ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 8, Issue 1, pp: (1-11), Month: April 2021 – September 2021, Available at: www.paperpublications.org

Design and Advancement of Portable Compact 3 Roll Slanted Belt Conveyor for Stacking and Emptying the Grains

Ajit Saruk

Research and Development Engineer

Abstract: **Belt transports can permit to move the discrete and continuous load. The greater part of the manufacturing time in industries spent on material dealing with which causes to increment in the tact time. In warehouses, ordinary usage of the conveyors is to stack and purge the wide scope of material. Masters have tackled the inclined level belt transport to fulfill the need in such applications. This exploration work center around change of conveyor system to transport grains so that the general load of the conveyor system lessen altogether to limit the push to migrate the conveyor system. Wire ropes are recently acquaints in the belt conveyor with accomplish decrease in the weight by lessening the structural components of conveyor frame. The present conveyor system is introduced on the suspension with the pneumatic system to accomplish conveyor inclination. The objective of this examination is to give the belt transport data base to the expansion and improvement of the belt conveyors to upsurge the generations.**

Keywords: **Conveyor, Conveyor Capacity, Idler, Load, Pulley, Shaft.**

Abbreviation-

MHS- Material handling system

CPH- Capacity tons per hour

F_c, F_e, F_l- Equipment friction factor

L- Horizontal center to center distance

t_f – Terminal friction factor

C- Capacity

Q- Mass of moving parts

S- Belt Speed

H- Net change in elevation

K- Drive factor

T_e- Effective tension

B- Belt width

μ- Coefficient of friction

T_2- Slack side tension

T_1- Tight side tension

T_{max}- Maximum tension

$W_{mtl.}$- Weight of material

W_b- Weight of Belt

W_i- Weight of carrying idlers

W_{ii}- Weight of impact idlers

W_{ir}- Weight of return idlers

M_b- Mass of belt

P- Power

D_h- Diameter of head pulley

D_t- Diameter of tail pulley

D_r- Diameter of roller

CIL- Calculated idler load

K_1- Lump adjustment factor

SI- Spacing of idlers

SI_I- Impact idler spacing

SI_r- Return idler spacing

IML- Idler misalignment load

CILR- Calculated return idler load

L_t- Transition distance

m- Mass

a- Acceleration

F- Force

t- Time

t_c -Time cycle
W_R- Resultant load
S_{ut}- Ultimate tensile strength
S_{yt}- Yield tensile strength
$\urcorner_{permissible}$- Permissible shear stress
Π- Pi
n- Rated speed
N- Output speed
G- Gear Ratio
T- Torque
M- Moment
d_h- Shaft diameter for head pulley
d_t- Shaft diameter for tail pulley
k_b- Shock factor
k_t- Fatigue factor
ρ- Material density
ϴ- Arc of contact
B_t- Belt thickness

I. INTRODUCTION

Material handling systems is used in manufacturing and distribution industries. It doesn't enhance the item yet it diminishes the expense altogether. The attributes of the material to grabbing the heap, moving and putting the heap down. Creation viability can be expanded by having the correct nature of material at opportune time and at ideal spot. MHS design requires joining the all-out sensible and physical parts of material stream and after that legitimize the structure from execution and monetary points of view [1]. Out of the absolute time spent for assembling an item, 20% of the time is used for real preparing on them while the staying 80% of the time is spent in moving starting with one spot then onto the next, waiting for the processing [2].

MHS assumes a significant job in stacking and emptying the grains from ranch field to trucks, trucks to grain warehouse, trucks to trucks and so forth. In every one of these applications a belt conveyor is appropriate in light of the fact that it is need to move the material regardless of its continuous flow. Conveyors are fixed path material handling framework [2]. Relies upon the application referenced above conveyor system should be adjusted regarding tendency, capacity to reach up to variable statures, versatility of the transports and its revolution degrees of freedom.

Fig. 1. Shows the overview of the proposed design. This examination work center around the compact 3 roll slanted belt conveyor system, where wire rope system is intended to slope and decay the transport from the two closures to give stacking and emptying adaptability from either terminals, chassis intended to help the transport by permitting wanted degrees of opportunity. Wire ropes are intended to limit the basic component and altogether decrease in the heaviness of the transport framework with the end goal that it is anything but difficult to move the conveyor system.

