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Design and Development of Pipe Climbing Robot

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Abstract:
This project describes the concept, design and prototype implementation of a wheeled pole-climbing-robot. Pole climbing robots have become an interesting area for research in the last years. Several robots have been developed to solve this given problem. Every construction has its own advantages and disadvantages. The goal of this work was to design another pole climbing robot that uses a new clamping principle.Pipe climbing robot has many applications in industrial field as we know in chemical industry, there are many chemicals that are harmful to human health and the pipelines of which are needed to be inspected frequently. Human cannot be allowed to do such operations, hence this robot can be very useful in such tasks of inspection. Boilers also have the similar conditions, as temperature and pressure inside the boilers is very high, hence to check the pipelines this robot can be used at such places.

Keywords: ***Pipe climbing robot, DC motor,***

INTRODUCTION:

The design is inspired by the human-climber's action which relies on a strap around his waist. A climber may push his weight back to provide more torque around his waist to create higher force on his foot. The principle of the construction is that the centre of mass has a fix distance to the pole, representing the body of the climbing man, which has the effect that the normal force between the wheel and the pole is high enough to drive upwards. Robots that can climb poles are under development and are expected to be used in the inside/outside maintenance of buildings, observations of disaster scenes from a height, pruning trees, and more. As an alternative, we developed and analyzed a climbing method.

Based on this definition a very flexible walking machine, which can walk on very rough and steep terrain should not belong to the class of climbing robots. In the following climbing robots will be distinguished into 3 classes based on their locomotion ability:

(1) wheeled-driven or chain-driven machines,
(2) Legged locomotion,
(3) Locomotion based on arms and grippers.

Since the end of the 80ties climbing robots are examined for different types of application scenarios all over the world. E.g. at the end of the 80ties and begin of the 90ties in Japan several national projects concerning climbing robots for specific application scenarios have been developed. These include cleaning robots for glass walls, ship hull cleaning robots, rescue robots for fire brigades, inspection robots for steel tanks and wall.

Most of the developments were stopped because there

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still exists adhesion problems. Also the cost for the development of such machines were too high. At the end of the 90ties mainly in Europe several different prototype machine have been developed for different types of applications like the inspection of pipes and ducts in the petrochemical industry, maintenance and inspection work in the construction and nuclear industry or cleaning robots for huge class walls.

Problem statement:

Design and develop a prototype model of showing the concept of automatic pipe climbing robot which will show the working of application of robot climbing vertically over a pipe. Also fabricate the model of the same which will show the working desired by pipe climbing robot.

LITERATUREREVIEW:

Tim Bret et.al. [1] Says in the paper "toward autonomous free-climbing robots" that the goal of this research is to enable a multi-limbed robot to climb vertical rock using techniques similar to those developed by human climbers. The robot consists of a small number of articulated limbs. Only the limb end-points can make contact with the environment—a vertical surface with small, arbitrarily distributed features called holds. A path through this environment is a sequence of one-step climbing moves in which the robot brings a limb end-point to a new hold. The robot maintains balance during each move by pushing and/or pulling at other holds, exploiting contact and friction at these holds while adjusting internal degrees of freedom to avoid sliding. The paper first considers a planar three-limbed robot, then a 3-D four-limbed robot modeled after a real hardware system. It proposes an efficient test of the quasi-static equilibrium of these robots and describes a fast planner based on this test to compute one-step climbing moves. This planner is demonstrated in simulation for both robots.

Salice Peter et.al. [2] Says in the paper "design and construction of a tree climbing robot" that The project presented here, focuses on designing a tree climbing robot. Our prime consideration in designing tree climbing robot is of the motion planning and method of gripping. With arms involving four legs and sharp end as feet. The mechanical structure is designed to move the structure upwards against the gravitational forces in successive upper body and lower body movements similar to a tree climber. The gripping is designed in a way to dig the upper or lower part of the structure in to the tree facilitating the upward movement. The results shows that it can successfully climb the trees. Tree climbing robot has the potential to be applied to various pursuits, such as harvesting, tree maintenance, and observation of tree dwelling animals. R. Saltarén et.al. [3] Says in the paper "climbing with parallel robots" that inherently, parallel robots present many advantages to climb in comparison with robots that use serial legs. The availability of a great number of redundant degrees of freedom on the climbing robots with legs does not necessarily increase the ability of those types of machine to progress in a complex workspace. The serial legs mechanisms have a sequential configuration that imposes high torques on the actuators placed on the base.S-G platforms can offer a solution of interest as mobile robots for the development of tasks on structural frames, such as those used in buildings. The use of S-G platforms as CPRs means a new approach that allows resolving some typical problems that can concern in the kinematic and dynamic behavior of a robot climbing through complex structural frames.

