Fabrication of Vacuum Assisted Climber

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Abstract: In order to perform maintenance on the outer walls of a high-rise building, fire rescue, inspection of high pipes and wall, evaluation and diagnosis of a storage tank in nuclear including sweeping, painting and repairs, a device that enables the easy attachment or detachment of working equipment such as a gondola to the outer wall of building is necessary. Though vacuum suction pads can be used to fasten equipment to vertical wall easily and without causing damage to the contact surface, their suction force should be designed by considering both external conditions and the loads of working equipment. In project, one performed a basic experiment on the vacuum suction force of suction pads attached to a vertical wall under various load conditions.

Keywords: Suction pads, Suction Force, Suction motor, Vacuum pressure.

I. INTRODUCTION

Vacuum Assisted Climber (VAC) is a machine which can enable human beings to climb up vertical plane walls. It was one of their dreams to climb up huge vertical walls like a superhero. Our project is aimed at giving wings to this dream of humans.The project is aimed at the design and development of a machine which enables human to climb vertical wall with reduced effort. To make this possible we decided to use the sticking property of vacuum for binding the human to the wall. The very advantage of using of sticking property of vacuum is that, we can ensure that the walls which we climb upon will neither be destroyed nor be made dirty or affected in any manner.

No change will be made to the wall while we climb using VAC. The project has various applications including emergency wall scaling in a military situation, fire and rescue operations, high altitude maintenance and service, cleaning of glass windows of high buildings etc.This was actually an inspiration for us to proceed with our idea as our final year project. We set our objectives and ensured that the objectives are met in the time limit. We decided to tackle the challenges in a progressive manner. We decided to start with the designing process. Our team mates, we joined together and discussed about the capabilities that the machine should possess, the general structure of the machine, the different components of the machine etc.

The conventional methods used for climbing the vertical walls include the use of ladders or providing projections on the wall etc. The disadvantage of these methods is that it cannot be used for staying at heights. Also when we use such methods it is the human effort alone which act as the climbing force. The conventional methods cannot be adopted when the heights are large and when the time duration of climbing is higher.

It has long been a dream of man to possess the power to walk up vertical surfaces. Now vacuum assist wall climber will fulfill this dream of climb over a vertical surface against the gravity which may provide some super human abilities to normal human. This is a wall climbing machine which uses its vacuum pumps to produce a grip against the wall surfaces. It is worn like a backpack, can climb up to any height on any surfaces including glass, brick or rock without a rope. But the most important element was to come up with technology that can grip to any vertical surface. So we developed the vacuum assisted wall climber, which is made from two suction pads and household vacuum pump.

The pads, unsurprisingly, form an airtight seal when pressed against a vertical surface which is strengthened by the suction from the vacuum. It can also be operated hands free, allowing a soldier to wield a weapon or other device without falling to the ground. This is Industrial applications, where vacuum pressures used include materials handling, lamping, sealing and vacuum forming.

II. HEADING S

1. Literature Survey

Chikesh et al. [1], founded that vacuum assisted wall climber is not only efficient but best option for the wall climbing. This assist wall climber gives chance to carry heavy work to the climb. They made the entire system with less weight and aesthetics and ergonomic consideration this assist wall climber reduce the human efforts.

Gosavi [2], founded a new efficient way of scaling vertical surfaces by using vacuum pressure. By designing a new device, they found a new light weight method of carrying heavy load on vertical surfaces. They concluded that this equipment has reduced human effort and have saved time.

Avvaru et al. [3], analyzed on completing the project that the robot is facing difficulty in climbing the normal surfaces where air leakage is problem. The robot is facing difficulty in climbing more than 900 slant angles on walls. Robot is capable of carrying loads of weight around 4 kg. Compared to normal walls, it is working fine on glass walls and wooden walls.

Kolhalkar and Patil [4], studies 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 colour 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.

