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Skyscrapers Wall Climbing and Glass Cleaning Automated Robot

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ABSTRACT

The objective of this analysis is to develop the small-size and lightweight window cleanup robot. The model of window cleanup robot has been developed. The size of a prototyped robot is roughly 700mm x 500mm x 100mm and its weight is roughly 6 kilogram. The prototyped robot consists of 4 severally suction cups. The system which has traveling direction controller using an accelerometer and traveling distance controller using Arduino and edge sensors were put in for autonomous operation. This paper includes background and objectives of this analysis, prototyped mechanical systems, moving system, experimental results of basic traveling management and window rolling brush by examination to with or while not of motioned system, some discussions in every experiment and a conclusion.

Keywords: Cleaning Robot, Suction cups, D.C.Motor, Vacuum Pump, Arduino

I. INTRODUCTION

Climbing automatons are devices that are used in the large scope of applications of maintenance, building, inspection and safety in the process and construction and industries. Such systems are widely adopted in places where direct interference of a human operator is very difficult and unconditional, because of the need for scaffolding, or very dangerous path or due to the presence of hostile environment [1]. In recent times, Increasing pollution and dusty environment lead to the deposition of precipitate on the surface of glass and walls. So, there has been increasing demands of cleaning system on the surface of buildings such as window glass of modern architectures such as skyscraper. In places like Dubai, there is a vast demand for such mechanism and systems. Some of the customized windows cleaning robots have already been installed in practical use for the same purpose. However, most of them are mounted on the wall of the buildings and are expensive in cost and in maintenance. So, the demand of small, lightweight, portable and cheap window cleaning robot are increasing in the market [2].

So, the following must be noted before designing a skyscraper cleaning device.

- It should be small size and lightweight for portability.
- Automatic operation during moving
- Large range for remote control.

A wall climbing robot must be small and can be able to produce large payload, the optimum suction pressure reduces the cost and weight of pump and D.C motor and hence the overall weight of the system [3]. Till now, considerable research works devoted to these mechanisms and machines are done and various types of experimental models have come into the picture. The two major points of concern in designing such mechanism are their locomotion and surface sticking method or adhesion methods. In locomotion, three different types of mechanisms are possible: the crawler, the wheeled and the legged types. As per adhesion method, following three possible types of robots are possible: vacuum or suction cups, magnetic, and gripping to the surface. Recently, new methods for assuring the adhesion, based on biological findings have also been proposed, unfortunately, were less successful.

The study and fabrication of robots for cleaning with such attitude and the fast rate is a recent field of study. Such robots are actually in continuous development because of demand of cleaning. Huge surface cleaning, and even of skyscrapers glass windows or building walls is a study in construction fields with very a unique characteristics and innovations. Our target is to build a wall-climbing robot for glass cleaning application [4].

The Wall rising automaton must have the ability to stick on a vertical as well as inclined surface and can easily move over it [5]. The targeted capability to stick with the surface can be done with suction cups. Suction cups create a vacuum pressure used to stick with the surface. The climbing mechanism is used for movement of a robot. It is important that two out of four suction cups stay stick while two can release at a time. Afterward, next two can stick and other can release. By this mechanism, the robot can move over wall Movements of a frame is carried out by rack & pinion type mechanism. The control memory of the system is 8bit microcontroller 89V51RC.

In this paper, Section II reviews the structure of cleaning robot. List of components used in cleaning robot is given in Section III. Section IV gives the specification and details of components used and Section V discusses robot mechanism and Section VI shows basic design calculation and finally conclusion, acknowledgment & references.

II. STRUCTURE OF CLEANING ROBOT

The cleaning robotic system consists of a mobile climbing robot, a compressor, and a switch control system. The climbing robot sticks on the glass surface to perform the cleaning job. The supporting vacuum pump supplies pressure to the suction cup and the compressor acts as the air source. Through communication between the suction cup and the robot, the human operator can examine and control the operation of the robot.

