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Design of vacuum operated wall climbing robot

Doshi Sachindra J.

Asst. Prof.,Mechanical Engineering,Government Engineering College,Bhavnagar, India.

Abstract- *It is always difficult to create device that walk through vertical surface and replace human worker. This research article is focused on designing and development of wall climbing robot to helps people easy to inspection of the boiler shell etc. Major characteristics of interest of wall climbing robots are climbing speed, payload capacity; obstacles overcome ability and transitioning capacity on other wall. A wall climbing robot is able to maneuver ascend and descend various horizontal and vertical surfaces. Wall climbing robot is having a chassis, suction pads, nozzles, actuators. Suction pads are provided for adhering to surface during climbing with robust support frame. Vacuum chamber is provided to preserve vacuum during operations. Robot is capable to mount accessories like camera, temperature detector and various sensor and radio-control remote operation and wireless communication.*

Keywords *: Wall climbing robot, Vacuum operated robot, adhesion*

1. Introduction

It is always great challenge for engineers to inspect machine, parts and closed cavities which are damped, hazardous, heighted and blind. This challenge demands a replacement of human work with machine or device that can move in such awkward environments and carry out the intended task. Considering this challenge, a wall climbing robot is designed to inspect such areas like boiler shell, furnaces, cooling towers, large underwater pressure pipes etc...
A wall climbing robot is a device which is used for metal surfaces or smooth surfaces like glass or ceramic inspection for vertical wall and boiler shells. A wall climbing robot is basically operated by vacuum pump. Its linear movement is achieved by pneumatic actuators. The pair of two suction cups get the vacuum alternately and linear forward motion is manipulated. The linear motion of robot on the vertical direction is given by hydraulic or pneumatic system.

2. Literature Review

Many researchers have worked on wall climbing robot mechanisms and specialized applications. The summary of major researchers work and their patents are discussed in subsequent paragraphs.
Patrice A. Kroczynski et al. has discussed in his patent that about an independent apparatus capable of moving along a non-horizontal surface, for example along a vertical surface or on a ceiling. One application of such equipment relates to the painting or the scraping of ships 'hulls.
Luigi Paris et al has discussed in his patent that the robot is apt to climb along the trestle structure, particularly trestle of a pole for high-voltage overhead electric lines, in order to carry work tools from the base to the top of the pole.
James J kerley et al has conferred in his paper about invention of robotic devices, especially to a mobile robot that is able to move in caterpillar fashion along a variety of different surfaces
Robert T et al have researched in his patent that the climber robot have wild field and big opportunity for research and development. It's generally used in industry and awkward field where human cant run effectively. By the modification of the robot it will be used for defense also.
Tomoaki yano, et al has developed a semi self-contained wall climbing robot with scanning type suction cups which has two vacuum pumps that gave positive results
Henry R.seemann et al has discussed in his patent that various types of surfaces, such as stationary surfaces, or such as mobile surfaces, have periodic needs for cleaning, inspection, and other repair or maintenance operations
Mark R. Cutkosky ,Sangbae Kim et al has showed in his patent that the objective function of the optimization is the theoretical factor of safety of robot. The primary purpose of the climbing robot is to carried out some task, which have good performance and it can achieve the intended performance objective
Jean-Christophe Fauroux et al has mentioned in his patent that his invention is apply to field of safety of property and people and contributes most particularly to civil "crisis management"
Daniel and Karsten has reviewed in his paper that the current state-of-the-art in climbing robots which could be applied for maintenance, inspection or construction tasks. Authors concluded that only some special solutions in terms of robotic prototypes exist which are limited to a specific setup or certain environments. The challenge for a universal robot are contradictive requirements demanding a light-weighted, small and fast robot which is able to navigate on a vertical wall safely, to overcome steps and obstacles and to carry a high payload. Further research on adhesion and locomotion is necessary to bring these systems to commercial application.
Lee et. al. has developed a series of MCT-type climbing robots with different objectives. MCT robots have advantages in climbing speed, payload capacity, and obstacle overcoming ability. Authors developed joints between tracks, which were

designed using torque-controlled, or position-controlled methods by considering the external condition of the environment and the adhesion mechanism.

Lee et al. has developed robots for use in cleaning the facades of high-rise buildings. This climbing robot is based on pneumatic technology and a multilinked module mechanism. The MultiTrack has a 15 kg payload capacity on a vertical surface and can climb a vertical surface at a velocity of 3 m/min, can move horizontally and sideways, and can perform a 0°–90° internal transition and a thinwall transition with dexterous and continuous locomotion.

Zhao et. al has developed climbing robot, called Vortexbot that used a vortex suction unit. That unit uses vortex flow to generate a negative pressure and provide a sufficient stable suction force. Authors also evaluated robot on walls with various surface conditions.

Huanga et. al. has developed wall-climbing robot for non-destructive ship inspection. The robot has a wide climbing speed range with the maximum speed up to 7 m/min and was able to move steadily. It has high payload capacity and excellent obstacle-overcoming performance with its semiautomatic control system and probe clamping device suitable for different detector.

