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Design of Belt Conveyor to Reduce Loss Batch-Cullet

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Abstract

In a glass-making production process, the quality of the raw material is very important to produce good quality of glass. But sometimes not all of material have a good quality, there must be foreign object contamination in the raw materials so that do not match with the expected material quality and has an impact on rejected material and can interfere with the production process or the glass quality. The purpose of this paper is to reduce metal contamination, so that batch-cullet material is not wasted by designing and realizing a batch-cullet reject conveyor which consists of two conveyors. Conveyor A has a total length of 7.5 meters with a height of 3.5 meters, a slope of 20^0, has a power of 2.62 kW with a suspended magnet and metal detector. Conveyor B has a total length of 4.5 meters, has a power of 1.29 kW and both conveyors can accommodate a production capacity of 620000 kg / day. From the design of the two conveyors, it was found that the amount of batch-cullet loss per day was reduced by 87.92% from 7890 kg/ day to 952.6 kg/day

Keywords: batch-cullet, belt conveyor, metal, contaminant.

1. INTRODUCTION

The word of glass comes from Teutonic word "Glaza" which means yellow. The oldest blueprint that is found and printed on clay in 669-627 BC which describe the initial composition of glass making, there is 60 parts of sand, 180 parts of ash from marine plants and 5 parts of [1]. The properties of glass are unique and varied for chemical of glass, and can be adjusted by changing the composition or production technique of the glass [2]. Along with the development of the era, the method of glass making is growing [3]. The current most popular sheet glass production process is the float process method.[1]. The flow of the glass production process with the float process is illustrated in Figure 1

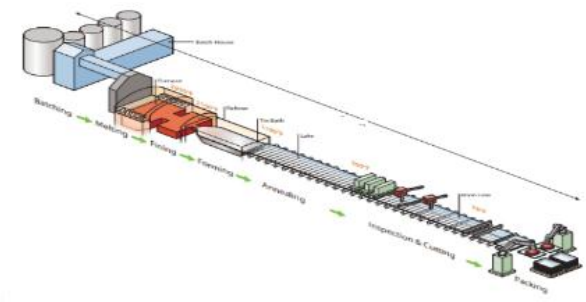

Figure 1. Flow production of float process [4].

One of the companies that produce flat glass is PT Muliaglass Float Division in Indonesia. Figure 2 describes the raw material batching process:

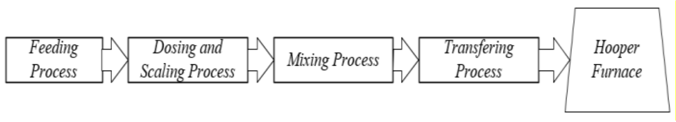

Figure 2. Batching process [5].

The problem that often occurs in the batching process is the amount of material that is discarded due contamination in the raw material, one of the sources of contamination in the glass raw material is from foreign objects [6]. According to Sugito, Head Section of The Batch Plan Department at PT Muliaglass Float Division Float 3, there are several types of contamination that cannot pass into the melting process such as metal, aluminium, and rock. Figure 3 shows the contamination that can be filtered out:

Figure 3. Examples of contaminations.

The wasted material of batch-cullet by metal contamination causes new problem. The problem is the waste batch-cullet that increase every day by metal contamination in the batch-cullet material. Figure 4 show that the one of flow process in Batch Plan:

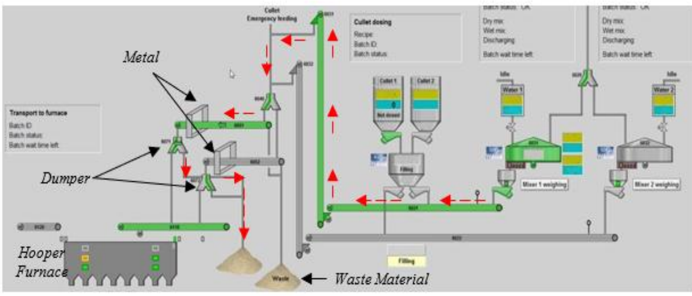

Figure 4. Flow process of batching-plan

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Observation of the area becomes a reference for designing a conveyor that can distribute batch-culet material and reduce metal contamination in the material. Belt conveyor system is an economical equipment for transporting large quantities of material [7]. The addition of this belt conveyor system is an innovation in the Batch Plan Department that is considered effective, because it has function to distribute and move material from one place to another place by adding a magnet which function is to attract metal contamination in the material and metal detector to detect metal contamination. Figure 5 shows the example of conveyor support structure:

