DESIGN AND ANALYSIS OF AUTOMATIC GLASS WINDOW CLEANING AND INSPECTION ROBOT

Seeram Srinivasa Rao¹, Billa Naveen²
¹Professor, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Greenfields, Vaddeswaram, Guntur, India.
²Student, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Greenfields, Vaddeswaram, Guntur, India.

ABSTRACT

This paper explains the design of cleaning robot for cleaning the dirt and rectifying the cracks on the glass wall. This device can be used in high rise buildings, airports, etc. This robot is designed with optimized weight, so that this can easily move on the glass wall. It made human beings life safe and easier. This automatic device is compact in size, so that this will clean and cover maximum area including borders of the wall. The size of our glass cleaning robot design is about 300mm X 260mm X 200mm. This robot is designed with fully automated system. The cleaning robot has a free hand movement which can be easily directed by the user, where this feature is unique when compared with existing wall cleaning robots and this robot used less power consumption, some more unique features have been designed. The mechanical construction drive method and some unique features are presented in detail. Instead of any pattern movement, a free hand movement is given for cleaning the wall, this is an added feature.

Beginning:

Presently a days people are centering into advanced mechanics since we see our life is a higher priority than robots, so we use robots for some troublesome reason that individuals can't do. The point of this venture is to plan a self-sufficient robot called Glass Cleaning Robot. Activities of this robot are cleaning, recuperating and climbing glass and veneers in air terminals, public stations and elevated structure productively.

KEYWORDS: Cleaning fluid pump, rectifying fluid pump, hub motors, vacuum pump (1.4bar pressure), copper pipes, vacuum and cleaning fluid chamber.

I. INTRODUCTION:

Presently a days people are centering into mechanical technology since we see our life is a higher priority than robots, so we use robots for some troublesome reason that individuals can't do. The point of this undertaking is to plan a self-governing robot called Glass Cleaning Robot. Tasks of this robot are cleaning, mending and climbing glass and exteriors in air terminals, public stations and tall structure effectively.

As indicated by the outcomes from various fields like mechanical, gadgets, web of things and robot is being intended for simple working and streamlining in plan. The Wall Cleaning Robot framework is intended to have a decent contact with glass divider. The center engines and vacuum siphon has a decent contact with glass divider surface which is set upward where it should apply a low strain to stay away from harm on the divider surface. The plan of robot framework is enhanced by the presentation that is fundamentally centered around weight and size of the divider cleaning robot. The cleaning robot framework is given an underlying recuperating liquid framework where this assists with mending the glass divider surface. When contrasted and other existing divider cleaning robot framework this robot accomplishes a large portion of the inclusion territory toward the sides of the glass divider surface, this is examined in detail in additional themes. The weight advancement in the robot
framework is accomplished by utilizing a light weight material and high Strength to weight proportion where weight is decreased to 33% of existing cleaning robot framework.

In this plan we utilized center engines gathered with tires that will help the robot for the free hand development which can be guided by the client as per their necessity and furthermore with a circled bearing development which is pre-introduced in the framework. The vacuum chamber likewise called attractions chamber is put by the focal point of gravity of the entire framework which is bond to the glass divider. This situation of attractions chamber helps in smooth development of framework on the glass divider.

The center point engines assists the framework with moving with no jerk, this is accomplished by amassing the tires straightforwardly to the pivoting part of the engine. A straightforward framework with a basic system consistently helps the gadget for enhanced weight, which is the fundamental boundary of this plan. Another significant detail in plan of divider cleaning robot is cleaning liquid chamber and mending liquid chamber are talked about in detail in additional themes. This paper incorporates foundation data, techniques and materials utilized in planning and building the robot, aftereffects of the trial of the robot.

II. OBJECTIVES:

- By providing aerodynamical outer design it helps for easy robot movement process by avoiding air disturbances.
- Normal cleaning method takes place with help of air suction and delivery process used in exist models but we planned spray nozzles with cleaning fluid pump that helps robot to clean glass surface effectively. Wiper feature also added.
- Hub motors plays crucial role in this robot for easy accessing of its movement (Turning action) towards preferred directions.
- Exist models have sensor to detect position but we planned additional feature like glass surface crack detection by sensing change in glass surface thickness.
- Repairing fluid chamber with pump also provided to repair the damaged glass surface. Now a days we have different kinds of resins for treating glass surfaces.
- If there is chance of heat generation inside the robot during operation, that heat should be released through porous outer design area. Fresh cooling will be provided.
- The cleaning robot has a free hand movement which can be easily directed by the user.

III. LITERATURE SURVEY:

S.Ramesh Kumar explains a design that can be utilized to clean the glasses connect to the structure. In this paper we are introducing the plan of a framework that can be utilized in cleaning of glasses, covering a restricted territory and afterward a similar framework can be utilized to finish the work by just repositioning the whole framework which has a portable base along the glass divider. As such we can clean the whole glass joined to the Skyscraper's and structures with in brief timeframe.

