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CALCULATION OF BELT CONVEYOR FOR TRANSFERRING STEEL GRIT IN SAND BLASTING ROOM

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This paper presents a study of belt conveyor for transferring steel grit as main sandblasting material in blasting room. The belt conveyor was designed to replace the existing screw conveyor that frequently breakdown due to the repair of bearings that was damaged by insertion of steel grit into the bearings. In addition, the screw conveyor transport capacity was considered inefficient because some of the steel grit was not transferred as it was left in the gap between the screw and the cover plate. The design process initiated with an examination of the existing problem, then a series of calculation was carried out to determine its specification refering to the existing conveyor data. As a result, the belt conveyor was designed with the capacity of 236.81 tons per hour which is larger then the existing screw conveyor and have less breakdown since there will be no bearing damage as it occurs in the screw conveyor.

Keywords: *Belt Conveyor, Screw Conveyor, Steel Grit, Sandblasting, Bearing, Capacity*

1. INTRODUCTION

Transportation system of medium-heavy abrasive materials, such as steel grit used in sandblasting process, generally use screw conveyor. The screw conveyor is used to return the steel grit that has been used in sandblasting process for recovery or recycling and is fed back to storage hopper as it can be seen in Figure 1. However, in the actual operation there are a common problem of screw conveyor after several years of use, such as damage of bearings due to steel grit inclusion into the bearings that lead to system break down for repair; and inefficient transfer capacity as steel grit material left in the gap between the screw and cover plate.

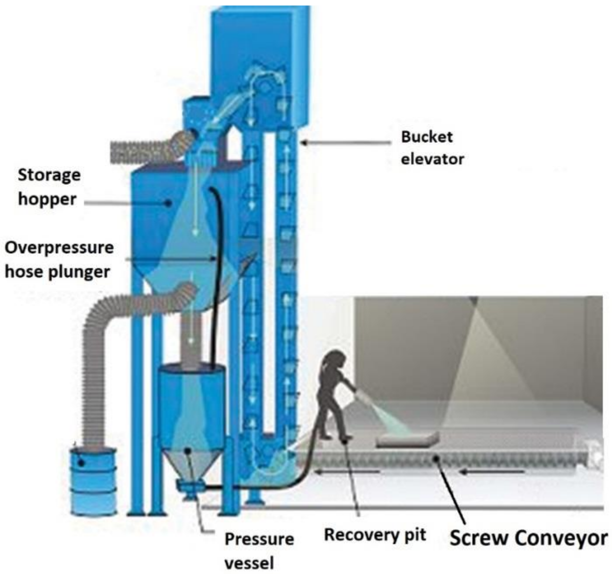

Figure 1: The screw conveyor in sandblasting room

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Due to some inefficiency of screw conveyor being discussed due to frequent breakdown and less transport capacity, the company may require to replace the conveyor system because in the global competitive market, companies are under constant pressure to improve their products, efficiencies and respond to continually changing market demands. One of the alternatives for replacement of the screw conveyor is belt conveyor; this is another common system for transporting object or materials. The belt conveyor is often chosen as a sustainable transportation medium for continuous transportation in modern production as belt conveyor has large capacity, long distance, low energy consumption, low freight, high efficiency, smooth operation, and convenient loading and unloading, and is suited to bulk-material transportation [1].

To replace existing screw conveyor with belt conveyor, a thorough evaluation and calculation need to be performed in order to define the ideal specification of the belt conveyor for the said purpose. One of the reasons is, even though the usage of belt conveyor covers several fields in the industry for transporting objects or materials, the models and materials used in the belt conveyor will differ according to needs. Therefore, this study focuses on calculating the belt conveyor main components with refers the data taken from existing screw conveyor system, including: calculation of the capacity of belt conveyor for replacement of the existing screw conveyor; determine the power used in the belt conveyor; and the type of conveyor belt suitable for this purpose.