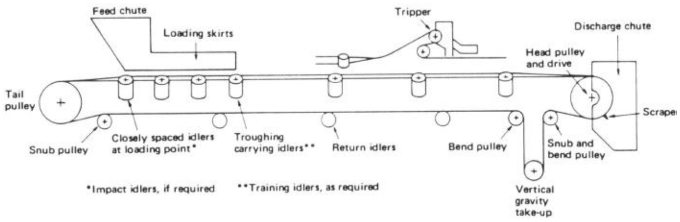

Figure 5. Support structure of belt conveyor [7].

2. METHOD OF DESIGN

The flow chart design of batch-cullet reject conveyor is shown in Figure 6:

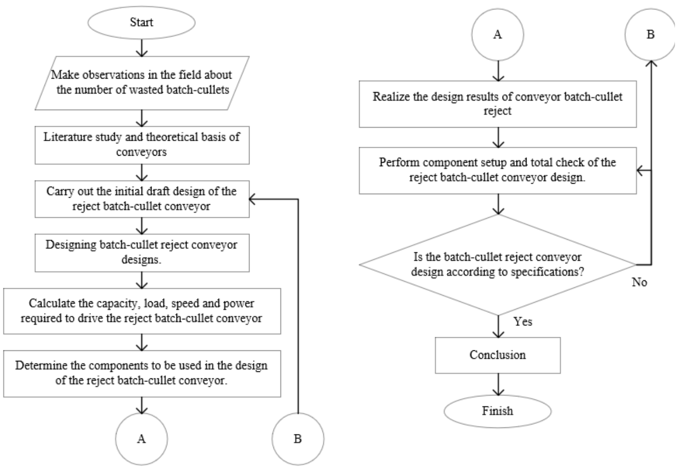

Figure 6. Flow chart of conveyor batch-cullet reject design.

The belt conveyor can be characterized by a belt or steel wire that rotates around a driving pulley supported by several roll with a structure [7]. The use of belt conveyors in several industries is different according to needs of each industry. In designing a conveyor batch-cullet reject there are several steps that need to be done. The first thing to do is conduct a field study on the wasted batch-cullet material, and then looking for literature on conveyor design [8-10], make the initial design of batch-cullet reject conveyor, determine what components will be used, then proceed with calculating the capacity, tension and power required, after that realize the conveyor of batch-cullet reject and then make adjustment of component and total checking all of components. If the design is successful, conclusions will be drawn. However, if it is not fit, it can be reset several components or make another priority design. To get more detailed technical data such as the capacity used, belt speed, tension and power required, and this is several equations can be used to calculate them [11]:

1. Capacity and belt speed:

$$Q_t = 3{,}6 \; x \; A \; x \; \gamma \; x \; k \; x \; v \qquad \dots (1)$$

Where,

Qt =Belt conveyor capacity (ton/hr)

A = Cross section area (m^2)

γ = Material density (kg/m^3)

v = Belt speed (m/s)

k = Incline or decline factor.

Table 1. Material Density [12].

Material	Density (kg/m3)	Angle of repose	Angle of surcharge
Chips, paper mill - *softwood*	190-480	*	25°
- *yellow pine*	320-400	*	25°
Clay - dry, loose	1010-1440	40°- 45°	15°- 25°
- *brick, ground fine*	1760	35°	15°
Coal - *150mm domestic sizes*	830-900	*	25°
- *run-of-mine*	720-880	35°	25°
- *slack*	690-800	37°	25°
- *pulverized for coking*	480-590	*	10°
- *lignite, broken*	720-880	*	25°
Cocoa	480-560	*	*
Coke - run of oven	400-480	30°	25°
- breeze	380-560	30°- 45°	20°
Concrete, wet, on conveyor	1760-2400	*	5°
Copper ores, crushed	2080-2400	*	25°
Copra	350	*	*
Corn grits	670	*	*
Cryolite - *50-75mrn lumps*	1600-1680	*	20°
- *15mm screenings*	1440-1600	*	15°
- *dust*	1200-1440	*	5°
Dolomite - *lump*	1440-1600	See limestone	*
Earth - *as excavated, dry*	1120-1280	30°- 45°	20°- 25°
- *wet, mud*	1600-1760	*	5°
Foundry refuse, old sand, cores, etc.	960-1280	*	15°
Garbage - *household*	800	*	*
Glass - *batch*	1680	*	*
- broken	1280-1600	*	*
Granite - *40-50mm lumps*	1360-1440	25°	*
- *15mm screenings*	1280-1440	*	*
- *broken*	1520-1600	*	*
Gravel -*dry, sharp*	1440-1600	30°- 45°	25°
- *wet*	1600-1920	32°	25°
Gutta percha	960	*	*
Gypsum - *50-75mm lumps*	1200-1280	30°	20°

