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PLC Controlled Suction Adhesive Lead Screw Mechanism Based Autonomous Wall Climbing Robot for Surface Cleaning

Mangala. S. Hiremath[1], Krishnamurthy Bhat[2], H. M. Ravikumar[3]

PG Student, Department of ECE, PES Institute of Technology and Management, Shivamogga, Karnataka, India[1]

Faculty, Department of ECE, Basaveshwar Engineering College, Bagalkot, Karnataka, India[2]

Faculty, Department of ECE, PES Institute of Technology and Management, Shivamogga, Karnataka, India[3]

ABSTRACT: The Autonomous machines are quite extensively used in industries due to the inherent advantages such as faster work, capability of dynamically adjusting to work environment, lowering labour and insurance rates, reducing the risk of personal injury. The AGV has got many applications in different areas, sometimes doing multiple operations and many times in places where humans cannot perform.

In this paper, design and development of an AGV for vertical surface cleaning suitable for multiple applications such as glass surface cleaning on multistorey buildings is discussed. This AGV is called Suction Cup based Autonomous Wall Climbing Robot (SCAWCR). The SCAWCR has to climb the wall more elegantly and safely. Hence both suction cup mechanism and lead screw mechanism are used for implementation. The suction cup will ensure sufficient adhering force and the lead screw mechanism will make the movement more efficient with sufficient force to pull/push the total pay load against the gravity. Four miniature vacuum pumps and an 11.2V Lithium Polymer (LIPO) battery are used on-board to make the robot wireless. A control protocol is implemented through Ladder programming in a resident Programmable Logic Controller (PLC). Wireless Communication is to be implemented to control the activity of AGV through a local microcontroller on the robot. The proposed work is initiated for practical implementation and its functionalities are to the acceptable level. Testing of this robot on a real time application is yet to be done.

KEYWORDS:AGV, Suction cup, Lead screw mechanism, Microcontroller, PLC.

I.INTRODUCTION

Design and development of wall climbing robot is neither new concept nor an engineering story. It has several years of history. Over the last decade, researches have proposed, designed and tested varieties of methods, models and approaches. Climbing robot by name Alicia3 is discussed neatly presented with three modules by Domenico Longo and Giovanni Muscato. They have developed a system which finds a variety of applications, such as maintenance, building, inspection, and safety, in the process and construction industries. This system could be adopted in many places where direct access by a human operator is very expensive because of the need for scaffolding or very dangerous due to the presence of a hostile environment [1]. A robot using vertical pane with negative pressure adsorption mechanism is designed by Nobuhiro Okada *et al.* The mechanism to climb the robot in a vertical plane can be classified into two: negative pressure adsorption mechanism and magnet adsorption mechanism. The negative pressure adsorption mechanism is a mechanism that adsorbs onto the wall by negative pressure of the vacuum pump. The magnet adsorption mechanism adsorbs onto the window with permanent magnet and runs with wheel for drive. The robot developed her has the mechanism of climbing the wall with an easy mechanism that does adsorb and peel off the glass by the suckers. It conserves the energy as it does not need electric energy for adsorb the window [2]. Masataka Suzuki*et al.* have presented a unit of anchor climber which is swarm type for wall climbing. The anchor climber robot system is composed of two child units and a parent unit. The three types of special wall climbing robots are developed as child units and are called adhering mobile units (AM Units). This robot had both high mobility and large payload capability [3]. Electro-adhesive Robot for Wall Climbing is tested and implemented by many researchers .Electro-adhesion is an electrically controllable adhesion technology which involves inducing electrostatic charges on a wall substrate using a power supply. It is suitable for a wide variety of common building substrates, both rough and smooth as well as both electrically conductive and insulating as it is having fast and electrically controllable clamping and

