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Design and modeling of a tractor wheel-based climbing robot for circular pole with two degree of freedom

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Abstract

This paper describes the development of climbing robot for a uniformly cylindrical structure, such as an outdoor telephone pole. This robot, centre shaft motor of 12 V-mass 2.5 kg, pole diameter 10-15cm and 4 tractor wheels includes several features, linkage designs, to provide high speed climbing. The primary goal of this project was to design, construct and testing a robot that could successfully climb on a circular pole with two degree of freedom. After analyzing existing climbing robot designs, a robot prototype was built using calculations. Our prime consideration in designing pole climbing robot with simple in design and light in weight. The mechanical structure is designed to move on the circular pole in upwards against the gravitational forces. To provide gripping we used tractor wheels. The results show that the robot can successfully climb the pole having two degree of freedom. Pole climbing robot has the potential to work as spray painting, welding, pipe cutting, and extreme height repairing work.

Keywords: Actuator, Adopter, DC Motor, Gears, Tractor wheels.

Introduction

Climbing robots are unusual mobile robots that exhibit energy autonomous behavior, efficient adhesion mechanism and intelligent sensors integrated together such that they can adapt to various wall surfaces to conduct given tasks[1].

Climbing robots have various applications in industrial use. Inspection of vertical and inclined pipes in nuclear power plants, high voltage power transmission towers, and chimneys are some known examples of such applications[2]. Moreover, some new and important tasks for climbing robots can be introduced. Cleaning electric lights on lampposts in highways, high repairing works, spray painting and for load lifting is one of these new tasks.

The need of this project is limited to pole having diameters between 10 to 15 cm. The most critical challenge here is to move upward the robot against gravitational force. Therefore, maintaining sufficient friction force capable of handling the self-weight, maintaining the stability of the structure while in motion, reducing the total weight, and achieving the precise gripping are the important parameters that have to be considered.

In this paper, we focus on the simple mechanism designs that allow the robot to climb rapidly, driven by power-dense actuators, with compliance properties that match requirements of the climbing task. With our prototype machine, we demonstrate experimental results on a circular PVC pipe of diameter 10-12 cm.

Applications: Climbing robots may be capable of replacing human beings to perform dangerous and tedious operations with high efficiency and low cost for space applications[3].

This paper is motivated by a need for robotic systems capable of providing remote access[4].

There are many applications for these systems. Each of these applications requires climbing, as: i. Pipe cutting, ii. Extreme height repairing work, iii. Spray Painting, iv. For load lifting, v. TIG welding.

Objective of Work: i. The goal of this project was to design and implement a climbing robot which is a, simpler, advanced, and automatic than the other ones. ii. To design a climbing robot with two degree of freedom. iii. To make a robot for stiff structure like that can climb on external diameter of pipe, pole and their mechanism are freely motorized to lock and work with high friction. iv. To make a robot this can climb without any slippage and wear.

Preparation of the solid works model: For the modeling of pole climbing robot we use SOLIDWORKS software. This is CAD software which, helps to create 2D or 3D solid models without any complexity, faster and in cost effective way.

The main advantage of the solid modeler is that easy to use, draw, understands and much more friendly than other CAD softwares and help you to design products better, faster, and more cost-effectively[5]. The SOLIDWORK design of pole climbing robot is shown in Figure-3.

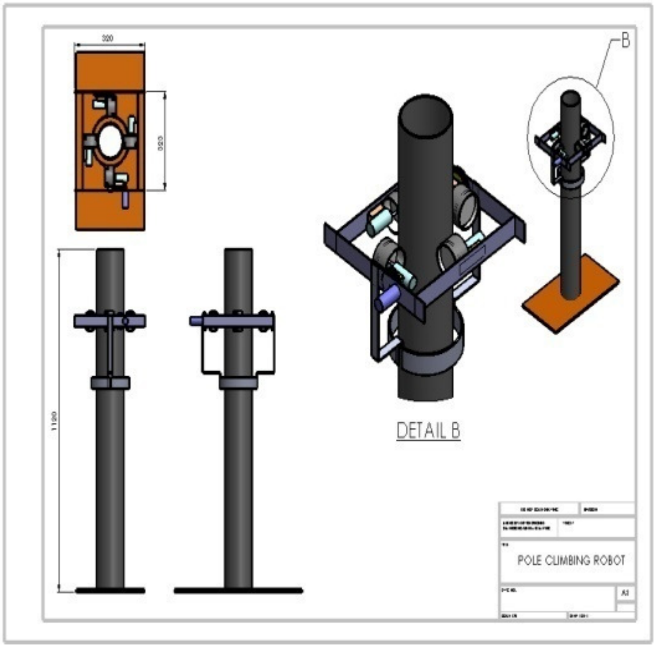

Figure-1: Solid works design of pole climbing robot.

Material Selected: For making our design successful and fabricating the pole climbing robot we use aluminium for the structure[6]. Aluminium having medium strength. It has a good surface finish, high corrosion resistance, it is light in weight, and can be melted, cast, formed and machined easily. It can conduct electric current hence thermal conductivity is good[1].

The low density of aluminium accounts for it being light weight but this does not affect its strength[7].

Weight of the model: M = chassis weight, m = motor weight, r = radius of wheel, F_t = tangential force, F_n = normal force, g = gravitational acceleration.

Table-1: Weight of various parts of the model.

