ANALYSIS OF THE SHORT DISTANCE GRAVITY ACTUATED OSCILLATORY TROLLEY CONVEYOR (G.A.O.T.C.)

Chetan Kothalkar[1*], T. Wankar[2], R. S. Wankar[3]

[1]Scientific Officer, BRIT, BARC- Vashi complex, Vashi, Navi Mumbai- 400705, India
[2]Research Associate, CIRCOT, Matunga, Mumbai, India
[3]Student, Sinhagad college of Engineering, Pune, India
* Corresponding author e-mail ID (clkothalkar@hotmail.com)

Abstract

An oscillatory type short distance gravity actuated trolley conveyor is conceptualized to be used for conveying light material to and fro to shorter distances. This is a unique conveyor which uses the gravity principle of the gravity conveyor but differs from it. It has two hinged platforms at its ends on which the wheeled Trolley rests. To move the trolley, Platform is to be raised by an angle more than the limiting angle of friction (ϕ) between the platform and the trolley wheels. Overcoming the static friction, the trolley moves in the direction of the slant and gains momentum. It covers a distance before coming to halt, which depends on co-efficient of friction, trolley mass, energizing length of the platform (L), angle of inclination(θ) etc. Analysis of the GAOTC has been done using the computer program. This paper is discussing the study on length of travel of the trolley using various combinations of the L and θ of the platform with applications.

Key words: Gravity Actuated Oscillatory Trolley Conveyor, motion curve, energizing length, angle of inclination, limiting angle of friction.

1 INTRODUCTION

Conveyors are the most important part of the process industry. Today, Conveying material from one facility or work station to another has become easy and less labour dependent because of the technological advancement in the field of material transfer. For any problem of material transfer, thousands of technological solutions are available. This is because of the proved basic designs of the conveyors and also the software solutions available.

The conveyors can be classified on the basis of the Use, material to handle, Method of Transport, distance to cover etc. Some of the basic types of conveyors are: screw conveyor, flight and apron conveyor, the bucket conveyor, the skip hoist, bucket carriers, unit loads, the continuous–flow conveyor, pneumatic and hydraulic conveyors, the belt conveyor and chain conveyor etc. [1]. Conveyors carry material to long distance, which is used mainly in coal industry. Belt conveyor, flight and apron conveyor, continuous flow conveyor etc can be called as medium distance conveyors. But most of these conveyors are unidirectional. But some conveyors like linear motion slide units, X-Y slide units, motor powered ball screw apron, with rod or rod less pneumatic cylinders, hydraulic cylinders, gravity actuated trolley etc which convey material to short distance can move the material in both direction. They have to couple to a suitable carrier and powered [7]. A GAOTC is such a conveyor with characteristics of both gravity conveyor and the tow conveyor or the trolley conveyor. It has two hinged platforms at its ends on which a wheeled Trolley rests. To move the trolley, Platform needs to be raised by an angle more than the limiting angle of friction (ϕ) between the platform and the trolley wheels. Overcoming the static friction, the trolley moves in the direction of the slant and gains momentum. It covers a distance before coming to halt, which depends on static and kinematic co-efficient of friction, trolley mass, energizing length of the platform (L), angle of inclination(θ) etc. Kinematic analysis of the conveyor is based on the motion curves. To find out limitations and optimum combination of the above parameters for this conveyor, an analysis has been done using the computer programme. This paper is discussing the study done on GAOTC characteristic like distance traveled by the trolley after destabilization using various combinations of the L and θ of the platform and the conclusion arrived at.

2 THE G.A.O.T.C.

The GAOTC works on the principle of the gravity conveyor as seen in fig. 1. The wheeled trolley in place of the block, as shown in fig. 2, will provide least resistance to motion as the co-efficient of the rolling friction is less, thus requiring smaller tilt (θ_s) to achieve desired results. Working of the GAOTC can be seen in fig. 2. This conveyor is

