A Linear Sliding Frame - Wall Climbing Robot

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ABSTRACT

Climbing robots are highly sophisticated robotic devices that have been engineered for specific tasks. The purpose of this research has been to design a miniature sized climbing robot based on suction mechanism. A wall climbing robot with simple mechanism has been developed with lower cost. This robot uses a sliding frame mechanism actuated by stepper motors for precise position of the frames. Vacuum grippers are used for climbing vertical surfaces. This robot has a overall length of 35cm, a height of 16cm and weight approximately 1.7kg, and will be able to carry the necessary equipment such as sensor for the range of task required. The weight and size of the robot are reduced by using low power, light weight and high-torque motors. In this robot stepper motor is used for linear motion. The kinematic analysis of this model is analyzed by ADAMS software package. The microcontroller is used to command the robot motion and controls the valves of all pneumatic components.

I. INTRODUCTION

The climbing robot with continuous motion similar to the SADIE [1] and ROBICEN [2] robot has been constructed and simulated as shown in fig [1]. However, it incorporates special mechanism that allows the robot to maintain continuous transactional motion without using wheels, or suction tracks. This climbing robot will become the tools used to safely and efficiently inspect ageing infrastructure, such as building, bridges and tanks in chemical plant. An inspection robot is most useful when it carry sensors into inaccessible or hazardous areas, thereby making the task safer for human inspectors. Most of today's climbing robots use vacuum grippers to generate an adhesive force to the climbing surface. The movement of the mobile platform is generally based on a sliding frame principle or a legged vehicle. Some solutions use a track that is equipped with suction cups or magnets.

II. MECHANICAL DESIGN

Several designs were considered prior to selecting the format of the robot. The linear sliding frame mechanism was chosen for making the body of the robot because of its simplicity and space savings. Sliding frame climbers are commercially available whereas legged robots have reached the state of research demonstrators. This is due to the fact that the sliding frame control system is less complex and the corresponding propulsion system is more robust compared to the more flexible legged robots. The L-(linear)-sliding frame uses a prismatic joint for propulsion.

A. VACUUM GRIPPER FOOT

Wall climbing robots that have been developed use either suction cups or magnetic gripper for attachment to vertical surface. The reported suction cup mechanisms have been quite large in foot print, size, and weight. They are not self constrained, and both the power and air, are supplied through tube. An important factor in the design of the vacuum feet was the requirement for the feet to be able to grip on a vertical surface. This paper describes the design of vacuum gripper foot. A vacuum generator and suction cup are its two major components. A vacuum generator is used as a vacuum source. The vacuum generator (model VAD-1/4) measures 30×40×60 mm in size and having weight of 91g. A flat suction cup with cleats is used for adherence. The cleats provide a large contact area and vertical slippage. A connector is used to attach the suction cup to the vacuum generator. This robot has three foot which is used to support to the wall. Here the standard suction cups (VAS-55-1/4-PUR) are used. The weight and diameter of suction cups are designed as 32g and 55mm.

Total force required at suction cup is calculated from the equations given below. The fully assembled foot weights 135g. In this vacuum gripper foot the suction cup is activated by sending air through the electric solenoid valve (2/2) which is in the ground level. Each Foot has separate pneumatic cylinder to lift the suction cup from surface and move close to surface which is fixed at top of the vacuum generator. The vacuum force at suction cup is calculated by the given equations.

Resultant force (horizontal)

$$R_H = P\cos\theta + W\sin\theta + C\sin\theta$$

Resultant force (vertical)

$$R_V = W\cos\theta + W_1\cos\theta - P\sin\theta$$

Here W1 = Total weight of Foot
W = Total weight of Body
P = Sliding force for linear motion
θ = Angle between climbing surface and Horizontal surface

B. BODY DESIGN

The sliding structure using translational joint has been selected for this robot. Illustrated diagrams of the robot can be seen in figure [1]. Minimization of weight and size was given the highest priority during the design of the prototype. In this design front and back rectangular blocks are connected by two circular rods. The middle rectangular block is sliding in these supporting rods. The blocks are made of nylon material. The length and diameter of this supporting rod are 360 and 7mm respectively. The weight of this rod is 95.4g which is made of mild steel. In this robot middle part are moved by belt drive which is connected to the stepper motor. The middle part moves up when the stepper motor rotates clockwise direction, and the front and back parts are moving up when the stepper motor rotates anticlockwise direction. The stepper motor is driven by the driving circuit controlled by microcontroller which is situated in ground. Further weight reductions have been achieved by removing by removing excess material from the structure of the robot. The completed prototype of this robot weights 1.7 kg and its longest configuration is 350×115×140mm.

