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DESIGN & ANALYSIS OF MANUALLY OPERATED ECO-FRIENDLY ROAD CLEANER

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Abstract: Cleaning has become a basic need for all human beings and it is unavoidable daily routine process. The conventional road cleaning machine is most widely used in railway stations, airports, hospitals, Bus stands, etc. also this machine needs electrical energy for its operation. It is not user friendly as well as eco-friendly. In summer time there is power crisis and most of the roads cleaning machines are not used effectively due to this problem particularly. In our project we are using easily available materials with low cost. It is the better alternative for conventional machine.

Keywords: Road Cleaner, Manually Operated, Eco-Friendly, Human Powered, Analysis.

Introduction:

Effective cleaning and sanitizing helps and protect the health of the human beings directly and indirectly. Also, cleaning and sanitizing prevents the pest infestations by reducing residues that can attract and support bees, pests etc. It also improves the shelf life of the floor, walls etc. due to regular cleaning and maintenance. In recent years, most of the people prefer to use trains or buses for commuting and hence these places are littered with biscuits covers, cold drink bottles etc. Hence, it is necessary to clean the bus stands and railways stations at regular interval. There is no one single cleaning method that is suitable for all locations and occasions and effective cleaning depends upon type of cleaning device, cleaning technique and also the equipment should be user friendly. [2] Cleaning work can be physically demanding and a need has been identified to developed methods for systematic ergonomic evaluation of new products. In recent years, floor cleaning robots are getting more popular for busy and aging populations due to lack of workers. However in India, unemployment is more and hence there is a need to develop less labor oriented cleaning machine. Hence, the present work is aimed to design, development and evaluation of a manually operated road cleaning machine. [3] Liu et al [4] carried out a technical analysis of residential floor cleaning robots based on US granted patents. They observed that the macroscopic analysis of patents and patent bibliometrics or patent maps, is useful tools to make an overview for designated technical topics and they observed that the Samsung is the top one patentee in cleaning robot after macroscopic of view. Imaekhai Lawrence et al [5] evaluation has shown how the use of multiple assessment techniques can provide a comprehensive appraisal of the design, usability and musculoskeletal loading upon the operator. They suggested that the trials with a larger number of subjects would certainly strengthen the conclusions. Abhishek Chakra borty et al [6] reported that the most significant cause of road dust to the total suspended particulate burden is vehicle traveling on paved and unpaved' surfaces. Consequently data directly relating dust to road accidents are rare, but in a study if dust is the cause of 10% of these accidents casualties then the cost could amount to as much as 0.02% of GDP in some developing countries and total about $800 million annually. The present state of the road cleaning process is described below. There are two ways for road cleaning 1) Manual process 2) Machinated process. In manual process, the road cleaning is done with the help of and shovel to clean off the debris, waste etc. hand to clean the road by spreading the dust all over in the air. While in the Machinated process, a vehicle containing broom at bottom continuously rotating, clean the road as well as sucks the dust spread by rotating broom. If one carefully observes the first process, then he could find the following limitations which are given below:

1. This process renders fatigue to the hand and even it cause damage to the shoulder.
2. As it is a continuous process, it produces
3. It is time consuming, and laborious process so, no one wants to do it.

On the other side, in the second process following limitations have been found out, which are discussed below:

1. The requirement of petrol is prerequisite for this process and continuously.
2. The cost of machine is quite high cost and the rural people could not afford it to buy.

Background of Present Road Cleaning:

The manual operated machines are time consuming and laborious, on other side of the flip, the

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diesel operated machines are very costlier. These problems actually instigate to think an alternative arrangement which would nullify the limitations of former said processes. Further its initial cost is also less. The new evolved concept is a road cleaning machine is operated by human power. To accomplish this new idea, the present work is well carried out which is as under.

1. Firstly, the complete market review and literature survey based on the Road Cleaning processes been done.
2. On the basis of the demand power the machine component are designed.
3. On the basis of obtained designed dimensions the fabrication work of the proposed manually operated road cleaning machine is carried out.
4. At last, the testing and trails have been taken to ascertain the load capacity of the machine.

Objective of Manually Operated Eco-Friendly Road Cleaner:

- To provide the alternative method for road cleaning
- To reduce human efforts
- To save the time
- To reduce the cost
- To avoid noise pollution

Literature Survey:

Mohsen Azadbakht et al 2014 [1] - *"Design and fabrication of a tractor powered leaves collector machine equipped with suction-blower system"***-** The authors explained about the fabrication of leaves collector machine by tractor powered with suction blower system. He has framed the machine by using chassis, pump, blower, gearbox, hydraulic jack. They concluded total power consumption of that machine is around 14634 W.

