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Design of Glass Cleaning Robot for High Buildings

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***Abstract*— In recent decades, robotic technology has emerged. The objective of the glass purification robot is to ascend to the vertical surface of the glass and to clean its surfaces. The effective fixation and dissociation of the glass surface can achieve this goal. The dangerous task such as cleaning glass surfaces of high-rise buildings, extinction of fire and inspection of high structures can take place by people. This robot may also be utilized for high building measurements. The objective of this project is to create a robot that can move on vertical glass surfaces and clean up the clean and dirty glass surfaces. In this work, the difficulty is to make the robot's weight and the correct adhesion and automation with reasonable costs as low as feasible. The proposed cleaning robot can be controlled easily by a single staff and is portable.**

Keywords— DC motors; Glass cleaning robot; Pneumatic cylinders; Suction cups; Vacuum pump.

I. INTRODUCTION

During daily life, the need to build various automated service equipment to replace people with dangerous tasks is growing [1][2]. Washing and cleaning windows releases dust and grime from the architectural glass. Building windows are traditionally cleaned manually by cleaners or specialist staff. While washing the window from within the room is straightforward, it doesn't appear easy from outside. Cleaning big windows in multi-story and high-rise buildings is more hazardous. Hefty, heavy and highly expensive automatic cleaning machines for manual cleaning or big [3][4]. Due to the lack of windows of equipment, the shape-outside that can obscure the view of the tenant remains generally clever or dirty. On high-level windows with big glass areas, the normal cleaning technique of bureau/house windows cannot be applied. There is a great deal of inaccessibility behind the windows [5]. The use of climbing equipment dominates in India's conventional cleaning of the high elevation glass. However, time and cost consumption is very significant for this sort of cleaning method. Unmanned cleaning equipment is becoming required since accessibility is easy[6]. Windows need specific tools to clean from the outside and are very hazardous. The suggested glass cleaner is unmanned equipment that is controlled by a certain controller. This gadget is safer than conventional high-level window washing procedures, which raise the danger of loss of human life.

The vacuum chamber cleaner is much more costly and excessively heavy, so that when the glass surface shifts it will raise the crucial probability of failure. The cleaning of the surface also takes a lot of time. The suction is performed first in the glass windows. The cleaning procedure begins with the spinning brush or with the use of

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a water and soap wiper [7]. Many research projects on robot involvement for glass cleaning have been found, which have grown up over a decade. In several sky-cleaners are explored which are operated by pneumatic actuators for the concomitant movement and glass surface cleaning by utilizing vacuum aspirate cups[8][9][10].

In addition, the suggested robot must be equipped with a high payload carry capacity [11]. The robot's design is based on three fundamental concepts which are the Adhesion principle, Locomotion principle, Pneumatic principle [12].

The example this may pick is lizards to get the notion that the robot sticks to its glass surface and moves it across. On a closer inspection it can observe that Lizards have an extract, and therefore, they can cling and move effortlessly on vertical surfaces in the form of their limbs [13].

The dimensions and weight of a robot of this kind are approximately 508 mm x 342 mm x 90 mm. This prototyped slider is made up of 4 sleeve cups.

Fig.1 shows the actual representation of the proposed Cleaning Robot.

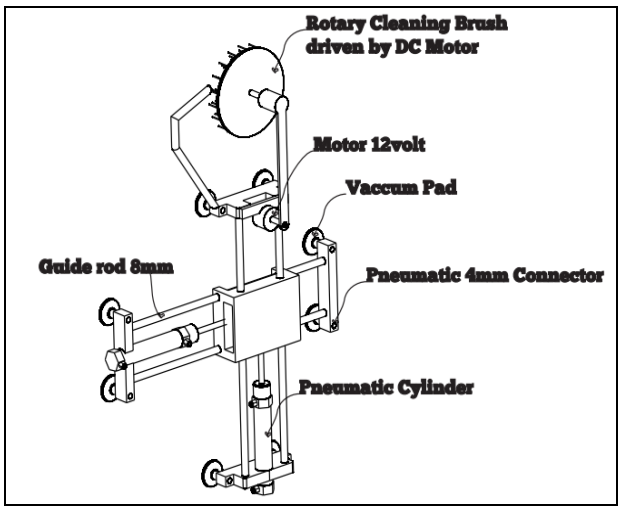

Figure 1. Actual diagram of Robot

II. Components Used In Cleaning Robot

The main components needed to produce the necessary automation are Suction Cups, DC motors, Pneumatic cylinders, Vacuum Pump, Water Pump, Compressor, Two-way 5/2 directional valve and FRL unit.