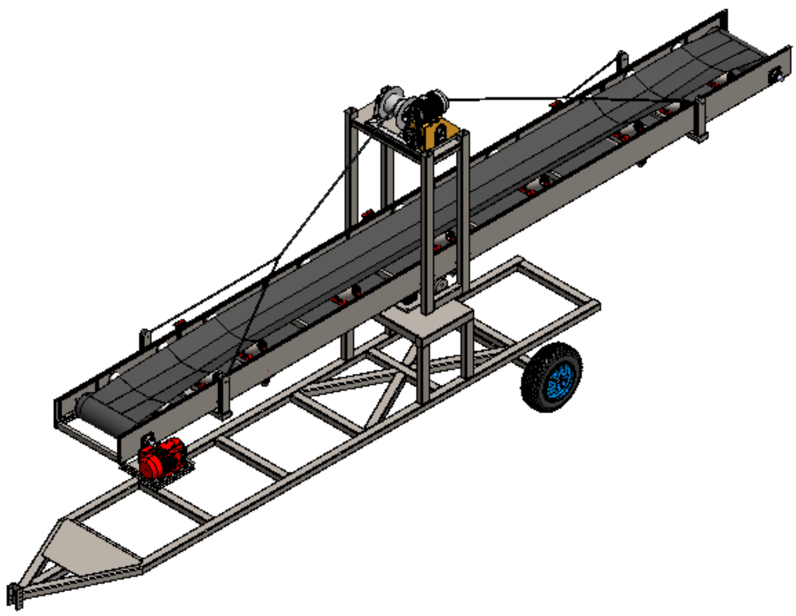

Fig. 1. Isometric view of the proposed design

ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 8, Issue 1, pp: (1-11), Month: April 2021 – September 2021, Available at: www.paperpublications.org

II. LITERATURE REVIEW

Rahul. K. Bhoyar, Sandeep.M. Pimpalgaonkar, Swapnil.J. Bhadang [3] design a transport structure for flavors producing industry, where the transport stature can be balanced by methods for pneumatic actuators to improve the throughput and psychologist the expense. R.K.Bhoyar, Dr. C.C.Handa [4] quickly conscious the structure worry of outspread and slanted belt transport course of action which has Rotational degrees of opportunity to stack and empty the material. I. A. Daniyan, A. O. Adeodu and O. M. Dada [5] examine about structure computation and determination of part sizes of belt conveyor for lime stone utilizing 3 roll idlers guaranteeing that the proportion of dead weight to payload is least. The load acting on the idler bolts is estimated with the assistance of strain gauges through which bolt size can be chosen for shear strength which has incredible effect on the efficiency of the belt conveyor, this trial examination done by Lech Gładysiewicz, Robert Król, Waldemar Kisielewski [6]. Olanrewaju T. O., Jeremiah I. M., Onyeanula P. E. [7] presumed that, the transport limit can be influenced by the situation of the conveyor, as the point of tendency increases the output capacity diminishes and power required to drive the conveyor increments. S.Rajeshkumar, M.Sathish, K.Soundar, R.Vijayakumar, T.Sathiyaprakash [8] plan a belt conveyor for bolstering the harmed papers into the pulper to decrease the handling time. Nick Civetz [9] create a report on conveyor utilized for diminishing the almond drying time. Development and testing has been finished by the creator so as to check the plausibility of the passing on framework.

III. CONVEYOR DESIGN

In this work the design references taken from conveyor handbook [10]. While designing the Conveyor, material need to be conveyed and its lump size are important consideration. Every material has inclination to shape edge at which the slanting surface of the material is steady. This work has thought about the wheat as a passing on material. Wheat has a portion of the accompanying properties which are valuable regarding designing the conveyor.