M. Ranjith Kumar et al 2015 [2] - *"Design and Analysis of Manually Operated Floor Cleaning Machine"***-** The authors has been designed and analyzed manually operated floor cleaning machine. From his research he concluded the stress level in the manually operated machine is within the safe limit.

Sandeep. J. Meshram et al 2016 [3] - *"Design and Development of Tricycle Operated Street Cleaning Machine"* **–** He has developed the street cleaning machine by tricycle operated. In this research article he framed a model especially for rural area. He concluded that the cleaning is less effective where the street seems to be very rough and damaged.

Liu et al 2013 [4] – *"A Technical Analysis of Autonomous Floor Cleaning Robots Based on US Granted Patents,"* **–** He carried out a technical analysis of residential floor cleaning robots based on US granted patents. They observed that the macroscopic analysis of patents and patent bibliometrics or patent maps, is useful tools to make an overview for designated technical topics and they observed that the Samsung is the top one patentee in cleaning robot after macroscopic of view.

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Components used in road cleaner

- Bearings
- Shafts
- Frames
- Gutter brushes
- Roller brush
- Sheave grooves
- Wire ropes

Scope of the project: Existing road clean methods are two types i) Electrical operated ii) manually operated. Manual cleaning may causes shoulder problem due to continuous sweeping. Electrically operated road cleaner's uses electrical energy to run the motor. In our project manually operated road cleaning machine is alternative concept for avoiding such problems. It works very efficiently with respect to covering area. It is very economical to use.

Gutter brush: Brushes are tools composed of bristles that are fixed into a mounting board, and, like other types of brushes, they are elastic, flexible, and conform to irregular or flat surfaces. Due to these features, a gutter brush can reach difficult or specific areas without damaging the bristles or the surfaces to be swept.

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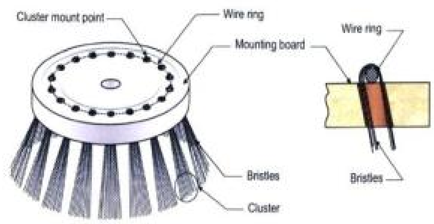

Methodology:

Literature Survey
↓
Identification of design parameters
↓
Design
↓
Analysis
↓
Fabrication
↓
Testing
↓
Result & Discussion

Design calculation:

1. **Design of spur gear:**

Given:

- Power transmission ratio i = 1.3
- Gear speed N_2 = 50 rpm

Assume:

- Shear stress $\tau = 28\ \mathrm{N/mm^2}$ (assume)
- Arrangement: External

We know $\mathbf{i} = \frac{Z_2}{Z_1} = \frac{N_1}{N_2}$ So, $1.3 = \frac{N_1}{50}$

$$\mathbf{N_1 = 65rpm}$$

STEP: 1 ***To Find Power***

We know $\mathbf{T} = \frac{\pi}{16} \times \tau \times d^3$

Given: Shaft diameter, d = 25mm

$T = \frac{\pi}{16} \times 28 \times 25^3$ =85.902Nmm.

Also know $\mathbf{P} = \frac{2\pi NT}{60} = \frac{2\pi \times 50 \times 85.90}{60}$

$$\mathbf{P = 0.45Kw}$$

STEP: 2 ***Material Selections***

→From PSGDB.Pg.No: 8.5

S.No	Description	Material	σ_c kgf/cm^2	σ_b kgf/cm^2
1	Pinion	C45	5000	1400
2	Gear	C45	5000	1400

STEP: 3 ***To Find Minimum Center Distance***

→From PSGDB.Pg.No: 8.13

$$\mathbf{a \geq (i+1)\sqrt[3]{\left(\frac{0.74^2}{\sigma_c^2}\right) \times \frac{E[M_t]}{i\varphi}}}$$

Here known data's are

- i = 1.3
- $\sigma_c = 5000\ \mathrm{kgf/cm^2}$
- E = 2.15 $\mathrm{kgf/cm^2}$ (From PSGDB Pg. No: 8.14)