Basically, belt conveyors are one of the material handling systems that are widely used in industrial and mining fields. There are various types and models of belt conveyors that in their manufacture can adapt to existing needs. Ananth *et al.* [2] study on conveyor belt development, the belt conveyor has experienced many developments where since the early 90s the first belt conveyor was created to be used in transporting mining material. Riberio [3] revealed that the implementation of belt conveyor showed considerable security and economic gains while lessoning environmental impacts and demonstrated an ability to fight the trend of high operating costs.

The performance of screw conveyor was also one of the interests in several researches. In the study conducted by Olanrewaju *et al.* [4], a domestic granular screw conveyor was developed to eradicate the labor intensiveness involved in transporting grain into silo, bin or trailer to save time. The machine was fabricated using locally available materials; hence, the ease of maintenance and repair is ensured to the local/peasant users. This machine can be driven by electric motor where there is electricity or with an IC Engine where electricity is not available. The result obtained from the tests carried out on the conveyor indicated a 99.95% efficiency showing that the conveyor is effective to transport granular materials through an elevated location.

The improvement of the reliability of belt conveyor systems was studied by Liu [5]. The reliability of a belt conveyor system is the integrated reliability of all components. Considering idler rolls are still a big challenge for the reliable performance of belt conveyors, the study investigated how to improve the reliability of idler rolls and the emphasis of the research is on enhancing the predictability of idler roll failures. In order to design a belt conveyor, several considerations need to be taken into account [6], namely dimension, capacity and speed, roller diameter, belt power and tension, idler spacing, pulley diameter, motor power, and type of drive unit.

In this study, a design of belt conveyor to transfer sandblasting materials in sandblasting room as a replacement to the existing screw conveyor was examined. The belt conveyor was designed based on the capacity of the existing screw conveyor. The design includes the selection and calculation of rubber belt, the calculation of the power needed by the belt conveyor, and an improvement to make the belt conveyor as a special material handling system for sandblasting room.

2. METHODOLOGY

This study was carried out in the following ways: firstly reviewing of the existing screw conveyor, including conveyor capacity and transfer time; secondly determination of belt conveyor, including determining belt conveyor width and configuration based on the available belt and idler roller in the market; and finally doing calculation of belt conveyor capacity and transport time based on conveyor cross section area, material density, conveyor speed, and calculation of the power required to drive the belt conveyor.

2.1 Review of Existing Screw Conveyor Capacity

Since the new belt conveyor was designed based on the capacity of the existing screw conveyor, we need to know the existing conveyor capacity. The capacity discussed here means how much mass can be transported by the translational motion produced by the rotation of the screw conveyor. From existing studies, the rotational speed of the screw is directly related to the transport capacity. To determine the transmission capacity of a screw conveyor, apart from the rotational speed, we need to consider the dimensions and geometry of the conveyor and the characteristics of the material to be transmitted. As suggested by Dasanayaka [7], equation (1) can be used to calculate the screw conveyor capacity.

$$Q = 3600 \,.\lambda \frac{\pi(D-d)^2}{4} \,.\, \frac{t\,.n}{60} \,.\, \rho \,.\, k \tag{1}$$

Where

- Q Screw conveyor Capacity
- λ Fill coefficient of the section (see Table 1)
- D Screw diameter [m]
- d Shaft diameter
- t Screw pitch [m]
- n Screw rotating speed [rpm]
- ρ Material density [tons/m^3]
- k Conveyor housing inclination coefficient (see Table 2)

The value of Fill Coefficient of the Section (λ) of a screw conveyor is determined by the type of material characteristic to be transported. Table 1 shows load types and value of FCOS that can be used as a guide in calculating the capacity of a screw conveyor.

Table 1: Fill coefficient of the section (FCOS)

TYPE OF LOAD	λ
Heavy and Abrasive	0.125
Heavy and Little Abrasive	0.25
Light and Little Abrasive	0.32
Light not Abrasive	0.4

Table 2: Conveyor housing inclination coefficient

CONVEYOR HOUSING INCLINATION	0^o	0^o	0^o	0^o	0^o
k	1	0.9	0.8	0.7	0.6

The coefficient of the conveyor housing inclination (k) is basically influenced by the inclination of a screw conveyor housing installation. Table 2 exhibits the coefficient figures of conveyor housing inclination. In addition, the conveyor linear speed can be obtained using equation (2).

$$v = \frac{p \times n}{1000 \times 60} \tag{2}$$

where

- v Screw conveyor linear spees [m/s]
- p screw pitch [mm]
- n screw rotation speed [rev/minute]

Hence, the time taken for screw conveyor to transport steel grit from end to end based on the linear speed of the screw conveyor can be found using equation (3).

