DESIGN AND FABRICATION OF FACADE CLEANING MINIBOT

A PROJECT REPORT

Submitted by

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in partial fulfilment for the award of the degree

of

BACHELOR OF ENGINEERING

in

MECHATRONICS ENGINEERING

SRI KRISHNA COLLEGE OF ENGINEERING AND TECHNOLOGY

(An Autonomous Institution, Affiliated to Anna University Chennai – 600 025)

APRIL 2023

SRI KRISHNA COLLEGE OF ENGINEERING AND TECHNOLOGY
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BONAFIDE CERTIFICATE

Certified that this Mini project report **DESIGN AND FABRICATION OF FAÇADE CLEANING MINIBOT** is the bonafide work of **HERBERT BEVAN T (20EUMT023), KINGLSEE RABEL J (20EUMT030) & KISHOOR H S (20EUMT031)** who carried out the project work under my supervision.

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INTERNAL EXAMINER EXTERNAL EXAMINER

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SYMBOLS

ø - ANGLE IN RADIANS

μ - PERMIABILITY

π - Pi

ACKNOWLEDMENT

At this juncture, we take the opportunity to convey our sincere thanks and gratitude to the management of the college for providing all the facilities to us.

We wish to convey our gratitude to our college principal, **Dr.J.JANET**, for forwarding us to do our project and offering adequate duration to complete our project.

We would like to express our thanks to **Dr.M. LYDlA**, Head of the department, Department of Mechatronics Engineering for her encouragement and valuable guidance in this project.

We extend my gratitude to our beloved guide **Dr.V. NARASIMHARAJ**, Associate Professor, Department of Mechatronics engineering for her constant support and immense help at all stages of the project.

We would like to express our sincere thanks to all the staffs of Department of Mechatronics Engineering for their encouragement and valuable guidance in this project.

ABSTRACT

This abstract describes an automated mini-bot designed for cleaning by climbing walls. The bot is equipped with specialized suction mechanisms and sensors to navigate various surfaces and clean efficiently. The bot can operate autonomously, and its compact size allows it to access tight spaces and hard-to-reach areas, making it ideal for cleaning walls and other vertical surfaces. Its smart technology allows for efficient and thorough cleaning while reducing the need for human labour.

This innovative cleaning solution is not only practical but also environmentally friendly, as it reduces the use of harmful chemicals and minimizes energy consumption. Overall, the automated mini-bot is a promising technology that could revolutionize the cleaning industry, providing an efficient and cost-effective way to keep surfaces clean and hygienic. The mini-bot's design is optimized for manoeuvrability and stability, allowing it to cling to walls and other surfaces with ease. It can also detect and avoid obstacles, ensuring safe and efficient operation.

With its compact, the mini-bot is ideal for use in homes, offices, and other commercial settings. Its versatile design allows it to clean a variety of surfaces, including walls, ceilings, and even windows. The automated mini-bot for cleaning is a cutting-edge technology that combines efficiency and convenience to revolutionize the way we clean our living and workspaces.

Moreover, the mini-bot's climbing ability eliminates the need for ladders, scaffolds, or other equipment, making it an ideal solution for high or hard-to-reach areas. This not only saves time but also minimizes the risk of accidents and injuries associated with manual cleaning methods. The mini-bot is also equipped with a rechargeable battery, allowing for extended operation times without the need for frequent recharging. Its compact design and portability also make it easy to store and transport when not in use. Overall, the automated mini-bot for cleaning is a game-changer in the cleaning industry, offering a safe, efficient, and cost-effective way to keep surfaces clean and hygienic, without the need for human intervention.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

There is an increasing need for climbing robots to clean, weld or inspect different kinds of surfaces of high buildings, large oil tanks and rough concrete facilities. Currently, most wall-climbing robots are intended for maintenance or inspection in certain environments, such as the exteriors of buildings, bridges, or dams. These robots can replace humans in some tasks such as glass exterior wall cleaning. Most of these robots use propulsion force from propellers to attach to a wall during cleaning tasks. They can overcome obstacles using propellers, by changing the propulsion force.

Window cleaning is usually a tedious, boring and repetitive task and thus a clear candidate for this job is application of robotics. By implementing this application, the cleanliness of glass doors and windows can be assured in commercial showrooms.

This technique may result perfection in the overall cleaning process. With its compact design, the mini bot can easily navigate tight spaces and hard-to-reach areas, making it an ideal tool for cleaning windows in homes, offices, and other commercial buildings. It can be programmed to move in different patterns to ensure that every inch of the window is cleaned thoroughly. The mini bot typically consists of a small motor, a set of wheels, and a cleaning pad or cloth.

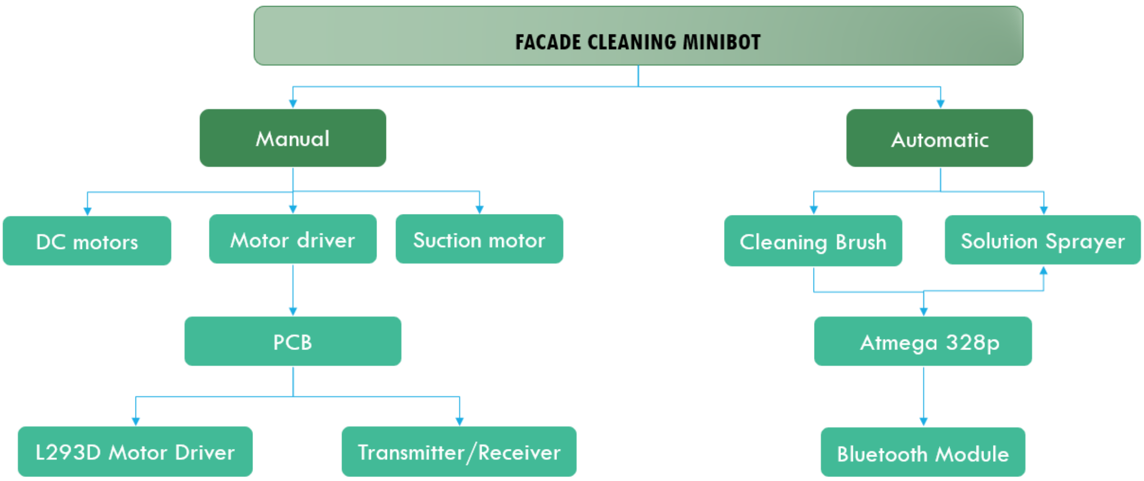
It is designed to move across the window in a controlled and precise manner, ensuring that it covers the entire surface and removes all dirt and grime. It is a highly specialized device that can navigate across the surface of a window and clean it thoroughly without leaving any streaks or smudges. The mini bot is an excellent tool for cleaning windows in a variety of settings, including homes, offices, and other commercial buildings. It is highly efficient and can save a lot of time and effort compared to manual window cleaning methods.

1.2 OBJECTIVE OF THE PROJECT WORK

To Design and Fabricate a mini bot for cleaning windows that runs automatically which can be controlled using Bluetooth and the cleaning is done fully automatically without human intervention.

1.3 METHODOLOGY

The development of a minibot for cleaning involves several steps including Manual and Automatic controls. The manual mode consists of DC Motors, Motor Driver and Suction Motor. The Motor driver is connected with PCB and then a Driver motor and A Transmitter/Receiver is also connected to control the bot manually. The Automatic mode consists of Cleaning Brush and Solution Sprayer which is controlled using Arduino and Bluetooth Module.



1.4 REPORT OUTLINE

CHAPTER 1 discusses the basic outline of the project and where the project has been used. The outline of the project is also been discussed in this chapter.

CHAPTER 2 discusses the critical analysis and evaluation of existing research on wall climbing robot and window cleaning bot. It involves identifying, analysing, and synthesizing relevant literature to gain an understanding of the current state of knowledge and identify gaps or areas for further research.

CHAPTER 3 deals with the design of the components for the minibot. The design of bot components is a critical component of bot development. By following a structured methodology, detailed design, prototyping, iterative refinement, finalization, quality assurance, and deployment, bot components can be optimized for functionality, reliability, and cost-effectiveness.

CHAPTER 4 discusses the process of designing and developing the minibot. SBy following a structured methodology that includes defining the design criteria, analysing forces and stresses, determining dimensions and materials, calculating loads and capacities, determining power requirements, and verifying the calculations, engineers can ensure that bots are optimized for functionality, reliability, and safety.

CHAPTER 5 deals with the block diagram and CAD model of the minibot. It consists of visual representation of the different components and their interconnections in a system and a digital 3D representation of the physical design of a component or system.