The developed climbing robot has a length of 700 mm, a width of 500 mm, a height of 100 mm, and a weight of 6 Kg. The body of the robot is mainly composed of two-rod cylinders perpendicular to each other, as shown in Fig. 1. The stroke of the horizontal (X-) cylinder is 700mm, and that of the vertical (Y-) cylinder is 500mm. actuating these two cylinders alternately, the robot moves in the X or Y direction. In z direction medium carbon steel sheet installed for holding the moving brush. By stretching out or drawing back with the help of timing belt and timing pulley the movement of cylinders in the horizontal and vertical direction. At the intersection of two-rod cylinders, a rotational brush installed in the lower portion of the robot and movement of a brush with the help of servo motor. The robot employs suction pads for adhesion. One suction pad, each with a diameter of 80 mm, are installed on each foot of the robot. The total 4 pads provide a suction force enough to withstand 6 Kg payload. The robot uses a translational mechanism for the movement. With the operational mode of sticking-moving-sticking, the automaton will complete a series of motions together with moving, rotation, and crossing obstacles. The rotation of the robot is controlled by adjusting rotation angles of the rotational cylinder. The robot can rotate 1.6 degrees per step of a robot. The control system of the robot is based on switch remote control mode. The switch control mode is embedded in the body of the robot. Using the feedback signal of sensors installed on the robot, the switch control movement and the posture of the robot to achieve automatic navigation on the glass surface.

III. COMPOENTS USED IN CLEANING ROBOT

The major elements required for creating the desired automaton are as:

1. Suction Cups
2. DC motor
3. Timing Belt and Timing Pulley
4. Vacuum Pump
5. Relay Module
6. Arduino
7. SMPS
8. Toshiba Driver

Auto CAD drawing for robot structure:

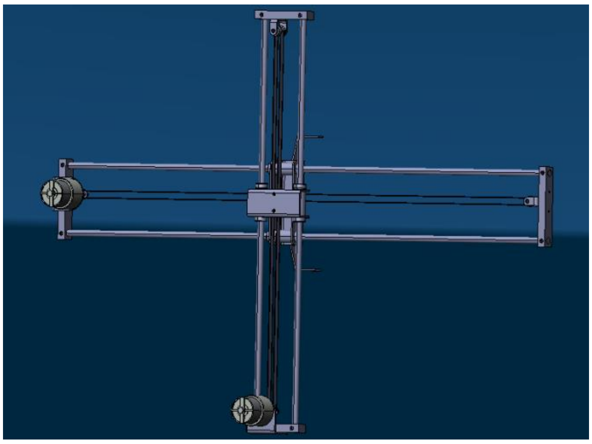

Figure 1: Robot Structure

IV. SPECIFICATION AND DETAILS OF COMPONENTS USED IN ROBOT STRUCTURE

A. Suction Cups:

There are 4 suction cups are required, in which 2 suction cups attached in horizontal and another 2 in the vertical direction. Suction cups used in automaton are of ESS50-FESTO type.

Table 1: Specifications

Property	Value
Design structure	Vacuum connection at top
Design structure	Perpendicular rod, standard
Ambient temp	-22 - 50 °C
Operating medium	Atmospheric air
Symbol	00991485
Breakaway force at 70% vacuum	106 N
Shore hardness	62

B. D.C. Motor

DC motor is a type of device which is using to convert electrical energy into mechanical energy or in other words say direct current system conversion. The basic construction of a DC motor is having current carrying armature which is connecting to the supply end and goes through commutator segments and brushes. And the armature is placing in between north-south poles of an electromagnet. The operating principle of DC motor is based on the left hand Fleming's rule to determine the direction of force acting on the armature conductors of DC motor. The current within the rotor is switched by the commutator to even be stationary in the area. This is often, however, the relative angle between the stator and rotor magnetic flux is maintained close to 90 degrees, that generates the maximum force. DC motors have a rotating armature winding, however, nonrotating armature magnetic flux and a static field winding or magnet. Completely different connections of the sphere and armature winding give different inherent speed/torque regulation characteristics. The speed of a DC motor will be controlled by changing the voltage applied to the armature or by changing the field current. The introduction of variable resistance within the armature circuit or field circuit allowed speed management. Trendy DC motors are usually controlled by power electronics systems referred to as DC drives. The introduction of DC motors to run machinery eliminated the necessity for native steam or combustion engines and line shaft drive systems. DC motors will operate directly from rechargeable batteries, providing the locomotion for the primary electrical vehicles. Nowadays DC motors are still found in applications as little as toys and disk drives, or in massive sizes to control steel rolling mills and paper machines.