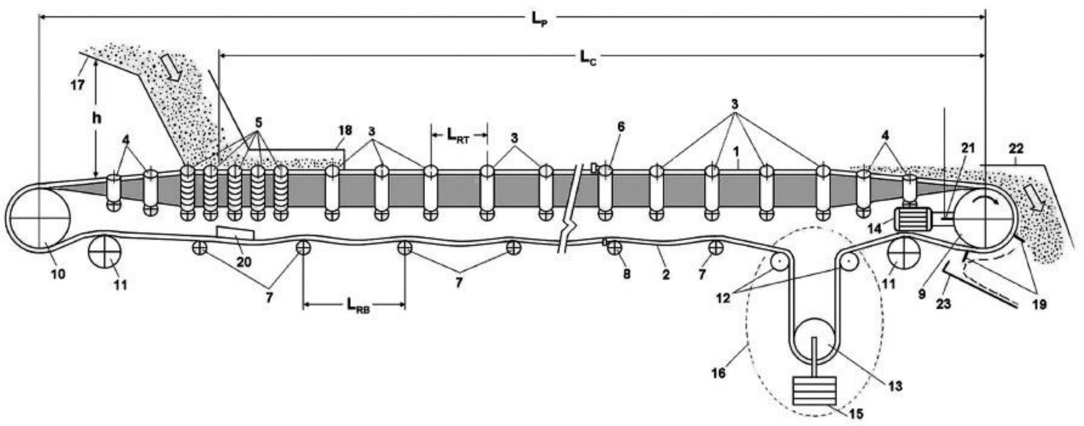
$$t = \frac{L}{v} \tag{3}$$

where

- t time take for transport from end to end [s]
- L length of screw conveyor [m]

2.2 Belt Conveyor Width and Configuration

Belt conveyor is a means of transporting goods or materials that are known to have high efficiency, especially for bulk materials because the operation can be used for short and long distances in accordance with the design of the belt conveyor itself, where the biggest operational cost in the operation of a belt conveyor is on energy consumption for move the belt conveyor. There are two ways to reduce the energy use of the belt conveyor: one being to improve the performance of the equipment and the other being to optimize operation parameters such as the belt speed. There are three suggested drive configurations by Mathaba *et al.* [8] that allow potential energy savings obtained from implementing, variable speed control, internal use of downhill conveyor energy and the export of energy to the grid. Figure 2 shows the components of belt conveyor [9].



1. Top strand of the belt
2. Bottom strand of the belt
3. Carrying troughing idlers/rollers
4. Transition idlers/rollers
5. Impact idlers/rollers
6. Carrying training idlers/rollers
7. Return idlers/rollers
8. Return training idlers/rollers
9. Drive or head pulley
10. Tail pulleys
11. Snub pulleys
12. Bend pulleys
13. Take-up pulleys
14. Drive motor
15. Counterweights
16. Vertical take-up arrangement
17. Feed chute
18. Skirt plates for guiding the material
19. Belt cleaners for the carrying side of the belt
20. Belt cleaner for the bottom side of the belt
21. Pulley cleaner
22. Discharge chute
23. Dribble chute.

Figure 2: The components of belt conveyor

2.2.1 Belt Width Determination

Before performing determination of the minimum value of belt width, the loading requirement and minimum belt width for troughing should be considered, which are extracted from Fenner Dunlop Conveyor handbook [10] (Table 3). To select the type and width of the conveyor belt to be used, a catalog from belt producer can be used as reference. Table 4 exhibits one of the catalog examples from Roulunds handbook [11].

