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Design of The High-Productivity of Coffee Cherry Processing Machine for Small Industry

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Abstract: The coffee cherry processing machine is a tool used to facilitate the process to produce coffee beans. The processing of coffee cherries into coffee beans is highly complicated in various ways. This thesis project is carried out to design a high productive coffee cherry processing machine for a small industry. The time to complete the processing of coffee cherries will be taking more longer when using the manual peeling machine of the coffee cherry. The honey method can produce coffee beans that retain the aroma and flavor of the coffee is very suitable for this study. Therefore, this study aims to design automation of coffee cherry processing machine that benefits the small industry in Malaysia. Through this project, the productivity to produce the coffee has been shall be increased. The machine is designed based on small industry technical needs in terms of their specification of product. The design shall meet the necessary aspect such as sustainability, safety, maintenance, ergonomics, and functional performance. On the other hand, the selection of material and engineering design analysis shall be considered during the design phase to meet the requirement. George E. Dieter's design process shall be referred to throughout the project design. The modeling and simulation of the product were done using Solidwork software to explain the detail of the concept of the product and all the dimensions of the components. The final design has an expected 803.7 kg/h of capacity and 95% efficiency. The estimation of the weight is 80.32kg with dimension 1324.5x534x1014. The selling price for the coffee cherry processing machine is RM 3,989.00.

Keywords: Customer Needs, Coffee Cherry, Design Phase, Efficiency, Honey Process

1. Introduction

Coffee is being consumed by an increasing number of individuals, and it is becoming a more common beverage, particularly among young millennials. Malaysia is one of the top 50 coffee-consuming countries in the world (Rahim, Jin, and Fong, 2019). In line with technological advances nowadays, new technology has been developed to process the coffee cherry known as the honey processing method. The honey processing method is a hybrid that combines elements of both techniques

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to create new differentiations in flavor, it is also called semi-dry processing. In this semi-dry process coffee cherries are de-pulped without subsequent fermentation steps (Duarte, Pereira, & Farah, 2010).

Current operations of the honey processing method are mostly based on traditional methods that required a manual machine to pulp the coffee cherry skin to be removed. This greatly affects the production rate of coffee cherry and thus will affect the company sales. Through machines that will design to the pulp, the coffee cherry will ensure the product quality dan boost the efficiency of the processing coffee cherry. The need to produce an efficient and effective coffee cherry machine is needed to assist the coffee industry in Malaysia.

The purpose of this project is to design a complete machine manufacturing to enhance the efficiency and capacity of the coffee cherry processing machine. The machine's design is primarily focused on improving the machine that has already been available on the market in terms of specification with a high-efficiency and high-capacity machine. The design study in this project will be carried out by the technical requirements demands specified by the market so that the final product may be sufficient for the market's needs.

2. Materials and Methods

2.1 Project Design Method

Specifications The design phase of the coffee cherry processing machine George Dieter Eggert (2000), the design process is a sequence of design stages used to establish the appearance of the product needed by the customer. Design processes begin with an analysis of the problem and then proceed to the study of the literature. Conceptual design is the next step after the study of the literature. The conceptual design consists of the problem statement, benchmarking, product dissection, and House of Quality (HOQ) and PDS. After the conceptual design, the next phase is embodiment design. In this phase product architecture, configuration design, and parametric design are determined. The last step in the design phase is detail design which is detailed drawings and product specifications included in this phase. Figure 1 shows the stage in the design process.

2 .2 Design Analysis

The design analysis was carried out with a view to determining the necessary design parameters, and material for consideration in the selection of components part.

