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Development of a Belt Conveyor for Small Scale Industry

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ABSTRACT

Most small scale industries rely on human effort for transporting raw materials from one stage of processing to another thereby reducing the overall system performance. The work discusses the development of a belt conveyor system for small scale industry. The conveyor is of height 0.75 m at 0º angle of inclination, 35º troughing angle and a surcharge angle of 25º. It also consists of a belt whose width is 410 mm, length 2.4 m and a basic length 4.54 m. The conveyor has an average capacity of 43.75 tonnes/hr. The evaluation of the conveyor was carried out by conveying 12 packs of bottled water of different weights across a distance of 2 m at a different speeds ranging from of 200-400 rpm. Results obtained indicated that the time of conveying the materials increases with increase in weight of the bottled water. The successful completion of this work provides a conveyor system which will aid the movement of material from one place to another with little or no human intervention. This will help the industry in reducing cost in acquiring labour that will be used in material movement thereby reducing cost of production.

Keywords: *Angle of inclination, Belt conveyor, System performance, Surcharge, Troughing*

INTRODUCTION

Conveyor system is a mechanical framework utilized as a part of moving materials starting with one place then onto the next and discovers application in most handling and assembling commercial enterprises, for example, substance, mechanical, car, mineral, pharmaceutical, hardware and so on [1,2]. It is easier, safer, faster and more efficient to transport materials with high degree of automation. Treatment of materials which is a critical element in assembling is a necessary piece of offices configuration and the productivity of material taking care of gear add to the performance level of a firm [1,2]. Conveyor systems are durable and dependable in materials transportation and warehousing. In view of various standards of operation, there are diverse transport frameworks to be specific: gravity, belt, screw, pail, vibrating [3,2], chain, spiral, grain conveyor systems etc. The decision however relies on upon the volume to be transported, stature or separation of transportation, nature of material, strategy for generation utilized [4]. Material taking care of hardware reaches from those that are worked physically to self-loader frameworks and to the ones with high level of robotization. The level of computerization however depends on handling requirements. A belt comprises of an interminable and adaptable belt of high quality with two end pulleys (driver and driven) at settled positions upheld by rollers. In this work, 3 move idlers are required for satisfactory backing of materials transported. Pulleys are utilized for giving the drive to the belt through a drive unit gear box fueled by an electric engine. It likewise helps in keeping up the correct pressure to the belt. The drive bestows energy to one or more pulleys to move the belt and its heaps. Materials are transported over the required separation as a consequence of rubbing created between the roller surface and the moving belt get under way by a rotating pulley (drive pulley). The other pulley (driven or idler pulley) goes about as a wheel around which the material turns and returns in a constant procedure. Constant procedures are described by relentless movement of mass or unit loads along a way without end for stacking and emptying [5,2]

Different methods such as fork lifting, utilization of can lifts, conveyors systems, crane, etc. have been distinguished for lifting or transporting mass materials or items starting with one place then onto the next in the assembling commercial ventures relying upon the rate of taking care of, stature of transportation, nature, amount, size and weight of materials to be transported [2]. Be that as it may, incidental stop or fatalities encountered while loading and unloading in the industry are source of concern. Moreover, most small scale industries rely on human effort for transporting raw materials from one stage of processing to another thereby reducing the overall system performance. In addition, existing design of conveyor systems have been reported without incorporating design calculations into fabrication, therefore performance evaluation of the designed system cannot be carried out. In a view to address these challenges, a semi-automated conveyor system for conveying packs of bottled water is being developed to enhance optimum productivity with less fatigue. Also, a model of the system will be fabricated so as to evaluate its performance. The conveyor system will ease the flow of production on the factory floor and will increase the productivity rate of the industry thereby increasing profit. The aim of this work is to develop a conveying for conveying packs of bottled water for small scale industries.

