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A simple wall-climbing mechanism for a window cleaning robot

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Abstract: In this paper, a new type of wall climbing robot to clean window is proposed. The developed robot can climb the pane by using a crawler with ordinary suckers. The suckers of the crawler sequentially stick to the window and the robot climb the pane. The robot will be low-cost and simple. The robot was tested to see whether it have performance to climb the window and to carry cleaning equipments. As the result, it was confirmed that the developed robot can move on the window. This paper gives motivation of this development, concept design of this robot, the details of the system, the experimental result, conclusions and future work.

Keywords: robot, window cleaning, crawler, ordinary sucker

1 INTRODUCTION

Recently, the automation of the window cleaning is requested. The number of high-rise building which uses large-scale panes is increasing. And window cleaning has been done by human or by large equipment. They are very dangerous and expensive. It is important that developing safer and cheaper robot to clean the window [1][2].

Many small robots to clean the window have been developed. Such robots can be classified into four types according to the adhesion methods [8]: magnetic, hand-hold, biologically inspired and vacuum suction pad type.

The magnetic method is used magnet for absorbing and wheel for driving [3]. This method has the can steadily absorb the wall and not need electric power for absorbing. However, it has the problem that it is difficult to put the window and that the robot makes the window dirty like stripes by stick slip motion [4] because the frictional force between the magnet and the window. The other, there is a mechanism that adsorbs the wall of iron by permanent magnets and move in itself as wheel [5]. But it is possible to use only for the wall of iron, and can't adopt for window cleaning robot.

The hand –hold method can support very strong adhesion force but it requires special equipment like knobs.

The biologically inspired method does not need no electric power for creating the absorb force. However the possible payload is very small.

The vacuum suction pad type method is a mechanism that adsorbs onto the wall by negative pressure of the vacuum pump, and to run with the wheel for the drive [6][7]. The robot have this mechanism can freely set the adsorption force, easily put the window and easy to control. However, the robot has danger of falling when the trouble is caused in the supply of electrical energy because the vacuum pump of the robot needs the electric power.

Thus, the proposed mechanisms of climbing the wall have the fault respectively, and the development of a new mechanism for wall climbing robot is demanded.

In our laboratory, from such back ground, develop climb the window by rotating a crawler that has general purpose suckers. This robot has the mechanism that climb the wall with an easy mechanism that does adsorb and peel off the glass by the suckers, and the following merits exist.

1. There is no fear of the fall by the electric power cutting.
2. It is suitable for lightening and lowering the cost because the robot has easy mechanism
3. It contributes to conservation of energy because it doesn't need electric energy for adsorb the window.

From the above reason, it is thought that the robot will be lower-cost and simpler than other methods.

We perform some experiment to evaluate this robot.

2 CONCEPT DESIGN OF THE ROBOT

This paper takes the building that has ruggedness o n the wall because it is difficult to adapt by the large-scale cleaning system.

The function demanded from the window cleaning robot is to adsorb outside in the window that is neede d cleaning in some means and to wipe up the window while automatically moving the all aspects of the win dow. For this function, function that moves from objec ted window to another window and that moves with a dsorbing the window are needed.

In the case of the large-scale cleaning system, the hanging crane mechanism must set up in the rooftop t

o fix the cleaning mechanism to the vicinity of the pa ne, which makes this system more expensive.

On the other hand, small window cleaning robot ne eds to adsorb window and move with adsorbing windo w steadily. Additionally, it also needs the function that wipes all aspects of the window without the lack of wipe and the wipe mark to clean the window perfectly. Then, it is hoped that the robot clean the window wh ile climbing it autonomously.

A small window cleaning robot is needed to move from objected window to another window while getting over the ruggedness, but it is very difficult to develop such function. Then, in this case, we make the approach to develop such function a deferment, and try to achieve to plan that a user set the robot in each window and the robot clean each one window sequentially.

Fig.1 shows the plan that we summarized such idea. We presume that this plan becomes the following procedures.