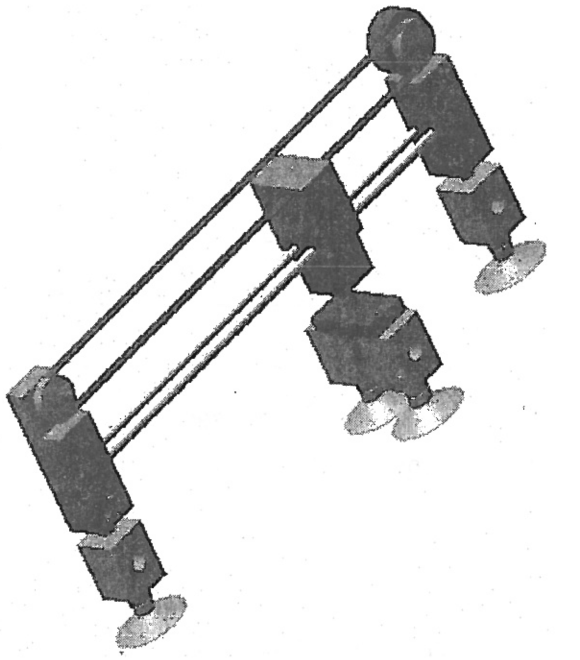

Fig 1. Robot view

III. WALL CLIMBING ROBOT MOVEMENT

Based on structure of robot it require atleast One foot remain in contact with surface all in time. In the initial position suction cups of all Legs are resting on the wall. The Robot moves forward by the following two steps. In first, step suction cup of Front and Back Leg are activated by the solenoid valve and, the suction cups of middle leg is deactivated and move up word by retracting the cylinder. Then middle Leg move upward direction by the rotation of stepper motor in anticlockwise direction. In second step suction cup of the middle part come down close to the surface and are activated by the Solenoid valve. After few seconds suction cup of Front and Back Leg are deactivated, and then moves up. Front and Back Legs are moving up by rotation of stepper motor in clock wise direction. The sequence of movement is designed for slow operation. These movements are shown in flowchart. The robot can reach a length of 30cm in every two steps. When a predefined strategy does not work, each Leg may be controlled manually to assist the robot in achieving a secure grip.