Material to be conveyed- Wheat

ρ- 770 Kg/m^3

Angle of repose- 28^0

Angle of Surcharge- 10^0

Angle of Inclination- 15^0

H- 2.7m

Lump size- 150 mm

A. Belt Capacities

In this examination, conveyor is intended for 3 roll idlers where belt capacity is subject to belt width, belt speed, trough angle and the Cosine of inclination angle. Lump size of 150mm choose the required belt width which is 750mm. Kind of material should be transport and belt width choose the protected speed of the conveyor line which is 3.5 m/s. To move the grains most extreme admissible incline is 15^0 above which grains will begin sliding down.

$$\text{Capacity TPH} = \frac{\text{Capacity} \times \rho \times \text{Capacity factor} \times S \times \text{Cosine of inclination angle}}{1000} \quad \text{.....(1)}$$

= 1642.3 TPH

B. Belt power

Belt drives are depend on the measure of friction among belt and pulleys and to conquer this while designing the belt power, friction factor should be consider just as mass of moving parts, Q is 46. As indicated by the conveyor design handbook, for portable short centre conveyors, F_c is 0.030 and for horizontal & elevating conveyors, t_f is 60 m. utilize every one of these qualities in condition (2) to compute belt control.

$$((F_c \times (L + t_f)\ (C + 3.6\ Q \times S)) / 367) \pm (CH / 367) \quad \text{.....(2)}$$

= 41 KW

To conquer the frictional factor standard 45 KW gear motors are accessible.

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 8, Issue 1, pp: (1-11), Month: April 2021 – September 2021, Available at: www.paperpublications.org

It is important to know every single individual segment tensions to defeat the part frictions. In the wake of emptying, the belt need to recycle to the stacking point with assistance of return idlers which causes to build up the Return Side Friction.

F_e x Q x L x 0.4 x (9.81 x 10^{-3}) …..(3)

= 0.036 KN

Total empty friction

F_e x (L + t_f) x Q x (9.81 x 10^{-3}) …..(4)

= 0.632 KN

By subtracting the return side friction from total empty friction leads to Carrying side friction

= Total empty friction – Return side friction

= 0.596 KN

At the point when the material is stacked on the conveyor due to mass of material Loading Friction is created. Load friction can be calculated from equation (5)

F_l x (L + t_f) x (C / (3.6 x S)) x (9.81 x 10^{-3}) …..(5)

= 2.24 KN

When the conveyor is inclined by 15^0 and loaded with material it develops a Load slope tension which can be calculated from equation (6)

= ± (C x H / (3.6 x S)) x (9.81 x 10^{-3}) …..(6)

= 3.45 KN

Loaded inclined conveyor will develop tension in the belt. Belt slope tension can be calculated from equation (7)

± B x H x (9.81 x 10^{-3}) …..(7)

The elixir of the all out tension in belt really effective while moving the belt. Effective tension is the distinction between tight side tension and slack side tension and can be determined by including the total empty friction, load friction, and load slope tension.

T_e = Total empty friction + Load friction + Load slope tension

= 6.32 KN

While situating the end pulleys, the tight side must approach towards the driving pulley which is alluded as tight side tension and slack side must approach towards the driven pulley which is alluded as slack side tension. Once in a while to improve the traction there are various strategies for tensioning are accessible, usually utilized methods are Counterweight take-up and Screw take-up. In this work Screw take-up strategy is utilized. Relies on the strategy for tensioning and arc of contact (180^0) the drive factor, K should be consider, which is 0.97

$T_2 = T_e$ x K …..(8)

= 6.13 KN

μ, depends on the Θ and type of pulley. In this study the bare pulley is selected causes to μ to be 0.30. To know the T_2, put the values in equation (9)

$$\frac{T_1}{T_2} = e^{\mu\Theta} \quad …..(9)$$

= 15.73 KN

Maximum tension at head and drive pulley can be determined from the following equation.

At head pulley

$T_{max} = T_e + T_2 = 12.45$ KN

At tail pulley

$T_{max} = T_e + T_2 = 12.45$ KN

C. Belt Selection

Selection of belt carcass is mainly dependent on maximum tension present in the conveyor belt and the belt width. Maximum belt width results into minimum required working tension and vice versa.

Required working tension = T_{max} / B

= 16.6 KN/m

The selected belt has allowable working tension of 24 KN/m and #2 of plies. So,

Required working tension < Allowable working tension

Under consideration of worst case scenario where conveyors are operated at moderate impact, infrequent start and good loading the peak tension should not exceed 140% of allowable working tension.

Peak tension = 140% Allowable working tension

= 33.6 KN/m

After referring the standard conveyor belts, PN 150-160, Plain weave belt is selected which can easily withstand the amount of tension generated during moving of the material.