2.2.1 Power requirement

To determine the force per unit area on the material using the formula below:

$$\frac{F}{A} = \frac{\text{Sus}}{F.o.s} \quad \text{Eq. 1}$$

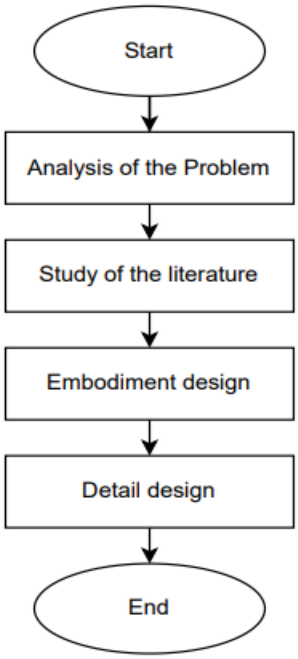


Figure 1: Design Phase

F= shear force based on the material, Sus= ultimate strength in shear of the material (Mpa), A= cross-section area of the cutter blade, F.o.s= factor of safety. Assume the cross-section is 4 and Sus is Sut x 0.77. After determining the shear force of the material for stainless steel grade 304 and cherry, using the formula below to calculate the power requirement for rotating the drum of coffee cherry processing machine.

$$P_{req} = T_{req} \times \omega \quad \text{Eq. 2}$$

$$\omega = \frac{2\pi n}{60} \quad \text{Eq. 3}$$

$$T_{req} = F \times r \quad \text{Eq. 4}$$

P_{req} = power requirement, T_{req} = torque requirement, ω = angular velocity, r = perpendicular distance from shaft (radius of the shaft)

2.2.2 Gearbox analysis

Adding gearbox to the machine is to control the speed from the motor to the belt and pulley. As a result, torque output is affected by the revolution speed from the gearbox. In order to calculate the overall gear ratio based on torque, T using the formula equation 5.

$$M_{o-G} = \frac{Torque\ output\ (torque\ requirement, Nm)}{Torque\ input\ (torqur\ from\ motor, Nm)} \text{ Eq. 5}$$

After determining the overall gear ratio, number of gear teeth, N is calculated by using the formula, which is used to avoid interference.

$$N_P = \frac{2k}{(1+2M_G)sin^2\emptyset}\left(M_G + \sqrt{{M_G}^2 + (1+2M_G)sin^2\emptyset}\right) \quad Eq. 6$$

N_p = number of teeth, k = 1 (full depth teeth), pressure angle, $\emptyset = 20°$. Thus the torque and speed of the gear can be calculated by

$$\frac{T_O}{T_i} = \frac{N_O}{N_i} \quad Eq.7$$

$$\frac{N_O}{N_i} = \frac{n_i}{n_o} \quad Eq.8$$

T_O = torque output, Ti = torque, n_i = speed input, n_o = speed output, N_O = number of teeth output, N_i = number of teeth input

2.2.3 Belts and Pulleys

The belt length was determined to know the actual dimension to drive the drum. Belt length are important for effective power transmission from components. The following expressions for a length of the belt were applied.

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{1}{4C}(D_2 - D_1)^2 \quad Eq.10$$

L= length of the belt, C= distance between two centripetal forces, D_1 = diameter pulley driver and D_2 = diameter pulley driven.

2.2.4 Blowing Fan

A rotating fan was selected due to its capacity to generate a high-volume, high-pressure air stream with reasonably low power consumption. As noticed by studies, the velocity of the cleaning air must be smaller than the terminal velocity of the fruit to be cleaned in order to prevent the harvest from being blown away. According to the formula, the maximum speed, Vt, of a spherical particle is:

$$v_t = \sqrt{\frac{2mg}{\rho_a A C_D}} \quad Eq.11$$

v_t – Terminal velocity, m/s, g – gravitational force, m – Mass of falling object, A – Cross sectional area of falling object, ρ_a – Density of the air =1.225 kgm3, C_D – Coffee bean sphericity =0.75

2.2.5 Capacity of The Coffee Cherry Processing Machine

The coffee processing machine's hopper is placed at the top and is used to transfer coffee cherry. Capacity of the coffee cherry processing depends on the mass of the output of green coffee per duration of operation in 1 hour. The equation 12 shows the capacity of the machine.

$$Capacity\ of\ the\ machine = \frac{mass\ of\ the\ output\ (kg)}{duration\ of\ operation\ (1\ hour)} \quad Eq.12$$

2.2 Evaluate and Select Concept

The evaluation and select the concept is alternative combination of various concepts is produced for further evaluation of the concept then after the process weighted decision matrix method is the used for selection of the design concept.