Table 2. Cross section of load [11].

Belt Width		A-Cross-Section of Load (m^2)						A-Cross Section of Load (ft^2)					
		Surcharge Angle						Surcharge angle					
mm	(in)	0°	10°	15°	20°	25°	30°	0°	10°	15°	20°	25°	30°
450	(18)	0.008	0.012	0.014	0.016	0.017	0.019	0.089	0.128	0.147	0.167	0.188	0.209
600	(24)	0.016	0.023	**0.026**	0.030	0.033	0.037	0.173	0.246	**0.283**	0.320	0.359	0.399
750	(30)	0.026	0.037	0.043	0.048	0.054	0.060	0.284	0.402	0.462	0.522	0.585	0.649
900	(36)	0.039	0.055	0.064	0.072	0.080	0.089	0.423	0.596	0.684	0.774	0.866	0.960
1,050	(42)	0.055	0.077	0.088	0.100	0.112	0.124	0.588	0.828	0.950	1.074	1.201	1.332
1,200	(48)	0.073	0.102	0.117	0.132	0.148	0.164	0.781	1.099	1.260	1.424	1.592	1.765
1,350	(54)	0.093	0.131	0.150	0.169	0.189	0.210	1.002	1.407	1.613	1.822	2.037	2.258
1,500	(60)	0.116	0.163	0.187	0.211	0.236	0.261	1.249	1.753	2.009	2.270	2.537	2.812
1,800	(72)	0.170	0.238	0.272	0.308	0.344	0.381	1.826	2.560	2.933	3.312	3.701	4.102
2,100	(84)	0.233	0.327	0.374	0.423	0.472	0.524	2.513	3.519	4.030	4.551	5.085	5.635
2,400	(96)	0.307	0.430	0.493	0.556	0.621	0.689	3.308	4.631	5.302	5.986	6.687	7.411

Table 3."k" factor for incline and decline conveyor.

Belt Slope	5°	10°	15°	17,5°	20°
Cos φ	0.996	0.985	0.954	0.940	0.906

2. Effective tension and power requirment

$$T_e = L\ x\ K_t \left(K_x + K_{yc}\ x\ W_b + 0{,}015\ W_b\right) + W_m \left(L\ x\ K_{yr}\ \pm H\right) + T_x + T_y + T_z + T_{ac} \quad \ldots(2)$$

Where,

Te = Effective tension (kg).

T_x = The Tension to move the empty belt (kg).

$$= G\ x\ f_x\ x\ L_c \quad \ldots(3)$$

T_y = The tension to move the load horizontally (kg).

$$= W_m\ x\ f_y\ x\ L_c \quad \ldots(4)$$

T_z = The tension to lift the load (kg).

$$= H\ x\ W_m \quad \ldots(5)$$

T_{ac} = The tension as a result of adding accessories (kg).

$$= \frac{f_s\ x\ W_m\ x\ L_s}{v\ x\ b} \quad \ldots(6)$$

L = Horizontal length of conveyor (m)

Lc = Corrected length of conveyor (m).

K_t = Temperature ambient corrected factor

Kx = Idler friction factor (kg/m).

Kyc =Factors for calculating the belt force and flexure load on the idler roll. (0,022).

Kyr =Factors for calculating the belt force and flexure loan on the return roll (0,015).

W_m = Material weight (kg/m)

W_b = Belt weight (kg/m)

G = Mass of moving parts (kg/m) (Table 5)

f_s = friction coefficient for skirt board (Table 6)

f_y = friction coefficient for loaded belt (Table 6)

f_x = friction coefficient for empty belt (Table 6)

Table 4: Belt weight [12].