Table 3: Minimum belt width for troughing

DESIGNATION	MINIMUM BELT WIDTH FOR TROUGH ANGLE [MM]		
	20°	35°	45°
ST500	600	600	600
ST1000	600	600	750
ST1600	600	750	900
ST3550	900	900	1050
ST5000	900	1050	1200

Table 4: RO PLY rubber belt data

BELT TYPE	MAX WORKING TENSION [N/MM]	THICKNESS [MM]	WEIGHT PER M^2 [KG]	BELT WIDTH [MM]					
				400	500	650	800	1000	1200
200 / 2	20	5.2	6.8	x	x	x	x	x	x
250 / 2	25	6.6	8.4	x	x	x	x	x	x
315 / 2	31.5	6.8	8.6	x	x	x	x	x	x
400 / 2	40	7.3	9.1		x	x	x	x	x
630 / 2	63	10.5	13.4			x	x	x	x

2.2.2 Configuration of Conveyor Roller Idler

The most usual configuration for conveyor roller idler is three rolls of equal length. The cross sectional drawing of the configuration shown in Figure 3. There is a common trough angle for three roller idlers of belt conveyor is 35°. Other trough angles are 25° and 45° but they are not commonly used in the belt conveyor with three roller idlers configuration, even though increasing the number of trough angle will increase the capacity of the belt conveyor [12].

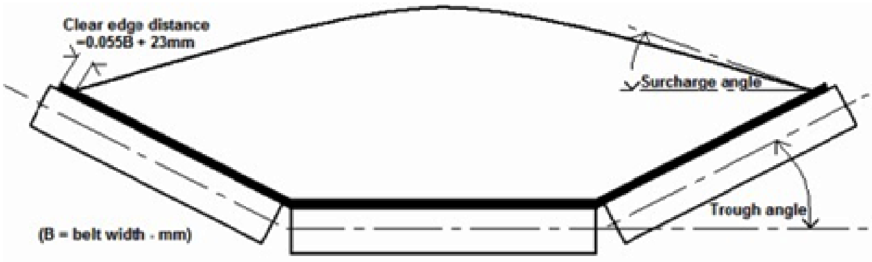


Figure 3: Troughed belt cross section [9]

3.3 Belt Conveyor Capacity Calculation

One way to determine the capability of a belt conveyor is to look at the capacity of the belt conveyor. To calculate conveyor belt capacity, the Fenner Dunlop handbook [10] and Erinofiardi [13] proposed equation (4) for calculating conveyor belt capacity.

$$C = 3.6 \text{ x } A \text{ x } \rho \text{ x } v \tag{4}$$

Where

- C Capacity [tons/h]
- A Conveyor's belt cross-sectional area [m^2]
- ρ Material density [kg/m^3]
- v Belt speed [m/s]

The cross-sectional area (A) can be calculated according equation (5) based on Figure 4.

$$A = \frac{\left(L+\frac{X}{3}\right).h}{2} \tag{5}$$

Where

X = Belt width [mm] (see Table 4)
L = X/3 + 2z [mm]
h = X/3 Sin 35^o [mm]
z = X/3 Cos 35^o [mm]

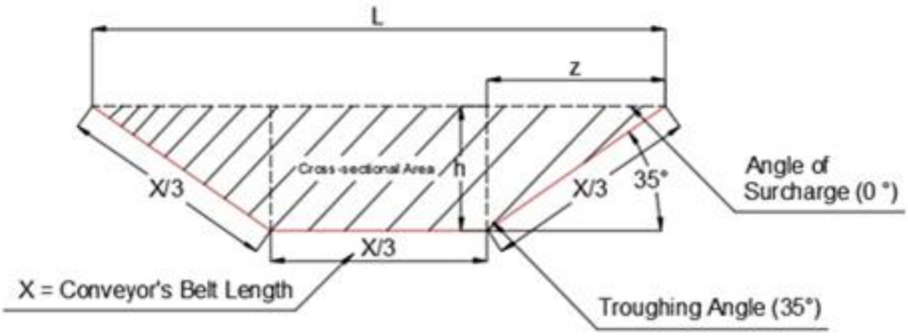


Figure 4: Conveyor's belt cross-sectional area

For materials with bulk density more than 1000 kg/m^3 can use equation (4) with the inclusion of Capacity factor (cf) for troughed belt that can be found in Table 5. Therefore, the modified basic equation for calculating the conveyor belt capacity with 3 roller idlers can be seen as in equation (6).