Elkmann et al. [5], overviewed the different facade cleaning robots developed by the Fraunhofer IFF The facade cleaning robot, SIRIUSC, for use on skyscrapers, the robot to clean the 25,000 m/sup 2/ vaulted glass hall of the Leipzig Trade Fair in Germany, as well as the completed concept for a balloon-based robot for cleaning the inner side of atriums and glass roofs are discussed here. These robots and concepts are based on various motion systems (i.e. walking mechanisms, wheeled vehicles, balloon-based systems, etc.) that are specially-suited for motion along different building types.

2. Objectives

The main objectives of this project are:

- To develop a machine which provide assistance in climbing vertical walls.
- To reduce the human effort required in climbing vertical walls.
- To enable human to stay freely up on the vertical walls without external support.
- To develop an optimized working model of VAC (Vacuum Assisted Climber).
- Manufacturing improvements to save on time and money.
- Weight optimization to reduce climbing fatigue.

3. Working Principle

The working principle of Vacuum Assisted Climber (VAC) is described as follows

- The climber puts on the backpack, consisting of two vacuum motors and the hose pipe is connected to each suction pad.
- The suction pad is held on each hand and the vacuum motors are turned ON. The climber locks the release mechanism for both suction pads.
- The seal in the suction pads helps to contain the vacuum inside the suction pad to obtain a negative pressure which will allow the climber to stay firmly on any vertical surfaces.
- The seal also helps to provide friction between the surface and the pad so that the pad does not slips due to less friction between the wall and the pad.
- The first suction pad is placed on the wall, due to the negative pressure created, the suction pad will attach firmly to the wall.
- Then the next suction pad is placed on the wall at a higher distance which is comfortable to the user and then closes the pressure relief valve by means of activating the switch which produces vacuum on that pad.
- The climber then places the suction pad on the next higher step, by balancing his weight on the other foot harness and handle.
- The climber releases the valve mechanism on the second suction pad, enabling him to lift the suction pad and place it over the next higher step.
- The vacuum motor with the bag pack helps the climber in stabilizing the weight excreted by the vacuum motor so that it is comfortable for the climber to scale the vertical surfaces.

- An external weight harness system is used to equally distribute the weight of the entire system throughout the body so that stress while climbing is reduced otherwise there will be more stress acting on the user shoulders which will lead to fatigue of arms and decrease in the efficiency of climbing.

4. Components of VAC

By using the suction force of vacuum as a climbing force we are able to reduce the human effort required for climbing to a great extent. The VAC that we designed is in the form of a backpack which can be carried on shoulders while you climb up the vertical walls. Also the VAC suit is designed similar to a climbing suit which can secure the climber safely on it so that the climber can stay safely at heights. Some of the major components are.

- Suction Pads:

Suction pads are the most important part of the VAC. The working principle of the suction pads is based sticking property of vacuum. The suction pads are used similar to the hands of Spiderman. Once we press the suction pads on to the wall it gets stick on to it and we can support our entire weight using the handle of the suction pads and the foot rest attached to it.

The vacuum is created between the sealing and the vertical wall by pumping out the air through the vacuum creator port using a vacuum pump. When the hole was open, it allowed for the vacuum pressure to be released and new air to circulate in cooling the motors.We designed is in the form of a backpack which can be carried on shoulders while you climb up the vertical walls suction pads are used similar to the hands of Spiderman. An extension spring was attached to the vacuum pressure release to spring it back into its original closed position. This allowed the pads to seal and be under vacuum again.

Vacuum creator port is used to suck out the air in the space between the suction pads and the wall. The vacuum creator port is placed near to the top side of the suction pads in order to prevent the vacuum hose from creating any obstructions to the person who climbs using the machine. The vacuum hose from the vacuum pump is connected to the suction gloves by means of a vacuum adapter. The restoring force is due to the preponderance of wrinkled conformations over more linear ones. It continuously sucks the air out from the vacuum space, so that the destruction of vacuum and hence the sticking force, due to the inefficiency of the sealing or any leakage losses can be avoided.

