouse gas emissions and environmental degradation. Recognizing the need for eco-friendly alternatives, this project centers on the design, development, and implementation of an Electric Vehicle-based sugarcane harvester. By leveraging the advancements in electric mobility, the project aims to not only enhance operational efficiency but also minimize the carbon footprint associated with traditional harvesting practices.

This report delves into the technical aspects of the EV-based sugarcane harvester, emphasizing the integration of electric powertrains, energy storage systems, and intelligent control mechanisms. Additionally, it explores the potential economic and environmental benefits, such as reduced fuel costs, lower emissions, and improved sustainability in the agriculture sector.

As we navigate the intersections of agriculture and clean energy, the EV-based sugarcane harvester emerges as a pioneering solution, embodying the synergy between technological innovation and ecological responsibility. The following sections provide a comprehensive analysis of the design, performance, and implications of this sustainable approach to sugarcane harvesting [1].

In recent years, the global agricultural landscape has witnessed a transformative shift towards sustainable practices and eco-friendly technologies. As the world grapples with the pressing challenges of climate change and environmental degradation, the agriculture sector is under increasing pressure to adopt innovative solutions that mitigate its impact [2]. One such pioneering advancement is the integration of Electric Vehicles (EVs) into traditional farming equipment, heralding a new era in sustainable agricultural practices.

Against this backdrop, this report aims to explore the design, implementation, and impact of EV technology in the realm of sugarcane harvesting. By analyzing the key components of electric sugarcane harvesters and evaluating their performance metrics, we seek to provide a comprehensive understanding of the potential benefits and challenges associated with this transformative technology [3]. Additionally, the report investigates the broader implications of adopting EV-based solutions in agriculture, considering factors such as energy efficiency, cost-effectiveness, and the overall sustainability of farming practices.

As we navigate through the intricate details of EV-based sugarcane harvesters, it is our endeavor to shed light on how these innovations can usher in a more sustainable and environmentally conscious future for the agricultural sector. Through this exploration, we hope to contribute valuable insights that inspire further research, development, and adoption of electrically powered agricultural machinery, ultimately paving the way for a greener and more resilient agricultural landscape [4].

Electric vehicles (EVs) are gaining traction in agriculture due to their potential to reduce greenhouse gas emissions and operational costs. Several studies highlight the benefits of integrating EV technology in farming practices:

2. Methodology

2.1 Design and Development

To solve the identified problems, we designed the harvester with a lightweight ladder frame chassis. This structure provides the necessary strength while minimizing weight, making it suitable for our application.

2.2 Powertrain

- Motor Selection: A Brushless DC (BLDC) motor was chosen for its high efficiency and low maintenance requirements. The motor's specifications were selected to ensure adequate power and torque for the harvester's operational needs.
- Gearbox: An 18:1 gear ratio gearbox was integrated to reduce the motor speed and increase torque. The gearbox was selected based on calculations of rolling resistance and grading resistance forces to ensure optimal performance.
- Battery: A lithium-ion battery pack was used for its high energy density and reliability. The battery's capacity was calculated based on the motor's power consumption and the desired operational duration.

2.3 Braking System

- Drum Brakes: Drum brakes were chosen for their reliability and effectiveness in agricultural settings. The braking system was designed to provide sufficient stopping power while maintaining durability in harsh environments.

2.4 Steering System

- Recirculating Ball Steering: A recirculating ball steering system was implemented to facilitate easy turning without hydraulic power assistance. This system was selected for its simplicity and effectiveness in low-speed, high-torque applications.

2.5 Cutting Mechanism

- Rotary Motor-Powered Cutting Blade: The cutting mechanism consists of a rotary motor-powered blade attached to the lowest part of the harvester. The blade's height can be adjusted electronically to adapt to varying land levels [6].

Guideways and K2 Chains: The harvested sugarcane is transported via guideways and K2 chains with rubber belts to the side of the harvester for collection. This system ensures efficient handling and minimizes damage to the cut sugarcane.

