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Design of A Screw Conveyor in Palm Oil Mill Malaysia

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Abstract: Moving heavy goods, sharp items, raw materials, and mass-produced products are extremely helped by screw conveyors. During the process of dry separation of palm kernel mixture, there is a screw conveyor between the outlet of the cracking machine and the inlet of the winnowing column system, where the screw conveyor is used to convey the mixture of kernels and shells to the winnowing column system to carry out dry separation process. There is no standard design practice for engineer for designing purpose to design a proper screw conveyor for palm oil mills in Malaysia. The purpose of this project is to design a screw conveyor to convey the mixture of kernels and shells of palm fruits in dry separation process in palm oil mills. The design and analysis of screw conveyor is done to select appropriate components according to an assumed situation. Furthermore, this project also has to design a 3D model for screw conveyor to carry out appropriate analysis to have proper design of screw conveyor by generating the 3D model after designing the screw conveyor and selecting the components for screw conveyor. Additionally, the 3D model of screw conveyor is completed and analysed by using SolidWorks software to evaluate the product specification. The final design of screw conveyor is expected to convey the mixture of palm kernels and palm shell with an assumed capacity of 1000kg per hour.

Keywords: Screw Conveyor, Dry Separation Process, Palm Kernel Mixture

1. Introduction

The screw conveyor is widely used in palm oil mills as bulk handling system. It plays an important role to contribute a great service for palm oil mills in Malaysia unless it will affect directly to the production rate of the palm oil mills. There is uses of screw conveyor in dry separation process of palm fruit, which convey the mixture of the palm shells and palm kernels. However, there is no standard design practice for engineer to design a screw conveyor for palm oil mills in Malaysia. The design process of screw conveyor is complicated if the screw conveyor is designed without follow the standard operation procedure step by step. The purpose of this research is to design a screw conveyor to convey the mixture of kernels and shells of palm fruits in dry separation process in palm oil mills and to design

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a 3D model for screw conveyor to carry out appropriate analysis to have proper design of screw conveyor. The screw conveyor is expected to convey the 1000kg/hour palm mixture with 30 degrees of inclination.

2.1 Roles of Screw Conveyor in Palm Oil Mills

In this session, the applications of screw conveyor will be discussed since the screw conveyor plays an essential role in palm oil mills. In this project, the screw conveyor used in dry separation will be discussed. First, the screw conveyor is used as under thresher conveyor in threshing station and convey the palm fruit to next screw conveyor [1]. This screw conveyor known as Bottom Cross onveyor is used in the palm threshing station, to convey the palm fruit which the bunches is separated to the elevator from next section. The palm fruit is the elevated to digester [1].

Before entering the digester, the Distributed Screw Conveyor is used to receive the palm fruit from the fruit elevator. Furthermore, when the fibrous bulk material is between the process of digester and screw pressing process known as Digester Feed Conveyor, the screw pressed is mounted below a crew conveyor and it is feed by a horizontal digester. The perforated screw conveyor is allowed to release the oil in digester [2] [3]. The Fruit Recycle Conveyor from pressing station is also one of screw conveyor used to convey the extra palm fruit from upper distributing conveyor to bottom distributing conveyor before entering the digester [4].

During the process of dry separation of palm kernel and palm shell, there is a screw conveyor between the outlet of the cracking machine and inlet of winnowing column system, where the screw conveyor is used to convey the mixture of kernels and shells to the winnowing column system to carry out dry separation process [5].