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unclamping [4]. A technical paper presented by Carlo Menon*et al.* focuses on the development of gecko inspired synthetic dry adhesives for wall climbing robots which can scale vertical walls. Gecko has the ability to climb the surfaces, whether wet or dry, smooth or rough. It is a new technique for fabricating synthetic microfibers for use as dry adhesives. The locomotion of this Robot is possible in almost any kind of surface without contaminating the environment [5]. Remote Guided Vehicle designed for performing operations quickly, repeatedly and accurately has a long heritage in the manufacturing industry, operating in relatively static environments and in large numbers. Trends in the oil and gas industry to improve safety and efficiency and reduce environmental impact suggest the use of robotized vehicle. New developments in regions difficult or dangerous for human to work in could be enabled with maintenance, inspection and repairs carried out by remotely-controlled Automated Guided Vehicle (AGV). Programmable Logic Controller (PLC) is an integral part of any industrial work. Therefore, we have designed and developed a PLC based automated remote guided vehicle for filling and disposal of toxic chemical for unmanned application. This paper discusses aspects of different components used to develop an AGV and controlling its movement and on board utilities. Further, this AGV is interfaced to a 23-point PLC using wireless transmitter and receiver pair. This ensures the wireless communication to suit any such applications where human beings cannot access and control. Automated guided vehicle is used to transport toxic chemicals in areas where humans cannot reach. PLC program is written to control the AGV to follow the predetermined path and then, load the chemical at a point and unload at the other point [6]. Fabrication of flexible electrodes and plastic film for electrostatic adhesion for wall climbing is discussed in literature. The adhesion so designed was tested on both conductive and non-conductive surfaces. Results shown by Akio Yamamoto *et al.* have presented models for both types of surfaces. They have revealed that flexible electrodes can work as suction cup on conductive surfaces and surface pre-charging and comb electrodes for non-conductive surfaces. Further, they have designed and tested small robot based on these mechanism to prove their working [7]. A wall-climbing robot or mobility platform is designed and patented by Thomos L. De Fazio which is able to ascend and descend various horizontal and vertical surfaces. This robot has a chassis, a rotor rotatable with respect to the chassis, one or more prominences on the rotor, and means for adhering to a surface attached to the prominences. The robot is suitable for making transition from horizontal travel to vertical travel. In certain embodiments, the means for adhering to a wall is a pressure sensitive adhesive. In addition, multiple rotor configurations and radio-control are used for remote operation [8].

II.OBJECTIVES AND AIM OF THE WORK

- The main aim of this work is to construct a suction cup based autonomous wall climbing robot (SCAWCR) for the cleaning of glass surface on a multistorey building.
- To construct, SCAWCR must have on board suction mechanism with sufficient adhering force, vacuum pumps, local controller (Microcontroller), Battery which will add to the total payload on the bot.
- Robot must be constructed with on board motorized cleaning mechanism.
- It has to climb the vertical plane and clean the surface accordingly.
- SCAWCR must be controlled by a resident PLC.
- This will greatly avoid/reduce the human work in risky situation.

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III.BLOCK DIAGRAM

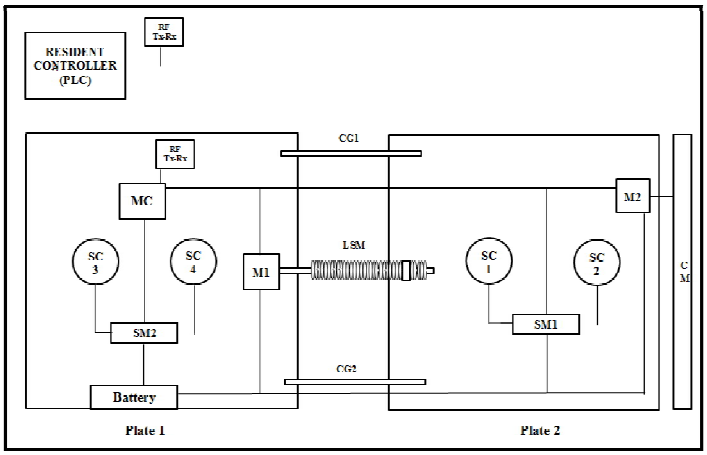

Fig .1Block diagram representation of the work

Where
SC: Suction Cup
SM: Suction Motor
MC: Microcontroller
M: Motors
CM: Cleaning Mechanism
CG: Channel Guide
LSM: Lead Screw Mechanism

IV. CONSTRUCTION AND WORKING

The SCAWCR is constructed using indegeneous materials as shown in Figure 1. It consists of two rigid plates mounted on which a motor with lead screw mechanism, suction motors with suction cups, channel guide, resident microcontroller, onboard battery, cleaning mechanism with motor and a pair of RF transceiver. Channel guides provide sufficient strength and ensure linear movement of the complete robot. Johnson motor has to run in both direction to make the movement of plate1 with respect to plate2 or viceversa.
The control algorithm is implemented through ladder programming in a GE-Fanuc 23 point PLC. The communication between the microcontroller on board the robot and PLC is through a 433MHz RF Tx-Rx pair. The microcontroller will be programmed for the coordinated movement of two plates and the cleaning process.

