Design & Fabrication of Wall Climbing Robot

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Abstract— Now-a-days, in these rapidly developing world robotic devices is seen in all the technical fields of developing countries. Whether in automation for industries & business or used for off world exploration in space. In today`s world, Accuracy & human safety are most concern things in all industries. So, we rely on robotics in day to day work to achieve that much amount of accuracy & human safety. The aim of this project is to develop the efficient wall climbing robot which can move on the vertical direction surfaces. Suction pumps is used which generate the low pressure area for proper adhesion on the vertical wall. The robots are required to have high maneuverability to steer in various directions. Here, six leg locomotion system which gives proper traction over the vertical surfaces. The suction pads which are going to use for attaching the robot on vertical plane are activated in sequence. Apart from the reliable attachment principal the robot should have low self-weight and high payload capacity. The cleaning of the glass can be achieved by wiper mechanism which is attached on the front side of the wall climber.

Key words: Wall Climbing Robot, Suction pump, Locomotion System, Wall Climber

I. INTRODUCTION

Wall climbing robots (WCR) are adopted in places where direct access by a human operator is very hazardous because of the need for scaffolding, or very dangerous due to the presence of a hostile environment. Climbing robots can increase operation efficiency, protect human health and save cost. For example, in military field, they can implement tasks such as aircraft inspection, surveillance and reconnaissance and target acquisition; in chemical field, they can be used for maintenance and sand blasting of storage tanks, inspection of pipelines or gas ducts and spray painting. These are widely used for maintenance of surfaces of sea vessels; oil tanks, glass slabs of high rise building, inspection and surveillance works in places where there human access is difficult or very dangerous due to unfriendly environment of social infrastructures. These infrastructures such as buildings, bridges, nuclear power plants, oil reservoirs, marine structures, and space ships, which play very much important roles in our daily lives. To increase the operational efficiency and to protect human health and safety in hazardous tasks make the wall climbing robot a useful device.

The remarkable progress in manufacturing automation and robotics in the second half of the 20th century allowed replacement of humans in dangerous, inaccessible working environments. A wall climbing robot should not only be light but also have large payload so that it may reduce excessive adhesion forces and carry instrumentations during navigation. It is capable to adhere vertical walls and able to move vertically and horizontally with payload carrying capacity to perform various tasks. The substitution of WCR to mitigate human beings, from performing variety of high-risk applications, has much attracted the attention of researchers over the past few decades.

Basically, the research on the wall-climbing robot has focused on two aspects: locomotion mechanism and adhesion mechanism. From the locomotion point of view, wall-climbing robots can be divided into four categories: legged structure, tracked structure, wheeled structure and combined structure. According to the adhesion method, these robots are generally classified into four groups: magnetic, vacuum or suction cups, gripping to the surface and propulsion type. The robot employing legged locomotion mechanism usually adapts vacuum suction technique or magnetic adhesion technique. These robots have good trafficability and adsorption capacity with low working noise. However, their moving speed is usually slow.

II. TYPES OF MECHANISM

A. Adhesion Mechanism

Adhesion mechanism has one of the important functions of wall climbing robot because with the help of adhesion mechanism robot can stick on the wall properly without any failure. To develop the proper adhesion mechanism it requires vacuum pump to create vacuum for adhesion system of the wall climbing robot. The suction cup is attached with the vacuum pump via. Rubber tube through which the vacuum is produced inside the suction cup and it could adhere on the wall. Six vacuum pumps, which produce 30 Mpa pressure each, is used to stick the robot against the gravity on the wall.

B. Locomotion Mechanism

It is one of the major parts of wall climbing robot by which robot can move on the wall without adversely affecting the adhesion system. Selection of locomotion system for robot is depends upon the work/task which we want to perform, pay load capacity and the working environment. Here, as per our objective for wall climbing robot which we want to move over vertical surfaces so for that we require light weight robot and for that we require proper traction over the surfaces.

C. Cleaning Mechanism

Wiper mechanism is used to clean the glass effectively & efficiently. The 12v wiper motor is attached with standard wiper to achieve the desired cleaning of glass. Water is used as a washer fluid which is sprayed via. Nozzle.

III. ROBOT DESIGN

A. Specification of Components

COMPONENTS	SPECIFICATION
BASE PLATE	400mm×400mm
ARMS	200mm×20mm×10mm
LEGS	150mm×20mm×20mm
DRIVE MOTOR	10 RPM, 12v (Geared)
VACUUM PUMP	Max. Vacuum (250mm of Hg.)