2.2 Dry Separation Process

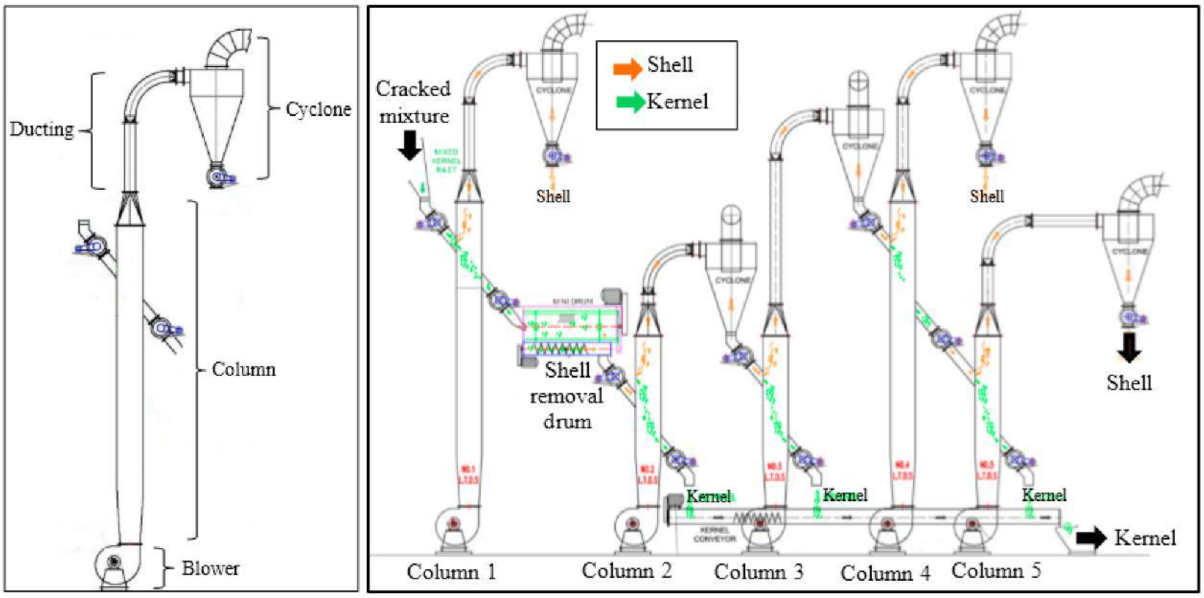


Figure 1: The Winnowing Column System [5]

The purpose of dry separation process is to separate the kernels and shells of palm fruit. Most of the shell is discharged after cyclone unit in 1st column. Hence, by sending the kernel and heavy shell to 2nd column, and most of the kernels are discharged. In 3rd column, the remaining shells and light kernels from 2nd column will be transferred. The process will be repeated until column 5 if there are still remaining of small broken kernels and small shell. As mentioned previously, the screw conveyor is used to convey the mixture of kernels and shells from 3rd stage cyclone to the 4th stage separating column [5].

Other than that, there is another method for dry separation process which known as vibrating table [6]. Pouring the cracker mixture on the top of vibration table and the vibrating table will be vibrated mechanically. As the vibrating table vibrates, the kernels will be moved to the other side of table and the shell will be moved to another side, and therefore the cracker mixture is separated. However, the separation rate is lower when there is used of winnowing column system. In fact, the cracked mixture is hard to separate by only gravity since the weight of palm kernel and shell are close.

Methodology

Figure 5 shows the flow chart of this project. The research is conducted until methodology in final year project 1 whereas the design and analysis until the conclusion are done in this porject. The design flow chart is illustrated below.

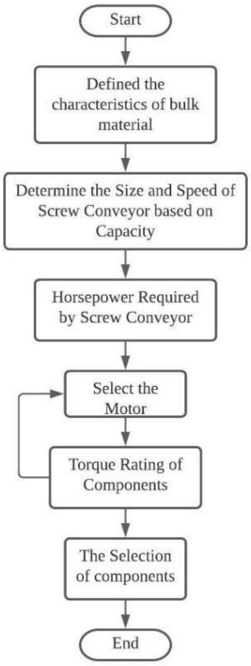


Figure 2. Design Flow Chart of Screw Conveyor

3.1 Design and Analysis of Screw Conveyor

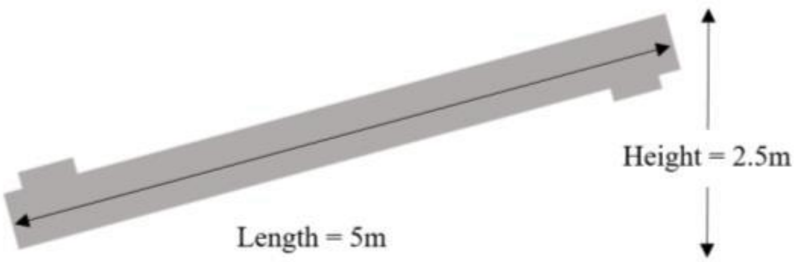


Figure 3: Layout of Screw Conveyor

3.1.1 The Characteristics of Bulk Material

Since there is missing information about palm kernels and shells in bulk material table, the assumption is made for all bulk material characteristics except maximum particle size and bulk density, which tung nuts is assumed as its bulk material characteristics is similar with palm kernels and shells. The average length, width, thickness for tung nut were 22.61 mm, 20.35 mm, 13.95 mm respectively [7] which is close with the major diameter of palm kernel which is 15.7 mm and 13.9 mm for palm shell [8]. There is specific gravity of palm kernel and shell, which is 1.07 and 1.20 relatively [8]. So, we need to set 1.20 as relative density of bulk material since the value is higher. The bulk density is then calculated by using eq.1.