C. Vacuum Pump

A vacuum pump could be a device that removes gas molecules from a sealed volume therefore as to go away behind a partial vacuum. The primary vacuum pump was fictional in 1650 by Otto von Guericke and was preceded by the suction pump, which dates to antiquity. Vacuum pumps are combined with chambers and operational procedures into a large form of vacuum systems. Generally, more than one pump are going to be used (in series or in parallel) in an exceedingly single application. A partial vacuum sometimes created employing a positive displacement pump that transports a gas load from a recessed port to an outlet port. As a result of their mechanical limitations, such pumps will solely accomplish a low vacuum. To attain a better vacuum, alternative techniques should then be used, usually asynchronous (usually following an initial quick pump down with a positive displacement pump). Some examples can be the employment of an oil sealed rotary vane pump (the most typical positive displacement pump) backing a diffusion pump, or a dry scroll pump backing a turbo molecular pump. There are alternative mixtures depending on the extent of vacuum being sought-after.

Achieving high vacuum is tough as a result of all of the materials exposed to the vacuum should be rigorously evaluated for their outgassing and pressure level properties. Often, all of the surfaces exposed to the vacuum should be baked at a warm temperature to chase away absorbable gasses and during this project that vacuum pump we tend to used work with 12 volts DC motor.

D. Timing Belt and Timing Pulley

A timing belt could be a non-slipping mechanical drive belt and also the term could refer to either:

- Toothed belt, a versatile belt with teeth shaped onto its inner surface.
- Timing belt, a toothed belt wont to drive the camshaft(s) within an inside combustion engine.
- A timing belt is usually rubber with high-tensile fibres running the length of the belt as tension members.

The belt itself is made of durable materials like shaped polyurethane, synthetic rubber or welded ester with numerous standard, non-standard or metric pitches.

Figure 2: Timing Belt

A pulley could be a wheel on a shaft that's designed to support the movement and alter a direction of a taut cable, supporting shell is mentioned as a "block." A pulley may additionally be referred to as a sheave or drum and should have a groove or Grooves between 2 flanges around its circumference. The drive component of a pulley system is a rope, cable, belt, or chain that runs over the pulley within the groove or grooves and therefore the size of a pulley is 8mm.

Figure 3: Timing Pulley

E. Relay Module

A relay is an electrically controlled switch. Several relays use a magnet to automatically operate a switch, however different operational principles are used, like solid-state relays. Relays are used wherever it's necessary to manage a circuit by a separate low-power signal, or wherever many circuits should be controlled by one signal. For long distance telegraph circuits, the primary relays were utilized: they perennial the signal coming back in from one circuit and re-transmitted it on another circuit. Relays were used extensively in phony phone exchanges and early computers to perform logical operations. A kind of relay which will handle the high power needed to directly manage electrical motor or different masses is called a contactor. Solid-state relays manage power circuits with no moving components, rather than employing a semiconductor device to perform switching. Relays with label operational characteristics and typically multiple operational coils are used to shield electrical circuits from overload or faults; in trendy electrical power systems these functions are performed by digital instruments still referred to as "protective relays".

