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INTERNATIONAL JOURNAL OF ADVANCED PRODUCTION AND INDUSTRIAL ENGINEERING

IJAPIE-2020-07-347, Vol 5 (3), 39-48

https://doi.org/10.35121/ijapie202007347

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Solid Waste Management: Design and Dynamic Analysis of Waste Particle Inside the Trommel Screen Supporting Belt Conveyer Mechanism

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ABSTRACT: The purpose of the paper is to analayse a daily waste generation of 5 ton from a municipality which includes dynamic analysis of the waste particle inside the trommel screen,to obtain the design values of the waste segregator machine(trommel screen), design the belt conveyer carrying the waste, residence time of particle inside the trommel and departure angle.All analysis have been studied theoretically which involves quantitative studies as well.The results obtained are useful for developing a miniature solid waste management plan for a local municipality.Solid waste management is a crucial step to avoid unnecessary littering and contamination and thus this study could prove to be beneficial. There has been a significant research in the particular domain but we have focussed in the design prospect of the segregation machinery(trommel screen) which is necessary to carry out the operation.Although the research has been summarised briefly ,it aims to cover all the substantial qualitative and quantitative aspects for the study.

Keywords: trommel,waste,analysis,disposal.

NOMENCLATURE

R- radius of the trommel(m) n- revolutions per minute β- angle of inclination(rad) α – departure angle(rad)
L-Length of the trommel(m)
Nc- Total no. Of cycles inside K-flowability factor
T_R - Residence Time(s)
M-Capacity(kg/s)
ρ- Density of Material(kg/m ^{3})
B- belt width(m) V-Belt Speed(m/s) α- Angle of inclination of the belt
L_1- Distance from the driving pulley to idler(m)
L_2- Distance from the driven pulley to the idler(m) t_c – Pitch of carrying idler(m)
t_r – Pitch of return idler(m)

I INTRODUCTON

Solid waste management has become essential for the sustainable living of urban as well as rural areas. It involves scientific approach towards towards handling and disposal of the waste generated.Waste disposal should be efficient as well as environmental factors should be considered. Muncipal solid waste management consists of six steps: Segregation, Collection Transportation, Pro cessing, Treatment, Disposal.

A trommel screen is mechanical cylindrical screen rotating around a axis which is perforated in circular or square forms in order to become a rotating screener.It may be inclined and the inclination angle varies according to the usage. It is primarily used in solid waste differentiation operations.

The study involves the following:
To prepare a solid waste management plan for a municipality producing 5ton/day amount of waste
To study the analysis of the waste particle inside the trommel screen and thus obtaining various important results and parameters such as the departure angle of the waste particle, Residence time of a particle inside the trommel screen and no. of cycles a particle completes before exiting the trommel screen.
To study the design of belt conveyer mechanism that transports the waste particles to the inlet of the trommel screen.
The results obtained were iterated using excel to obtain feasible values for the design of the trommel screen.Emperical relations and equations are used for calculation purposes .

II. LITERATURE REVIEW

The desired research based on solid waste management is conducted considering that the essential requirement it has become to dispose waste properly.It has been observed that there has been a increasing trend in the amount of waste generation from both households as well as industries.Thus it becomes the need of the hour to formulate techniques regarding segregation of waste which could be further processed and finally disposed off.

Research paper by JOHN C. GLAUB, DANIEL B. JONES, and GEORGE M. SAVAGE Cal Recovery Systems, Inc. Richmond, California have shown studies about the design of trommel and the analysis of waste particle present inside the trommel screen.A lot of quantitave analysis have been studied and referred from the paper.[1] Separation techniques have been discussed and studies have been descripted by Jansen, M. L., and Glastonbury, J. R..[2] . The analysis and modelling of a belt conveyer mechanism have been discussed in detailed by Rohini N. Sangolkar.[3]. Analysis of belt conveyer system for crushed biomass has been shown in the study by Aniket A Jagtap, Shubham D Vaidya, Akash R Samrutwar, Rahul G Kamadi and Nikhil V Bhende.[4] . Study described by Prasad V. Shastri1, Abhishek V. Bende2, Devendra V. Chopade3, Sagar T. Ubhe4 , Prof. Dilip P. Borse has shown the use of calculation of of capacity of belt conveyer system which is useful for the our study.[5]

All studies regarding segregation of the solid waste have been gone through by the authors and then taken trommel screen(particle segregator) as our area of study as it is involved in majority of the waste segregation process.It has been observed as one the most prominent and efficient techniques used in large scale segregation.The segregation done on the basis of size of the waste particle is further procesed and finally disposed.