M. Latif and Jung-il Song explains that the affirmation of results got, the break morphological examination of the cross breed framework after flexural and sway test were certified that the mechanical properties of the composites may be improved by the utilization of the half and half sap. In this way, the current methodology of getting ready of crossover network for the manufacture of mixture lattice composites shows an extraordinary potential for different applications like aviation, car, covering, electronic, energy and in numerous modern applications.

Tutor Anand, Sunny Kumar Kushwaha, S. EmaldaRoslin and N.M. Nanditha explains that study on different computerized robots utilized for cleaning reason and the standards behind the activity is finished. Subsequent to, looking over a few headways made in this field in the new years we have additionally proposed a model plan of a self-sufficient robot for glass cleaning application. Their proposed model can limit human exertion and hazard, energy utilization, capital and can likewise be adequately productive to perform. The thought is to utilize the rule...
of negative push strain to make vacuum under the robot utilizing air blowers. The created model guarantee less weight contrasted with different models present in the writing.

**Ran LIANG, Rong LIU, Chunwei YANG and Ke Wang** explains that for reliable adsorption and stable motion of the robot, the friction forces of the front and rear wheels are determined by equations related to the robot size, weight, location of the mass centre and other parameters. All those theoretical analyses are foundations for the robot’s mechanical design. Finally experiments of climbing and inspection on a skyscraper have been conducted to validate the correction of the analysis.


**ShunsukeNansai, Keichi Onodera, and Mohan Rajesh Elara** explains that design challenges of the glass façade cleaning robot is discussed from sides of glass cleaning process and area coverage, and basic strategy based on the modular robot system is proposed. And, a control system for a biped type module robot based on the strategy consists of the inverse kinematics, the fifth polynomial interpolation and the sequential control. Finally, an experiment of the developed module on a glass surface is performed.

**TaeWon Sew, YoungjaeJeon, Changmin Park and Jongwon Kim**2 explains that the robot are classified by types of climbing and attaching mechanisms, and their cleaning methods, mobility, and obstacle-overcoming performances are analysed. They also included some suggestions for making the robots more effective in real environments, and we expect that our work can provide reference to assist in the development of façade-cleaning robots for the real world.

**AnubhavJagtap**explains that the automated robot is one of the robots that have emerged in recent decade. That robot can be used in large buildings. The main target was to design a robot that can clean exterior glass surface of skyscrapers efficiently and rapidly even in dangerous and hazardous places. The robot is being controlled using the Programmable Logic Controller (PLC), its motion is generated by the use of D.C. motors.

**Lad PranavPratap, Pawed MansiShailendraSingh, AmanAnand and Tharun V. P** explains that at the point when a specific measure of air is siphoned in. Those actuators can be considered as a solitary level of opportunity (DOF), as they have recently a solitary bowing side. In their venture, they have utilized three such sorts of actuators which go about as the 3 (DOF). The robot plan and beginning exploratory outcomes are introduced including the anxiety estimation.

**Tohru MIYAKE MIRAIKIKAI, Hidenori ISHIHARA, Ryu Shoji and Shunichi Yoshida**clarifies that the control framework which incorporates voyaging bearing regulator utilizing accelerometer and voyaging distance regulator utilizing rotational encoder and edge sensors product introduced for self-ruling activity. Incorporates foundation and destinations of this exploration, prototyped mechanical frameworks, moving control framework, trial consequence of fundamental voyaging control and window cleaning movement by contrasting with or without of motioned control framework, a few conversations in each examination

**IV. SYSTEM OVERVIEW**

This glass cleaning robot will clean the glass, it moves in a client characterized course i.e free hand development and it can likewise move a restricted or certain way. The interaction of the cleaning robot isn't proficient for corner to corner and furthermore it isn't covers the boundaries of the glass divider without any problem. A vacuum siphon is the one in particular which keeps the gadget in contact with the glass divider via impenetrable lock.
In this glass cleaning robot an IR sensor is likewise positioned, this IR sensor is utilized to identify the glass, when the gadget is in contact with glass divider the sensor will distinguish the glass and it will consequently controlled pressing factor. Here arduino will control the interaction time.

In this gadget a PLC-Programmable Logic circuit, engines, liquid siphon, vacuum siphon, fumes, pull chamber is been set. This divider cleaning robot is a remote framework. At the point when the clients switch on the gadget and set on the glass divider surface and afterward it will move in a specific way and this gadget can be transformed it free hand development.

Presently a days this sort of existing gadgets are more costly and furthermore wipers are not cleaning as expected on the grounds that the ill-advised wiper plan and not productive. A vacuum pull cups isn't in appropriate in position and afterward when any development given, those sort of gadgets may tumble down whenever and they are not having legitimate corner to corner cleaning movement. These are the issues which are going to re-designing it.

