DESIGN, FABRICATION AND ANALYSIS OF PERSONAL VACUUM ASSISTED CLIMBER

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Abstract—There are various instances where a human as to climb the walls of a high-rise building. Some of them are inspection of high pipes and wall, fire rescue operations, painting and repairs. Unlike the traditional method of using grappling hooks used for wall climbing, this device uses the principle of vacuum to scale the walls. The major motive of this project is to make the manufacturing and usage of this device simple. The suction is produced using the vacuum motor setup and a release valve mechanism is used to help the climber take successive steps. The suction force produced by suction pads is designed by considering both the external conditions and the loads of working equipment. In this research work we have performed a basic experiment on the vacuum suction force of suction pads attached to a vertical wall under various load conditions

Keywords—suction pad, vacuum pump

1. INTRODUCTION

It has been a dream for man to scale heights. In order to make this dream come true, mankind as invented equipment such as Rope, Carabiners, Quick draws, Harnesses, Ascenders, Sling etc.., But still this equipment may not be handy for day to day usage in domestic and industrial purposes. These could only be used if there is a strong support at the elevated destination and also needs immense training to master the usage of this equipment. This makes the activity of climbing walls a problem to those who lack the effective training. Vacuum assisted wall climber will assist climbing vertical surfaces against gravity. It is equipment which uses its vacuum pumps to produce a grip against the wall surface. The assembly is enclosed in a backpack, which helps us to climb heights over the flat surface. So we came up with the idea of vacuum assisted wall climber, which consist of two suction pads and household vacuum pump. To have an air tight seal we used rubber material so that lip of the suction pad creates a friction against the wall surface. The larger the suction pad more weight it can hold. This could also be used as a lifting device to carry the things which are heavy with ease. But the object which we are lifting needs to have flat surface and it should be within the suction limit. If the air inside the cup is removed thus creating a perfect vacuum seal inside the cup whose pressure is very much lesser than atmospheric pressure. The method of using concept of vacuum to climb the walls is technique that has been developed in recent years. It is mainly designed to meet the stated requirements.

2. APPLICATIONS

A. Military Applications

Military applications could include fighting environments where climbing over large obstructions was necessary. Stealthy operations might also be used for Covert Operations.
B. Rescue Operations:
Rescue tasks could include firefighting situations where accessing the interior of a building is not viable option or could be life threatening to the firefighter. Roofing operations could also use the personal assisted vacuum climber for a temporary anchor point if the surface cannot be fastened too. The window washing industry might even be able to use the personal assisted vacuum climber if it seemed feasible.

C. Recreational Use:
For recreational use, the obvious use would be at a local rock-climbing facility or a carnival. The personal assisted vacuum climber could be sold to the public if proper standardized ASTM tests were passed. Small-scale personal assisted vacuum climber systems could also be built for the young children or teenagers.

D. Pipe Inspection:
It could also be used in the taller building for undergoing inspection in pipe systems.

3. DESIGN CALCULATION
We tested the raise of water by inches tube. The level of water raise is found to be about 141cm

1cm of water = 1/2.54 = 0.393701 inches of water

**cm of water to inches:**
141 cm of water = 141/2.54 = 55.5 inches of water raise
55.5 inches of water raise = 4.4 inches of Hg
1 inches of Hg = 1/ (2.036) = 0.491 psi
4.4 inches of Hg = 4/ (2.036) = 1.96 psi

**psi to bar conversion**
1 psi = 1/ (14.504) = 0.0689476 bar

Therefore, we have
1.96 psi = 1.96/ (14.504) = 0.135 bar

The vacuum pressure at the end of the suction line = 0.135 bar

From Fluid dynamics, we know that,
- Pressure = Force/Area
- Area = Force/Pressure

Let the mass of the climber be 100 kgs
Therefore, Mass = 100kg
Then, force = 100*g = 100x9.81 = 981N
Where g =acceleration due to gravity in (m/s2)

**Calculation of diameter of suction pad**
\[ \pi/4*(d^2) = 981/(0.135\times10^5) \]
\[ \pi/4*(d^2) = 0.07266 \]
\[ d^2 = \sqrt{0.07266} \]
\[ d = 27 \text{ cm} , \]
That implies \( d = 30 \text{ cm} \) (approx.)

where,

\( d \) - Diameter of the suction pad in cm
\( P \) - Pressure generated at the end of the suction line
\( F \) - Force that is being generated by the human body

**Calculation of Absolute pressure**

Gauge pressure is zero-referenced against ambient air pressure, so it is equal to absolute pressure minus atmospheric pressure.

