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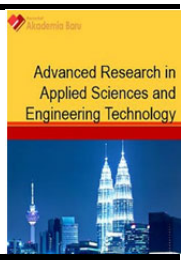

Mobile Robot Climber Model for Experiments Application

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ABSTRACT

This article presents a Wall Climbing Robot (WCR) that able to move on ferromagnetic vertical surface to carry out visual inspection process. Visual inspection process is important in the industry to check the condition of storage tank, surface of building, piping or equipment thus can prevents structures collapsing or explosion which would bring a huge loss to the company. Moreover, most of the structures nowadays is expose under the sun and rain, corrosion and cracks could easily occur on the surface after exposing under sunlight and rain a long period of time. Therefore the periodic visual inspection process need to be carry out to detect the damaged occur on the surface of the structure and take action at the fastest time to ensure the safety of the structures and extend the lifespan of the structures. With the well maintenance to the structures, the condition of the structures is monitored and the lifespan is longer. The risk of collapse of the building is decrease by a large margin. Normally, the periodic visual inspection process is performed by operator. Sometime the temporary scaffolding is needed to reach the higher place to carry out the inspection. However, this method create a hazardous environment to the operator and cause the safety of the operator threatened. Therefore, the proposed WCR could help operator to work at the hazardous environment. The permanent magnet is used to provide adhesion for WCR, thus WCR able to move on vertical ferromagnetic surface. The WCR is controlled by operator via wireless remote to reach the higher place or the hazardous environment. The operator then can stream the on the real time images via web browser which connected to the same network with the WCR. Hence, the condition of the surface can be observed.

Keywords:

Wall Climbing Robot, visual inspection process, maintenances, ferromagnetic structures

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1. Introduction

As most of the structures is expose under the sun and rain, corrosion and cracks could easily occur after a period of time. If the small damages do not detected and repair immediately, it will brings the severe consequences. However, it is impossible to recondition all the old structures as it needs a huge financial resources required and times. Therefore periodic visual inspection process need to be carry out to detect the area of damaged occur and repair it at the fastest time to ensure the safety of the structures and extend the lifespan of the structures. Normally, the periodic visual inspection process is performed by operator by climbing the temporary scaffolding to reach the higher place. However, this method create a hazardous environment to the operator and cause the safety of the operator threatened [1]. Wall Climber Robot (WCR) could move around the given environment includes the vertical wall [2]. It could reach the hazardous environment to carry out the inspection process depends on the operator who controlled it. The operator could observe the condition of the surface via the camera on the robot.

There are a lots of mobile robot climber have been developed to carry out the visual inspection process [4-10]. Every study have developed different types of WCR which have their own advantage and also limitation. The only similarity of WCR from different studied which is all of them built to assist human to reach the hazardous environment and done the dangerous job. For examples, the limbed types WCR is developed which imitates the locomotion of human, animals or even bugs which have a sharp craw at the end of every limb to move on vertical surface [4][5]. Besides, WCR have been developed with the special magnetic wheel [6-9]. There are many magnet is attached on a wheel to assist the WCR to move on vertical ferromagnetic surface. The WCR also have been developed with the idea from DRONE which used the propeller to move on the vertical surface [10]. After consideration from the previous study, the permanent magnet is chosen as the method of adhesion. As permanent magnet could produce a strong adhesion force and need not any energy. The WCR of this project used two wheel as moving mechanism, one wheel as support wheel and the permanent magnet is equipped under the chassis of WCR but do not directly contact to the ferromagnetic surface. The magnetic force is strong enough to hold the WCR on the vertical surface.

2. Performances of WCR

The WCR have been developed and there are some requirement need to be fulfil so that the WCR able to carry out the visual inspection process. Below are the basic requirement needed for a WCR to carry out the inspection process.

1. The movement of WCR on vertical ferromagnetic surface.
2. The efficiency of WCR to carry out the inspection process.
3. The operating range of WCR.
4. The adhesion force of magnet able to hold the WCR.
5. The camera able to send the real time image to operator.

3. Results and Discussion

3.1 Motor Control

The PWM/Voltage value obtained from every motor used. Although both of the motor is purchased from the same company, the speed of every motor also have a small different from each

other's. Therefore, the PWM/Voltage value need to be determined so that the voltage supply to each motor could be control correctly.

