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Design and Fabrication of Motorized Solar Street Sweeping Machine

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Cleanliness is one of the good values which people have been looking at since the beginning of human existence. Street sweeping plays significant role in this regard in order to make our street clean. Street sweeping is a daily activity of the sweepers of the society. As a result of limited human - resources and vast development of geographical area, this cleaning activity cannot be more effective in daily basis in all the area. Automation of the street sweeping activity is hence gaining significance. In the cities cleaning of the street is usually carried out by using certain cleaning attachments mounting over vehicles. There are others machine tools available in the society which are either operated using petrol, diesel or in the form attachments to the moving vehicles. Considering the need for eco-friendly powering of the sweeping machine and automated cleaning using less human power, we designed and fabricated a solar powered street sweeping machine that can be used for sweeping streets. The machine consists of two watts of solar panel mounted on its top and a battery unit which can be used to powered the entire machine. The electricity generated using the solar panel is stored in the battery which can be used to provide energy to operate the motor. The machine has been designed and fabricated for consideration for low energy consumption, minimizing human effort, eco-friendly and easy to operate and handle.

Keywords: Solar panels, Battery, Galvanize iron sheet, sweeping machine, dust collecting bin.

1. Introduction

Cleanliness is one of the good values which people have been looking at since the beginning of human existence. This value has been maintained from generation to generation. People always want to see a clean place, and in order to achieve this, manufacturer had developed numerous mechanisms such as brooms, vacuum cleaner, and mechanized or motorized road sweeper *(Barbalace, 2003).* In addition, environmental cleanliness reduces pest infestations by reducing residues that may attract and support flies. It also improves the shelf life of floors, walls etc. due to regular cleaning and maintenance. In recent time people prefer to littered the environment with covers and containers of the products been purchased such as biscuits covers, sachet water nylon, drink bottles container and soon. Therefore, it is important to sanitize the environment by develop a cleaning machine.

Street sweeping is not much of a new idea as so many equipment and machines have been developed from ages past from the traditional method of using brooms to the invention of mechanized sweepers to vacuum cleaners all in a bid to aid in the process (Squatriti, 2002).

The relevance of this work cannot be over emphasized as it meets the daily requirement for creating comfort, the sanitization of the environment and eco-friendly as it is built by using solar power to enable cleaning where there is readily no power supply and also on streets without being mounted on a vehicle. Therefore, the aim of this present work is to design and fabricate motorized solar street sweeping machine.

Considering the need for eco-friendly powering of the sweeping machine and automated cleaning using less human power, we designed and fabricated a solar powered street sweeping machine that can be used for sweeping streets. The machine consists of two watts of solar panel mounted on its top and a battery unit which can be used to powered the entire machine. The electricity generated using the solar panel is stored in the battery which can be used to provide energy to operate the motor. The machine has been designed and fabricated for consideration for low energy consumption,

minimizing human effort, eco-friendly and easy to operate and handle.

2. Materials/Components

The materials selected in the fabrication of the components of sweeping machine were carefully selected considering cost, availability, ease of construction, quality as well as the various properties considered.

2.1 The Frame

The frame of the sweeping machine was constructed using mild steel square pipe of the size 20 mm by 20 mm this was selected for the rigidity, strength, workability and durability it offers in service.

2.2 The Body

In the construction of sweeping machine body 0.5 mm thickness of galvanized steel sheet were selected and were joined by arc welding using electrode. Galvanized steel sheet were selected due to it aesthetics, strength, workability, rust resistance and durability it offers in use.

2.3 The Whirling Brush and Wheels

The whirling brush are made up of bristle-like plastic material in which hot electrical soldering iron, epoxy glue were used for boring and gluing of the bristle to make it become brush. The brush length is 500 mm long and the diameter is 150 mm.

A typical wheel mainly made up of a metal hub, wired tension spoke and a metal or a carbon fibre rim which holds a rubber tyre. Tyres used are made of rubber as best suited for the wheels which are to aid the movement of the sweeping machine during operation and provide a versatile cushion.