The centerengines assists the framework with moving with no jerk, this is accomplished by gathering the tires straightforwardly to the turning part of the engine. The center engines amassed with tires that will help the robot for the free hand development which can be guided by the client as indicated by their necessity and furthermore with a circled bearing development which is pre-introduced in the framework.

There are three sections they are miniature regulator, engine driver and center engine. First miniature regulator will send the data to engine driver so the center engine will pivot in charge of engine driver and the heading is constrained by miniature regulator that is free hand development (client characterized development or programmed development).

There are two center point engines are associated in equal gathered with the edge, so once the sign got then it begins to pivot at clockwise bearing that is forward and furthermore its turns at against clockwise course that is in reverse. At the point when it begins to pivot at inverse bearing then it will turn or have a u-turn.

V. SYSTEM ARCHITECTURE:

In this system architecture all the parts used for modelling are represented with part names.

VI. OVERALL DESIGN:

This cleaning robot system is designed in Autodesk Fusion 360 software. This system is designed in size of about 300mm X 260mm X 200mm. The parts included in this design are vacuum pump, cleaning and healing fluid pump assemblies, servo motor, hub motor, frame (main and sub – frame), copper pipes, base plate, outer body, vacuum chamber, cleaning fluid chamber, healing fluid chamber and wiper.

In this design we have used a vacuum chamber to collect the dust and to maintain air tight lock on the glass wall surface. In this design vacuum pump will have an inlet and an outlet valve, where inlet valve helps the cleaning robot by maintaining pressure of 1.4 bar on the glass wall to have air tight lock and by this, dust suction is also done. And coming to outlet valve, the dust from the inlet valve is sent out by the outlet valve.

![Diagram of cleaning robot system]

Vacuum pump is designed with two blades and when these two blades starts to rotate a pressure difference is created. Where on the upper part of the vacuum pump, a high vacuum pressure is created and on the lower part of the vacuum pump, a low vacuum pressure is created. Therefore this pressure difference helps for suction of dust and air tight lock on the glass wall surface. The size of the holes present in vacuum chamber is of 2mm diameter.

Two pumps are assembled on the frame, where these pumps are designed with in built storage where one contains with cleaning fluid and another contains with healing fluid. The pump also has a piston and it is assembled with a gear(G1), the gear(G1) is attached with the gear(G2) to pump the fluid by the piston. The gear(G2) is assembled with a servo motor where this motor helps to rotate the gears. The piston moves in one way direction only, by this loss of fluid is minimized.

After the fluid is used, an inbuilt refilling cap is also assembled in the pump. The cleaning fluid chamber is attached with the wiper to clean the glass. This fluid pump is designed with less weight and also it has less power consumption.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Size</td>
<td>300mm X 260 mm X 200 mm</td>
</tr>
<tr>
<td>2.</td>
<td>Weight of the Robot</td>
<td>4.579 Kg</td>
</tr>
<tr>
<td>3.</td>
<td>Factor of Safety</td>
<td>5</td>
</tr>
<tr>
<td>4.</td>
<td>Frame Weight</td>
<td>0.196 Kg</td>
</tr>
<tr>
<td>5.</td>
<td>Frame Material</td>
<td>Aluminium AlSi10Mg</td>
</tr>
<tr>
<td>6.</td>
<td>Pipe Diameter</td>
<td>2 mm</td>
</tr>
</tbody>
</table>
DIFFERENTIAL WHEELED CHASSIS AS BASE

A differential wheeled robot is a portable robot whose development depends on two independently determined wheels set on one or the other side of the robot body. It would thus be able to alter its course by differing the general pace of revolution of its haggles doesn't need an extra guiding movement. To adjust the robot, extra wheels or casters might be added as demonstrated.

If both the wheels are driven a similar way and speed, the robot will go in an orderly fashion. In the event that the two wheels are turned with equivalent speed in inverse ways, as is obvious from the graph appeared, the robot will pivot about the essential issue of the hub.

Something else, contingent upon the speed of pivot and its heading, the focal point of turn may fall anyplace on the line characterized by the two contact points of the tires. While the robot is going in an orderly fashion, the focal point of pivot is a limitless separation from the robot. Since the course of the robot is subject to the rate and bearing of revolution of the two driven wheels, these amounts ought to be detected and controlled definitely.

A differentially guided robot is like the differential cog wheels utilized in cars in that both the wheels can have various paces of pivots, yet dissimilar to the differential outfitting framework, a differentially controlled framework will have both the wheels fueled. Differential wheeled robots are utilized widely in mechanical technology, since their movement is not difficult to program and can be very much controlled.