In all the previous studies there has been no comprehensive study that could be found about segregation of waste using a trommel screen.Researchers are usually concentrated to the theoretical aspect of the solid waste management. Also there has been no prominent study about the belt conveyer and trommel screen taken under a one dimensional consideration.

III DESCRIPTION OF SETUP

The figure depicting the setup which is considered for our analysis and designing purposes. It comprises of the excavator machine,belt conveyer mechanism and trommel screen.Here,the excavator machine is used as waste lifting and transportation machinery and the bucket size of the excavator is same as the width of the belt on which the waste is loaded.The belt conveyer is placed 1.2m above the ground with an inclination of αo above the horizontal.The centre of the trammel screen is 2.8m above the ground level and and is inclined βo above horizontal in clock wise sense.

Here the belt length x is calculated as:
$X=0.45/\sin\alpha$

Therefore, $x=0.45/\sin 10^{o}$; $x=2.591m$;
where x is the belt length

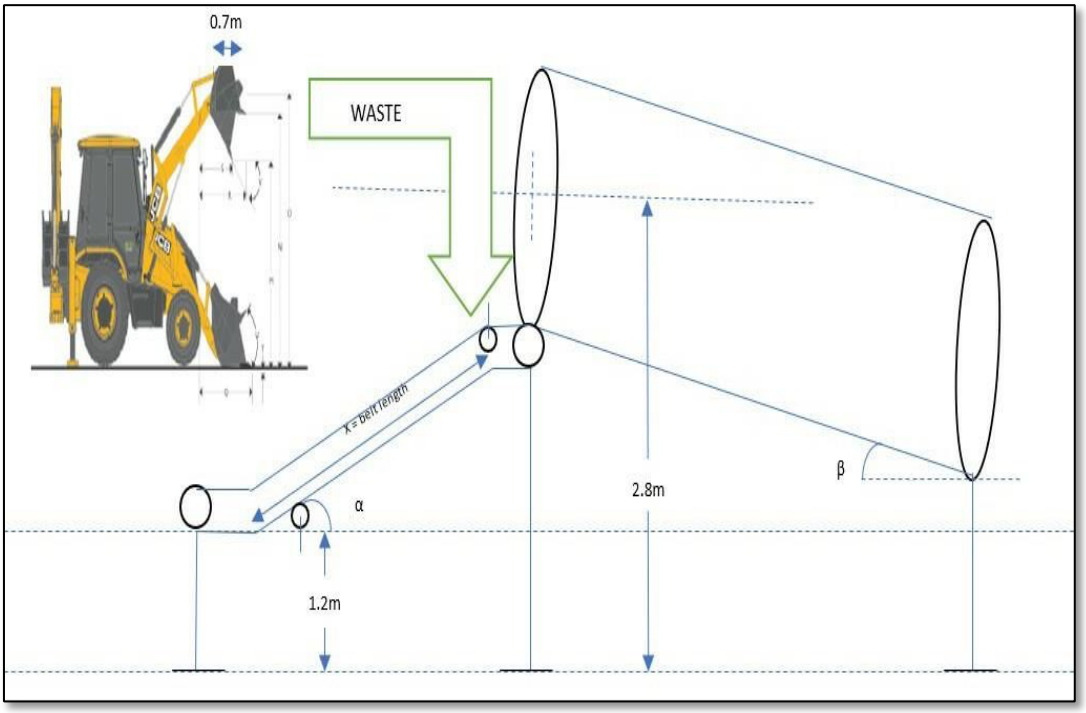

Figure 1: Schematic representation of complete setup under consideration

IV QUANTITATIVE ANALYSIS

Analysis of waste particle inside the trommel:

The following study has been conducted in which the action of forces on the particle inside the trommel is shown

Consideration of centrifugal and gravitational forces have been taken for the analysis

Various parameters of trommel screen have been explained below:

1) Radius of the Trommel Screen(R):

The inlet radius of the drum is used for design consideration for the trommel.

2) Inclination angle(β) :

It the elevation of the trommel screen above the horizontal.

3) Angular velocity(ω):

It is the rotating velocity about the axis of the trommel drum.

4) Residence time(T_c):

It is the total time duration of the particle inside the trommel before impinging out of it.

5) No. of cycles inside Trommel Screen(N_c):

It is the sum total of all the cycles the particle revolved before exiting the screen.

In the analysis studied below Departure angle, Residence time of the particle and the total no. of cycles were obtained considering the empirical values for the dimension of the trommel to handle the desired amount of waste.

