DESIGN AND FABRICATION OF RAILWAY TRACK CLEANING MACHINE

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Abstract - *Indian railways is the largest transportation because of its reliability and cost-effectiveness. Daily millions use it as it is safe and affordable to all categories. Besides its merits, there are some demerits about its disposal of dry and wet waste on tracks. Waste disposal has become a challenging task for the railway department. To overcome this, the government has taken various initiatives by implementing environmentally friendly green toilets to overcome night soil disposal to some extent, still, railway tracks are littered with all kinds of waste. In many places, cleaning process is done manually, but the people in manual cleaning are affected by health problems. In this paper, a portable prototype of a manually operated machine that cleans the railway track, removing both dry and wet waste, was proposed for the railway department. The machine consists of two compartments in the shape of a cuboid with a small water tank, two vacuum cleaners, a jet with a nozzle, and two pairs of freely moving wheels for smooth movement on the track. It is designed in CATIA V5 software and constructed with stainless steel material for lightweight. In every railway station, the machine is moved freely on the track by refilling the water tank with the water taps installed in the middle of the tracks and a guide to start the device. Vacuum cleaners collect the dry waste such as plastic bottles and wrappers and the jet nozzles powered by compressor clean the wet waste. This cost-effective machine replaces manual scavenging.*

Key Words: Catia V5, Rotating Nozzles, Battery, Inverter, Gear, Vacuum cleaner

1. INTRODUCTION

The development process in any country is transportation, which is an inevitable important infrastructure and plays a major role in the integration of the country and economic development, in that Railways transportation is one. In India, since British times to this date, there was a wide increase in the railway infrastructure along with the growing population. From 1950, the entire railway department was taken under control by the Government of India. Indian railways are considered as one of the largest transportation in Asia and also in the World (Ankit Gupta and Vidya Bhat, 2007) covering 66,000 km and more than 8,000 stations. It is said as 'Lifeline of Nation' as it is the largest and oldest and connects all the cities within a single network. Moving towards the cleaning initiatives, the railway has lost glory in terms of cleanliness and sanitation. It has turned as the biggest challenge to manage high amounts of disposed of wastes off on to the railway tracks. Unclean toilets, wastes thrown out by the people on tracks, clogged basins, and open defecation through railways, train vendors, packed meals available from station stores are some of the examples of poor sanitation and cleanliness. The passengers on the platforms and the residents living alongside the railway tracks are facing inconvenience due to this growth rate of garbage disposal. This poor sanitation, in turn, leads to various pollution problems, health problems by the spread of microorganisms on the track. Across the entire network, many implementations were done by the railway department to improve the cleanliness, but are not meeting the growing demand.

As the cleanliness of the surroundings and railway tracks is a social problem, the wastes thrown by the passengers and the human waste are being cleaned by the humans only. The people involved in manual cleaning are facing a lot of health problems. In order to overcome this issue, a robot is constructed to clean the railway track which consists of a waste collecting unit, power supply, cleaning part, disposed of part, a control part, and sensing device (Thiyagesan Jesin James et al.,). Human wastes which are exposed directly on the railway tracks cause very serious health problems. To rectify this government has introduced eco-friendly bio-toilets, but expensive. To the exiting toilet system, this system is embedded without any changes in working procedure (Novel Kumar Sahu et al). In addition, awareness must be created simultaneously regarding railway track sanitation and also about various types of pollution such as land, water, and air pollution due to poor sanitation (Balasahed kasure et al). Using communication technology, a system consisting of a microcontroller, IR sensors, and hardware parts were constructed to identify the cracks in the railway tracks. The sensor is connected to the system that moves on the track. When it detects any cracks the system stops moving and the location is submitted to the controller through GPS and GSM (G.Kasthuri et al). As sanitation is considered a major important issue, a manual cleaning trolley consisting of a micro controller, sensor, and the vacuum cleaner is constructed that detects the cracks and cleans the railway tracks (Renupriya. G et al).

