Inch worm mechanism for solar panel cleaning robot

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Abstract

This paper describes a design of mechanism for robot of solar panel cleaning process. Cleaning process is requires the robot to be able to travel on the Solar panel module in specific area. The movement of the robot is due to Inch-worm mechanism with the help of two cables. Our proposed design having two body with two grippers placed at either end of its body, the inchworm's mode of locomotion is to decisively attach the rear portion of its body on a cable via its gripper, extending the remainder of its body forward, attaching it on the cable and bringing the rear part of its body to meet the forward part. This design has two servos. One servo is responsible for the closing and opening of first gripper as well as linear motion on the cable. Second one is responsible for closing and opening of the second gripper. Both grippers provides latching and unlatching of robot on the cable. In this way, the inchworm always has at least one portion of its body firmly latched on the cable. Robot has its own solar module. That converts solar energy to electrical energy and feed to robot. Robot has its own solar module. That converts solar energy to electrical energy. That mechanism will be very useful for surface cleaning robot.

Keywords: *Inch-worm mechanism, Solar panel, Cleaning robot, Latching, Cable*

1 Introduction

The increased attention given to the problems on removal of dust, enhancement of power generation of PV system and safety in the work place has raised the demand on cleaning robots. The power generation enhancement and safety of human operators in hazardous environment have always been the main concern which then resulted in implementation of robots for several inspection and cleaning purposes. Conventional panel cleaning robots are normally large in size depending on the fixed rail system. In 2013, Rui Chen and his team reported kinematics of gecko inspired climbing robot [1] and H. Albitar investigated new concept in water surface cleaning robot [2]. In 2009, Xiaobo Lai investigated on driving wheel control of cleaning robot based on fuzzy adaptive turning PID [5]. The plan here is to surpass all these weakness or element that prevents the full efficiency of a cable climbing robot. To achieve this, few important points have been chosen in this paper and design a novel inch worm mechanism. Some parts of it have to be implemented with new sources to give it the

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edge of performance. Through this project a light weight, fast, low power consuming and a cost effective cable climbing robot (RCR) is to be produced for cleaning of solar panels. Movement principle of inchworm is the common name of geometridae larvae. Inchworm moves with the operation of bending and extending its body. In 2006 Chang Hwan reported feeder pipe inspection robot using an Inch worm mechanism with Pneumatic Actuators [7]. It is forefoot and rear foot contact the surface with two attachment point while it is trunk is up, and then the front foot moves towards the other attachment point while the trunk keeps close to the surface.so inchworm completes one gait and moves forward. With the cycle exercise inchworm can perform its movement. The overall complexity of the robot construction should be minimal to reduce the total cost for practical usage of the robot. Smooth operation is important to carry a weight with it very smoothly. In 2009 ND Hewapathirana analyzed on four legged multipurpose cable climbing robot [3]. In 1987 T. Fukuda made Autonomous pipeline inspection and maintenance robot with inch worm mobile mechanism [11]. In 1993 H. T. Roman developed a pipe crawling inspection robot and In 2009 A.M. Bertetto designed robot in pipe inch worm pneumatic flexible robot [10]. For example, this type of cable climbing robot can be used in cleaning and rescue operations. The demands for efficient automatic cleaning system on solar panel array. One of the useful types of robots is the cable climbing one, which could be adopted in variety of tasks such as exploring in a hazardous environment, non- destructive evaluation, fixing and welding in construction and cleaning and maintaining of high rise buildings. In 2006 Tohru developed a small- size window cleaning robot a travelling direction control on vertical surface using acceleration [6]. The robot could work beyond the environmental and geographical limitation which could stop a human from work. Some customized remote controlled window cleaning machines have already been installed into the practical use in the field of building maintenance, but onboard computerized robot which could exceed the environmental and geometrical limits have not been developed in large quantity yet. In 2014 Arvind and his team reported a control for an autonomous robotic vacuum cleaner for solar panel [4]. The most challenging part of designing a climbing robot is developing and choosing an appropriate adhering mechanism for the robot to stick to the surface without any slip and overcoming the weight of the robot itself. In this paper a solar panel cleaning based on cable climbing robot has been developed.

2 Mechanical Design of Inchworm mechanism

2.1 Design of Inchworm mechanism

A mechanical model, formulated based on the observation of the caterpillar and beetle insects. The entire body of the robot and the grippers can be modelled as inchworm mechanism, performing actions similar to that of the inchworm insect. Beginning with the first segment, it can be modelled if it were to be thought of as a trunk with two finger gripper at the end. That gripper is known as fore end gripper.

2.2 Design of Grippers

The design of the gripper is an essential part of the cable climbing robot. During the vertical, inclined climb, the gripper has to bear the entire weight of the robot and the payload. This, is the main consideration for the design of the gripper.