2.4 The Electric Motor

A 12 volts DC electric motor was installed considering the fact that it is a motorized sweeping machine which is meant to propel the whirling brush for the sweeping process to be achieved.

2.5 The Power System

Two 40 W solar panel was installed and electrical energy is stored in 12 V DC battery. The battery supply is provided to the electrical switch board of the machine.

2.6 Dust Collecting Bin

The main function of dust collecting bin is to collect the dust being swept by the whirling brushes. The sheet metal is use to made the bin. The bin is attached with hand for easy disposal of dust when full.

3. Methodology

3.1 Design and Calculations

3.1.1 Weight of the Machine

The total weight of the sweeping machine comprise of summation of the masses of the frame support, the body of the machine, the brush, the wheels, the electric motor, the battery and the solar panel.

3.1.2 Mass of the Frame Support

The mass of the frame was measured and found to be approximately 3.9 kg.

3.1.3 Mass of the Body of the Machine

The mass of the body was calculated by weighing the various parts and found to be 5.5 kg.

3.1.4 Mass of the Brush

The mass of the fabricated brush measures approximately 0.70 kg.

3.1.5 Mass of the Wheels

The mass of the wheels is measured and calculated as:

Mass of one (1) rear wheel = 0.4 kg ……3.1
Mass of two (2) rear wheels = 0.8 kg …...3.2
Mass of one (1) front wheel = 0.1 kg …….3.3
Mass of two (2) front wheel = 0.2 kg …….3.4
The mass of the wheels (rear and front) is 0.8 kg + 0.2 kg = 1 kg ……3.5

3.1.6 Mass of the Electric Motor

The mass of the electric motor was determined by weighing it to be 1.15 kg.

3.1.7 Mass of the Battery

The mass of the battery was determined by weighing to be 2.5 kg.

3.1.8 Mass of the Solar Panel

The mass of the solar panel was determined by weighing it to be 3.7 kg using weighing balance.

The total mass of the machine = 3.9 + 5.5 + 0.70 + 1 + 1.15 + 2.5 + 3.7 = 18.45 kg……3.6

Therefore, the total weight of the machine is 18.45 kg × 10 m/s^2 = 184.5 N

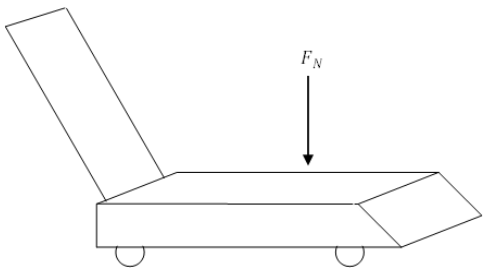

Figure 1: Force acting on the sweeping machine

$\boldsymbol{W}$, is the weight of the machine;

$F_N = mg$ ……..3.7

$F_N = 18.45 \times 10$

F_N = 184.5 N

F_N is the normal force due to machine weight, the force (F) perpendicular to the surface on which the wheel is rolling. The "rolling resistance coefficient" C_{rr}, according to Evans, (2001) is defined by the following equation,

$$F = C_{rr} F_N$$

C_{rr} is coefficient of rolling resistance, which is 0.015 for car tyre on concrete (Evans, 2001).

F = 0.015 × 184.5

F = 2.7675 N

Where, F is the rolling resistance force;

C_{rr} is the coefficient of rolling friction.

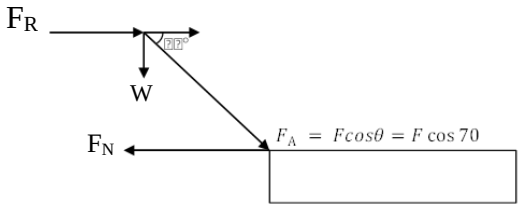

Figure 2: Diagram of Force on machine

Where F_N is the normal Force required to roll the sweeping machine

F_R is the reaction force required of the sweeping machine

W is the weight of the sweeping machine which tends to act downward due to acceleration due to gravity.