Belt Width (mm)	Belt Width (in)	Operating Conditions		
		Light Duty kg/m (lb/ft)	Medium Duty kg/m (lb/ft)	Heavy Duty kg/m (lb/ft)
500	20	4.1 (2.75)	6.2 (4.16)	10.3 (6.92)
600	24	5.0 (3.36)	7.4 (4.97)	12.3 (8.26)
750	30	6.2 (4.16)	9.3 (6.25)	15.5 (10.41)
900	36	7.4 (4.97)	11.1 (7.46)	18.5 (12.43)
1050	42	8.6 (5.78)	13.0 (8.73)	21.6 (14.51)
1200	48	9.8 (6.58)	14.8 (9.94)	24.7 (16.60)
1350	54	11.0 (7.39)	16.7 (11.22)	27.8 (18.68)
1500	60	12.3 (8.26)	18.6 (12.50)	30.9 (20.76)
1650	66	13.5 (9.07)	20.5 (13.77)	33.9 (22.78)
1800	72	14.7 (9,88)	22.3 (14.98)	37.0 (24.86)

Tabel 5: Mass of moving parts [12].

Belt Width (mm)	Belt Width (in)	Mass of Moving Parts (kg/m) (lb/ft)			
		Light Duty 4" Idlers Light Belt	Medium Duty 5" Idlers Moderate Belt	Heavy Duty 6" Idlers Heavy Belt	Extra Heavy Duty 6" Idlers Steel Cord Belt
450	18	23 (15.4)	25 (16.8)	33 (22.2)	
600	20	29 (19.5)	36 (24.2)	45 (30.2)	49 (33.0)
750	24	37 (25.0)	46 (31.0)	57 (38.3)	63 (42.3)
900	30	45 (30.0)	55 (37.0)	70 (47.0)	79 (53.0)
1050	36	52 (35.0)	64 (43.0)	82 (55.0)	94 (63.2)
1200	42	63 (42.3)	71 (47.7)	95 (63.8)	110 (74.0)
1350	48	70 (47.0)	82 (55.0)	107 (72.0)	127 (85.3)
1500	54		91 (61.2)	121 (81.3)	143 (96.0)
1650	60		100 (67.2)	132 (88.7)	160 (107.5)
1800	66			144 (96.7)	178 (119.6)
2100	72			168 (112.8)	205 (137.7)
2200	84			177 (119.0)	219 (147.2)

Table 6: Friction factor [12].

Symbol	Description	Value of the friction factor		
		Normal operating conditions. Horizontal length up to 250 m (820 ft)	Normal operating conditions. Horizontal length more than 250 m (820 ft)	Very well aligned structure. No tilted idlers. Horizontal length more than 500 m (1640 ft)
f_c	Friction coefficient for scrapers	0.600	0.600	0.600
f_s	Friction coefficient for skirtboards	0.650	0.650	0.650
f_x	Friction coefficient for empty belt	0.022	0.020	0.020
f_Y	Friction coefficient for loaded belt	0.027	0.022	0.020

3. Power of conveyor:

$$P = (T_e\ x\ v)/75 \quad \ldots(7)$$

Where,

P = Belt power (HP).

T_e = Effective tension (kg).

v = Kecepatan belt (m/min)

3. DESIGN OF CONVEYOR BATCH-CULLET REJECT

Conveyor design specifications are planned based on field conditions or installation areas which are also adjusted to production, so that it fits to the production process in the Batch Plan area, Table 7 describes the required conveyor specifications:

Table 7: Product design spesification

No	Item		Spesification	Wish / Demand
1	General Function	:	Capable to transport batch-cullet materials.	D
2	Performance	:	1. Transport capacity 620 tons/day or 150 times of mixing process.	D
		:	2. Capable to filtering metal contamination in batch-cullet reject.	W
3	Dimension	:	1. Conveyor A: maximal length of 8 meters with angle icnlined 30^0 dan maximal height of 5 meters.	W
		:	2. Conveyor B: maximal length of 5 meters.	W

The conceptual design of conveyor batch-cullet reject is arranged based on all the sub-functions listed in Table 8:

Table 8: Sub-function of conveyor batch-cullet reject**.**

No	Sub-function	1ST Solution	2ND Solution	3RD Solution	4TH Solution	5TH Solution	6TH Solution
1	Drive Arrangemnts	Single drive without snub pulley	Single drive with snub pulley	Tandem type single drive	Tandem drive	Dual drive	Multiple drive
2	Belt tension adjustment	*Screw take-up*	*Gravity take-up*	*Horizontal gravity type*	*Power sistem type*	-	-
3	Belt support	*2 Idler roll*	*3 Idler roll*	*5 Idler roll*	-	-	-
4	Contamination filter	*Suspended magnet*	*Suspended electro magnetic*	-	-	-	-
5	Contamination detector	Metal *detector*	-	-	-	-	-
6	Dumper drive	Motor	Pneumatic	-	-	-	-

The combined results of all function will form overall function that qualify the design product specification. There are several variants of solutions, design priority is given based on technical and fields need. The first option is considered to be the first priority that will lead to the selection of a conceptual design. Here is a combination of solutions with sub-function as the basis for conceptual design:

1. 1ST conceptual design: 1-1, 2-1, 3-2, 4-1, 5-1 and 6-2.
2. 2ND conceptual design: 1-2, 2-1, 3-3, 4-2, 5-1 and 6-1.
3. 3RD conceptual design: 1-1, 2-1, 3-3, 4-1, 5-1 and 6-2.
4. 4TH conceptual design: 1-2, 2-1, 3-2, 4-1, 5-1 and 6-2.

The conceptual design is determined based on the assessment of each alternative solution based on the technical requirements and operational conditions in the area and the first conceptual design variant is the main priority. Based on the specification in Table 1, the drive system uses a single drive without a snub pulley, belt tension adjustment using screw take-up [13], belt support using 3 idler-roll [14], contaminant catcher using a suspended magnet [15], contamination detector using a metal detector and dumper driver using a pneumatic system [16-17].

4. DETAIL DESIGN OF CONVEYOR BATCH-CULLET REJECT

Figure 7 shows the design of batch-cullet reject conveyor which consist of two types of conveyor, first conveyor is conveyor A (inclined conveyor) and the second one is conveyor B (horizontal conveyor).

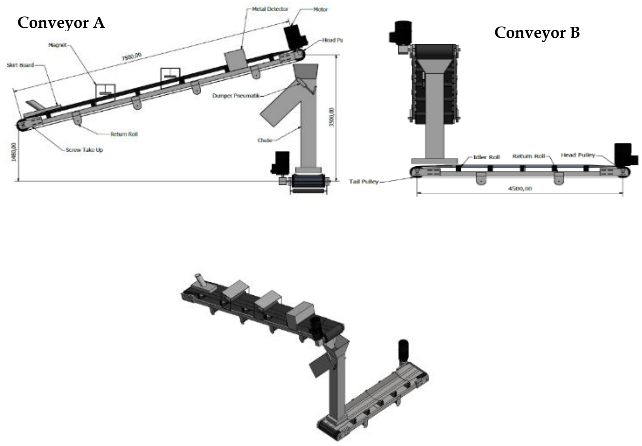

Figure 7: Design of batch-cullet reject conveyor.

Figure 7 shows the detailed design of batch-cullet reject conveyor that has been adjusted to the specification needed and with the conceptual design that has been determined. The technical data for conveyor batch-cullet reject will be described based on the equation used to calculate the conveyor capacity, belt speed, the tension generate by the belt and the power required of batch-cullet reject conveyor.

1. Conveyor A

- The conveyor capacity to be used is based on production capacity = $\frac{620\ ton/day}{150\ mixing\ x\ 60}\ x\ 1000\ =\ 68.83$ kg/s
- Belt speed:

$$v = \frac{Q_t}{3{,}6\ x\ A\ x\ \gamma\ x\ k} = \frac{68{,}83}{3{,}6\ x\ 0{,}043\ x\ 1680\ x\ 0{,}906} = 0.292\text{m/s} \quad \ldots(1)$$

- Tegangan efektif:

$$T_e = L\ x\ K_t\left(K_x + K_{yc}\ x\ W_b + 0{,}015\ W_b\right) + W_m\left(L\ x\ K_{yr} \pm H\right) + T_x + T_y + T_z + T_{ac} \quad \ldots(2)$$

Where,

Tx = 67.62 kg …(3)

Ty = 137.10 kg …(4)

Tz = 229.32 kg …(5)

Tac = 217.68 kg …(6)

