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Design of Scraper Conveyor for Palm Oil Mills Industry

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Abstract: The handling process of oil palm fresh fruit bunch (FFB) from its loading site to the sterilizer in a palm oil mill is a crucial process, and should be carryout efficiently conceivably to maintain the quality of crude palm oil (CPO) extracted. There are a small number of machines being used in palm oil industry are incapable to transport the desired amount of palm oil fruit bunches, which practically influencing the CPO extraction progress. To overcame that, a scraper conveyor for the use of oil palm FFB transportation from reception site to sterilizer in palm oil mill is designed, to replace handling mechanism of human operated machine. A simulated computer aided design (CAD) model for the conveyor designed had been developed, by referring to suitable resources of mechanical parts supplier. The designed conveyor had a theoretical transportation capacity of 150 tons per hour, it can handle FFB to 10m higher from the inlet level. The length of the conveyor designed can be altered accordingly to suit specific situation since it is composed from various number of casing that detachable.

Keywords: Scraper Conveyor, Fresh Fruit Bunches, Computer Aided Design

1. Introduction

Conveyor system is a fast and efficient mechanical handling equipment that spontaneously deliver loads and materials within certain track or orbit, able to move almost all imaginable materials effectively from certain position to another, and are very convenient for industry relate with heavy, sharp, raw material, and mass-produced products [1]. Conveyor as a material handling system, does not add value to the product, but usually adds unignorable cost [2]. Therefore, a good design is essential to ensure that system will provide expected benefits.

The type of conveyor discussed was scraper conveyor (SC), it is a type of drag conveyor, mainly composed of driving unit, hydraulic coupling, reducer, shaft coupling, sprocket, pipe casing so called trough, a feed inlet, a discharge outlet, tensioner, traction components including long chain and numerous of flights [3], is suitable for slower transportation speeds, shorter distances, and moderate inclines. Currently, palm oil milling industry is being dominated by South-east Asia. There are plenty of processes in a palm oil mill, from reception of (FFB) to waste disposal. The used of SC are inevitable

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in a palm oil mill including transportation of oil palm fruit bunch from a work station to another during different process for instance it conveys FFB to a sterilizer.

This design mainly focuses on the SC for the use of FFB handling and transfer. Currently, there are a small number of conveyors being used in palm oil industry are incapable to transport the desired amount of palm oil fruit bunches, which practically influencing the CPO extraction progress. Or in the worst case, the fruit bunches handling process in a smaller palm oil plant is done by human operated machine such as crane or forklift. In this case, properly design on the fruit bunches handling conveyor, or more precisely, SC is required, consequently to achieve a sufficient amount of fruit bunches capacity in those palm oil mill.

The objective of this study is to design a SC for the use of oil palm FFB transportation in palm oil mill. Specifically, in between the FFB reception to sterilizer, to replace handling mechanism of human operated machine, and to develop a simulated computer aided design model for the conveyor designed.

2. Methodology

With the flow chart shown in the figure below, the design process is explained. Design of the SC includes identifying the basic specification of the conveyor, selection of conveyor component, design of the shaft used, etc. The design process is including various educated assumptions, either on specific part parameter or the situation. The design flow chart is show in Figure 1.

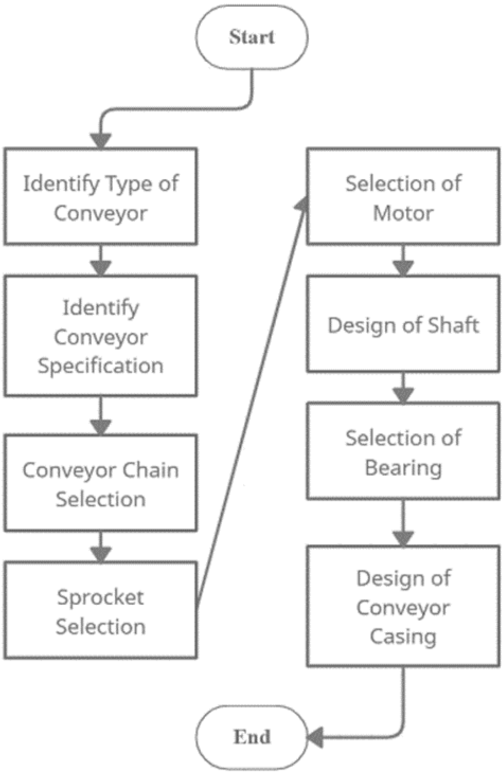

Figure 1: Design Flow Chart

2.1 Components Selection and Design

The type of conveyor is selected from either scraper conveyor with sliding chain, or with rolling chain, its layout is identified depending the situation assumed. Conveyor specification including its capacity, length and width is identified by assuming the average size of FFB using its known average volume and density. Next, design of scraper is carryout by using CAD program, this is done before the selection of chain, in order to identify the scrapers' mass that will required in the calculation of chain pull. The factor to be concern when designing scraper is the scraper shape, analysis on the scraper needed to done with the CAD application too, to ensure the reliability and rigidity.

