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ON THE DEVELOPMENT A PNEUMATIC FOUR-LEGGED MECHANISM AUTONOMOUS VERTICAL WALL CLIMBING ROBOT

Mohamad Shukri Zainal Abidin,
shukri@suria.fke.utm.my

Shamsudin H.M. Amin
sham@suria.fke.utm.my

Dept. Of Mechatronics and Robotics Engineering
Faculty of Electrical Engineering
Universiti Teknologi Malaysia
Locked Bag 791, 80900 Johor Bahru, Malaysia
Fax: 607 5566272

ABSTRACT

The paper describes the design of a prototype legged mechanism together with suction mechanism, the mechanical design, on-board controller and an initial performance test. The design is implemented in the form of a pneumatically powered multi-legged robot equipped with suction pads at the sole of the feet for wall climbing purpose.

The whole mechanism and suction system is controlled by controller which is housed on-board the robot. The gait of the motion depended on the logic control patterns as dictated by the controller. The robot is equipped with sensors both at the front and rear ends that function as an obstacle avoidance facility. Once objects are detected, signals are sent to the controller to start an evasive action that is to move in the opposite direction.

The mechanism has been tested and initial results have shown promising potential for an autonomous mobile.

Key Words
Wall climbing robot, pneumatic, suction.

1. Introduction

The development of a wall climbing robot is currently requested strongly which performs, on behalf of human operator, dangerous operations on the surface of a wall at altitude such as maintenance and inspection of high buildings and various plants, assistance for constructions work, aids for fire fighting and rescue operation.

Several robot using wheels or crawler, and wall climbing mechanisms having a simple leg mechanism have been proposed and developed so far [1][2][3][4]. However they could only move on continuos and almost flat surface of a wall.

In addition to the mobile function, the wall climbing robot must produce a secure sucking force with a light-weight mechanism. To attain the above mentioned function the authors has developed the pneumatic four legged wall climbing robot "ROBUC UTM-1" using four pneumatic cylinders for climbing and four suction pads that capable of producing the sucking force. This paper will describe overall design in section 2, the body structure in section 3, section 4 detailed the control system, the climbing operations in section 5 and the conclusion in section 6.

2. Design for overall system

To produce high mobility, safely and payload performance, the configuration of the wall climbing robot should be carefully studied. The subsections studies the overall configuration design.

2.1Selection of sucking system and leg

The objective of the robot is move on a wall. In this case the vacuum sucker is most generally used to produce a sucking force. The walking system, which uses legs equipped with a sucker at the foot, has is very limited of locomotion speed, but it has the following advantages:

a. Adaptable to various wall surfaces by using the degrees of motion freedom of the legs.
b. Capable of producing a powerful sucking force because it is able to move while the sucker is closely adhered to the wall surface.
c. Capable to be a steady outrigger for the robot, when it makes some stationary operations. It can also be utilized as the active platform to assist the task of manipulator mounted on the vehicle.

Attached importance to these facts, the legged configuration with sucker on the sole is selected for the wall climbing robot.

In the legged locomotion, the selection of the number of the feet should be first determined. In this study, four feet are selected for the following reason: To generate high adaptability to a wall surface, two or more degree of freedom are required for each legs. So the number of leg should be small to minimize the weight of the body. But a robot with single leg cannot move on the wall surface at all. Two legged can move while one of them is supporting, but when one leg stretches sideways a great moment works on the sucker, causing them to fall down. Three legged robot can move while two of them are supporting, however such selection still causing a great moment on the sucker while in the process of sideways locomotion. Four legged robot can climb while three of them are supporting, and enable climbing without any moment occurring on the sucker [4]. Thus four is the suitable leg number for wall climbing robot.

2.2Actuators

The use of pneumatic actuators is central to the design. Compared with geared electric motors they are lighter and environmentally more rugged [5]. Pneumatic cylinders provide high trust directly, without the need of gearing. Those used in the robot can provide trust up to 70N and weight under 500gms. Another advantage gained by the use of pneumatic is the simple way in which compliance can be introduced. With compliance, loads are shares more equitably and machine is more tolerant of abuse [6].