Based on the above data maximum and minimum width of belt should be between 900 mm and 400 mm respectively to support the load. Selected belt conveyor width is 750 mm which is under limit, 400 mm < 750 mm >900 mm. Selected belt has following properties-

Mass = 3.7 kg/m^2

Thickness = 2.7 mm

Total belt weight would be-

W_b = m x L

= 2.775 Kg/m

D. Pulley Selection

Belt pulley dimensions can be selected confidently by referring the conveyor handbook [10]. To operate the belt, by considering the required belt working tension and allowable working tension it can be concluded that belt is operating at over 60% of allowable working tension. So by referring the standards [11] the recommended minimum pulley diameters are as follows-

Head pulley - 315 mm

Tail Pulley – 250 mm

As all the belts wander a bit during operation, the overall face width of the pulley should exceed the belt width by minimum 150 mm [10] to avoid serious edge damages.

E. Idler selection

The design of idlers is based on the manufacturing catalog of CEMA [12]. Before starting the selection procedure idler spacing should be known. Recommended average carrying idler spacing is dependent on belt width and material density [10].

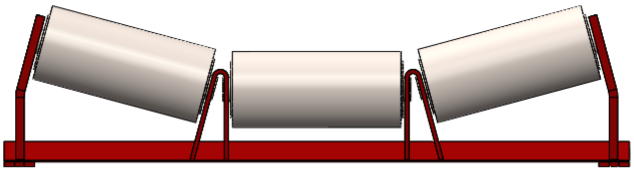

Fig. 2. Carrying Idlers

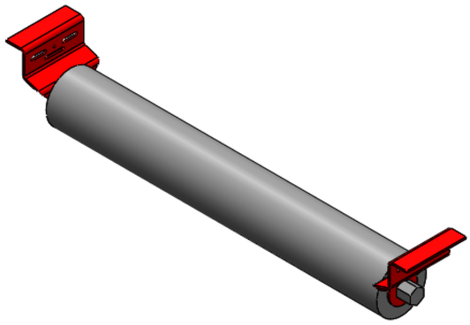

Fig. 3. Return Idler

So for belt width of 750 mm and material density of 770 kg/m^3 the idler spacing distances would be as follows-

Carrying idler spacing = 1.5 m

Return idler spacing = 3 m

Impact idler spacing = ½ to ¼ carrying idler spacing = 0.8 m

When the material is in movement the portion of the load would be carried be the idlers. Material weight can be calculated by

$W_{mtl.} = (C / (3.6 \times S))$

= 130.34 Kg/m

Calculated idler load –

$CIL = ((W_b + (W_m \times K_1)) \times SI) + IML$ …..(10)

= 199.97 kg

The standard idlers series is selected which can carry 408.2 kg which is safer to convey the material.

Fig. 2. and Fig. 3. Shows the carrying and return idlers.

When the empty conveyor belt is approaching toward the loading point the belt weight would be carried by the return idlers. So it is necessary to know the load carried by the return idler to know the standard available dimensions of the return idler.

Return idler series selection –

$CILR = (W_b \times SI) + IML$ …..(11)

= 6.24 Kg

In equation (10) and (11) IML value is unknown so multiply the equations by 1.5 of an IML service factor.

F. Transition distance

If the 35^0 troughing angle idler set is used the belt would stretch more between the gap of idler and terminal pulleys because suddenly the belt at angle in idler set coming as a flat on pulley leads to the failure of the belt. To avoid this minimum gap needs to be maintained between the pulley center and the first set of idlers.

So as per the standard catalog [10] transition distance for terminal pulleys should be-

Transition distance for head pulleys = 2.6 B

= 1.95 m

Transition distance for tail pulleys = 5.2 B

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 8, Issue 1, pp: (1-11), Month: April 2021 – September 2021, Available at: www.paperpublications.org

= 3.9 m

Number of idlers required in conveyor-

#of carrying idlers = $((L - L_t) / SI) - 1 = 5$

#impact idlers = $(L_t / S_{ii}) - 1 = 2$

#return idlers = $(L / S_{ir}) - 1 = 3$

As per the standard manufacturers catalog the Masses of conveyor components:

Carrying idlers = 22.68 kg

Impact idlers = 25 kg

Return idlers = 13.6 kg

Mass of moving parts and belt:

$$Q = 2B + \frac{W_t}{SI} + \frac{W_{ir}}{SI_r}$$

= 273.15 Kg/m

G. Mass of terminal pulleys

Average standard weight of head pulley = 66 kg

Average standard weight of tail pulley = 46.3 kg

Total mass of the material, belt and rotating parts = (Q + (C / (3.6 x S))) x L = 3471.5 Kg

Addition to this mass of terminal pulleys and idlers need to be added, so the total mass would be 3645.08 Kg.

