A Study on Stair Climbing Mechanism using Epicyclic Gear Train

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Abstract— Today, commercial and industrial robots are in widespread use performing jobs more cheaply or with greater accuracy and reliability than humans. They are also employed for jobs which are too dirty, dangerous or dull to be suitable for humans. Robots are widely used in manufacturing, assembly and packing, transport, earth and space exploration, surgery, safety, laboratory research and mass production of consumer and human goods. A mobile robot has been developed for climbing the stairs and obstacles in its path. The main feature of locomotion system is the planetary gear assembly with small wheels. This mechanism has been designed to be able to go over the stairs and obstacles with stability. In this paper a procedure for climbing stairs autonomously is presented. "ESCALATOR" can climb stairs with inclinations. Its weight is distributed in a way that the center of mass is located on its center, which reduces the probability of falling upside down when climbing stairs or obstacles.

Key words: Stair Climbing Mechanism, Epicyclic Gear Train

I. Introduction

As mobile robotic systems become more complex robotic software architects will need more rigorous software models behind their system structure. More advanced models will enable many new features, such as reconfigurable user interfaces for a single system, more efficient sensor fusion, reusable software and hardware, and simpler training cycles for new operators. In this paper, we demonstrate modular software architecture with a tracked robot that climbs stairs in an urban environment.

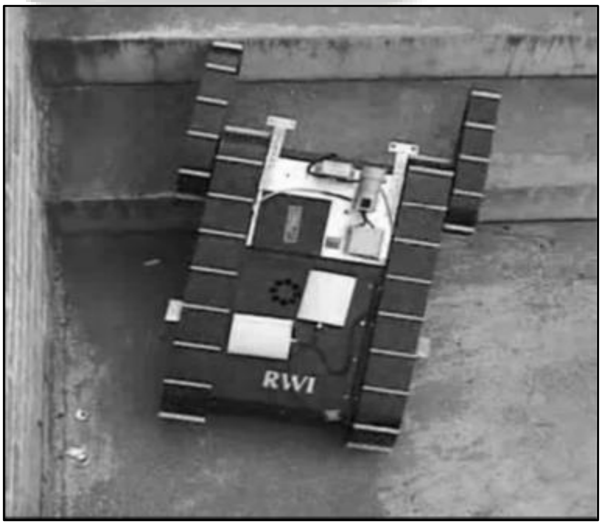


Fig. 1: A Model Based Sensor Fusion Approach

A. The Octopus Robot

The sophisticated locomotion mechanism of Octopus has 15 degrees of freedom. The payload support and the two bodies on each side are linked in a passive differential configuration. The two arms and the body on each side of the robot are linked in a motorized parallelogram configuration. The forearms are linked to the arms by a motorized joint. Each forearm has two tactile, motorized wheels attached to it. This mechanism architecture allows the robot to have all the wheels touching the ground at the same time, independently of the terrain profile.

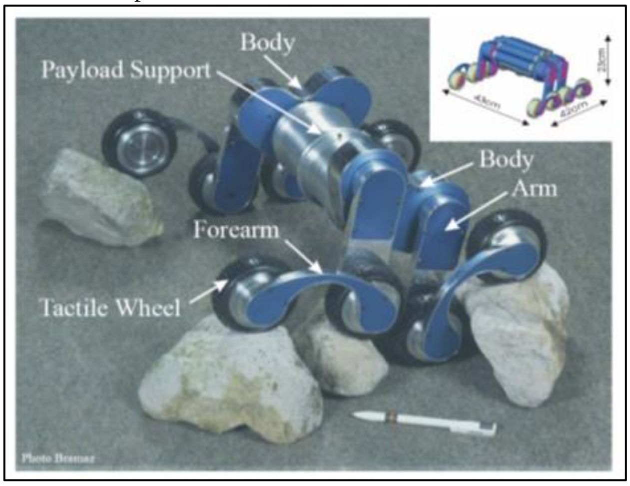


Fig. 2: All the parts touching ground

A step-climbing sequence is depicted on the Figure 3.to show the capabilities of the robot. The lines at contact points represent the external forces acting on the robot.

1) The robot is rolling in his flat terrain configuration with the center of gravity between the central wheels.
2) The front wheel touches the step.
3) The front forearm raises as the robot continue its advance until the second wheel touches the step.
4) The rear forearm motor and the motorized parallelogram act to raise the body, the front arm, the front forearm and the two front wheels. The front forearm motor acts so that the front wheel follows the terrain profile and reaches the horizontal part of the step.
5) The robot continues its advance until the third wheel touches the step.
6) At this moment the two forearm motors act to raise the body, the two arms and the two central wheels. The weight of the robot is shared between the two external wheels.