Besides, near the railway stations, as of now, the Indian Railways relies on manual scavenging, which basically is the collection of these wastes using inappropriate tools like boards, brooms and collecting them into sacks. By adopting this type of cleaning method in job, these employees are being subjected to unhygienic conditions which show up health related issues in terms of respiratory diseases, infections, cardiovascular or musculoskeletal disorders, and finally causing risk to their lives. The waste accumulated on the railway tracks is more near the stations, but the railway officials who are providing the best mode of transportation find it difficult to dispense this off the track. Moreover, it takes more man force to clean up the railway track and this cleaning should be done in a short span since the tracks at the railway station will be busy. So, there is a need for a machine that can clean the railway track completely in a very short interval and must be cost-effective. This is what explained how it can be done and became the main aim of this study.

2. STUDY OBJECTIVES

1. To prepare a cost effective railway track cleaning machine.
2. To clean wet waste on railway tracks using power supply.
3. To collect dry waste on railway tracks using power supply.

3. MATERIALS AND METHODS USED

3.1 Heavy Duty vacuum cleaner

The Heavy-duty vacuum cleaners are suitable for collecting all types of dry waste, for instance, plastic bottles, covers, papers, etc. These heavy-duty vacuum cleaners are very robust, compact cleaners with large suction capacity through a powerful by-pass, single or three-phase motor. However, there are limitations like size and weight. The heavy-duty cleaners have large fixed collecting bags with a capacity of 30 to 105 liters.

3.2 Storage water tank

A storage water tank is a tank in which the water is stored for the cleaning process. For the cleaning process, to remove all types of deposits of regular maintenance, cleaning for inspection or rehabilitation this high-pressure water unit is used. All most 90% cleaning process is done by this method and considered as a universal process. Generally, this high-pressure water unit consists of a hose with a cleaning nozzle at the end. This cleaning nozzle has holes through which the water flushes out. In this research work, a 100 liters pressurized water unit is installed made of Low-density polyethylene (LDPE). In general, Low-density polyethylene (LDPE) can hold a capacity of 1000 liters. It is a thermoplastic made from the monomer ethylene. Using a high-pressure process via free radical polymerization this first-grade polyethylene is produced by Imperial Chemical Industries (ICI) in the year 1933. In the study, this materialis used as it was estimated that about 5.7% of Low-density polyethylene (LDPE) is being recycled.

3.3 Centrifugal pump

The centrifugal pump increases the flow rate of the water from the tank to the nozzles to attain the required pressure. The principle used in the centrifugal pump is simple andwell described. In addition, the pump is robust, inexpensive to produce, and effective. Based on the principle of centrifugal pump, there is a wide range of variations with some basic hydraulic parts. The centrifugal pump that is used in the study, works on 220V input voltage, 50 Hz power supply so the power used is raised, converted to AC source and usedto power the inflator. It is placed at the middle side of the model in the study, which passes the water from the tank to the high pressurized nozzle with great velocity. The specifications of the centrifugal pump are as follows:

Table-1: Specifications of the centrifugal pump

Input Voltage	220V
Discharge Pressure	220 psi
Flow rate (LPM)	100-600 lit/min

3.4 Nozzle design

This is the nozzle used in the centrifugal pump. A nozzle is either a pipe or tube used for the flow of a fluid. They are used to control the flow rate, the direction of the flow, speed of the flow, shape, mass, stream pressure. The purpose of this nozzle is to remove the human wastes that still remain on rail tracks. There are two similar nozzle pipes fixed facing each other at the bottom of the machine. The most commonly used nozzle is a rotary turbo nozzle and this nozzle is used in the prototype. The rotary turbo nozzle which is used spins a zero degree spray automatically in a 4-8 inch circle at 3000 rotations per minute. The water jet which is coming out of the pump hits the surface area from multiple angles, quickly breaking down caked-on dirt and grime. As a result, the time is reduced to half due to these rotary nozzles. Every pressure washer needs high-pressure nozzles.

