STUDY AND DESIGN OF SEMI-AUTOMATIC ROAD CLEANING MACHINE

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Abstract - *The quality of air has been considerably harmed as a result of unchecked industrialization and mismanaged building and development initiatives in emerging nations such as India. People are forced to absorb dirty air and large amounts of dust particles. The World Health Organization's (WHO) norm for air quality has been sufficiently damaged, and this has become a severe concern. One of the major reasons is the spread of dust particles from the road to the atmosphere by vehicles travelling on the road, where roads are dug up for construction purposes only to be abandoned due to the political, financial, and personal interests of the elite groups and construction company owners. This can lead to serious health hazards like sever allergy, lung cancer and other problems related to breathing. To solve this issue, we created a prototype of the 'Semi Automatic Garbage Cleaning Machine,' which is both financially feasible and socioeconomically advantageous. This machine operates on the simple concept of centrifugal motion of a cylindrical brush discharging dust particle from the road surface into a container, employs local resources, is less expensive than other machines, and is also more efficient. This can be utilized in roadside areas where there has been a lot of dust collected up*

***Key Words*: Garbage cleaning machine, scrubber, sweeper, sustainable.**

1.INTRODUCTION

Street sweeping is one component of a solid waste management system; yet, relatively little information on the many components of street sweeping is accessible in the literature. Wastes dumped on the streets cause health issues, pollution, and a terrible aesthetic impact, notably on visitors, and so have an indirect influence on the economy of cities and towns. Despite the fact that governments may spend10% to 20% of their budgets on street cleaning and sweeping the procedure is not often optimized. For street cleaning, several tools, equipment, and methods (both manual and mechanical) are available. Because of the duties and expenses involved in the process, street cleaning is also a system where savings may be realized by merely enhancing the process's efficiency.

2. CONVENTIONAL MECHANISM

The bulk of mechanical sweepers are mobile devices that gather garbage using a suction system. In most cases, the suction action is supplemented by one or more revolving brushes for dislodging residues that attach to the road's surface. Mechanical sweepers come in a variety of styles. They range in size from extremely small pedestrian-controlled devices to big mechanical sweepers mounted on a truck chassis. Large mechanical sweepers typically have an auxiliary motor to provide the suction and, in some circumstances, a hose that can be operated by an operator to pick up waste from difficult-to-reach regions. The operating speed of the smaller machines is around 2 to 3 km/hr, while that of the larger sweepers is around 10 km/hr or higher. Mechanical sweepers are effective in removing light litter, fine dust, and sand from highways

Mechanical sweepers' usefulness in economically underdeveloped countries is limited to just assisting manual sweeping. Mechanical sweepers are often seen in developing-country big urban centres. The extent to which mechanical sweepers are used for a certain application should be dependent on careful consideration of the benefits and drawbacks, as well as the costs involved with employing them vs hand sweepers. Furthermore, mechanical sweepers are notoriously difficult to keep in good working order. Internal systems may be harmed while gathering huge materials unlawfully discarded on the streets. As a result, these devices should be supported by well-equipped maintenance facilities that keep a full inventory of replacement components

3. SCOPE OF STUDY

The goal of this study was to create a semi-automatic driven system for cleaning street surfaces by assessing debris features, kinds, and distributions.

4. DESIGN CONCEPTS & PRODUCT ARCHITECTURE

The main focus of the conceptual design phase was on determining the general layout and design of the road cleaning system. The determination of design goals was the initial step in this phase. The following basic machine requirements were determined based on customer needs:

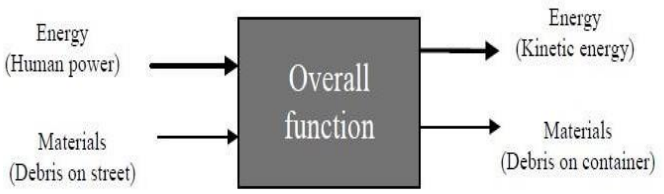
1.It's simple to use: there's no need for extensive instructions.
2. Capacity for cleaning: collects wet, dry, fine, and coarse litter. Clean without causing damage to the road surface.

