Design and Development of a Wall Climbing Robot

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Abstract

In today's highly globalized world we have big buildings but its cleaning and maintaining work is carried out manually .Sometimes it is risk to the life of workers when they clean the wall by climbing on the wall. Every year, thousands of worker's got into diverse kinds of accidents at construction sites. Minor wounds of a mishap can be tended to, however undying wounds or setbacks stays unanswered. In the assortment of operations at the development site, one of the essential, however complex assignment is a vertical development for hoisted works, for example, for investigation, maintenance, cleaning, painting and so on. The intense condition and danger of life amid such operations requires the inclusion of specialized help (or technical support). Robots are now days preferred everywhere to replace human activities, specifically in case of hazardous environment or unsafe condition, the risk of life, quick handling and so forth. In this project, we proposed the design and development of a wall climbing robot. Thus we are designing wall climbing and cleaning mechanism this project will ensure safety of worker while working on tall building. The main objective of the project is to design a lightweight and efficient wall climbing mechanism, fabrication, 3-D modeling, simulation and experimental validation. The manufactured model will be helpful for cleaning and painting operations as a set target. It can be additionally reached out to numerous applications where vertical development and high raised works are required.

Keywords: *Design concept, Bernoulli's principle, duct theory.*

1. Introduction

Recently automation technologies becoming keen interest in robotic industries. The interest in development of climbing robot has grown rapidly in past years. Wall climbing robot mainly depends upon the adhesion mechanism on which robot is stick on the wall. There are various types of adhesion mechanisms like magnetic adhesion, vacuum based adhesion, bio-inspired adhesion, and pneumatic based adhesion etc. All the mechanism have their prospective advantages and disadvantages.

Magnetic adhesion method may offer fast and reliable mobility and large adhesion force however, they are only useful on ferromagnetic surfaces and not energy efficient.

Suction based adhesion method comprises active and passive suction method. These suction based climbing robots may climb over surfaces with any material and strong attachment forces but are only useful and relatively smooth and non-porous surfaces

Pneumatic based adhesion mainly comprises of propulsion based adhesion in which propeller duct fan or suction adhesion is used. Propulsion based climbing robots may climb on various wall surfaces and suitable for tasking large areas with good mobility, but they make loud noise during operation have significant energy consumption (usually 10 of watts) cannot be used in space application and are difficult to control.

Bio-inspired climbing robots can have better adaptability to climb on various surfaces and conduct complicated wall transition (such as vertical wall to ceiling transition) however this method has relatively bulky structure and it is not mature enough.

2. Propulsion based adhesion with duct fan

The purposed method comprises of propulsion based adhesion mechanism using duct fan theory.

2.1 Bernoulli's principle

The basic concept of subsonic airflow and the resulting pressure differentials was discovered by Daniel Bernoulli, a Swiss physicist. Bernoulli's principle, as we refer to it today, states that "as the velocity of a fluid increases, the static pressure of that fluid will decrease, provided there is no energy added or energy taken away." A direct application of Bernoulli's principle is the study of air as it flows through either a converging or a diverging passage, and to relate the findings to some aviation concepts.

Ex: when low weight thin plate is held in air and if fluid is flowing across it then it try to lift the plate. The reason behind this is as the fluid moves across the plate the fluid moving from top of the plate pressure exerted is lower and low pressure bubble is created and at the bottom side high pressure bubble is created. Thus force is acted on the plate from downside and plate gets lift up.

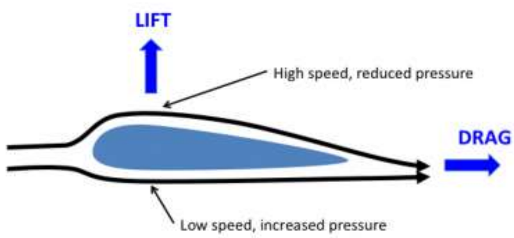

Fig 1: Working of airfoil shape on Bernoulli's principle

The working of propeller is based on two basic laws first is Newton's third law and second is Bernoulli's principle. Cross section of the propeller is of airfoil shape. As the curvature is present on the upper side of the airfoil shape the flowing fluid moves faster than the bottom side so the pressure on the top is low and pressure on the right side is high. Low pressure bubble is created on top and high pressure bubble is created on the bottom side hence the lift force is acted on the bottom side.