CHAPTER 6 discusses the creating a virtual model of a system or process to study its behaviour and performance. Simulation can be used to test and optimize a bot design before it is built, or to study its performance in different operating conditions.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Robotics technology has been constantly developing during the past two decades. Over recent years, several researches have been conducted to develop climbing robots to eliminate humans from laborious and dangerous tasks. The idea of having a compact and autonomous office or house window cleaning robot is quite simple and very attractive.

This small window climbing robot with pneumatic suction cups should be able to move autonomously along an outside surface of high-rise building office window with a relatively large area and meantime clean and wash it. Being manually attached to the outside surface of the room window the robot will execute and accomplish the task of window cleaning automatically.
Cleaning of walls of tall buildings is one of the applications of the climbing robot.

This robot is designed in such a way that the cleaning module alone can also be used to clean the floor in which the EDF acts as a vacuum cleaner along with a vacuum pump to spray the cleaning fluid. Hence both dry and wet cleaning of floor can be done.

The movement is manually controlled using Bluetooth signal from a smart phone, while wall cleaning is carried out automatically using sensors.

2.2 PROBLEM STATEMENT

SMART INDIA HACKATHON 2022

PROBLEM STATEMENT DETAILS

Description	To reduce the workforce of the mankind, novel robots should be introduced to perform the day to day dedicated task as like as human beings in the betterment and fast completion process of the task
Organization	Government of Rajasthan
Category	Hardware
Domain Bucket	Robotics and Drones
Youtube Link	
Dataset Link	NA

2.3 LITERATURE REVIEW

Design of dual-purpose cleaning robot. Raj Vishaal *et al. [1]*By installing an Electric Ducted Fan (EDF) and support ropes from base module placed on the parapet for adhering the clearing module to the glass wall. EDF acts as a vacuum cleaner which can also be used to clean the floor. It is manually controlled using Bluetooth signal from a smart phone. here are many vertical climbing robots that climb buildings and various other structures through different mechanisms. However, each of them has their own limitations [9]. Until now, several types of wall cleaning robots with special locomotion have been proposed. Most of them are using vacuum suction alone as an adhering unit. Some of them have the driving wheels to make continuous movement on the wall. Others use legged motion to make a discreet walking on the wall. But it is difficult to apply these kinds of vacuum suction-based window cleaning robots to the real domestic environments. The robot should be mechanically stable from falling down and must possess an autonomous operating system with no human interference during the entire cleaning stage. Most of vacuum suction-based window cleaning robots do not meet such requirements. Some small size window cleaning robots have also been developed during past researches. Also, there are commercially available window cleaning robots such as Windoro, Winbot and Hobot that clean windows of domestic places. But these are limited to cleaning glass windows indoors. To overcome these above limitations, we have proposed a simple dual purpose cleaning robot in this paper. This robot is capable of cleaning floor and plane glass wall without any obstacles. The robot consists of a base module and cleaning module whose functions will be explained in further sections of this paper. We have used an EDF similar to the one which was used by GECO wall climbing robot for adhering the robot to the wall.

Wall Climbing Glass Cleaner Robot. Manish Donode *et al. [2]* The purpose of this paper a capable of a simple and light weight robotic structure. It combines a set of motions composed of parallel linear motion, rotational motion and interference avoidance motion. In modern society, there is an increasing need for climbing robots to clean, weld or inspect different kinds of surfaces of high buildings, large oil tanks and rough concrete facilities, replacing workers in these hazardous environments. Consequently, robotic technologies have been developed and applied according to the need sin different fields. However, some problems, such as difficulty in overcoming barriers and complex structures, also emerge. So, the robotic structure developed in this paper will be designed to clean wall glass. Main motive of robot is to climb and move on glass surface. Centrifugal impeller is used for generating low-pressure area for proper adhesion on the wall surface. The motions that can be performed by the robot are, Parallel linear and rotational motion, Interference avoidance motion.

Design of window-cleaning robotic manipulator with compliant adaptation capability. Joo young Hong *et al.[3]* Efforts have been made to substitute robotic solutions for human workers. Wall Bot and Skypro use propulsion force from propellers to attach to a wall during cleaning tasks. A building façade maintenance robot (BFMR) moves in vertical and horizontal directions on guide rails installed on the buildings. ROPERIDE moves in the horizontal direction by using a winch system in the platform that winds up a rope tied to the roof of the building. KITE robotics developed robots using wires connected to the four edges of buildings; the robots move on the window by changing the length of the wire(s). One unmanned high-rise façade cleaning robot mounted on a gondola ("FCR-M1") uses a two-degree-of-freedom (2-DOF) manipulator to maintain contact with the window against the gondola swing. Also, HOBOT and WINBOT are the window cleaning robots that attached on windows using suction motor making vacuum between the robots and the windows.

Review of classification for wall climbing robots for industrial inspection applications. Ahmad Hajeer *et al. [4]* Climbing Robots (CR) are robots that are capable of ascent and descent over rough terrain, stairs, trees, cables and any other objects. Thus, WCR are a subsection of CR. WCR are robots that are capable of ascending and descending vertical surfaces freely using adhesion, whereas CR usually lack an attachment method. The main feature of WCR is that they have the ability to climb walls and vertical surfaces freely, without external assistance. On the other hand, CR can only climb on objects, e.g., poles or trees, and not only vertical flat surface. The adhesion or attachment method is the second feature that is associated with the WCR. Differentiation between CR and WCR is vital for identifying the capability of a robot to climb vertical flat surfaces and walls. Moreover, the division makes it easy for the industry end-user to categorise the requirements for the use of CR or WCR.

A pressing attachment approach for a wall-climbing robot utilizing passive suction cups. Ding Xin Ge *et al.[5]* Adhesion materials can be used on complex surfaces, but they are difficult to use on rough surfaces. Grasping mechanisms can also be employed on complex surfaces, but they damage the surface. Therefore, the choice of adhesion mechanism plays determinant role in the design of wall-climbing robots. Since suction cups can achieve non-destructive examination and navigate on smooth surfaces, suction cups are extensively utilized as the adhesive mechanism for wall-climbing robot. Suction cups can be divided into active suction cups and passive suction cups. Wall-climbing robots using active suction cups possess the advantage that the status of attachment and detachment can be easily controlled. However, a pump needs to output continuous energy to maintain the attachment, and a large amount of noise is generated. In addition, pumps result in a heavy payload for wall-climbing robots. On the other hand, wall-climbing robots utilizing passive suction cups offer the features of no noise and light weight because there is no need for a pump to provide energy to maintain attachment. However, it is quite challenging to control the attachment and detachment.

Design and control of a wall cleaning robot with adhesion-awareness. M. A. Viraj J. Muthu gala *et al. [6]* Vacuum suction mechanisms are widely used in this regard. The suction force acting on the robot due to the negative pressure built up is used by these robots for the adhesion. A robot will fall off or overturn when the pressure difference drops down a certain threshold. In contrast, if the pressure difference becomes too high, the excessive number of frictional forces will hinder the locomotion ability. Moreover, a wall cleaning robot should be capable of adapting the adhesion force to maintain the symmetry between safe adhesion and reliable locomotion since adhesion forces which are too low or too high hinder the safety of adhesion and reliability of locomotion respectively. Thus, the pressure difference needs to be sustained within a desired range to ensure a robot’s safety and reliability. However, the pressure difference built up by a vacuum system may unpredictably vary due to unexpected variation of air leakages due to irregularities in surfaces. The existing wall cleaning robots that use vacuum

suction mechanisms for adhesion are not aware of the adhesion status, or subsequently responding to them. Therefore, this paper proposes a design for a wall cleaning robot that is capable of adapting vacuum power based on the adhesion-awareness to improve safety and reliability. A fuzzy inference system is proposed here to adapt the vacuum power based on the variation of the adhesion and the present power setting of
the vacuum.

Design of an adhesion-aware façade cleaning robot. M. A. Viraj J. Muthu gala, *et al. [7]* Many glass facade cleaning robots that use passive suction cups for attaching to vertical wall surfaces have been developed. One critical shortcoming of suction cups-based mechanism is the loss of negative pressure due to air leaking and subsequently fails to attach a robot to a wall. Approaches have been developed to overcome this. For example, the method proposed in uses a complex mechanical and control functionalities to push a suction cup periodically. However, such mechanisms cause much overhead for robots. Furthermore, glass façade cleaning robots should be capable of manuring within a windows frame as well as transiting from a window frame to another window frame for efficient operation. This kind of transitions and some advanced manoeuvring cannot be achieved without performing detaching and attaching of a robot to a wall by controlling the suction cups attached to the robot. For achieving such controllability from a suction cup-based mechanism requires complex mechanical designs and controls. In contrast, vacuum pump based adhesive mechanisms have greater flexibility in controlling their suction force. Moreover, vacuum pump based on electrical motor-based impeller systems can be easily controlled by varying the electrical signals to the motor. Therefore, vacuum pump based adhesive mechanisms are widely used in glass facade cleaning robots. Furthermore, this mechanism is well suited for reconfigurable robots that can transit through window frames since it provides the ability to control the suction force easily]. Nevertheless, there can be issues in sealing of the mechanism with the wall surface that endangers the safe and reliable stay of a robot on the glass surface.

