DESIGN PARAMETERS OF A PROPELLER TYPE WALL CLIMBING ROBOT

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Abstract : Robots were invented 70 years back to help humans to work efficiently. Robots were made to depict human-like behavior without causing any causalities or errors, thereby eliminating the limitations of human workers. Wall climbing robots were specifically made to access places that are hazardous or hard to reach for humans. They have numerous applications like inspection, spray painting, putting out fire in high rise buildings etc. Wall climbing robots can have different mechanisms like mechanical, magnetic, vacuum type and propeller type. A propeller type wall climbing robot is faster and can mobilize itself in any direction easily on any vertical surface. Thus, our paper presents a review on design of a propeller type wall climbing robot which is feasible and reliable. The proposed wall climbing robot creates a downward thrust to cohere to the wall and changes the direction of the thrust to shift its direction. Thus, the paper offers insight on the eclectic challenges faced during the formulation and modelling of the design.

***Keywords* - wall climbing robot, thrust, Creo, 3D printing, modelling, materials, design.**

I. INTRODUCTION

The mechatronics field has developed several folds in the recent years and the need for more skilled force for its implementation has also escalated. The drawback to an entire human force is that they have physical limitations and get exhausted and cannot be made to work in dangerous environments. For such reasons, robots make a really good substitute. Robots can combat these issues and work efficiently. Wall climbing robots are used to climb vertical surfaces and have applications such as spray painting. Inspection, surveillance, firefighting in high rise buildings etc.

A wall climbing robot is supposed to mobilize itself on a vertical surface and move in the required direction. The adhesion and locomotive methods pose a major question during the designing. Gravitational force acting against the robot, make it important for the robot to generate enough thrust while having minimum weight. Wall climbing robot can be administered by various mechanisms. A. Nishi et al., 2016 [1] has mentioned three type of mechanisms and proved that out of three, only the propeller type robot overcome the many pitfalls of the other mechanisms. The propeller type robot was faster and could move on any irregular or regular surface. Kanjanapan et al., 2017 [2] has also demonstrated the downsides of other mechanisms in comparison to our proposed robot. In conclusion, we have analysed, researched and designed the robot body and made efforts to provide understanding of the development to the reader. As propeller type wall climbing robots have to be made cost efficient thus, our work focuses on the mathematical modelling and the designing procedure considering the various forces and material cost availability.

II. DESIGN PROCEDURE AND STRUCTURAL MODELLING

This section comprises of the formulation of the design for the proposed robot and its structural modelling. It also speculates on the possible materials and also gives comprehension of the practical design procedure.

A. *Structural modelling:*

We started by assuming the dimensions of a single part to be constant and the dimensions of others variable and dependent on the former part. Propeller of a 10*4.5 $inch^2$ was made constant. Thence, the inner diameter of the rotating ring/disk was set at a considerable distance from the propeller blade's end. The outer diameter was 1 inch more than the inner d. This was done to facilitate easy rotation of the propeller without causing any damage to the ring. After inducing the distance between the two rotating disk as 15 inch, the length of the chassis was decided. The distance between the outer diameter and the width of the frame was realized by motor and clamp dimensions and finally clearance.

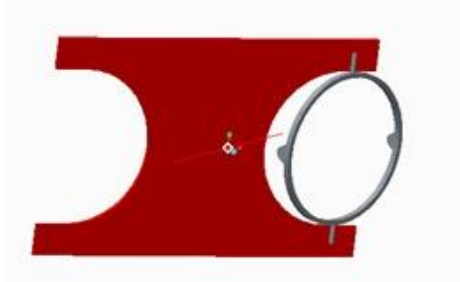
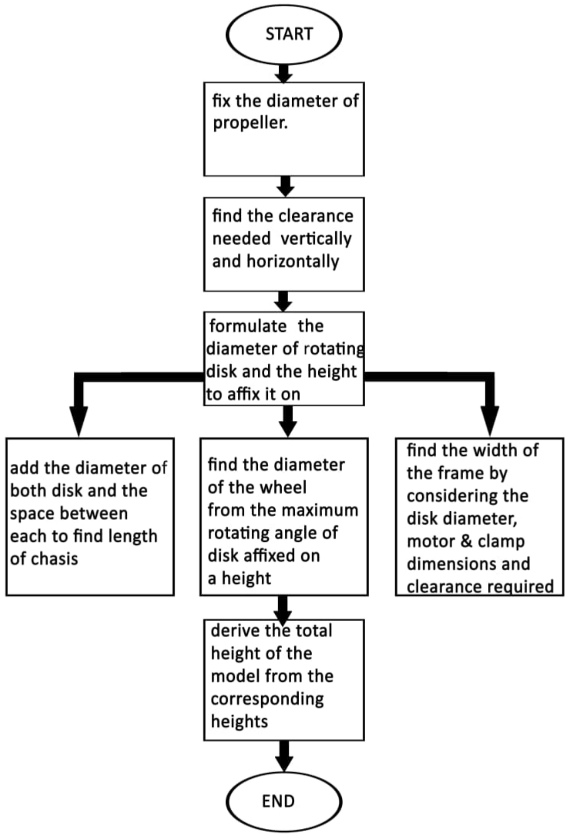