3. Lightweight: simple to push, turn, handle, and move from one location to another.
4. Space requirement: following cleaning activities, the machine must be placed or transported in a minimum amount of space.
5. Low-cost: sellable to middle- and high income neighborhoods, small businesses, private and public institutions, and organizations.

6. FUNCTIONAL STRUCTURE

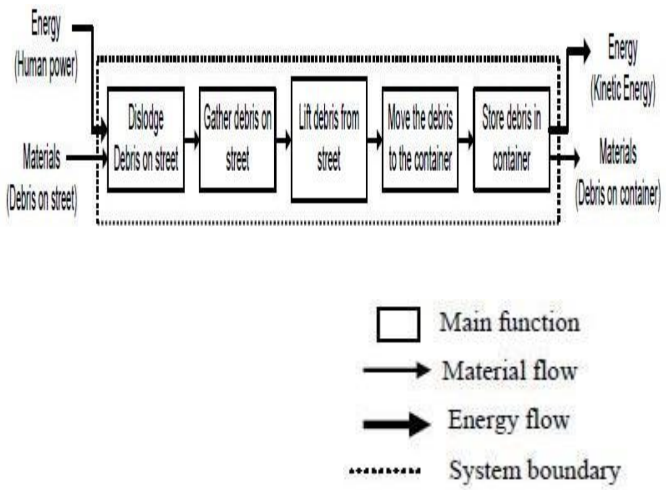
To simplify the design process and to get plenty of alternative concepts, it important to establish function structures. The function structures are classified into overall function structure and sub functions structure.

Overall function structure: The overall function depicts the problem with input-output interaction sin general. The inputs are material (road trash) and energy (human power), whereas the outputs are material (dirt container debris) and energy (human power) (kinetic energy). The entire function organization is depicted in the diagram.

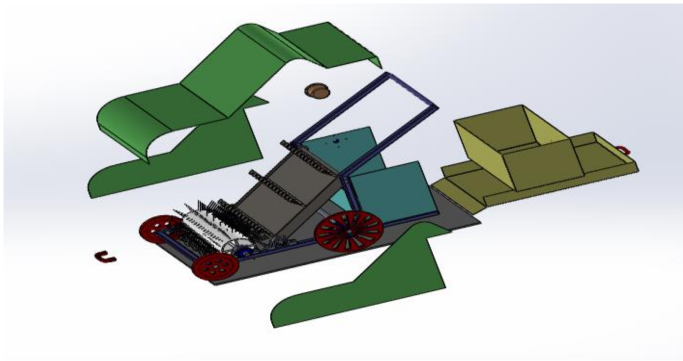


6.1 Sub-Functional Structure

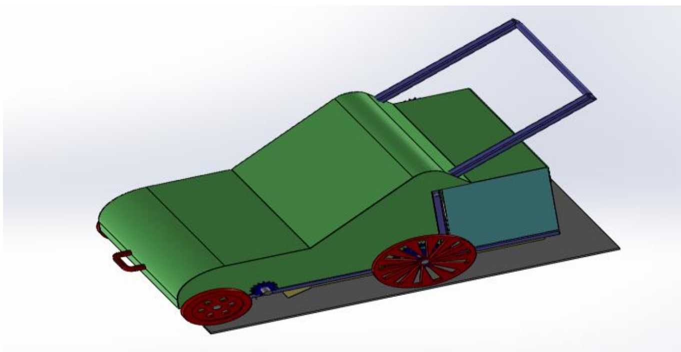
Because many design difficulties are too complicated to tackle as a single problem, decomposing large problems into simpler sub issues is critical. As a result, the overall function structure was broken down into sub‑functions in order to find alternative solutions for each sub-function