Bulk Material	Maximum Particle Size (in.)	Bulk Density (lbs/ft³)	% Trough Loading	Material Factor (MF)	Component /Bearing Series	Abrasive-ness	Corrosive-ness	Flowability	Special Notes
Tung Nuts	-3	25-30	30A	0.7	B1-B2	I	I	I	V

Figure 4: Bulk Material Table for Tung Nuts [9]

$$Relative\ Density\ of\ Bulk\ Material = \frac{\rho_{bulk\ material}}{\rho_{water}} \quad \text{eq.1}$$

$$1.20 = \frac{\rho_{bulk\ material}}{1000\ ^{kg}/_{m^3}}$$

$$Bulk\ Density = 1200\ ^{kg}/_{m^3}$$

$$Bulk\ Density = 74.91\ ^{lbs}/_{ft^3}$$

3.1.2 Size and Speed of Screw Conveyor Based on Capacity

Next, the speed of the screw conveyor based on capacity is calculated as shown below. The capacity factor,CF is two since there is a 30 degrees of inclination for screw conveyor and there is a need for make half pitch for screw to overcome loss in efficiency due to gravity. Therefore, the capacity of the screw conveyor is initially set as $1000kg/hr$ which is $2204.6lbs/hr$.

$$Required\ Capacity, CFH = \frac{Capacity}{\rho_{palm\ mixture}} \quad \text{eq.2}$$

$$CFH = \frac{2204.6\ ^{lbs}/_{hr}}{74.91\ ^{lbs}/_{ft^3}}$$

$$CFH = 29.43\ ^{ft^3}/_{hr}$$

$$Selection\ Capacity, SC = CFH \times CF \quad \text{eq.3}$$

$$SC = 29.43\ ^{ft^3}/_{hr} \times 2$$

$$SC = 58.86\ ^{ft^3}/_{hr}$$

$$Actual\ Conveyor\ Speed, S = \frac{SC}{Capacity\ at\ 1\ RPM} \quad \text{eq.4}$$

$$S = \frac{58.86\ ^{ft^3}/_{hr}}{5.5\ ^{ft^3}/_{hr}}$$

$$S = 10.7\ RPM$$

Trough Loading	Screw Dia. (in.)	Max. RPM *	Capacity in ft^3/hr	
			At Max. RPM	At 1 RPM
	4	139	57	0.4
	6	120	179	1.5
	9	100	545	5.5
	12	90	1,161	12.9
	14	85	1,768	20.8
	16	80	2,496	31.2
	18	75	3,375	45.0
	20	70	4,375	62.5
	24	65	7,085	109.0
30% A	30	60	12,798	213.3
	36	50	18,440	368.8

Figure 5: Select The Screw Diameter Using Capacity Table [9]

Screw Dia.	Pipe Size	Pipe O.D.	Radial Clearance	Class 1 (R = 1.75)	Class 2 (R = 2.5)	Class 3 (R = 4.5)
4"	1-1/4"	1-5/8"	1-11/16"	3/4"	1/2"	1/4"
6"	2"	2-3/8"	2-5/16"	1-1/4"	3/4"	1/2"
9"	2"	2-3/8"	3-13/16"	2"	1-1/2"	3/4"
	2-1/2"	2-7/8"	3-9/19"	2"	1-1/4"	3/4"

Figure 6: Bulk Material Lump Size Table [9]

The pipe size is known after knowing the screw size. The screw diameter had been chosen, that is 9 inches. Then, the pitch of screw is known. As mentioned earlier, the screw conveyor is inclined 30 degrees from ground. The pitch screw has reduced to 12⁄ pitch diameter which is 4.5 inch because it is more efficient than full pitch screw.