① The user takes out the robot from the inventory location, and supply to the robot for window cleaning such as water.
② The user adsorbs the robot onto the window and start up the robot. The robot cleans the window autonomously and returns the first position. In this case, the provision of the electrical energy for the robot assumes the power source from indoor by power code which also behaves as a safety rope.
③ The user gets out the robot from the window, and returns it the inventory location.

Thus, we try to trim the weight and to reduce the risk of fal out by using power code from indoor power source an- d combine with the safety rope.

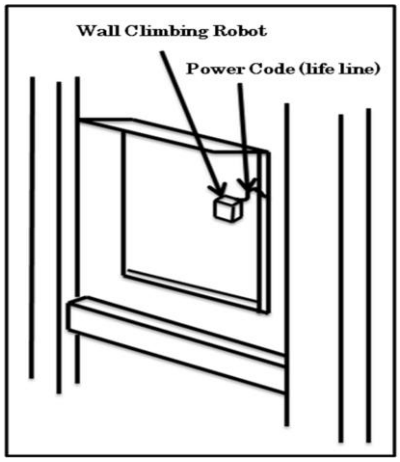

Fig.1. Concept of automated window cleaning

The robot needs the following condition because many robots are needed to carry out such plan and general public use it.

1. The costs about one robot are cheap.
2. It is easy to maintenance.
3. It is a safe for all the people.

Then, we spot the mechanism use the crawler installed s ome ordinary suckers, and climb the vertical pane by adsorb the suckers onto the window and rotate the crawler. The idea suitable to trim weight and to develop cheaper by compared with negative pressure adsorption mechanism an d magnet adsorption mechanism. And it doesn't have the ris k of fall out by electricity failure.

For the above- mentioned reasons, we decided to adopt this mechanism for this plan.

In our laboratory, one robot was made on the basis of this plan [9].The length of the robot that has been made before in the laboratory is 630mm. It is too bi g. In addition, the weight of robot was 4.0kg, it was not working properly. Then, a new smaller robot is developed. The goal was reduced to about 200mm, wh ich is about one-third the size of the robot prior to a size that can easily carry. Sucker which is used in the previous robot was 56mm in diameter. In order to red uce the size of the robot, a sucker diameter of 42mm is selected in ordinary suckers. The size is the smaller one in the ordinary suckers.

Experiment was carried out as shown in Fig.2 in order to know the performance of this sucker. Fig.3 shows the result of the experiment. It can be seen that approximately 8.2kg withstand the load of one suction cup to be used from the experimental result. Design of the robot is performed based on the performance of this sucker.

Fig.2. The outline of a perpendicular load experiment

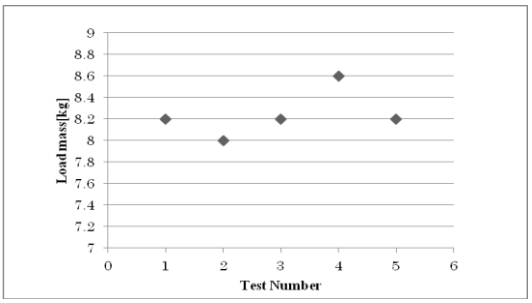

Fig.3. The result of a perpendicular load experiment

3 THE DEVELOPMENT OF THE ROBOT

3.1 The spec of the robot

Fig.4 shows the picture of the developed robot. And Fi g.5 shows the diagrammatic illustration of a wall cleaning robot. This robot is composed of a crawler that has suckers that have a knob, sprocket, and pulley. Then a DC motor is used to drive the crawler.

Total weight of system is 0.8kg. Therefore, the robot can

afford to have equipment such as cleaning unit because the one of the suckers can hold 8.2kg. The robot's dimensions are 100mm width, 210mm length, and 150mm height. This size is about a third of test model which was made in our earlier study, and the weight is about one-fifth of it. We have refined the concept design so that the size will become suitable to the performance of the suckers. It also contributes in a downsizing of the robot.