Table 1 The summarise of the concept generated

NO.	FUNCTION/PART	Concept 1	Concept 2	Concept 3
1	Washing and softening	Continuous washing	Human washing	Spray washing
2	Soring mechanism	Hand Sorting	Color sorting	Machine sorting
3	Coffee transfer mechanism	Human transfer	Conveyor belt	
4	Rotate motor	Chain drive	Belt drive	Gear
5	Pulping coffee	Fluted cylinder	Ripple mill	Rolling machine
6	Pulp removal	Floor strainer	Vacuum pump	Slotted plate
7	Mucilage removal	Hot air blower	Sack soaking	Water washing
8	Drying mechanism	Open sun drying	Greenhouse drying	

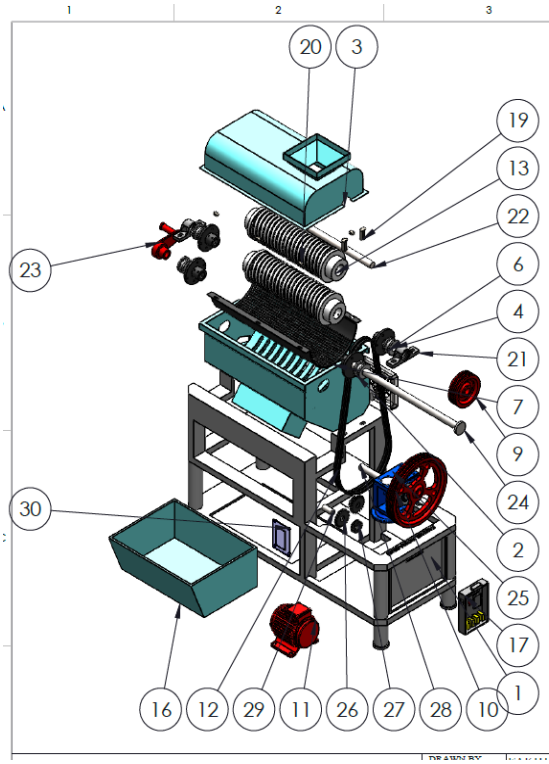
Concept 1 was selected because has the highest value compared to other combinations and the best selection that can be made

2.3 Mode of Operation

The processing of coffee cherry starts with coffee cherry beans that is transferred from sack to the hopper or feeder which lies at the top section of the cover , From the feeder the coffee cherry beans reaches the circulating fluted cylindrical drum, The work of the cylindrical drum is to separate the coffee pulp with other parts, the small clearance between the rotating fluted drum enables the meshing of the cherry beans causing the outer layer (Pulp) of the cherry beans to get separated, then after the separation the outer covering(pulp) gets collected in pulp collector and the rest of the coffee beans with mucilage is then hot air blown to dry the mucilage and separate the pulp properly this is achieved through hot air blower that is connected to the back of rotating drum and then through gravitational force the heavy coffee cherry beans along with the mucilage is collected below in a container, the system starts by AC power supply provided through the switch board to the motor which is responsible for rotating the shaft and the motor is then connected to the gear box , The gear box acts as speed controller for the rotating drum. Having a certain gear arrangement for the required speed, the gearbox is then connected to the flywheel which contains a belt that is joined to another flywheel that is connected to the main shaft containing. Cylindrical drum and through the speed controller (Gearbox), the drum rotates at a certain speed causing the pulp and coffee beans to get separated and collected in their respective collection container.

2.4 Machine Description

The machine consists of the several components. The main part of machine is cylinder drum, frame, motor and power transmission system as shows in figure 2.