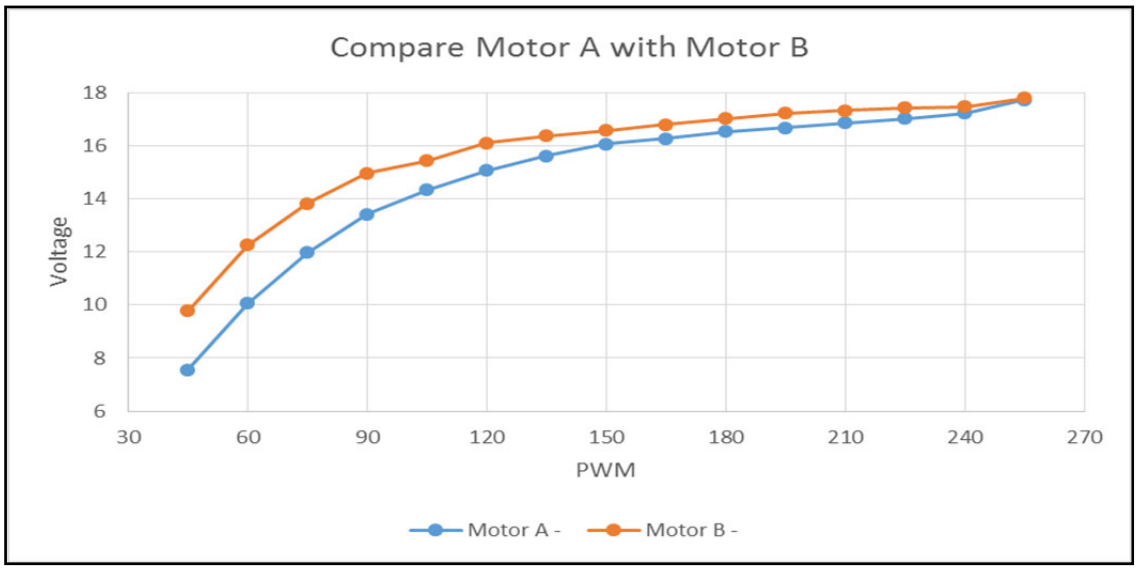

Fig. 1. Comparision of PWM/Voltage value for Motor A and Motor B

From Figure 1, it indicates that when supply 16V to both motors to for the WCR to move in straight line, PWM value for Motor A needs to be set approximately to 150 while PWM value for Motor B is set approximately to 120. With these conditions, the motor could move in same speed thus the WCR could move in straight line. With the Figure 1, the movement of the WCR can be control correctly either to move in straight line or turn left and right.

3.2 Optimum Operating Range

There are different types of wireless transceiver used in WCR which is radio frequency for the controller and Wi-Fi for the camera. Every wireless transceiver have the different operating range, thus the best operating range of both radio frequency and Wi-Fi is obtained and compared to find out the optimum operating range of the WCR.