$$C = 3.6 \text{ x } A \text{ x } \rho \text{ x } Cf \text{ x } v \tag{6}$$

Where

- C Capacity [tons/h]
- A Conveyor's belt cross sectional area [m^2]
- ρ Material density [kg/m^3]
- Cf Capacity factor (See Table 6)
- v Belt speed [m/s]

Table 5: Capacity Factor – Three Equal Though Idlers

SURCHARGE ANGLE	IDLER TROUGHING ANGLE				
	20°	25°	30°	35°	45°
0°	0.43	0.53	0.61	0.69	0.81
5°	0.52	0.61	0.69	0.77	0.88
10°	0.61	0.70	0.77	0.84	094
15°	0.70	0.78	0.86	0.92	1.04
20°	0.79	0.87	0.94	1.00	1.08
25°	0.88	0.96	1.03	1.08	1.15

3.4 Belt Conveyor Speed Calculation

The available belt speed of the belt conveyor is influenced by three important factors such as belt conveyor capacity, belt width, and material density. However, in some cases the conveyor belt speed refers to the capacity of the belt conveyor to be designed, because the magnitude of the speed can change the capacity of the belt conveyor. Thus, by rewriting Equation (6) the belt conveyor speed can be calculated using equation (7).

$$v = \frac{C}{3.6 \text{ x } A \text{ x } \rho \text{ x } Cf} \tag{7}$$

3.5 Mass of Material Calculation

In determining belt width, it is necessary to consider the maximum working tension acting on the belt [14]. Therefore, to calculate the maximum working tension, it is necessary to first calculate the Mass of Material using the equation (8) as suggested by Vanamamne [15] :

$$M_m = C/(3.6 \text{ x } v) \tag{8}$$

Where

- M_m Mass of material [kg/m]
- C Belt conveyor capacity [tons/h]
- v Belt conveyor speed [m/s]

3.6 Pulley Diameter Selection

The pulley is one of the main parts of the belt conveyor which facilitates the angular and linear movement of the belt. While choosing the pulley diameter, it needs to consider the type of belt, number of plies for the belt and rated tension working on the belt. The rated working tension can be obtained from equation (9)

$$\text{Rated tension} = \frac{\text{Total working tension}}{\text{Maximum working tension}} \times 100\% \tag{9}$$

Therefore, the pulley diameter can be determined based on number of plies, rated working tension, and belt class, as it is shown in Table 6.

Table 6: Minimum pulley diameter

NO. OF PLIES	% RATED TENSION	BELT CLASS							
		200	250	300	400	500	630	800	1000
2	100	350	400	400	400	450	500	650	750
	80	300	350	350	350	400	450	500	600
	60	300	300	300	300	350	400	450	500
	40	250	250	250	250	300	350	400	400
	Tail & snubs	250	250	250	250	300	350	400	400

3.7 Revolution Speed of Belt Conveyor Pulley

The revolution speed of the conveyor belt pulley is a value that must be determined prior to finding the type of motor and gearbox that will be used in the design of the conveyor belt [12]. The conveyor handbook published by Fenner Dunlop [10] states that to calculate the revolution speed of the belt conveyor pulley, you can use the Equation (10):

$$N = \frac{v \times 1000 \times 60}{D \times \pi} \tag{10}$$

Where

- N The revolution speed of conveyor belt pulley [rpm]
- v Belt speed [m/s]
- D Pulley diameter [mm] (see Figure 4)