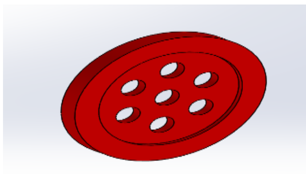
7 PARTS AND MODELS



7.1 Chassis and Frame



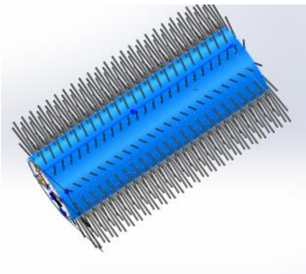
7.2 Wheels



Front Wheel		Rare Wheel	
Material of the tire	nylon	Material of the tire	nylon
Material of the rim	Cast iron	Material of the rim	Cast iron
Diameter of the wheel	200mm	Diameter of the wheel	300mm
Diameter central bore	25.40mm	Diameter of the central bore	25.40mm
mass of the wheel	1kg	mass of the wheel	2kg
Number of the wheel	2	Number of the wheel	2

Table : Specifications of Front & Rare Wheel

7.3 Brush



Brush ring	Material	Mild steel
	External diameter	150mm
	Internal diameter	120mm
	Thickness of flat bar	3mm
	Breadth of the side bar	40mm
	Thickness of side bar	3mm
	length of side bar	90mm
	Bore Diameter	25.40mm
Brush support	Numbers	15
	Breadth	2mm
	Height	75mm
	Gap between side bars	5 mm
Brush	Material	Polypropylene bristles
	Length of brush base	460mm
	Diameter of thread	2 mm
	Length of the thread	75 mm

7.5 Chain Drive

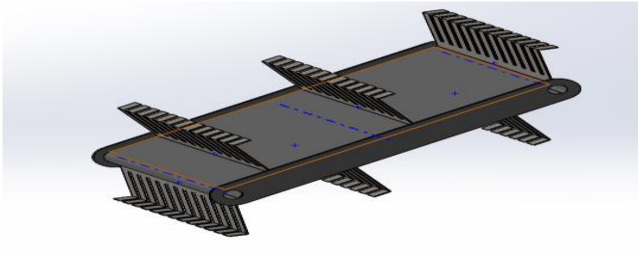
Diameter of first sprocket = 60 mm
Speed of first sprocket = 60 rpm
Diameter of second sprocket= 60 mm

Speed ratio = $driven/driver$
=60 / 60
= 1:1

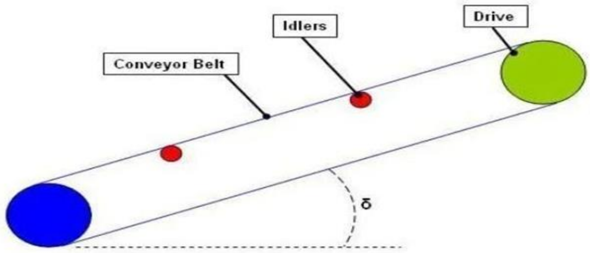
Speed of the driven sprocket,
=Velocity ratio × speed of first sprocket
= (1/1) *60

= 60 rpm

7.4 Conveyor



Design of conveyor Belt
Conveyor has one purpose, i.e. to transfer the debris in Container



Belt tension: The belt of the conveyor always experiences a tensile load due to the rotation of the electric drive, weight of the conveyed materials, and due to the idlers.

The belt tension at steady state can be calculated as:
Tb = 1.37 x f x L x g [2 x mi+ (2 x mb + mm) x cos (δ)] + (H x g x mm)

Where, Tb is in Newton.

f = Coefficient of friction
L = Conveyor length in meters
Conveyor length is approximately half of the total belt length.
g = Acceleration due to gravity = 9.81 m/sec2
mi = Load due to the idlers in Kg/m.
mb = Load due to belt in Kg/m.
mm = Load due to the conveyed materials in Kg/m.
δ = Inclination angle of the conveyor in Degree.
H = vertical height of the conveyor in meters.