ITEM NO.	PART NUMBER	DRAWING NO	QTY.
1	FRAME	CM01:01:01	1
2	bottom cover	CM01:01:02	1
3	Hopper	CM01:01:03	1
4	Part14	CM01:01:04	4
5	blower part 2	CM01:01:05	1
6	Part6	CM01:01:06	4
7	filter	CM01:01:07	1
8	blower part 1	CM01:01:08	1
9	polea small	CM01:01:09	1
10	medium polea	CM01:01:10	1
11	Motor	CM01:01:11	1
12	belt	CM01:01:12	2
13	drum disk	CM01:01:13	2
14	hot air	CM01:01:14	1
15	fan	CM01:01:15	1
16	storage	CM01:01:16	1
17	CONTROL PANEL	CM01:01:17	1
18	PHT 8x35x32.9-slot-AB-N		4
19	screww		4
20	screw filter		6
21	chumacera	CM01:01:18	2
22	shaft	CM01:01:19	1
23	handler	CM01:01:20	1
24	shaft 3	CM01:01:21	1
25	gearbox		1
26	Gear 1		2
27	gear 2		2
28	shaft motor	CM01:01:22	1
29	shaft motor 2	CM01:01:23	1
30	motor cover	CM01:01:24	1

Figure 2 The Exploded view of the machine

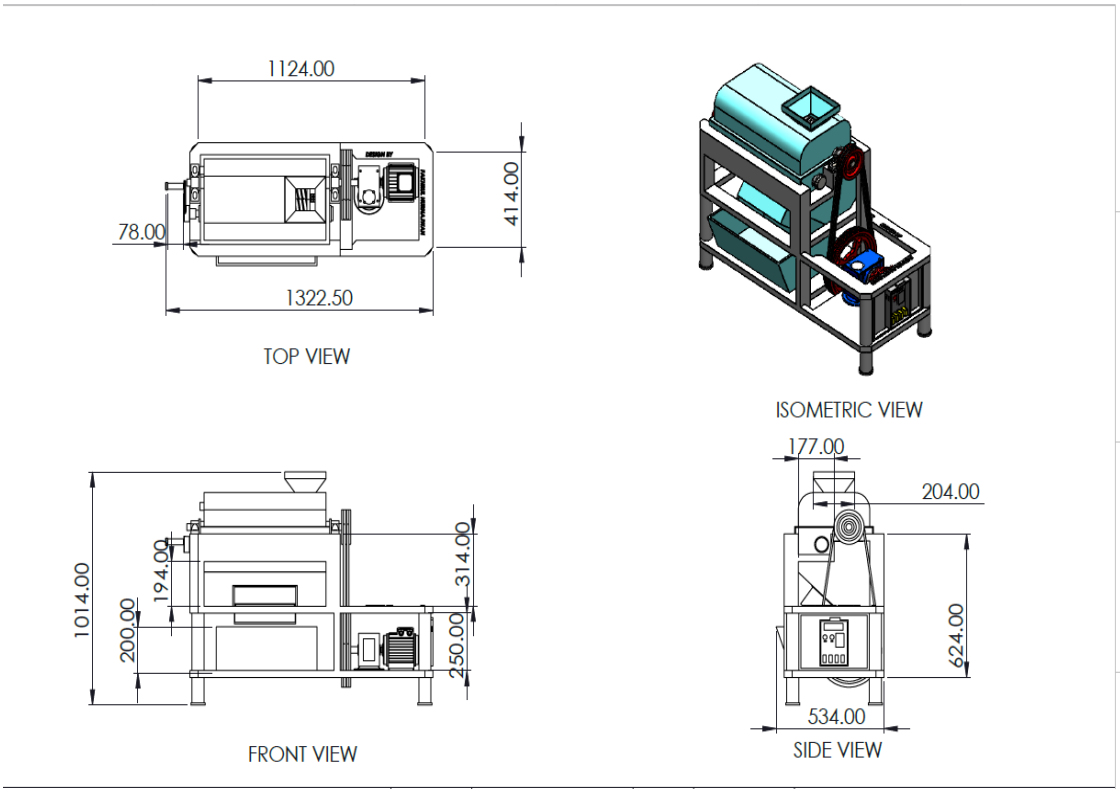


Figure 3 The Orthographic views of the machine

2.5 Estimation cost of machine

The cost of a coffee cherry processing machine can be n divided into raw material and transportation cost and the fabrication process before the selling product in the market. After the cost of raw material

was determined, fabrication cost and assembly are calculated for the estimated price of the coffee cherry processing machine.

Table 2 Estimated cost of the coffee cherry processing machine

No	Raw material/ Item	Quantity/ Weight	Rate	Total cost
1	6016 Aluminium Alloy	26.7 kg	RM 4.40	RM 117.48
2	AISI 304	48.35 kg	RM 5.68	RM 274.63
3	Motor	1	RM 1750.90	RM 1750.90
4	Gearbox	1	RM 110.50	RM 110.50
5	Blowing fan	1	RM 46.90	RM 46.90
6	V- Belting	2	RM 25	RM 50
7	Fastener			RM 50
8	Logistic		RM 466.10	RM 466.10
9	Fabrication process		RM 1321.58	RM 1321.58
10	Assembly process		RM 280.40	RM 280.40
	Selling price	RM 3989.00	Total cost	RM 3621.78

3. Results and Discussion

The design concept of the coffee cherry processing machine is automatic operation, efficient, and ergonomic. The intended purpose of the machine is to increase production capacity, remove manual peeling and improve efficiency. The product's functional performance has high productivity and performance. The production capacity of the machine is 803.7 kg/h with 95%effiency. The honey-method coffee resulting from processing will be increased with the use of the machine The weight of the machine is 80.32 kg. The design of the machine is easy to assemble and disassemble and the dimensions of the machine are 1324.5 x 534 x 1014 mm. The machine is an ergonomics design with automatic system operation to simplify the milling process and decrease human labor. The machine is expected to be safe in operation in