Degrees of freedom of differential drive base

\[
\text{Dof} \cdot \delta M = \delta m + \delta s
\]

Where,

\(\delta m = \) degree of maneuverability – number of degrees of freedom robot can directly control=2

\(\delta s = \) steering constraint – steerable wheels can be steered=1

\[\delta M = 2 + 0 = 2\]

VII. STATIC STRUCTURAL ANALYSIS

STATIC STRUCTURAL ANALYSIS ON OUTER BODY SHELL:

1. TOTAL DEFORMATION: Maximum total deformation in body = 0.00251606471m
2. MAXIMUM PRINCIPLE ELASTIC STRAIN:

MAXIMUM PRINCIPLE ELASTIC STRAIN = 0.00080128603

3. MAXIMUM PRINCIPLE STRESS

MAXIMUM PRINCIPLE STRESS = 3276 pa

4. STRAIN ENERGY

MAXIMUM STRAIN ENERGY = 0.00028816189J

STATIC STRUCTURAL ANALYSIS ON FRAME:

1. TOTAL DEFORMATION:

Maximum total deformation in body = 0.06123809409m

2. MAXIMUM SHEAR ELASTIC STRAIN

MAXIMUM SHEAR ELASTIC STRAIN = 0.0303581715
STATIC STRUCTURAL ANALYSIS ON HUB MOTOR:

1. TOTAL DEFORMATION: Maximum total deformation in body = 0.01749751161m

2. MAXIMUM SHEAR STRESS: MAXIMUM SHEAR STRESS=3665.087 pa

VIII. CALCULATION AND RESULTS:

- Size of the Robot
  300mmX260mmX200 mm;

- Weight of the Robot (Design only)
  W1 = 4.579 Kg;

- Weight of the Robot (Considerable)
  W = 4.7 Kg;

- Safety Factor (F.O.S)
  n = 5;

- Co-efficient of Friction
  μ = 0.5;

- Force acting on the Vacuum Chamber
  F = 47 N;
Effective Vacuum Chamber Area (A)

\[ A = \text{Number of holes (Suction holes)} \times (\pi r^2) \]

\[ = 140 \times (3.14 \times (0.5)^2) = 109.9 \text{ mm}^2 = 0.011 \text{ m}^2 \]

Pressure in Vacuum Chamber (P)

\[ P = \frac{F \times n}{A \times \mu} \]

\[ = \frac{47 \text{ N} \times 5}{0.11 \text{ m}^2 \times 0.5} = 42727.2707 \text{ Pa} = 42.727 \text{ KPa} \]

Total Pressure in Vacuum Chamber (P1)

\[ P1 = 0.43 \text{ bar} = 322.5265 \text{ Torr} \]

Hub motor Speed (S)

\[ S = 28 \text{ r.p.m} \]

Effective Speed of Robot (S1) \( S = 20 \text{ cm/min} \)

Volume of Tank (V)

\[ V = \pi \times r^2 \times h = 52.65 \text{ cc.} \]

IX. CONCLUSION:

This paper proposes a plan and examination of glass cleaning robot utilized for cleaning and mending the glass divider surfaces as a model. The advancement of an upgraded glass cleaning robot is finished. Henceforth this gadget can be utilized in tall structure, air terminals, and so forth. Subsequent to getting the outcomes it is shown that this gadget is effectively proceed onward the glass divider, by this individuals life is made protected and simpler. Since it has high limit siphon stockpiling, it can cover greatest territories on the glass divider surface including borders. What's more, the mechanical development drive technique for this plan is likewise introduced. The special highlights of the divider cleaning robot are likewise introduced in detail. The reproduction study is additionally done including fixed limitations and burden cases. At long last glass cleaning robot has been shown fit for cleaning the glass surfaces.

X. FUTURE DIRECTION:

1. Upgrading the robot versatility. Up until now, the robot can move upward at 0.2m/s, however the speed isn't sufficient for inspection on higher regions. This issue will be improved by additional decrease of the robot weight.

2. Improving the robot detectivity. As of now, the robot prepares a gas pedal for glass investigation. In future the robot will utilize more sensors, including microcamera, motivation radar and other nondestructive sensors which empower the robot to review other surface material with the exception of glasses.
REFERENCES:
1. Design of cartesian type automated glass cleaning system for skyscraper’s by S. Ramesh Kumar.
2. Flux Controlled BLDC Motor for AutomatedGlass Cleaning Robot by TusharAnand, Sunny Kumar Kushwaha, S. EmaldaRoslin, N.M. Nandhitha.
5. Development of a Module Robot for Glass Fa cade Cleaning Robot by ShunsukeNansai(B), Keichi Onodera1, and Mohan Rajesh Elara2.
8. Wall Climbing Robot using Soft Robotics by Lad PranavPratap, PawarMansiShailendrasingh, AmanAnand, Tharun V. P.,