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Design and Fabrication of a Semi-Automatic Road Cleaning Machine for Sustainable Urban Maintenance

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ABSTRACT

Urban cleanliness plays a critical role in ensuring public health, aesthetic appeal, and environmental sustainability, especially in the context of growing urban populations and rapid infrastructure development. However, traditional street cleaning methods, predominantly reliant on manual labor, often fall short in terms of efficiency, consistency, and worker safety. These methods not only demand substantial human effort but also expose sanitation workers to hazardous environments, thereby necessitating an improved approach to urban waste management.

This research focuses on the design and fabrication of a semi-automatic road cleaning machine tailored to address these issues. The proposed machine incorporates a motor-driven rotating brush mechanism coupled with an integrated waste collection bin, offering a practical alternative to fully manual cleaning. Powered by a rechargeable battery, the machine is designed to be energy-efficient, environmentally friendly, and capable of operating in narrow urban pathways where large cleaning vehicles cannot access.

The machine's modular design ensures ease of assembly, maintenance, and operation, while its compact structure supports maneuverability across a variety of road conditions. Field tests demonstrate a significant reduction in physical labor and cleaning time, along with improved collection efficiency compared to manual sweeping. This study highlights the potential of semi-automated solutions in advancing sustainable urban maintenance and sets the groundwork for future developments, including the integration of renewable energy sources and autonomous navigation technologies.

Keywords: Semi-automatic cleaning machine, urban maintenance, sustainable design, mechanical engineering, road cleaning

1. INTRODUCTION

A street sweeper or street cleaner may refer to either a person's occupation, or a machine that cleans streets. A street sweeper cleans the street, usually in an urban area. The Street sweepers have been employed in cities since sanitation and waste removal became a priority. A street sweeping person would use a broom and shovel to clean off litter, animal waste and filth that accumulated on streets. Later, water hoses were used to wash the streets. In recent years cleanliness is becoming an important factor for the betterment of the nation and so, to support the cause we have conducted a study, prepared a design and working of a Semiautomatic Road Cleaning Machine. The cleaning machine is an approach to deliver easy and time efficient cleaning of roads, by reducing human efforts. There are in numerous functions of the road cleaning machine mainly 1) Cleaning of dust and dirt by use of brush. 2) Collecting the dust into the collector tank

It is also most precursors to the photochemical smog Component of smog irritate eyes and throat, stir up asthmatic attacks, decrease visibility and damages plants and materials as well. By dissolving with water vapour NOx from acid rain which has direct and indirect effects both on human and plants. To overcome the difficulties associated with pure ammonia, urea is selected. Urea can be hydrolyzed and decomposed to generate ammonia. An injected aqueous solution of urea solution is decomposed into ammonia and water vapour, then decomposed ammonia reacts with oxides of nitrogen and reduced into eco-friendly nitrogen and water vapour.

Effective cleaning and sanitizing help and protect the health of the human beings directly and indirectly. Also cleaning and sanitizing prevents the pest of the floor, walls etc. due to regular cleaning and maintenance. In recent years, most of the people prefer to use train soar buses or computing and hence these places are littered with biscuits covers, cold drink bottles etc. Hence, it is necessary to clean the bus stand sand railways station locations and occasions and effective cleaning depends upon type of cleaning device, cleaning technique and the equipment should be user friendly

2. LITERATURE REVIEW

The sweeping of streets is such a simple and humble occupation that it rarely attracts technical interest of the managers responsible for such activities. However, many cities spend between 30 to 50 percent of their solid waste budgets on street cleaning. It is a service for which a wide variety of tools, equipment and methods, both manual and mechanical, are available, and it is one in which there is often great scope for financial saving by the introduction of more efficient methods.

The rapid pace of urbanization has increased the demand for efficient and cost-effective road cleaning solutions. Traditional manual sweeping methods are not only labor-intensive but also time-consuming and often ineffective in maintaining urban cleanliness. Mechanical road sweepers have been introduced to address these issues; however, their high cost and maintenance make them unsuitable for small municipalities and rural areas.