terms of comfort and easy to operate. Stainless steel in the selection of the material is expected to have a longer lifespan for the machine and good corrosion resistance will improve the sustainability of the machine. The estimated cost of the machine is expected to be RM 3898.00 which is affordable for the small industry to process the coffee cherry machine with high capacity and efficiency.

4. Conclusion

The coffee cherries are invariably intermingled with perfectly ripe cherries regardless of the harvesting method and must be separated during coffee processing. The objective of this project is to design a high productive coffee cherry processing machine for small industries. Then, the result of the machining process is automation to ease an employee. This product is targeted at the small industry, especially in Malaysia. The generated concept is suitable for honey processing methods for processing the coffee cherry. Based on this project, a new conceptual idea was generated by designing the coffee cherry processing machine to increase productivity and ease the user's design, function, and operation with automation. To adapt the conceptual idea into the real designed product, a study on the project has been implemented through the person who had experience using a coffee cherry processing machine with surveys from the entrepreneur to capture the design's idea that meets their requirements. Several design concepts were generated and advised from the existing product used in factory industries throughout the study. Therefore, data collection and summarization in terms of the objective tree, quality function development (QFD), and engineering design specification (EDS) also need to collect the data and strengthen customer relationships with this research study. Following the ideals of brainstorming, the morphological chart clearly outlined all key components of the projected product. Once all of the elements have been decided, the product implementation design begins. Following that, we must execute the product analysis as required to guarantee that our design product is working

properly. The comprehensive drawings of components and assemblies are created, and the simulation process is carried out using SolidWorks Simulation software in accordance with the product specifications. The prototype was produced when the simulation result was satisfied. At this stage, sustainability is critical in limiting the negative influence on the environment as well as the function of the product being created.

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