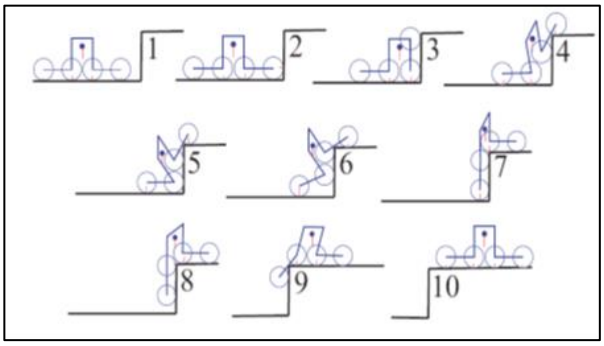


Fig. 3: Steps to climb the stairs

7) The second wheel reaches the horizontal part of the step before the last wheel touches the vertical part of the step.

The weight of the robot is shared between the two front wheels and the last wheel.

8) The front forearm motor and the motorized parallelogram act to raise the body, the rear arm, the rear forearm and the rear wheels. The weight of the robot is shared between the two front wheels. We remark that the position of the COG is outside the two contact points of the front wheels. In this case some friction on the front wheels is necessary to prevent falling back.
9) The third wheel reaches the horizontal part of the step. The rear forearm rises until the last wheel reaches the summit of the step.
10) The climbing sequence is over.

II. Construction And Working

The (ESCALATOR) ROBOT setup is as shown in Figure 4. In this setup the main parts and functions are listed below. The main components used for the robot are as follows

– Frame
– Triplate
– Gears
– Bearings

The staircase climbing robot (ESCALATOR) is basically operates due to sun and planetary mechanism of gears and tri-wheel assembly. The robot developed adopts 2DW1S (2 Driving wheel, 1 Steering). This mechanism enables the robot to run on the floor by small wheel and to go up and down the stairs by planetary gears. The rotation angles of rear left and right wheels are equivalent to each other because the robot developed does not need the steering motion during climbing stairs. With this drive two wheels normally stay in contact with the ground for travel over relatively smooth surfaces or rough surfaces also. Once the leading wheel meets the stairs the remaining wheels leapfrog it. On a stairway, successive leapfrogging easily brings the mechanism upstairs.

Fig. 4: Robot Assembly

For controlling "stair climbing robot ESCALATOR" we have used DC series motor and switch.

III. Design

A. Dimensions of steps

Steps: As our project is "stair climbing robot" i.e. robot is climbing on stairs so first of all we take dimensions of stairs which is given in dia.

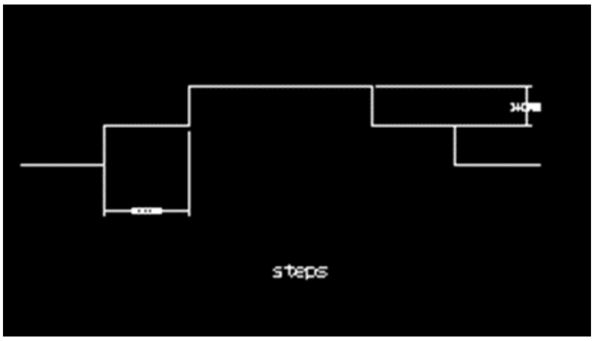


Fig. 5

B. Frame Design

1) Specifications

Dimensions: - 300*450*12 mm
Weight:-1.5 kg.
Qty: 1
Material: - mild steel sheet

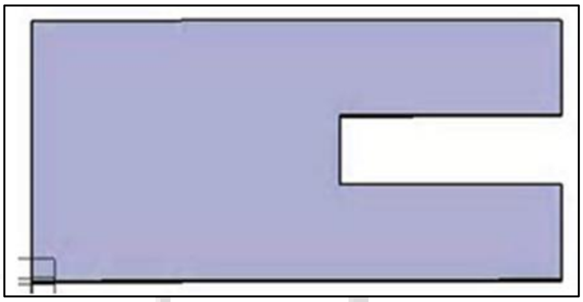


Fig. 6: Frame

C. Triplate Design

1) Specifications:

Dimensions: - 150*150*3 mm
Weight:-0.325 kg
Qty: 08
Material: - Mild Steel

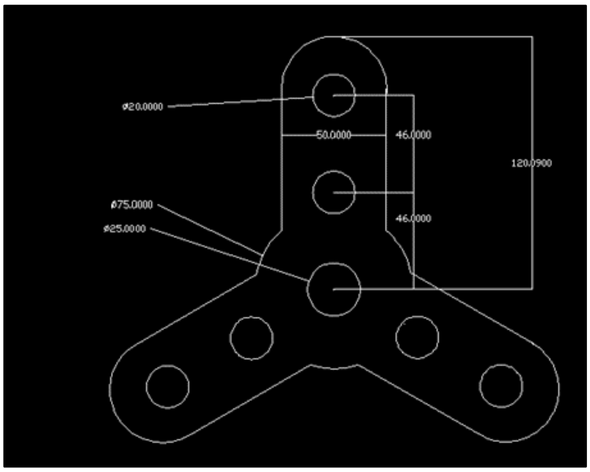


Fig. 7: Triplate

D. Gear Design

1) Given Data

$Z_p = 15$; $Z_g = 30$
$d_p = 30mm$; $d_g = 60mm$
$K_a = 1$; $K_m = 1.6$
$n_p = 7.5$ rpm; $n_g = 15$ rpm
$T = 367.875$ N-m; $\sigma_u = 56$ N/mm^2

Grade 12 ; $\Phi = 20°$
b= 10 mm, Material – Acetal (Delrin)
Bending Stress $\sigma b = \sigma u / 2.5 = 22.4$ N/mm²
Yp = 0.289
Yg = 0.358
∴ (σb *Yp) = 6.4736 N/mm²
∴ (σb *Yg) = 8.0192 N/mm²
As (σb *Yp) < (σb *Yg) pinion is weaker in bending hence it is necessary to design pinion for bending.
Bending Strength
Fb = σb*m*b*Yp = 129.472 N
Wear Strength
dp = m*Zp= 30mm
$Q = \frac{(2*Zp)}{(Zg+Zp)} = 1.33$
K = 1.05 N/mm²
Fw = dp*b*Q*K= 418.95 N
As Fb<Fw gear pair is weaker in bending & hence it should be designed for safety against pitting failure.
Effective Load
V = (π*dp*np) / (60*1000)
= 0.0117 m/s
P = (2* π*n*T) / (60*1000)
= 577.85 KW
Ft = P/V
= 49.38 N
Kv = 3/ (3+V)
= 0.996
Feff = (Ka*Km*Ft) / Kv
= 79.31 N
Fb = Nf * Feff
Nf = 1.59
Check for Design
ep = 79.84*10^-3 mm
eg = 82.68*10^-3 mm
e = *ep*+ *eg* = 165.52*10^-3 mm.
Buckingham's Equation:
$Fd = \frac{21*V*(b*C+Ftmax)}{21*V+\sqrt{b}*c\_Ftmax}$
Ft = 49.38 N.
Ftmax = Ka*Km *Ft
V = 0.0117 m/s
$C = K*e*[\frac{Ep*Eg}{Ep+Eg}]$
$C = 5.0511 * 10^{\wedge} - 4$
∴ Fd = 2.1252 N
∴ Feff = 81.10 N
∴ $Nf = \frac{Fb}{Feff} = 1.6 \cong 1.59$
Therefore available Factor of safety is same as required. Therefore the gear pair is safe against bending failure.

E. Design of Shafts

1) Driving Shaft
Total length = 577 mm
Mass = 1.5 Kg
Quantity = 2 nos.
Material = Mild Steel

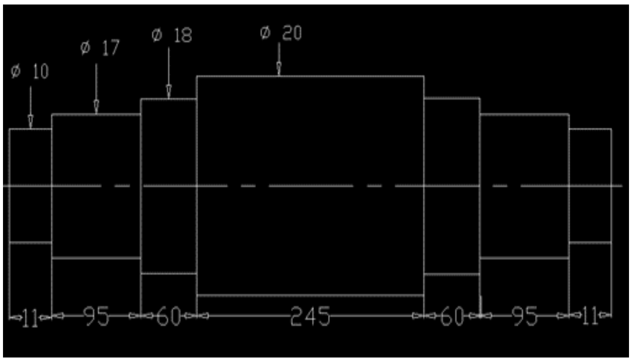


Fig 8: Driving Shaft

2) Idler Shaft
Total length = 26 mm
Mass = 0.030Kg
Quantity = 12 nos.
Material = Mild Steel