Next, conveyor chain, the selection is complying to Renold's designer guide [4], while the chain is selected from challenge chain catalogue [5]. The type of chain is first selected, followed by decision of chain pitch size, calculation of chain speed, masses to drive, coefficient of friction, and required parameters. The relationship between chain speed and conveyor capacity can be formulated in equation 1 below.

$$Load\ capacity\ per\ length(kg/m) = \frac{Capacity(kg/s)}{Chain\ Speed(m/s)} \qquad \text{Eq. 1}$$

Consequently, selection of sprocket is critical because it directly connected to the conveyor chain, it must select according to the chain's pitch. This selection of the sprocket is accordance to Renold's guide, it is selected under the recommended maximum chain speed. With a suitable sprocket size chosen, the head shaft RPM can be identified, shown in equation 2 below.

$$RPM = \frac{Chain\ speed(m/s) \times 60}{Sprocket\ pitch\ circle\ diameter(m) \times \pi} \qquad \text{Eq. 2}$$

The motor selection process is done according to Renold R series catalogue [6]. The process of selecting motor is first determine the service factor, followed by identify the requirement specification such as the speed and torque at the output. Then, determine the motor that is best for the application by refer to the selection table, the selected motor should always have one motor size larger than absorbed power.

The shaft is designed to connect sprocket and bearing at each end of the shaft. With the aided of simple conveyor shaft's free body diagram, calculation of bending moment and twisting moment (torque) on the shaft had to be carried out. The minimum shaft diameter is then determine using equation 3 below.

$$d = \left(\frac{16n}{\pi}\left\{\frac{1}{S_e}\left[4\left(K_f M_a\right)^2 + 3\left(K_{fs} T_a\right)^2\right]^{\frac{1}{2}} + \frac{1}{S_{yt}}\left[4\left(K_f M_m\right)^2 + 3\left(K_{fs} T_m\right)^2\right]^{\frac{1}{2}}\right\}\right)^{\frac{1}{3}} \qquad \text{Eq. 3}$$

The bearing selection process will be accordance to SKF Roller Bearing Catalogue [7]. The performance and operating conditions are first to be identified, followed by selecting bearing types base on the condition at the connection with the shaft, then identify bearing size, lubrication condition, operating temperature and speed, bearing execution, and lastly sealing, mounting and dismounting.

2.2 Design of Conveyor Casing

This whole process is done by using Solidworks CAD software, some feature to be considered is the chain guiding track, allow rollers to be rolling and running on it. The casing should be reinforced by certain structure of material to act as the reinforcement, for example ribs, in order to strengthen the design. Another factor is the size of inlet and outlet of the conveyor had to be emphasized, to ensure the loading and unloading can run in a smooth condition. Last, a layer of protective lining is needed to be pasted or mounted on the chain guiding track and also the conveyor floor, to reduce the direct wear on the conveyor body itself, this helps to ease the maintenance process.

3. Results and Discussion

3.1 Results

The overview of the design model is shown in the Figure 2.

Figure 2: Full 3D Model of SC Designed

It composed of 13 total sections of casing from 5 different casing varieties, two shafts with dissimilar length, 4 bearings, 4 bearing housings, 4 sprockets, two stands of chains, 102 scrapers, a coupling connecting headshaft and motor, and a geared motor. Next, the following simple table give an overall view of all designed and selected parts, including dimensions and the considerations when designing/selecting these parts.

