Design and Fabrication of Automated Glass Curtain Cleaning Machine

Vinod kumar M V, Prem kumar naik, Prasad B G, Syed Razeequlla

Abstract - Window cleaning makes the building's architectural glass free from dust and dirt. The traditional way of cleaning office windows cannot be applied to high rise windows with huge sections of glass. Cleaning the windows from outside requires special tools in going up and it's really unsafe. The Window cleaner proposed is an unmanned device which would be controlled by using a microcontroller. This device would be safer compared to traditional methods of window cleaning in case of high glass structures that increases risk in loss of human life. Structure of the proposed device consists of a triangular frame and uses suction cup based adhesion technique to adhere on the glass surface. The movement of the frame over the glass is done by using special rigging. The frame consists of an automated cleaner which is run by motors and pre-programmed microcontrollers. The automated cleaner moves in vertical direction within the frame using the threaded shaft.

I. INTRODUCTION

There exists increasing demand for the development of various service equipments to relieve human beings from hazardous jobs and inspection of high pipes and walls. Window washing and cleaning makes the building's architectural glass free from dust and dirt. The traditional way of cleaning office windows cannot be applied to high rise windows with huge sections of glass. The reason is because windows are extremely inaccessible. Cleaning the windows from outside requires special tools in going up and it's really unsafe. This paper is based on a climbing system aimed to clean glasses of high-rise buildings, using suction cups for adhering to the glass. The idea is to build a small window climbing robot with suction cups which is able to move autonomously along the outside surface of window with a relatively sufficient area and meantime clean and wash it. Traditionally cleaning of building/house windows is commonly done manually by cleaners or specialized personnel. Although the window cleaning is easy from inside the room it is not that easy from the outside. Cleaning of wide windows on tall and multi-story buildings is even more tedious and very dangerous procedure. It needs either hoisting machines for manual cleaning or large, heavy and very expensive automatic cleaning machines. As a result windows normally remain dirty or dusty form outside which might obstruct the room occupant's view. Instead our cleaning machine can be attached to the outside surface of a room window. The machine will execute and accomplish the task of window cleaning automatically [1].

II. LITERATURE REVIEW

Because of the increasing number of high-rise buildings and large glass facades and the resulting problem of safe and effective cleaning, a lot of effort has taken place in the last few years to develop automated cleaning systems. The majority of systems conceived and developed thus far are in Japan and Europe (Schraft et al., 2000) (Gambao & Balaguer, 2002).

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The first automated cleaning systems for high-rise building were used in Japan in the middle of the 80's. These systems were mainly designed for use on specific buildings. For safety purposes or in order to guide the robot's movement on the facade, they often required additional construction such as guidance rails to the facade. The practical application of the existing systems mostly failed because of either a weak safety concept, poor cleaning quality, required additional construction to the facade, or simply due to expensive initial or operating costs [1]. Cleaning robots are among the first members of the service robot family to reach the marketplace with practical and economical solutions. The traditional way of cleaning office windows cannot be applied to high rise windows. The reason is because windows are extremely inaccessible. Cleaning the windows from outside requires special tools in going up and it's really unsafe. Only the experts can do this incredible job, with all their skills and special body movements when doing it. In cleaning services, the provider will use distinct tools appropriate for height, size, and materials of the windows. For instance, window cleaners can use long tools that can clean and reach up high windows, without using or setting up scaffolding. A key issue to the success of the climbing robot application lies in an effective sensing capability. To do the cleaning work on the glass surface, the cleaning robot must know when to begin or stop the cleaning job, how to control the orientation and how to cross the window frame. Therefore, it is necessary to measure the robot orientation, the distance between the robot and the window frame, and the distance between the robot and the dirty spot to be cleaned.