An Autonomous Wall-Climbing Robot for Inspection of Reinforced Concrete Structures. Gabriela Gallegos *et al. [8]* To design climbing robots for industrial applications, it is important to consider the operating environment and the task to be carried out. Robots that can climb on nonferrous surfaces tend to employ either suction cups or dynamic vortex adhesion methods which produce a vacuum with fast-spinning impellers. These methods require constant energy supply lines for long inspection times which result in long umbilical cables. To climb on structures constructed from ferrous materials, permanent magnets or electromagnets are preferred as they provide higher adhesion forces. Electromagnets control the adhesion force on demand but again require a constant energy supply to maintain adhesion to a structure. Permanent magnet adhesion is the best method for robots climbing on ferrous structures as the force is constant and can be engineered to be high with magnetic flux focusing techniques, does not need the application of power, and is fail-safe in the event of power failure to the rest of the robot. SIRCAUR has been designed to use permanent magnets to adhere to reinforcement bars (rebars) buried in concrete and to use GPR to detect rebar corrosion and other concrete defects. The design of the climbing robot has attempted to increase payload capacity, mobility, adhesion safety, and to minimise energy consumption. Permanent magnets are used for the adhesion method for two reasons: The method does not require energy consumption, therefore, avoiding the use of heavy batteries that will increase the payload. In case of a power failure, the crawler will remain attached to the surface providing a safety feature. Our previous research to develop the technology to focus magnetic flux to couple with rebars buried in concrete and develop concrete climbing robots has been reported.

Development of a wheeled wall-climbing robot with a shape-adaptive magnetic adhesion mechanism. Haruhiko Eto *et al. [9]* Welding is one of the most critical manufacturing processes in heavy industries. Shipbuilding, for example, requires a number of welding operations. Fully autonomous welding machines are still impractical and difficult to use owing to the complexity of the environment and the variety of workpieces. Although various welding robots, including portable platforms, have been developed and summarized in [1] and [2], most of them have been designed for well-organized environments, which are approximately a straight shape or a uniformly curved surface relative to the robot size. However, there are many uneven workpieces in our shipbuilding factory. Because existing robots are not able to work on such workpieces due to their poor mobility, human workers are required to work on scaffolds to perform welding tasks. Our objective is to build a new mobile robot mechanism that can work on actual shipbuilding workpieces. The robot mobility should cover two capabilities in this context: Climbing capability: The robot should be able to move on surfaces of a three-dimensional (3D) object. The surface can be a wall or a ceiling for the robot. The robot must always stick to a surface with any incline angle. Surface shape adaptability: The robot should be able to fit on uneven surfaces. The robot structure should not only be compliant to the shape of the surface, but also structurally rigid to work as a base part of a torch manipulating mechanism. Wall-climbing robots are the only robot type that has the highest mobility of the existing welding robot technologies. Various locomotion and adhesion principles for wall climbing tasks have been studied and developed not only for welding applications. Legged locomotion has been popularly studied with negative pressure adhesion mechanisms. Legged climbing robots that use suction cups have the capability of adapting to a large variety of surface geometries and materials.

Portable autonomous window cleaning robot. Nazim Mir-Nasiria *et al.[10]* The robot climbs on the surface of window glass by means of four suction cups and wipes the surface simultaneously with a rotational wiper. WCR is characterized as lightweight and mini-size. Various shapes and mechanical structures of robots were designed by the researchers. The proposed was a robot which consists of a triangular frame and uses suction cup-based adhesion technique to adhere to the glass surface. The frame consists of an automated cleaner which is run by motors and pre-programmed microcontrollers. The automated cleaner moves in the vertical direction within the frame using the threaded shaft. Another work highlights the development of washing-cleaning or periodical inspection of operational robot's systems, proposed to use at the exterior frontage of buildings that are built from modular glass panels. Some other designed robots are able to independently climb and descend in the vertical direction and cleans in the horizontal direction. It takes the circling tracks as supports for climbing up and down between strips and moving horizontally along one strip around the ellipsoid. In a separate work, a machine is proposed that can stick on dividers and climb upwards to clean the glass of high-rise buildings. he aim of another work is to design, develop and implement Window Washing Robot which helps to achieve low-cost window cleaning device. Some simulation studies were conducted to demonstrate the feasibility of a robot system to act and mimic the human operator; an end effector had to be designed to accommodate different tools such as applicator and squeegee; the payload for tool handling, sensory feedback requirements; force and compliance control; and finally, the cost of the overall system had to be feasible.

2.4 GAP ANALYSIS AND DESCRIPTION

- A very few implementations has been taken over in this case of cleaning glass doors and windows in commercial showrooms.
- As of now, manpower is used to achieve this specific task.
- By implementing our project, we can find a solution by turning this into fully automated process and this will result in a one time investment and a long term benefit.

CHAPTER 3
DESIGN OF BOT COMPONENTS

3.1 INTRODUCTION

The prime motive of this chapter is to provide the fine details about the components being used, their material, and the quantity of each component involved in the project. It also illustrates the processing steps to complete the project.

3.2 COMPONENTS

- BLDC Motor
- Wall adherence control PCB board
- Miniature vacuum pump
- Bluetooth module
- Arduino
- Rechargeable battery
- Brush

3.2.1 Single shaft BO Motor

A single shaft BO motor, also known as a single-shaft brushed DC motor, is a type of electric motor that is commonly used in a wide range of applications. The motor consists of a stationary stator and a rotating rotor that is connected to a single output shaft. The shaft rotates when the motor is powered, and this rotational motion can be used to drive other mechanical components such as wheels, gears, or pulleys.

Figure 1.1 Single shaft BO motor

3.2.2 Wall adherence control PCB board

Printed circuit boards are used in nearly all electronic products. Alternatives to PCBs include wire wrap and point-to-point construction, both once popular but now rarely used. PCBs require additional design effort to lay out the circuit, but manufacturing and assembly can be automated. Electronic design automation software is available to do much of the work of layout. Mass-producing circuits with PCBs is cheaper and faster than with other wiring methods, as components are mounted and wired in one operation. Large numbers of PCBs can be fabricated at the same time, and the layout has to be done only once. PCBs can also be made manually in small quantities, with reduced benefits.

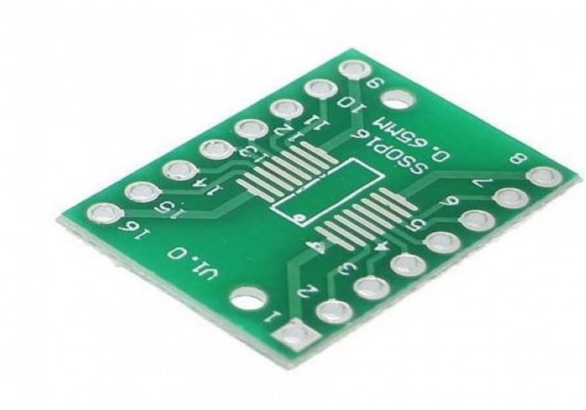


Figure 1.2 PCB

3.2.3 BLDC MOTOR

BLDC motor, short for Brushless DC motor, is a type of electric motor that operates on DC current but uses a different type of commutation system compared to brushed DC motors. Instead of using brushes and commutators to switch the direction of current flow in the motor windings, BLDC motors use electronic controllers to energize the stator windings at the right moment to create a rotating magnetic field. The rotor in a BLDC motor contains permanent magnets, and the magnetic interaction between the stator and rotor creates the torque that drives the motor.

Figure 1.3 BLDC motor

3.2.4 BLUETOOTH MODULE

A Bluetooth module is a small electronic device that enables wireless communication between electronic devices using Bluetooth technology. It consists of a small circuit board that contains a Bluetooth chip, antenna, and other necessary components for wireless communication. Bluetooth modules can be classified into several types based on their form factor and functionality, including plug-in modules, surface mount modules, and system-on-chip (SoC) modules. Plug-in modules are designed to be plugged into a pre-existing electronic device or system, while surface mount modules are directly mounted onto a PCB. SoC modules integrate both the Bluetooth chip and microcontroller onto a single chip, providing a more compact and integrated solution.