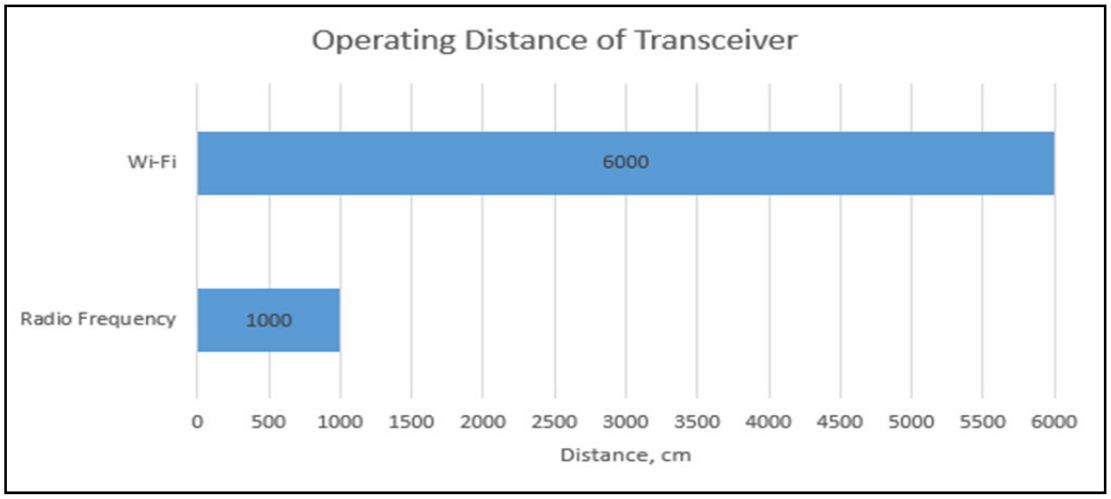

Fig. 2. Operating Distance of Transceiver

The operating distance of both transceiver used in WCR is obtained and plotted in Figure 2. From Figure 2, the optimum operating range of WCR is 1000cm as both of the transceiver can function well.

3.3 Speed

The performances of the WCR is affected by it speed. If the moving speed of WCR is too slow, the working efficiency is affected. Hence, the maximum speed of the WCR is tested and recorded in Figure 3.

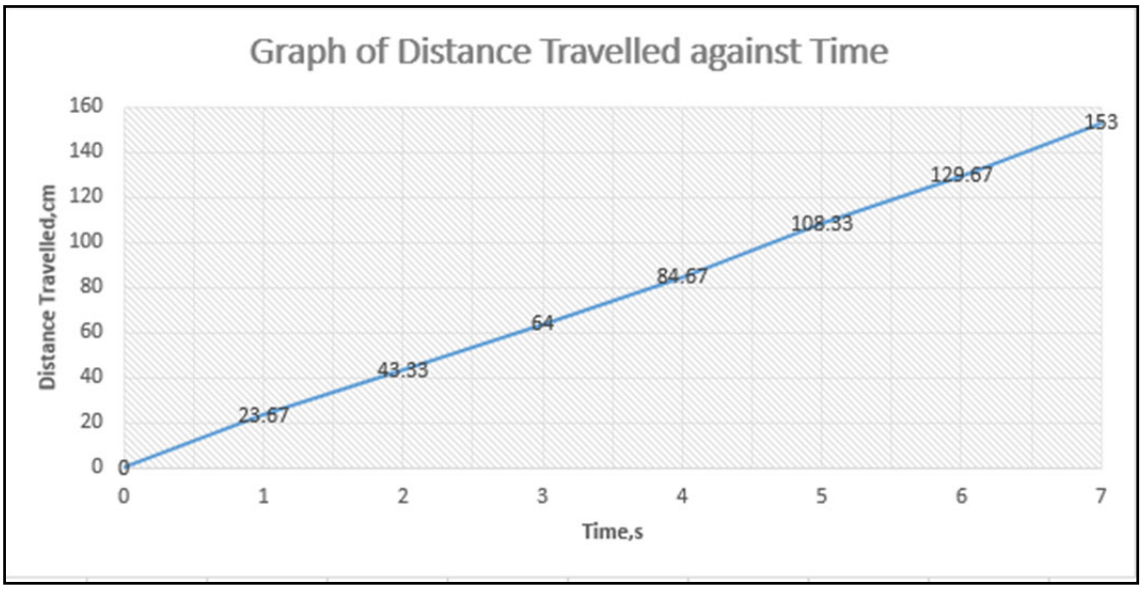

Fig. 3. Graph of distance travelled against times

From Figure 3, the point (0,0) and point (3,64) is used to calculate the speed with formula given in (1),

$$Speed = \frac{(0.64-0)m}{(3-0)s} \tag{1}$$

$$Speed = 0.213ms^{-1}$$

The speed of the WCR is calculated which is 0.213m/s. The speed of WCR might be increased because the motor used in this project is high torque motor but not high speed motor. The motor used should be balance in torque and also speed to optimise the movement.

3.4 Camera

The camera used is Raspberry Pi 5MP camera. It have been set to 640x480 pixel which theoretically could stream video in 60fps. The camera is programmed to stream the real time video on web browser with IP address of 192.168.43.65:8080. The user need to connect to the network that same with Raspberry Pi Camera to stream the video.

Besides, every camera could captured image with different angle of wideness which is fixed by the manufacturer. Thus, after the camera is attached on the WCR, the view of camera is illustrated in Figure 4.