2.2 Duct theory

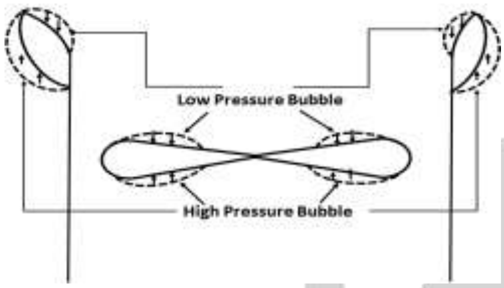

Fig 2: Principle of duct theory

During the motion of the fluid over the airfoil shape low pressure and high pressure bubble is created on top and bottom side respectively. Due to the centrifugal force acting on the low and high pressure bubbles during spinning of the bubbles they move towards the edge of the propeller along with that the natural tendency of fluid is to move from high pressure to low pressure hence high pressure bubble try to move towards the low pressure bubble which created vortex on the edge of the propeller which is nothing but the loss of energy. To restrict this vortex the duct is introduced at the edge of the propeller. It blocks the creation of the vortex and becomes the physical barrier between the low and high pressure bubble. The interesting thing that comes with curling of the duct edges that increase the lift force and efficiency of the duct fan dramatically high.

3. Applications

Climbing robots are generally adopted in automation technology where human operator is very expensive and no surety of safety. This leads various applications such as inspection, testing, civil construction, cleaning.

Inspection

For checking cracks and any type of problem in bridges, wind turbines, nuclear power plant etc.

Testing

For testing electrical component which is located on tower, eg: to test telephone wires, electrical wires etc.

Civil construction

For inspection and repair of dam, hydro power plant, etc

Cleaning

The wall climbing mechanism is also used for cleaning of wall and ceiling of sky-scrapers like restaurant industries. To achieve such kind of application we can use wall climbing robots with cleaning mechanism.

4. Design Calculations

Consider the total mass of robot be "m kg".

When robot is climbing on vertical wall, the force acting is :-

mg – Weight of robot acting downward

F_t - Friction force acting upward at wheel

N – Normal force, reacting force by wall

F_s – Suction force acting on the wall

μ - Friction coefficient between wall and wheel.

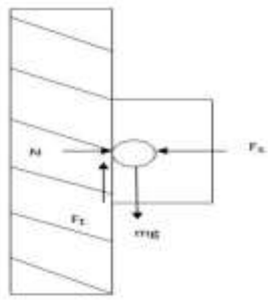

Fig 3: Forces acting on vertical robot

By balancing all the forces:-
In X-direction:
$\sum F_x = 0$
$F_s - N = 0$
$F_s = N$ ------------------------ 1.
In Y-direction:
$\sum F_y = 0$
$mg - F_t = 0$
$F_t = mg$ ------------------------ 2.
We know that,
$F_t = \mu N$ ------------------------ 3.
By equating 2 & 3:
$\mu N = mg$
$N = mg/\mu$ --------------------- 4.
Now, equating 1&4:
$F_s = mg/\mu$
Hence, F_s net suction force required for adhesion.

5. Design of Control System

A switch must have at least two terminals, one for the current to (potentially) go in, and another to (potentially) come out. That only describes the simplest version of a switch though. More often than not, a switch has more than two pins. So how do all of those terminals line up with the internal workings of the switch? This is where knowing how many poles and throws a switch has is essential.
The number of poles on a switch defines how many separate circuits the switch can control. So a switch

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with one pole, can only influence one single circuit. A four-pole switch can separately control four different circuits.

