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DESIGN AND DEVELOPMENT OF AUTOMATIC 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. The basic idea during the whole work has been "the journey is the reward". It was not the forceful goal to create a fully optimized working robot but rather to learn the design and construction steps, which are needed for a new product from the engineering point of view.*

Key Words: Pipe Robot, Wheel Based Climbing, Pipe Climbing.

1. 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 pipe is high enough to drive upwards. Robots that can climb pipes 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.

2. LITERTURE REVIEW

Cengiz Yilmaz, Prof. Dr. Roland Y. Siegwart[1]

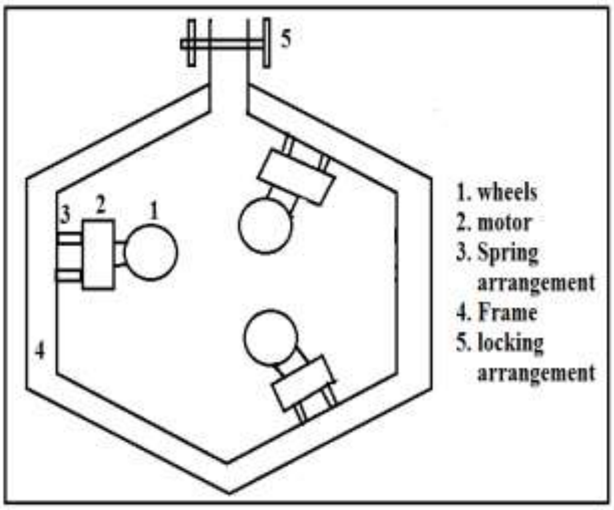
This is a research project in the field of pole climbing robots for the autonomous systems Lab at the ETH Zurich. The following thesis describes the analysing and the design of a pole climbing robot that uses a new clamping principle. At the beginning former designs are compared. After the analysing of the new mechanism, further development steps are shown with the focus on the chassis, where computer simulations are used. Finally the construction of a scaled prototype with his characteristics is presented.

Yasuhiko Ishigure, Haruhisa Kawasaki [2]

A climbing robot with a postural adjustment mechanism for conical poles is presented. The climbing method driven by servomotors with a warm-wheel reduction mechanism can rest on a tree by using its own weight without any energy expenditure. To realize both straight climbing and spiral climbing for conical poles, a postural adjustment mechanism is needed to move the steering mechanisms of the active wheels smoothly. We present the design of the robot's two-link arm mechanism with 1 DOF as the postural adjustment mechanism.

3. SYSTEM DESCRIPTION

3.1Working diagram



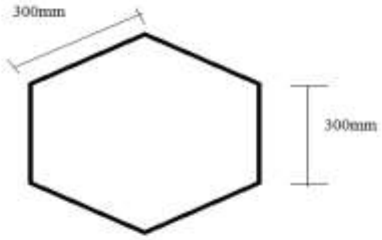
3.2 Working principal

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.

4. CALCULATION AND CAD MODEL

1. Design of Frame:



Frame design for safety FOR 50*25*3 rectangle angle mild steel channel

Maximum height of frame is 724.26 mm

b = 25 mm, d= 50 mm, t = 3 mm.

Consider the maximum load on the frame to be 10 kg.

Max. Bending moment = force*perpendicular distance

= 10*9.81*362.13

M = 35524.95 Nmm

We know,

M / I = σb / y

M = Bending moment

I = Moment of Inertia about axis of bending that is; *Ixx*

I = BD^3/12-bd3 /12

= 50*25^3 / 12 -44*19^3/12

I = 39954.49 mm4

σb = My / I

= 35524.95*25 / 39954.49

σb = 22.22 N /mm2

The allowable shear stress for material is σallow = Syt / fos

Where Syt = yield stress = 210 MPa = 210 N/mm2

And fos is factor of safety = 2

So σallow= 210/2 = 105 MPa = 105 N/mm2

Comparing above we get,

σb<σallowi.e 22.22< 105 N/mm 2

So design is safe.

SPRING CALCULATION:

Specification:

δ=150-56=94mm

Material=steel wire

Ultimate tensile strength=1090 N/mm^2

Modulus of rigidity=81370 N/mm^2

Permissible shear stress for spring wire should be taken as 50% of ultimate tensile strength.

We are finding the following values:

1. Wire diameter.
2. Mean coil diameter.
3. Number of active coil.
4. Total number of coils.
5. Free length of spring.
6. Pitch of the coil.