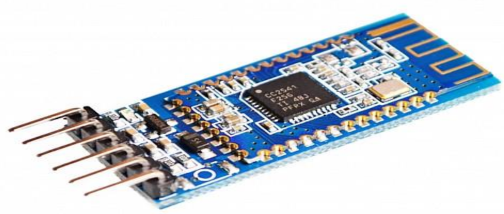


Figure 1.4 Bluetooth Module

3.2.5 ARDUINO

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It consists of a single-board microcontroller, programming language, and development environment, which allows users to build and program electronic devices and interactive objects. The Arduino programming language is based on C/C++, but is simplified to make it more accessible to non-expert users. The Arduino development environment provides a simple and user-friendly interface for writing, compiling, and uploading code to the Arduino board. Arduino is widely used in a range of applications, including home automation, robotics, and education. It provides a low-cost and flexible platform for building and experimenting with electronic devices and systems.

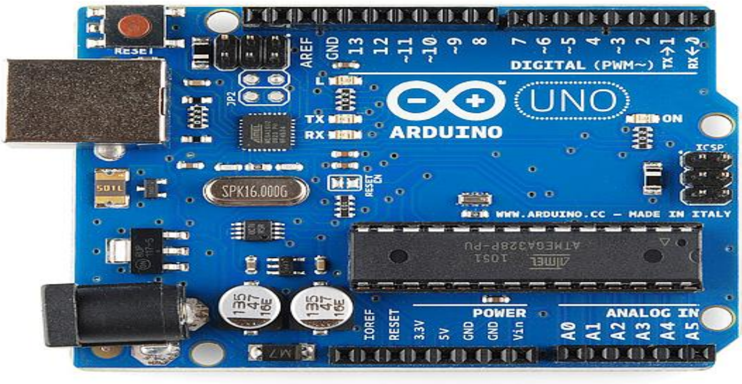


Figure 1.5 Arduino

3.2.6 RECHARGEABLE BATTERY

A rechargeable battery is a type of battery that can be recharged and used multiple times, rather than being disposed of after a single use. It consists of one or more electrochemical cells that can be charged by applying an electrical current to the battery. There are several types of rechargeable batteries available, including nickel-cadmium (NiCad), nickel-metal hydride (NiMH), and lithium-ion (Li-ion) batteries. Each type has its own advantages and disadvantages, and the selection of the appropriate battery depends on the specific application requirements. Li-ion batteries are currently the most popular type of rechargeable battery, due to their high energy density, low self-discharge rate, and long cycle life. They are commonly used in portable electronic devices, such as smartphones and laptops, as well as in electric vehicles and renewable energy systems.

Figure 1.6 Li-po Battery

3.2.7 BRUSH

A cleaning brush is a tool designed to remove dirt, dust, and debris from surfaces or objects. Cleaning brushes come in a variety of shapes, sizes, and materials to suit different cleaning needs. Cleaning brushes can be used with or without cleaning agents. They can be manual, electric or battery-powered. Some cleaning brushes also come with attachments such as extensions or interchangeable heads to make cleaning easier and more efficient.

Figure 1.7 Brush

CHAPTER 4
DESIGN CALCULATIONS

4.1 INTRODUCTION

This chapter will infer the mechanical design and analysis calculations required for Mini bot for cleaning.

4.2 DESIGN AND DIMENSION

Mass = 350g = 0.35Kg

Length = 250mm

Breadth = 120mm

Height = 80 mm

Wheel Radius = 35 mm

Suction Cup radius = 25.4mm

4.2.1 VELOCITY OF THE MINIBOT

Let us assume the velocity of the model as

$$v = 0.15 \text{ m/s} = 0.504 \text{ km/hr.}$$

4.2.2 POWER REQUIRED BY THE BOT

$P = (F + mg) * v$

$mg = 0.35*9.81 \Rightarrow 3.43$

$P = (3.43+3.43) * 0.15$

$P = 1.029 \text{Nm/s}$

4.2.3 SAFETY FACTOR OF THE MINIBOT

1.5 applicable for smooth surface

4.2.4 LOAD CASE

F = m*(g + a) *s

where m = mass

a = acceleration

s = safety factor

a = (F*μ)/m

a = (3.43*0.5)/0.35 = 5m/s^2

F = 3.43*(9.81+5) *1.5

F = 76.19N

Horizontal Suction cup, vertical direction of force

4.2.5 GRIP FORCE FOR CLIMBING THE GLASS

(With reference to the wall/Glass)

Grip force = μ*N

Grip force = 0.5*3.43

Grip force = 1.71N

4.2.6 SUCTION PRESSURE OF THE BLDC

Contact area of Suction Cup = A = πr^2

r = 2.54cm

A = π (2.54)^2 = 20.26cm^2

F = P*A

$F = 76.19N$

$P = F/A = 76.19N/20.26cm^2$

$P = 3.75N/cm^2$

4.2.7 NORMAL FORCE OF THE BOT

Normal force = m* cos ø

At 0˚

Normal force = 0.35*cos (0)

Normal force =0.35N

At 45˚

Normal force =0.35*cos (45)

Normal force =0.24N

At 90˚

Normal force =0.35*cos (90)

Normal force =0 N

4.2.8 GRIP FORCE

μ*m*cosø

At 0˚

Grip Force =0.5*0.35*cos (0)

Grip Force =0.175N

At 45˚

Grip Force =0.5*0.35*cos (45)

Grip Force =0.123N

At 90˚

Grip Force =0.5*0.35 * cos (45)

Grip Force =0 N

4.2.9 MOTOR FORCE

Grip Force + F_f +mg

At 0˚

Force = 0.175+1.715+3.43 =5.32N

At 45˚

Force = 0.123+1.715+3.43 =5.26N

At 90˚

Force = 0+1.715+3.43 =5.14N

4.2.10 SELECTION OF BATTERY

Travel Factor = Total Range/Travel Speed

Here we assume the total range as 1Km

We Know Speed is 0.15m/s =0.54Km/hr

Travel Factor = 1/0.54

= 1.851

Power of Motion Motors

Energy = Weight*Gravity*range

= 0.35*9.8*1000

=3430 J

Power = work/time taken

Assume t=5mins = 300 seconds

Power = 3430/300

= 11.43 watts

According to the power consumed we choose Li-io Battery(12V)

RPM Calculation:

RPM = Battery voltage*Motor Kv

RPM = 12v*2600Kv

RPM = 31200 rpm

Efficiency 80-90%: Battery pack capacity needed

4.2.11 TORQUE WHEN ONLY SUCTION MOTOR RUNNING

Speed of Armature = 31200 rpm

Voltage = 12v

Load Current =0.41amp

Output Power:

P=v*I

= 12*0.41

P= 4.92 Watts

4.2.12 TORQUE DEVELOPED IN SUCTION MOTOR ARMATURE

T=(P*60)/(2*π*N)

T=(11.42*60)/(2*π*31.2)

T= (685.2)/195.36

T=3.50Nmm

4.2.13 TORQUE WHEN SUCTION MOTOR AND WHEEL RUNNING

Speed of suction motor =31200rpm

V=12v I = 0.72amp

Speed of DC Motor(N)=60rpm

Work done/s = F* 2πr*N/60

r=0.45cm

T=f*r

= 3.43* 2πr*60/60

=9.7Nm/s

4.2.14 WORK DONE IN 2 DC MOTORS FOR MOTION

=9.7*2

=19.4Nm/s

4.2.15 SPEED OF MOTOR BRUSH

N=60rpm

T=(P*60)/(2*π*N)

=685.2/376.8

T=1.81Nmm

No. of Motor Brush =2

=1.81*2

=3.62Nmm

Totally 4 motors

So, 4*11.43 = 45.72 watts

=45.72*1.851

=84.62

=84.62/0.85

=99.55 kwh

4.2.16 BENDING MOMENT FOR SIMPLY SUPPORTED BEAM

Calculation of Ma-:

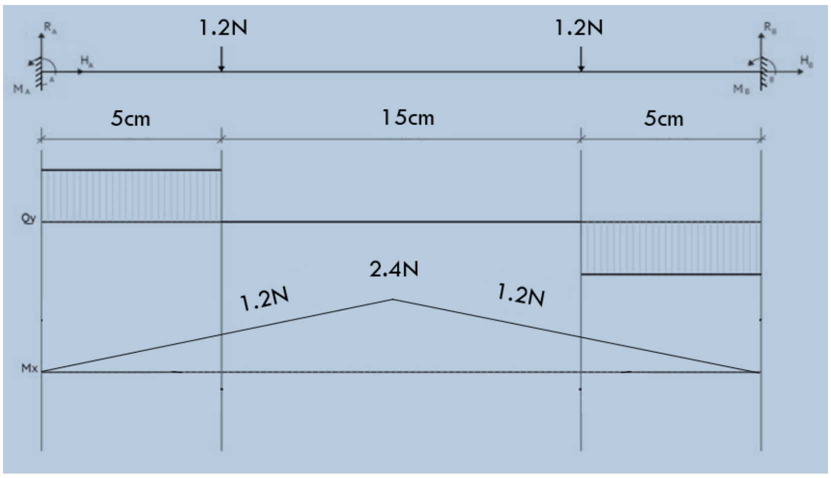
Assume mass of the beam as 0.245Kg

So, W= 0.245*9.8 = 2.4N

For Beam 1=> W_1=W/2

= 2.4/2

= 1.2N



Shear force at A = 1.2N

Shear force at D = 1.2+0 =1.2N

Shear force at C = -1.2+1.2 = 0N

Shear force at B = -1.2N

$m/I = \sigma/y$

$\sigma = my/I$

$y=t/2$

$I = (2t)\, t^3/12$

$\sigma = \sigma_{yield}/FOS$

FOS => Plastic => 3 to 5, Here we can take 4

m=1.2N

σ_{yield} (yield stress of plastic)=(12 to 43.5), Here we can take 20

$\sigma=20/4 = 5$

$\sigma = \frac{1.2*t/2}{2t^4/12}$

t = 0.89mm

b=2t

b = 1.78mm

CHAPTER 5

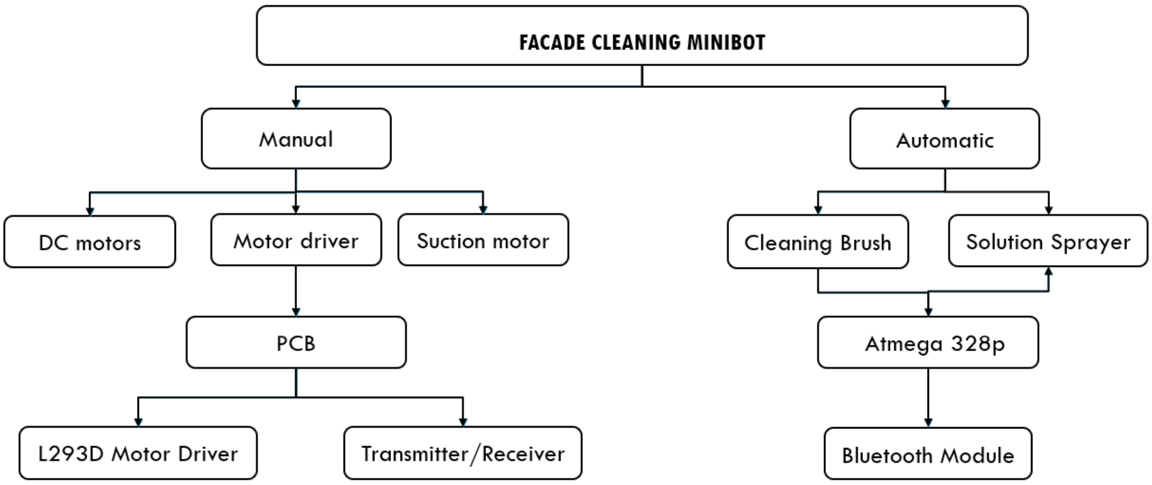
BLOCK DIAGRAM AND CAD MODEL

5.1 INTRODUCTION

This chapter consists of the project cad model and drawing. For fabrication, it is necessary to have a CAD diagram and drawing of each component. The dimensions of the components and different views are mentioned in this chapter.

5.2 BLOCK DIAGRAM OF CIRCUIT

The following diagram represents the block diagram of the system. Various components used in the system are represented as blocks to describe their working.