III. SYSTEM DESIGN

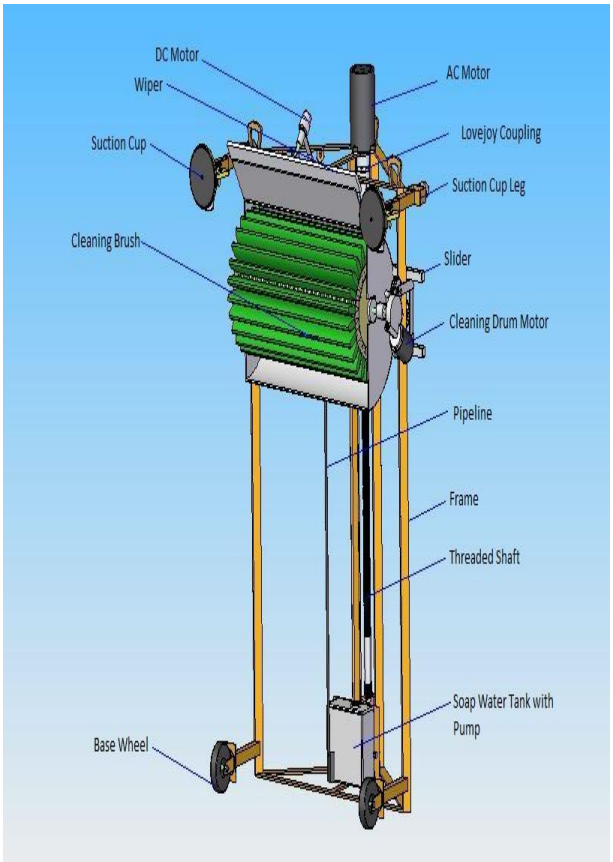

Figure 3.1: Automated Glass Curtain Cleaner

IV. LIST OF COMPONENTS USED IN AUTOMATED GLASS CURTAIN CLEANER

The major components used in automated glass curtain cleaner are as follows:

1. Main Frame
2. Threaded Shaft
3. Lovejoy Coupling
4. AC Motor
5. Slider
6. Cleaning Drum
7. Cleaning Brush
8. Outer Casing
9. Wiper
10. Base Wheel
11. DC Motor
12. Suction Cups
13. Reed Switch
14. Micro Switch
15. Microcontroller

V. WORKING PRINCIPLE OF AUTOMATED GLASS CURTAIN CLEANING MACHINE

A glass curtain cleaning machine is designed to clean the surface of glass wall of high rise buildings. It consists of a triangular metallic frame on which the slider is attached with nylon rollers. A Cleaning drum along with brushes is fixed to the slider. It is fixed in such a way that half the diameter of the drum protrudes outside the frame. Such an arrangement of the drum does not allow the frame to touch the glass wall preventing from any damage occurring to the glass. A threaded shaft is provided to give vertical movement to the slider. The nylon rollers assist the vertical movement of the slider over the frame. The shaft is coupled to an AC motor which rotates the shaft at 60 revolutions per minute using a Lovejoy coupling. The cleaning drum is coupled to wiper motor which rotates the drum at 50 revolutions per minute. The cleaning drum is covered using a sheet metal casing which is fastened to the slider. The casing is fitted with 8 nozzles out of which 5 nozzles spray pure water and 3 nozzles spray soap water. The supply of pure water can be done by pumping it from an external source and the supply of soap water is done by using a pump which is attached to a separate tank fastened at the bottom of the frame. Pure water is sprayed through the 5 nozzles on the glass wall. Remaining 3 nozzles spray soap water on to the brushes to ensure efficient cleaning. A wiper is riveted to the casing which is actuated by a DC motor, controlled by the microcontroller. The reed switch is fixed to the frame and two magnets are placed at appropriate positions on the slider. As the slider approaches the upper/lower limit of the threaded shaft, the reed switch gets actuated by the presence of the magnetic field. This will send a signal to the microcontroller which reverses the direction of the slider. Cleaning of the surface is done in two passes. In the first pass the slider moves from bottom to the top of the threaded shaft. At this time the nozzles spray the soap water solution and cleaning brush rotates throughout the pass. This ensures in the even application of the soap solution on the glass surface. In the second pass the slider moves from top to the bottom of the threaded shaft. The nozzles spray pure water throughout the pass. Wiper is actuated on to the surface using a motor such that the water is wiped off in this pass. In the end of second pass wiper returns to its initial position. The machine is of hanging type which can be raised or lowered by using pulley mechanism. The machine is made to hang in such a way that only the brushes come in contact with glass which is possible by using the rigging as shown in the figure 5.1. As the machine moves up there are chances for the brushes not to touch the surface glass wall due to wind or due to height of building, to make sure the brushes touch the glass wall two suction cups are provided on the top of the frame which creates contact between the brushes and the glass wall there by helping in proper cleaning. The suction cups are pushed forward towards the glass by a DC motor and the adhering is done by another motor with the help of wedges. The micro switch limits the movement of the suction cups such that when the suction cups touch the glass wall, the switch gets actuated and sends a signal to the toggle switch to stop the suction cup movement. Two rubber wheels are provided at the bottom of the frame to