Absolute pressure = Atmospheric pressure – Gauge pressure

\[ = 1.013 - 0.135 = 0.878 \text{ bar} \]

**Calculation of area of suction pad**

Inside area = \( \pi/4*(0.265)^2 \) = 0.055 m^2

Outside area = \( \pi/4*(0.300)^2 \) = 0.0706 m^2

Pressure force = \( P_{\text{out}} \times A_{\text{out}} - P_{\text{in}} \times A_{\text{in}} \)

\[ = (1.013 \times 10^5 \times 0.0706) - (0.878 \times 10^5 \times 0.055) \]
\[ = 2322.78 \text{ N} \]

4. **LITERATURE REVIEW**

Avvaru Subramanyam, Y.Mallikarjuna, S.Suneel, L. Bhargava Kumar [1] deals about the Design And Development Of A Climbing Robot For Several Applications of a wall climbing robot using quasi static motion and it is capable of moving over the vertical natural terrain. The designed robot is capable of being stick to the wall at any point of instant and the robot is made of light weight material like thermocol. They experimentally calculated the speed of motor propeller as well.

Manuel F. Silva and J. A. Tenreiro Machado [2] ISEP - Instituto Superior de Engenharia do Porto Portugal A Survey of Technologies and Applications for Climbing Robots Locomotion and Adhesion found two issues found in their design is that terms associated with their locomotion and adhesion methods. Four types are usually considered with respect to the locomotion type of their robot. Even though the crawler designed by them is capable of climbing flat surfaces but not that much adequate to climb over the rough surfaces. The legged type easily copes with obstacles found in the environment, whereas generally its speed is lower and requires complex control systems. Regarding the adhesion to the surface, the robots should be able to produce a secure gripping force using a light-weight mechanism. The principle associated vacuum is very lightweight and easy to control whereas the magnetic type principles generally implies heavy actuators. The thrust force type robots make use of the forces developed by thrusters to adhere to the surfaces, but are used in very restricted and specific applications.

Guido La Rosa, Michele Messina, Giovanni Muscato, R. Sinatra, [3] "A low-cost lightweight climbing robot for the inspection of vertical surfaces", proposed a low cost climbing robot which is almost capable of climbing vertical, cylindrical painted iron surfaces by means of eight suction cups, to change its climbing direction, and using an appropriate system and they designed it carry the
ultrasonic probe or the related nondestructive test equipment in order to have proper evaluation of thickness and the integrity of metal involved in the storage tank. They have came up with the solution in relation to the forward kinematics of the robot trajectory. Then they came up with different inclination angles in order to have a correct functioning of its movement and adhesion on to the surfaces where they are employed.

Hwang Kim, Dongmok Kim, Hojoon Yang, Kyouhee Lee, Kunchan Seo, Doyoung Chang and Jongwon Kim, [4] “Development of a wall-climbing robot using a tracked wheel mechanism” had realized by adopting a series chain of two tracked wheels on which 24 suction pads are being installed. The suction pads which attach to the vertical plane are activated in sequence by specially designed mechanical valves. It is a self-contained robot in which a vacuum pump and a power supply are integrated and is controlled remotely. The climbing performance, using the proposed mechanism, is being evaluated by them on a vertical steel plate.

5. MODEL

![Fig. 1: CAD Model of the Suction Pad](image1)

![Fig. 2: CAD Model of the PVAC](image2)
FIG. 3: EXPERIMENTAL VALIDATION OF THE PVAC

| S.No | Part name            | Qty | Cost per unit | Total cost |
|------|----------------------|-----|---------------|------------|
| 1.   | Suction Pad          | 2   | 500           | 1000       |
| 2.   | Vacuum pump          | 2   | 1700          | 3400       |
| 3.   | Handle               | 2   | 30            | 60         |
| 4.   | Foot prong           | 2   | 150           | 300        |
| 5.   | Rope                 | 1   | 40            | 40         |
| 6.   | Hose pipe            | 2   | 75            | 150        |
|      | Switch               | 2   | 20            | 40         |
| 7.   | Bag pack             | 1   | 500           | 500        |
| 8.   | Electric Wire        | 1   | 50            | 50         |
| 9.   | Plug                 | 2   | 10            | 20         |
| 10.  | Extension cord       | 1   | 150           | 150        |
| S.No | Part name | Qty | Cost per unit | Total cost |
|------|-----------|-----|--------------|------------|
|      |           |     |              | TOTAL 5710 |

6. CONCLUSION

After the design and analysis of the personnel assisted vacuum assisted climber, various inspections were made on the equipment based on certain criteria. These include varying amount of load acting on the suction pads, the effective friction force between the surface of the wall and the rubber coating of the suction pads et., based on the results obtained during the analysis and experimental stages, the design for suction pads were modified accordingly in order to have an optimizes design for the wall assisted climbing equipment.

Several components changed with the new design of the personal assisted vacuum climber system. These components were modified and it has been replaced by the new materials. The overall improvements compared to the original system were:

- Decreased personal assisted vacuum climber system weight by 10 lbs.
- Enhanced ergonomics and ease of climbing
- Improved manufacturing and assembly
- Cost to build one system reduced
- Increased time of operation

7. REFERENCE

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