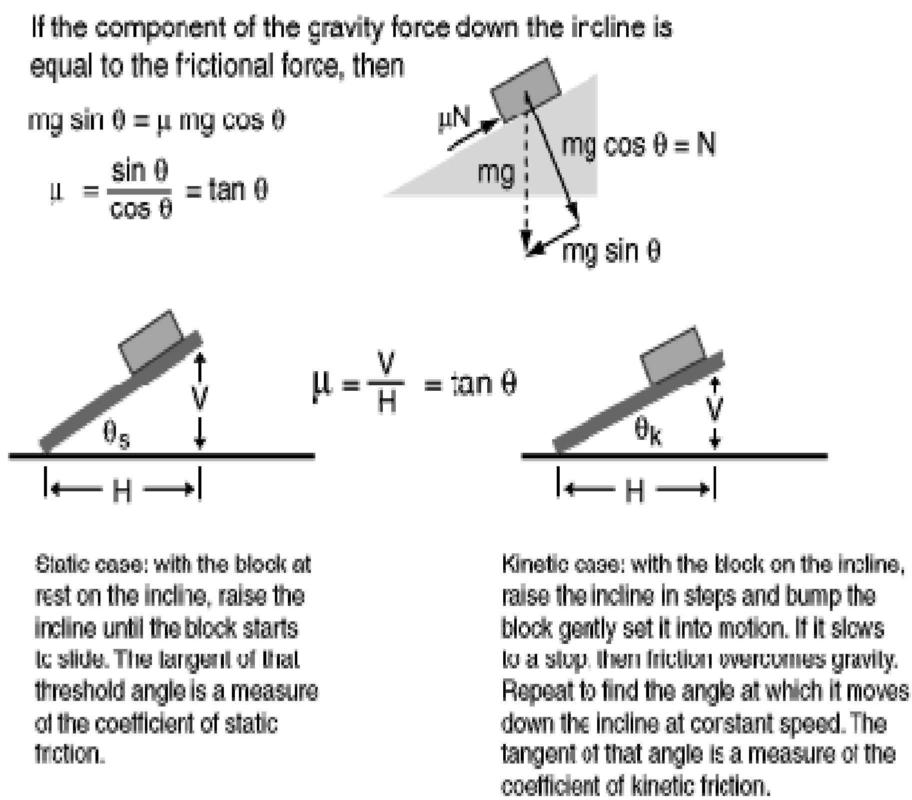


Fig. 1: Principle of the Gravity Conveyor

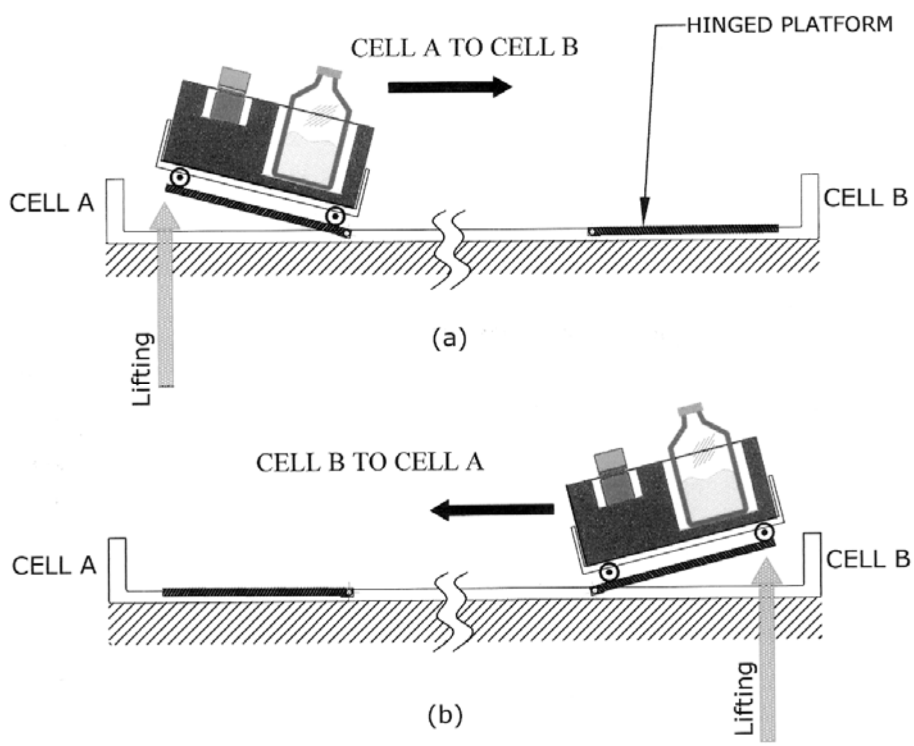


Fig. 2 Schematic of the GAOTC

transporting material from cell A to cell B and back. The conveyor is having two hinged platforms at the end positions of the conveyor such that when the trolley is required to transport the material to other cell, the free end of the hinged platform is raised by using a linear actuator, thus destabilizing the trolley. Minimum tilt of the platform is governed by following factors:

a. weight of the trolley including the material to transport,
b. Co-efficient of friction: rolling friction and the kinematic friction.
c. distance to travel and
d. Stability of the trolley against topples when the platform is in tilt condition.

2.1 Kinematics of the G.A.O.T.C.

Since the trolley is moving in straight line, it is a case of rectilinear motion. To find out the distance an object will cover or time required to travel a specified distance after it gains the momentum due to gravity component of the weight of the trolley down the plane, considering either motion with uniform acceleration or motion without uniform acceleration. In real life, uniform acceleration does not persist. The reason behind this is mass of the object, rolling and kinematic friction.

Any rolling object will stop after covering some distance. Equations for uniform acceleration are as follows:

Velocity of the moving object at time t is given by,

$$\nu = \nu_0 + a\,t \qquad (1)$$

Distance covered by the object,

$$s = \nu_0 t + \tfrac{1}{2} a\, t^2 \qquad (2)$$

And

$$\nu^2 = \nu_0^2 + 2\,a\,s \qquad (3)$$

For solving this problem using the non-uniform acceleration consideration, use of *Motion Curves* is preferred. This method shows the variation of s, ν and a with time. The method is useful when the motion has distinct phases, each requiring its associated set of equations. This method provides a means of using experimental data to determine the s-t, ν-t, a-t curves when any one of them is known. (See fig. 3) [3].

Assuming that the velocity ν_1 and displacement s_1 are known at the time t_1. The velocity ν_2 at any other time t_2 is found by writing a definition of acceleration in the form

$$d\nu = a\,dt \qquad (4)$$

integrating this equation we get

$$\Delta\nu = \int_{\nu_1}^{\nu_2} d\nu = \int_{t_1}^{t_2} a\,dt \qquad (5)$$

$$\nu_1 - \nu_2 = \Delta\nu = (\text{area})_{a\text{-}t} \qquad (6)$$

Similarly writing definition of velocity in the form

$$ds = \nu\,dt \qquad (7)$$

and integrating we get

$$\Delta\nu = \int_{s_1}^{s_2} ds = \int_{t_1}^{t_2} \nu\,dt \qquad (8)$$

$$s_2 - s_1 = \Delta s = (\text{area})_{\nu\text{-}t} \qquad (9)$$

Further solving, we get,

$$s_2 - s_1 = \Delta s = \nu_1(\Delta t) + \int_{\nu_1}^{\nu_2} d\nu\,(t_2 - t) \qquad (10)$$

Substituting $d\nu = a\,dt$
We get ,

$$\Delta s = \nu_1(\Delta t) + \int_{\nu_1}^{\nu_2} (a\,dt)\,(t_2 - t) \qquad (11)$$

Analysis of the GAOTC can be done by finding following characteristics using equations 1 to 11,

1. maximum velocity and velocity at time t
2. acceleration at time t
3. time required to cover a distance
4. Distance the object will cover after removal of the driving force.

2.2 Analyzing the GAOTC

As mentioned above, analysis of the GAOTC can be done by studying the characteristics like velocity, acceleration, time required to cover a desired distance and maximum distance the trolley will cover before coming to halt etc. Since the no. of variables in this study is more, it was decided to study the most desired one that is the maximum distance the trolley will travel before coming to halt. For ease of analysis, a computer programme has been developed which calculates the desired characteristic parameters like maximum velocity, time required to cover distance etc. Study has been concentrated on two variables: Platform length (L) and the angle of tilt of platform (θ). These two variables are responsible for the distance traveled by the trolley. To know the importance of the L and θ, Study has been carried out by assuming two cases:

1. Case 1: assuming the θ (more than limiting angle of friction ϕ) as constant and varying the L
2. Case-2: assuming length of the platform L as constant and varying the angle θ which is more than ϕ.