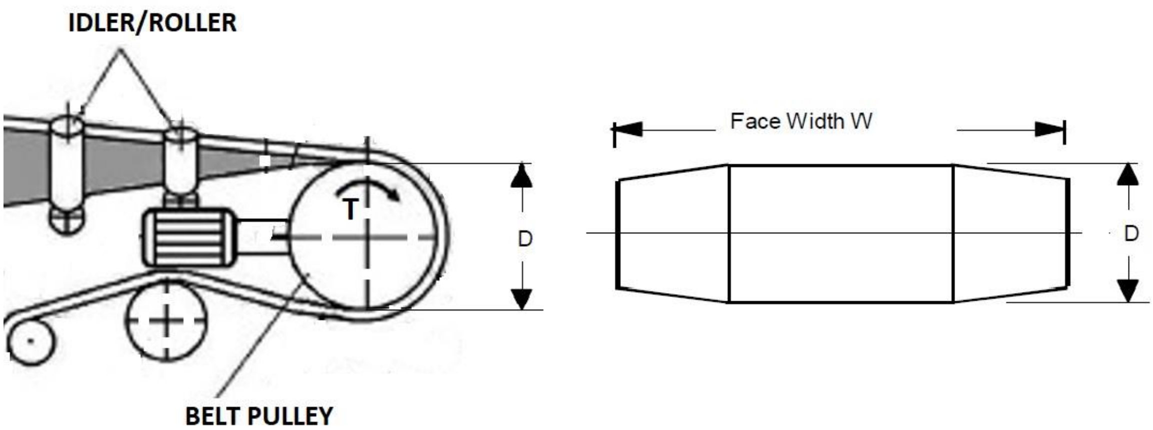


Figure 5: Belt pulley

3.8 Power Required to Run Belt Conveyor

In moving a belt conveyor system, it requires minimum power generated by an electric motor. To determine the minimum required power, one needs to calculate the effective belt tension T_e [14] using equation (11) as follows:

$$T_e = T_c + T_l \tag{11}$$

Where

$T_c = F_1 \times L \times C_w$

$T_l = F_2 \times L \times M_w$

T_c Tension required to move empty belt [N]
F_1 Normal friction factor for average condition to move empty belt (0.035)
L Belt length [m]
C_w Weight of conveyor belt component [kg]
T_l Tension required to move load horizontally [N]
F_2 Normal friction factor to move load horizontally [0.04)
M_w Material weight [kg/m]

Thus, the minimum power can be obtained using equation (12) as described by Sochib et al. [16] as follows:

$$P = T_e \times v \tag{12}$$

Where
P Belt power [kW]
T_e Effective belt tension [N]
v Belt speed [m/minute]

3. RESULT AND DISCUSSION

3.1 Existing Screw Conveyor Capacity

The first step in designing a belt conveyor fro replacing the existing screw conveyor in sanblasting room is finding the main data of the screw conveyor. The data obtained from the screw conveyor is needed to determine the capacity of the existing screw conveyor. Here are some data obtained from the observation on the existing screw conveyor, as shown in Table 7.

Table 7: Screw conveyor data

NO	DATA	SPECIFICATION
1	Screw Conveyor	12,000 (L) x 300 (ø) mm
2	Shaft	As ST 41 ø 5" + Pipe SCH 80, ø 5"
3	Screw Pitch (p)	130 mm
4	Screw Rotating Speed (n)	20 rpm
5	Motor Power	3.7 KW / 380 V/ 3 Phase /4 Pole
6	Bearing Unit	SKF, UCFS 313 ø 65 mm

Since the material type is abrasive, $\lambda = 0.125$, k =1, and $\rho = 7.6$ ton/m^3 [17].Therefore, by using Equation (1) the screw conveyor capacity can be calculated as below:

$$Q = 3600 \times 0.125 \times \frac{3.14\ (0.3-0.127)^2}{4} \times \frac{0.13\ .\ 20}{60} \times 7.6 \times 1 = 3.4785 \text{ ton/h}$$

The conveyor linear speed can be calculated using Equation (2) and based on the data in Table 9, as follows:

$$v = \frac{p \times n}{1000 \times 60} = \frac{130 \times 20}{1000 \times 60} = 0.043 \text{ m/s}$$

Hence, the time taken for screw conveyor to transport steel grit from end to end based on the linear speed of the screw conveyor can be found using the Equation (3) and based on the data in Table 9 is:

$$t = \frac{L}{v} = \frac{12}{0.0433} = 277.136 \text{ seconds}$$

3.2 Proposed Belt Conveyor Specification

A series of design and calculation of a new belt conveyor to replace the existing screw conveyor for transporting sandblasting material has been performed, by firstly reviewing of the capacity of existing screw conveyor system and secondly calculating and determining belt conveyor's configuration, dimension, speed, capacity, and power.

