Design and Manufacturing of Automatic Classroom Vacuum Cleaning Robot

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***Abstract*— Automation is one of the trending subjects surrounding the manufacturing industry in the 21st century. Not only does it help manufacturers keep up with growing global demand, it also helps create new job opportunities as well as help a manufacturer progress into the 21st century. With the advancement of technology, robots are getting more attention of researchers to make life of mankind comfortable. This paper discusses the design of prototype of Automatic Classroom Vacuuming Robot (using User Interface Elements in Power Control of Electronic Devices employed in Office/Consumer Environments). The robot works autonomously within a confined space (in this case classroom) and requires human intervention only to transfer it from one class to another. The robot is designed to replace human efforts with automation and can be a radical technology if made affordable.**

***Keywords*— Automatic, vacuum, lobed wheels, classroom cleaning.**

I. INTRODUCTION

Robot - an electromechanical device automates the work in many areas like industrial power plants, military applications, Domestic works, agricultural applications, etc. Robots are reliable means to bring objects, do settings, clean area, etc at places where human interventions are rather impossible or can cause hazardous effect on human health i.e., at nuclear power plants, chemical factories.

The paper focuses on the development of an automatic vacuum cleaning robot. The robot mainly vacuums the classroom by entering into the benches.

Need of the project:

Cleaning of classrooms is a very difficult task for humans, as it is required to clean below the benches. Most of the dirt (mud, paper, wrappers, etc.) is found in the space below the benches. When humans clean the classrooms nearly all dust is stuck under the rods of the benches. Also, the person cleaning the room needs to kneel down after every bench in order to clean it. This makes cleaning the classroom a very tedious task.

II. LITERATURE REVIEW

In “Autonomous Vacuum Cleaner” (Robotics And Autonomous Systems) by Iwan Ulrich the Authors talk about broad topics which include Selection of shape of robot, selection of Cleaning mechanisms, Sensor systems and mapping of obstacles using these Sensors.

In this paper their Robot relies on the 54 tactile sensors placed on the robot and the area they are trying to clean have uncertain extent and obstacles. So they have assumed only four kinds of obstacles (wall, legs, concave and convex corners) for programming purposes. They have also considered the type of vacuum cleaner that needs to be used based upon the power supply available. Navigation is explained in terms of obstacle identification, hypothesis and map creation. [1]

The paper “Development of a Vacuum Cleaner Robot” (Alexandria Engineering Journal) by T.B. Asafa gives us information about the characteristics that need to be considered while developing the robot. It gives us an idea about the considerations taken in order to design the aspects like Geometry, sweeper position, Dustbin size, cooling provisions, Electrical equipment, Controllers, Chassis and sensors. [2]

The paper “Design of Dual Purpose Cleaning Robot” (International Conference on Robotics and Smart Manufacturing) by Raj Vishaal gives information about the design of a dual purpose cleaning Robot which can be used for cleaning walls as well as the floor. The author also gives information about Electric Ducted Fan and how it is used in Adhering the robot to the glass walls. The floor cleaning system is manually controlled using Bluetooth signals from a Smartphone while the wall cleaning is carried out automatically. The robot has been designed in two parts namely the base module and the cleaning module. These two are attached by the supporting ropes. [3]

The paper “Floor Cleaning Robot with Mobile-App or Autonomous” by Vatsal Shah deals with the research and development of Manual Phone application controlled as well as fully autonomous Robot. It highlights the key parameters that need to be taken into consideration while designing the robot like Obstacle avoidance, Floor detection, Collision detection, Fan motor monitoring, Light Sensing, Real time Clock, etc. The paper also gives a detail description of methodology followed as well as the components used in the development of the robot. [4]

III. DESIGN OF WHEEL

The main obstacle for wheel was to cross over the side rod of 30 mm height. The following alternative wheel designs were considered:.

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A. Origami Wheels:

These wheels are deformable in shape and size.