Conveyor capacity (Cc) calculations –

Belt displacement in one min – 3 meters
Let 1kg material is shifted in 1-meter distance of conveyor belt
So, material shifted in 1minut = 3 x 1 = 4 kg / min
Therefor material shifted in 1 hr = 4 X 60 = 240 kg/ hrs
Belt speed (V) = 0.05 m/sec = 3 m/ min
Material Weight = 2kg
Conveyor height (H) = 0.617 m
Conveyor length (L) = = 0.64 m
Mass of a set of idlers (mi) = 0.4 Kg

Idler spacing (l') = 0.216 m
Inclination angle of the conveyor (δ) = 55
Coefficient of friction (f) = 0.5
Start-up factor (Ks) = 1.5
Drive efficiency (Kd) = 0.9
Friction factor (Cr) = 15
Breaking strength loss factor (Cv) = 0.75
Thickness of rubber belt (T) = 5mm

Total Weight of the belt (mb)-

Volume = L X W X T
= 0.64 X 0.96 X 0.005
= 0.00372 m^3

Therefore Rubber Density = 1360 Kg/m^3
Total Weight of Belt = 4.17 Kg

First, we will use the for finding out the load due to idlers
mi = (mass of a set of idlers) / (idlers spacing)
mi = 0.4 / 0.216
= 1.85Kg/m

Belt tension:

Tb = 1.37x f x L x g [2 x mi+ (2 x mb + mm) cos (δ)] +(H x g mm)
= 1.37 x *0.5 x0.64 x 9.81 (3.7 + 2 x 4.17 + (0.06 / 1.5) x cos 55] + (0.617 x 9.81 x (0.06 / 1.5))*
= 55.45 N

Belt tension while starting the system: Initially during the start of the conveyor system, the tension in the belt will be much higher than the tension in steady state. The belt tension while starting can be calculated as:

Tbs ***=Tb x Ks***
= 55.45 x 1.5
= 83.17 N

Power at drive pulley: The power required at the drive pulley can be calculated from the belt tension value as below:

Pp *= (Tb x V)/1000*
= (55.45 x 0.05) / 1000
= 2.7 Kw

Sizing of the motor:
The minimum motor power can be calculated as:
Pm *= Pp/Kd*
= 2.7 / 0.9
= 3 Kw

Acceleration : The acceleration of the conveyor belt can be calculated as:

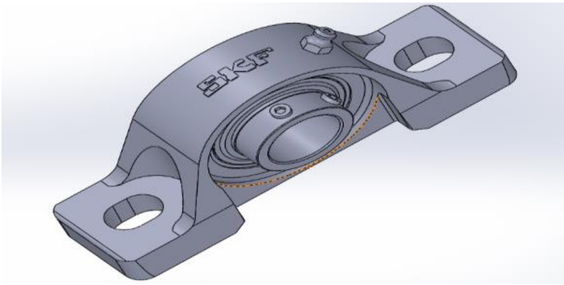
A= (Tbs – Tb)/ [L(2 x mi + 2 x mb+mm)]
= (83.17 – 55.45) / [0.64 (2 x 1.85) + (2 x 4.17) + (0.06 / 1.5)]
= 3.75 m/ sec^2

Belt breaking strength:
This parameter decides the selection of the conveyor belt. The belt breaking strength can be calculated as:

Bs *= (Cr x Pp)/ (Cv x V)*
= (15 x 2.7) / (0.75 x 0.05)
= 1080 N/ mm

This **Bs** value is used to select the conveyor belt from the manufacturer's catalogue

7.5 Ball Bearings



Here, we have used SKF UCP-205 ball bearing

For 25mm Diameter bearings.
Given: Shaft diameter, d = 25mm
Assume:

- Radial force, Fr = 50 N
- Axial force, Fa= 100 N

STEP: 1
To Find Radial Factor (X) & Thrust Factor (Y)

For shaft diameter, 5mm
Static load, C0= 190N
Dynamic load, C = 360N

$$\frac{Fa}{Co} = \frac{100}{190} = 0.52$$

For this value corresponding e value is 0.44

$$\frac{Fa}{Fr} = \frac{100}{50} = 2$$

Therefore , $\frac{Fa}{Fr} > e$

X = 0.56
Y = 1.0

STEP: 2
Calculation of Equivalent Dynamic Load
P = [X Fr + Y Fa] S

Assume: Service Factor, S = 1.1 So,

P= [0.56 x 50 + 1 x 100] 1.1
P=140.8 N

STEP: 3
Calculation of Bearing Life
Hours used per day is 3 hours
So, hours used per year is 3x365
Bearing life = 1095 Hours

