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Design of a Horizontal Conveyor System for Scrap Rubber in FGV Pasir Besar

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Abstract: In FGV Pasir Besar, scrap rubber are transported form the cutting section to the processing pool with a backhoe. The usage of a backhoe to transport the scrap rubbers contributes to a lower efficiency and production rate for the production line. The objectives for this project are to produce a complete design of a horizontal conveyor system that is able to transfer cast amount of scrap rubber that will help in reducing the logistical cost of transferring scrap rubber in rubber processing plant. Consequently, design processes that are proposed by George E. Dieter and Rudolph J. Eggert are altered and utilized. This design process provides the guide form problem definition to detail design of the system. Additionally, SolidWorks is utilized to produce engineering drawing and simulation to estimate the functionality of the system. The system that is developed is expected to carry up to 143 ton of scrap rubber per hour. The manufacturer also can extend their services from providing the particular components to providing multiple components so that the components that are used in the conveyor system can be easily chosen and invariable.

Keywords: Scrap Rubber, Horizontal Conveyor System Design

1. Introduction

Rubber is an elastic material extracted from exudates of some tropical plants which is natural rubber or from petroleum and natural gas which is synthetic rubber. Rubber is the basic component of tires used in automotive cars, aircraft, and bicycles due to its elasticity, durability, and toughness. Natural rubber produced in a living organism consists of solids suspended in a milky fluid called latex, which circulates in the inner sections of the bark of many tropical and subtropical trees and shrubs. The processing of rubber comprises of four fundamental steps which is mastication, mixing, viscous mass shaping, and curing.

As technology developed gradually, automated system seems to be used a lot especially in the manufacturing industries. This is because automated system relies on minimum

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supervision and eliminates human dependency as a tasks doers. In FGV Pasir Besar, scrap rubber are transferred from a loading area to another station by using a backhoe. This causes inefficiency and low rate of productivity in their production line. A backhoe can transferred only 6612.48 kilograms of scrap rubber per hour. This is far from the 10 ton per hour of capacity that proposed by the company. Thus, low rate of productivity within the production line mostly contributes by this process. Furthermore, the usage of a backhoe contributes to the carbon footprints. Internal combustion engine emits a numerous amount of harmful by-product. Besides, heavy machinery relies on regular maintenance schedule because it operates by a complex system such as a diesel engine and series of hydraulic parts. The aim of this project is to produce a complete design of a horizontal conveyor system that is able to transfer vast amount of scrap rubber in FGV Pasir Besar. This will help in reducing the logistical cost of transferring scrap rubber for the rubber processing plant

2. Materials and Methods

Conducive to produce or designing a product, a method that is called engineering design process is often used. In this project, engineering design processes introduced by George E. Dieter and Rudolph J. Eggert are altered and assigned. This is due to, the technical specifications are already given by the company and it is not necessary to proceed with the conceptual design phase as stated in George E. Dieter design process except with the gather information stage. Thus, it is matched with part configuration design in one of the Rudolph J. Eggert design processes.

