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Design, Fabrication and Analysis of Vacuum Assisted Wall Climber

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ABSTRACT: Vacuum Assisted Climbing Device is a new way to climb vertical surfaces like wall, buildings easily and faster than the conventional methods like ladders and ropes etc. This device works on the vacuum to climb the vertical surfaces as its name indicate and this vacuum is utilized by two suction pads which are available in the hands of the climber and the suction pads are connected with the suction motor (vacuum pump) with the hoses. With the help of vacuum suction pad, we can climb vertical surfaces like wall easily and without causing damage to the contact surface, their suction force should be designed by considering both external condition and the loads of working equipment. In this project we performed a basic experiment on the vacuum suction force of suction pads attached to a vertical wall under various load condition. This mechanism enables a person to climb up wall and remain suspended with no handholds.

KEY WORDS: High-Rise Building, Vacuum Suction Force,

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. LITERATURE REVIEW

2.1 Chikesh et al, 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.

2.2. Gosavi, 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.

2.3. Avvaru et al, 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 90° 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.

2.4. Kolhalkar and Patil, 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.

2.5. Elkmann et al, 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 m² 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.

III. MAIN COMPONENTS OF THE VACUUM ASSIST WALL CLIMBER

Components of vacuum assisted wall climber:

- Vacuum Pump
- Electric Source
- Hoses
- Suction Pads

IV. METHODOLOGY

The methodology for a vacuum-assisted wall climber involves rigorous planning, component selection, assembly, testing, operation, and maintenance. Initially, project requirements are defined, followed by the selection of suitable components such as vacuum pumps and suction pads. Integration of these components into a cohesive structure ensures optimal performance and safety. Thorough testing and calibration validate climber functionality and stability, with a focus on fine-tuning suction power and control mechanisms. Safety measures, including emergency stop features, are integrated into the design, with user training emphasizing proper operation and emergency procedures. Maintenance routines are established to sustain performance, ensuring regular inspections and component replacements. This systematic approach prioritizes safety, reliability, and efficiency, enabling vacuum-assisted wall climbers to excel in diverse applications such as construction, maintenance, inspection, and rescue operations.

V. CONSTRUCTION



5.1. Suction Pad

The plywood of 25mm thick was selected due to its light weight and machinability. To create the suction pad, the plywood was cut to the required dimension of 500×00mm. Suction pads are the most important part of the VAC. 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 relieved 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.

5.2 Pressure release mechanism

A vacuum suction pad functions as a pressure release mechanism by utilizing negative pressure or suction to securely hold objects in place. When the vacuum suction pad is activated, it creates a low-pressure environment between the pad and the object's surface, effectively gripping it. To release the pressure and detach the object, the vacuum is simply turned off or the seal is broken, allowing air to rush in and equalize the pressure. This causes the suction pad to release its grip, enabling easy removal of the object. Vacuum suction pads are commonly used in various applications such as handling materials in manufacturing, lifting glass panels, or securely gripping objects in robotics and automation processes.

5.3. Backpack system

Handling the vacuum-assisted wall climber backpack involves understanding its operation and safety measures. The

user wears the backpack, which contains the vacuum system and suction pads. To adhere to a wall, the pads create a vacuum seal when activated. To release pressure and detach from the surface, the user typically operates a valve or switch on the backpack, allowing air to enter the vacuum system. Proper handling includes ensuring a secure fit, understanding weight limits, and following safety protocols to prevent falls or injuries during operation. Regular maintenance and inspection of the backpack are also essential for safe and effective use.

5.4. Foot support system

In the vacuum-assisted wall climber foot support system, suction pads are connected to a belt worn by the climber. The belt serves as a central hub for distributing vacuum pressure to the suction pads located on the climber's feet. When activated, these suction pads create a secure vacuum seal between the climber's feet and the climbing surface, providing stability and traction. To release pressure and detach from the surface, the climber can deactivate the vacuum system through controls on the belt, allowing air to enter and break the seal. This design enhances mobility and safety for climbers navigating vertical or inverted surfaces, making it suitable for various applications, including industrial maintenance, construction work, or rescue operations.

VI. 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 slip 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 exerted 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 climb in.

VII. DESIGN PARAMETER

In order to find the maximum normal load acting on the equipment, the vacuum pressure generated by the motor is measured. A vacuum gauge is used for finding the pressure at the suction end.

Vacuum pressure at the end of the suction line = 25kpa
= 0.24675 bar

Standard atmospheric pressure (P. atm) = 1.013 bar
Absolute pressure at the end of suction line (Pab)
= (Standard atmospheric pressure) – (vacuum pressure at the end of suction line)
= (1.013 – 0.2467)

= 0.7663 bar.

Area of suction pad

Inside area = $0.4 \times 0.3 \text{ m}^2 = 0.120 \text{ m}^2$
Outside area = $0.5 \times 0.4 \text{ m}^2 = 0.20 \text{ m}^2$

Pressure Force

Pressure Force = $P_{out} \times A_{out} - P_{in} \times A_{in}$

= $(1.013 \times 0.2) - (0.7663 \times 0.12)$
= $0.2026 - 0.0919$
= 0.110644×10^5

= 11064.4 N

Maximum normal load

Maximum normal load (in kg) = $11064.4/9.8$

= 1128 kg say 1100kg

Factor of Safety =5

Total weight = $1100/5$ =220kg say 200kg

This is safe load for carry.

VIII. APPLICATIONS

These are applications of vacuum assisted wall climber:

- Inspection and Surveying,
- Rescue Operations:
- Window Cleaning
- Film and Photography,
- Industrial Applications,
- Military and Defense,
- Adventure Sports

IX. CONCLUSION

Due to the negative pressure created inside the vacuum pads it gets attached to the wall firmly. For taking the next higher step the pressure release mechanism is been used, which allows the atmospheric air to enter into it. Due to which the climber is able to release the suction pad away from the wall. The climber then places the suction pad on the next higher step, by balancing his weight on the 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. Theoretically, the climber can climb the vertical wall over the infinite distance. But for safety purpose, we have conducted the experiment to the limited height only.

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