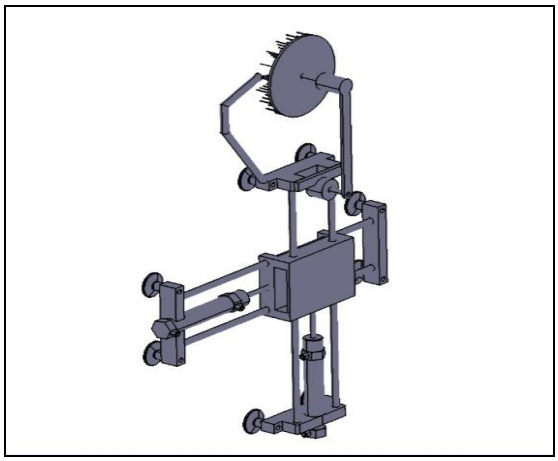

Figure 2. CAD model of proposed Robot

III. Detailed Description of Components Used in Robot

A. Suction Cups

An item that employs negative fluid pressures of air or water to cling to nonporous surfaces is a suction cup, also commonly called a sucker. They occur as manmade devices and as anatomical characteristics of some creatures such as octopuses and calamars. There is a curved surface on the functioning side of the suction cup. The volume of the gap between the suction cup and the flat surface is reduced when the center of the suction cup is pressed against a flat, non-porous surface and so the fluid between the cup and the surface is ejected past the circle cup [14].

B. DC Moto

A DC engine is an engine in a class of electric devices that converts direct current into mechanical power. This sort of engine usually depends on the forces produced by the magnetic fields. The speed of a DC motor is regulated using a changeable supply voltage or by adjusting the current force of its field winches. During the production of appliances, tools, toys, and car mechanics, smaller DC drivers are widely utilized [15].

C. Pneumatic Cylinders

Pneumatic cylinder(s) are mechanical devices that employ compressed gas power to create a force in reciprocal, linear motion. Air cylinder(s) are mechanical devices. Something like hydraulic cylinders causes a piston

to move in the desired direction. The piston is a disc or cylinders and the piston rod transmits the strength to the moving item. Engineers sometimes utilize pneumatic products since they are quieter, cleaner, and don't have much fluid storage space [16].

D. Vacuum Pump

A vacuum pump might be a device for removing gas molecules from a screened volume to flow into a partial vacuum. In 1650 Otto von Guericke fictionally produced the primary vacuum pump and was predated by the ancient suction pump. Vacuum pumps are integrated into a big type of vacuum system with chambers and operating processes. In general, in an extremely single application, more than one pump is utilized (in series or parallel). Sometimes a partial vacuum was generated using a positive pump that carries the gas charge from an inbuilt port to an output port. These pumps are only vacuum-dependent due to their mechanical constraints. Alternative approaches (typically asynchronous following an initial fast pump with a positive displacement pump) should then be employed to get a better vacuum [17].

E. Water Pump

There are several kinds of water pumps that perform the same service but work differently, including positive displacement pumps and centrifugal. A water pump's fundamental principle is the use of a motor to transform rotational or cinematic energy into flowing water or fluid energy (hydrodynamic energy) [18].

F. Compressor

An air compressor is a pneumatic instrument that transforms power into a potential energy stored in pressured air using an electric motor, diesel or fuel, etc (i.e., compressed air). Using one of many techniques, an air compressor exerts rising pressure into a storage tank.

G. Two-way 5/2 directional valve

A two-way directional valve is made of two ports that are linked and disconnected from each other through passageways. Port A is open to port B at one extreme spool position; the valve flow route is open. The enormous diameter of the bobbin closed the trail between A and B in the opposite extreme, blocking the flow channel. The on-off operation of a two-way directional valve. (Open flow path and shut down flow path).