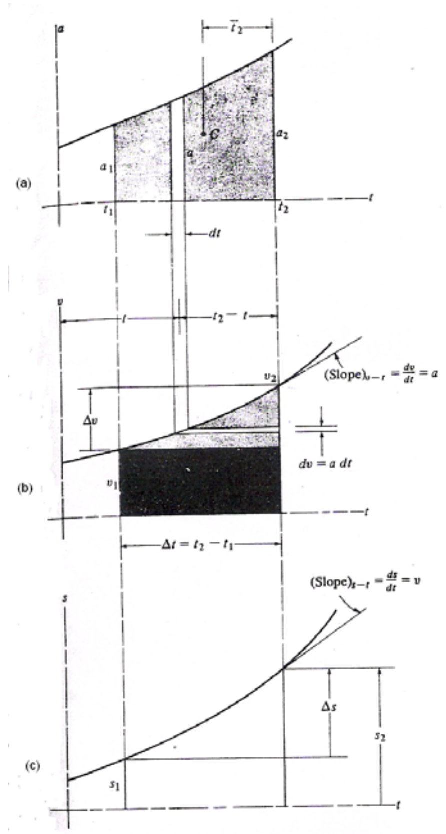


Fig. 3: Relation among a-t, ν-t and s-t curves [3]

For mathematical analysis, consider a wheeled trolley mass weighing around 16Kg. To move the trolley, hinged platform is raised by linear actuator through the coupling. Because of gravity instability, Trolley moves down the slant and gains momentum to travel a distance before coming to halt. Distance traveled is governed by various parameters called as variables. Using these variables distance that the trolley will cover can be calculated. Let's get accustomed with the variables as follows:

t_p – time taken to raise the platform, sec = 1sec
t_{tp} - time taken by the trolley to leave the platform, sec (t_{tp} should be more than t_p)
t_{th} - time taken by the trolley to come to halt, sec
x- Lift of the platform in mm
μ_s – static co-efficient of friction = 0.02
μ_k - kinematic co-efficient of fiction = 0.002
$\phi = \tan^{-1}(\mu_s)$= limiting angle of friction (ϕ) between the trolley and platform
L – Platform length, mm
L_{tc} – distance in mm the trolley will cover after leaving the platform in mm
θ - Angle of tilt of platform in degrees
F_s – Static resistance to the motion of the trolley in N
W_t – weight of the trolley with lead brick = 17 Kg
a- acceleration; Δv – Change in velocity
N_f – vertical component of the force after the platform is lifted, N
V_{max} – maximum velocity of the trolley, m/s

Using these variables and equations from 1 to 11, various characteristics can be measured. Equations are governed by the limitations and conditions and so are simplified to suit to requirement. Calculation of the maximum distance the trolley will cover before coming to halt is a step-by-step approach and can be given by:

1. $\phi = \tan^{-1}(\mu_s) = 1.145^o = \theta$
2. $\sin(\theta) = x/L$; find x
3. $N = \cos(\theta)\, W_t$
4. F_s = static resistance to motion = μ_s N
5. find out the acceleration, $a = F_s / W_t$
6. find t_{tp} use equation ; $S = V_{st}\, t + ½\, a\, t^2$;
   Here $V_{st}\, t = 0$; Therefore; $S = L = ½\, a\, (t_{tp})^2$.
7. Rolling friction = $\mu_k\, W_t \,.\, 9.81$
8. max velocity of the trolley; $V_{max} = (F_s\, t_{tp} - \mu_k .W_t .1)$
9. time the trolley will move before coming to halt :
   $\Delta v = 0 = 1/\, W_t\, (F_s\, t_{tp} - \mu_k .W_t \,.\, 9.81\, (1+ t_{th}))$
10. Max distance the trolley will move before coming to halt
    $L_{tc} = (1/17)\ \{(F_s\ t_{tp}\, (t_{tp}/2 + t_{th}) - (\mu_k .W_t \,.\, 9.81\, (1+ t_{th})\, (1+ t_{th})/2)\}$

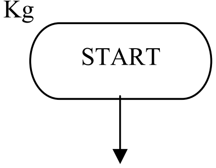
Using above equations two different algorithms for the two cases have been developed (see fig. 4 and 6). A computer programme in C has been developed based on the algorithm. Let's discuss the two cases in brief.