Jean-Christophe et.al. [4] Says in the paper "design of a climbing robot for cylindro-conicpoles based on rolling self-locking" that This linkage uses revolute joints for simplicity and allows to move C21 and C22 on circular trajectories that approximately ensure the equilateral condition mentioned above. This mechanism must be actuated when the pole diameter varies in order to maintain a suitable value of length b.

It can also be interpreted in term adjustment of the holding forces Fc and F'c. This work describes the

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design of the pole climbing robot Pobot V2 based on the innovative principle of rolling self-locking that uses no energy to maintain itself at a given altitude.

The robot can also perform axial rotation, can cross tangential obstacles and climb poles with a strong conical shape thanks to passive normal force regulation with springs and a force amplifying linkage.

The first experiments showed excellent stability during vertical climbing. Future work must be done to make the robot more rigid, more Compact and lighter. The robot was jointly patented by Thales and IFMA.

SYSTEM ARCHITECTURE:

The prototype model consist of six wheels mounted in two rows, each wheel has its separate motor for driving purpose. Also the spring arrangement is provided for gripping the pipes having different diameters. The toggle switches are provided which control the motion of the wheels either forward or backward. The frame has hinge joint for opening and closing the model.

When we fix the robot over any pole and press the toggle switch the all the six motors start working and moves the robot in forward or reverse direction according to the input signal. The forward or backward motion of the motor is depend on the polarity of the motor, which is changed with the help of toggle switches.

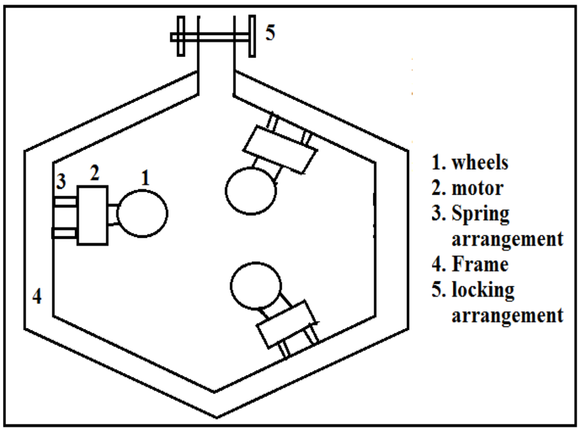

Figure: 3.1 Schematicmodel of pipe climbing robot

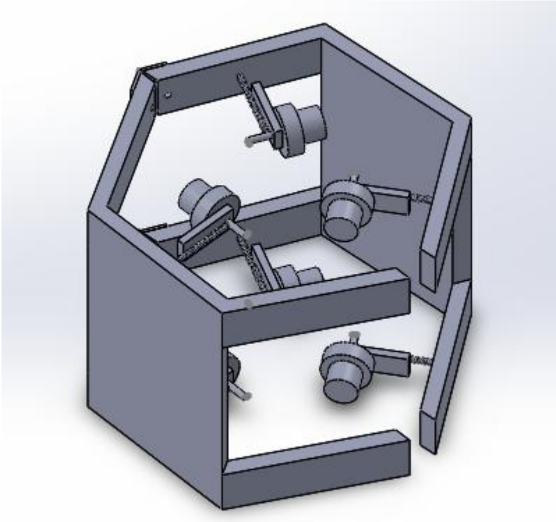

Figure: 3.2Proposedmodel of pipe climbing robot using SOLIDWORKS

SYSTEM DESIGN:

DC MOTOR:

Almost every mechanical movement that we see around us is accomplished by an electric motor. Electric machines are a means of converting energy. Motors take electrical energy and produce mechanical energy. Electric motors are used to power hundreds of devices we use in everyday life. Motors come in various sizes. Huge motors that can take loads of 1000's of Horsepower are typically used in the industry. Some examples of large motor applications include elevators, electric trains, hoists, and heavy metal rolling mills. Examples of small motor applications include motors used in automobiles, robots, hand power tools and food blenders. Micro-machines are electric machines with parts the size of red blood cells, and find many applications in medicine.

Here we are using 3 DC motors one for clamping purpose i.e. for vice, second for linear movement the pipe and the third for driving the cutter blade.

Features:

RPM=100 rpm

5 kg torque-DC motor

Voltage-12v

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WHEELS:

A wheel is a circular component that is intended to rotate on an axle bearing. The wheel is one of the main components of the wheel and axle which is one of the six simple machines. Wheels, in conjunction with axles, allow heavy objects to be moved easily facilitating movement or transportation while supporting a load, or performing labor in machines. Wheels are also used for other purposes, such as a ship's wheel, steering wheel, potter's wheel and flywheel.

SPRING ARRANGEMENT:

Springs are flexible machine elements used for controlled application of force (or torque) or for storing and release of mechanical energy. Flexibility (elastic deformation) is enabled due to cleverly designed geometry or by using of flexible material.