Table 1: Example of presenting data using a table

Parts	Term	Consideration	Selection/Decision
Overall conveyor characteristics	Conveyor Type	Able to operate even with FFB fruitlet exist Suitable for FFB size	Scraper Conveyor
	Conveyor Layout	Loading of FFB in horizontal level and different in level between FFB inlet and outlet (Experienced max. inclination is 30°)	Horizontal + inclined (28° from horizontal)
	Capacity	Experienced capacity limitation is 300TPH	Take about half, 150TPH
	Length	Assumption, needed outlet level is higher than inlet for about 10m	10m horizontal+20m Inclined
	Sectional width	The FFB diameter calculated assuming it is in ellipsoid shape (> 420.7mm)	About two of assumed FFB diameter, 800mm
	Sectional high		TBD in sprocket design
Design of scraper	Shape	Cylindrical shape, reduce the mass	Hollow pipe shape
	Distance between scrapers	Max. pitch of chain catalogue is 152.4	Assumed 4 times of pitch 609.6mm
	Material	Force endured for each scraper	ASTM A36
Chain Selection	No. of chain strand	Reduce (split) chain pull for each chain strand	Double strands
	Chain pitch	Largest in selected category (palm oil Chain)	152.4mm
	Chain Selected	Mass of load, 138kg/m	RCC-Z260C152.4-EP4
		Mass of chain, 11.7kg/m	

		Coefficient of friction and parameter assumed	
		Chain pull required, 40904.7N	
	Chain speed	Capacity, FFB transfer per meter Experienced limitation speed, 0.5m/s	0.302m/s
	Required power	Chain pull, chain speed	11.43kW

Table 2 (continued): Example of presenting data using a table

Sprocket Selection	No. of teeth	Max. recommended speed Normal teeth range for SC, 8-12, More teeth, increase stability	12
	PCD	Greater than 420.7mm, no. of teeth	588.82
	Sprocket Selected	Chain pitch, no. of teeth	202305##
Motor Selection	Service factor:	Load classification, start factor	1.5
	Motor selected	Required power, 11.43kW	R1632112BMC-B315.A—(15kW, 12rev/min, 11250Nm)
		Required speed, 9.8rev/min (calculated using chain speed and PCD)	
		Required torque, 11138.4Nm	
		Mounting position, base mounted, position 1	
Design of Shaft	Length of shaft	2 chains attached separate by 887.13mm	TBD in bearing and casing design
	Max. Moment:	Chain pull (static)	6135.7Nm
	Min. diameter:	Calculated with 2 FS, 120mm Selected sprocket max. bore is 110mm	110mm
	Material	To withstand endurance limit	AISI 1050 cold drawn
Coupling Selection	Service factor	Chain type conveyor	1.0
	Coupling type	Type (metallic), Shaft capacity range, Max. torque capacity	Grid
	Coupling selected	Selected motor torque, 11250Nm	1120 TGH
		Selected motor shaft diameter, 120mm	
		Headshaft diameter, 110mm	
Bearing selection	Bearing type	Loads are considered almost pure radial	Spherical roller bearing
		Misalignment may occur	
		No requirement in super precision	
		No shoulder, way to ensure axial positioning taper bore	
	Bearing size (life)	Required rating life, 30000hours	TBD
		Shaft diameter, 110mm	
		Fatigue load limit	
	Bearing selected	Bearing type and size	22224 EK
	Adapter sleeve selected	Selected bearing has tapered bore	H 3124
Design of Casing	Ease of manufacture	Too long to be manufact overall	Divided into several part
		Too large to be manufact	Composed by steel thin plate
	Strength	Between two conveyor walls	Truss connected between two walls
		Below the conveyor floor	Reinforced below conveyor floor
	Cut out of FFB loading and unloading	Inlet and outlet	Inlet - at 3 of the horizontal casings' side Outlet – at last casing (conveyor head)
	Sustainability	Wear and tear on conveyor floor	Protective thin steel plate adapted along the floor.

4. Conclusion

The conveyor is designed to assist the handling of FFB from the reception site to FFB sterilizer in a palm oil mill. The design doesn't belong to a certain case study, hence a lot of parameters are assumed in the design process. It has a rated capacity of 150 TPH, which best operates with a chain speed of 0.302m/s. It required to be working with a FFB reception site that utilize the principle of gravity, meaning that the FFB should load to the conveyor in the aid of gravity. It has a FFB inlet of 7.5m long at the horizontal section. Besides, it can transfer the FFB to a level that approximately 10m higher from its inlet.

The CAD model for the designed conveyor had been done. However, the model for the part selected, including chains, sprockets, motor, and coupling is produced depending on limited dimension of each part from their corresponding catalogue. Meanwhile for the bearing and its adapter sleeves, the 3D CAD file is obtained through its official source, which is SKF website.

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