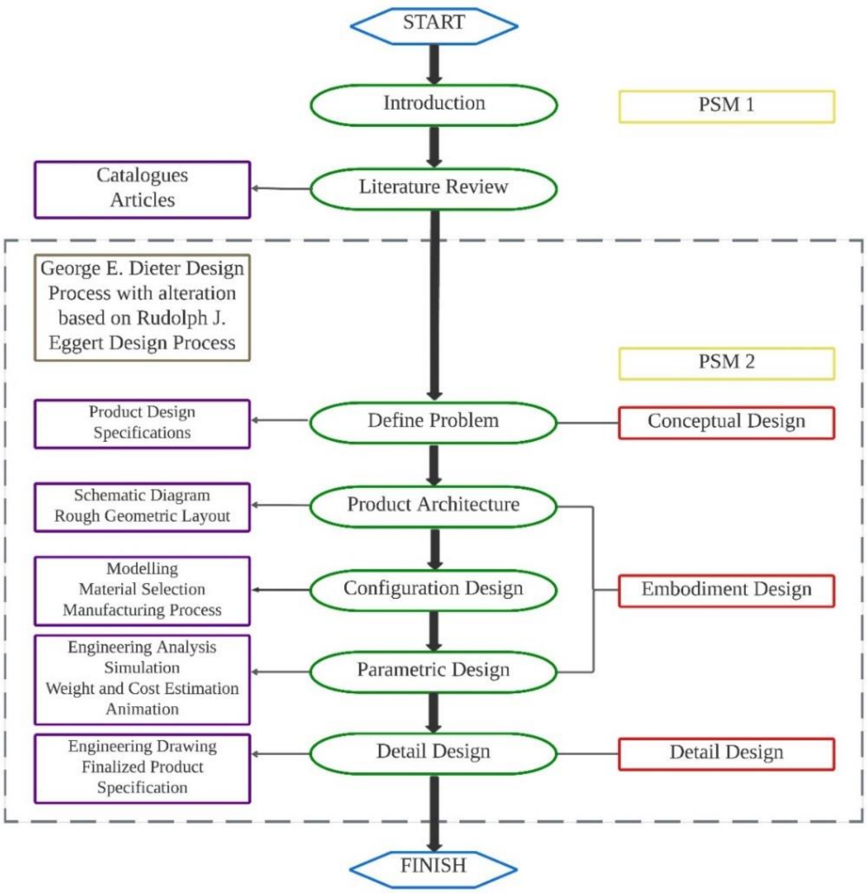


Figure 1: Engineering Design Process Flow

3. Design Process and Results

3.1 Define Problem

Define problem is the first phase that proposed by George E. Dieter in his design process. It is used to determine the problem that needs to be solve in order to fulfill the customer's requirement. On this phase, Product Design Specifications is utilized to identify the customer's needs.

Table 1: Product Design Specifications of the System

INTRODUCTION	
Title	Horizontal Conveyor System
Design Problem	Transferring of scrap rubber not efficient
Intended Purpose	To transfer scrap rubber
Special Features	Automated system
CUSTOMER REQUIREMENTS	
Functional Performance	• Transfer scrap rubber from elevated conveyor system to the processing pool. • The system able to transfer scrap rubber at the minimum rate of 10 tons/hour. • Should be able to transfer scrap rubber with maximum lump size of 150mm.
Geometric Limitation	• Should be elevated 5 meter from the road. • Should give 4 meter clearance for the backhoe. • Troughed conveyor.
Maintenance, Repair	• Has walkway and sunroof for maintenance workers. • Should has stair to provide access between the conveyor sections.

3.2 Product Architecture

In order to explain more about the product architecture, the elements in schematic diagram were divided into the section as shown in figure below.

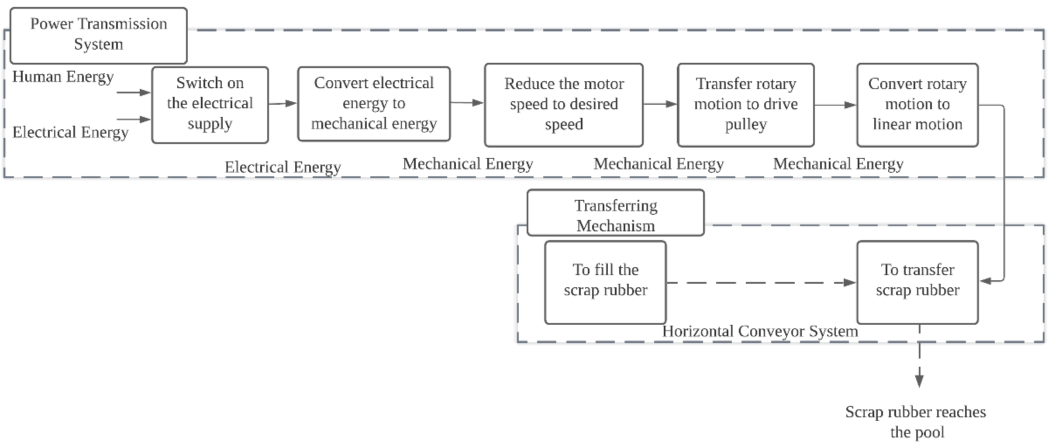


Figure 2: Clustered Diagram for Horizontal Conveyor System

3.3 Configuration Design

In configuration design, there are three phases that involved based on the design process. Those phases are modelling, selection of material and manufacturing process to produce each components. The combination of listed phases produces the dimension and physical shape of the system.