Figure. 1 creo assembly

The dimensions of wheels were hereby ascertained by taking in consideration various factors. The disk will be mounted a few cms above the surface of the frame to furbish the clamping of motors. The major factor determining the diameter of the wheel was the maximum angle the disk can rotate. That could be assumed at 180 degrees. The condition that is to be applied is:

R > r - h
Where, R=radius of the wheel length
r= total radius of the disk
h= height of the axis of motor from frame surface.



Flowchart for the design process is given below:

Figure 2.a) Prototype model b) wheels

The weight of the total robot has to be less than 2 kgs. One BLDC 1400KV motor can carry a maximum payload of 1 kg. Hence two motors can carry upto 2 kgs. The calculations for the total robot weight is shown below:

1. Total frame weight = 284g
2. 2 BLDC 1400 KV motor = 124g
3. 2 propellers= 28g
4. 2 servo motor= 110g
5. 4 wheels= 140g

6. 2 aluminium strips= 60g
7. 2 clamps= 100g
8. 2200 mAh li-ion battery= 160g
9. Miscellaneous weight= 300g

Hence, total weight is approximately 1306 g.
By applying the momentum conservation theory to the rotor, we find that the thrust for the disk[6] is

$$T_h= 2\wp A V_i^3 \qquad (1)$$

Where, $\wp$= air density
A= area of the disk
V_i= induced air velocity
This thrust has to be maximum in order for to robot to adhere to the wall.

Additionally, considering the forces on the airfoil structure, theory of lift[3] is essential to note. The forces act in the directions show in the figure below. The following forces are:
Gravitational force = mg
Where, m= mass of the robot
g= 9.8 m/s^2

$$\text{Lift force}= X_\Lambda*(1/2\Box\varsigma^2)*\Sigma \qquad (2)$$

Where C_L=lift coefficient
$\wp$= density
V= velocity of air
S= wing area

$$\text{Drag}= X_\Delta*(1/2\Box\varsigma^2)*A \qquad (3)$$

Where C_D=drag coefficient
$\wp$= density
V= velocity of air
A= cross sectional area of flow

$$\text{Thrust force of the foil}= m*a \qquad (4)$$

Where m= mass of the aerofoil
a= acceleration of flow

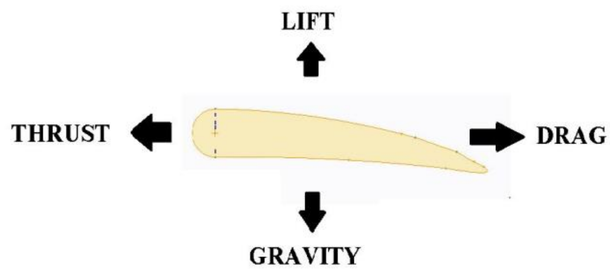


Figure 3. Forces on the blade

B. Material selection:
We analysed different materials for the robot body frame and wheels. The most appropriate material is carbon fibre. saifeldein et al., 2015 [4] has shown that carbon fibre has higher strength and lighter materials and very less density. But, due to its extreme price and unavailability in the region, it failed to satisfy our requirements. The other materials that were analysed were polycarbonate and PVC. Both have low densities and are lighter materials hence can be used. Although compared to polycab, PVC has higher impact strength at 20 Kj/m^2, polycab has greater advantages over PLC in terms of material strength, durability etc.

For the wheels, we have used PLA thermal plastic. They have been printed by 3D printers. 3D printers have used because of the intricate design of the wheels. 3D printers produce extremely accurate dimensions in lesser time and money than manual methods or any other machine. Ashish et al., 2017 [5] has shown the benefits of using 3D printing and PLA. PLA is a biodegradable material derived from renewable resources. It is a environmental friendly thermal plastic among other plastics. It also has a density of 1.3 g/cm^3 and strength to weight ratio of 38 kN-m/kg.

C. Design procedure:
Robot consists of four main parts: robot body, wheels, actuating system and electronic components. The initial step was to calculate the dimension of the chassis in consideration with the results from the mathematical modelling. Then, after finding the dimensions, Creo is used to make a 3D model of the frame. Similarly, for the wheels. Finally, it is printed using 3D printer. Clamps and other supporting elements were also created in creo and printed. The rotating disc is manually cut out of polycarbonate sheet.