Magnetic latching relays need one pulse of coil power to maneuver their contacts in one direction, and another, redirected pulse to maneuver them back. Perennial pulses from a similar input don't have any impact. Magnetic latching relays are helpful in applications wherever interrupted power shouldn't be ready to transition the contacts. Magnetic latching relays will have either single or dual coil. On a single coil device, the relay can be operated in one direction once power is applied with one polarity and may reset once the polarity is reversed. On a dual coil device, once a polarized voltage is applied to the reset coil the contacts can transition. AC controlled magnetic latch relays have single coils that use steering diodes to differentiate between operate and reset commands.

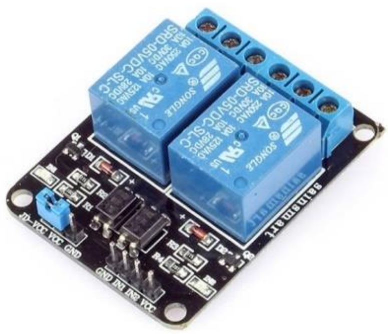

Figure 4: Relay Module

F. Arduino

Arduino is an open source, hardware and software organization, project, and user community that designs and manufactures microcontroller kits for building digital devices and interactive objects that may sense and manage objects within the physical world. The project products are distributed as open-source hardware and software package that are authorized beneath the gnu Lesser General Public License (LGPL) or the gnu General Public License (GPL), allowing the manufacture of Arduino boards and software package distribution by anyone. Arduino boards are offered commercially in preassembled type, or as homemade kits.

Arduino board designs use a range of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that will be interfaced to numerous enlargement boards (shields) and different circuits. The boards feature serial communications interfaces, together with Universal Serial Bus (USB) on some models that are used for loading programs from personal computers. The microcontrollers are generally programmed employing an idiom of options from the programming languages C and C++. Additionally to mistreatment ancient compiler toolchains, the Arduino project provides an integrated development environment (IDE) supported the process language project.

The Arduino project started in 2003 as a program for college students at the Interaction design Institute Ivrea in Ivrea, Italy, reaching to offer a low-priced and straightforward approach for novices and professionals to form devices that move with their atmosphere using sensors and actuators. Common samples of such devices meant for beginner hobbyists embrace easy robots, thermostats, and motion detectors.

G. SMPS

A switched-mode power supply is an electronic power supply that includes a switching regulator to convert power expeditiously. An SMPS transfers power from a DC or AC supply to DC loads, like a private PC, whereas changing voltage and current characteristics. In contrast to a linear power supply, the pass electronic transistor of a switching-mode supply frequently switches between low-dissipation, full-on and full-off states, and spends a little time within the high dissipation transitions, that minimizes wasted energy.

Ideally, a switched-mode power supply dissipates no power. Voltage regulation is achieved by varied the quantitative relation of on-to-off time. A linear power supply regulates the output voltage by oftentimes dissipating power inside the pass transistor device.

This higher power conversion potency is a very important advantage of a switched mode power supply. The switched mode power supply might also be considerably smaller and lighter than a linear supply because of the smaller transformer size and weight. Switch regulators are used as replacements for linear regulators once higher potency, smaller size or lighter weight is needed. They are, however, a lot of complicated; their switch currents will cause electrical noise issues if not fastidiously suppressed, and easy designs might have a poor power issue.

H. Toshiba Driver

A device driver is a program that controls a specific form of device that's connected to a PC. A driver provides a software system interface to hardware devices, sanctioning operating systems, and different computer programs to access hardware functions without understanding precise details of the hardware getting used.

A driver communicates with the device through the communication scheme to that the hardware connects. Once a calling program invokes a routine within the driver, the driver issues command to the device. Once the device sends information back to the driver, the driver might invoke routines within the original calling program. Drivers are hardware dependent and operating-system-specific. They typically offer the interrupt handling needed for any necessary asynchronous time-dependent hardware interface

V. ROBOT MECHANISM

The assembly of the system is shown above cleaning brush is placed in the centre which is driven by a DC motor of 12 volts two parallel roads are arranged both in horizontal and in vertical without support both side suction cup is placed at the end of the rods to stick and to hold the device on a wall. Two timing belts are placed in between the parallel rods which are again device by two independent servo motors of 12 volts. This belt ensures the motion of the respective rods for brushes are used to attach motion in fixed degree of freedom parts like pumps, batteries are mounted on a ground unit to reduce the overall weight of the assembly.