3.3.1 Modelling

SolidWorks, a computer aided design software is used to develop a complete 3D modelling for the system. Idlers, pulleys, structures, take up and motor are produced by using SolidWorks. All components were assembled together to produce a complete horizontal conveyor system.

Combination of components produces a segment

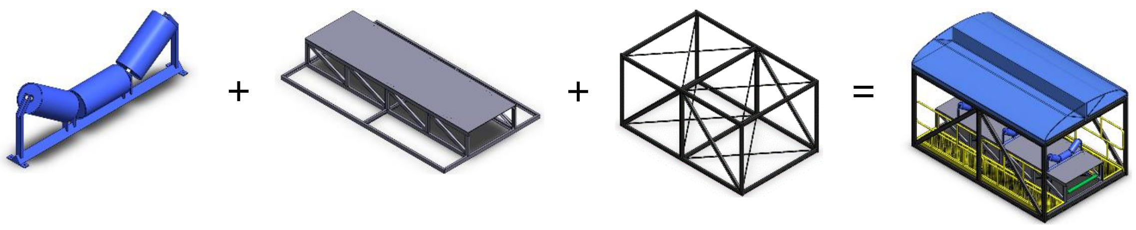


Figure 3: The Formation of Conveyor Segment

Combination of segments produces a section

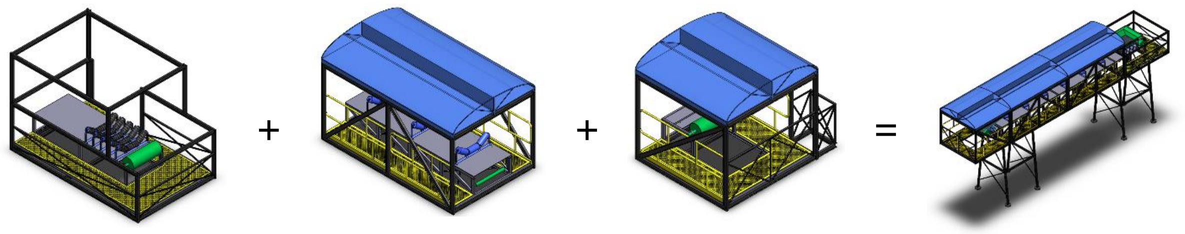


Figure 4: The Formation of Conveyor Section

Combination of sections produces a horizontal conveyor system

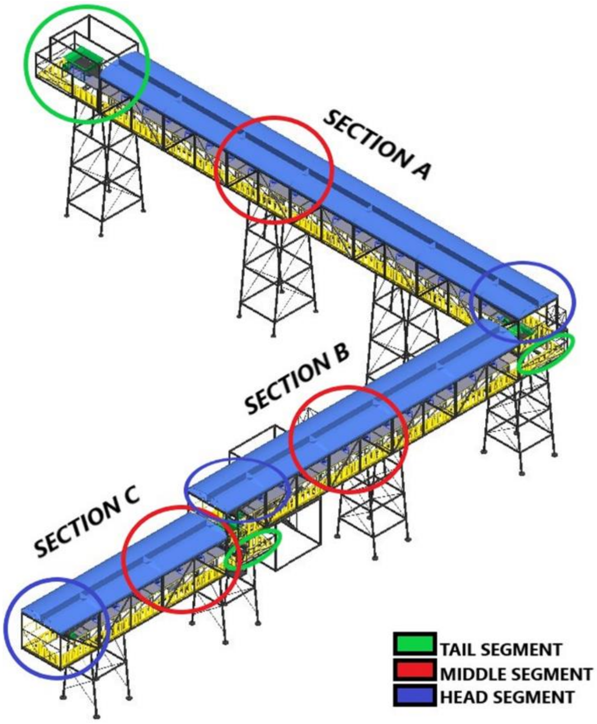


Figure 5: Full Assembly of Horizontal Conveyor System

3.3.2 Material Selection and Manufacturing Process

To make sure the system that is designed can sustain despite harsh working conditions, it is important to choose suitable material for the task. The materials should be consider based on their mechanical properties. The manufacturing processes need to be determine in order to make sure that the costs not exceed the budget that set by the company.