3.1.3 Horsepower Required by Screw Conveyor

The capacity for the conveyor is 2204.6 $ft3/hr$, but the system might double the load, therefore, the capacity is assumed as 4400 $ft3/hr$.

$$Friction\ Horsepower, FHP = \frac{DF \times HBF \times L \times S}{1{,}000{,}000} \quad \text{eq.4}$$

$$FHP = \frac{31 \times 1 \times 17 \times 10.7}{1{,}000{,}000}$$

$$FHP = 0.006\ HP$$

$$Material\ Horsepower, MHP = \frac{CFH \times MF \times L}{1{,}000{,}000} \quad \text{eq.6}$$

$$MHP = \frac{4400 \times 0.7 \times 17}{1{,}000{,}000}$$

$$MHP = 0.05\ HP$$

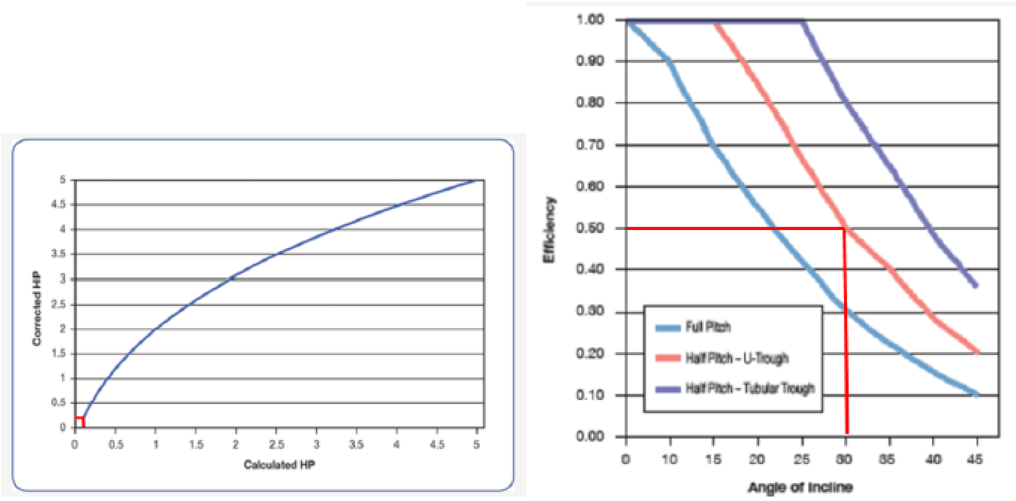


Figure 7: (i)The Corrected Material HP Chart [9] (ii) Pitch Efficiency against Angle of Incline Graph [9]

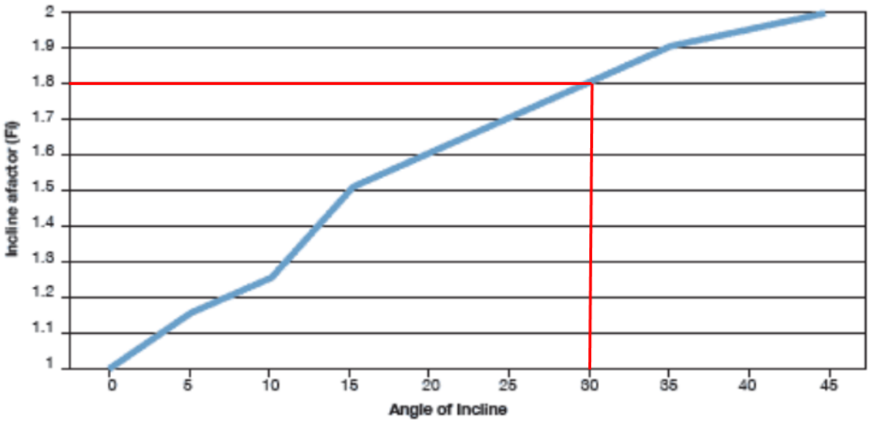


Figure 8: The Incline Factor (Fi) against Angle of Incline Graph [9]

The MHP is corrected since the calculated MHP is less than 5HP. After corrected the MHP through corrected MHP Chart, the corrected MHP is now 0.10 HP. From the pitch efficiency against angle of incline graph, we get 0.50 as efficiency(e) whereas there is a 30 degrees of inclination. From the incline factor against angle of incline graph, the incline (Fi) is 1.8.

$$TSHP(i) = \frac{FHP + (MHP^{*} \times Fi)}{e} \qquad \text{eq.7}$$

$$TSHP(i) = \frac{0.006 + (0.10 \times 1.8)}{0.50}$$

$$TSHP(i) = 0.37HP$$

3.1.4 Motor Selection

Conveyor drive from NORD Gear has been selected. Therefore, since the clincher parallel shaft gearmotor for screw conveyor is chosen due to it's selection step is more simple. The drive is suspended, the gearmotor is shaft mounted. The AGMA service is 1.0 where there is a 3-10 hours per day uniformly operation expected. Thus, 0.5Hp gearmotor has been selected as it possesses a higher horsepower than the TSHP which is 0.372 Hp. The output speed is also higher than the actual conveyor speed which is 10.7 rpm. The information for gearmotor is shown in figure below.

