Design and development of pneumatic suction based wall climbing robot for multiple applications

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Abstract - *Robots are quickly moving from industrial domain to service field. The design and development of robot depends on the application for which it is intended for. This paper discusses the design of pneumatic suction mechanism based vertical surface climbing robot. This robot is suitable for inspection of concrete walls, accessing of underside of bridges, reactor pressure vessel inspection, cleaning tall buildings, and many such applications where the robot must be autonomously functioning. Suction cup mechanism has superior performance due to greater gripping capability which ensures more payload and task specific tool carriage. Typical adhesion force and payload calculations are also discussed in this paper.*

Key Words: Suction mechanism, Double acting cylinder, Solenoid valves

1. INTRODUCTION

Robotics is one of the fascinating technologies, which has world wide applications. There are many different reasons for using a robot but the central reason for most applications is to eliminate a human operator. They can work longer than humans and do the task repeatedly without fatigue. Potential application are quite numerous and may vary from replacing human in repetitive or heavy task or work in unsafe and/or contaminated sites. Wall climbing robots are intended for motion on vertical and sloping surfaces in complex and extreme conditions. These robots have the potential to provide revolutionary steps in doing dangerous tasks that are usually performed by humans. Wall-climbing robots are helpful systems for various applications on vertical surfaces. There are a variety of potential applications of robotics for climbing operations that increase efficiency and safety. These include inspection of concrete walls, to access of underside of bridges, reactor pressure vessel inspection and cleaning tall buildings which are difficult to be performed by humans. Recently, there have been many demands for automatic cleaning system on outside surface of buildings such as window glass by 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 need very expensive initial and maintenance cost. Therefore, requirements for small, light weight and portable window cleaning robot are also growing in the field of building maintenance. The prospect of climbing robots is coveted because they can take the place of humans to carry out hazardous and maintenance job such as cleaning glass surfaces of skyscrapers, fire rescue, and inspectionof high pipes and wall, cleaning and inspection of high rise buildings, evaluation and diagnosis of a storage tank in nuclear power plants and petrochemical facilities, maintenance of ship, aluminum aircraft wing inspection with the consideration of operational efficiency, safety and human health. Due to the ability to relieve human beings from these hazardous works, more and more people are interested in developing various service climbing robots in recent years. Based on a classification of different types of climbing machines examples of robots are presented, which are typically developed for industrial and commercial use. Considering the application environment the system requirements of climbing robots will be presented. A climbing robot used for the inspection of concrete bridges is presented as an example with a huge commercial potential [1], [2]. The robot carries on board sensors which are used for inspection of the nuclear power plants where human are restricted [3]. For micro-scale application the size of the robot scaled down. The macro-scale robot is also used in space for repair, cleaning, inspection and surveillance [4]. The robot has to adapt to unevenness surface of motion which payload to be carried on porous and rough surfaces [5]. The most common attachment principle is the vacuum adhesion, where the robot carries an onboard pump to create a vacuum inside the cups, which are pressed against the wall. This system enables the robots to adhere on any type of material, with low energy consumption. But vacuum adhesion is suitable for usage on smooth surfaces, because the roughness can lead to a leakage in the vacuum chamber such as suction cup. The force in the normal direction when a suction cup adheres to surfaces is measured and compared for dry and respectively wet conditions [6]. Due to gravitational force the stress distribution deform the suction cups. The robot can incline in dangerous angle which the safety of robot matters [7]. Electrostatic wall adhesion is an attractive method if the robot is to climb smooth surfaces such as glass or door. Akio Yamamoto et al. have designed and developed a wall climbing mechanism based on electrostatic attraction. The electrostatic attraction was generated by flexible electrodes of plastic film and conductive foil [8]. Tomoaki Yano et al. have discussed semi self contained wall climbing robot which uses scanning type suction cups. They have tested the designed robot on the walls, steps cracks and gaps. This design is somewhat similar to the design presented in this paper, except that we use pneumatic cylinder/piston driven arrangement for movement [9].

1.1 TYPICAL CALCULATION FOR PAYLOAD

Assuming four suction cups, each of diameter 5.5 cm the payload is calculated as follow [10]:

We use an equation

$d=1.12*(m*S/Pu*n*\mu)^{½}$ where,

m- Mass of the robot, d- Diameter of suction cup, Pu- Pressure.

If, m = 2 kg, d = 5.5cm, n = 4, μ = 0.5 for glass and S = 4 for vertical and 2 for horizontal, then, by substituting these values in above equation. We get Pu = 0.16587 bar

Pu = 0.16587 x 1.019716 = 0.169048069 kg /cm^2. This is pressure created by suction cup. Now, if A is the area of the surface covered by the cup and if we have 4 suction cup of dia. 5.5cm, then the mass carried by single suction cup = A x Pu = 23.7583 x 0.1690 = 4.0152 kg. Hence the total payload together by four suction cups will be 4 x 4.0152 = 16.0606 kg.