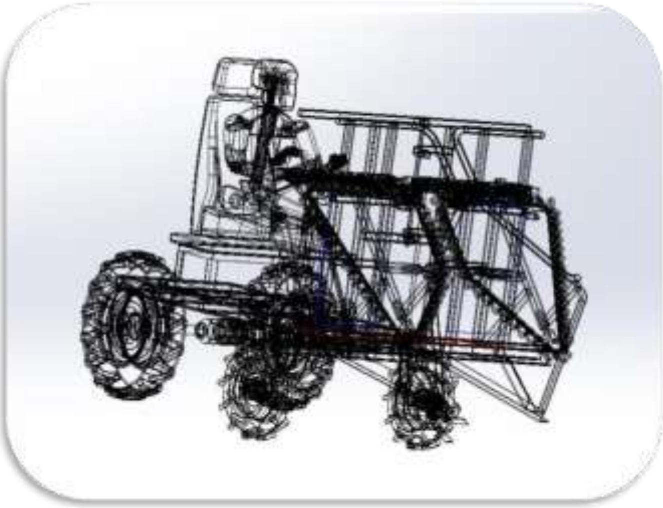

Fig 1. Assembly drawing

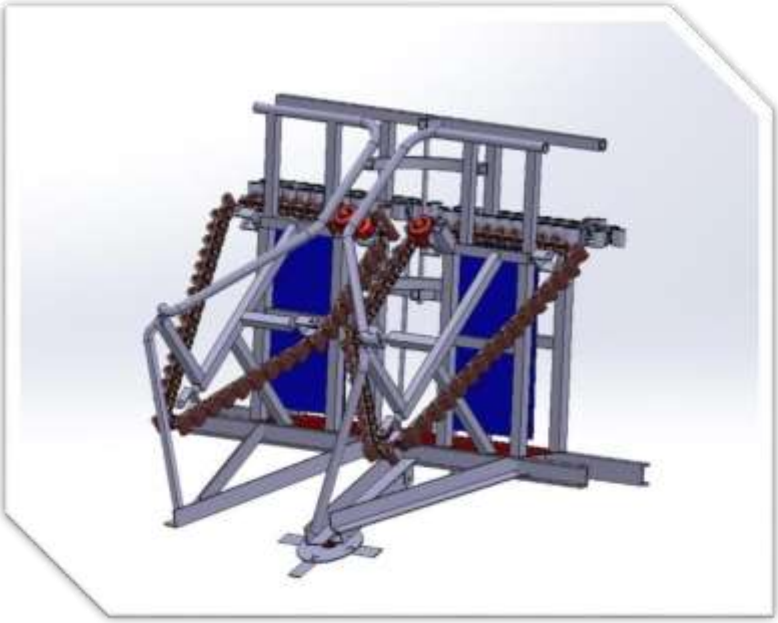

Fig 2. Cutter Design

Equations

Powertrain Calculations:

Power=2πNT\60

Where:

N = Motor Speed in RPM

T = Torque in Nm

Rolling Resistance:

Frr=Crr×m×g

Where:

Frr = rolling resistance force

Crr = coefficient of rolling resistance (typical value for agricultural land: 0.1

m = mass of the harvester (500 kg)

g = acceleration due to gravity (9.81 m/s2^22)

$F_{rr}=0.1\times500\times9.81=490.5N$

Gradient Resistance:

$F_{grad}=m\times g\times \sin(\theta)$

Where:

θ = slope angle (for example, 5 degrees)

$\sin(5\circ)=0.0872$

$F_{grad}=500\times9.81\times0.0872=427.26N$

Total Tractive Force:

$F_{total}=F_{rr}+F_{grad}$

$F_{total}=490.5+427.26=917.76N$

Battery Capacity Calculation:

Considering the motor's rated current of 60 A and a voltage of 48 V:

$P=V\times I=48\times60=2880W$

Energy consumption per hour=2880Wh

For 8 hours of operation:

Total energy required=2880×8=23040Wh

Battery Capacity=

Total energy required/Battery Voltage=23040/48=480Ah

Sugarcane Cutting Calculations:

Cutting Force:

$F_{cut}=(\tau x A)/r$

Where:

F_{cut} = cutting force

τ = shear stress of sugarcane (typically 3-5 MPa)

A = cross-sectional area of sugarcane (for a diameter of 30 mm: $A=\pi\times(0.015)2=7.07\times10\text{^}-4m\text{^}2$)

r = radius of the cutting blade

Assuming τ=4 Mpa:

$F_{cut}=(4\times7.07\times10\text{^}-4)/0.015=188.53N$

Cutting Power:

$P_{cut}=F_{cut}\times v$

Where:

v = cutting speed (assuming 1 m/s)

$P_{cut}=188.53\times1=188.53W$

Efficiency:

Assuming the cutting mechanism's efficiency is 85%:

$P_{input}=0.85P_{cut}=0.85188.53=221.8W$

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