3. Design of Wall Climbing Robot

The wall climbing robot is a device which is used for metal surface inspection for vertical walls and boiler shells etc... Vacuum operated wall climbing robot use suction pad, actuator, air compressor, air reservoir and nozzle. Basic schematic diagram of wall climbing robot is shown below in figure 1 and figure 2.

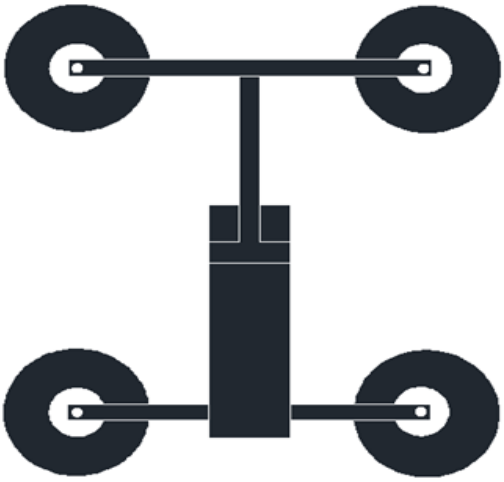

Figure 1: Schematic diagram of wall climbing robot

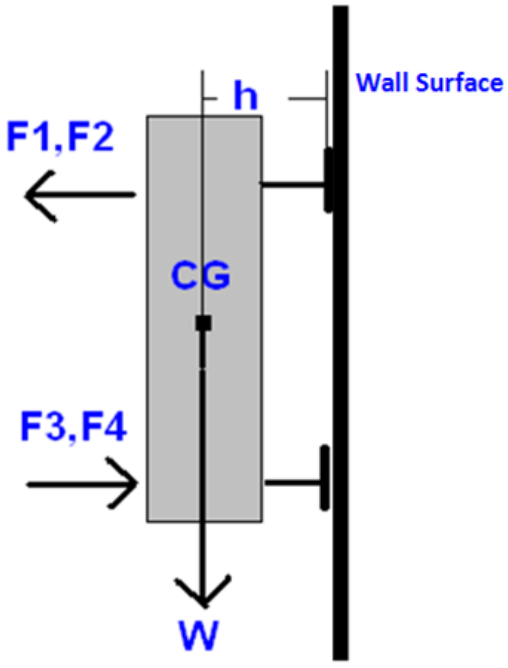

Figure 2 : Side view of wall climbing robot

4. Development of Wall Climbing Robot

A suction cup is used to suck an air and negative fluid pressure of air or water to adhere to flat surfaces. The suction cup have curved surface. When the center of the suction cup is pressed against a flat surface, the volume of the space between the suction cup and the flat surface is reduced, which causes the fluid between the cup and the surface to be expelled past the rim of the circular pad. When the user applying the physical pressure to the center of the outside of the cup, the elastic substance of which the cup is made, its tends to resume its original, curve shape.

Vacuum pump is used to create a very low pressure and suck the air from the suction cup by the help of reservoir. The pressure of the vacuum pump is below to atmospheric pressure. The factors which must be consider while selection of the vacuum pump are capacity of the maximum suction and flow rate capacity of the pump. The air reservoir is used to store the air and remove the air from the suction cups. The vacuum reservoir avoids the fluctuation of the suction from the vacuum pumps and it gives the static suction pressure.

Pneumatic cylinder is used to get reciprocating linear motion. Double acting cylinder is used to force air to move in both extend and retract stroke. It has two ports to allow air into the cylinder, one for outstroke and one for in stroke. The stroke length is limited according to piston capacity and large stroke length may cause piston rod buckling and bending.

The solenoid valve consists of a coil plunger and sleeve assembly is used. In a normal condition a plunger return spring holds the plunger against the orifice, eliminating the flow through the valve. When the coil of solenoid valve becomes started, a magnetic field is produced, raising the plunger and allowing a flow through the valve.

The actual construction of wall climbing robot is shown in figure 3. The pressure of compressor is maintained at 150 psi. and cylinder stroke length is kept 75 mm. Four suction pads joined together by means of suction tube at the lower body of the wall climbing robot. The diameter of suction tube is 5 mm. Tare weight of the robot is 410 gm and pay load capacity of the robot is minimum 500 gm. The acrylic sheet is used to connect cylinder and other lower parts of the body carrying the suction pads through the copper fittings.

Figure 3 Wall Climbing Robot

5. CONCLUSION

Developed wall climbing robot fulfilled following basic objectives satisfactory and the important observations are summarized as follows:

- The robot can climb on fine finished surface, glass wall and smooth metal surfaces.
- By increasing the area of suction pads, it can also climb on the surfaces having little curvature and deformed surface.
- The wireless camera, temperature sensor, direction control headset can be placed on the robot body for carrying out intended task.

Wall climbing robot control was manual, therefore the speed of climbing is very less and depends on the manual control. However adherence of robot on wall is very good with linear upward motion.

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