3. The whole body

The structure of the ROBOC UTM-1 body adopts a modular design approach. The robot uses 25mm and 20mm bore diameter cylinders for each leg. The larger diameter cylinder is the main actuator for the robot to climb. There are four large diameter cylinders arranged under the body where two are facing up and the other two down as shown in figure 1. The smaller diameter cylinder is fixed at the end of the larger cylinder shaft and used to position the vacuum sucker on to the wall surface as in figure 2.

The robot is still on the development where the structure is being modified from time to time in order to overcome problems that arise while in the present design. Recently the robot weight up to 10kg. In the configuration used for the trials the wall are 4m height. The robot is 700mm long and 500mm wide. Fully extended is 1000mm long. The robot can pull up load up to 20kg. Air is supplied via a light 6mm bore flexible pressure hose from a small portable compressor at 6 bar.

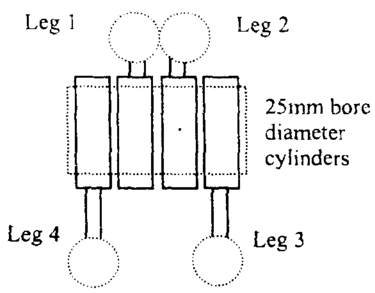

Figure 1. The large cylinders are arranged parallel where two are facing up and another two down

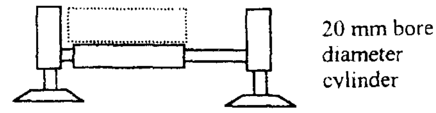

Figure 2. The small diameter cylinders are fixed to the rod of larger cylinders

4. Control of pneumatic cylinder and suckers

The robot motion is commanded from the hand held controller that is connected to the programmable logic controller (PLC) located on board. The PLC is programmed to coordinate the output signals to each valve that connected to each pneumatic device such as cylinders and vacuum pads. The controller also requires input signals from vacuum sensors and photoelectric sensor located in front and at the back of the robot. The vacuum sensor measure the vacuum pressure inside the vacuum pad in order to achieved the sufficient vacuum force. The photoelectric sensors as in figure 3 will detect any obstacle ahead while climbing and soon change the moving direction reverse as in figure 5. This will ensure safe movement and avoid collision with object.

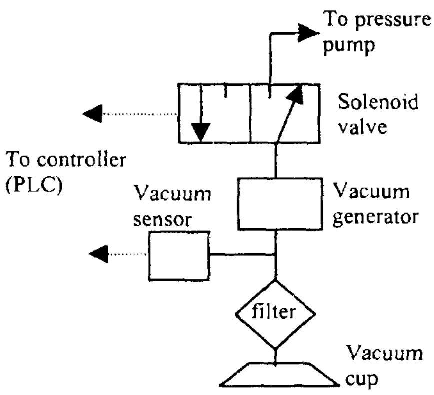

Figure 3. The vacuum system devices and pressure sensor (control signal)

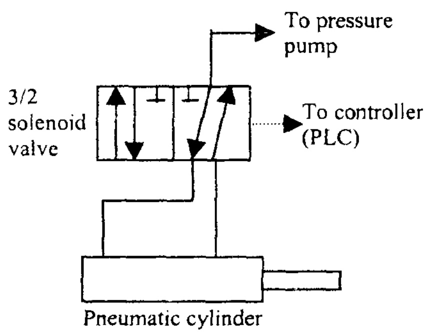

Figure 4. The cylinder system with the control signal

The operator guides the robot through elemental orders: straight forward, straight backward, stops, hold suction and release suction. The PLC is in charge of translating the order to on/off electronic valves that actuates each pneumatic component including the vacuum suckers. The motion is made up of discrete translation of legs.