A switch's throw-count defines how many positions each of the switch's poles can be connected to. For example, if a switch has two throws, each circuit (pole) in the switch can be connected to one of two terminals.

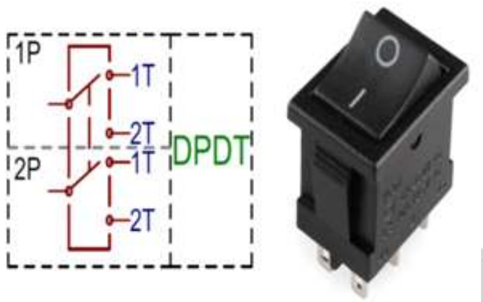

Fig 4: A DPDT circuit symbol and switch

MOVEMENT	LEFT-DPDT SWITCH	RIGHT-DPDT SWITCH
FORWARD	TOP	TOP
REVERSE	BOTTOM	BOTTOM
RIGHT	TOP	....
LEFT	....	TOP
360 LEFT	BOTTOM	TOP
360 RIGHT	TOP	BOTTOM

Knowing how many poles and throws a switch has, it can be more specifically classified. Commonly you'll see switches defined as "single-pole, single-throw", "single-pole, double-throw", "double-pole, double-throw", which are more often abbreviated down to SPST, SPDT, and DPDT, respectively. A single-pole, single-throw (SPST) switch is as simple as it gets. It's got one output and one input. The switch will either be closed or completely disconnected. SPSTs are perfect for on-off switching. They're also a very common form of momentary switches. SPST switches should only require two terminals.

Adding another pole to the SPDT creates a double-pole, double-throw (DPDT) switch. Basically two SPDT switches, which can control two separate circuits, but are always switched together by a single actuator. DPDTs should have six terminals.

6. Construction of Robot

The main part of Wall climbing robot are EDF deducted fan, dc geared motors, DPDT switch, ESC (electronic speed controller), the steering motor is similar to the rack and pinion. Since a brushless dc motor is used the speed is reduced. The directions of wheel are changed by changing the polarity of the motor. This is the driving motor for forward and reverse motion. The forward and backward motion are achieved by changing the polarity of the motor. The speed can be varied by varying the voltage. The torque can be varied by varying the current.

A] EDF DEDUCTED FAN

A ducted fan is a propulsion arrangement whereby a mechanical fan, which is a type of propeller, is mounted within a cylindrical shroud or duct. The duct reduces losses in thrust from the tips of the props, and varying the cross-section of the duct allows the designer to advantageously affect the velocity and pressure of the airflow according to Bernoulli's Principle. Ducted fan propulsion is used in aircraft, airships, airboats

Fig 5: EDF deducted fan

Item Name: 70mm 12 blades Ducted Fan
Motor: 2860
KV1850rating
Weight: 240g
Usage: Suitable for RC Airplane

6S Comparion Test

FMS Ducted	25.0V	64A	Thrust: 2.25KG
Other Duted	16.5V	63A	Thrust: 1.89KG

Required Configuration:
Battery: 6S 2600-4000mAh 35C Lipo Battery
ESC: 70A Brushless ESC

Conclusions

Considering the severity of many environments where there is the need for human labor, the exploitation of wall-climbing robots has undoubtedly a broad prospect. The main intended applications of these machines ranges from cleaning to inspection of difficult to reach constructions. Up to now, considerable research was devoted to these machines and over 200 prototypes aimed at such applications had been developed in the world by the year 2006. Nonetheless, the application of climbing robots is still limited. Apart from a couple successful industrialized products, most are only prototypes and few of them can be found in common use due to unsatisfactory performance in on-site tests. To make wall-climbing robots a popular replacement of manual work, indispensable prerequisites are an high reliability and high efficiency, and, on the other hand, affordable prices. The fulfillment of these requirements is still far, which indicates that there is yet a long way of development and improvement.