WIPER MOTOR	12v, 60(WPS)
BATTERY	12v

B. Adhesion Force Calculation

1) Required Vacuum Force of WCR:

a) Capacity of vacuum pump:

Industrial applications where a vacuum pressure is used include materials handling, clamping, sealing and vacuum forming. In terms of materials-handling applications, a pneumatic vacuum can be used to lift smoothly objects that have a flat surface and are not more than several hundred pounds in weight. Figure 2 shows a materials-handling application where a vacuum cup called a suction cup is used to establish the force capability to lift a flat sheet.

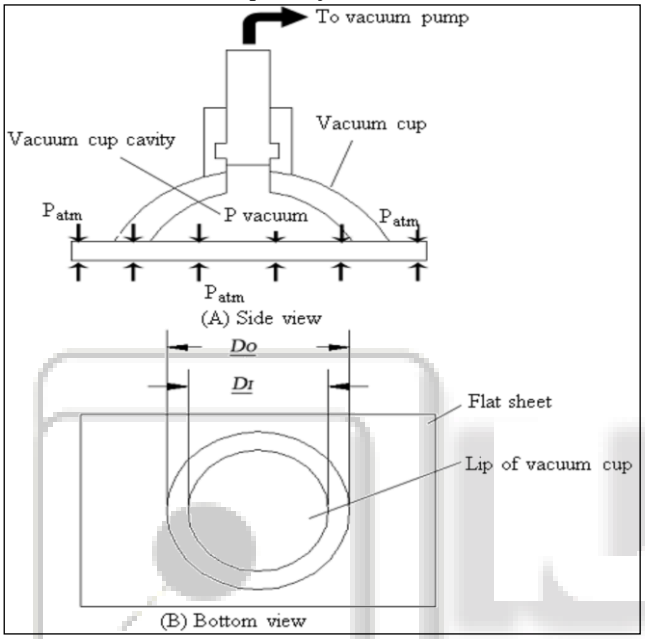

Fig. 1:

The cup is typically made of a flexible material such as rubber so that a seal can be made where its lip contacts the surface of the flat sheet.

b) Pneumatic vacuum systems:

A vacuum pump is turned on to remove air from the cavity between the inside of the cup and top surface of the flat sheet. As the pressure in the cavity falls below atmospheric pressure, the atmospheric pressure acting on the bottom of the flat sheet pushes the flat sheet up against the lip of the cup. This action results in vacuum pressure in the cavity between the cup and the flat sheet that causes an upward force to be exerted on the flat sheet. The magnitude of this force can be determined by algebraically summing the pressure forces on the top and bottom surfaces of the flat sheet as follows, as in:

$$F = P_{atm} \times A_o - P_{suction} \times A_i$$

Where:

F = Upward force, the suction cup exerts on the flat sheet

P_{atm} = Atmospheric pressure

A_o = Outer area of the suction cup lip

$P_{suction}$ = Suction pressure inside the cup cavity

A_i = Inner area of the suction cup lip

C. Required Vacuum Force of WCR

Robot has to stick on the vertical surface for that minimum adhesion force is required. From vacuum pump pressure is created and due to difference between atmospheric pressure and negative pressure robot can stick on the wall properly. To hold the robot on the vertical wall required suction force can be analyzed from the free body diagram as shown in figure. We can analyze all the forces acting on the wall from 0 to 90 degree in vertical direction. Free body diagram includes robot weight, vacuum force, frictional force, reaction force. Frictional force is exerted due to irregularity on the wall surfaces. Robot's weight is depends on the robot mass (M) and acceleration due to gravity (9.81 m/s^2) in downward direction. We can calculate the vacuum force required from the following equation

$$\mu (F_{vacuum} + M \times g \times \cos\theta) = M \times g \times \sin\theta$$

Where,

μ is coefficient of friction between wall surface and robot wheel.

g is acceleration due to gravity.

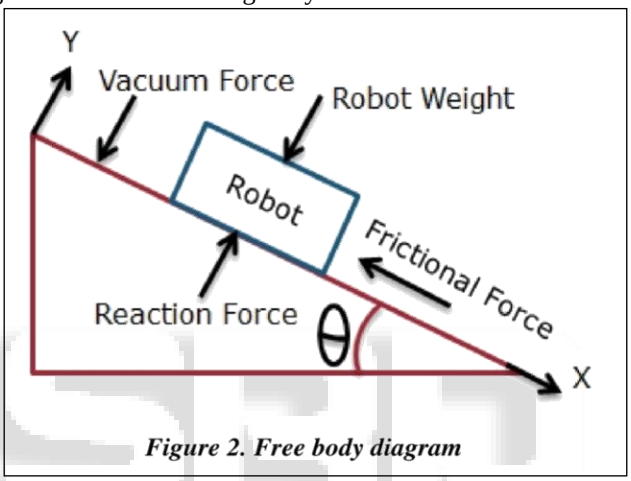

Figure 2. Free body diagram

IV. MODELLING OF WCR

The modeling of the WCR is done in the CREO software. All the parts are assembled accordingly using several assembling mechanisms and the power required for operating all the motors is supplied by a battery inside the base plate.