ease the vertical movement of the machine on the glass wall.

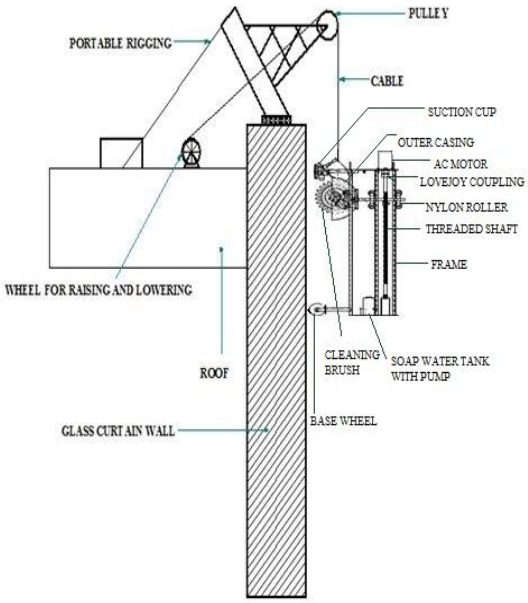

Figure 5.1: Schematic representation showing working principle of the machine

VI. TEST RESULTS

Traditionally, dirt on glass window is detected and evaluated by human subjectively [2]. A quantitative dirt detection method by measuring amount of transmitted light which decreases in dirty place has been proposed. In this method, a light emitting section and a light receiving one are necessary to face each other at a constant distance, because amount of light is in inverse proportion to a distance from illuminant. Dirt is detected by measuring amount of reflected light which is in proportion to the amount of dirt. Photo diode is used as the sensor for detection of dirt. The illuminated light source is kept at a particular distance (about 40 cm) from the photodiode. To study the variation of photocurrent with the intensity of illumination the reserve bias voltage is set to 3 volts and 5 volts. In between the light source and the photodiode the five glass windows namely A, B, C, D, E of plain with different dirty state are kept. The intensity of illuminated light source varies as it passes through the windows.

Window A Window B Window C Window D Window E

Figure 6.1: Windows with different amount of dirt

As shown in fig.6.1, there are 5 glass windows A, B, C, D and E of plain which are in different dirty state. Mud is used as dirt. Windows A is clean which is cleaned by human as much as possible. Window B is least dirty one, Window C, D are normally dirty ones and window E is most dirty one.

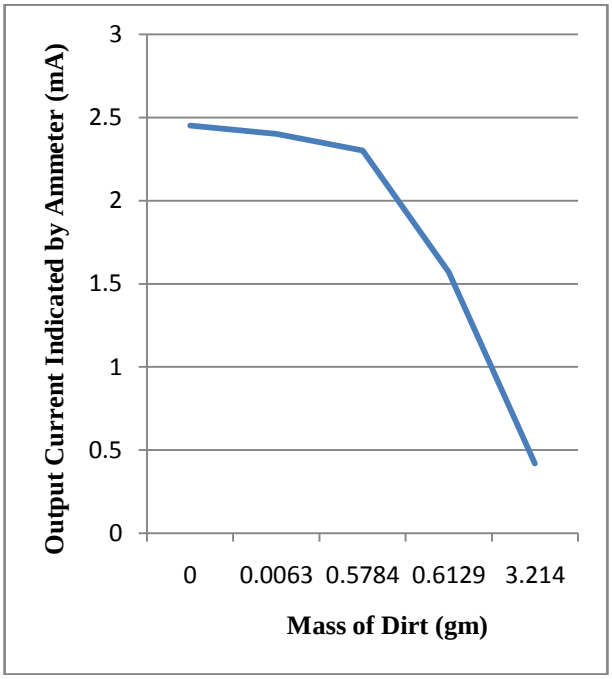

Figure 6.2: Comparison between the dirt detecting sensor and the estimation by mass of wiped dirt for plain glass for 3 volts