The rubber sealing of the suction pads was designed as a custom forged Styrene Butadiene Rubber sealing with a semi-circular cross section. The flat side of the rubber sealing is attached to the suction pads using an adhesive. The adhesive used is Flex Kwik. The rubber sealing is used to seal the space between the suction pads and the vertical wall. The design of the rubber sealing should be done so as to minimize the leakage losses. On a microscopic scale, relaxed rubber is a disorganized cluster of erratically changing wrinkled chains. In stretched rubber, the chains are almost linear. The restoring force is due to the preponderance of wrinkled conformations over more linear ones. The design of the rubber sealing should be done so as to minimize the leakage losses. On a microscopic scale, relaxed rubber is a disorganized cluster of erratically changing wrinkled chains. In stretched rubber, the chains are almost linear. For the quantitative treatment see ideal chain, for more examples see entropic force.

The vacuum destroyer switch is used to nullify the vacuum created by the motor by switching it off. A switch is used instead of a port because it is the most convenient way and is good for the motor since the motor is relived from frequent loading. A switch may be directly manipulated by a human as a control signal to a system, such as a computer keyboard button, or to control power flow in a circuit, such as a light switch. This arrangement was not very satisfactory because, if the throttle were wide open, the wipers would slow down, or even stop. Automatically operated switches can be used to control the motions of machines, for example, to indicate that a garage door has reached its fully open position or that a machine tool is in a position to accept another work piece. Switches may be operated by process variables such as pressure, temperature, flow, current, voltage, and force, acting as sensors in a process and used to automatically control a system.

- **Vacuum Motors:**

A1500watts centrifugal type vacuum pump was used to power the suction pads. It has straight radial blades. This type of vacuum pump provides a suction of negative 20 KPa which corresponds to a low vacuum range. Two vacuum pumps are used in the VAC. Each one is used to power single suction pads only. The Vacuum pump is attached to the climbing suit so that it can be carried comfortably like a back pack. The centrifugal type vacuum pump is simpler in construction and has lesser weight compared to reciprocating type vacuum pump.

In a vacuum motor, the partial vacuum is created by an external pump. These motors were commonly used to power railway turntables in the UK, using vacuum created by a steam locomotive's vacuum brake ejector. The operating principle is similar to a steam engine in both cases power is extracted from a difference in pressure.

Small vacuum motors were also used to operate windscreen wipers in automobiles. In this case, the motors were powered by manifold vacuum. This arrangement was not very satisfactory because, if the throttle were wide open, the wipers would slow down, or even stop. Modern automobiles use electrically powered wipers. Modern automobiles still use a vacuum motor of a kind, however, the vacuum servo. Brakes are operated by a hydraulic system, but they use a 'vacuum motor' to amplify the force provided by the driver. Small vacuum motors were also used from the late 1960s to control servomechanisms such as door locks, heater controls or movable bonnet ventilation flaps.

A vacuum system can be used for power transmission, although the maximum power that can be transmitted to a vacuum motor is less than conventional pneumatics. There is an optimum pressure for the operation of a vacuum power transmission system, of around 0.4 bar (8 psig), as Downie also shows. Although less efficient than pneumatics, it can be perfectly workable. For example, a 22 mm (7/8") pipe on vacuum can transmit as much power on 0.4 bar (8 psig) as a 6 mm (1/4") pipe on 8 bar (100 psig). Two vacuum pumps are used in the VAC. Each one is used to power single suction pads only. Small vacuum motors were also used to operate windscreen wipers in automobiles. In this case, the motors were powered by manifold vacuum. The Vacuum pump is attached to the climbing suit so that it can be carried comfortably like a back pack. The system is efficient enough that Boulton and Watt used vacuum power transmission in their factory.

- **Vacuum Hose:**

We suggest high strength fiber reinforced PVC hose cover bonded to coated helix. This vacuum hose offers excellent flexibility for use with vacuum pad attachments that require bending in tight areas. This is excellent for all commercial or industrial vacuum handling applications where medium to high vacuum flow is required.

