DESIGN AND FABRICATION OF VACUUM ASSIST WALL CLIMBER

Chikesh Ranjan, Shahid.J.Akhtar, Ajit Kumar Choudhary, Vivek Vishal Jaysawa
Dept. of Mechanical Engineering, RTC Institute of Technology, Anandi, Ormanjhi, Ranchi, India.

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/detachment of working equipment such as a gondola to the outer wall of a building is necessary. Though vacuum suction pads can be used to fasten equipment to a 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 this project, we performed a basic experiment on the vacuum suction force of suction pads attached to a vertical wall under various load conditions.

Key words: Vacuum Suction Force, Suction Pads, High-rise Building, Vertical Outer Wall, Fastening Equipment.


1. INTRODUCTION

It has long been a dream of man to possess the power to walk up vertical surfaces. Now vacuum assist wall climber will fulfil 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 assist 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 a vacuum pressure is used include materials handling, lamping, sealing and vacuum forming. In terms of materials-handling applications, a pneumatic vacuum can be used to lift smoothly objects that have a flat surface and are not more than several hundred kg in weight. A materials-handling
application where a vacuum cup called a suction cup is used to establish the force capability to lift a flat sheet. The cup is typically made of a flexible material such as rubber so that a seal can be made where its lip contacts the surface of the flat sheet. A vacuum pump is turned on to remove air from the cavity between the inside of the cup and top surface of the flat sheet. As the pressure in the cavity falls below atmospheric pressure, the atmospheric pressure acting on the bottom of the flat sheet pushes the flat sheet up against the lip of the cup. This action results in vacuum pressure in the cavity between the cup and the flat sheet that causes an upward force to be exerted on the flat sheet. The magnitude of this force can be determined by algebraically summing the pressure forces on the top and bottom surfaces of the flat sheet. The atmospheric pressure on the top and bottom surfaces of the flat sheet cancels out away from the outer circle area of the cup lip. If all the air were removed from the cup cavity, we would have a perfect vacuum and thus the suction pressure would be equal to zero in absolute pressure units

2. COMPONENTS OF VACUUM ASSIST WALL CLIMBER

Vacuum pump
2.2. Electric source
2.3. Pipelines
2.4. Suction pads

3. DESIGN PARAMETER

The main parameters in the design are maximum normal force at suction pad, maximum altitude of operation of equipment and co-efficient of friction of the friction material. 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

\[ = 200 \text{mmHg (mm of mercury)} \]
\[ = 200 \text{mmHg} = 0.26675 \text{ bar}. \]

Standard atmospheric pressure (P.atm) = 1.013 bar

Absolute pressure at the end of suction line (P_{ab})

\[ = (\text{Standard atmospheric pressure}) – (\text{vacuum pressure at the end of suction line}). \]
\[ = (1.013 – 0.2667) \]
\[ = 0.7462 \text{ bar}. \]

3.1. Area of suction pad

Inside area \[ = 0.33 \times 0.25 \text{ m}^2 = 0.082 \text{ m}^2 \]

Outside area \[ = 0.38 \times 0.30 \text{ m}^2 = 0.114 \text{ m}^2 \]

3.2. Pressure Force

Pressure Force \[ = P_{out} \times A_{out} – P_{in} \times A_{in} \]
\[ = (1.013 \times 0.114 - 0.7462 \times 0.082) \]
\[ = (0.115 – 0.062) \]
\[ = 0.0530 \times 10^3 \text{ N} \]
\[ = 5300 \text{ N} \]
3.3. Maximum normal load
Maximum normal load (in kg) = 5300/ 9.8
= 540.81 ~ 500 kg.

There is a safe altitude up to which the equipment can safely operate. Also it depends upon the load acting on equipment. Since the machine has an ultimate normal load capacity of 500 kg, margin of 200 kg is given. So the ultimate is 300 kg.

3.4. Safe load
Safe load 150 kg can be assumed

4. DESIGN FORMULA
Horizontal suction pads, vertical force.
\[ F_{th} = m \times (g + a) \times f.s \]
Vertical suction pads, vertical force.
\[ F_{th} = m \times (g + a/f) \times f.s \]

Where,
\[ F_{th} = \text{Theoretical holding force [N]} \]
\[ m = \text{mass [kg]} \]
\[ g = \text{acceleration due to gravity [9.81 m/s}^2\text{]} \]
\[ a = \text{system acceleration [m/s2] [max x, y & z axis = 5 m/s2]} \]
\[ f.s = \text{factor of safety [min=1.5 ,max =2.0]} \]
\[ f = \text{co-efficient of friction} \]

5. DESIGN AND FABRICATION

5.1. Modeling Using CATIA
CATIA V5, developed by Dassault Systemes, France, is a completely reengineered, next-generation family of CAD/CAM/CAE software solutions for Product Lifecycle Management. Through its exceptionally easy-to-use state of the art user interface, CATIA V5 delivers innovative technologies for maximum productivity and creativity, from concept to the final product. CATIA V5 reduces the learning curve, as it allows the flexibility of using feature-based and parametric designs.

The final Design of the Vacuum Assist Wall Climber with a tooling device on it is modelled in CATIA V5 R19.
5.2. FABRICATION

A physical prototype is being fabricated by using low cost, low weight materials which are available in market to give a rough idea of how the robot will be and how it will work.

Table 4.1 Parts Used for Fabrication

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Part Name</th>
<th>Materials Used</th>
<th>Manufacturing Method</th>
<th>Specifications</th>
<th>No of Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Suction Pad</td>
<td>wood</td>
<td>Manual operations</td>
<td>38×30×2.5mm</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Vacuum Pump</td>
<td>Plastic</td>
<td>-</td>
<td>1400W flow rate 5.3 ltr/sec</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Handle</td>
<td>Steel</td>
<td>Manual operations</td>
<td>15×1×0.5 cm</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Pedal</td>
<td>wood</td>
<td>Manual operations</td>
<td>20×15×1.5 cm</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Rope for Pedal</td>
<td>plastic</td>
<td>-</td>
<td>Length-100cm</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Pipeline</td>
<td>Plastic</td>
<td>-</td>
<td>Diameter-4cm Length-140cm</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Switch</td>
<td>Plastic</td>
<td>-</td>
<td>6A</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Bag pack</td>
<td>Cloths</td>
<td>-</td>
<td>50×45×25 cm</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Electric Wire</td>
<td>copper</td>
<td>-</td>
<td>400 cm</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Plug (Male-Female)</td>
<td>Plastic</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>Extension code</td>
<td>-</td>
<td>-</td>
<td>50 Meter</td>
<td>1</td>
</tr>
</tbody>
</table>
6. EXPERIMENTAL SET UP

Figure 4.1 Suction Pad

Figure 4.2 Vacuum Pump

Figure 4.3 Pedal

Figure 4.4 Vacuum assist wall climber assemblies

Figure 4.5 Bag for vacuum pump
6. CONCLUSION
From our work and this research paper, we can conclude that vacuum assist 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. We make the entire system with less weight and aesthetics and ergonomic consideration this assist wall climber reduce the human efforts. This project is cheaper and its production cost will reduce more if it produce in large scale.

7. FUTURE RESEARCH SCOPE
In future research we can use battery supply to the vacuum pumps so the chances of the failure of the vacuum can be minimized. We can reduce the system self-weight by using lightweight material for the pads. Chances of the leakage in the pads are minimize by using high quality seals.

REFERENCES

http://www.iaeme.com/IJMET/index.asp
editor@iaeme.com