For each of those windows, dirt is detected by the proposed sensor and the estimation by mass of wiped dirt. The results are shown in graphs. X-axis is a mass of dirt scale and Y-axis is an output current scale. It shows average output current in 5 trials for two different voltages.

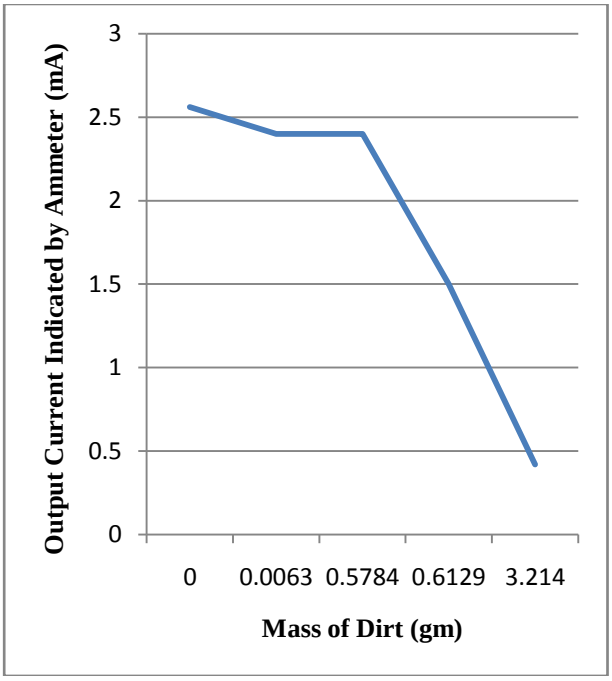

Figure 6.3: Comparison between the dirt detecting sensor and the estimation by mass of wiped dirt for plain glass for 5 volts

From figure 6.2, mass of dirt on window A is 0.0(gm), B is 0.0063(gm), C is 0.5784(gm), D is 0.6129(gm), E is 3.214(gm) and output current for dirt on window A is 2.45(mA), B is 2.40(mA), C is 2.30(mA), D is 1.57(mA), E is 0.42(mA).
From figure 6.3, mass of dirt on window A is 0.0(gm), B is 0.0063(gm), C is 0.5784(gm), D is 0.6129(gm), E is 3.214(gm) and output current for dirt on window A is 2.56(mA), B is 2.40(mA), C is 2.40(mA), D is 1.50(mA), E is 0.42(mA).

VII. CONCLUSION & FUTURE WORK

The automated glass curtain cleaning machine has been successfully designed and fabricated. The project work implements a simple glass cleaning machine that uses a portable rigging for the motion there by reducing the cost of climbing mechanism. This machine can work well for buildings having completely glass exterior. The machine construction is able to perform its intended function: the efficient cleaning of glass surfaces. The suction cup attachment system ensures good contact with the support surface, is simple and reliable. Comparing with the traditional suction cup robots [3], the suction cup in this project does not need any onboard vacuum pump and it has advantages of no noise, little volume and weight. The overall weight of the machine is around 20kg. The cleaning process takes about 5 minutes to finish a glass window pane. Uniform cleaning by using rubber brush and optimal in-line water pump deliver soap water for removing stubborn stains and controlled spray of water by using microcontroller to reduce wastage of water. Cleans at faster rate when compared to other robots [4]. With some modifications the machine can also be used for wall painting. Moreover, a dirt detecting technique is developed which detects dirt by measuring amount of dirt on the glass. Results of experiments using the dirt detecting technique show the validity of the discussions.

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