H. Acceleration and deceleration

The acceleration generated due to effective tension or force and total mass need to move is-

F = m x a

A=1.73 m/s^2

Time required for acceleration or deceleration

t = S / a

= 2 sec

Time cycle for conveyor:

$t_c = (2 \times L) / S$

= 5.7 sec

I. Motor Selection

To move the conveyor standard gear motor is selected with following specifications:

n = 1482 RPM

N = 222 RPM

Gear ratio = 6.66

ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 8, Issue 1, pp: (1-11), Month: April 2021 – September 2021, Available at: www.paperpublications.org

Output torque = 1930 N-m

Service factor = 1.55

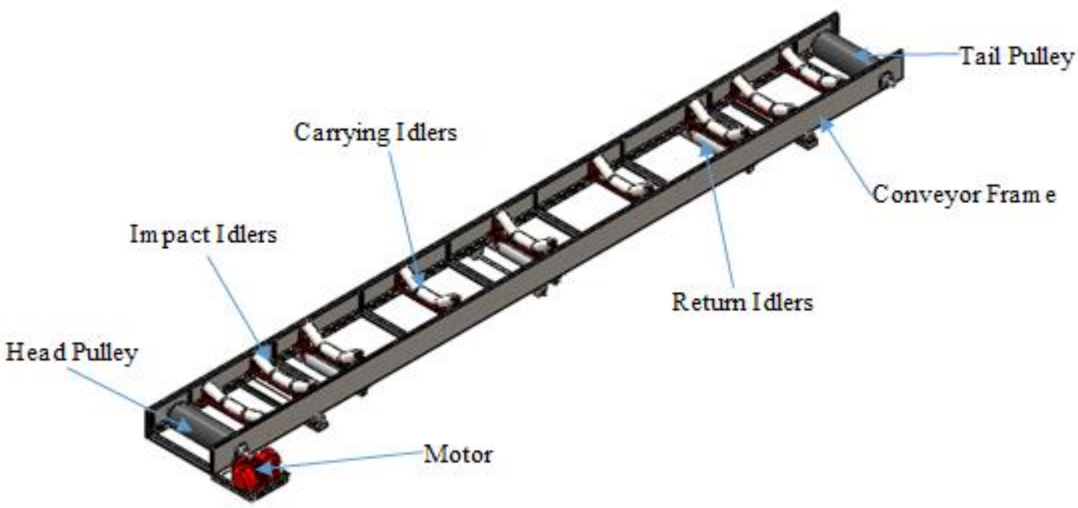

Fig. 4. Conveyor without belt

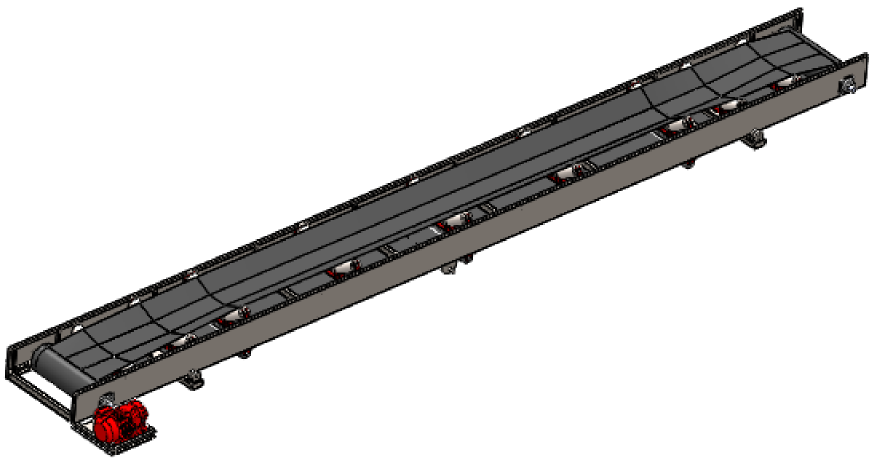

Fig. 5. Conveyor with belt

J. Design of shaft

By considering the strength as a main parameter the shaft is designed on the strength basis. Plain carbon steel is selected as a material for conveyor shaft which has S_{ut} and S_{yt} of 400 MPa and 220.594 MPa respectively. As per the ASME codes, permissible shear stress for shaft without keyway is taken as 30% of yield strength in tension or 18% of ultimate strength of material whichever is lower.