Table 1:Departure Angle Calculations

Parameter	Iteration 1	Iteration 2	Iteration 3
R	**1.15**	2.3	2.3
N	**8**	16	16
β	**0.034**	0.069	0.102
cos(β)	**0.999422056**	0.9976204	0.99480251
α	**1.54568894**	1.3682128 1	1.36763094

To find the departure angle(α):

EQUATION USED:[1]

$\alpha=\cos^{-1}(n^2r/\cos\beta)$

Below is the graphical variation of

departure angle(α) with the parameters affecting it:

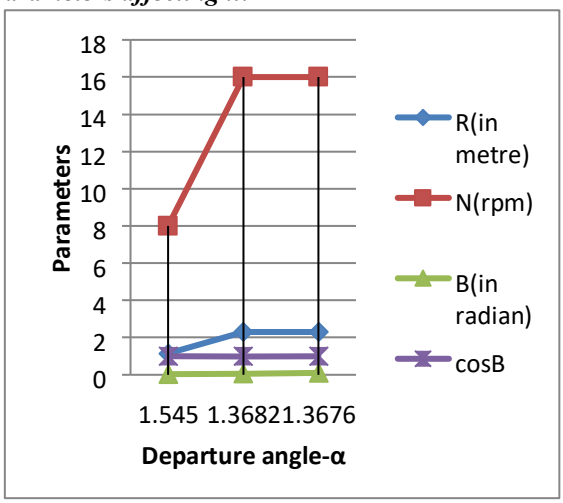

Figure 2: Line Graph-Variation of parameters with Departure Angle

To find the Total No. of Cycles of a particle inside the trommel:

Table 2: No. of cycles in trommel calculations

Parameter	Iteration 1	Iteration 2	Iteration 3
L	**16**	20	10
N_c	**2037.998024**	81.468622	27.4324744

EQUATION USED:[1]

$Nc=L/8r*\tan\beta*\cos\alpha*\sin^2$

RESIDENCE TIME IN THE SCREEN:

Table 3:Residence Time Calculation

Parameter	Iteration 1	Iteration 2	Iteration 3
T_R(in seconds)	**15266.7043**	339.197404	114.251728

EQUATION USED:[1]

$T_R=L(3604\alpha+229.2*\cos\alpha*\sin\alpha)/48*n*r*\tan\beta*\cos\alpha*\sin2\alpha$

Size of apertures:

Square apertures of size 90mm(3.5 inches) are considered which are better than the round aperture as they are consistent with the boundary.

Design and Analysis of Belt Conveyer Mechanism:

The belt conveyer mechanism is designed so as to transport the solid waste to the inlet of the trommel screen.

In this analysis below,a belt conveyer mechanism is designed which the following have been evaluated:

1)Capacity of the belt conveyer (5ton/day waste)

2)Determine the velocity of the belt conveyer

3)To find the no. of idlers required so that the system does not slack.

The width of the belt conveyer was assumed to be equal to the bucket of the excavator machine which puts the waste of the belt conveyer mechanism.

Capacity of Belt Conveyer:

It can be obtained using the following relation:[5]

$M=\rho K(0.9B-0.05)^2V$

Angle of inclination of the belt is defined the elevation of the belt from the horizontal surface.(Ref. Figure 1)
It is can be visualized as shown below:

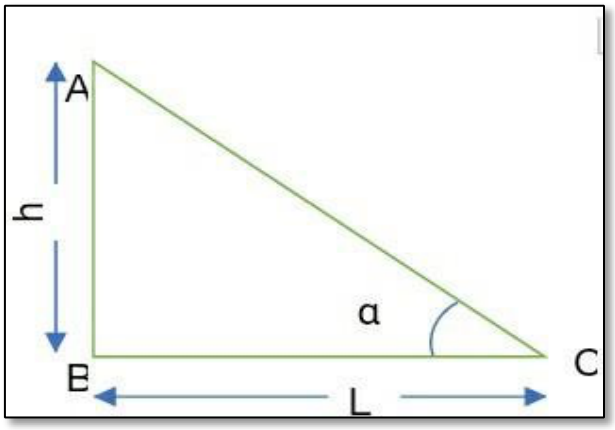

Figure 3: Schematic representation of inclination of belt

It can be obtained using the relation **$\tan\alpha=h/l$**

Further calculations to obtain the desired result is exhibited below:

Density of the waste =**0.8ton/m^3**

Volume of waste for which the system is to be designed = **5 ton/day=6.25m^3**

Volume of the bucket of the excavator machine=**1.575m^3**

In case of the trommel,using formula;
$2\Pi rl=1.575*15$

(where **15** is the no. Of cycles after which the particle leaves the trommel)

We get **r=0.75 m** (length of the trommel =5 m)

Now to find the linear velocity of the particle inside the trommel;using **$v=r\omega$** ***here*** $\omega=2\Pi n/60$ *(where n=30)* We get **$\omega=3.14$ rad/s**