TOGGLE SWITCH:

For use in many applications from automobiles to industrial machinery, toggle switches are a fairly simple Electrical device. Electric toggle switches control the current to power equipment. From basic toggle switches to industrial toggle switches, an electrical toggle switch can be a simple single-pole single-throw (SPST) device, or a more involved double-pole double-throw (DPDT) configuration. It might help to learn toggle switches basics in order to know what type of electric toggle switch you need for your particular equipment. You'll soon find you can choose anything from an electronic switch to lighted electrical toggle switches.

Fasteners (NUT AND BOLT):

A nut is a type of fastener with a threaded hole. Nuts are almost always used in conjunction with a mating bolt to fasten two or more parts together. The two partners are kept together by a combination of their threads' friction, a slight stretching of the bolt, and compression of the parts to be held together.

Bolts use a wide variety of head designs, as do screws. These are designed to engage with the tool used to tighten them. Some bolt heads instead lock the bolt in place, so that it does not move and a tool is only needed for the nut end.

The first bolts had square heads, formed by forging. These are still found, although much more common today is the hexagonal head. These are held and turned by a spanner or wrench, of which there are many forms. Most are held from the side, some from in-line with the bolt.

CALCULATIONS:

DC motor selection
Specifications
Voltage =12v
Current=7.5 amp
Application-pipe climbing robo
Voltage=current*resistance
12=7.5*R
R=12/7.5
R=1.62 ohm

From paper FAVLHABER
The major constraint on motor operation is thermal
Pdis=I2*R
Heat Heat dissipated= current through the motor squared, multiplied by the terminal resistance
Pdis= (7.5)^2*1.6
Pdis= 90
force required to move weight on motors assume 10 kg
F=10*9.81
=98.1 N
Torque required for motor
T=f*r
Assuming wheel radius 40 mm
T=98.1*0.04
T=3.924 Nm
Power
p=2*π*N*T/60
P=V2/R (where v= 12 volt, and R= resistance 1.62)
=12^2/1.62

P=88.8888watt
P=90 watt
To find RPM of motor
90=2п*N*3.924/60
N=219 rpm…..maximum
Specifications
RPM=100 rpm
5 kg torque-DC motor
Voltage-12v

SPRING CALCULATION:

The outer diameter of coil is, D=10mm.
Because, The outer diameter of shaft is 8-10 mm.
Carbon steel material
(e)13.25 to 24.25mm
Allowable shear stress is=z=315 MPa
Modulus of rigidity,G=80kN/m2
Modulus of elasticity,E=210kN,mm2
n'=20

pitch=Lf/(n^'-1)=120/(20-1)=120/19=6
Free length=Lf=nd+(n-1)=n'-2=20-2=18
120=18(d)+(18-1)
d=5
assume standard d=4-6 mm
d=4mm
free length=LF = Solid length + Maximum compression + *Clearance between adjacent coils (or clash allowance)
= n'.d + δmax + 0.15 δmax
120=20(8)+(1.15)
δmax=34.78mm
Spring index:-
C=D/d=10/4=2.5
Spring rate:-
δ=15%max
δ=15/100*34.78=5kw/f

K=1.746

Stresses on helical spring;
Torsional shear stress,
τ 1=(8*58*10)/(π*4^3)=23.07N/mm2.

Torsional shear stress τ 1=23.07N/mm2

Twisting moment
T=w*D/2=588.6*10/2
T=2943Nmm
Direct shear stressτ 2=588.6/(π/4*(4)^2)
Direct shear stress τ 2=46.83N/mm2
We know that resultant shear stress induced
τ = τ1+τ2
=23.07+46.83
τ =69.9 N/mm2

ADVANTAGES:

- Saves manual effort
- Good gripping power.
- Can climb on pipes of variable diameters

APPLICATIONS:

- Pipe inspection in chemical systems
- Ship cleaning/inspection
- Welding robot
- Airplane cleaning and inspection
- Oil tank inspection
- Nuclear plant inspection
- Steal bridge inspection
- Cleaning and Inspection of glass wall

CONCLUSION AND FUTURE SCOPE:

We developed a novel climbing robot which can move in upward and downward direction. Also it can remain stationary based on its own weight. So we have really made a nice experience with this work and have learned a lot of new things in this section, which were alien for me at the beginning. I have the knowledge to design and produce a mechanical construction for research and alsofor my interests in the free time. From this point of view the goal is attained.

There is large scope for further development in the robot we designed, we have discussed some of the points below:

1. Microcontroller can be designed to better the control of the robot movement.

2. Obstacle detection and path finding can be integrated in the project prototype.
3. Further improvements like appropriate mechanism for turning the robot, performing lateral motion can be implemented.

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