3.5 Operating buttons and sensors

As sometimes the suction unit and water storage capacity differ from position to position due to high wastage on the tracks a sensor is placed at the feeder unit and water tank unit so that it could determine the storage capacity. This sensor helps the operator to find out whether the water tank is about to empty or not. When the level of water falls below 1 liter, the sensor triggers a notification to the operator reminding them to refill the water tank. It also determines the remaining power of the battery that is used to run the machine. As the machine is moving forward the operator will press the button of either a water pump or vacuum pump based on the usage. In a few cases, there could be only dry

Waste on the track in that case the operator uses the operating buttons to run a specific unit in order to save the power from draining. So, the operating buttons are provided near the operator cabin to use according to the need.

3.6 CATIA V5

Catia V5 is multi-platform software developed by the French Company name Dassault Systems. Various software's like computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE), PLM and 3D are also supported by CATIA V5. Besides, it supports various stages of product development from design, conceptualization and engineering to manufacturing. Therefore, it is considered a CAx software referred to as a 3D Product Lifecycle Management software suite. With an integrated cloud service, it helps collaborative engineering and is used across many disciplines including surfacing and shape design, electrical, electronic and fluid systems design, mechanical engineering and systems engineering. With the use of this software, a conceptual design has been made in the study for better understanding and making.

The following commands are used in the CATIA V5 to design a prototype machine.

3.6.1 Sketcher Module:

2D geometries can be created by sketcher workbench which is having a set of tools. Features like (pads, pockets, shafts, etc...) create solids or modify them using these 2D profiles. Sketcher workbench can be accessed in many ways. There are two simple ways. One is by using the top pull-down menu (Start – Mechanical Design – Sketcher) and others by selecting the Sketcher icon. When the sketcher icon is selected, a plane is to be chosen to sketch on. This plane can choose either before or after selecting the sketcher icon. Exit Workbench icon is selected in order to exit the sketcher.

3.6.2 PAD command:

In CAD software, EXTRUDE is used for the addition of extra material, but in CATIA PAD option is used. This command helps to add the material in the third direction, which is other than the sketch direction. This command is used to draw solid objects. Here this PAD command is used to draw solid components like the wheelbase, battery box, and the centrifugal pump.

3.6.3 POCKET command:

The POCKET commands are the opposite of the PAD command. It simply helps remove material from an already created part. The POCKET command helps to create a cylinder hole in the middle of the cube. This command is used to draw hollow components like tanks as there is a hollow portion inside and for the vacuum cleaner.

3.6.4 RIB command:

This command which is usually known as SWEEP in AUTO-CAD is called RIB IN CATIA. This command adds material along a guide curve. Components like springs, pipes, etc are made using the command RIB. This command is used to draw circular wires, pipes which are connected from the diaphragm pump to the nozzles in the design.

3.6.5 SHAFT command:

In CAD software we use the REVOLVE command but in CATIA, the SHAFT command is mostly used to make circular parts like shaft. This command requires an axis, around which the sketch will be created and material is added. This command is used here to draw the connecting rods which are used to connect the two wheels.