Considering maximum weight acting on the system is =100kg

Maximum loadd acting on spring=P=1000 N

Maximum deflection of spring=δ=75 mm

Spring index=C=6

Ultimate tensile strength=Sut=1090 N/mm^2

Modulus of rigidity=G=81370 N/mm^2

Permissible shear stress =T=0.5 Sut

Permissible shear stress=T

1. Wire diameter:

The permissible shear stress is;

T=0.5*Sut

=0.5*1090

T=545 N/mm^2

- $K=\frac{4c-1}{4c+4}+\frac{0.615}{c}$

$=\frac{4*6-1}{4*6+4}+\frac{0.615}{6}$

k=1.2525

- **T=k*$\frac{9*P*c}{\pi*d^2}$**

545=1.2525*$\frac{8*638*6}{\pi*d^2}$

d=4.733=5mm

where;

d=wire diameter

Di=inside diameter

Do=outside diameter

D=mean coil diameter

2. Mean coil diameter:

D=c*d

=6*5

D=30 mm

3. Number of active coil:

$\delta=\frac{8*P*D^3*N}{G*d^4}$

$100=\frac{8*1000*30^3*N}{81370*5^4}$

N=22.13==22

4. Total number of turns:

It is assumed that the spring to spur and gear ends. The number of inactive coils is 2.

N_1=N+2=22+2=24

5. Free length of spring:

The actual deflection of spring is;

$\delta=\frac{8*P*D^3*N}{G*d^4}$

$\delta=\frac{8*1000*30^3*24}{81370*5^4}1$

δ=101.93mm

Solid length of spring:

It is assumed that here will be gap of 2 between consecutive coils which spring is yy subjected to max force . Total number of coils is 24.
Axial gap($N1_1$)=(24-1)*2=46 mm
Free length=solid length+axial gap+δ
=94+46+101.93

Free length=241.93 mm

6. Pitch of coil:

$P=\frac{freelength}{N1-1}$

$=\frac{242}{24-1}$

p=10.52 mm

p=12mm

7. stiffness of spring
$K=G*d^4/(8*D^3*N)$
K=81370*5^4/(8*30^^{3}*22)
K=10.7 N/mm
K=11 N/mm

Motor

For angle

Volume of angle per Ft=4*25*300*3=90000 mm^3

Mass=volume *density

=90000*7.7*10^-6

=0.693 kg

Therefore mass of 6 ft square angle is =6*0.693=4.158 kg

Volume of shaft =pi*r^2*h==pi*5^2*120=9424.78 mm^3

Mass=volume *density

=9424.78 *7.7*10^-6

=0.075 kg

Mass of 4 shaft=4*0.075=0.3 kg

Weight of Johnson motor=300 gm

Weight of 4 Johnson motor=1.2 kg

Other components like spring, electronics component etc=1kg

Total weight=6.658 kg

Considering FOS=1.5

Total WEIGHT=9.987 kg

Weight carried by 1 motor=2.5 kg

Diameter for wheel=50mm

Torque required for 1 motor

Torque=force*length of link

2.5 *9.81*50

=1226.25 Nmm

=1.226 Nm

=12.26 kgcm

So torque required for 1 motor is =12.26 kgcm

Therefore we are selecting motor with 25kgcm torque.

Power output of DC motor is =voltage *current

=12*0.8

=9.6 watt

Power=2*pi*N*torque/60

9.6 =2*pi*N*2.5 /60

N=36.67 rpm

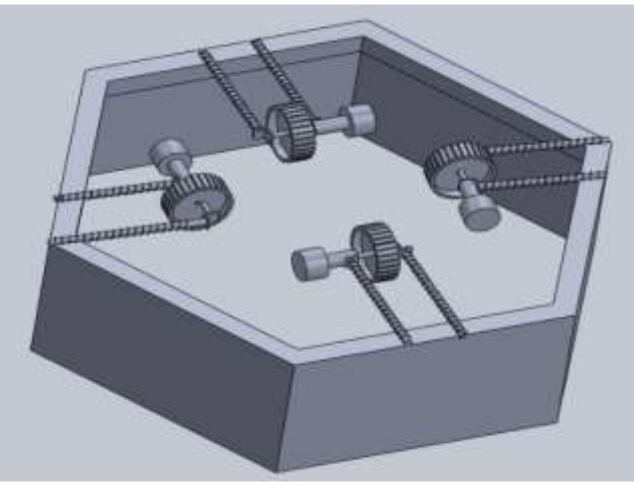
BUT FOR OUR SYSTEM WE NEED MOTOR WITH LESS RPM

So ,We are selecting motor with 10rpm

motor specifications

- 18000 RPM Base Motor, Shaft Diameter - 6mm (with internal hole), Shaft Length - 15 mm
- Dimensions : Gearbox diameter - 37mm; Motor Diameter - 28.5 mm; Length (body only) - 63mm
- Weight - 300 gms, Torque - 5kgcm to 20kgcm (depending on RPM)
- Voltage - 6 to 24 (Nominal Voltage - 12v), No-load current = 800 mA(Max), Load current = 9 A(Max)
- Available in following RPM (at 12v): 10, 30, 60, 100, 200, 300, 500, 1000

CAD MODEL



CONCLUSION

We developed a novel climbing robot which can move in forward and backward direction. Also it can remain stationary based on its own weight.

So I 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 also for my interests in the free time. From this point of view the goal is attained.

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