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DEVELOPING THE PROTOTYPE OF WALL CLIMBING ROBOT

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Abstract—In this paper the aim is to develop the efficient wall climbing robot which can move on the vertical direction as well as ceiling surfaces. Centrifugal impeller is used which generate the low pressure area for proper adhesion on the vertical wall surfaces possible. No perfect sealing is required which is the main advantage of this wall climbing robot. Here four wheeled locomotion system is used which gives proper traction over the vertical wall surfaces. Minimum required adhesion force is calculated to stick the robot on the vertical surfaces properly. Actual prototype model is made & tested experimentally on the wall & ceiling surfaces. One of the challenging task is to make the robot's weight as light as possible with proper adhesion and locomotion system at low cost.

Keywords-Wall Climbing Robot, Adhesion System, Centrifugal Impeller, Locomotion System, Robot.

I. INTRODUCTION

All The application of mobile robots in high places doing work such as cleaning outer walls of high-rise buildings, Surveillance, search and rescue operation, construction work, painting and inspecting large vessels and inspecting storage tanks in nuclear power plants [12,18] is required because in present they are performed by human operators and workers and they are extremely dangerous and difficult. For this reason, as a specific research field of mobile robotics, a number of climbing robots capable of climbing vertical surfaces have been researched and developed all over the world. Wall climbing robot has to be light weight, compact, highly efficient, safe and easy to operate at low cost. In the present time, the inspection of storage tanks of nuclear power plants and chemical plants are done manually by workers manually which is very dangerous for them and safety and health issues occur to them. Window cleaning of high rise buildings are done manually by workers on cable tray platform which is dangerous and difficult to clean the windows and it is time consuming task. For that researchers invent different kind of wall climbing robot for different kind of task which robots can take place of human[9]. The most challenging task of wall climbing robot is its own weight and its payload capacity because the work has to done in opposite direction of gravity. Most climbing robots developed at the present can be classified into two main functions: locomotion and adhesion. Adhesion system is helpful to adhere the robot on the wall or ceiling. Many type of adhesion systems are use in the wall climbing robot for different kind of work.

Different types of adhesion systems are use like suction cups for industrial robots which has high payload capacity[11], By magnetic force robot can adhere on the ferromagnetic surfaces only[8]. Robot can adhere on the rough surfaces by claws which require large amount of components and power but it cannot move on the flat wall surfaces and glass surfaces[3]. Robot can adhere on the wall surface and glass surfaces by negative pressure suction method. Negative pressure is generated continuously by rotating the centrifugal impeller with backward curves connecting with high speed dc motor so that robot can easily stick on the wall surface and glass surface[1,2]. In some wall climbing robots series of

small suction pads are attached on the tracked locomotion system and on each suction pad actuator is connected which is helpful for proper adhesion system[4,15].

In the other case the locomotion systems, it can be divided into Wheeled locomotion system, legged locomotion systems and tracked locomotion systems. each has its own advantages and disadvantages. Wheeled type locomotion system can be use on the flat surfaces[2]. It requires less power compare to legged and tracked locomotion systems. Control over wheeled type locomotion system is easy as compare to legged and tracked type locomotion systems. Robot can move faster by the wheeled locomotion systems. Legged locomotion system is quite efficient to move on the uneven surfaces of the wall[3]. Legged type locomotion system has complex mechanism because it has large number of actuators and it requires large amount of power to operate. Robot can move slower by legged locomotion system than wheeled and tracked locomotion systems. Tracked type locomotion system can move on the rough surface as well as slippery surfaces[1]. It gives better traction over rough and uneven surfaces. Due to large surface area covered between surface and tracks, tracked locomotion system can damage the surfaces and it require more power and its speed it moderate than other locomotion systems. The main purpose of this project is to develop the wall climbing robot which can move on the wall surface as well as on ceiling surfaces. Weight of the robot should be as light as possible with proper payload capacity. Robot should move on plain wall surfaces as well as wooden and glass surfaces.

This paper represent the prototype of wall climbing robot which can move over vertical as well as ceiling surfaces in the efficient way at low cost. Here suction is created by the centrifugal impeller and movement of the robot is done by the wheeled locomotion system which gives high torque to move against the gravity. Its weight is made as light as possible with more payload capacity. In the second section adhesion and locomotion mechanism is reviewed and third section discusses the adhesion force require from the model. Experimental results are presented in the fourth section and conclusion is made from it.

II. ADHESION AND LOCOMOTION MECHANISM

A. Adhesion Mechanism

Adhesion mechanism has one of the important function 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 impeller to create vacuum and suction motor which rotates the impeller with very high speed and creates vacuum for adhesion system of the wall climbing robot. In centrifugal impeller, air enters from the eye of the impeller and exits radially. The Inlet area where the air enters, creates negative pressure and this is the required adhesion pressure, which is quite helpful for proper adhesion system. An impeller is a rotating component of a centrifugal pump, usually made of iron, steel, bronze, brass, aluminum or plastic. The suction pressure can be easily generated by impeller with backward curved vanes. we can found them readily from market at low cost. Here we select the closed type impeller for suction. As the number of vanes in the impeller increases suction pressure is also increased[1,2].

B. Foam Sheet

Here foam sheet is used as the main body of the wall climbing robot which is lighter than other materials like acrylic and wooden sheet. Foam board is a superb building model material that consists of a thin sheet of foam sandwiched by two layers of paper (or other laminate). The result is a very lightweight but stiff section of material that can be cut cleanly with a sharp knife yet remains durable and rigid. It has uniform fine closed cell structure and easily cut with a sharp craft knife. It is tough, rigid, smooth, glossy with high impact strength, scratch-proof material. It has excellent fabrication properties like sawing,

drilling, screwing, bonding and glue bonding. Foam sheet is capable to hold the robot on the wall with the help of centrifugal impeller.