The flexibility of the hose makes it suitable for high bend applications without wall collapse under vacuum.Vacuum hoses were needed so air could ow from the pads to the vacuum motor exhausts.

Using quick connectors, the vacuum hoses snapped into place providing a pathway between pads and vacuum motors. Excellent for all commercial or industrial vacuum handling applications where medium to high vacuum flow is required. Due to its flexibility, this hose shrinks along its length under vacuum.

- **Supporting Structure:**

Supporting structure is connected to the bag pack containing the vacuum motors and to the suction pad to balance the weight of the person using the device.

The climbing harness is use to secure the human safely when he climbs using the VAC. The vacuum pump is fixes behind the climbing harness in the form of a backpack providing suitable insulations.

In its simplest form, a harness can be made from a length of rope or nylon webbing tied round the waist. More sophisticated harnesses exist in many patterns, designed to give greater comfort and security, and more options for carrying equipment.

A full-body harness is the combination of a sit harness and a chest harness which are permanently or semi-permanently connected to each other. This kind of harness normally offers a wide range of attachment points. Harnesses should be attached to dynamic (stretchy) rope, except possibly when abseiling where the rope is always taut. Falling onto a system consisting entirely of static components e.g. slings over even a very short distance e.g. a meter or two is enough to deliver large forces to the body and possibly cause the equipment to fail altogether. For via ferrata, the harness is attached to lines via a shock absorber that can absorb some of the impact in the event of a fall.

In addition to the weight bearing parts of the harness, there are parts of the harness that are not designed to be part of the safety system. These include the gear loops, used for carrying equipment e.g. protection devices, carabineers, etc., and the elastic cords which pass behind the buttocks for the purpose of keeping the leg loops from slipping down while not under load. Any attempt to tie the safety system into these components could lead to failure and an unprotected fall. It is acceptable to attach the rope to a leg loop via a Prusik knot and carabineer, but this should only be done with the brake end of the rope in an abseil system in order to keep the Prusik clear of the belay plate.

5. Development of Suction Pad

The suction pads are the most important component of a VAC. It is the most crucial part and needed to be designed with extreme care. The area of the suction pads should be well enough to support the weight of the human and the machine. It consists of a rubber sealing which prevents the escape of air into the vacuum space created between the suction pads and the wall. The rubber sealing should have sufficient strength so that it will not undergo tearing upon the action of the load. Also the coefficient of the friction of the rubber sealing should be high so that the sliding down of the climber due to shear force can be prevented. Also the suction paddle consists of a handle which can be used to hold the suction pads. The important sub components of the suction pads are:

- **Vacuum:**

The main force that we use in VAC to climb is the sticking property of vacuum. So it was desired to understand what is vacuum, the different types of vacuum, about the type of vacuum that can be created conveniently according to the requirements.Vacuum is space that is devoid of matter. The word stems from the Latin adjective vacuus for vacant or void. Figure gives the relation between voltage vs time of the vacuum motor. An approximation to such vacuum is a region with a gaseous pressure much less than atmospheric pressure. Physicists often discuss ideal test results that would occur in a perfect vacuum, which they sometimes simply call "vacuum" or free space, and use the term partial vacuum to refer to an actual imperfect vacuum as one might have in a laboratory or in space. The quality of a partial vacuum refers to how closely it approaches a perfect vacuum. Other things equal, lower gas pressure means higher-quality vacuum. For example, a typical vacuum cleaner produces enough suction to reduce air pressure by around 20%.

Our next objective was to find out the amount of suction force required to carry the human and the climbing suit safely. Also the area of the suction gloves should not be too high. Therefore, the next priority was to conduct the area calculation and find out and adjust the suction force that would be required.

- **Geometric Modelling:**

The suction pads should be designed in such a manner so that it should be able to accommodate the vacuum creator port, handle, the hook to connect the foot rest and the rubber sealing. So it was considered better to select a rectangular shape for the suction gloves to accommodate all these components in a compact manner.