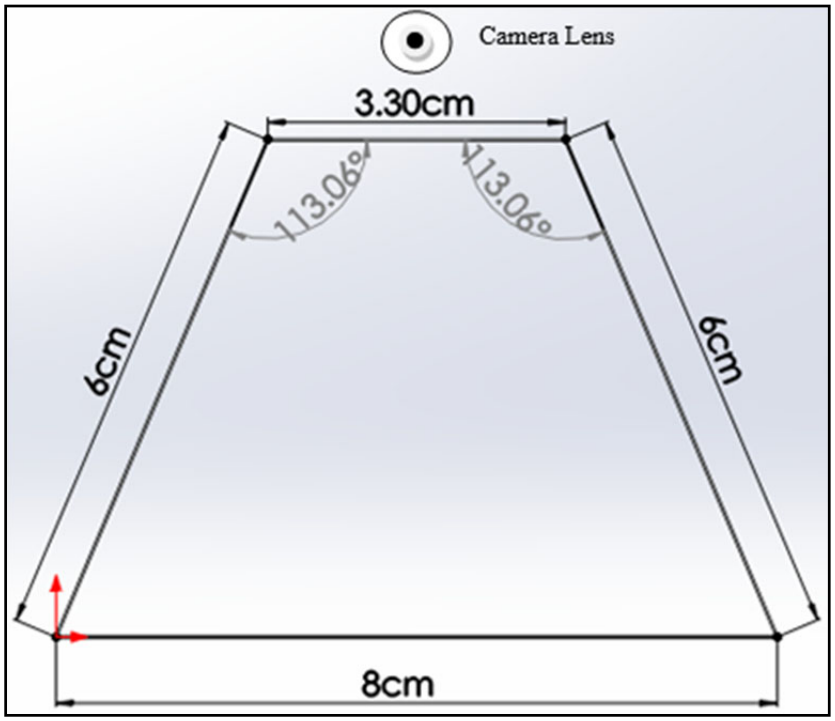

Fig. 4. Plan of camera view illustration

3.5 Adhesion Force

The magnet is the only part that provided adhesion force for WCR. Thus, the WCR only could stick to the ferromagnetic surface. To ease the movement of the WCR, the magnet attached do not directly stick to the surface but have a little gaps between the magnet and the ferromagnetic surface. The test is carried out to find out the maximum distance between magnet and surface and the data is recorded in Table 1.

Table 1
The maximum distance between magnet and surface

Distance between magnet and surface (mm)	Adhesion to the vertical surface
0	YES (WCR couldnot move)
1	YES
2	YES
3	YES
4	YES
5	NO
6	NO

From previous studied, the bigger the gaps between magnet and surface, the smaller the magnetic adhesion force provided [11]. The magnet used in WCR only provides adhesion force for WCR when the gaps between magnet and surface is smaller than 4mm. After 4mm, the adhesion force not enough to hold the WCR on the vertical surface. Besides, number of magnet also affected the adhesion force. The more the magnet used, the stronger the magnetic force [11]. The WCR used only one magnet which can only provide the adhesion force for the gaps smaller than 4mm.

4. Conclusion

In conclusion, the WCR to carry out the inspection process is successfully developed. The challenge of reaching the higher place to carry out the inspection process is solved and the safety of the operator is secured.

The first objective is achieved as a Wall Climber Robot is developed. The WCR have three wheels where two wheels connect to output shaft of the motor and the other one is just a support wheel. The two front wheels which connect to the output shaft of motor is providing the movement for the WCR. There is a permanent magnet attach at the bottom parts of the WCR. The permanent magnet does not directly touch the surface where there is a gaps of 3mm between the surface and the magnet. This would aid the WCR attach to the ferromagnetic vertical surface and do not falling down. The WCR could move on the vertical ferromagnetic surface

The second objective is achieved as the WCR is able to carry out the visual inspection on the vertical wall. The operator can stream the real time video via the camera attached on the WCR. The operator need to connect the network that same with the camera and browse the IP address 192.168.43.65:8080 to stream the real time video.

The third objective is achieved as the performance of WCR is analyzed. The motor voltage is adjusted by suitable PWM value and the magnet is place 3mm away from the ferromagnetic surface. The speed of WCR is about 0.213 m/s and the optimum operating distance is 1000cm. The view of camera is illustrated.

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