2. SYSTEM COMPONENTS

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Pneumatic cylinder: Cylinders are linear actuators. They convert air pressure into straight line motions and forces. Double acting cylinder with maximum air pressure of 10mBar is used. The maximum air pressure range expected for this work is 2mBar-4mBar.

Fig -1: Double acting pneumatic cylinder

Suction cups: Thin layered fiber suction cups are used. The robot contains two pair of active cups to adhere to wall and three supportive cups to with stand robot weight**.**

Fig -2: Suction cups

Solenoid and flow control valves: There are two flow control valves operating at 24V providing alternate path to two pair of suction cups and one solenoid valve operating at 230V main supply provides pressured air signal to two inlets of cylinder.

Fig -3: 5/2 Solenoid valve

3. METHOD

Robot uses negative air pressure to adhere to flat surfaces. In order to make a model of the robot supported by suction cups, an analysis of different functional states for a suction cup in correlation with the depression applied. The most common attachment principle is the vacuum adhesion where the robot carries an onboard pump to create a vacuum inside the cups, which are pressed against the wall. This system enables the robots to adhere on any type of material, with low energy consumption. But vacuum adhesion is suitable for usage on smooth surfaces, because the roughness can lead to a leakage in the vacuum chamber such as suction cup.

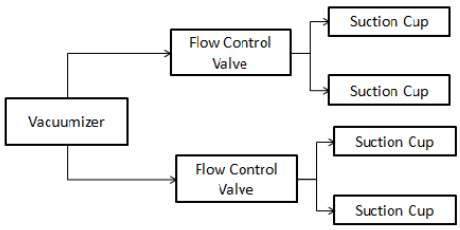

Fig -4: Suction process

4. BLOCK DIAGRAM

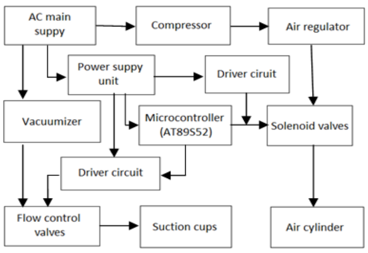

Fig -5: Block diagram of robot control

The block diagram represents different components and their interconnections of the robot. The working mechanism involves, there are two hardware platforms with suction cups beneath and solenoid and flow control valves with microcontroller unit fixed on platforms surface. At the first step, vacuumizer through one of the flow control valve causes rear end platform to attach to the wall surface, air compressor is turned on, piston moves along with front end platform. In the second step, through another flow control valve the front end platform attaches to the wall surface mean while releasing rear end platform, again compressor is turned on pulling up the rear end platform. Now rear end platform attaches to the wall surface and front end platform is released. This cycle repeats.

5. ALGORITHM

Step1: Clear the Port 0, initialize the loop count say variable A=2.
Step2: Turn on valve, V2 for a specific duration.
Step3: Turn on valve, V3 for a specific duration.
Step4: Turn on valve, V1 for a specific duration.
Step5: Decrement loop count by one (A=A-1).
Step6: Repeat the above five steps until A=0.
Step7: Turn on valve, V1 for a specific duration.
Step8: Turn on valve, V3 for a specific duration.
Step9: Turn on valve, V2 for a specific duration.
Step10: End

6. FLOW CHART

The flow chart for robot control is presented in Figure 6.