2.Materials and Methods

2.1 Design Considerations

The design of an efficient material handling system which will increase productivity and minimize cost entails the followings; designing the system for continuous flow of material (idle time should be zero); going in for standard equipment which ensures low investment and flexibility; incorporating gravity stream in material stream framework; and ensuring that the proportion of the dead weight to the payload of material taking care of gear is least [1,2]. The transportation course influences the general expense of material taking care of. An effective material taking care of gear will decrease cost per volume of material transported and guarantee that materials are conveyed to the creation line securely. The outline of belt transport framework includes determination of the right measurement of the belt transport parts and other basic parameter values in order to guarantee ideal effectiveness amid stacking and emptying conditions. A portion of the segments are; Conveyor belt, engine, pulley and idlers, rollers, pneumatic chamber and so forth. The design of a belt conveyor system takes into consideration the followings: dimension, capacity and speed, roller diameter, belt power and tension, idler spacing, pulley diameter, motor, type of drive unit, location and arrangement of pulley, control mode, intended application and maximum loading capacity

2.2 Belt Details Dimension, Capacity and Speed

The diameter of the driver and driven pulley is dictated by the sort and measurement of transport belting. The distance across of the pulley must be composed such that it doesn't put undue weight on the belt. The length of a belt transport in meters is the length from the focal point of pulley parallel to belt line. Belt length is reliant on both the pulley measurements and focus separations [6,2].

The circumference of the rollers is given as Equation 1.

$$V = d \times \pi \qquad (1)$$

where;

V is the belt speed (m/s); D is the diameters of rollers (m); and π=pi

Capacity is the product belt cross sectional area, material density and speed as expressed by Equation 2.

$$B.C = 3.6 \times A \times \rho \times V \qquad (2)$$

where;

A is the belt sectional area (m^2); ρ is the material density (kg/m^3); and V is the belt speed (m/s)

The mass of material M_m (live load) per metre (kg/m) loaded on a belt conveyor is given as Equation 3.

$$M_m = \frac{C}{3.6 \times V} \qquad (3)$$

where

C is the conveyor capacity (43.75 tonnes/hr); and V is the belt speed (0.25m/s).

$$M_m = 48.6 \text{ kg}$$

The magnitude of belt speed V (m/s) can be determined from Equations 1, 2, 3 and can as well be gotten from the catalogue for standard belt. Belt speed v (m/s) relies on upon stacking, discharge and transfer arrangement, maintenance standards, lump size [7,8].

The determination of belt width is largely dependent of the quantity of conveyed material which is indicated by the design of the conveying belt [9]. The value of belt capacity from Equation 2 determines the value of size factor.

Another important variable in deciding the belt limit is the troughing edge. Belts are troughed to permit the transport load and transport materials. As trough edge builds, more materials can be transported. For standard 3 idler rollers of equivalent length the most recognized trough point is 350. The belt width must be sufficiently wide to manage the material size.

Edge of extra charge is a standout amongst the most imperative qualities in deciding the conveying limit as it straightforwardly administers the cross sectional territory of material in the belt and henceforth the volume being passed on [8]. The extra charge point relies on upon grating between the belt and the material and how the material is stacked. The more extreme the transport, more noteworthy the belt limit and the lesser the extra charge point belt of minimum width of 410 mm and speed of 0.25 m/s is preferred according to design values [10]. For 3 equal roll idlers with surcharge angle of 25° and troughing angle of 35°, the capacity factor is 1.0 [8]. The capacity in tonnes/hr of a conveyor consisting of 3 equal roll idler is given as Equation 4.

$$C = \frac{C_T \times \rho \times C_f \times V}{1000} \qquad (4)$$

where

C is the capacity in tonnes/hr of a belt conveyor consisting of 3 equal roll idler;

C_T is the capacity of troughed belts for 3 roll equal length idler (175);

ρ is the material density in kg/m^3 (1000);

C_f is the capacity factor (1.0); and

Vis the belt speed in m/s (0.25)

From equation 3.4, the overall capacity of the belt conveyor consisting of 3 equal roll idler is 43.75 tonnes/hr.