Table 2: Components' Material Selection and Manufacturing Process

Components	Material Selection	Manufacturing Process
Base	ASTM A36 Steel	Process Involve: Cutting, Welding, Grinding
Module Stair	ASTM A36 Steel	Process Involve: Cutting, Welding, Grinding
Feed Chute	1060 Alloy	Process Involve: Cutting, Welding, Grinding
Roof	PC High Viscosity	Process Involve: Thermo-forming, Trimming
Stringer	ASTM A36 Steel	Process Involve: Cutting, Welding, Grinding
Truss Frame	ASTM A36 Steel	Process Involve: Cutting, Welding, Grinding
Walkway Grating	1060 Alloy	Process Involve: Cutting, Welding, Grinding
Walkway Handle	1060 Alloy	Process Involve: Cutting, Welding, Grinding, Bending
Take Up Casing	1060 Alloy	Process Involve: Cutting, Bending
Snub Bend Pulley Hanger	1060 Alloy	Process Involve : Cutting, Bending

3.4 Parametric Design

In order to explain more details of the system, engineering analysis, simulation, weight estimation and cost estimation, and animation are studied in parametric design.

3.4.1 Engineering Analysis

Engineering analysis is important to produce a safe and well-worked system by analyzing parameters for standard components that made up the system. For the system, there are two crucial analysis that are done which are on the conveyor belt and helical gear motor that drives the pulley.

Capacity calculation

$$\text{Maximum Capacity} = \text{Capacity} \times \text{Capacity Factor} \times \rho \times {}^{\text{v}}/_{1000}\ \text{(tonnes/hour)}$$

$$\text{Maximum Capacity} = 185 \times 1.08 \times 960 \times {}^{0.75}/_{1000}$$

$$= 143.846\ \text{tonnes/hour}$$

Power Requirement

$$P_{req} = \frac{\mathrm{F_e(L + t_f)3.6QS}}{367} + \frac{\mathrm{F_l(L + t_f)C}}{367} \pm \frac{\mathrm{CH}}{367}\ \text{(kW)}$$

$$P_{req,A} = \frac{0.02(29.5 + 60)3.6(53)(0.75)}{367} + \frac{0.025(29.5 + 60)63}{367} \pm \frac{63(0)}{367} = 1.082\ \text{kW}$$

$$P_{req,B} = \frac{0.02(20.5 + 60)3.6(53)(0.75)}{367} + \frac{0.025(20.5 + 60)63}{367} \pm \frac{63(0)}{367} = 0.973\ \text{kW}$$

$$P_{req,C} = \frac{0.02(11.7 + 60)3.6(53)(0.75)}{367} + \frac{0.025(11.7 + 60)63}{367} \pm \frac{63(0)}{367} = 0.867\ kW$$

Motor Specifications

Once the required power is obtained, the catalogue that provided by motor manufacturer can be referred. In this case, Nord System (2019) gives a detail guide to choose the suitable motor.

Table 3: Selected Helical Gear Motor Specifications

Criteria	Value	Selected
Motor Power (kW)	1.635-2.029	2.2
Motor Torque (kNm)	0.416-0.519	0.534
Rotational Speed (rpm)	20	39

P_1 [kW]	n_2 [min^{-1}]	M_2 [Nm]	f_B	i_{ges}	F_R [kN]	F_A [kN]	$F_{R\,VL}$ [kN]	$F_{A\,VL}$ [kN]	Type
2.2	32	663	1,0	46,25	3,2	9	8,8	10,6	SK 32 - 100 LP/4
	39	534	1,1	37,23	4,4	9	9	10,2	
	47	447	1,1	31,16	4,8	9	9,1	10	
	48	437	1,5	30,43	4,9	9	9,2	10,2	
	54	391	1,5	27,24	4,8	9	9,2	10,1	
	55	380	1,1	26,57	4,7	9	9,2	9,8	
	63	331	1,9	23,12	4,7	9	9,3	9,9	
	71	296	2,2	20,70	4,6	9	9,3	9,7	
	79	267	2,4	18,67	4,5	9	9,4	9,5	
	88	239	2,2	16,66	4,4	8,6	9,4	9,2	
	90	233	2,7	16,25	4,4	8,7	9,4	9,3	
	98	215	2,4	15,03	4,3	8,4	9,4	9,1	
	101	208	3,2	14,55	4,3	8,5	9,4	9,1	
	125	168	4,2	11,71	4,1	7,9	9,4	8,6	