H. FRL Unit

It is an air conditioning device for use in pneumatic systems. A filter-regulator-lubricator combination is FRL. FRL units feature a semi auto-drain function and are composed of aluminum casting alloy, which makes them robust for industrial use.

In several sectors such as food processing, paper and packaging, pharmaceutical and textual applications, the FRL units are employed. FRL units are strong in design, construction and are available at low rates, and are excellent for usage under severe working circumstances.

IV. Specification

- Battery- 12V
- Slider Rod - d= 8 mm, l = 312 mm
- Vacuum Pump
  Rated voltage: AC 230V.
  Operating voltage: DC 12V.
  Suction capacity: 25L/ min.
- Water Pump
  Rated voltage: 12V DC
  Max flow rate: 4L/MIN (1.06G/MIN).
  Max Head (lift height): 3m
  Pump material: ABS.
- Double acting Pneumatic Cylinder:
  Bore = 20 mm
  Stroke = 100 mm
  Working Pressure: 2 - 3 bar
- DC Motor: Model: SF-578VA
  Speed = 300 rpm
  Voltage = 10 - 12 volt
  Torque = 0.8 Kg-cm
- High speed brush motor:
  Speed = 20000 rpm
  Voltage = 12 volts

- Suction Pump:
  No. of Stages = single stage
  Max flow rate = 4 L/min
  Rated voltage: 12 v DC
- Suction cups:
  Diameter = 30 mm
  Stroke (cup deflection) = 15 mm
  Working temperature = -10°C to 50°C

V. Design Calculations

- Safety analysis

$$d = 1.12\sqrt{\frac{m\,S}{P_u\,n\,\mu}} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Mass of robot m = 7 kg,
Diameter of Suction cup, d = 3 cm,
No. of suction cups n = 8,
μ = 0.5 for glass.
Factor of safety, S = 1.5

By substituting these values in equation (1) Pu = 0.586 bar. This is the pressure created by the suction cup, it takes approx. 0.6 kg/cm^2. Now it has 4 active suction cups at a time of dia. 3 cm.

Area of the suction cup

$$A = \frac{\pi}{4} d^2$$

Hence mass carried by a single suction cup

$$m = A\,P_u = 4.2411 \text{ kg}$$

Now mass hold by 4 suction cups will be 16.9644 kg. This robot's weight is 7 kg, Still, it is taking 8 cups for balancing and symmetry of robot in the vertical glass. Max Force Required by Suction Cup is 9.31 N. Total Force Required for All Suction Cup is 74.48 N. Suction Pressure for a cup is 0.01317 bar, total Suction Pressure is 0.10536 bar. Required working vacuum/suction pressure to hold robot at stationary position is 0.10536 bar

- Pneumatic Cylinder Force Calculation
  Diameter of piston = d = 20 mm
  A= 314 mm²
  P= F / A
  F = 317.14 N
  F= 32.32 Kg.

So, have selected a pneumatic cylinder that move 32.32 Kg. of force at 10 bar pressures. As load required to slide is only 2.5 to 3 kg so if low pressure i.e., 3-4 bar is also sufficient for us to drive the unit

VI. Result and Discussion

In an analytical analysis, it is found out the maximum stress is 10.179 MPa and in theoretical analysis, it's 22.38 MPa. Results in the above table show that the overall Factor of safety for materials i.e., Aluminum, Structural steel, and Rubber is more than 1 means it passed the safety law i.e. "If the factor of safety exceeds the value of 1, the design is safe."

The mechanical modeling analysis above shows that the structural design of the cleaning robot can be well guided. The relationship between the diameter d, the vacuum pressure - pu and the gravity G of the suction cup without slipping was obtained through analysis, and the best adsorption force was determined. To ensure the safe and reliable adsorption force and the flexibility of wall movement, the above analysis can improve the sport performance of glass cleaning robots, providing a good theoretical basis for design optimization and motion control of cleaning robots. The experimental results showed that the glass wall cleaning robot is stable on the surface, and the adsorption force is sufficient for the robot to walk freely on the glass.