L = 7.5 meters

W_m = 65.52 kg/m

Wb = 9.9 kg/m

G = 39.66 kg/m

K_{yc} = 0.022

K_{yr} = 0.015

Kt = 1

Kx = 1.96 kg/m

Then,

$$T_e = L \, x \, K_t \left(K_x + K_{yc} \, x \, W_b + 0{,}015 \, W_b\right) + W_m \left(L \, x \, K_{yr} \pm H\right) + T_x + T_y + T_z + T_{ac}$$

= 7.5 x 1 (1.96 + 0.022 x 9.9 + 0.015 x 9.9) + 65.52 (7.5 x 0.015 + 3.5) + 67.62 + 137.10 + 229.32 + 217.68

= 905.81 kg

- Power of conveyor :

$$P = \frac{T_e \, x \, v}{75} = \frac{905.81 \, x \, 0.292}{75} = 3.52 \text{ HP} = 2.62 \text{ kW}$$ …(7)

2. Conveyor B

- The conveyor capacity to be used is based on production capacity = $\frac{620 \, ton/day}{150 \, mixing \, x \, 60} \, x \, 1000 =$ 68.83 kg/s
- Belt speed:

$$v = \frac{Qt}{3{,}6 \, x \, A \, x \, \gamma} = \frac{68{,}83}{3{,}6 \, x \, 0{,}043 \, x \, 1680} = 0.264 \text{ m/s}$$

- Tegangan efektif:

$$T_e = L \, x \, K_t \left(K_x + K_{yc} \, x \, W_b + 0{,}015 \, W_b\right) + W_m \left(L \, x \, K_{yr} \pm H\right) + T_x + T_y + T_z + T_{ac}$$ …(2)

Where,

Tx = 65 kg …(3)

Ty = 145,79 kg …(4)

Tz = 229.32 kg …(5)

Tac = 266.35 kg …(6)

L = 4.5 meters

W_m = 72.48 kg/m

Wb = 9.9 kg/m

G = 39.66 kg/m

K_{yc} = 0.022

K_{yr} = 0.015

Kt = 1

Kx = 1.96 kg/m

Then,

$$T_e = L \, x \, K_t \left(K_x + K_{yc} \, x \, W_b + 0{,}015 \, W_b\right) + W_m \left(L \, x \, K_{yr} \pm H\right) + T_x + T_y + T_z + T_{ac}$$

= 4.5 x 1 (1.97 + 0.022 x 9,9 + 0.015 x 9.9) + 72.48 (4.5 x 0.015 + 0) + 65 + 145.79 + 0 + 266.35

= 492.54 kg

- Power of Conveyor

$$P = \frac{T_e \, x \, v}{75} = \frac{492.54 \, x \, 0{,}264}{75} = 1.73 \text{ HP} = 1.29 \text{ kW}$$

The detail design of batch-cullet reject conveyor produces technical specification for conveyor A and conveyor B which are described in Table 9 based on the calculation that have been carried out

Table 9: Technical spesification

Conveyor A		Conveyor B	
Technical Spesification		**Technical Spesification**	
1. General Data Conveyor		**1. General Data Conveyor**	
Length	: 7.5 meter	Length	: 4.5 meter
Height	: 3.5 meter	Height	: -
Max Inclined	: 20^0	Max Inclined	: -
Capacity	: 68.83 kg/s	Capacity	: 68.83 kg/s
Belt Speed	: 0.292 m/s	Belt Speed	: 0.264 m/s
Belt Width	: 800 mm	Belt Width	: 800 mm
Effective Tension	: 905.81 kg	Effective Tension	: 492.54 kg
Conveyor Power	: 2.62 kW	Conveyor Power	: 1.29 kW
2. Pulley Diameter		**2. Pulley Diameter**	
Head Puley Diameter	: 406 mm	Head Puley Diameter	: 406 mm
Tail Pulley Diameter	: 318 mm	Tail Pulley Diameter	: 318 mm
3. Carry Roll		**3. Carry Roll**	
Idler Roll Diameter	: 101,6 mm	Idler Roll Diameter	: 101,6 mm
Idler Roll Length	: 200 mm	Idler Roll Length	: 200 mm
Idler Roll Spacing	: 1200 mm	Idler Roll Spacing	: 1200 mm
Troughing Angle	: 20^0	Troughing Angle	: 20^0
4. Return Roll		**4. Return Roll**	
Return Roll Diameter	: 106,68 mm	Return Roll Diameter	: 106,68 mm
Return Roll Spacing	: 1800 mm	Return Roll Spacing	
5. Skirt Board		**5. Skirt Board**	
Length	: 1000 mm	Length	: 1000 mm
Width	: 670 mm	Width	: 670 mm
6. Material Data		**6. Material Data**	
Material Density	: 1680 kg/m^3	Material Density	: 1680 kg/m^3
Surcharge Angle	: 10^0	Surcharge Angle	: 10^0
Cross section of load	: 0.043 m^2	Cross section of load	: 0.043 m^2