For belts running horizontally and loaded evenly, the volumetric belt load also is given as Equation 5:

$$V_L = \frac{L_C}{W} \qquad (5)$$

where;

V_L is the volumetric belt load (m^3/hr), L_C is the load capacity of the belt conveyor (tonnes/hr); and

W is the specific Weight of the conveyed material (tonnes/m^3)

As belt tend to wander a bit in operation, the overall face width of the pulley should exceed the belt width by 100 mm [9], if serious edge damage is to be avoided.

For haulage productivity, transports ought to be worked completely stacked at the greatest prescribed pace and limit.

2.3 Roller Diameter

The roller bolster belt and encourages simple and in addition free pivot of the belt transport in all course.

The right decision of roller measurement must mull over the belt width [10]. The relationship between the most extreme belt speed, roller measurement and the relative

Revolution per minute is expressed as Equation 6.

$$N = \frac{1000V}{\pi D} \qquad (6)$$

Where

N is the no of revolution per minute; D is the roller diameter (mm); and V is the belt speed (m/s)

The belt width is designed as 410mm, the belt speed is 0.25 m/s, the roller diameter is therefore designed as 80 mm [10].

From Equation 6, the no of revolution per minute N is 6.36 rpm, (nearest speed is 7 rpm)

The conveyor length= $\frac{horizontaldis\tan ce}{inclinationangle\theta}$

(7)

The inclination angle is 0º, the conveyor length is 2.4 m, and the conveyor height is 0.75 m.

Belt basic length= 2 × length along convening route *(8)*

Basic belt length = $2 \times 2.27 = 4.54\ m$

The roll diameter for belt is expressed as Equation 9.

$$D = \sqrt{d^2 + (0.001273 \times L \times G} \quad (9)$$

where;

D is the overall diameter (m); D is the core diameter (m); L is the belt length (m); and

G is the belt Thickness (mm)

The length of a belt on roll is given as Equation 10.

$$L = (d + (\frac{D-d}{2}) \times \pi \times N \quad (10)$$

Or

$$L = H \times N \times \pi \quad (11)$$

where;

D is the outside diameter of the roll (m); D is the diameter of the roll centre (m);

N is the no of wraps of the belt H is the height of the centre core (m); and $\pi = 3.1416$

2.4 Belt Power and Tensions

The longer the length of the belt, the more the force required for the transport and the higher the vertical separation of the lift, the higher the greatness of force required.

The force PP (kW) at drive pulley drum expressed as Equation 12.

$$P_P = \frac{F_U \times V}{1000} \quad (12)$$

=0.12 kW

where;

F_U steady state belt tension is (469.43kN); and V is the belt speed (0.25m/sec)

The belt of the conveyor always experience tensile load due and the belt [11]. Belt tension at steady state is given as Equation 13.

$$T_{SS} = 1.37 \times f \times L \times g[2 \times M_i + (2 \times M_b + M_m)\cos(\theta)] + (H \times g \times M_m) \quad (13)$$

Where

T_{ss} is the belt tension at steady state (N); f is the coefficient of friction (0.02)

L is the conveyor length (2.27 m); (Conveyor belt is approximately half of the total belt length)

g is the acceleration due to gravity (9.81 m/sec^2); M_i is the load due to the idlers (12 kg);

M_b is the load due to belt (70.6 kg); M_m is the load due to conveyed materials (48.6 kg);

θ is the angle of inclination angle of the conveyor (0º); and H is the vertical height of the conveyor (0.75 m).

From Equation 13, T_{ss}= 469.43 kN

During the start of the conveyor system, the tension in the belt will be much higher than the steady state. The belt tension while starting is given as Equation 14.

$$T_s = T_{ss} \times K_S \quad (14)$$

Where

T_s is the belt tension while starting (N); T_{SS} is the belt tension at the steady state (469.43 kN); and

K_S is the startup factor (1.08).