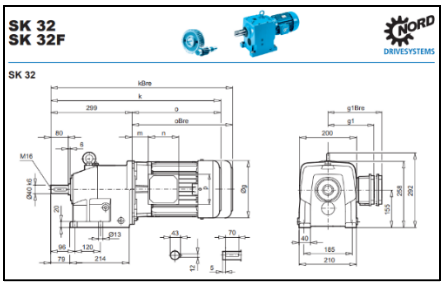


Figure 6: Dimensions and Specifications of Helical Gear Motor

Pulley Structure

There are three type of pulley which are Type A, Type B and Type C. Type A is suitable for the drive pulley while Type B is used for tail pulley and take up pulley and Type C pulley is suitable for snub bend pulley. However, just because the working tension percentage for an entire conveyor system is below than 30%, the drive pulley can be reduced to Type B pulley.

Table 4: Dimension of Pulleys

Pulley	Head	Tail/Take Up	Snub Bend
Diameter	360	360	280

Pulley face width needs to exceed 150mm with the width of the conveyor belt between 750mm to 1400mm. Thus, the face width of each of the pulleys in the system needs to be 950mm.

3.4.2 Simulation of Product

In order to make sure that the developed system reliable when working in a real world, simulation gives a complete insight of their physical behavior. There are various types of simulations that has been offered in SolidWorks. In this project, static analysis are used for the stringer and the combination of truss frames and bases.

Simulation of Stringer

Stringer absorbs majority of force that exerted when the horizontal conveyor system carries scrap rubber. The deck plate of a stringer where the force has been exerted by the scrap rubber. Before advancing into the simulation part, the weight of the item that exerted the force onto the surface of the stringer needs to be determined first. The total weight of the components except maintenance platform and stringers is 8170.33 kg.

$$\text{Total force exerted} = \left[\left(\frac{\text{Total weight}}{\text{Length of Section A}}\right) \times \text{Length of observed stringer}\right] \times 9.81$$

$$\text{Total force exerted} = \left[\left(\frac{8170.33}{28.78}\right) \times 2.51\right] \times 9.81 = 6990.23\text{ N}$$

Table 5: Von Mises and Axial Stress of a Stringer

Result	**Maximum**
Von Mises Stress	29.7 MPa
Axial Stress	1.39 MPa

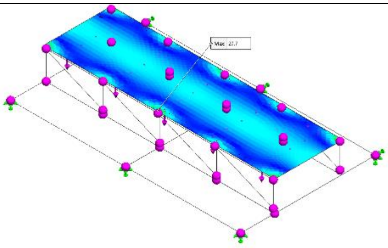
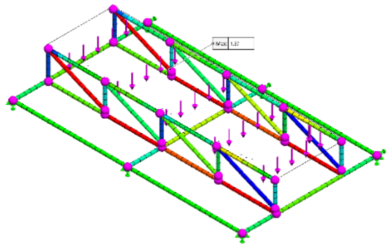
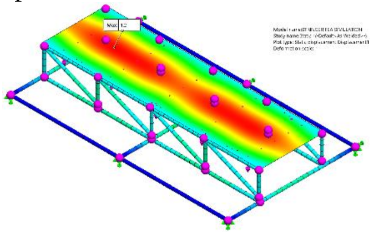
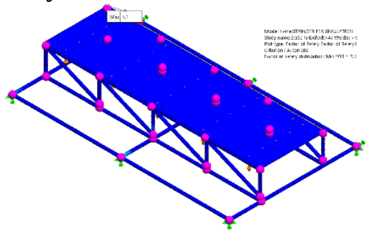
	

Table 6: Displacement and Safety Factor of a Stringer

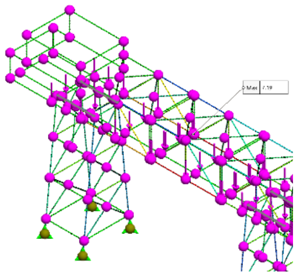
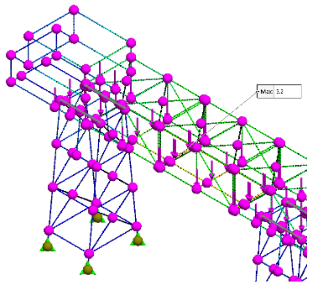
Result	Maximum	Result	Minimum
Displacement	1.2 mm	Safety Factor	7.1
			