Solid modeling and geometric modeling refers to computer modeling of three dimensional solids. It supports the creation, exchange, visualization, animation interrogation and annotation of digital models of physical objects.

- **Testing:**

Three tests were conducted during the project. By the conduction of each test the knowledge gained was put together in the completion of the project in a successful manner. Each test provided us external knowledge about the working of the equipment and how to enhance it for the better usage. A vacuum motor for suction purposes was taken and connected to the suction pad. The vacuum cleaner was of 1500 W and the suction pressure was unknown.

The pad was tested on various surfaces such as vertical walls, ceilings, glass, granite and wood. Of the surfaces tested, the equipment showed a higher adhesion with granite and glass surfaces. The reason was very clear. It was due to the uneven surface texture of the walls, ceilings and wood. Vacuum motor for suction purposes was taken and connected to the suction pad. There were leakages of air into the system due to unevenness of the surface. The above result led to the need of a sealing material. The sealing material must possess higher flexibility and adaptability. Of the different material tested, a layer of foam showed high flexibility.

III. INDENTATIONS AND EQUATIONS

The area of the suction pads should be designed taking various factors into considerations

- Outside Area = 0.4 * 0.3 = 0.12 m^2
  Inside Area = 0.3* 0.25 = 0.075 m^2

By considering all these factors, we decided to provide a factor of safety of 5. So, the final area of the suction pads was calculated. Table 7.2 shows Dimensions of Suction Pads.

- Factor affecting area of suction pads
  Suction Pressure = 25 Kpa (Negative)
  Coefficient of Friction = 1
  Load to be Carried = 1000 N
  Maximum Air Flow = 2.5 m^3/min