With refer to existing conveyor capacity, the capacity of belt conveyor is assumed equal to screw conveyor capacity, hence the by using Equation (7) belt conveyor speed is 0.003 m/s and using Equation (10) the pulley rotation speed is 0.205 rpm. Unfortunately, the gearbox that provide output 0.205 rpm is not available. Therefore, the lowest available output speed of gearbox taken from Chiaravalli catalogue[18] is selected, it exhibits that the lowest output speed (N) is 14 rpm and the output to input ratio being 1:100. Now, the conveyor belt speed being re-calculated become 0.256 m/s and hence the transfer time become 47 seconds.

To determine the diameter of the roller, there are 2 parameters that must be referred: the belt width and the type of roller configuration used in the design, so the selected roller diameter is 89 mm from the Transroll Catalogue [19].For more details, it can be seen in Table 8. The belt conveyor design data obtained from the previous calculation is summarized in Table 9. The capacity of the proposed belt conveyor is higher compared to the existing screw conveyor as it is exhibited in Table 10.

Table 8: Roller data

PARAMETER	VALUE
Roller Diameter	89 mm, Flat
Bearing Type	6204
Roller Length for 3 Roller Idlers	250 mm
Supporting Structure Width	950 mm
Maximum Belt Speed	3.15 /s

Table 9: Belt conveyor design data summary

NO.	DESCRIPTION	OBTAINED DATA	REMARKS
1	Rubber Belt Type	RO-PLY 250/2	Table 4 and Equation (8)
2	Belt Conveyor Capacity	236.81 ton/h	Equation (6)
3	Belt Width	650 mm	Table 4
4	Belt Speed	0.256 m/s	Equation (7)
5	Total Working Tension	20.166 kN/m	Equation (8)
6	Rated Tension on Belt	80%	Equation (9)
7	Belt Conveyor Pulley Diameter	350 mm	Table 8
8	Belt Conveyor Roller Diameter	89 mm	Table 10, Transroll Catalogue [19]
9	Motor Specification	1400 rpm, 9 kW	Equation (12)
10	Gearbox Ratio	100: 1	Chiaravalli catalogue [18]
11	Rpm Working on Pulley	14 rpm	Chiaravalli catalogue [18]

Table 10: Comparison between Existing Screw conveyor and proposed Belt conveyor

PARAMETERS	SCREW CONVEYOR	BELT CONVEYOR
Capacity	3.5 ton/h	236.81 ton/h
Linear speed	0.043 m/s	0.256 m/s
Transfer time	277 second	47 seconds

4. CONCLUSION

To improve operational activities in the sandblasting process, which frequently experienced obstacles caused by pillow block bearing damage of the screw conveyor and lack of efficiency in the transport of steel grit, a design of belt conveyor is examined to replace the screw conveyor as a more efficient material handling system and prevent the occurrence of existing problems. In terms of capacity, the capacity of the conveyor belt is far greater than the screw conveyor, which is 236.81 ton/h, where the screw conveyor only has a capacity of 3.4785 ton/h.

With belt speeds reaching 0.256 m/s, it enables the steel grit to return to the blasting pot from end to end of the conveyor belt in 47 seconds, which is almost 6 times faster than the screw conveyor which takes 277 seconds. Based on calculations, final data is obtained to be used in designing the belt conveyor for sand-blasting material handling systems. The calculation and design of belt conveyors are in accordance with international standards and product catalogues available in the market. In addition, to prevent the entry of steel grit into the components of the conveyor belt, a cover has been designed around the gap of each part of the belt conveyor.

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