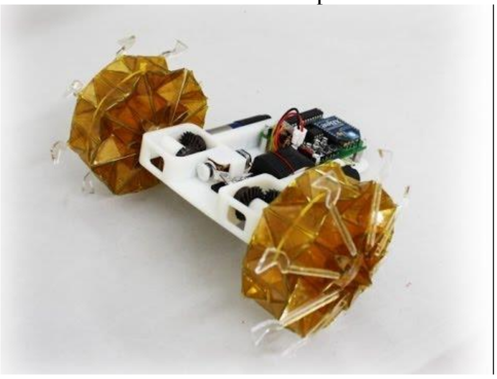

Fig. 1. Origami wheels [5]

B. Track Wheels:

These wheels are mainly used in tank robots

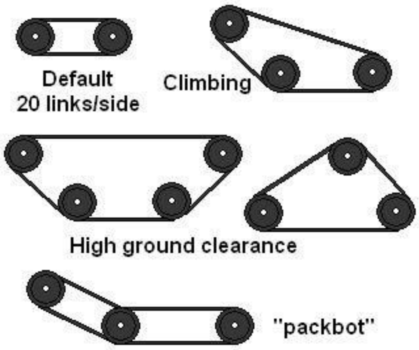

Fig. 2. Track Wheels [6]

C. Loper wheels:

These are the wheels from which the wheelsused in this robot have been derived, according to the requirement.

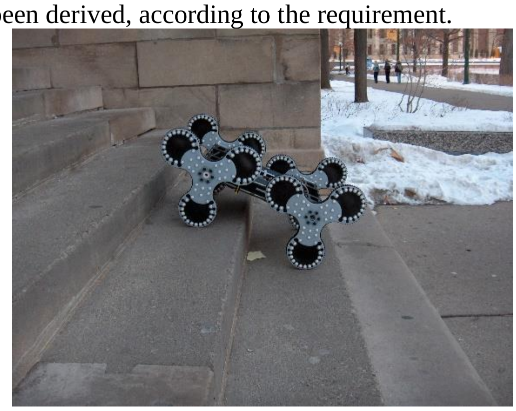

Fig. 3. Loper Wheels [7]

It was observed that Loper wheels would be easier to manufacture and economic as well. So prototyping was performed with a three loped loper wheel.

- *Selection of wheels:*

The Loper wheels were manufactured and tested. The three loped loper wheels had the problem of sequential fluctuations. In order to overcome this problem, a wheel having five lopes was tested. The results showed that the fluctuations were reduced at some scale. After testing it was observed that the fluctuations decreased as the number of lopes increased. So, a seven loped wheel was manufactured and tested. The results of this wheel's testing indicated a considerable reduction in fluctuations, so, the seven loped wheel was selected.

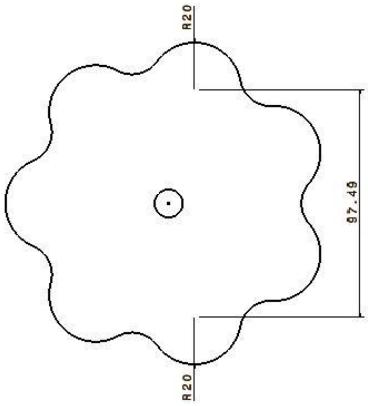

Fig. 4. Draft of Seven Loped wheels

IV. DESIGN OF CHASSIS

Figure 5 shows the overall dimensions of the designed chassis. The chassis was designed considering the required motion and the load to be carried.

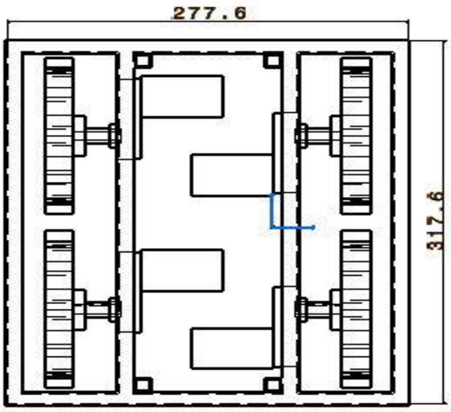

Fig. 5. Overall Dimensions of chassis

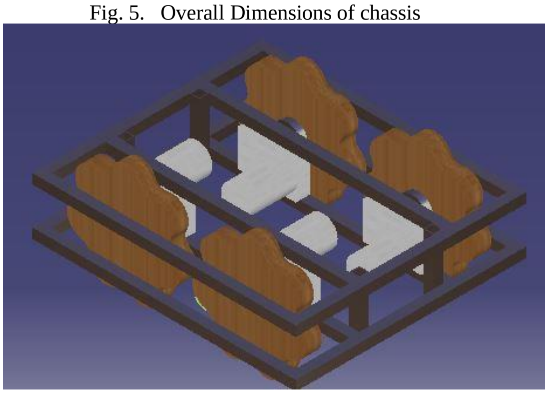

Fig. 6. 3D model of chassis

V. MOTOR CALCULATIONS FOR NAVIGATION

$$F_{\max} = m_{bot} \times g \times \mu \quad (1)$$

Equation (1) is used to calculate the maximum Friction force acting between the wheels of robot and the floor.