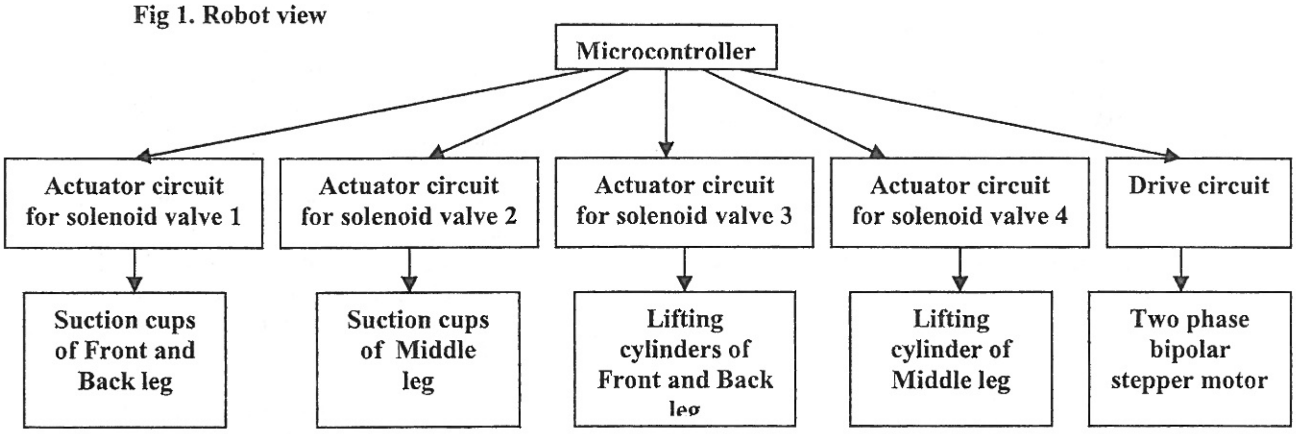

Fig 2. Control system of the robot

IV. CONTROL SYSTEM

It consists of microcontroller, actuator circuit for solenoid valve and drive circuit for stepper motor. All solenoid valves for pneumatic cylinder and suction cups are 2/2 - way type. On-off type solenoid valves offered a lightweight, low cost alternative to the solenoid valves.

The vacuum generator of the suction cup of both Front and Back Leg has been controlled by electric solenoid valve 1. The vacuum generators of suction cups of middle leg are controlled by electric solenoid valve 2.

The cylinder in the front and back leg are controlled by electric solenoid valve 3. The cylinder in the middle leg is controlled by electric solenoid valve 4. The driving circuit for two phase bipolar stepper motor has been designed using ICs L 297 and L298N. The various input for drive circuit such as direction, full or half step are has been given from microcontroller depends upon forward motion. The microcontroller gives signal to all solenoid actuator circuit and stepper motor drive circuit depends upon robot movements.

V. RESULTS AND CONCLUSION

We analyze the model in ADAMS software package and its results are verified. In the first step the displacement, velocity and acceleration of middle part, and total force on Front and back Leg is shown in graph. Similar results in second step are shown in graph. This paper describes the design, operation and control of a new wall climbing robot. This robot has one degree of freedom for linear movement. The vacuum suction cups allow the robot to be struck on almost any surface. So this climbing robot is applicable where continuous motions are needed. Further work will focus on experimental testing of the robot, increasing another degree of free dooms for rotational motion.

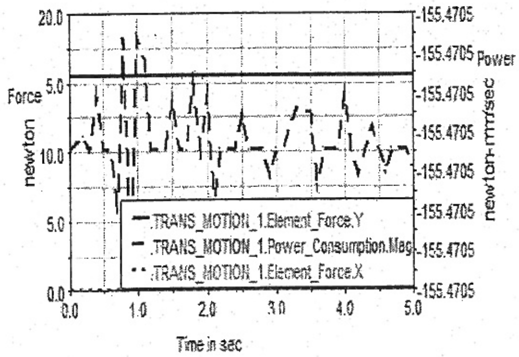

Fig .3 Required Force and power consummation for translational motion

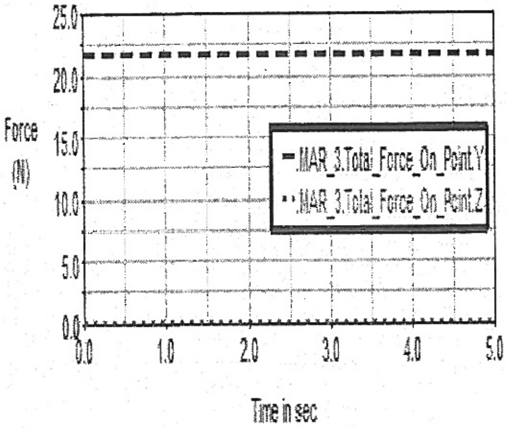

Fig . 4 Required force on Middle Leg in Second Step

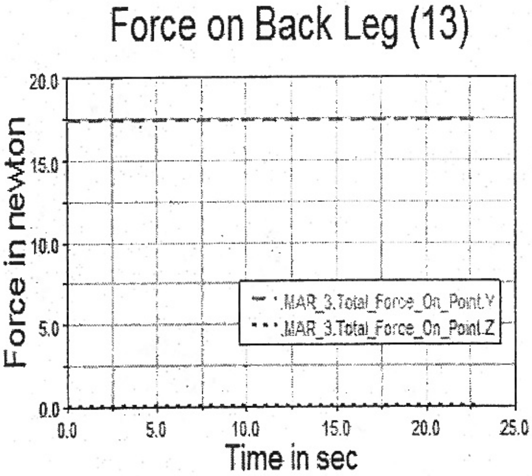

Fig 5. Required force on back leg in first step.

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