2.2.1 Case-1:

In this case angle of tilt of the platform (θ=1.145°) is considered as constant and trolley travel is calculated by considering length of the platform (L) varying from 50mm to 1000mm. A graph between L and the θ has been plotted (see fig. 5). Since in most of the practical cases angle of platform will be fixed, this assumption will help in selecting the most appropriate length of the platform at particular angle.

2.2.2 Case-2:

In this case angle of length of the platform (L) is considered as constant and maximum distance the trolley will cover before it come to halt has been analyzed by varying the angle of tilt of platform. here for analysis Length of trolley travel has been calculated by considering L= 200mm and tilt of the platform vary from 1.145 degrees to 44+1.145 degrees with difference of 2 degrees. Angle of tilt of platform has been limited due to chances of toppling of the trolley.



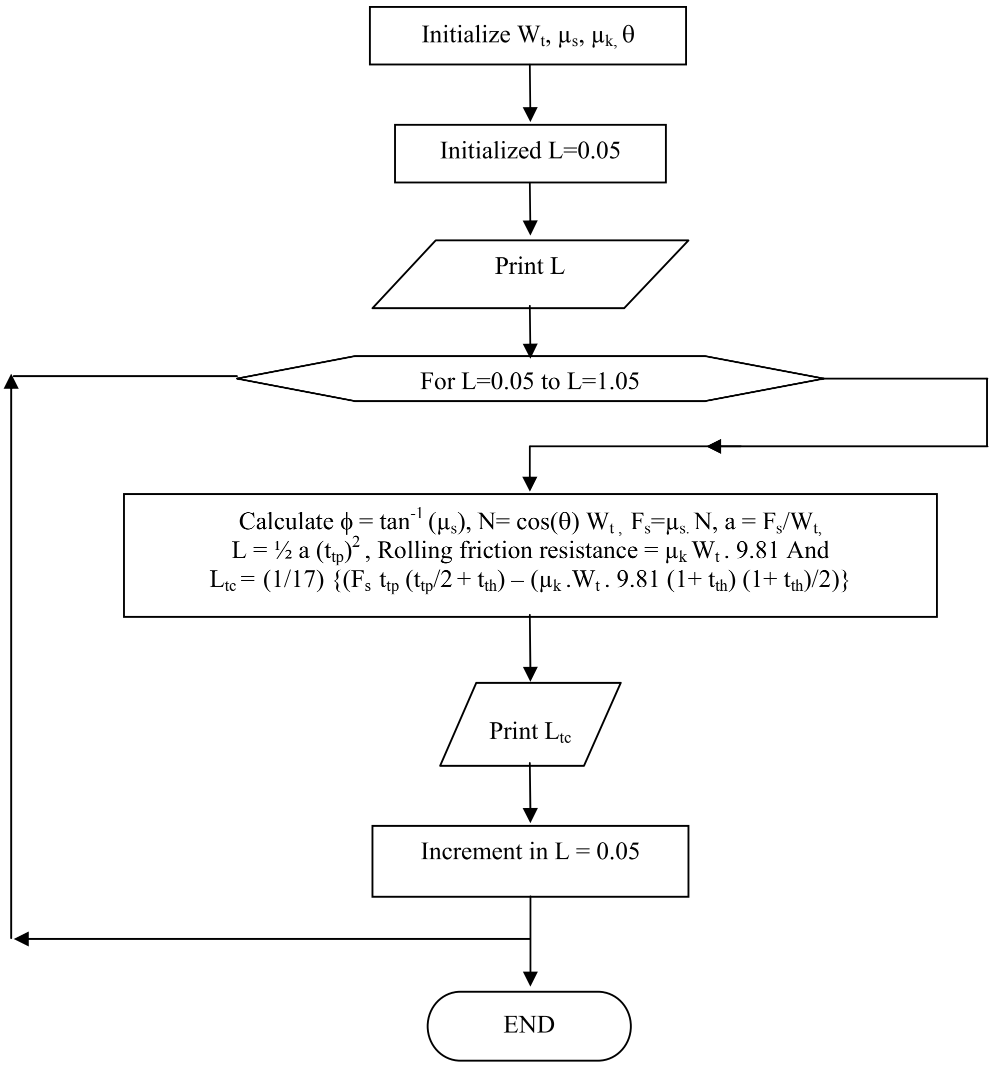


Fig.4 Algorithm for Case- 1

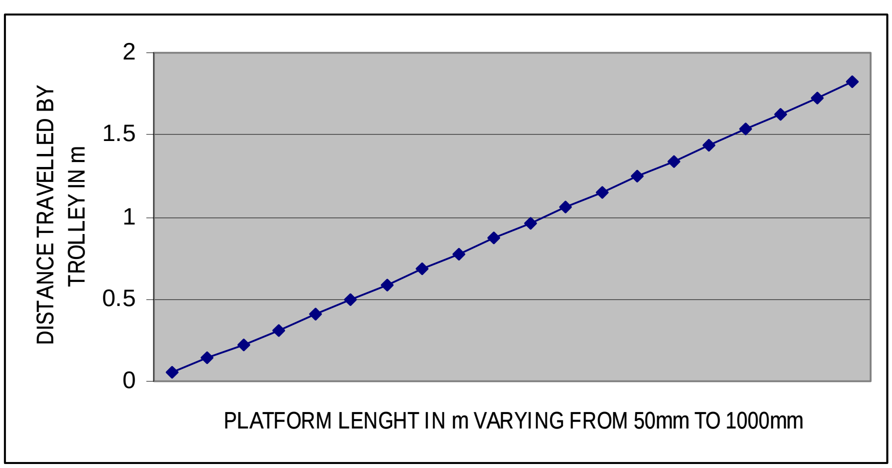
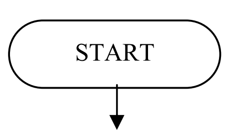


Fig. 5 Graph showing effect of length of platform on the distance the trolley will travel