➢ To find the remaining value

→From PSGDB.Pg.no: 8.14

Assume: Open type gearing

➢ $\varphi = \frac{b}{a} = 0.3$

→From PSGDB.Pg.no: 8.15

Design twisting moment $[\mathbf{M_t}] = \mathbf{M_t.K.K_d}$

Assume: $K.K_d$ = 1.3 (for symmetric)

Nominal twisting moment

$M_t = 97420\frac{kW}{n} = \frac{97420 \times 0.45}{65}$

M_t= 674.45kgf.cm

Therefore $[M_t] = 674.45 \times 1.3$

$\mathbf{[M_t] = 876.78kgf.cm}$

Substitute all the values

$$a_{min} \geq (i+1)\sqrt[3]{\left(\frac{0.74}{5000}\right)^2 \times 2.15 \times 10^6 \times \frac{876.78}{1.3 \times 0.3}}$$

$$a_{min} \geq 10.88\ \mathrm{cm}$$

$$\mathbf{a_{min} \geq 108.8\ mm}$$

STEP: 4 ***To Find Minimum Module***

→From PSGDB Pg.no: 8.13A

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$$m \geq 1.26 \sqrt[3]{\frac{[M_t]}{y\varphi_{m[\sigma_b]Z_1}}}$$

We know

- $[M_t] = 876.78$kgf.cm
- $[\sigma_b] = 1400\,\text{kgf/cm}^2$
- $Z_1 = 16$ (Assume)

→From PSGDB.Pg.No: 8.18

For Z_1= 16

Assume: Addendum modification coefficient, X=0

- Form factor, y = 0.355

→From PSGDB.Pg.No: 8.14

- $\varphi_m = \frac{b}{m} = 10$

$$m_{min} \geq 1.26\sqrt{\frac{[876.78]}{0.355\times10\times1400\times16}}$$

$$m_{min} \geq 0.28 \text{ cm}$$

$$m_{min} \geq 2.8\text{mm}$$

→From PSGDB.Pg.No: 8.2

- **Standard module, m=3mm**

STEP: 5 ***Corrected No. of Teeth***

→From PSGDB Pg. no: 8.22

- For spur gears

No of teeth on pinion: $\mathbf{Z_1} = \frac{\mathbf{2a}}{\mathbf{m(i+1)}}$

Therefore $Z_1 = \frac{2\times108.8}{3\times(1.3+1)}$

$$\mathbf{Z_1 = 32}$$

We know $\mathbf{i} = \frac{Z_2}{Z_1}$

$$1.3 = \frac{Z_2}{32}$$

$$\mathbf{Z_2 = 42}$$

STEP: 6 ***To Find Corrected Center Distance***

→From PSGDB.Pg.No: 8.22

$$\mathbf{a} = \mathbf{m}\times\left(\frac{Z_1+Z_2}{2}\right) = 3\times\left(\frac{32+40}{2}\right)$$

$$\mathbf{a_{corrected} = 111mm}$$

Therefore $\mathbf{a_{min}} < \mathbf{a_{corrected}}$

Since the corrected center distance is greater than minimum center distance. So our design is safe and satisfactory.

STEP: 6 ***To Find Face Width***

→From PSGDB.Pg.No: 8.14

$\varphi = \frac{b}{a} = 0.3$ b = 0.3× a = 0.3×111 b = 33.3mm

$\varphi_m = \frac{b}{m} = 10$ b =10×m = 10×3 b = 30mm

Take large value, **b= 33.3mm**

STEP: 7 ***To Find Actual Design Twisting Moment***

→From PSGDB Pg.no: 8.15

$$[\mathbf{M_t}]_{\mathbf{actual}} = \mathbf{M_t.k.k_d}$$

We know $M_t = 674.45$kgf.cm

To find load concentration factor k

→From PSGDB.Pg.No: 8.15

$$\varphi_p = \frac{b}{d_1} = \frac{b}{mZ_1} = \frac{33}{3\times32} = 0.343$$

(Assume: Bearings close to gears and symmetrical) **k = 1**

To find dynamic load factor k_d

→From PSGDB.Pg.No: 8.16

Assume: IS quality 8 (cylindrical gears) Hardness ≤ 350 HB

Pitch line velocity $V = \frac{\pi d_1 N_1}{60\times1000} = \frac{\pi\times mZ_1N_1}{60\times1000}$