3. RESULTS

After getting the technical spesification of the batch-cullet reject conveyor which is show in Table 9. The next thing to do is to realize the design and evaluate the results of the batch-cullet reject conveyor to reduce loss batch. Figure 8 is the result from design of batch-cullet reject conveyor based on conceptual design and detail design of batch-cullet reject conveyor

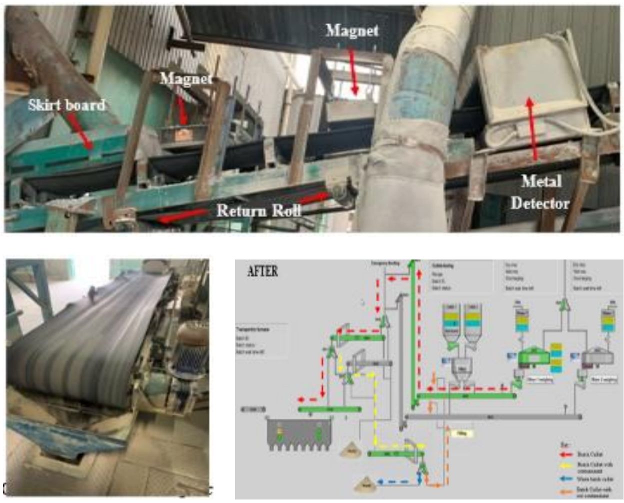

Figure 8: Conveyor A, Conveyor B and flow process of batching-plan after designing

The design of this batch-cullet reject conveyor affect the amount of batch-cullet loss produced per day, where the loss batch-cullet per day is 7890 kg. After the batch cullet reject conveyor realize, loss batch-cullet decreased by 87% or 952.6 kg per day. Figure 9 shows the difference in the number of batch-cullet reject produced per day before and after designing.

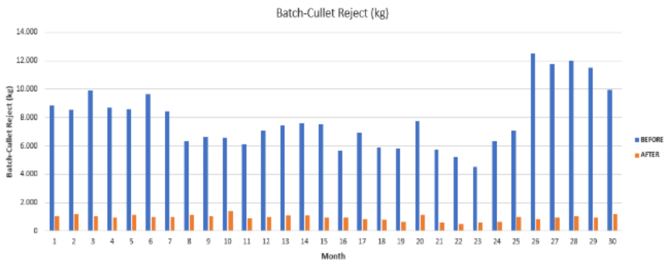

Figure 9: Loss batch-cullet.

Based on the results, that batch-cullet reject conveyor is able to reduce loss batch-cullet caused by metal contamination and the design result is qualify with specification which can accommodate a production capacity around 620000 kg per day and can split contamination in batch-cullet. Where the length of the conveyor A is 7.5 meters, 3.4 meters of conveyor height, slope angle is 20^0 and suspended permanent magnet and metal detector. The conveyor B has a 4.5 meters of conveyor length without magnet and metal detector

4. SUMMARY AND CONCLUSION

This paper describes the innovation of batch cullet recycling design that is contaminated by metal. Design of a belt conveyor using a single drive system without snub pulley, adjusting belt with screw take-up, belt support with 3 idler rolls, metal catcher with suspended permanent magnet, contamination detector with metal detectors and driving dumper with pneumatic system have been successfully and according to specifications.

The total length of the conveyor A is 7.5 meters, the height is 3.5 meters, conveyor angle is 20^0, and power generate by the conveyor is 2.62 kW with suspended permanent magnet as a contaminant catcher and metal detector as a contaminant detector. The total length of the conveyor B is 4.5 meters and power generate by conveyor B is 1.29 kW. The application of this conveyor batch-cullet reject is effective in reducing batch-cullet reject affected by metal contamination. The number of batch-cullet reject is reduced from 7890 kg/day to 952.6 kg/days or around 87.92% of 7890 kg/day

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