Where, F_{max} = maximum friction force without skidding,

m_{bot} = mass of entire bot,

μ = coefficient of friction between silicon rubber tyre & floor

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= 0.5

F_{max} = 5×9.81×0.5 = 24.525 N

a_{max}=F_{max} / m_{bot} = 9.81×0.5 = 4.905 m/s^2

F_{req} = (m_{bot}/2) × a_{req} = 2.5×2 = 5 N

Where, F_{req} = Force required at each wheel,

a_{req} = acceleration required

$$T_{req} = F_{req} \times r_{wheel} \qquad (2)$$

Equation (2) is used to calculate the torque that the navigation motor will be required to provide inorder to move the robot.

Where, T_{req} = Torque required,

r_{wheel} = Radius of wheel

T_{req} = 5×0.05 = 0.25 Nm

VI. VACUUM DESIGN

- *Principle*

Vacuum cleaner selection is based on Bernoulli's Principle. Bernoulli's theorem implies that if the fluid flows horizontally so that no change in gravitational potential energy occurs, then a decrease in fluid pressure is associated with an increase in fluid velocity. If the fluid is flowing through a horizontal pipe of varying cross-sectional area, for example, the fluid speeds up in constricted areas so that the pressure the fluid exerts is least where the cross section is smallest. This phenomenon is sometimes called the Venturi effect.

- *Vacuum*

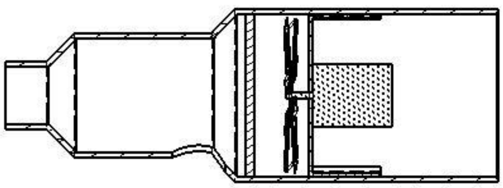

Fig. 7. Sectional View of the Vacuum

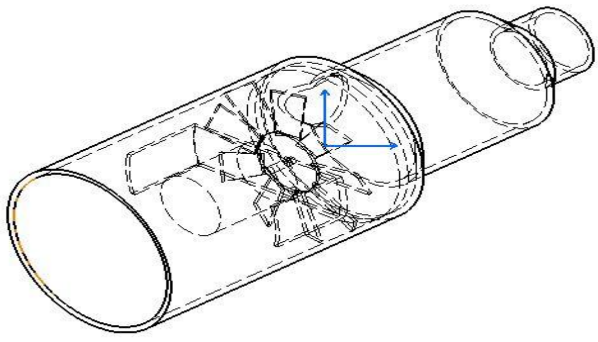

Fig. 8. Isometric View of the Vacuum Draft

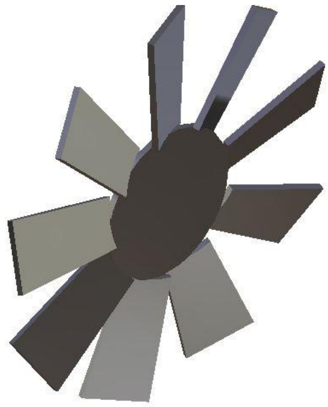

Fig. 9. Blade of Vacuum

VII. BLADE/VACUUM CALCULATION

$$Area = \frac{\pi}{4}(D^2 - d^2)$$

= 3873.58 mm^2

DE = DB × sin (15^0)

= 45/4 × sin (15^0)