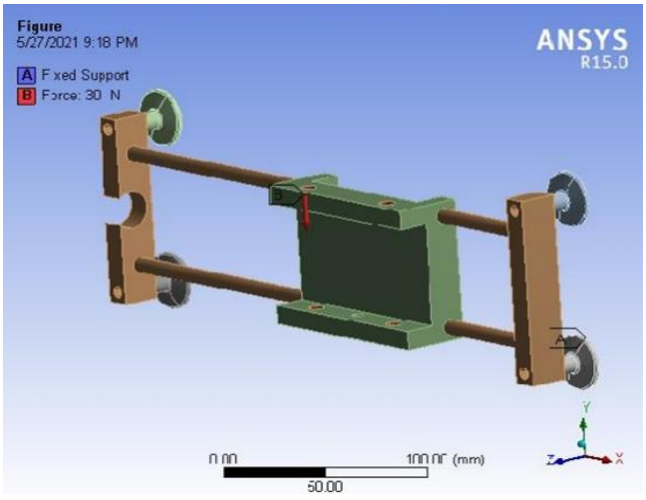

Figure 3. Static structure of window cleaning robot

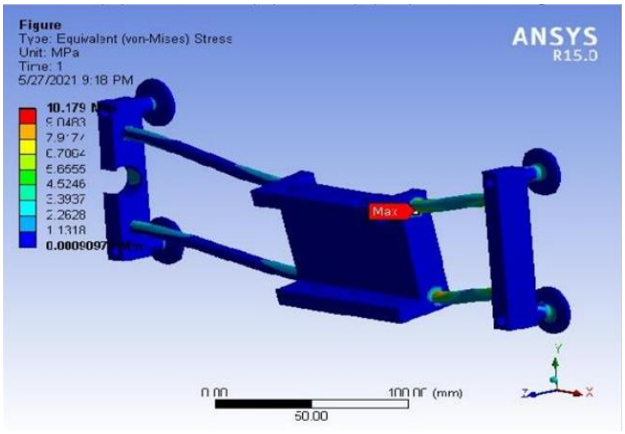

Figure 4. Equivalent stress developed

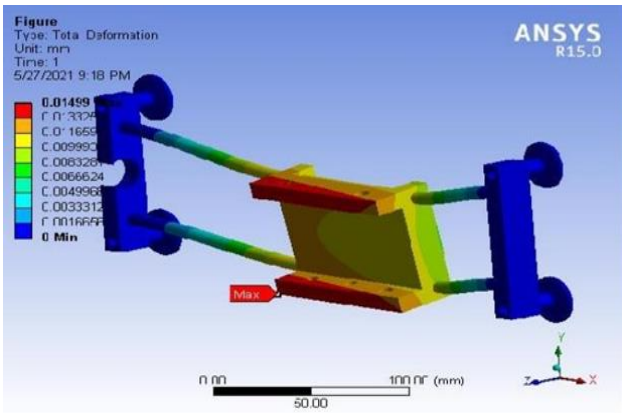

Figure 5. Total deformation

TABLE 1

CAMPARISION OF ANALYTICAL AND THEORETICAL RESULT

Parameters	Analytical results	Theoretical results
Equivalent stress	10.179 MPa	22.38 MPa
Force on Aluminum	14.24 N	6.47 N
Force on structural steel	17.68 N	8.04 N
Force on Rubber	2.94 N	1.34 N
Design safety	Design is safe	Design is safe

VII. CONCLUSIONS

In this study, a new cleaning robot was developed for use in cleaning the façades of high-rise buildings. This climbing robot is based on pneumatic technology and a multilinked slider mechanism. The main advantage of this robot is that it can be used to cleaning of high-rise building façades.

This mechanical setup is designed with pneumatics and electronics to provide better cleaning. This contemporary design of these kinds of cleaners helps to overcome the limitations of the existing technologies in the glass cleaning system. The rate of cleaning is moderate but the quality of the cleaning is much more superior with using efficient soap water. This robot can be the future of cleaning purposes of glass exterior building.

With some modifications, it can be used for surveillance purposes in defense, an inspection of buildings, fire extinguishing, etc.

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