Development of Glass Cleaning Unit

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Abstract— A Cleaning of glass walls of modern buildings or skyscrapers is most dangerous work for humans. To do the same task humans/workers should have to work in unsafe conditions. Our idea is to construct a cleaning unit for cleaning of those high-rise buildings which will minimize the risk of humans/worker's life. Climbing on glass is possible in two different ways 1) Magnetic 2) Vacuum. Climbing the glass using vacuum adhesion necessitates following demands to apply the glass cleaning unit for practical use: 1. Stick to glass surface by means of suction. 2. Clean the glass with the help of cleaning pad. 3. After cleaning climb the robot as per instructions of microcontroller.

Key words: Vacuum Adhesion, Microcontroller, Cleaning Pad, Suction Cup

I. INTRODUCTION

Climbing robots are useful devices that can be adopted in a variety of applications like maintenance, inspection and safety in the process and construction industries. These systems are mainly adopted in places where direct access by a human operator is very expensive, because of the need for scaffolding, or very dangerous, due to the presence of the severe environment. Recently, there have been many demands for increasing of modern architectures. Some customized window cleaning machines have already been installed into the practical use in the field of building maintenance. However, almost of them are mounted on the building from the beginning and they needs very expensive costs. Therefore, requirements for small, lightweight and portable window cleaning robot are also growing in the field of building maintenance. As the result of surveying the requirement for window cleaning robot, following features it should possess:

- It should be small and light weight for portability.
- It should have automatic operation during moving. A glass cleaning unit should be light and capable of taking large payload, reducing excessive adhesion forces and carrying instrumentation during navigation.

II. MECHANICAL STRUCTURE OF CLEANING UNIT

The cleaning unit consists of light weight material (acrylic fibre) and makes use of different climbing technique than those used in other robots reported earlier. Hence it is light in weight. It has microcontroller that can be operated by 6 volt lithium battery pack mounted on board.

The glass cleaning unit is capable of sticking on vertical as well as inclined surface. The desired capacity to stick to surface can be achieved by mans of vacuum. Vacuum pump creates a vacuum pressure used to stick to vertical or inclined surface. The unit sticks to the surface by means of suction cups. The movement of the cleaning unit can be obtained by wheels operated by 12V D.C. motor.

A. *Components used in Cleaning Unit*

The measure components used for cleaning unit are as follows:

1) Microcontroller
2) Vacuum pump
3) Suction cups
4) DC motors
5) Frame
6) Battery
7) Power and connecting cables

III. METHODOLOGY

A. *Calculating Suction Pressure Required.*

Calculation of suction pressure is important as it determines the weight holding capacity of cleaning unit. The holding force is calculated based on coefficient of friction between rubber and glass and the weight robot has to carry. Based on suction pressure required vacuum pump is selected.

B. *Calculating Torque & Speed Required for Motors of Wheels.*

The speed of cleaning unit should be high so that robot could clean the glass in a short time. But higher speed results in higher holding force and also cleaning also doesn't get sufficient time.

C. *Calculating Battery Life.*

Battery life very is important in glass cleaning unit as the unit is on the windows and complete discharge of battery would result in falling of cleaning unit off the window causing damage to robot as well as to the things over which it would fall.

D. *Calculating Frame Thickness.*

The material thickness is calculated according to weight it has to carry. Once the thickness is calculated and robot dimensions are decided, the frame can be made and all the components can be mounted on it.

IV. ANALYTICAL & CALCULATED RESULTS

A. *Holding Force*

For vertical direction of Movement

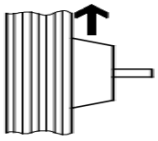

Fig. 1: Holding Force

$F_h = (m/\mu) \times (g + a) \times S$
$=(5/0.5) \times (9.81 + 0.036) \times 3$
$= 295.38\ N = 300\ N$
where F_h= holding force
m = mass of cleaning unit
μ = coefficient of friction glass and rubber
g = gravitational acceleration

a = acceleration of cleaning unit
S = safety factor
[a = $(v_2-v_1)/t$
Taking speed of the wheel, N=60 rpm & radius of wheel, r = 0.03 m & time, t = 5 sec

$$a = (\frac{2\pi*60*0.03-0}{60})/5=0.036 \text{ m/s}^2]$$

B. Selection of Size & Number of Suction Cups

As required holding force is 300 N, we can select two suction cups of 150 N holding capacity.

Hence we will select two suction cups of standard shape & 55 mm diameter.

Fig. 2: Suction Cups

C. Determination of Required Vacuum Pressure (P)

The two selected cups require the pressure of -0.7 bar (vacuum) for their operation. Hence we need to select vacuum of -0.7 bar pressure.

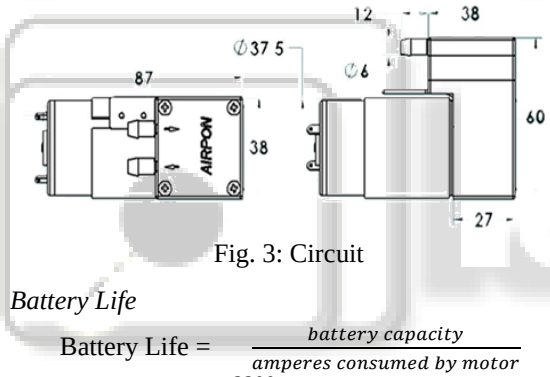

Fig. 3: Circuit

D. Battery Life

$$\text{Battery Life} = \frac{\textit{battery capacity}}{\textit{amperes consumed by motor}}$$

$$= \frac{2200}{0.48\times 1000} \text{ x } 4 = 18.33 \text{ hrs}$$

Fig. 4: Battery

E. Calculation of Thickness of Frame

Considering central load of 50 N & taking acrylic as frame material (bending stress, σ =100 MPa)
Maximum bending moment,
M = WL/4=50x300/4=3750 N-mm
Now, σ = M/z
Where z = section modulus = $bt^2/6=300\ t^2/6=50t^2$
Thus, $\sigma = 100 = 3750/50t^2$
Hence t = 0.866 mm.
Hence we will use material of standard thickness 3 mm.

V. COMPONENT SPECIFICATIONS

SR.NO.	COMPONENT	SPECIFICATION
1.	Microcontroller	5V, 20mA
2.	Vacuum Pump	Pressure = 0.7 bar (Vacuum)
3.	Electric Motor	Power = 0.033 W
4.	Battery	Life = 18 hrs
5.	Frame	300 x 300 x 3 mm

Table 1: Specifications

VI. CONCLUSION

This chapter presents application of glass climbing robot for cleaning purpose. The robot is constructed by means of frame, vacuum pump, suction cups, motors & microcontroller. Robot has capacity to stick to vertical as well as to inclined surfaces. The desired capacity is achieved with the use of vacuum pump. Future work will be towards developing more efficient robot that is completely autonomous and directs itself when obstacles are detected.

ACKNOWLEDGEMENT

We would like to acknowledge the assistance given by Prof. Mane & Prof. Shingane & other faculty members of of V.C.E.T.

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