Parts	Quantity	Weight
Motor	4	726gm
Tractor wheel	4	400gm
Actuator, spray	1	530gm
Caster wheel, MDF blocks	3	350gm
Chassis	1	500gm
Total	-	2500gm

Calculations and Equations:

Torque required lifting,

$$T = F_t * r \quad (1)$$

Tangential force,

$$Ft = (M) * g \quad (2)$$

Power,

$$P = (2\pi nT/60) \quad (3)$$

Angular velocity of wheel,

$$\omega = (2\pi n/60)$$

Linear Velocity of climbing robot,

$$V = \omega * r \quad (4)$$

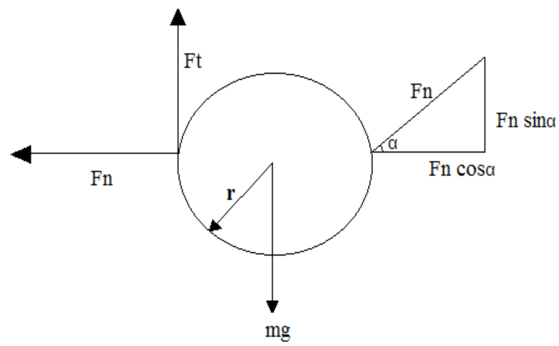

Figure-2: Sketch of wheel with forces.

Table-2: Calculated values.

Specifications	Value	Unit
Tangential force	24.5	N
Torque required	0.796	N-m
Required power	2.5	Watt
Available power	3.0	Watt
Linear velocity	0.1	m/sec

Working: For making pole climbing robot we use DC motors of 12V which are connected to power supply. We used an adaptor which rating 12 volt and 2 Ampere. The adaptor supply power to motor. We controlled the robot by using remote in this remote two way switch are used, this two way switch are first run the motor in clock wise direction to climb upward and after that to come in downward direction. We run motor in anti-clockwise direction by pressing the switch. To provide a two degree of freedom we use a center shaft motor which are connected to gear by help of this gear we turn the wheel to 90 degree for two degree of freedom[8].

We also use actuator; these actuators are used to run a spray by the help of spray we can easily fulfill our application of spray painting.

Methodology

As shown in experimental setup Figure-4 that we designed and fabricate the robot which can climb easily on a circular pole. The robot can easily hold the require weight as calculated in Table-1. And can be easily controlled by the automation. The above testing was done on a PVC pipe.

Results and Discussion

The results show: i. The robot can climb on PVC pipe or steel structure of diameters between 10 and 15 cm. ii. The climbing robot can move upward and also can rotate 360° hence we successfully designed the robot for two degree of freedom. iii. The climbing robot having a load carrying capacity of 0.50 kgs. iv. The measured value of current is during gripping was found to be 150mA. v. The robot requires 1 second to cover upward vertical distance of 10 centimeter.

Table-3 shows the various results obtained during the testing of the tree climbing robot implemented[9].

Table-3: Measured value of capacity with current.

Features	Measured value
Current during gripping	150 mA
Playload capacity	About 0.50 kg
Diameter of tree	10-15cm
Speed of motion	0.1 m / sec

Figure-3: One side assembly fixed on aluminium strip.

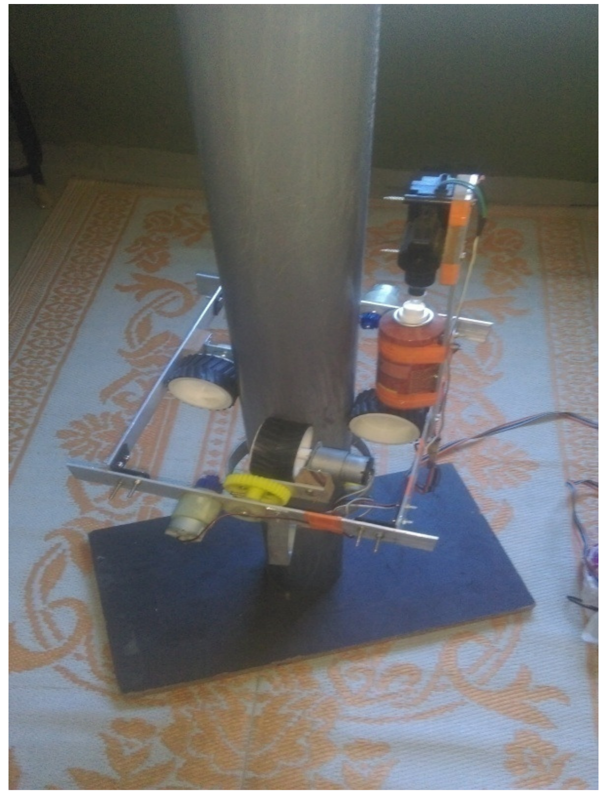

Figure-4: Experimental setup.

Table-4: Represent the cost analysis of different parts of the pole climbing robot.

Sr. no.	Name	Quantity	Cost
1.	Side Shaft motor	2	900
2.	Center Shaft motor	2	400
3.	Actuator	1	350
4.	Aluminum strips	-	700
5.	Wheels	4	200
6.	Electric accessories	-	500
7.	Gears	4	150
Total			3200/-

Conclusion

This project represents about an automation based pole climbing robot. The mechanical structure on tractor wheels and their control of the pole climbing robot was designed, create and implemented successfully. The pole climbing robot moves along surface of a pole by using its wheels and moves vertically in a constant velocity. A wired based remote is provided to control the motion and degree of freedom of the robot. The experimental set up is carried out on PVC pipe. The robot is simpler in design, construction, manufacturing, working and cost.

This research into the mechanical design has completed our list of objectives. This project can be extended to replace humans from plucking coconut as it reduces risk of accidents. In future we can do further modifications like using sensors, video camera for observation, special arms for harvesting purposes etc. and also we can increase the load carrying capacity of robot we can lift more weight.

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Nomenclature: T : Torque , P : Power, F_t : Tangential Force, Ω : Angular velocity, r: Radius of wheel, M : Chassis weight.

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