From Equation 14, T_s = 506.98 kN

The belt tension of a conveyor system is of a varying value along the system flight and is influenced by the following influencing factors: length and track of the system; number and arrangement of pulley; characteristics of the driving and braking equipment; type and location of the belt take up devices; and operating and loading state of the system [12].

2.5 Motor

The minimum motor power for the motor is given as Equation 15.

$$P_{\min} = \frac{P_p}{\eta} \quad (15)$$

Where

P_{min} is the minimum motor power (kW); Pp is the power at drive pulley (0.12 kW); and

η : drive efficiency (0.05)

P_{min}=2.6 kW/3.2hp

The next standard motor greater than P_{min} will be sufficient [13,14].

A standard motor of 3-5hp is chosen.

2.6 Pulley Diameter

Pulleys are manufactured in a wide range of sizes. The selection of pulley takes into account the wrap angle (180º), belt speed (0.25m/sec), method of belt strain, belt tension T, belt width (410 mm) also, kind of graft of the transport line. The pulley distance across is gotten from standard quality from the inventory. Once the pulley breadth is resolved, the measure of the coupling can also be decided from the catalogue [15].

Pulley wraps length at terminals = $2\pi D$ *(16)*

Where

Diameter of drive pulley (0.12 m) [9].

Pulley wraps length at terminals = 0.75 m.

Drive pulley can be slacked to expand contact and enhance transmission amongst belt and pulley [13] versatile slacking keeps pulley clean in order to expand length of friction while grooved lagging helps in removal of moisture so as to improve friction.

The acceleration of the conveyor belt is given as Equation 17.

$$A = \frac{T_S - T_{SS}}{[L \times (2 \times M_i + 2 \times M_b + M_m)]} \quad (17)$$

where;

T_s is the belt tension while starting (489.2 kN); T_{SS} is the belt tension at the steady state (528.3kN); L is the conveyor length (2.4 m); M_i is the load due to the idlers (12 kg/m);

M_b is the load due to belt (22 kg/m); M_m is the load due to conveyed materials (48.6 kg/m);

Acceleration (0.139 m/s^2)

2.7 Shaft Design

Shaft design constitutes primarily of determination of the proper shaft distance across that will guarantee unbending nature when the pole is transmitting movement under various working and stacking conditions. The estimations of belt width and pulley diameter helps in choosing the size of shaft diameter as 75 mm from different conveyors hand book.

2.8 Control

The conveyor is controlled by means of a control switch.

2.9 Intended Application

The conveyor will be used in small scale industries to move various materials around the production area.

The followings are designed values were obtained for belt conveyor system for small scale industries using 3 roll idlers

The design values for the belt conveyor system is presented in Table 1.

Table 1: Design Values for Belt Conveyor System

S/N	Parameter	Values
1.	Belt width (mm)	410
2.	Length of Conveyor (m)	2.4
3.	Basic belt length (m)	4.54
4.	Belt speed (m/sec)	0.25
5.	Height of Conveyor (m)	0.75
6.	Angle of inclination(degree)	0
7.	Troughing angle (degree)	35
8.	Surcharge angle	25
9.	Conveyor capacity (tonnes/hr)	43.75
10.	Equipment friction factor	0.0225
11.	Belt tension while starting (kN)	489.2
12.	Belt tension at steady state (kN)	528.3
13.	Load due to idlers (kg/m)	12
14.	Load due to belt (kg/m)	22
15.	Load due to materials conveyed (kg/m)	48.6
16.	Power at drive pulley (kW)	0.12
17.	Efficiency of reduction gear (drive efficiency)	0.05
18.	Minimum motor power (hp)	3.2
19.	Idler spacing (m)	1.2
20.	Diameter of drive pulley1 Intermediary Pulley1 Intermediary Pulley 2 (m)	0.12 0.9 0.19
21.	Pulley wraps length at terminals (m)	0.75
22.	Weight of material and belt (kg/m)	70.6
23.	Total live load (kN)	13.62
24.	Power required by conveyor (kW)	5.10
25.	Material density (kg/m^3)	1000
26.	Coefficient of friction	0.02
27.	Wrap angle (degree)	180
28.	Acceleration (ms^2)	0.139
29.	Belt thickness (mm)	1
30.	Torque (Nm)	0.38
31.	Capacity factor	1.08
32.	Belt revolution (rpm)	6.36
33.	Roller diameter (mm)	80