V. ALGORITHM

1. Switch on the robot supply.
2. Switch on the PLC with Master Reset = 0 and RF Transmitter module.
3. Microcontroller on the robot does the following:

   (a). At t=0 second (the instant when robot battery is switched on): Switch on SM1 for 10 seconds which ensures the adhesion of plate2.

   (b). At t=2 seconds: switch on M1 in clockwise direction for 3 seconds.

   (c). At t=5 seconds: Switch off M1 and at the same instant switch on SM2 for 10 seconds which ensures the adhesion of plate1.

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(d). At t=6 seconds: Switch on M2 for 4 seconds for cleaning the surface (the cleaning is done when both the plates are in adhesion to the surface to prevent the robot from falling due to weight).

(e). At t=10 seconds: Switch off M2 and SM1, at the same instant switch on M1 in anticlockwise direction for 3 seconds.

(f). At t=13 seconds: Swicth off M1 at the same time Switch on SM1 for 10 seconds.

(g). Repeat above steps until Master Reset on PLC is not activated.

(h). If Master Reset on PLC is activated, switch on both SM1and SM2 and wait for Master Reset = 0.

VI. STATUS OF IMPLEMENTATION

Components used for the implementation are: Rigid plates (Chassis), suction motors, suction cups, Johnson motor, power supply, and channel guides.
To construct the SCAWCR, at first, two equal sized rigid plates are placed one in front of the other. A Johnson motor is fixed to the plate-1 with a lead screw of 15cm length at the centre. This mechanism is used for the movement of the plates in the forward and reverse direction. To provide proper support to both plates, channel guides are fixed to the both sides of plates. Each channel guide is indigenously designed using two CPVC pipes one inside the other.
Two suction cups are fixed on each plate to ensure sufficient adhesion. Proper care must be taken while fixing these suction cups to avoid any leakage. 12V DC Suction motors are used to suck the air from the entrapment area of suction cups in order to stick the robot to the wall and release the air whenever it should be free to move. At any time, at least one suction motor has to be on to ensure the sticking of robot on the wall.
A microcontroller is used via relay drive circuit and a bank of relay to control suction motors, Johnson motor and cleaning motor. A Lithium Polymer (LIPO) battery of 11.2V, 5000mA is used. This battery is sufficient to drive the whole robot for at least one hour continuously. To make robot wirelessly controlled, a 433MHz RF transceiver is used on PLC side.Cleaning mechanism will be placed at the front plate. In the beginning all the suction motors will be in the active mode after some delay Johnson motor starts to rotate in the anti-clockwise direction with which front plate (plate1) will be moved for a particular distance and it sticks to the wall with the help of the suction motors (SM2). Again Johnson motor starts to rotate in clockwise direction such that plate2 moves forward and sticks to the wall with the help of suction motors (SM1). With the help of cleaning mechanism it cleans the wall. The process goes on as long as a master stop switch is not activated on PLC. A photograph of work implemented so far is shown in Figure 2.

Fig. 2 Snap shot of actual implemented SCAWCR

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VI.CONCLUSION

An autonomous wall climbing robot with suction cup mechanism for adhesion and motorized lead screw mechanism for movement is constructed. This robot is named as Suction Cup based Autonomous Wall Climbing Robot (SCAWCR) which is intended to climb smooth surfaces such as glass. The battery capacity, maximum total payload and extent of cleaning are to be still tested and recorded.

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BIOGRAPHY

Mangala. S. Hiremath is currently pursuing her M.Tech Degree in Digital Electronics at PESITM, Shivamogga, Karnataka, India. Her area of interest is Robotics.

K. Bhat is a full time faculty in E&IE Department of Basaveshwar Engineering College, Bagalkot, Karnataka, India. He has 25 years of teaching experience and actively involved in design and development of sensors, electromechanical systems and biodiesel extraction. One patent applied in his name and has more than 20 national/international papers

H M Ravikumar presently working as Professor and Head of the department in Electronics and Communication Engineering at PES Institute of Technology and Management Shimoga, Karnataka and is having 30 years of service. He did his PhD from Indian Institute of Technology Bombay in the year 2000. He was Professor and head of the department at JNN College of Engineering and has served during 1986-2008 also at Sahyadri Institute of Technology Mangalore during 2008-2011. He has joined as Professor and Head of the department at NitteMeenakshi Institute of Technology Bangalore in the year 2011 and he is currently on deputation at PESITM Shimoga. He has guided six PhD and one MSc (Engg.,). He has published many papers at National/ International Journals. He is the member of IEEE Power and Energy Society and Fellow of Institution of Electronics and Telecommunication Engineering(FIETE).