STEP: 4
To Find Dynamic Load Capacity

$$C = P[{}^{L}/_{L_{10}}]^{1/K}$$

Where, L10 = 1mr & K = 3

$$C = 140.8\ [\frac{1095}{1}]^{1/3}$$

C = 53.62 N

Therefore, $C_{actual} = 53.63\ N$

We know that, $C_{standard} = 360\ N$

$C_{actual} < C_{standard}$

Since the dynamic load rating of Bearing is more than required dynamic load capacity. Therefore, selected bearing is suitable. So, Design is safe and satisfactory.

7.6 Motor

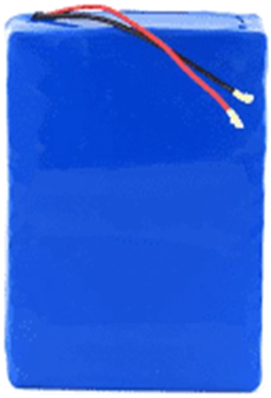
Motor is required to drive the conveyor belt & motor is selected from power required to drive the conveyor.

Brand	Mechatronics Treading
Type	BLDC
Power	0.5 HP
Insulation Type	Type B
No of Poles	8
Output Torque	59.39 Nm

7.7 Battery

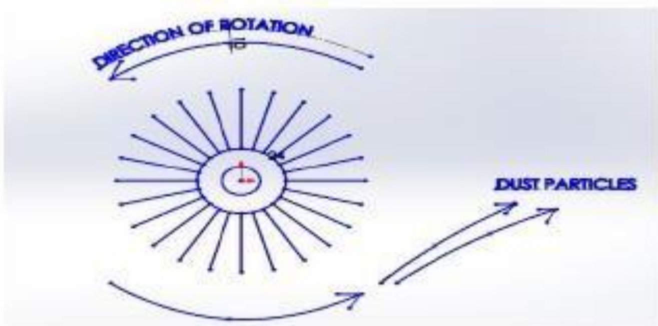
Battery is required to power the motor & should be light in weight. Compared with traditional battery technology, lithium-ion batteries charge faster, last longer and have a higher power density for more battery life in a lighter package. When you know a little about how they work, they can work that much better for you.

Type	lithium-ion battery
Capacity	40ah
Voltage	12V
Weight	4 Kg



8. WORKING PRINCIPLE & OPERATION

The brush linked to the shaft feels centrifugal force on the tip of the threads when the shaft is rotated with external power. The tip of the brush cylinder stayed in contact with the road surface, throwing dust particles away from the road surface in the tangential direction of the brush cylinder.



Mechanism of machine:

When the handle is pushed, the front wheel revolves clockwise, and a larger spur gear attached to the shaft powers a smaller spur gear positioned on the Brush shaft. This increases the speed of the smaller spur gear, which causes the brush to rotate. Brushes are next used to remove all of the dust and solid trash. Whereas dust is stored in separate cabinet, solid trash is transported to a larger cabinet by a conveyor belt powered by a motor.

9. APPLICATIONS

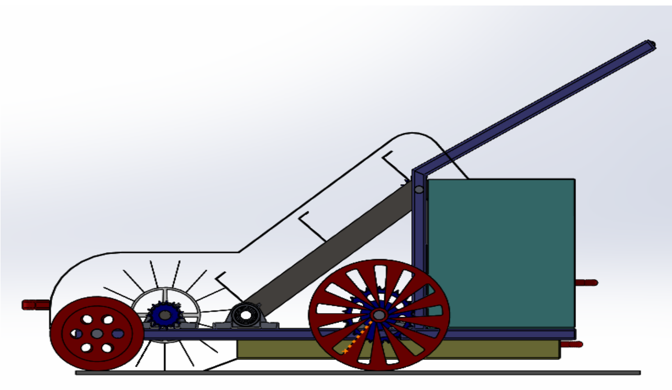
1. It can be used for general purpose.
2. Mostly used for industries and domestic purpose e.g. Used as a floor cleaning in schools and colleges.
3. Can be used for cleaning roads.
4. Industrial cleaning