IV. FIGURES AND TABLES

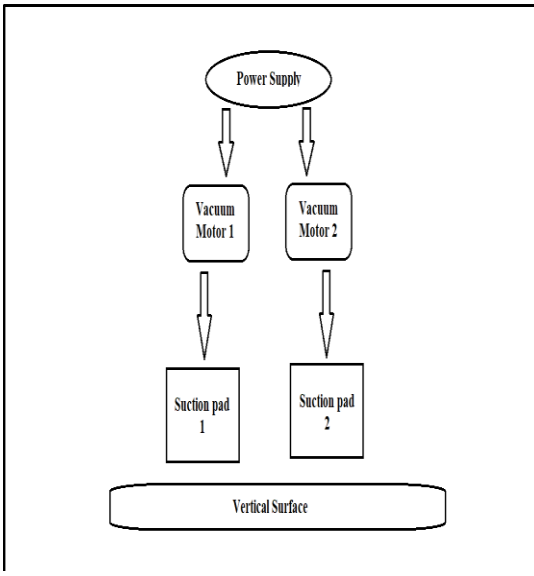

Fig. 1 Methodology

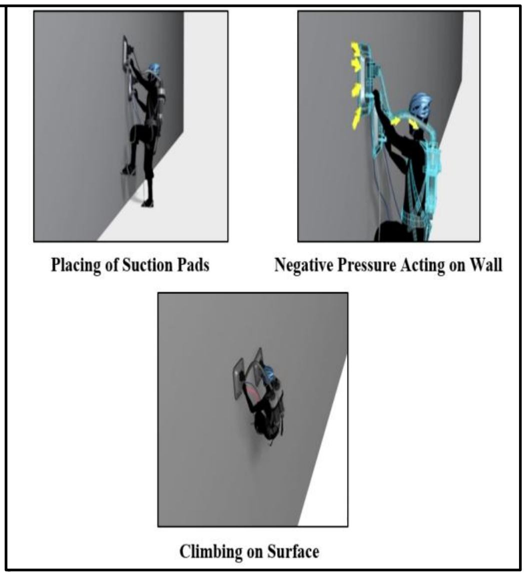

Fig. 2 Working Principle

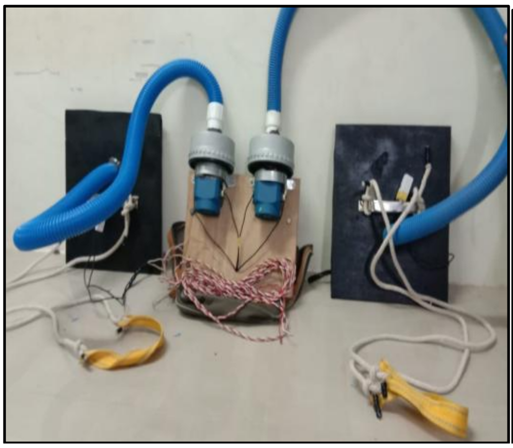

Fig. 3 Fabricated Model

Fig. Military Application of VAC

Table Vacuum Data

Types of Vacuum	Pressure Range (Pa)
High Vacuum	1×10^{-1} to 1×10^{-7}
Medium Vacuum	$3\times10^{+3}$ to 1×10^{-1}
Low Vacuum	$1\times10^{+5}$ to $3\times10^{+3}$
Ultra High Vacuum	1×10^{-7} to 1×10^{-10}
Extremely High Vacuum	$<1\times10^{-10}$
Outer Space	1×10^{-4} to $< 3\times10^{-15}$

Table Dimension of Suction Pad

Parameters	Dimensions (m)
Inner Length	0.3
Inner Breadth	0.25
Outer Length	0.4
Outer Breadth	0.3
Thickness	0.01
Diameter of VCP	0.04

V. CONCLUSION

During the last two decades, the interest in climbing systems has grown steadily. Their main intended cleaning to inspection of difficult to reach constructions. This project presented a survey of different technologies proposed and adopted for climbing equipment adhesion to surfaces, focusing on the new technologies that are presently being developed to fulfill these objectives. This simpler, compact and lightweight VAC platform provides a safe and effective means to deal with hazardous duty operations. Within the mechanical area our robust platform, it is developed to climb on relatively smooth surfaces. Various work related instruments or tools such as painting tools, cleaning tools, drilling tools etc. can be mounted on it to carry up on wall.

An improvement is expected in the future design of the Vacuum Assisted Climber depending upon its utility. This project gives a short review of the existing Vacuum Assisted Climber.

REFERENCES

[1] Chikesh Ranjan, Shahid. Akhtar J, Ajit Kumar Choudhary and Vivek Vishal Jaysawa, Design and Fabrication of Vacuum Assisted Climber, International Journal of Mechanical Engineering and Technology, Vol. 8, 2017, Pp. 365-371.

[2] Gosavi Sagar,Design and Fabrication of a Pedal Operated Floor Mopping Machine, International Journal of Emerging Technology and Advanced Engineering, Vol. 6, 2016, Pp. 2250-2459.

[3] Avvaru Subramanyam, Mallikarjuna Y and Suneel S L, Review on Applications of Robots, International Journal of Advanced Computer Technology, Vol. 3, 2009, Pp. 334-546.

[4] Kolhalkar N R and S M Patil, Development of Vacuum Cleaner with Suction, International Journal of Engineering and Innovative Technology, Vol. 1, 2012, Pp. 434-543.

[5] Elkmann N, Felsch T, Sack, Bohme, Hortig and Saenz, Modular Climbing Robot for Service Applications, Industrial Robot: An International Journal, Vol. 26, 1999, Pp. 460-465.

[6] Manisha Kunde, a Wall Climbing Robot Using the Thrust Force of a Propeller Mechanism and Control in a Strong Wind, International Journal on Search and Mechanical Technology, Vo1. 37, 1994, Pp. 172-178.

[7] Sushmita Deb, Sanjay Kumar K, Sushma T.P., Nadashree V.S. and Sahana.T., Design and Implementation of Low-Cost Vacuum Cleaner, International Journal of Engineering Technology Science and Research, Vol. 4, 2017, Pp. 2394-3386.