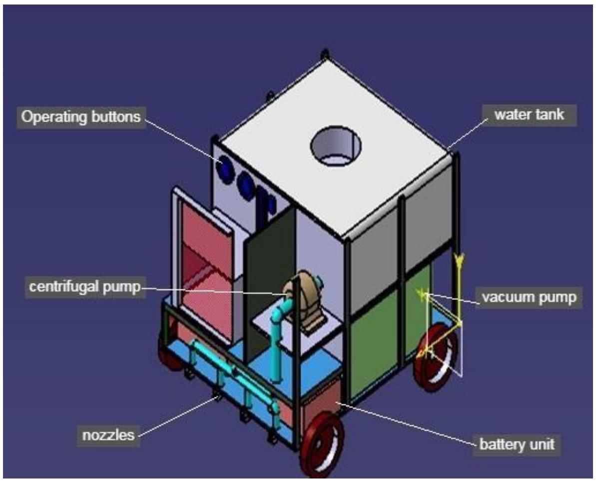

Fig-1: Model of Railway track cleaning machine in CATIA V5 software

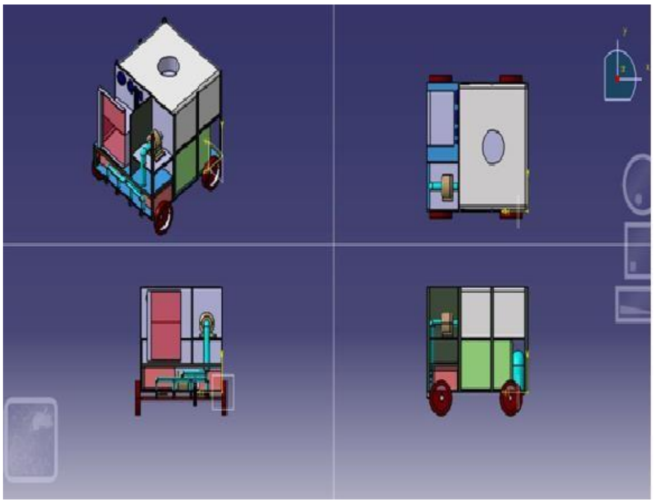

Fig-2: Views of the Railway track cleaning machine model in CATIA V5 software

4. METHODOLOGY

The main object of the study is to develop an efficient and economic self-cleaning device for cleaning the dry and wet waste across the railway network tracks. The working process is explained below along with a flow chart. A prototype machine design and the figures with calculations are also shown in this paper.

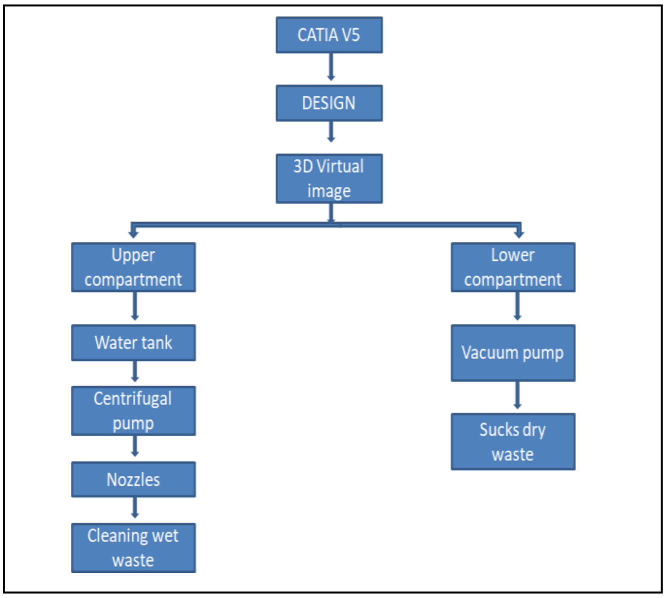

Fig-3: Flow chart of the Railway track cleaning machine

4.1 Specifications of manually operated Machine

As the operating machine is said to be time-saving and easy to use, a manually operated prototype machine is constructed for experimental purposes. The machine is designed in the CATIA software using the commands available in the software with appropriate dimensions. The dimensions of the machine are 1.8m X 1.4m X 1.2m. The machine is in the shape of a cuboid. The equipment used in the fabrication consists of an Aluminum frame, vacuum cleaner, Low-density polyethylene (LDPE) water tank (100 liters), diaphragm water pump, nozzles, water pipe, wheels, and electrical wires. The whole equipment is described in two compartments. The height of the first compartment is 600mm and the second compartment is 500mm with the length and width as 1800mm and 1468mm respectively. In the upper compartment, water tank and diaphragm pumps were set. On the backside, to the bottom of the equipment, two nozzles are positioned. These nozzles are connected to the diaphragm pump with pipes of 8mm diameter. For cleaning wet waste, the water in the water tank which is the upper compartment is forced through these two nozzles with calculated jet velocity. The specifications of the diaphragm pump used for the machine are as follows

Table-2: Specifications of the diaphragm pump

Volts	12V
Amps	3.0A
Flow rate	4 lit/min
Pressure	100psi

For cleaning of dry waste, a vacuum cleaner is equipped in the lower compartment. The specifications of the vacuum cleaner used are as follows.