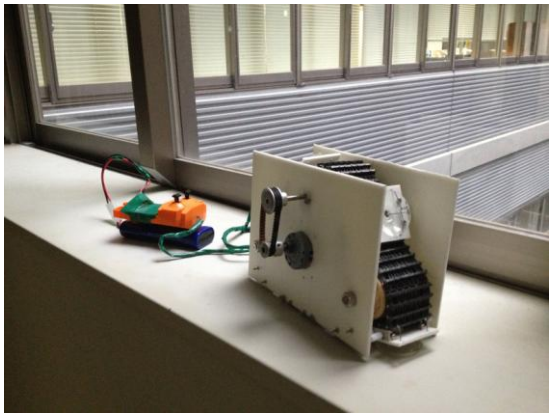

Fig.4. The picture of developed robot

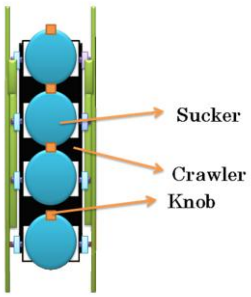

Fig.5. Overall view of robot of climbing the window

3.2. The system of the window climbing

The robot climbs the pane by using a crawler with ordinary suckers. The suckers of the crawler sequentially stick to the window and the robot climb the pane. The suckers are assembled to the crawler so that one or more suckers stick to the window at all times. Total weight of system is 0.8kg and one of the suckers can hold 8.2kg. It means that the robot doesn't fall down if one sucker falls of the window.

Fig.6 shows the outline of the system to climb the pane. When the crawler rotates, the sucker at adsorbing step is pressed to the wall by the rollers moving along the ledge. Then the sucker at holding step keeps absorbing the wall until the roller passes the ledge, also, push the sucker at adsorbing step. The sucker at peeling step peels off when the knob is pushed up by the movement of the crawler.
Thus, the robot keeps absorbing and moves ahead.

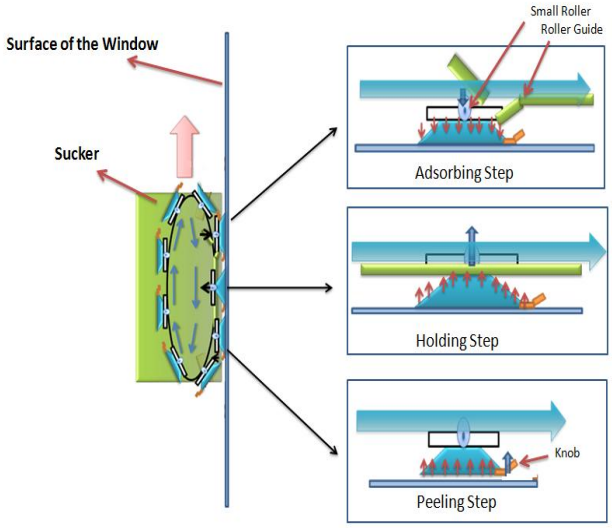

Fig.6. The outline of system

4 EXPERIMENT

In experiment, the robot was adsorbed onto the window and started up. Fig.7 shows the outline of the experiment. Then, we made sure whether the robot could climb the window.

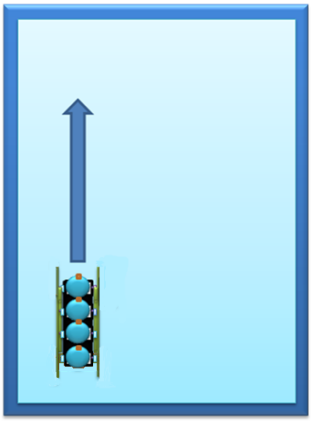

Fig.7. The outline of experiment

5 CONCLUSION

In this paper, the research and development of the window cleaning robot was described as an approach of the window cleaning on the automation. Firstly, we view an idea about the window cleaning using a small wall climbing robot. And propose the robot including the mechanism can climb the pane with simple suckers. Then we actually fabricated the robot and performed an experiment that made sure whether it could climb the window.

Future works are assembling equipments to turn the robot and to control the trajectory of the robot. For exampl e, we try to turn the robot by attach omni-wheel backward of the robot. And try to control the robot by attach the touch-sensitive switch and acceleration sensor to clean the

window more suitably.

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