F_A is the minimum force required to roll the sweeping machine while pushing from the handle.

$F_A = F \cos 70$ 3.9

Where F_A is the force perpendicular to the surface on which the wheel is rolling or rolling resistance force, which is 2.7675 N

F_A =2.7675 cos70 = 1.7527 N

3.2 Power Required for the Electric Motor

$$\text{Power} = \frac{\text{Force} \times \text{Distance moved}}{\text{Time}} \quad \text{.....3.10}$$

$$Power = Force \times Velocity \quad \text{..... 3.11}$$

$$= Mass \times Acceleration \quad \text{..... 3.12}$$

The total mass of the machine (M) = 18.45 kg; Acceleration due to gravity, $g = 10m/s$

Velocity for circular motion, V = $r\omega$ 3.13

$$\omega = \frac{2\pi N}{60} \quad \text{.....3.14}$$

Where the diameter (D) of the brush spindle, which is 100 mm was measured with Vanier Caliper, therefore, the radius r = 50 mm = 0.05 m;

N=120 rpm is the revolution of the brush spindle of the whirling brush,

$$\omega = \frac{2 \times \pi \times 120}{60}$$

$$\omega = 12.566 \text{ rad/s}$$

Therefore, the Velocity $V = r\omega$ = 12.566 x 0.05 = 0.6283 m/s

The power P, required for the electric motor

$= Mass \times Acceleration \times Velocity$

From equation (3.12), Power (P) = Mass (M) x acceleration (g) x Velocity (V)

V = 0.6283 m/s

Therefore, the power required P, = 18.45 × 10 × 0.6283 = 115.92135 W

4. Results and Discussion

The street sweeping machine consists of frame, body, whirling brushes, wheels, electric motor, power system and dust collecting bin. The frame was constructed using mild steel square pipes material of the size 20 mm by 20 mm which are welded together. The body of the machine was constructed using a galvanized mild steel sheet material of thickness 0.5 mm. A plastic bristles and plastic pipe material were used for whirling brush construction.

12 volts DC electric motor was coupled to the side of the machine using screwdriver, spanner and welding machine to weld and fasten the motor.

The electrical solar panel was mounted on the push handle of the machine by screwing, riveting bolting using screwdriver, riveting gun and spanner using latitude 20^0 NE as positioning of the panel.

12 volts DC battery was mounted, positioned and connected to the battery plate using spanner.

Totally others assemblies were done using bolts, nuts and rivets by screwing fastening and riveting. The machine was painted with paint thinner using brush and hand sprayer.

The next step involved connecting the wires to the solar panel and battery for ON/OFF of the machine. The final step was involved trial on actual machine to consider working and proper functioning of all connected electronic circuit. Fig. 3.1 shows the design of the machine and Fig. 4.1 shows the actual photo of the sweeping machine.

Fig. 3: Actual Assembly of the final machine

5. Conclusion

The cleaning process of the machine is achieved with use of whirling brushes according to the studies conducted on the machine. The machine move on the straight path without any deviation. Using this machine for cleaning effective cleaning is done. The design was simple and light weight material was used. The machine is powered by solar energy, therefore is eco-friendly machine without emission of dangerous chemicals to the environment. The machine can be operated by skilled and unskilled person due to the simple way of the design and construction. The machine helps to reduce human efforts in other to improve cleanliness of the environment and encourage well-being of people.

6. Recommendations

The design of solar sweeping machine can be used in wide range and commercial basis to ease the inconveniences experienced using the conventional way of cleaning and sweeping by broom. However further studies are recommended in the following area:

a) This work may be improved upon by making it more automated in which a sensor can be added which will send out signal to notify the operator when the garbage can is filled up so that the operator will dump the garbage in the can.

b) This developed solar sweeping machine should be improved upon in order to work in both levelled (even) and unlevelled (rough) surface for a wide range of application.

c) It could be deduced from the operation of the machine that when working without continuous charging, the machine tends not to work optimally; further study on this aspect should be done.

Conflict of interest

The authors declare no conflict of interest.

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