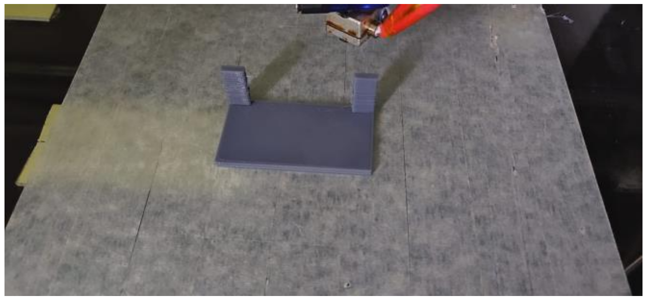


Figure 4. 3D printing of clamp

For the actuating system, two 1400KV Brushless DC motor have been used to generate thrust. The reasoning is given in the modelling section. For the rotating disc, we have used servo motors.

Electronic components consist of 30A ESC, li-ion battery and Flysky. ESC is used to control the speed and rotation of motor. Flysky is used to give command to the robot. Li-ion battery is used because of its light weight and excellent life.

III. CONCLUSION

Here, the authors have presented a review on the design parameters pertaining to a propeller type wall climbing robot. The benefits of a propeller type wall climbing robot can be observed over other mechanisms. It can be observed that the thrust generated by the robot should be greater than all the other forces applied on it to be able to move swiftly on a wall. This can be achieved by designing the robot in the proposed way. The availability and cost of materials have a major significance in the selection of the materials and designing of the robot. Furthermore, a number of different values contribute to the result of the value of the thrust which is to be generated. Thus, the designing of such a robot requires numerous considerations of several factors because the successful working of the robot depends cheifly on the structure of itself.

REFERENCES

[1] A. Nishi, H. Miyagi, and K. Ishihara, “Development of wall inspection robots,” Proc. 12th Int. Symp, on Automation and Robotics in Construction (ISARC), pp. 103–108, 1995

[2] Kanjanapan Sukvichai, Pruttapon Maolanon, Konlayut Songkrasin “Design of a double propellers wall climbing robot”International conference on Robotics and Biometrics, Proc. IEEE, December 2017

[3] MIT open courseware

[4] Saifeldein, Arabab, “Research in Carbon-Carbon composites” Southern Illinois university, Carbondale, 2015

[5] Ashish Tak, Prabhakar Ingavale, Chaitanya Khopatkar, Sumit Bhure, Vinod Barve, Avadhoot Rajurkar “Effect of 3D Printing Parameters on Dimensional Accuracy & Shrinkage on Printed Part”, Proc. National Conference on, Modeling, Optimization and Control, 4th -6th March, NCMOC – 2015

[6] A. Nishi and H. Miyagi, “Propeller type wall-climbing robot for inspection use,” Proc. 10th Int. Symp, on Automation and Robotics in Construction (ISARC), pp. 189–196, 1993

[7] Mohamed G. Alkallaa, Mohamed A. Fannib and Abdelfatah M. Mohamedc “A Novel Propeller–Type Climbing Robot for Vessels Inspection,” Proc. IEEE International Conference on Advanced Intelligent Mechatronics (AIM), 2015

[8] Rita Jelai Johnson and Mohd Helmi Sui “pressure control of wall climbing robot using PID controller”, ARPN Journal of Engineering and Applied Sciences, vol. 10, no. 21, November 2015

[9] H.V. Venkatasetty, YUJ “Recent advances in Lithium-ion and Lithium-Polymer batteries” Proc. 17th annual battery conf. Applications and advances, pp. 173 – 178, 2002

[10] K. T. Chau, Dong Zhang, “Design of a Magnetic-Geared Outer-Rotor Permanent-Magnet Brushless Motor for Electric Vehicles”, Proc. IEEE Transactions on Magnetics, Vol 43 , Issue 6, pp 2504 – 2506, 2007

[11] Weimin shen, Yanjun shen, “Proposed Wall Climbing Robot with Permanent Magnetic Tracks for Inspecting Oil Tanks”, Proc. International Conference on Mechatronics & Automation, 2015

[12] Minghui Wu, Gen Pan, “Design and Optimal Research of a Non-Contact Adjustable Magnetic Adhesion Mechanism for a Wall-Climbing Welding Robot”, International Journal of Advanced Robotic Systems, vol. 10, 2013

[13] 1. Sanju N Raju,Akhil G Ravi,Vijitha Sharma,Gauri Bala, A Novel Design Technique to Develop a Low Cost and Highly Stable Wall Climbing Robot. Proc. \4th International Conference on Intelligent Systems, Modelling and Simulation, 2014

[14] Jizhong Xiao, Ali Sadegh, Matthew Elliott, Angel Calle, “Design of mobile robots with wall climbing capacity” Proc. International Conference on Advanced Intelligent Mechatronics, 2015

[15] Arkadiusz Jakubowski, “Analysis thrust for different kind of propeller”, Poznan university of technology, Poland, 2016

[16] George W. Younkin, “Electric Servo Motor Equations and Time Constant”, Proc. IEEE, 2012

[17] Dr. husan.u.zaman, chowdhury, “Design, control and performance analysis of muktibot” Proc. IEEE/ASME, 2016