$\tau_{permissible} = 0.3\ S_{yt}$

$= 66.178$ MPa …..(12)

$\tau_{permissible} = 0.18\ S_{ut}$

$= 72$ Mpa …..(13)

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 8, Issue 1, pp: (1-11), Month: April 2021 – September 2021, Available at: www.paperpublications.org

From the above equation 66.178 < 72, so the shaft needs to be design for yield strength. Since the pulleys are keyed to the shaft, reduce the S_{yt} by 25%. $ꞁ_{permissible}$ is 49.63 MPa.

Tension ratio = $T_1 / T_2 = 2.57$

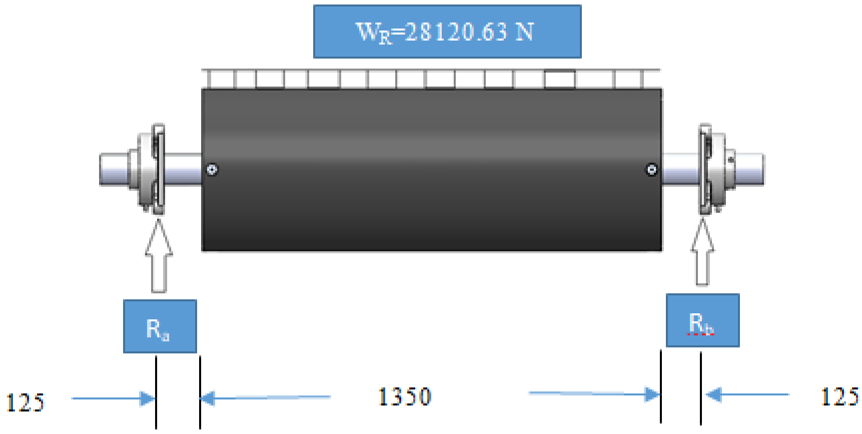

Fig. 6. Head pulley

After calculating horizontal and vertical forces 26993.8 N and 7233 N respectively.

Resultant Load:

$W_R = 28120.63$ N

The required conveyor speed

$$V = \frac{\Pi \times D_h \times N}{60}$$

N = 222 RPM

Required torque to move the loaded conveyor belt

$$P = \frac{2\Pi NT}{60{,}000}$$

T = 1935668.2 N-mm

Moment = 2530854 N-mm

After considering k_b 1.5 and K_t 1.0 the shaft diameter can be calculated as

$$ꞁpermissibl = \frac{16}{\pi d3}\sqrt{(kb * M)2 + (kt * ꞁ)2}$$

d = 75 mm for driving pulley.

Similarly d = 80 mm for tail pulley.

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 8, Issue 1, pp: (1-11), Month: April 2021 – September 2021, Available at: www.paperpublications.org

Wire ropes have great resistance for drum crushing and have high fatigue life. The weight of the conveyor is around 2 tons and to control the weight the wire rope size needs to be designed. Wire ropes are made up of different materials with different tensile strengths. For this application wire ropes made up of extra improved plow steel having tensile strength of 1960 N/mm^2. By considering the FOS of 5 the allowable stress is 392 N/mm^2. The diameter of wire rope can be calculated using stress formula.

$$\sigma = \frac{F}{A}\left(\frac{\mathrm{N}}{\mathrm{mm2}}\right)$$

The diameter of wire rope is 7.98 mm. The standard diameter of the wire rope available is 10 mm (3/8 in) with 6 X 19 fiber core.