Output Speed	Output Torque	SF	AGMA Class	Gear Ratio	Thrust Capacity		Gearbox	Motor Type	Reducer	CEMA DriveShaft				
n_2	T_2	f_a		i	Std Brg	H.D. Brg " VL"			C-Face Input	1-1/2"	2"	2-7/16"	3"	3-7/16"
[rpm]	[lb-in]				[lb]	[lb]								
19	1693	1.2	I	92.48	1607	1619	SK 1282 SCP	71 L/4	56C	X	X	X		

Figure 9: Gearmotor Selection for Screw Conveyor [10]

3.1.4 Full Motor Torque

The maximum torque generated by the drive unit is defined as full motor torque. One of criteria proper design of screw conveyor is the maximum torque rating shown in Figure 9 should be much greater than full motor torque generated by drive unit. Therefore, the screw conveyor component could possess an infinite life under normal operating condition. The motor selected from catalogue need to greater than the TSHP to make sure smooth operation, so the nameplate horsepower (HP) is 0.5 HP which selected from motor catalogue. The full motor torque is calculated by using equation (eq.8) below.

Shaft Dia.	Carbon Steel Torque Values							
	Shaft		Coupling Bolts (2-Bolt)		Pipe – Schedule 40			
	C-1045		Grade 5		A-53			
	Torsion		Bolts in Shear		Pipe in Shear		Pipe in Bearing	
	Safe Stress	Torque Rating	Safe Stress	Torque Rating	Safe Stress	Torque Rating	Safe Stress	Torque Rating
	PSI	In-Lbs	PSI	In-Lbs	PSI	In-Lbs	PSI	In-Lbs
1	8,750	1,000	15,500	3,400	6,700	3,100	6,700	2,200
1-1/2	8,750	3,800	15,500	9,100	6,700	7,600	6,700	5,600

Figure 10: Carbon Steel Torque Value for 1-1/2 Shaft Diameter [9]

$$Full\ Motor\ Torque\ = \frac{HP \times 63{,}025}{Actual\ Conveyor\ Speed, S} \qquad \text{eq.8}$$

$$Full\ Motor\ Torque\ = \frac{0.5 \times 63{,}025}{19RPM}$$

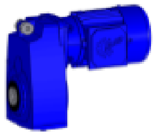
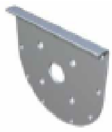
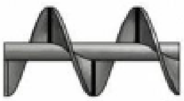
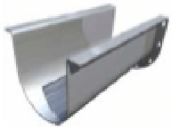
$$Full\ Motor\ Torque\ = 1658.55\ inch - lbs$$

3.1.5 Summary of Selection of Components

Table 1: Basic Information from Analysis of Incline Screw Conveyor

Basic information	
Capacity	1000kg/hr
Particle Size of Bulk Material	5/8 inch
Output Speed	9 rpm
Trough Loading	30%A Trough Loading 
Size/Diameter of Screw	9 inch
Screw Pitch	4.5 inch
Diameter of Shaft	1.5 inch
Center Pipe Size	2 inch
Radial Clearance	3.8125 inch
Trough Thickness	10 Ga
Cover Thickness	14 Ga
Total Shaft Horsepower, TSHP	0.37 Horsepower

Table 2: Basic Information from Selection of Components of Incline Screw Conveyor

Basic information	
Motor	0.50 Horsepower, NORD Geared Motor  - Clincher parallel shaft gearmotor for screw conveyor is chosen due to it's selection step is more simple. The drive is suspended and shaft mounted.
Trough End	Trough End without Foot (Tail End)  - It's used since there is use of U-trough and the tail end of screw conveyor is not mounted on any structure.
Type of Screw	Sectional Screw  - Made by steel and turn it into a helix which is easier manufactured than helicoid screw flight since the continuous helix is required a special machine to manufactured.
Type of Trough	Formed Flanged U-Trough  - It is chosen as it could support medium to heavy duty application anf it is connected by U-Trough plate end flange.
Hanger and Hanger Bearing	Style 226  - Both hanger and hanger bearing are used when the length of the conveyor is exceeded 14 feet which is 4.26 meter.

End Bearing	Flanged Ball Bearing (Tail End)  - Used on tail end to withstand radial load. Pillow Block Roller Bearing (Drive End)  - Used on trough end to withstand thrust load. -
	Torque Arm Trough End (Drive End)  - The torque arm trough end is used since the drive is suspended and shaft mounted, it could withstand the vibration that produced by motor.
Seals	Waste Pack Seal (Tail End)  - The seals is used to prevent leakage of the bulk material to cause hazard. Flanged Gland Seal (Drive End)  - It's used to prevent leakage of bulk material in order to protect the motor away from dirt or moisture.