$$V = \frac{\pi\times3\times32\times65}{60\times1000} = 0.326 \text{ m/s}$$

For V=0.326 m/s the value of $\mathbf{k_d = 1}$

Therefore $[M_t]_{actual} = 674.45\times 1 \times 1$

$$[\mathbf{M_t}]_{\mathbf{actual}} = \mathbf{674.45kgf.cm}$$

STEP: 8 ***Checking For Surface Compressive Strength***

→From PSGDB.Pg.No: 8.13

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$$(\sigma_c) = 0.74 \times \frac{i+1}{a}\sqrt{\frac{i+1}{ib} \times E \times [M_t]_{actual}}$$

$$= 0.74 \times \frac{1.3+1}{11.1}\sqrt{\frac{1.3+1}{1.3 \times 3.3} \times 2.15 \times 10^6 \times 674.45}$$

$$[\sigma_c]_{induced} = 4275.29 kgf/cm^2$$

But $[\sigma_c]_{material} = 5000\ kgf/cm^2$

Therefore

$$[\sigma_c]_{induced} \leq [\sigma_c]_{material}$$

Since the induced surface compressive stress is less than maximum surface compressive stress. So our design is safe and satisfactory.

STEP: 9 ***Checking For Bending Stress***

→From PSGDB.Pg.No: 8.13A

$$[\sigma_b] = \frac{i+1}{amby}[M_t]_{actual}$$

Here form factor for Z_1=32 is 0.4448

(Assume X=0, From PSGDB.Pg.No: 8.18)

$$[\sigma_b] = \frac{(1.3+1) \times (674.45)}{11.1 \times 0.3 \times 3.3 \times 0.4448}$$

$$[\sigma_b]_{induced} = 317.36 kgf/cm^2$$

But $[\sigma_b]_{material} = 1400 kgf/cm^2$

Therefore

$$[\sigma_b]_{induced} \leq [\sigma_b]_{material}$$

Since the induced bending stress is less than maximum bending stress. So our design is safe and satisfactory.

STEP: 10 ***Calculations of Other Parameters***

Given: Module, m = 3mm

→From PSGDB.Pg.No: 8.22

S.No	Description	Formula	Values
1	Addendum	1.25m	3.75mm
2	Dedendum	1m	3mm
3	Depth of cut	2.25m	6.75mm
4	Bottom clearance, c	0.25m	0.75mm
5	Height factor, f_0	---	1
6	Tooth depth, h	0.25m	0.75mm
7	Pinion pitch circle diameter, d_1	mZ_1	96mm
8	Gear pitch circle diameter, d_2	mZ_2	126mm
9	Pinion tip circle diameter, d_{a_1}	$(Z_1 + 2f_0)m$	102mm
10	Gear tip circle diameter, d_{a_2}	$(Z_2 + 2f_0)m$	132mm
11	Pinion root circle diameter, d_{f_1}	$(Z_1 - 2f_0)m - 2c$	88.5mm
12	Gear root circle diameter, d_{f_1}	$(Z_2 - 2f_0)m - 2c$	118.5mm

2. Design of Shaft

We know shaft material is ***MILD STEEL (MS)***
Assume Factor of Safety (FOS), n = 3

→From PSGDB.Pg.No: 1.9

- Tensile stress = 650 N/mm^2
- Yield stress, σ_y = 360 N/mm^2
- Yield shear stress, $\tau_y = {}^{\sigma_y}/_{2n}$ = 360 / (2 x 3) = 60 N/mm^2

We know M_t = 85.902 Nmm & d = 25mm
Also we know,

$$\tau = \frac{16 \times Mt}{\pi d^3}$$

$$\tau = \frac{16 \times 85.9092}{\pi \times 25^3} = 27.9\ N/mm^2$$

Therefore $\tau_{calculated}$ = 27. 9 N/mm^2
We know $\tau_{standard}$ = 60 N/mm^2

$$\tau_{calculated} < \tau_{standard}$$

Since, calculated shear stress of shaft is less than standard shear stress. So *Design is safe & satisfactory.*

3. Design of Bearing

For 25mm Diameter bearings.