Table-3: Specifications of the vacuum cleaner

Voltage	440v
Power	5500w
Suction	42kPa
Airflow	102 ltr/sec
Tank Capacity	100 ltr

All the sides of the machine are covered with a 3mm thick decolam sheet. Two individual switches for the vacuum cleaner and water pump are provided on the backside. The inlet of the vacuum cleaner is positioned at the front bottom. A battery of 1500 amperes is used for the operating purposes.

4.2 Working process

As explained in the design, the machine consists of two compartments i.e., upper compartment and lower compartment. The upper compartment consists of a water tank and diaphragm pump for cleaning wet waste and a vacuum cleaner along with a battery unit for cleaning dry waste. In the upper compartment, a water tank made of Low-density polyethylene (LDPE) of 100 liters is present, in which the water is stored. While cleaning the wet waste the water from the tank is passed through the centrifugal pump which is placed between the two compartments in order to increase the flow rate. The power to the centrifugal pump is supplied by the battery unit which is placed in the lower compartment. The high flow rate water is then passed through the rotating nozzles placed at the bottom side of the machine where the velocity of the water increases and cleans all the wet waste on the tank. The water will be empty in a single run of 15 minutes. When the water level falls below a certain limit, the operator will come to know with the help of the sensor which is placed inside the tank. Simultaneously, for cleaning of dry waste, the battery unit in the lower compartment provides power to the vacuum cleaner where all the dry waste such as paper plates, plastic bottles, and other dry waste materials are sucked into a bag.

Based on the usage, the operator shifts from one working to other with the help of the operating buttons placed near to him.

Fig-4: Prototype of the machine covered decolam with a tank inside

Fig-5: Inlet of the vacuum cleaner at the front bottom

Fig-6: Two nozzles at the bottom on back side

5. RESULTS AND DISCUSSIONS

The prepared prototype machine was made to run on a 100 meter track. It took 5 min to complete the whole process. The machine is placed on the surface facing 90 degree track. As the machine is moving forward the operator will press the button of either water pump or vacuum pump based on the usage or the wastage on the track. For a 100 meter long track, results of each unit were calculated and are shown in the following steps.

The outlet pipe from the pump is made into two. And these two pipes are connected to two individual nozzles as explained in the methodology. So, the flow velocity achieved from these nozzles is calculated as below.

$$Q_1 = A_1 v_1 \quad \text{...} (1)$$

Where,

Q_1 is the flow rate at inlet.

A_1 is the area of cross section at inlet.

v_1 is inlet velocity of the fluid.

Area of the cross section at inlet is calculated by taking the dimensions of the pipe having diameter as 8mm.

Therefore,

$$A_1 = \frac{\pi}{4} * d^2 = \frac{\pi}{4} * 8^2 * 10^{-6} = 50.26 * 10^{-6} m^2$$

And,

$$Q_1 = 4 \frac{\text{lit}}{\text{min}} = \frac{4}{60} \text{lit/sec}$$

Substituting the values Q_1 and A_1 in equation (1) and the velocity obtained is

$$v_1 = \frac{\left(\frac{4\,l}{60\,s}\right) * (10^{-3} m^3 l)}{\frac{\pi}{4} * 8^2 * 10^{-6} m^2} = 1.36\, m/s$$

Since the pipe is connected to two nozzles, the continuity equation can be written as

$$A_1 V_1 = A_2 V_2 + A_3 V_3 \quad \text{...} (2)$$

Where,

A_1 is the area of cross section of pipe.

V_1 is the velocity of water at inlet .i.e. in pipe.

A_2 and A_3 are the areas of cross section of nozzles tip.

V_2 and V_3 are the velocities at outlets of nozzles 1 & 2.

Since the dimensions of both the nozzles are same, therefore $A_2 = A_3$.