5.3 CAD MODEL

5.3.1 MOTOR

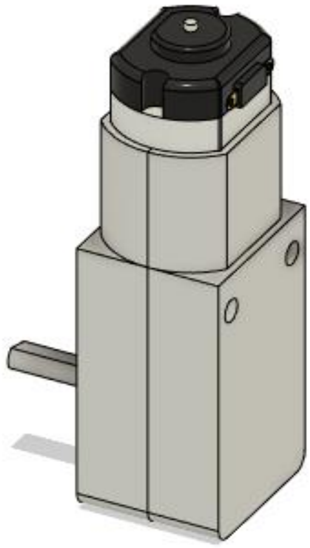


Figure 2.1 Motor

5.3.2 WHEEL

Figure 2.2 Wheel

5.3.3 CHASSIS

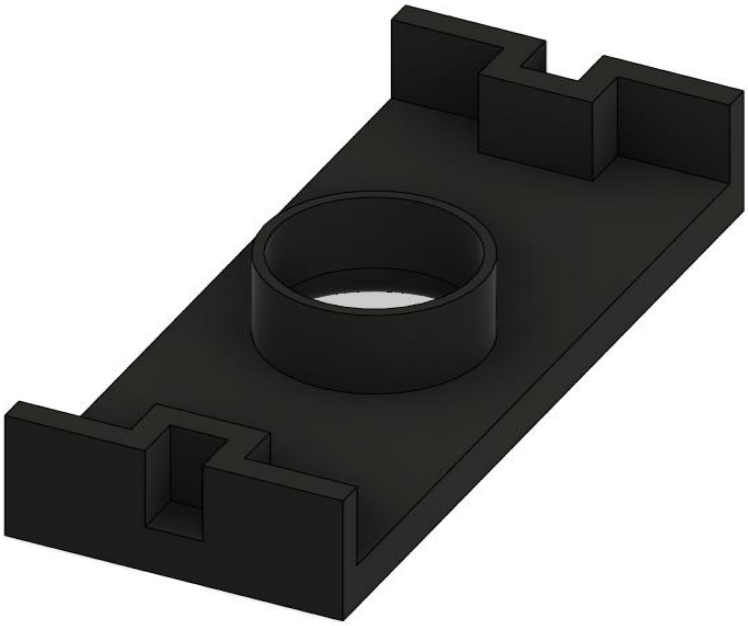


Figure 2.3 Chassis

5.3.4 BRACKET

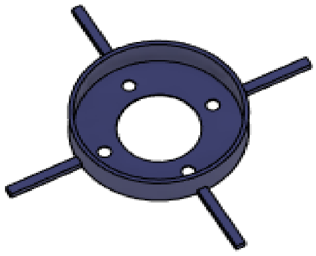


Figure 2.4 Bracket

5.3.5 BLADE

Figure 2.5 Blade

5.3.6 PCB

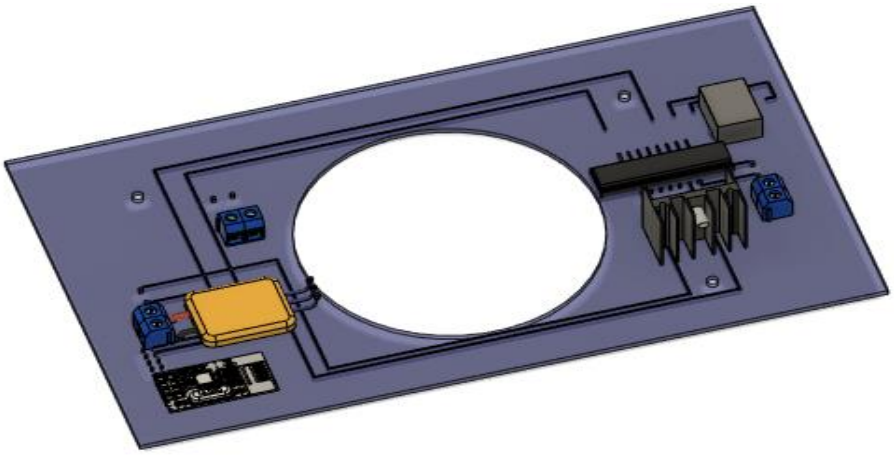


Figure 2.6 PCB

5.3.7 BRUSH

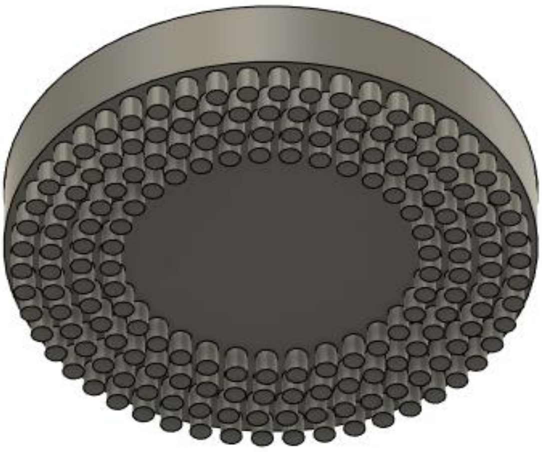


Figure 2.7 Brush

5.3.8 SUCTION MOTOR

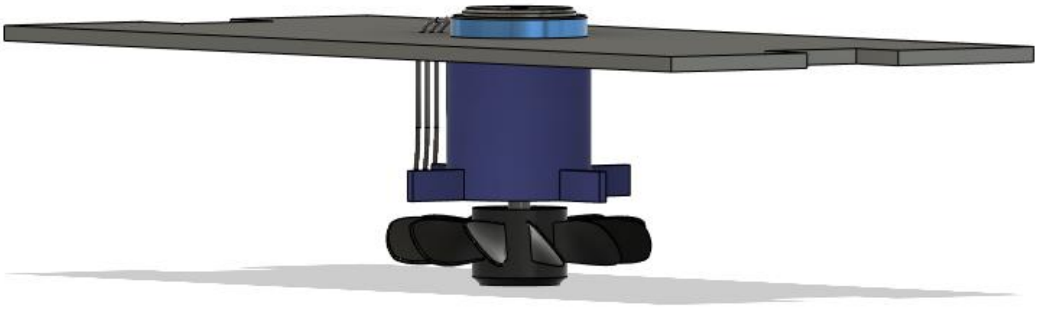


Figure 2.8 Suction Motor

5.3.9 FRONT VIEW OF BOT

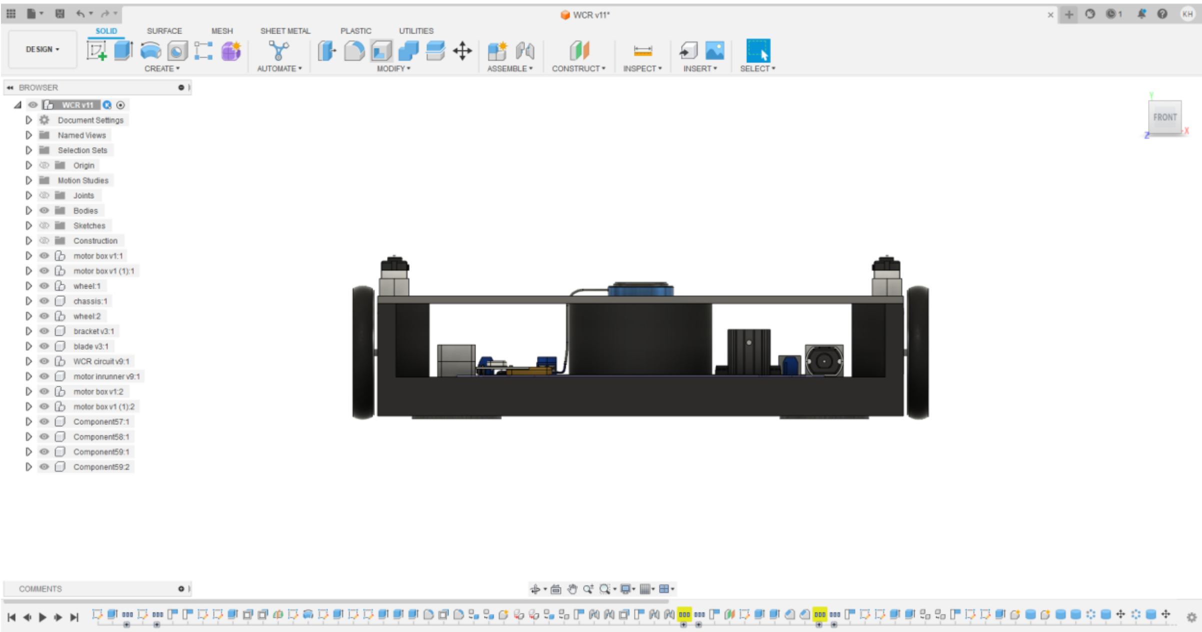


Figure 2.8 Front View

5.3.10 TOP VIEW OF BOT

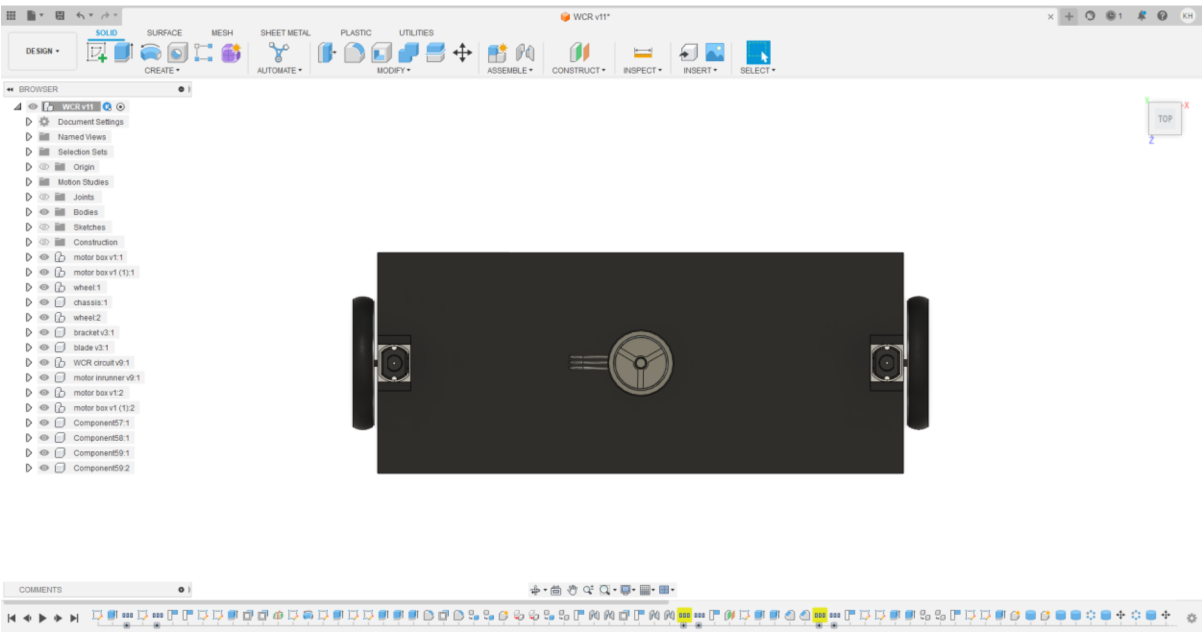


Figure 2.9 Top View

5.3.11 SIDE VIEW OF BOT

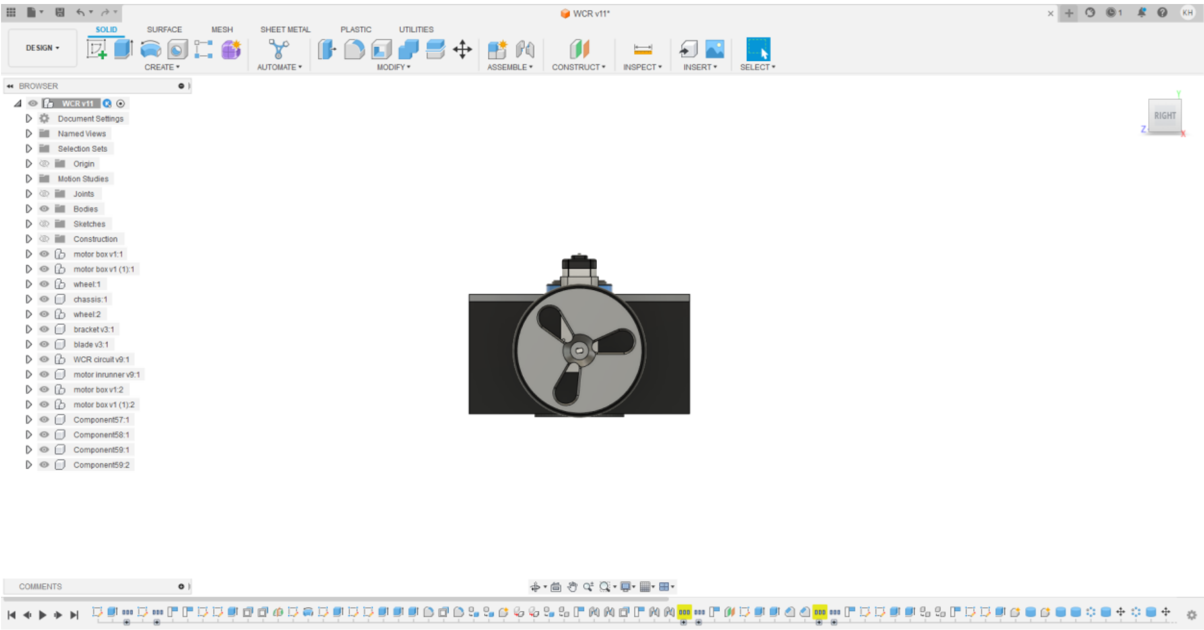


Figure 2.10 Side View

5.3.12 ISOMETRIC VIEW OF BOT

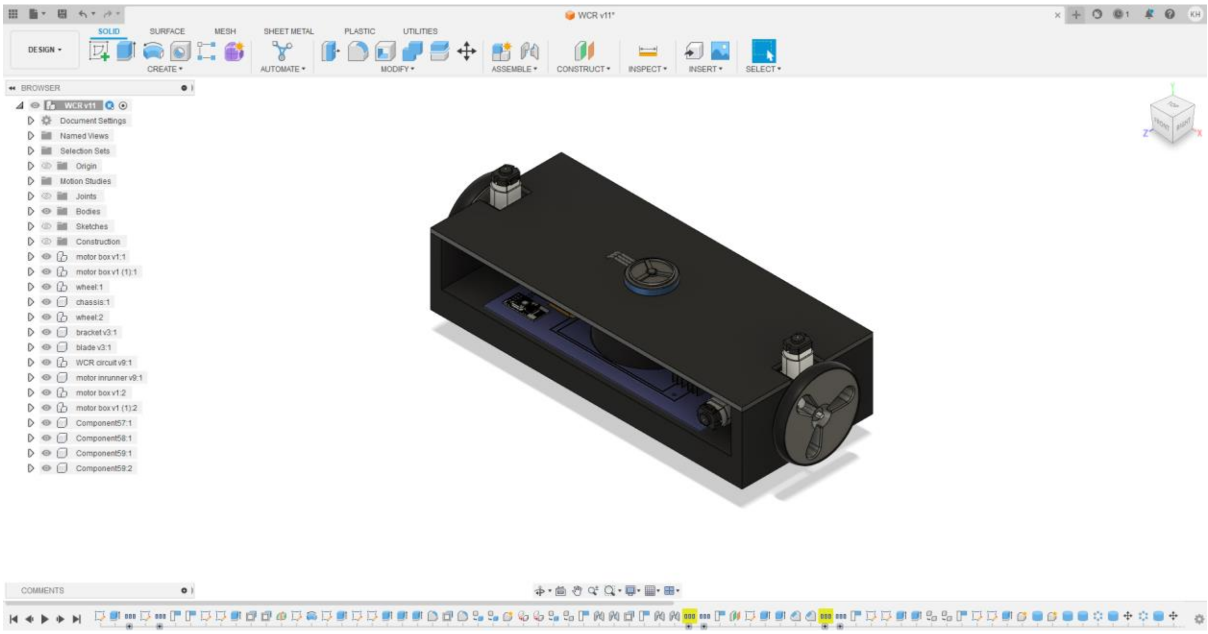


Figure 2.11 Isometric view

CHAPTER 6

DYNAMIC SIMULATION

6.1 INTRODUCTION

Dynamic simulation can be used to model and analyse the behaviour of a wall climbing robot, which is a type of robot designed to climb walls or other vertical surfaces. Wall climbing robots can be used for various applications, such as inspection of high-rise buildings or maintenance of tall structures.

6.2 SIMULATION ANALYSIS

6.2.1 SIMULATION ANALYSIS OF SUCTION BLADE