At the top surface, the wiper arrangement is attached to the base plate by which the cleaning of the glass can be done. All other component like water pump, vacuum pump etc., are in the central box.

The different views of the wall climbing robot are shown below:

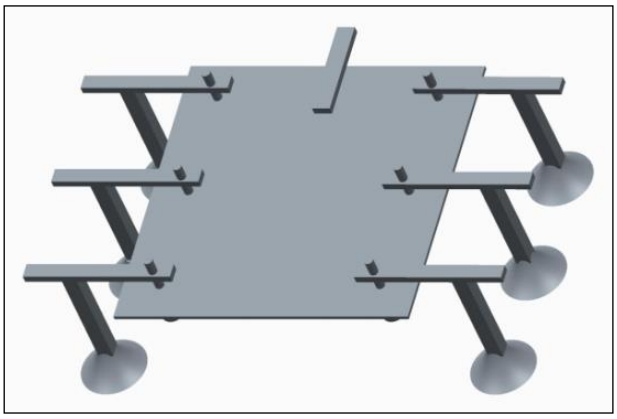

Fig. : TOP VIEW

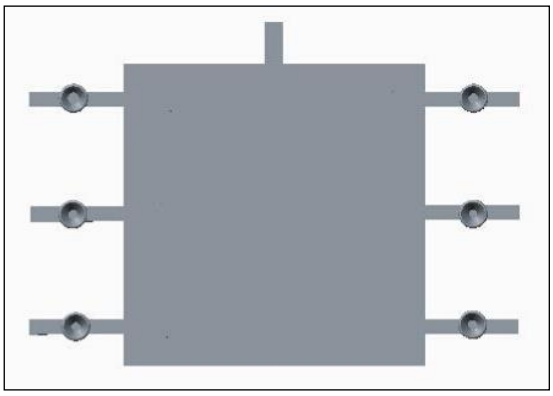

Fig. : Bottom View

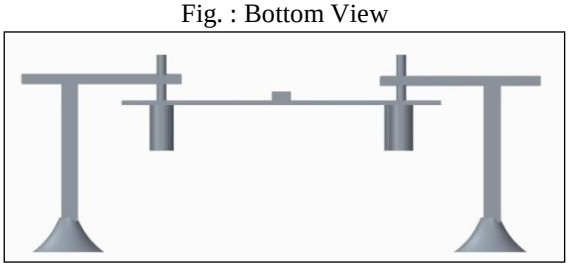

Fig. : Side View

V. FABRICATION OF WCR

The base plate is made up of alloy material (Fiber & Aluminum). The dimension of the base plate is 400mm×400mm. All the other components are incorporated within it. The drive motor is fitted on the base plate. The drive motor used is of 10 RPM with high torque to meet the requirement. Arms and legs are made up of wood which is light in weight compared to others & also it can sustain weight of the robot. The arms & legs are attached with L-clamps and fitted on the shaft of the drive motor.

The vacuum pumps are attached on the bottom of the base plate to create the required vacuum at the suction pads which is at the end of the legs. Rotary joints are used to prevent pneumatic tubes which link the vacuum pump. The wiper motor is attached on the top of the base plate so that the wiper can move freely & carry out the cleaning work.

The image of the final assembly is as follow:-

VI. RESULT & DISCUSSION

Based on the design, we had fabricated the wall climbing robot which climbs the vertical smooth wall and clean the glass efficiently. Through this robot, we can able to clean any glass with ease.

- The time taken by the robot to climb the vertical smooth glass is given in the following table

A. Travelling time of robot

DISTANC(mm)	TIME (sec)	VELOCITY (mm/sec)
200	134	1.49
400	266	1.50
600	400	1.50
800	533	1.50
1000	667	1.50

From the above table it can be illustrated that this robot could climb the 1 square meter glass in approx. 11 minutes with the average velocity of 1.50 m/s. The time taken by the robot to clean is more because when the robot is supposed to take turn, it takes more time because for that every individual leg has to be detach from the glass and move in required direction to execute the turn After that again the vacuum pump has to be started & the suction should be made between the glass surface & suction cup.

VII. FUTURE SCOPE

- The range of the proposed robot could be increased with the help of wireless sources & all the movements can be made precise.
- The bullet camera could be installed for surveillance purpose and also various sensors can be used along, for inspection purpose.

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