Consider, $A_2 = A_3 = A$

Area of cross section of nozzle tip
$= A = \frac{\pi}{4} * d^2 = \frac{\pi}{4} * 0.5^2 * 10^{-6} m^2 = 0.196 * 10^{-6} m^2$

Now, the continuity equation (2) can be written as

$A_1 V_1 = A(V_2 + V_3)$

$50.26 * 10^{-6} * 1.36 = 0.196 * 10^{-6} * (V_2 + V_3)$

$$V_2 + V_3 = 348.74 \text{ m/s} \quad \text{.............................}(3)$$

Since the dimensions of both the nozzles are same, assuming that the water flow will be equally distributed to both the nozzles.

Therefore, $V_2 = V_3$ ....(4)

Substituting equation (4) in equation (3) we get,

$2V_2 = 348.74$

$$V_2 = 174.37 \text{ m/s}$$

Therefore from calculations the following velocities are obtained,

Inlet velocity of water in the pipe = V_1 = 1.36 m/s

Outlet velocity of water at the tip of each nozzle = $V_2 = V_3$ = 174.37 m/s.

The above velocities are used at the nozzles for the water to clean the wet waste.

6. CONCLUSIONS

By using this equipment cleaning the railway track can be done faster and in a safe manner. This will reduce the effective cost for cleaning the track compared to manual labour since only one operator is required to control the machine. This equipment will be useful for maintaining cleanliness at railway station premises. It also eliminates the risk to labor while cleaning the track. This machine is also eco-friendly since the whole equipment is powered by batteries there will be no air pollution. The proposed equipment consumes less amount of water, is efficient in cleaning and is also portable when compared to the existing means of cleaning. Hence, by constructing this type of machine the requirement of railway track cleaning system is met and matched.

7. FUTURE SCOPE

1. Lot of improvements can be made in the future by the addition of modern sensors and information technology.
2. Installations of brushes with mechanisms andmore vacuum units will be helpful in cleaning the waste even on the sides of the track effectively.
3. The capacity of each component can be increased for cleaning a long stretch.
4. Adding some chemicals to water might be helpful for effective cleaning of wet waste.
5. Better vacuum cleaners with high suction power and other attachments can be equipped for cleaning even sides of the track.
6. Addition of sensor technology can be helpful in detecting the size and type of waste.

REFERENCES

[1] Dr. Manoj Hedaoo, Dr. Suchitra Hirde, Ms. Arshi Khan. “Sanitation in Indian Railway premises a great cause of concern”, International Journal of Advanced Engineering Technology, 2015

[2] Jesin James Jesse Wilson, Jovna Jetto, Alna Thomas & Dhahabiya V K(2016), “Intelligent Track Cleaning Robot”, Proceedings of IEEE International Conference on Mechatronics and Automation, pp. 332-337.

[3] Novel Kumar Sahu, B.Shahique Raza, Ashu Kumar Pandey &Rupendra Marre, “To Study Of Speed Controlled Railway Track Cleaning System“, International Journal of Mechanical And Production Engineering, , Vol. 5, No. 11, ISSN: 2320-2092, pp. 52-57.

[4] Balasaheb Kasure , Rohit Sondulkar , Rohit Zagade, Hatim Jalal &, Akash Chavan (2019), “A Review on SemiAutomatic Track Cleaning Machine International Journal of Research in Engineering, Science and Management”, Vol. , No. 2, ISSN : 2581-5792, pp 704-707.

[5] G.Kasthuri , E.Rosevangelin, J.Kiruba Golda & .A.Mabel Rajakumarim (2016), “Rail Robot: Autonomous Robot Can Clean And Monitor Your Railway Tracks Data Base To Smart Phone “,International Journal of Advanced Research Trends in Engineering and Technology (IJARTET), Vol. 3, No. 13.

[6] Renupriya.G, Hariharan.G, Deepadharshini.D , Suresh.K & K.Raja (2018), “Automatic Inspection Trolley For Railway Track Crack Detection With Track Cleaning”, International Research Journal of Engineering and Technology (IRJET) , Vol. 05 No. 03, ISSN: 2395-0072.

[7] P. Vamsi Krishna, Dr. S.Prakash, “Intelligent Railway Track Cleaning Robot with Waste Segregation”, International Journal of Advanced Engineering Technology, Vol.20, No 7s, 2020, pp 4895-4899