The simulation analysis of a suction blade in a suction motor involves the evaluation of the suction blade's ability to generate suction and move air or fluids through the system. while considering factors such as suction power, efficiency, pressure drop, blade design, and material. This analysis can be used to optimize the performance of the suction motor and improve its overall efficiency and effectiveness.

Figure 3.1 Suction Blade

6.2.2 SIMULATION ANALYSIS OF WHEEL

The simulation analysis of a wheel in a minibot involves evaluating the ability of the wheel to provide sufficient traction, stability, and maneuverability for the robot. This analysis can be used to optimize the design of the wheel and improve the overall performance of the minibot.

Figure 3.2 Rotation of Wheel

6.2.3 SIMULATION ANALYSIS OF CLEANING BRUSH

The simulation analysis of a cleaning brush in a minibot involves evaluating its ability to effectively remove dirt and debris from a surface while minimizing damage or wear to the surface being cleaned. This analysis can be used to optimize the design of the brush and improve the overall performance of the minibot for cleaning purposes.

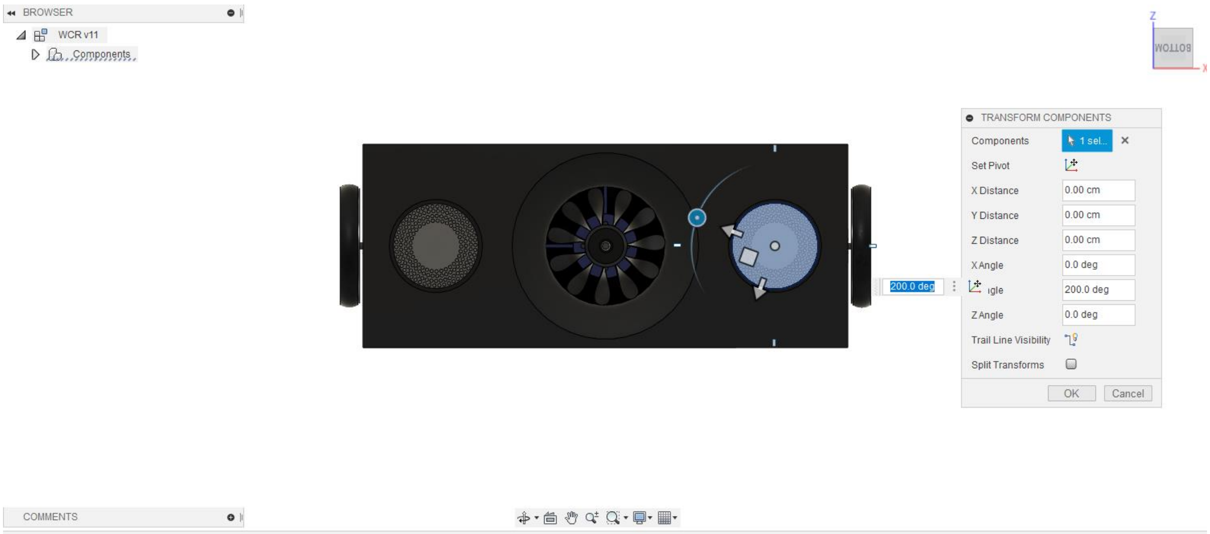


Figure 3.3 Rotation of Cleaning Brush

6.2.4 SIMULATION ANALYSIS OF MOTOR

The simulation analysis of a motor involves evaluating its ability to provide sufficient power and efficiency for a specific application. while also considering factors such as torque, speed, and durability. This analysis can be used to select the appropriate motor for the minibot and to optimize the design and operation of the motor to improve its performance.