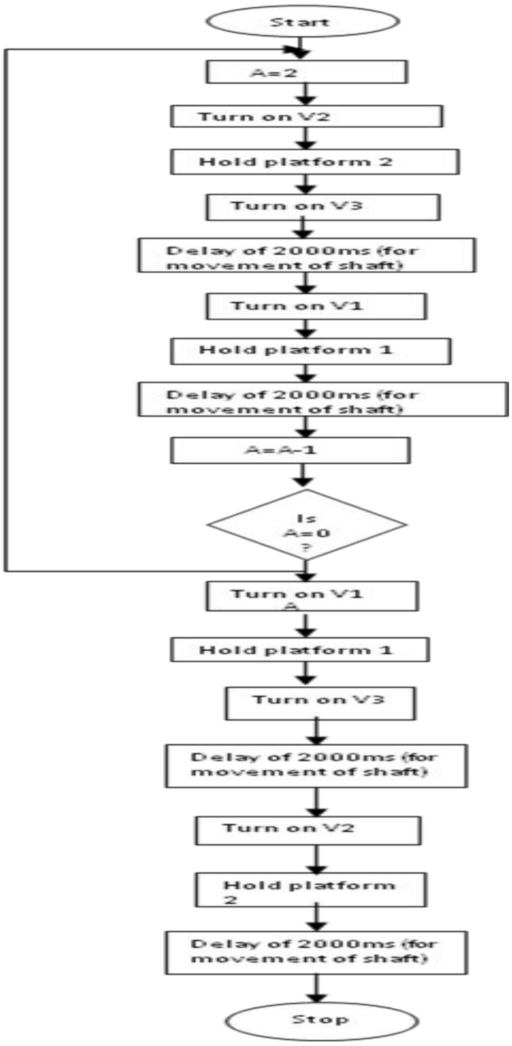

Fig -6: Flow chart for the process

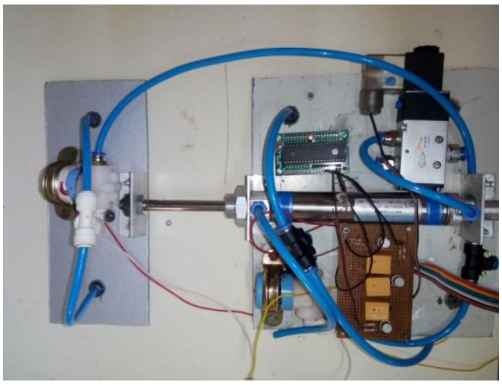

Fig -7: Practically implemented robot

7. APPLICATIONS

- Some of the wall climbing applications is listed below.
- Video recording in hazardous environment.
- Paint spraying

- A climbing machine used for the inspection of concrete bridges.
- Pipe inspection in chemical systems.
- Ship cleaning/inspection.
- Oil tank inspection and Nuclear plant inspection.
- Cleaning and Inspection of glass wall

8. CONCLUSIONS

Based on the requirements of an application several prototype robots exist which show the huge application potential of these kinds of machines. The inspection of the big concrete walls which is frequently necessary by law for stacks, bridges or dams etc. is the application area for our climbing robot. The climbing principle and the inspection subsystem were successfully tested. With respect to the locomotive and adhesion mechanisms, which are necessary requirements for climbing, climbing robots are classified into six and five groups, respectively. The main applications are: corrosion control using color cameras, welding joints inspection using X-ray sensors, rivet or screws joints, Lasers, etc. The mobility of this type of climbing robots is not yet defined and there are only a few robots of this type. They are, at the same time, a big social need and there is a big market for them. This paper has also discussed the method of estimating adhesion force and pay loads which are important issues for any wall climbing robot.

REFERENCES

[1] K. Berns, C. Hillenbrand, "A Climbing Robot for Inspection Tasks in Civil Engineering," FZI Research Center for Information Technologies, University of Karlsruhe, 1st International Workshop on Advances in Serves Robotics (ASCER), Borodino, Italy, 2003.
[2] Chu, Jung, Han Hong, "A survey of climbing robots: Locomotion & Adhesion," International Journal of Precision Engineering & Manufacturing, Volume 11, pp. 633-647, August 2010.
[3] Leoncio Briones, Paul Bustamante, Miguel A. Serna, "A Wall-Climbing Pneumatic Robot For Inspection in Nuclear Power Plants," Robot& Computer Integrated Manufacturing, Volume 11, No .4. pp. 287-292, 1994.
[4] Carlo Menon, Metin Sitti, "A Biomimetic Climbing Robot Based on the Gecko," Journal of Bionic Engineering No. 3, pp. 115-125, 2006.
[5] M. Rachkov, L.Marques, A. T. De Almeida, "Climbing robot for porous and rough surfaces," September 2002.
[6] Tudor Catalin, Nicolae, Constantin, Lucian, Georgeta, "Study on vacuum attachment cups for a robots with vertical displacement," UPB Science Bulletin, Volume 72, Issue 4, pp. 79-92, 2010.
[7] B. Bahr, Y. Li, M. Najafi, "Design And Suction Cup Analysis Climbing Robot," Computers Elect. Engg. Volume 22, No. 3, pp. 193-209, 1996.
[8] Akio Yamamoto, Takumi Nakashima, Toshiro Higuchi, "Wall Climbing Mechanisms Using Electrostatic Attraction Generated by Flexible Electrodes," DOI: 10.1109/MHS.2007.4420 886 · Source: IEEE Xplore Conference: Micro-Nano-Mechatronics and Human Science, 2007, pp. 389-394.
[9] Tomoaki Yano, Tomohiro Suwa, Masato Murakami, Takuji Yamamoto, "Development of a Semi Self-contained Wall Climbing Robot with Scanning Type Suction Cups," Procedings of Intelligent Robots and Systems (IROS – 97), 0-7803-41 19-8/97/$1001997 IEEE, 1997.
[10] Ritesh. G. Mahajan, S. M. Patil, "Development of Wall Climbing Robot for Cleaning Application," Inter national Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 5, May 2013.

BIOGRAPHIES

Mr. Santosh Gudi is pursuing B.E Degree in Instrumentation Technology at Basaveshwar Engineering College, Bagalkot, Karnataka, India. His research interests are sensors and signal conditioners, agro-instrumentation, and embedded systems.

K. Bhat is a full time faculty in E&IE Department of Basaveshwar Engineering College, Bagalkot, Karnataka, India. He has 25 years of teaching experience and actively involved in design and development of sensors, electromechanical systems and biodiesel extraction. One patent applied in his name and has more than 20 national/international papers