Given these considerations, this can presented a survey of several climbing robots, adopting different technologies for locomotion and for the adhesion to surfaces. Several possible applications of the presented robots have also been discussed. A special emphasis has been given on the new technologies (mainly propulsion based adhesion) that are presently being enveloped for the robots adhesion to surfaces

References

A. Nishi, Y. Wakasugi, K. Watanabe, Design of a Robot Capable of Moving on a Vertical Wall, Adv. Robotics. 1 (1986): 33-45.

M.F. Silva, J. Machado, J.K. Tar, A Survey of Technologies and Applications for Climbing Robots Locomotion and Adhesion, in: Climbing and Walking Robots, Behnam Miripour (Ed.),

InTech, Rijeka, 2008, pp. 1-22. B. Chu, K. Jung, C.S. Han, et al, A Survey of Climbing Robots: Locomotion and Adhesion, Int. J. Precis. Eng. Manuf. 11 (2010): 633-647.

D. Schmidt, K. Berns, Climbing Robots for Maintenance and Inspections of Vertical Structures - A Survey of Design Aspects and Technologies, Robot. Auton. Syst. 61 (2013): 1288-1305.

D. Dethe Raju, S.B. Jaju, Developments in Wall Climbing Robots: A Review, Int. J. Eng. Res.Gen. Sci. 2 (2014): 33-42.

Clancy, L.J., Aerodynamics, Chapter 3.

M. Spenko, M. Cutkosky, C. Majidi, R. Fearing, R. Groff, and K. Autumn, "Foot design and integration for bioinspired climbing robots," SPIE Unmanned Systems Technology VII, vol. 6230, 2006.

A. Asbeck, S. Dastoor, A. Parness, L. Fullerton, N. Esparza, D. Soto, B. Heyneman, and M. Cutkosky, "Climbing rough vertical surfaces with hierarchical directional adhesion," in Robotics and Automation, 2009. ICRA '09. IEEE International Conference on, may 2009, pp. 2675 –2680.

Longo, D., Muscato, G.: The Alicia/sup 3/ climbing robot: a three-module robot for automatic wall inspection. IEEE Robot. Autom. Mag. 13(1), 42–50 (2006).

Song, Y.K., Lee, C.M., Koo, I.M., Tran, D.T., Moon, H., Choi, H.R.: Development of wall climbing robotic system for inspection purpose. In: Procceding on IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 1990–1995 (2008).

Balaguer, C., Gimenez, A. and Jardon, A. (2005). Climbing robotsŠ mobility for inspection and maintenance of 3d complex environments, Autonomous Robots 18(2): 157–169.

Cepolina, F., Zoppi, M., Zurlo, G. and Molfino, R. (2004). A robotic cleaning agency, Proc. Of IAS'2004 – 8th Conf. on Intelligent Autonomous Systems, Amsterdam, The Netherlands, pp. 1153 – 1161.

Derriche, O. and Kouiss, K. (2002). A cleaning robot for spherical buildings, in P. Bidaud and F. B. Amar (eds), 5th International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines, Professional Engineering Publishing Limited, pp. 993–1001.

Hirose, S., Nagakubo, A. and Toyama, R. (1991). Machine that can walk and climb on floors, walls and ceilings, Proc. of the Fifth Int. Conf. on Advanced Rob., Pisa, Italy, pp. 753–758.

Longo, D. and Muscato, G. (2004a). Design of a single sliding suction cup robot for inspection of non porous vertical wall, Proc. of the 35th Int. Symposium on Rob., Paris, France, pp. 1153 – 1161.

Nishi, A. (1991). A wall climbing robot using propulsive force of propeller, Proc. of the Fifth Int. Conf. on Advanced Rob., Pisa, Italy, pp. 320–325.

Rodriguez, H. L., Bridge, B. and Sattar, T. P. (2008). Climbing ring robot for inspection of offshore wind turbines, in L. Marques, A. de Almeida, M. O. Tokhi and G. S. Virk (eds), Advances in Mobile Robotics, World Scientific, pp. 555–562.