IV. WINCH MOTOR SELECTION

After consideration of the conveyor load of 2000 Kg and the conveyor inclined travel speed of 1.8 m/min, winch motor is selected from the standard manufacturer catalog [13]. MCW 1700 electric worm gear winch with operating power requirement of 4 KW is selected from the EMCE winch manufacturer [14]. Winch motors drum dimensions are shown

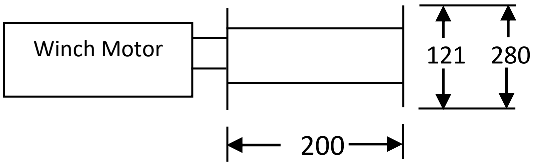

Fig. 7. Winch motor drum size

It is always safer to have 3 to 4 anchor wraps to maintain the contact between wire rope and drum at all time. The length of anchor wraps must be added to the total travel distance to determine the length of wire rope needed for application. Length of anchor wrap, a can be determined by

$$a = \frac{(\text{(Drum Dia.+Rope Dia.) X } \pi \text{ X No.of anchor wraps})}{12}$$

= 102.8 mm

Total length of wire rope depends on the maximum distance load will travel, the distance between drum & sheave and length of anchor wraps.

Total length of wire rope = Max. Distance load will travel + Distance between drum and sheave + length of anchor wraps

= 2700 + 5000 + 102.8

= 7802.8 mm

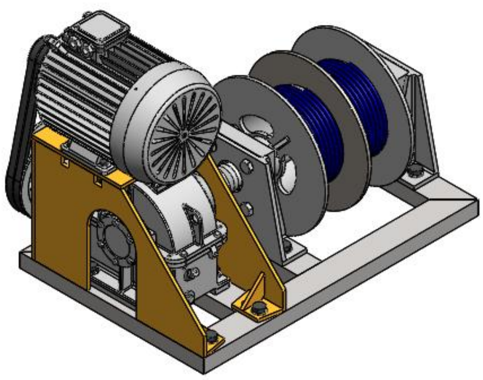

Fig. 8. Winch motor with drum

V. CONCLUSION

The design calculations are carried out for the 3 roll slanted belt conveyor to transport the grains or to load and unload the grain carrying trucks. The proposed design is capable of providing the flexibility in the conveyor. The forces acting on the conveyor at different positions under loaded and unloaded conditions are considered and standard components are selected from the manufacturers catalog respectively. The angle of slope is considered as 15^0 and the vertical height the conveyor can reach out is 2.7m. The wire ropes are designed to accomplish the height by replacing the pneumatic actuators from current designs. Based on the requirement the winch motor is selected to reduce overall cost and to minimize the weight. The proposed conveyor can have the 360^0 rotational motion and additionally the chassis can be added to make it portable.

REFERENCES

[1] Thoguluva Raghavan Vijayaram, Materials handling technology and significance of expert systems to select appropriate handling equipment’s in engineering industries: A review, Journal of Scientific & Industrial Research Vol. 65, August 2006, pp. 619-624

[2] Ayres, R. U. 1988. Complexity, Reliability, and Design: Manufacturing Implications. *Manufacturing Review* 1: 26–35

[3] Rahul. K. Bhoyar, Sandeep.M. Pimpalgaonkar, Swapnil.J. Bhadang, Adjustable Height Belt Conveyor for Small-Scale Food Processing Unit, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-8 Issue-2, December 2018

[4] R.K.Bhoyar, Dr. C.C.Handa, Design Consideration Of Adjustable Height And Radial Belt Conveyor System, *International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 10 - Oct 2013*

[5] Ilesanmi Afolabi Daniyan, Design of a Material Handling Equipment: Belt Conveyor System for Crushed Limestone Using 3 roll Idlers, January 2014

[6] Lech Gładysiewicz, Robert Król, Waldemar Kisielewski, Measurements of loads on belt conveyor idlers operated in real conditions, *Measurement*, S0263-2241(18)31004-2, 17 October 2018

[7] Olanrewaju T. O., Jeremiah I. M., Onyeanula P. E., Design and fabrication of a screw conveyor, AgricEngInt: CIGR Journal Open access at http://www.cigrjournal.org, Vol. 19, No. 3, October, 2017

[8] S.Rajeshkumar, M.Sathish, K.Soundar, R.Vijayakumar, T.Sathiyaprakash, Design and Analysis of Belt Conveyor for Finishing House Pulper, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 3, March 2017

[9] Nick Civetz, Design, Construction, And Analysis Of A Conveyor System For Drying Seasoned Snack Almonds, May 16,2014

[10] Conveyor Handbook- June 2009

[11] Heavy Duty Conveyor Pulleys Catalog- Martin

[12] CEMA Idler Catalog SPCT1015ENPR-01

[13] Product catalog - Thern winches and cranes

[14] EMCE product catalogue