2.3 Robot gripper sizing

The robot should move along the curved cable with a relatively small curvature. In order to determine the size of the robot that can travel along the targeted cable, a kinematic analysis is performed. Two condition are required; one is that the front gripper should not collide. The other is that the grippers should be aligned perpendicularly with respect to the cable. As for the first condition, considering the point P_4 at the front gripper and the corresponding point at the rear gripper, the vector P_4 can be represented as

$$P_4^0 = V_1^0 + A_1^0 V_2^1 + A_1^0 A_2^1 P_4^2 \quad \text{.....(1)}$$

Where V_1^0 and V_2^1 are the vectors indicating the origin of the reference coordinate system with orientation angle of ϕ_1 and ϕ_2, respectively. A_1^0 and A_2^1 represents the coordinate transformation matrices. Here the sub transcript represents the point index and superscript represents the reference coordinate system. Assume that the ϕ_1 is $\pi/2$, that is, the robot is located at the top of the circular cable, then the condition becomes $P_4^0 > 0$.

3 Proto type inch worm mechanism testing

The robot's bodies are made of wooden to reduce the weight, and the crank and joints are made. Two servos are there. Both servo is responsible for robot motion on the cable. The cable have enough mechanical roughness to hold the robot by gripper. Fig. (2) shows the simulation displacement of the forward and backward movements of the robot on a horizontal pipe when the robot moves one step with an interval time of 1.5, 1.2, 0.6 seconds per each step, respectively. Each servo model no- SG90 9g Micro Servo has torque of 1.8kgf-cm. Tiny and lightweight with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller.

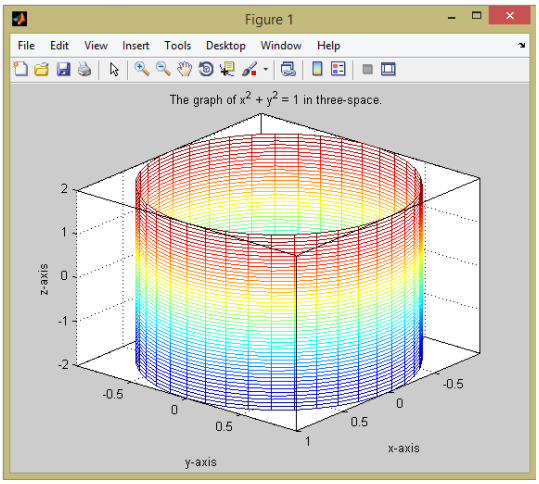

Fig. (2). Displacement of robot on cable per cycle

XY Shows the diameter of cylinder is the diameter of cable and z axis shows the total displacement of robot on the cable which is 10 mm.

4 Conclusion and Future work

In this paper one inchworm mechanism made and tested for the locomotion of the robot for solar panel cleaning. Locomotion give the proposed a mobile robot for cleaning solar panels using an inch-worm mechanism. An electromechanical robot is designed and manufactured. This design scheme reduces the robot size dramatically with a slim shape. The inchworm motion was studied in detail. CAD model, prototype model and a kinematic model were made. The first, second segments and the gripper were modelled. The base line experimental results in matlab show that the displacement of robot on the cable is 10 mm. In kinematics analysis setup a mathematical relation for gripper. Two condition are required; one is that the front gripper should not collide. The other is that the grippers should be aligned perpendicularly with respect to the cable. Mathematical expression was setup.

A control system for whole robot will design in future such that the gripper and the segments when operate in coordination would simulate the climbing motion of the robot. The task of climbing on cable could have been performed efficiently in base line experimental but the potential of the cable climbing robot or any other biomimetic device is much more. If the hinge joints in the segments of the robot were replaced by ball-and-socket joints, then the robot would have much more flexibility and smooth operation.

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Achivements

- Award Invitation from Shri Pranab Mukherjee **President of India** at Rashtrapati bhawan, INDIA and Dr. R.A. Mashelkar(Padma Shri (1991), Padma Bhushan (2000), Gomant Vibhushan Award(2013) and Padma Vibhushan(2014)) awarded Project titled "Inchworm Mechanism for solar panel cleaning robot" by "**Gandhian young Technological Innovation(GYTI) Awards-2015"** on March 8, 2015 at Rashtrapati Bhawan New Delhi, INDIA.
  http://gyti.techpedia.in/project-detail/inchworm-mechanism-for-solar-panel-cleaning-robot/4795
- Shortlisted for finalist of **IIT Delhi Class of 89 Innovation Award** 2015.
  http://www.iitdinnovationaward.org/2014-15
- **Patent** has been communicated through **FIIT, IIT Delhi.**

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Remark

This paper does not has too much detail about design of proposed robot because this concept are under the process of patent through IIT Delhi. It has result and the concept of the inchworm robot for solar panel cleaning process.