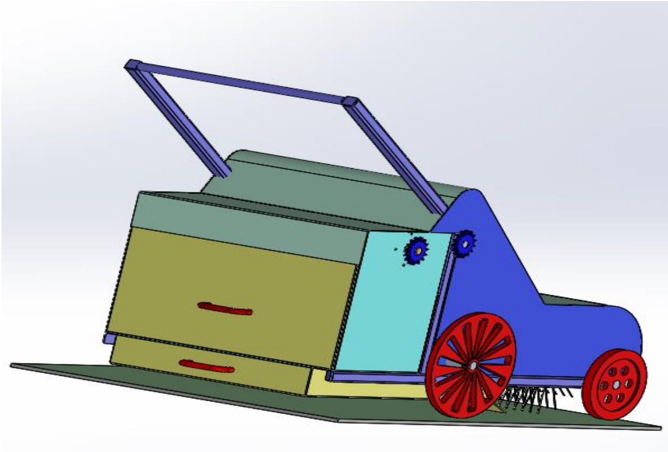
10. ADVANTAGES

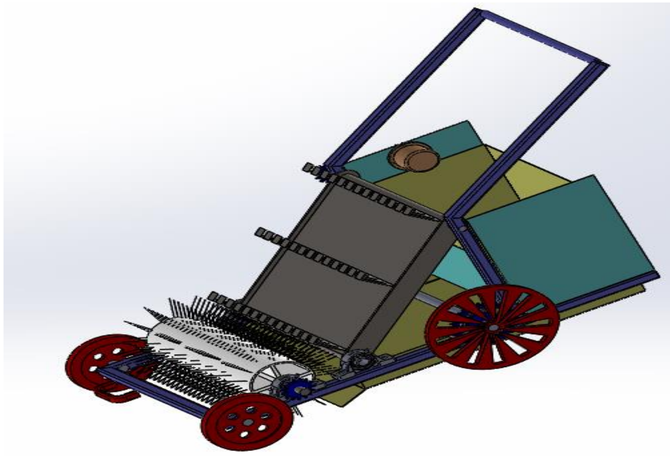
1. Do not have an engine and so make no sound when running. So, there is no noise pollution
2. Reduces human efforts.
3. To increase the effectiveness of floor cleaning.
4. The batteries are sealed and maintenance free. They do not need periodic topping up with distilled water. However, some vendors offer free servicing of these batteries during the warranty period.
5. Running expense is next to nil because electricity is cheap. The cost could be as little as 10paise / km. The government, which subsidizes electricity, is subsidizing your running expenses.
6. Cost effective.

11. DISADVANTAGES

1. It requires an external source for running the conveyor.
2. Required regular cleaning of the collecting tank.







12. CONCLUSIONS

Debris on streets and sidewalks is a major issue in cities and towns, particularly in poorer nations like India, where cleaning is done by hand with brooms, shovels, and handcarts. Because of the associated expenses and maintenance facilities, developing countries cannot afford to purchase mechanical broom sweepers and high-efficiency vacuum-assisted equipment. The street cleaning process must be mechanized by installing machines that assist street cleaners in improving the quality and efficiency of their work. A manually operated street cleaning machine was created for this purpose. To aid in the design of the SABO Machine, the characteristics, types, and distributions of debris on streets and sidewalks were studied by gathering samples from areas where different forms of debris were discovered. Following an analysis of debris on streets and sidewalks, the machine's core needs were presented. The product specification was determined based on the requirements. Various concepts were developed using concept generation methods during the concept development stage. Setting criterion was used to choose the best notion from among them. The main solution path was put out by the creation of a solution principle; the principle solution was specified by building function structures, searching for relevant working principles, and merging them into a working structure. The core physical building pieces of the product in terms of what they do and how they connect with the rest of the device were completed based on the specified principle solution. SolidWorks CAD software was used to create the 3-D part design.

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