According to Patel and Patel (2018), mechanized road sweepers significantly reduce human effort and increase cleaning efficiency, but their design and operation are often complex, requiring skilled labor for maintenance. Their study suggested the need for a simplified road cleaning mechanism that can be easily operated and maintained with minimal training.[3]

Kamble et al. (2019) focused on the development of a semi-automatic road cleaning machine aimed at reducing the dependency on manual labor. Their prototype used a rotating brush mechanism powered by a motor, which was mounted on a trolley-like frame. While their model was functional, it still involved a relatively high production cost due to the use of specialized parts. [4]

In another study, Bhosale et al. (2020) emphasized sustainability by designing a manually operated road cleaning machine. Their approach used pedal power to rotate brushes, targeting small towns and rural setups where electricity supply may be inconsistent. Their work demonstrated the potential for human-powered alternatives, but it faced limitations in cleaning efficiency and operator fatigue. [5]

Similarly, the work of Yadav and Kale (2021) proposed an eco-friendly, battery-powered road cleaner using basic mechanical components. While their design addressed the issue of fossil fuel consumption, the battery cost and limited operating time remained barriers to widespread adoption. [6]

Recent innovations have also looked into the integration of waste collection and dust suppression systems into compact units. Jadhav et al. (2022) presented a low-cost multifunctional road cleaning machine that combines sweeping, suction, and spraying features. Their findings highlighted the effectiveness of combining multiple cleaning actions, though the complexity and cost still posed challenges for mass deployment. [7]

From the existing body of work, it is evident that there is a growing interest in developing road cleaning machines that are efficient, eco-friendly, and economically viable. However, the challenge remains in fabricating a simple and low-cost model that can be easily operated and maintained, particularly in developing regions. Therefore, this project aims to design and fabricate a simple road cleaning machine that addresses these gaps by prioritizing ease of use, low cost, and basic mechanical operation.

3. DESIGN & FABRICATION

The fabrication of the semi-automatic road cleaning machine was carried out through a series of systematic steps involving material selection, component design, structural assembly, and system integration. The primary objective was to create a cost-effective, robust, and energy-efficient cleaning machine suitable for urban environments.

3.1. Material Selection

Materials were chosen based on durability, weight, corrosion resistance, and cost. The frame and chassis were constructed using mild steel (MS) due to its excellent mechanical properties and weldability. The waste collection bin was fabricated using lightweight galvanized iron (GI) sheets, while the rotating brush housing was made of high-density polymer to reduce overall weight and resist wear during operation.

3.2. Chassis and Frame Construction

The chassis formed the base of the machine and was built by welding square and rectangular MS tubes to create a rigid support structure. The frame was designed to house all functional components, including the motor, brush mechanism, wheels, and collection unit. Angular brackets and gusset plates were used at joints to enhance stability and support dynamic loads during movement.

3.3. Brush Mechanism Integration

A rotary brush mechanism was developed using a cylindrical shaft attached with nylon bristles, known for their flexibility and durability. The shaft was mounted using pillow block bearings on either side to ensure smooth rotation. The brush was positioned at the front underside of the machine at an angle optimal for directing debris toward the suction or collection chamber.

3.4. Drive and Power System Assembly

A DC gear motor (12V/24V) was selected for its torque characteristics and low-speed performance, suitable for both the rotary brush and the wheel drive. The motor was coupled to the brush shaft through a belt and pulley arrangement, allowing for efficient power transmission. The entire system was powered by a rechargeable lead-acid battery, placed securely in a protected compartment on the machine.

3.5 Waste Collection Unit

The collection unit consisted of a sloped surface that directed debris into a detachable bin positioned behind the brush. A simple vacuum fan mechanism was optionally installed to assist in lifting fine dust particles. The bin was designed for easy removal and cleaning.

Figure 1: Prototype of Road Cleaning Machine.

3.6. Control System

A basic electrical control panel was integrated with switches to control the motor functions—ON/OFF operations, forward/reverse motion of the brush, and machine movement. Safety features like fuses and circuit breakers were included to prevent electrical faults.

3.7. Assembly and Testing

All components were assembled and fastened using nuts, bolts, and welding where appropriate. The entire system underwent preliminary testing to verify functionality, brush efficiency, and wheel maneuverability. Adjustments were made to the brush angle, motor speed, and bin position to ensure optimal performance.

4. CONCLUSION

The primary objective of this project was to develop a simple, cost-effective, and efficient road cleaning machine as an alternative to expensive commercial sweepers, particularly for rural, semi-urban, and institutional use. Using basic engineering principles and materials like mild steel, nylon brushes, and bicycle wheels, a functional prototype was fabricated. Its manual or low-power operation ensures low energy use and ease of operation, even by unskilled users.

Real-world testing demonstrated the machine's effectiveness in cleaning dust, dry leaves, and small debris on flat and slightly uneven surfaces. The machine is lightweight, portable, low-maintenance, and significantly more affordable than motorized alternatives. User feedback during trials led to design refinements such as improved brush adjustment and a better dust collection system.

This project showcases how locally developed, sustainable solutions can enhance sanitation efforts while reducing environmental impact. With further development, this machine holds strong potential for deployment in municipalities, schools, hospitals, and smart village programs.

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