Simulation of Truss Frame and Base

Truss frames and bases provide a support for the horizontal conveyor system. The beam that situated at truss frames where the force has been exerted by the scrap rubber and the components in the system. Before the simulation is applied, the force exerted on a single beam needs to be determined first. Same as the stringer simulation before, the total weight of components and scrap rubber need to be determined first. As a result, the total weight is 8136.35kg.

$$\text{Exerted Force} = \frac{(\text{Total components weight} \times 9.81)}{\text{Numbers of beam}} = \frac{(8136.35 \times 9.81)}{27} = 2956.21\text{N}$$

Table 7: Static Analysis Result of Truss Frames and Bases

Result	Maximum	Result	Maximum
Axial Stress	7.19 MPa	Displacement	5.2mm
			
Result		Minimum	
Factor of Safety		2.9	

3.4.3 Weight Estimation

By using SolidWorks, the weight of every single parts involved in the system can be identified. The summation of all parts involves is 28738.97 kg.

3.4.4 Cost Estimation

Estimation of the costs involved is really important in order to make sure that the system is developed in allocated budget. In this system, there are two types of components that being used. Firstly, non-standard components which is the components that are fabricated with the proposed dimension. On the other hand, standard components stand for the components that are manufactured by the manufacturers of the suppliers and there are some catalogues that need to be referred to. The total upfront cost to setup the horizontal conveyor system in FGV Pasir Besar is RM 160915.

3.4.5 Animation of System

The animation of the system is produced in order to give a further explanation on how the horizontal conveyor system works in real life. On the other words, it provides an easy visual of the function and behavior of the developed design. The animation of the system is produced by using SolidWorks animation and motion analysis add-ins.

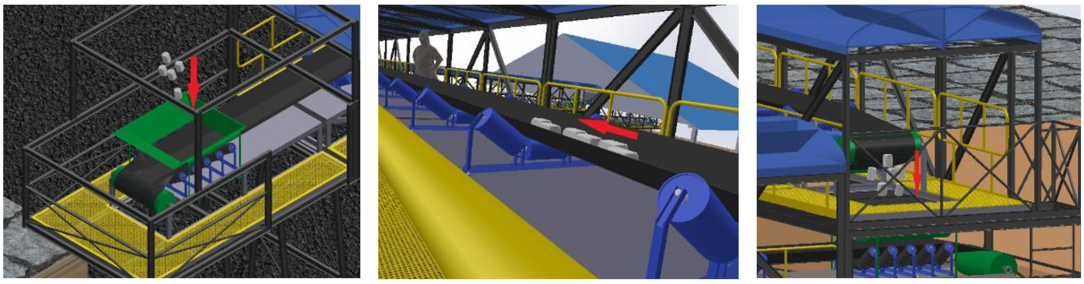


Figure 7: Animations Involved in the Horizontal Conveyor System

3.5 Detail Design

The last phase of proposed design process is detail design. Detail design explains the system specifications and illustrates engineering drawing before an entire system is developed or manufactured.

3.5.1 System Specification

Table 8: System Specifications

Specification	Description
Weight	28738.97 kg
Dimension (L x W x H)	68.67 m x 2.60 m x 9.59 m
Motor Power	2.20 kW X 3
Maximum Speed	0.75 m/s
Maximum Capacity	144.00 ton/hour

3.5.2 Engineering Drawing

Engineering drawings are produced by using SolidWorks software. The drawings are included with material used and its dimension for the perusal of operator and owner. The detail drawings for Horizontal Conveyor System can be referred in the Appendix.

4. Conclusion

To conclude, the design processes that are proposed by George E. Dieter and Rudolph J. Eggert are altered and combined together and being used to produce the Horizontal Conveyor System. This project are conducted in order to increase the efficiency of production line for rubber processing plant by increasing the transferring rate of scrap rubber. The Horizontal Conveyor System also gives an automated way to transfer the scrap rubber which eliminate most of the process that reduce the efficiency. Each of the components involved in the system is designed, simulated, analyzed with the utilization of SolidWorks. The system is able to carry up to 140 ton of scrap rubber per hour while the system weights 28.74 ton with the dimension of 68.67m, 2.60m and 9.59m in length, width and height.

Acknowledgement

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