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Design and Development of Three-way Trailer

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Abstract: *This project presents the design and development of an automated three-way tipping trailer using an electro- mechanical system for efficient material unloading. Unlike conventional trailers with rear-only tipping, this model can tip in left, right, and rear directions using a combination of spur gears, worm gears, a motor, and an Arduino-based control system. The worm gear ensures self-locking and controlled tipping, while the spur gear aids directional alignment. A motorized mechanism, programmed through Arduino, enables user-defined operation. The system was modeled using CAD software and analyzed for load distribution and stability. This design improves versatility, reduces manual effort, and enhances safety in agricultural and industrial applications*

Keywords*:* Spur Gear, Worm Gear, Electromechanical system

I. INTRODUCTION

In the fields of agriculture, construction, and industrial transportation, efficient material handling is essential. Traditional trailers typically offer only rear-side tipping, which can be inconvenient and time-consuming in confined or uneven areas. To overcome this limitation, a three-way tipping trailer is designed to allow unloading in three directions—left, right, and rear—enhancing operational flexibility and productivity. This project focuses on the development of such a system using a combination of mechanical and electronic components to create a semi-automated, user-friendly solution.

The trailer mechanism is powered by a motor and employs spur gears for directional engagement and worm gears for controlled, self-locking tipping action. An Arduino micro-controller is used to automate the tipping process based on user inputs, ensuring precision and safety. The structure is mounted on a mobile trolley, making it easy to maneuver. The entire system has been modeled using CAD software to simulate gear interaction, load behavior, and motion control. By integrating mechanical design with automation, this project provides a versatile and intelligent solution for modern unloading needs.

II. METHODOLOGY

Design Concepts

The design of the three-way tipping trailer was developed with a focus on mechanical simplicity, structural strength, and automation. The tipping mechanism is based on a motorized system using spur gears for directional control and worm gears for self-locking, controlled movement. The trailer body is mounted on a pivoting frame that allows tilting in left, right, and rear directions. The entire system is mounted on a trolley to ensure mobility. A CAD model was created using Solid Works to simulate motion, gear interaction, and overall structural stability before fabrication. The control system is powered by an Arduino micro-controller, programmed to manage the direction and activation of the motor based on user input.

- Design a three-way tipping mechanism using spur and worm gear.
- CAD modeling done in SolidWorks to simulate motion and structural behavior.
- Arduino used to automate motor control for tipping in left, right, and rear directions.

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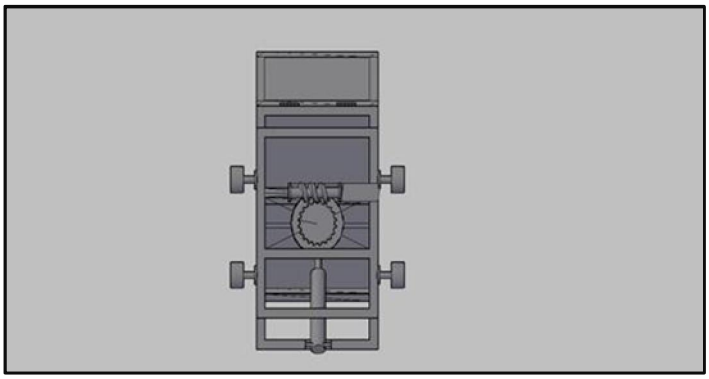

Fig. Spur gear and worm gear :-

2.2 Material Selection

To ensure strength, durability, and cost-effectiveness, materials were chosen based on their mechanical properties and intended application. The trolley frame is fabricated from lightweight aluminum for ease of mobility and corrosion resistance. The main chassis and load-bearing parts are made of mild steel (iron) due to its high strength and load-carrying capacity. Gears are selected based on required torque and precision: spur gears are made of hardened steel for high wear resistance, while worm gears are used where locking is necessary. The use of standard DC motors and Arduino UNO ensures easy integration and programmability.

- Aluminum used for trolley frame – lightweight and corrosion-resistant.
- Mild Steel (Iron) used for main chassis – strong and load-bearing.
- Hardened steel gears for durability; worm gear chosen for self-locking.
- Standard DC motor and Arduino UNO used for control and actuation.

2.3 Experimental Setup

The experimental setup includes the assembled trailer mounted on the aluminum trolley frame. The gear mechanism is fixed under the trailer bed with proper alignment for smooth operation. The DC motor, connected to the spur and worm gear assembly, is controlled via an Arduino circuit, which also includes a motor driver, power supply, and directional control switches. Limit switches are installed to prevent over-tilting in any direction. The system is tested under various load conditions to verify stability, tipping angle accuracy, and directional control. Observations were recorded to validate the mechanical performance and automation functionality.

- Mechanical assembly mounted on a mobile trolley.
- Gear system aligned under the trailer bed with motor connection.
- Arduino circuit controls direction and tipping, with limit switches for safety.
- System tested under different loads to check performance and stability.

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III. MATERIALS AND COMPONENTS

Mechanical Structure:

Chassis Frame: Made from mild steel (iron) for strength and durability. Trolley Base: Constructed using aluminum for lightweight and easy mobility.

Actuation System:

Spur Gear Assembly: Used to direct the tipping motion in the desired direction. Worm Gear Mechanism: Provides controlled, self-locking movement for safe tipping.

Control System:

Arduino UNO: Controls motor operation and tipping direction based on inputs.
Motor Driver Module (L298N or similar): Interfaces between Arduino and motor for bidirectional control.

Interface:

Push Buttons / Toggle Switches: For manual input to select tipping direction (left, right, rear). Limit Switches: Installed to stop motor at desired tilt angle and prevent over-rotation.

Miscellaneous:

DC Motor (12V or 24V): Drives the gear system for tilting operation. Power Supply/Battery: Provides power to motor and Arduino.
Wires, Connectors, Fasteners: Used for assembly and electrical connections.

IV. EXPERIMENTAL SETUP STEPS

Steps 1 : Frame and Mechanism Assembly:

Mount the aluminum trolley base and attach the mild steel chassis. Fix the spur gear and worm gear mechanism beneath the trailer bed.

Step 2 : Motor Installation:

Connect the DC motor to the gear system using proper couplings. Ensure alignment for smooth rotation and secure all mounts.

Step 3 : Arduino and Circuit Setup:

Connect the Arduino UNO with the motor driver (L298N) and input switches. Wire the power supply, limit switches, and motor connections.

Step 4 : Testing and Calibration:

Upload the control code to Arduino. Test tipping in all three directions using manual input and adjust limit switch positions.

Step 5 : Final Validation:

Load test the trailer with varying weights. Observe system performance for stability, response time, and gear engagement.

Fig. Side view of Three-way Trailer :

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Fig. Bottom view of Three-way Trailer :

V. FUNCTIONALITY

Effectiveness:

- Ability of the trailer to tip accurately in three directions (left, right, rear). Smooth functioning of the gear mechanism and control system.
- System response time and stability during operation.

Material Use:

- Appropriateness of selected materials for load-bearing and mobility. Durability and quality of fabrication (e.g., aluminum trolley, iron chassis). Efficiency of gear and motor integration with structural components

User Feedback:

- Ease of operation and control using Arduino interface.
- Safety and reliability of the mechanism as perceived by users. Suggestions and observations from test users for further improvement.

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