C. Locomotion Mechanism

It is one for the major part of wall climbing robot by which robot can move on the wall so it requires proper speed and wheels which cannot affect the adhesion system and capable to adhere robot safely on the wall. Selection of locomotion system for robot is depends upon the work/task which we want to perform. it is also depends upon the pay load capacity and the working environment. Here, as per our objective for wall climbing robot which we want to move over vertical surfaces and ceiling surfaces so for that we require light weight robot and for that we require proper traction over the surfaces. If we use the legged locomotion system so that makes the movement of the robot very slow and it has low efficiency, low payload capacity and high complexity which increases the cost of the robot. Wheeled locomotion system has better stability and we can easily adapt this system. Wheeled type locomotion system can make the robot simple and easy to operate so we can easily use wheeled locomotion on the wall climbing robot. It requires less power as compare to other locomotion systems so the cost will be decreases. Here, weight of the robot is distributed by arranging the four wheels with geared motors at each wheel which gives high toque.

III. ADHESION FORCE CALCULATION

Robot have to stick on the vertical as well as ceiling surfaces for that minimum adhesion force is required. From the centrifugal impeller vacuum pressure is created and due to difference between atmospheric pressure and negative pressure robot can stick on the wall properly. Model of wall climbing robot is shown in the figure 1 in which four wheeled locomotion system is there and adhesion is created by the centrifugal impeller.

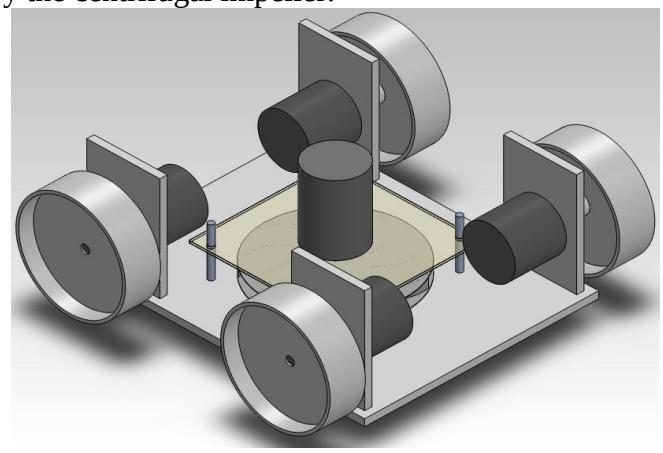

Figure 1. Model and view of wall climbing robot Figure

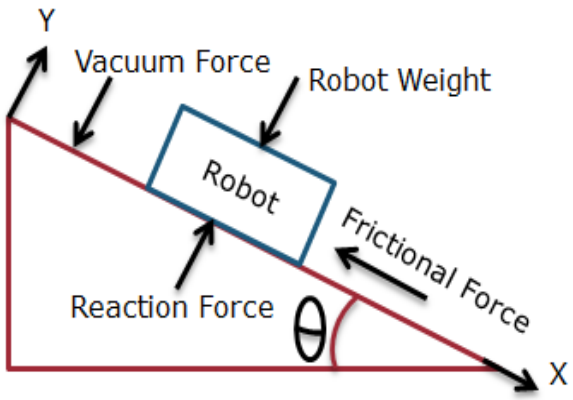

Figure 2. Free body diagram

To hold the robot on the vertical wall required suction force can be analyzed from the free body diagram as shown in figure 2. we can analyze all the forces acting on the wall from 0 to 90 degree vertical direction. Free body diagram includes robot weight, vacuum force, frictional force, reaction force. Vacuum force is exerted by the centrifugal impeller due to pressure difference. 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[1].

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

where, μ is cofficient of friction between wall surface and robot wheel and g is acceleration due to gravity.

IV. EXPERIMENTAL RESULTS

Here actual prototype model of wall climbing robot is tested experimentally on the vertical wall surface as well as ceiling surface which can move at the efficient manner. Performance of the robot on vertical wall surface and ceiling surface is shown in the figure 3 and 4. The overall weight of the robot is approximately 980 grams and its payload capacity is tested using the load weighting 1200 grams. Robot configurations are shown in table 1.

Figure 3. Robot on vertical wall surface

Figure 4. Robot on ceiling surface

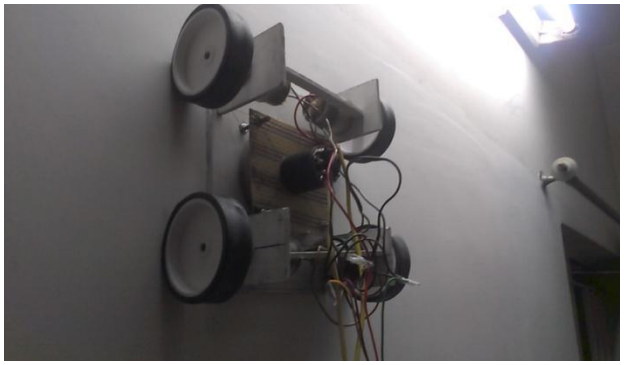

Figure 5. Close view of robot

Table 1. Configurations of the robot

Overall Weight	980 Grams
Dimensions	200 L x 160 W x 80 H [MM]
Step Clearance	0.5 MM
Drive Motor	Geared type DC
Power Supply	12 volts DC

V. CONCLUSION AND FUTURE WORK

Here robot is made of foam sheet material which make the robot weight very light and increases the performance of the robot. Results represent the climbing capability on the wall surfaces with great mechanical stability and high payload capacity. Cost of the robot is low and no perfect sealing is required to create vacuum by the centrifugal impeller for adhesion mechanism. We can install the bullet camera of the inspection purpose and window cleaning of high rise buildings in the future work.

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