Initially, the assembly is made to stick the wall with the help of servo motors and suction cups. In this stage, all the cups experience vacuum which is ensured by pumps. For the vertical motion of the robots, the motors on vertical rods start working. These robots the timing belts used, as a result, the vertical pair of parallel rods climbs up to a certain length. Before this happens, the vacuum in suction and must be removed. This is above by the pumps, before the operation of servo motors, the suction cups on respective rods experiences vacuum release. Once the motion of the rods ends again, a vacuum is created in the suction cup so that the device remains stick on the wall. Till this half cycle of operation completes the other half is the same sequence of operation, the only difference is that horizontal pair or rods and their compounds participate in motion.

Actually, the first half does not ensure any motion to the machine but provide a load to climbs. It is an important stage as without this stage it will be impossible for the robots to step ahead with the design we are using, second half is the actual motion stage in which the robots moves and cleaning is done in this vary stage. With the help of above mechanism, robots with climb up in a vertical direction only. For horizontal motion, the order of sequences reverses, the first half of operation is carried out on a horizontal pair of rods and their respective components in the same manner. The second half of operation is done in vertical pairs of rods in the same sequence of operation; one thing that should be noted is that for vertical motion both pairs of rods move in a vertical direction and for horizontal motion, both the pair's moves in the horizontal direction.

VI. BASIC DESIGN CALCULATIONS

A. Speed of the Model

The rpm of the motor taken into consideration: 100rpm

Diameter of the bearing: 8 mm

The distance that is covered in one revolution of the tire is equal to the circumference of the tire.
The Circumference = 2πr
= 2 * π * 4 mm
= 25.136mm

The distance covered in one revolution = 25.136mm
Hence the distance covered in 50 revolution = (50 * 25.136) mm
= 1256.8 mm
the distance covered in one minute is 1256.8 mm
or
1.2 meters approximately

Or the speed = 1.2 / 60 (m/s)= 0.02 kmph.
The speed can be varied according to the customer's requirement.

B. SAFETY ANALYSIS

d=1.12*(m*S/Pu*n*μ)½
m = 7 kg
d = 8cm
n = 4
μ = 0.5 for glass.
S = 1.5

By substituting these values in above equation.

We get Pu = 0.1029 bar

Pu = 0.1029 x 1.019716 = 0.104928 kg /cm2
This is pressure created by suction cup, we take approx. 0.104928kg/cm2

Now we have 4 suction cup of dia. 8cm
Hence mass carried by single suction cup
= A x Pu
= 50.2654 x 0.1049
= 5.27 kg

Now mass hold by 4 suction cup will be = 4 x 5.27=21.097
21.097kg

Our robot weight is 7 kg.
Still we are taking 4 for balancing and symmetry of robot in vertical glass. These are the initial calculations needed for our design.

Max Force Required By Suction Cup-

7 * 9.81 * 95 = F * 700

F = 7 * 9.81 * 95 / 700

= 9.31 N

Total Force Required For All Suction Cup

F = 9.31 * 4

= 37.24 N

Suction Pressure

p1 = F/A

= 9.31/ (3.14/4 * 6400)

= 1.852 *10^-3 MPA

= 1.85 KPA

= 0.0185 bar

Total Suction Pressure

P = p1 * 4

= 0.07408 bar

VII. CONCLUSION

This study presents an application of a rising automaton for the glass and wall clean-up service. The automaton is built by using 2 frames, Suction cups & Motor, Injection barrel automaton having capability that it will stick on a vertical also as an inclined surface and may simply ease up the surface. The targeted capability to stay on the surface is often achieved by suction cups. Suction cups produce a vacuum pressure used to keep on with the vertical or inclined surface. Future work is going to be toward developing a lot of efficient motion system and reducing size/weight of the rising automaton.

VIII. ACKKNOWLDGMENT

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