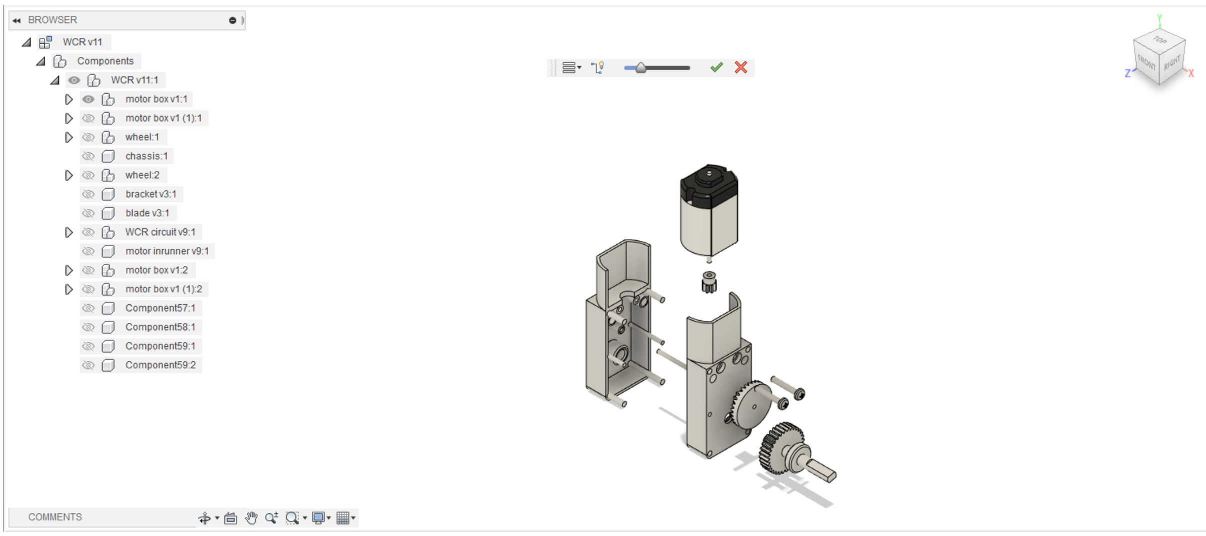


Figure 3.4 Exploded view of Motor

Figure 3.5 Exploded view of Wheel

Figure 3.6 Exploded view of Suction Motor

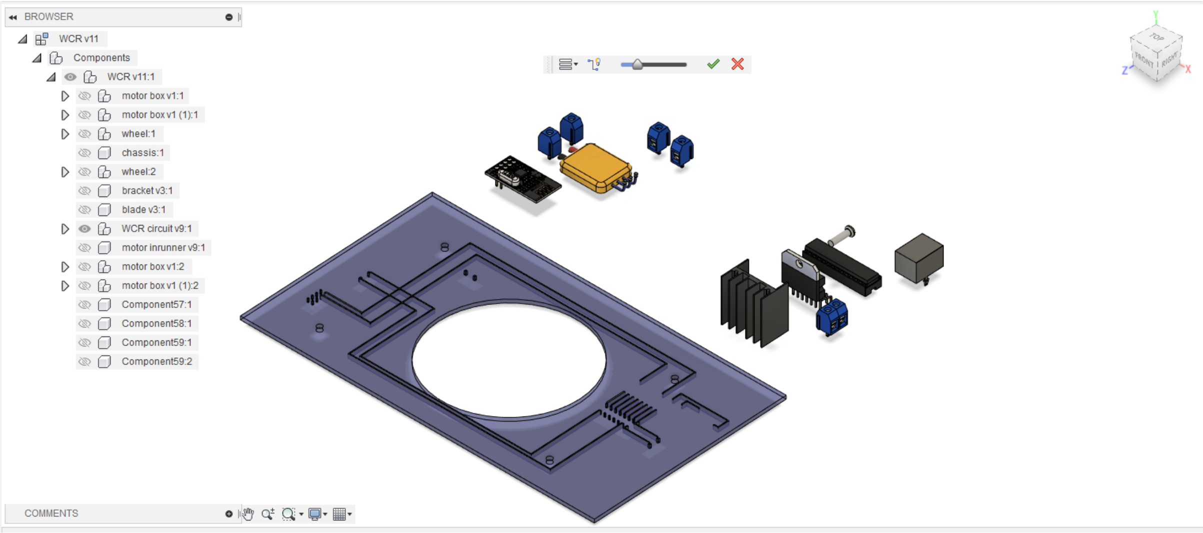


Figure 3.7 Exploded view of PCB

CONCLUSION

The development of a window cleaning bot using a suction motor is a significant step forward in the field of automation and robotics. The aim of the project was to design and build a bot that can clean windows efficiently without human intervention. The bot's design and construction were based on a suction motor that would hold the bot on the window surface while cleaning it. The window cleaning bot was designed to clean windows of different sizes and shapes, and it was tested on various window surfaces to assess its effectiveness.

They have a vast potential for future work, as there is still much room for improvement in their design, functionality, and overall efficiency. Advanced navigation and obstacle avoidance, Smart cleaning and suction mechanisms, Efficient power management, Robust and durable design, multi-functional capabilities, Remote control and connectivity are some the scopes for future work.

In conclusion, the window cleaning bot using a suction motor is a step towards automation and robotics in the cleaning industry. With further development and improvement, the window cleaning bot could revolutionize the window cleaning industry by reducing the need for human intervention and making window cleaning more efficient and cost-effective.

SCOPE FOR FUTURE WORKS

Artificial Intelligence (AI): Implementing AI in mini bots could enable them to learn and adapt to their environment, making them more efficient and effective at cleaning.

Multi-surface cleaning: Currently, mini bots are designed for cleaning flat and smooth surfaces such as windows. Future work could involve developing mini bots that can clean more complex surfaces such as textured or curved glass.

Integration with smart homes: Mini bots could be integrated with smart home systems to allow for remote control and scheduling of cleaning tasks.

LIMITATIONS

Surface Compatibility: Mini bots are designed for cleaning flat and smooth surfaces such as windows, and may not work well on other surfaces such as textured or curved glass. This limits their application in certain situations.

Size Limitations: Due to their small size, mini bots may not have the same cleaning power as larger window cleaning machines, making them less effective on heavily soiled surfaces.

Load Capacity: Due to their small size and lightweight construction, mini bots may not be able to carry heavy loads of cleaning fluid or equipment, limiting their cleaning capabilities.

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ANNEXURE

COST ESTIMATION:

COMPONENTS	COST
Electronic speed controller 30A BLDC	400
EDF 64mm 3500 KV Ducted BLDC Motor	5929
Motor Driver	500
Arduino UNO	800
Bluetooth Module	250
DC Dual Shaft Motor	4 x 80 = 320
Motor Wheels	4 x 50 = 200
Power Supply 5V	180
Li-po 2200mAh	1200
RC-PCB Board	330
TOTAL	**10,161**

ANNEXURE

```
int m1a = 9;
int m1b = 10;
int m2a = 11;
int m2b = 12;
char val;
void setup()
{
pinMode(m1a, OUTPUT);  // Digital pin 10 set as output Pin
pinMode(m1b, OUTPUT);  // Digital pin 11 set as output Pin
pinMode(m2a, OUTPUT);  // Digital pin 12 set as output Pin
pinMode(m2b, OUTPUT);  // Digital pin 13 set as output Pin
Serial.begin(9600);
}

void loop()
{
  while (Serial.available() > 0)
  {
  val = Serial.read();
  Serial.println(val);
  }
```

```
if( val == 'F') // Forward
  {
    digitalWrite(m1a, HIGH);
    digitalWrite(m1b, LOW);
    digitalWrite(m2a, HIGH);
    digitalWrite(m2b, LOW);
  }
else if(val == 'B') // Backward
  {
    digitalWrite(m1a, LOW);
    digitalWrite(m1b, HIGH);
    digitalWrite(m2a, LOW);
    digitalWrite(m2b, HIGH);
  }
  else if(val == 'L') //Left
  {
  digitalWrite(m1a, LOW);
  digitalWrite(m1b, LOW);
  digitalWrite(m2a, HIGH);
  digitalWrite(m2b, LOW);
  }
  else if(val == 'R') //Right
```

```
 {
  digitalWrite(m1a, HIGH);
  digitalWrite(m1b, LOW);
  digitalWrite(m2a, LOW);
  digitalWrite(m2b, LOW);
 }
else if(val == 'S') //Stop
 {
  digitalWrite(m1a, LOW);
  digitalWrite(m1b, LOW);
  digitalWrite(m2a, LOW);
  digitalWrite(m2b, LOW);
 }
else if(val == 'I') //Forward Right
 {
  digitalWrite(m1a, HIGH);
  digitalWrite(m1b, LOW);
  digitalWrite(m2a, LOW);
  digitalWrite(m2b, LOW);
 }
else if (val == 'J') //Backward Right
 {
```

```
    digitalWrite(m1a, LOW);
    digitalWrite(m1b, HIGH);
    digitalWrite(m2a, LOW);
    digitalWrite(m2b, LOW);
    }
   else if(val == 'G') //Forward Left
    {
    digitalWrite(m1a, LOW);
    digitalWrite(m1b, LOW);
    digitalWrite(m2a, HIGH);
    digitalWrite(m2b, LOW);
    }
  else if(val == 'H') //Backward Left
    {
    digitalWrite(m1a, LOW);
    digitalWrite(m1b, LOW);
    digitalWrite(m2a, LOW);
    digitalWrite(m2b, HIGH);
    }
}
```