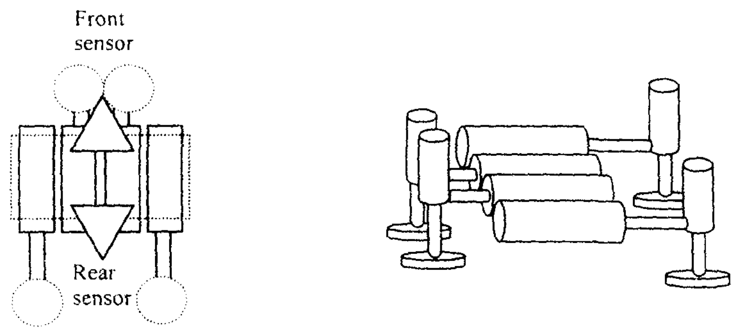

Figure 5. The location of photoelectric sensors and the overall structure

5. Wall climbing movement

In the normal resting position on the wall the gripper feet are firmly attached to the wall as shown in figure 6(a).Two cylinder for leg no. 1 and 2 facing up are in minimum stroke while the other two cylinders that facing down for leg no. 3 and 4 in maximum stroke as in figure 1 and 2. When the robot is moving forward, the following movements are implemented.

i. The robot releases the gripper for leg no. 1 and allowing it to rise. The small cylinder pull the pad of the wall. Figure 6(b).
ii. Then the leg is moved forward. The motion is done by the large cylinder. Figure 6©
iii. The robot then pushes the foot down in turn with vacuum enable. Figure 6(d)
iv. When the grip is secure then the robot will release the gripper for leg no.2 and allowing it to rise.
v. The same operation is repeated for leg no.2 , 3 and 4.
vi. There is different for leg no. 3 and 4, where the large cylinders shaft are move backward in order to pull the feet in.
vii. The robot then levers its body up and forward to a step ahead.

The above sequence of movement is design for slow operation. It was a secure movement which maintains maximum grip, only one leg will move at a time and the rest of the legs will continue to grip the surface.

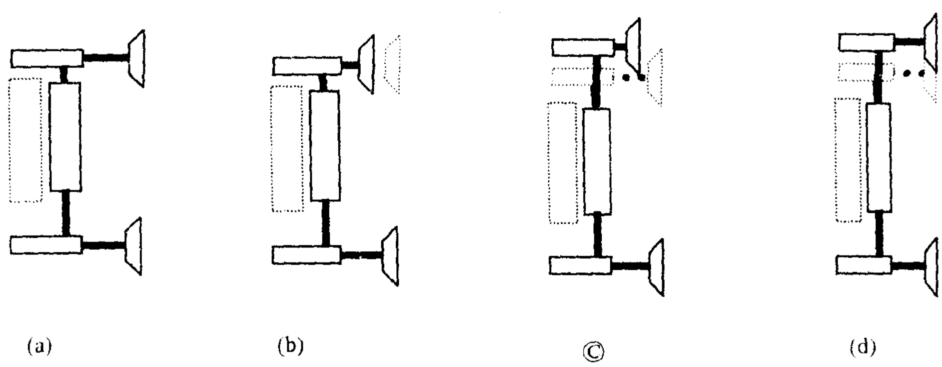

Figure 6. The climbing steps.

6. Conclusion

Currently the robot is able to climb smooth surfaces, moving straight forward or straight backward. The robot movement is limited to two directions only. Each legs have two degree of linear freedom generated by the cylinders.

Although design for "tameness" and ease of handling, the robot has considerable strength and its power- to-weight ratio enables it to pull double its mass up a vertical surface. A trivial in cylinder diameter will multiply the forces many times over at practically no cost in increase mass. However the diameter of the suckers must be considered before the robot pull up greater load.

The design of the robot is modular. Modules can be added to or removed from the current structured. This allows the robot to be modified easily and cheaply for variety of application. The wall climbing robot for future have to have the multiple mobile functions such as to move from floor to wall, from wall to ceiling, from northern wall to eastern wall, and to climb over obstruction such as pipeline and wall beams. Further work has already been carried out to improve the suction capabilities for rough surface.

Acknowledgement

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