= 2.9117

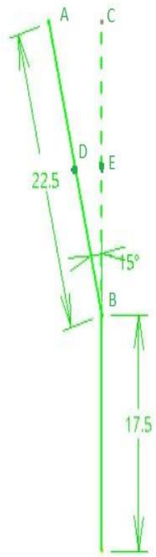

Fig. 10. Cross section of blade

Volume in 1 rotation

= 2.9117 × 3873.58 × 8

= 90230.06 mm^3

RPM = 7000 rpm

$$\frac{Volume}{min} = 90230.06 \times 7000$$

= 18.046 lit/sec

= 0.01805 m^3/sec

AT Dia (D) = 90 mm

$$Velocity = \frac{0.01805 \times 4}{\pi \times 90^2}$$

= 2.836 m/s

AT Dia (d) = 32 mm

$$Velocity = \frac{0.01805 \times 4}{\pi \times 32^2}$$

= 22.438 m/s

VIII. FINAL ASSEMBLY

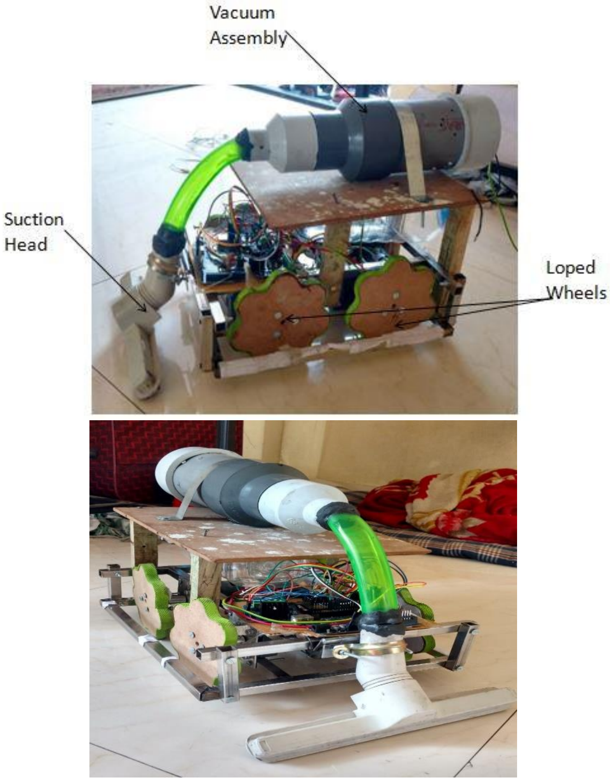

Fig. 11. Final Assembly

Figure (11) shows the complete assembly of the vacuum cleaner.

IX. TESTING AND OBSERVATIONS

- ***Testing Stage 1:***
  Test of Climbing Capacity of robot was performed.
  Observations:
  1. Robot climbed the rod successfully.
  2. The rpm provided during test was too high for the process.
  3. The robot was observed to deviate to right side. The PWM of right front motor was increased. Still the deviation continued at a certain scale.
- ***Testing Stage 2:***
  The linearity issues of robot motions during first test were sever.
  In order to improve that, PWM was changed but still the problem remained. Later it was observed that the torque providing capacity of a front right motor was reduced. Moreover due to some current rating issues we had to change all the four motors and replace them with new 200rpm Johnson's geared motors.
  The linearity of the robot was corrected and the robot stopped deviating towards right.
- ***Testing Stage 3:***
  The Vacuum arrangement was tested with an 8 V battery and it worked satisfactorily.
- ***Testing Stage 4:***
  The entire assembled robot was tested. After assembling all the parts on the robot, the testing of feedback code was performed.

  Observations:
  1. Robot navigation was tested and found to be satisfactory.
  2. The robot accumulated almost 55 to 65 percent of the dirt samples.
  3. Reduced suction capacity of the vacuum was observed which may have happened due to following two reasons.
     A. Due to distribution of same current from 12V battery to the navigation motors as well as vacuum motor, navigation motors draw more current and thus the capacity of the vacuum motor is found to reduce.
     B. The motor drivers use PWM to control the vacuum motor, the signals of which vary between its maximum and minimum value. The dc motor used found it difficult to draw more voltage from the motor driver. And hence motor driver were observed to heat at extreme level.
  4. During this testing phase the gears of the motor were observed to slip multiple times. This was due to jerk observed during the entry and exit of the robot from the rod.
  5. The average time for robot to clean and navigate through one bench was observed to be 22 sec.

X. SUMMARY

Problem statement of the project was decided by rigorous discussion about the problems faced in day to day life and their feasible solutions. After confirming the title we came up with an initial design. But later through internal discussions and advice by our guide it was observed that the proposed design wasn't economical to manufacture and more over the weight constrains were huge. So later a better design was introduced and finalized. Manufacturing of the proposed robot helped us to learn a wide range of manufacturing skills including carpentry, welding, fitting etc. Also a wide portion of the project included electronics and thus design and assembly of the same helped us to trigger the interdisciplinary approach within our mindset. After manufacturing the physical features and assembly of electronic circuits the robot was tested within a certain scope defined earlier, and was found to satisfy the predetermined objectives to a considerable extent.

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