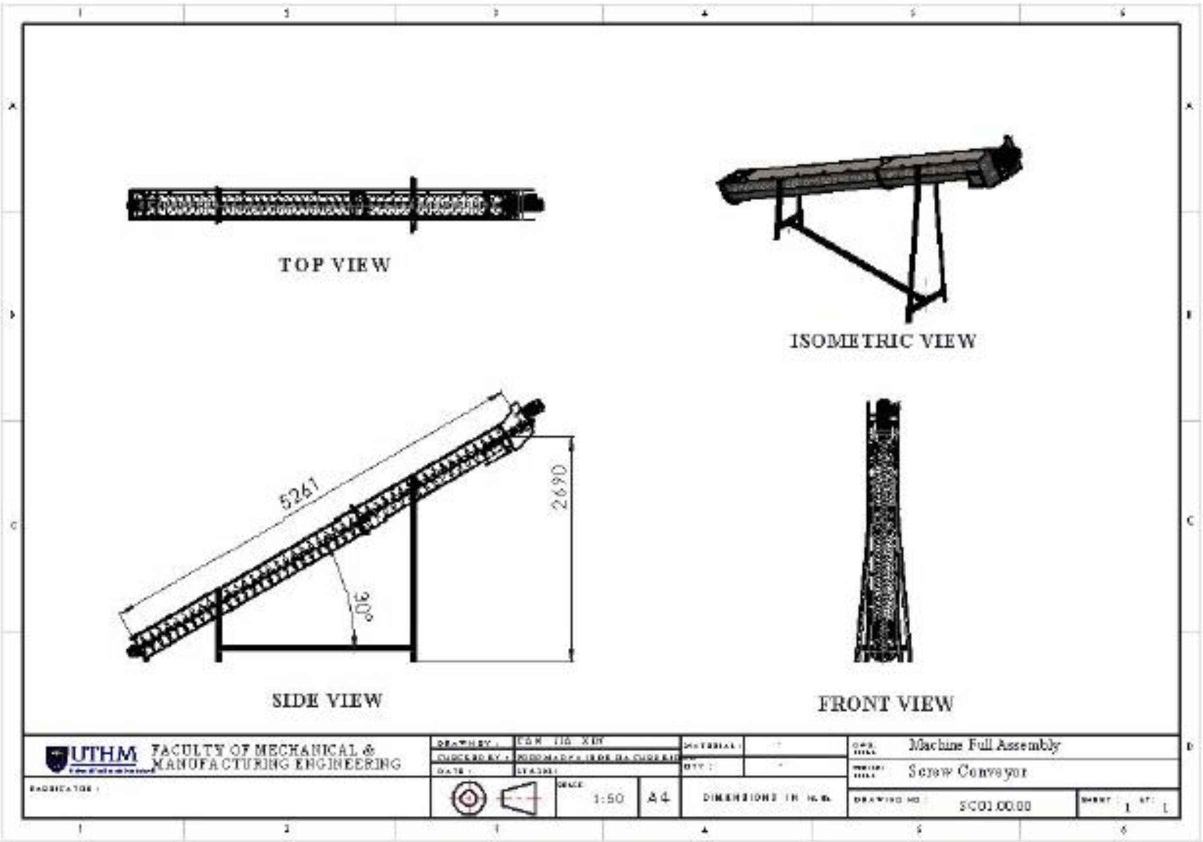


Figure 11: Full Assembly Drawing

4.0 Conclusion

In conclusion, the analysis of the incline screw conveyor is referred to the KWS Screw Conveyor. The objectives of this project is to design a screw conveyor to convey the mixture of kernels and shells of palm fruits in dry separation process in palm oil mills. By using SolidWorks software, the parts of the inclined screw conveyor have been designed, analysed and the engineering drawing model are generated. The final design of inclined screw conveyor is able to support the operation at the 1000kg/hr capacity with 19 revolutions per minute. The conveyor length is 5.26 meters with 30˚ of inclination and 2.69 meters' height. Furthermore, the mass of the screw conveyor is 381.664kg. Besides, to develop a 3D model for screw conveyor to carry out appropriate analysis to have proper design of screw conveyor. The project drawing of the design of a screw conveyor is drawn and attached in the appendices.

Acknowledgement

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