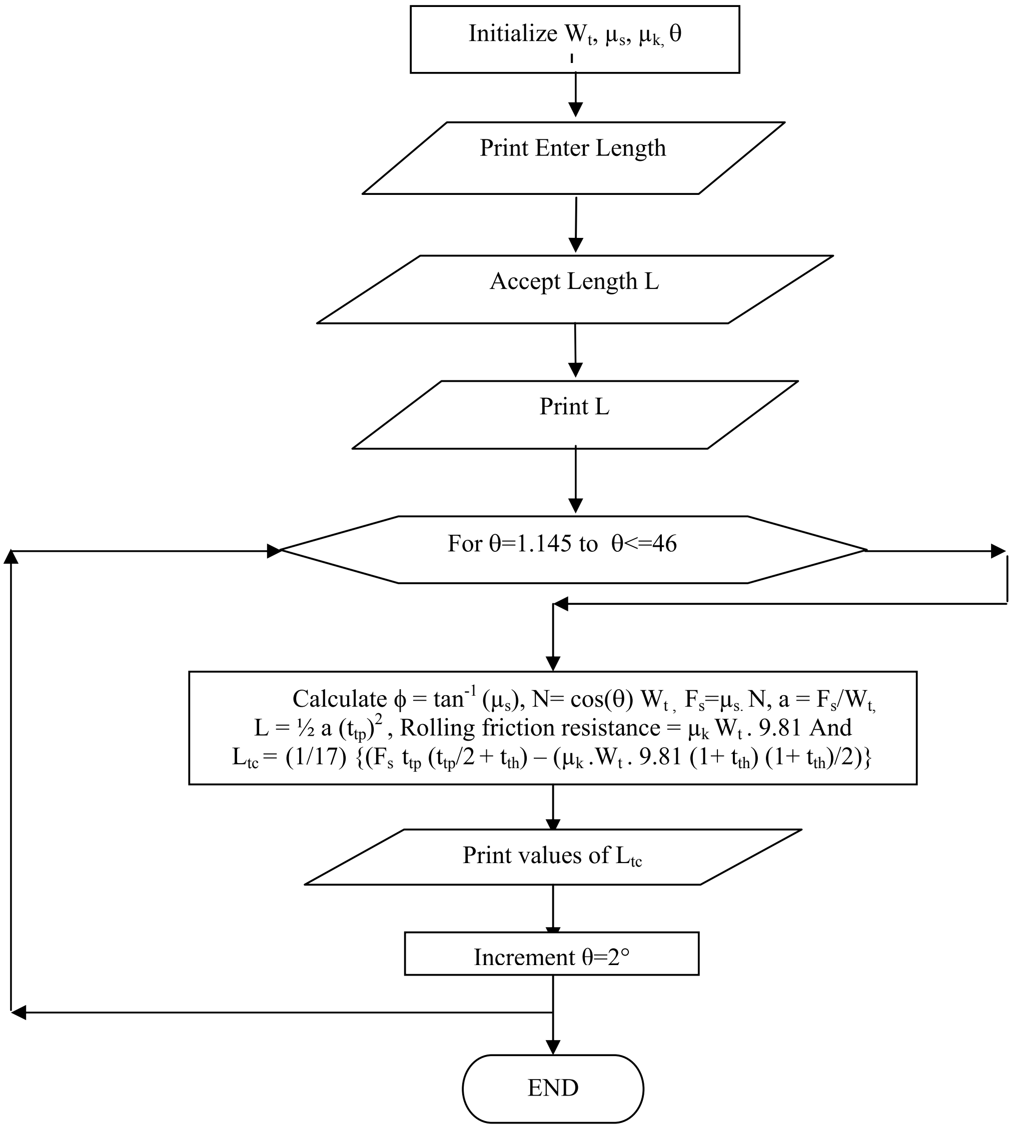


Fig. 6. Algorithm for Case- 2

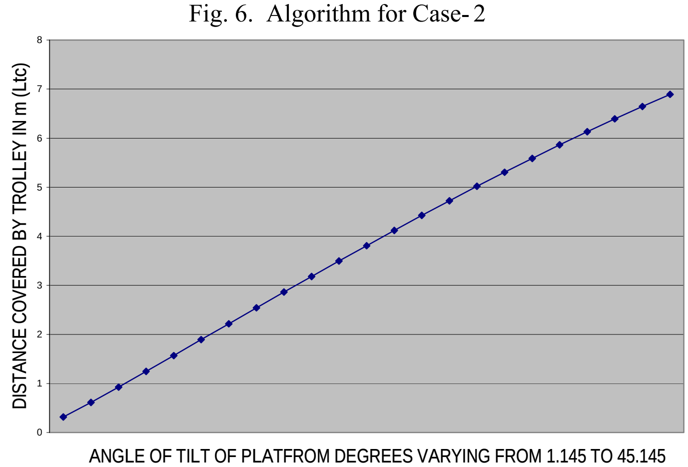


Fig. 7 Trolley Travel (L_{to}) Vs θ (case-2)

2.2.2.1 TOPPLING CONDITION

In case 1, the trolley will topple if horizontal component of the weight of the trolley is greater than it's vertical inertia component (m.g.sinθ > m.g.cos θ = N). The condition will appear when the trolley is still on the platform and platform it approaching angle more than 45^0.If the angle(θ) of the tilt of the platform is greater than 45^0 while the trolley is still on the platform then toppling will take place. So the angle of the tilt of the platform (θ) must be less than or equal to 45^0.

Fig. 7 shows the graph showing effect of angle of tilt of platform at constant platform length on the distance the trolley will travel. Practically this assumption is difficult to implement but by using proximity sensors with the actuators to control the lift of the platform it can be achieved. This assumption will help in getting the most effective results using the fixed length platform.

3. APPLICATIONS

This special conveyor has some limited applications like 1. In hazardous working places where two cells need to be isolated form each with a conveyor system connecting them, 2. Where material must come back to either receive fresh incomplete assembly or to deliver completed assembly. 3. Where there is a space restriction to use motor

4. CONCLUSION:

Study on various parameters of GAOTC yielded following results:

1. More the length of the platform, more is the length of the travel of the trolley; this is because of the energizing length (L). More the energizing length, momentum gained will be more.
2. More the angle of tilt of platform more will be the distance traveled by the trolley. This is because of the instability component of the weight of the trolley and the difference between the ϕ and θ.
3. For similar set of variables, the distance traveled by the trolley is found to be same in both cases.

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