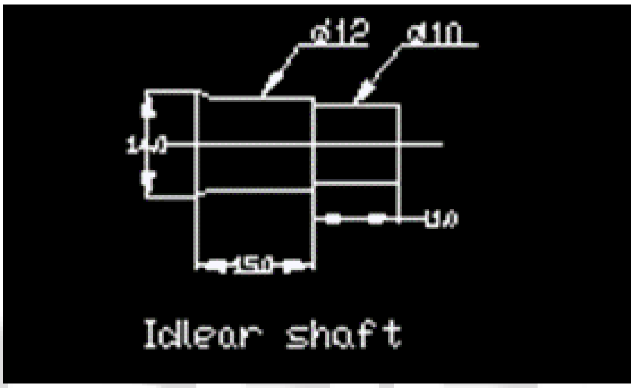


Fig. 9: Idler Shaft

3) Driven/ rollers Shaft
Total length = 106 mm
Mass = 0.060Kg
Quantity = 12 nos.
Material = Mild Steel

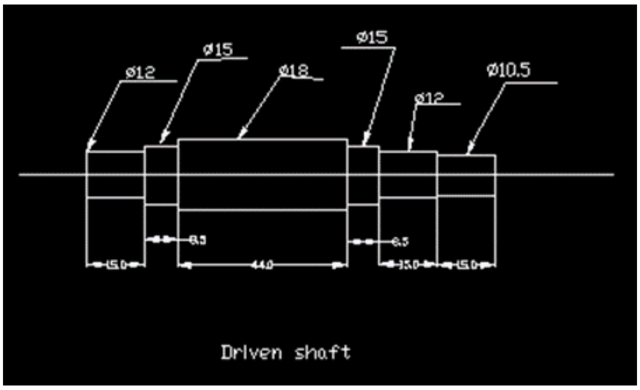


Fig. 10: Driven Shaft

F. Key design

*1) Dimensions = 5*5*28 mm*
Keyway depth in shaft t1= 3 mm
Keyway depth in shaft t1= 2.3 mm
Qty – 15
Material –Mild Steel

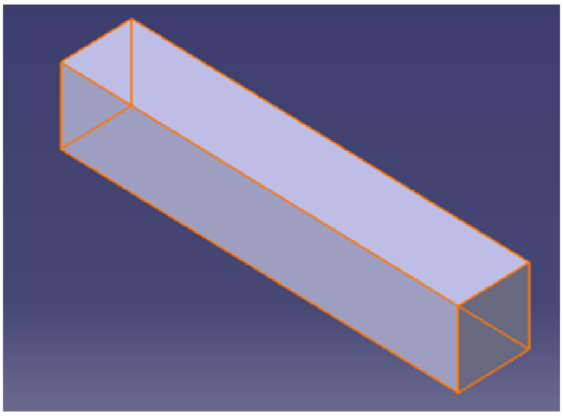
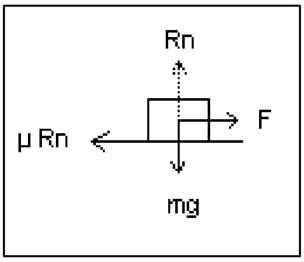


Fig. 11: Key

G. Bearing design

1) Bearing Type = Deep Groove Ball Bearing

d = 6 mm
D = 20 mm
B = 8 mm
Basic load capacity, C
C = 3924 N
Limiting speed, n
n = 20000 rpm
Mass, m
m = 0.020 Kg
Designation - SKF 6001
d = 17mm
D = 35 mm
B = 10 mm
Basic load capacity, C
C = 4562 N
Limiting speed, n
n = 20000 rpm
Mass, m m = 0.040 Kg
Designation - SKF 6003
Selection of motor



Total mass=15 kg (app.)
Assume that μ is neglected due to rolling of tires.
w = m*g
w = 15*9.81
w = 147.15N
w = Rn
∴ F = μ*Rn
F = μ*w
F = 147.15 N
T = F*r
Since, r = radius of drive sprocket
R=2.5cm,
T= 147.15 *2.5= 367.875 N-cm
T = 3.67 N-m
T = 37.5 Kg-cm

As we have to climb robot on stairs, we require initially more torque & less speed all these requirements can be fulfill by D. C. series motor.

As we know well, current is directly proportional to torque & inversely proportional to speed. Hence for our stair climbing robot we have selected **D.C.series motor.**

IV. CONCLUSION

The importance of development in this work is in providing a mobile robot that can be operated from a remote site to perform stair climbing tasks easily.

With the use of robot we are able to climb the steps with some load. Using robot we can stair climb with disable person. Also we can use where obstacles like in space, military application etc.

The project was carried out with a view to modify the process so that it becomes easy, effective, standard, and systematic and that which can be easily automated in the near future.

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