3.5 Fabrication Procedure Involved in the Production

The various angle iron pieces were cut to their respective sizes to hold the frame and acts as legs for the conveyor systems after which they were welded together to form a solid structure. Also, various shafts that have been machined on the lathe machine were used to hold the structure of the conveyor together. Then the shaft was fixed into the rollers and then further machined on the lathe machine to give a good finish. The finished roller was thereafter attached to the conveyor and it's held with the aid of the bearings, also the intermediary shaft was also attached to carry the intermediary pulley. This forms the skeletal structure of the conveyor system. The conveyor belt was attached to the skeletal structure fabricated. A base for the electric motor was fabricated to carry the motor. Castor wheel was added to the foot of the conveyor to enable the easy movement of the conveyor around the facilities. The developed belt conveyor system is shown in Figure 1.

Figure 1: The Developed Belt Conveyor

3. Results and Discussion

3 different sizes of 12 packs of water of 50 cl, 75 cl and 1.5 l are were used to carry out the performance evaluation. Given that the electric motor provides a constant speed of 200 rpm.

The following data was gotten from the evaluation of the conveyor across a 2 m distance (Table 2)

Table 2: Weight of Water Packs and Average Time taken

Capacity (l)	Weight (kg)	Average Time (sec)
0.50	6.8	20
0.75	10.2	24
1.5	19.5	30

The results gotten from the performance evaluation carried out on the conveyor system shows the various time it will take the conveyor to convey various packs of water of different weights across a distance of 2 m. The relationship between the weight of the packs of bottled water and the time it takes to convey the product is directly proportional (Figure 2). As the weight of the packs of water increases, the time it takes the conveyor to move the packs of water also increases and vice versa.

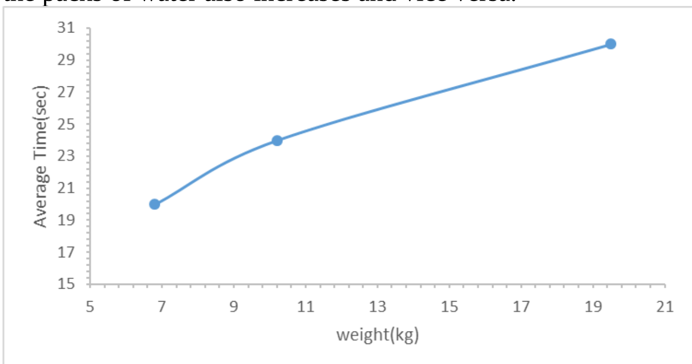

Figure 2: Weight of Water Packs and Average Time taken

4. CONCLUSION

A belt conveyor system with 3 roll idlers for conveying packs of bottled water was developed. The peculiarities of the belt conveyor is that it is easy and cheap to maintain, it has high loading and unloading capacity and can transport materials economically and at very high efficiency.

The followings are recommended;

i. The use of variable speed electric motor which will allow for evaluation of the system performance at different speeds.

ii. The developed system be subjected to test throughout the year for more performance evaluation.

The construction of a belt conveyor system requires high capital base. The evaluation of the conveyor system is limited to a conveyor speed of 200 rpm and as such the evaluation cannot be carried out at different speed of operation.

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