Given: Shaft diameter, d = 25mm

Assume:

- Radial force, F_r = 100 N
- Axial force, F_a = 150 N

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

→From PSGDB.Pg.No: 4.12

For shaft diameter, 25mm

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- Bearing type: ***SKF6005*** bearing.
- Static load, C_0 = 5200N
- Dynamic load, C = 7800N

→From PSGDB.Pg.No: 4.4

$\frac{F_a}{C_0} = \frac{150}{5200} = 0.0288$

For this value corresponding *e* value is 0.225

$\frac{F_a}{F_r} = \frac{150}{100} = 1.5\text{I}$

$$\frac{F_a}{F_r} > e$$

→From PSGDB.Pg.No: 4.4

X = 0.56

Y = 1.949

STEP: 2 ***Calculation of Equivalent Dynamic Load***

→From PSGDB.Pg.No: 4.2

$$P = [XF_r + YF_a]\, S$$

Assume: Service Factor, S = 1.1

So, P = [(0.56x100) + (1.949x150)]

P = 383.185N

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***

→From PSGDB.Pg.No: 4.2

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

Where $L_{10} = 1mr$ & K = 3

So, C = 383.185 x $[\frac{1095}{1}]^{1/3}$

Therefore C_{actual} = 3939.5N

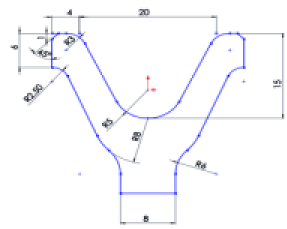
Also we know $C_{standard}$ = 7800N

$$C_{actual} < C_{standard}$$

Since the dynamic load rating of SKF6005 is more than required dynamic load capacity. Therefore selected bearing is suitable. So *Design is safe and satisfactory.*

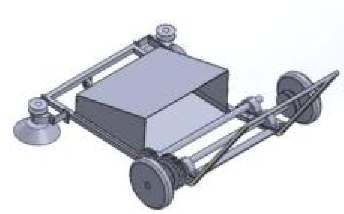
4. Design of Sheave

We know wire rope diameter is 11 mm. →From PSGDB.Pg.No: 9.10 For diameter 11 mm, the dimensions are



- a = 28mm
- b = 20mm
- c = 6mm
- e = 1.0mm
- h = 1.5mm
- l = 8mm
- r = 5mm
- r_1 = 3mm
- r_2 = 2.5mm
- r_3 = 9mm
- r_4 = 6mm

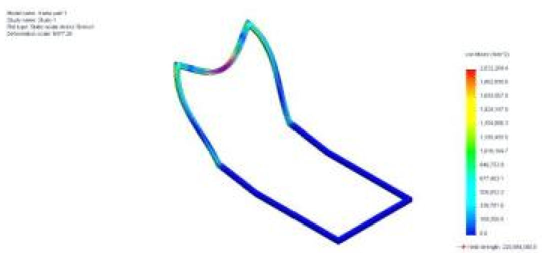
3D Modelling:



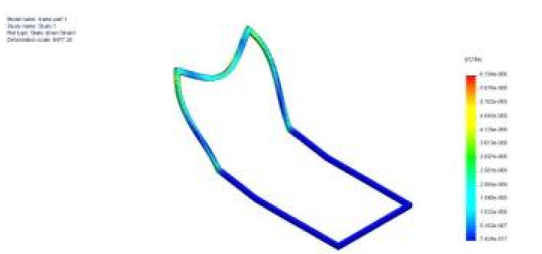
Analysis:

In analysis of manually operated eco-friendly road cleaner was carried out by using SolidWorks software. Analysis was used to find the deflection and stress on frames, brushes and wheels. The maximum deflection & stresses were checked and maintained with in the allowable limits for the materials of construction.

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.36278e-005 N/m^2 Node: 2430	2.03221e+006 N/m^2 Node: 4237



Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	7.43418e-017 Element: 754	6.19396e-006 Element: 636



Conclusion:

The manually operated eco-friendly road cleaner is successfully designed, analyzed and fabricated. This project works implements the manually operated eco-friendly road cleaner for road cleaning that reducing the cost, human efforts as well as time. It is the best alternative for automated road cleaning machine during power crisis. It is found that the existing road cleaning machines uses petrol and diesel. It can cause pollution and also the vibration produced in the machine causes noise pollution. While manual cleaning may cause healthy problem as the person directly comes in contact with dust. Also, the shoulder problem due to continuously sweeping occurs. A manually operated eco-friendly road cleaner is an alternative concept for avoiding such problems. The manually operated eco-friendly road cleaner can work very efficiently with respect to covering area, time and cost of road cleaning process compared with the existing machineries. Also it is economical. It was seen while testing of machine, that the cleaning is less effective where the road seems to be very rough and damaged. It can provide job to the uneducated person who is in need for such jobs as human energy is needed to drive the machine.

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