Therefore we get;**v=2.335m/s**

Now to calculate the capacity of the Belt
Conveyer,

$M=\rho K(0.9B-0.05)^2V$ We know,

ρ =800 kg/m^3 $K=2.65*10^{-4}$

B=0.7m

V=2.335m/s

Therefore, Capacity of belt,

M=0.166 kg/s=0.597 ton/hr

Variation of K according to the ranges of α(IN DEGREES):

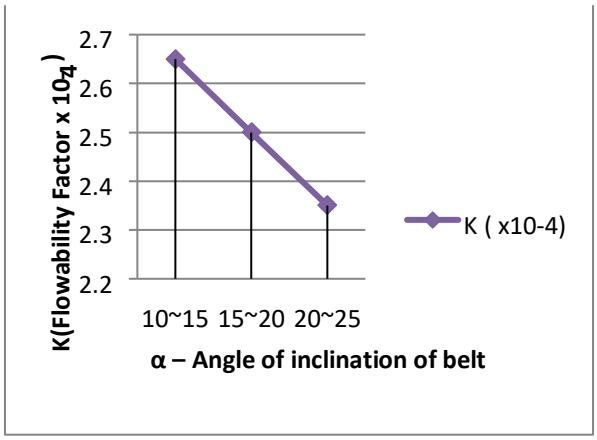

Figure 4: Line Graph- Variation of K against α

To design the belt conveyer mechanism for trommel of diameter= 2.3m

Here,

M=0.416 kg/s=1.5 ton/hr

Table 4: Calculation of Belt Speed,V To find the no. Of idlers required:

Parameters	Iteration10^0	Iteration-20$_o$	Iteration-30^o
A	**10^o**	20^o	25^o
K	**0.000265**	0.00025	0.000235
P	**800**	800	800
B	**0.7**	0.7	0.7
M	**0.416***	0.416	0.416
V	**5.833127678**	6.183115339	6.57778228

The requirement of idlers may vary according to the distance between the driving and driven pulley.

They are classified as:

Carrying Idlers

Return idlers

Our Aim:To find the no. of idlers (carrying as well as return idlers required in the belt conveyer so that the belt does not slack.Distance between the driving and the driven pulley is evaluated above as:

X=2.591m

This data is being used for further calculations.

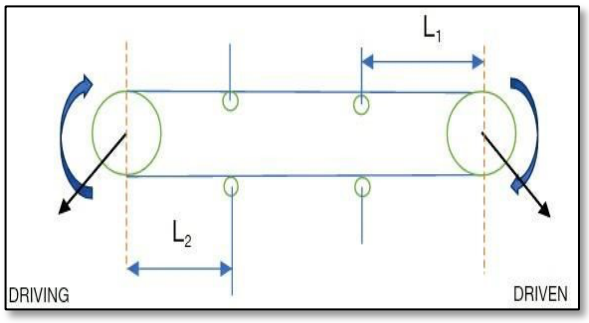

Figure 5: Schematic representation of idlers in belt conveyer mechanism

Relation for calculation:[6]

tc=l1/Zc+1 **tr=l2/Zr+1**

Under a practical situation in order to maintain the cost expenses only 2 idlers would

be appropriate for the setup

Table 5 Carrying and Return Idlers

Zc	**1**	**no. of carrying idlers**
Zr	1	no. of return idlers

V. RESULTS AND CONCLUSION

Study of solid waste management including design of trommel screen as well as design of belt conveyer was completed.All results were obtained in order to handle a waste generation of 5 ton per day.

The design values obtained after iteration using MS-Excel for the trommel screen are as follows:

Table 6:All Results

Radius of Trommel Screen(in metres)	**1.15**

N(in rpm)	**8**
β(inclination of trommel in radians	**0.034**
α(Departure angle in radians)	**1.54568894**

L(Length of trommel in metre)	**16**
N_c (No. of cycles)	**2037.998024**

T_R(Residence time in seconds)	**15266.7043**

The following results were obtained as calculated for belt conveyer:

α(angle of inclination of belt in degrees)	10^o
K(Flowability Factor)	**0.000265**
ρ(Density of Waste in kg/m^3)	**800**
B(Belt width in metres)	**0.7**
M(Belt Capacity in kg/s)	**0.416***
V(belt speed in m/s)	**5.833127678**
Carrying Idler	**1**
Return idler	**1**

The results obtained are similar to existing trommel but the size of trommel is reduces.Also since the rpm required is low it may consume les power.This type of trommel system can be used for handling a waste from a local municipality

The above results maybe useful for preparing a solid waste management plan for handling a local municipality.This would lead to a more efficient processing of waste in a city and thus help in avoinding littering and other forms of pollution.Proper processing would also be helpful in developing a new scientific temperament

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