Republic of Yemen
Ministry of Higher Education and
Scientific Research
University of Emirates
Faculty of engineering
Mechatronics

Design and Implementation of Coffee Sifting Machine

تصميم وتنفيذ آله غربلة البن

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Abstract

A coffee sorter is a specialized piece of equipment designed to separate coffee beans based on their size and shape. These machines use a combination of mechanical and electronic technologies to sort the coffee beans into different grades or qualities based on predetermined criteria. the sorting process usually begins with a hopper feeding the coffee beans into the machine. The grain is then moved through a series of sieves, sieves, or air jets that sift it based on its size, shape, and density. Optical sensors or cameras can also be used to detect and sort coffee beans based on their color, which may indicate a level of maturity or defects in the beans.

The problem that the machine solved is the sorting problem, so that it saves effort and time on the workforce, investors and farmers, as they spread the coffee in beds for drying, then they manually sort the coffee for each size separately, which takes a long time and is physically tiring, we solved this problem to take advantage of the time And the effort of the manpower to do other work and focus on the marketing and sale side to increase the productivity of coffee and its export and national support Economy.

We have designed a machine for sorting coffee beans in addition to five conveyor lines, one for transporting coffee from the stores to the machine's tank, and four for transporting coffee beans after sorting to the tanks or for packaging, and we have implemented on the ground the sorting machine into four different sizes at the request of the customer. As for the itineraries, it was not implemented due to the high cost.

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Student name	Signature	Date
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Supervisor Certification

I certify that the preparation of this project entitled …………………………
………………………………………………………………,
prepared by …………………………………………………………………
……………………………………………………………………..
was mad under my supervision at ……………. department as partial fulfillment of the
requirements of bachelor degree in ……………….

Supervisor Name
Signature
Date

Examiner Committee

Project Title: Autonomous Mobile Robot Indoor and Outdoor Application

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Department Head

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Chapter 1

INTRODUCTION

1.1 Overview:

Yemen has been famous since ancient times for cultivating coffee, and through the port of Mocha, Yemeni coffee was exported to the world, and the coffee tree was associated with the identity and history of Yemen.

Yemeni coffee is distinguished by its unique flavor and expensive quality, due to the diverse terrain and climate that Yemen enjoys, and the fertility of its soil, which has earned its agricultural products high quality, including the coffee tree.

In the past, Yemen was known as the Happy Arabic.

The Ministry of Agriculture and Irrigation declared the third of March of each year as a national day for Yemeni Coffee, with the aim of reviving Yemeni coffee identity and rooting it in the hearts of the Yemeni generations, Coffee grounds are commonly used. . Coffee bean is used as a brain stimulant and is also used to change the smell of perfumes. The coffee tree is an essential element in agriculture, and therefore coffee has wide used in various fields. Different volumes of coffee are required for different types of work. On a given job site, more than one volume of coffee is used to complete the work. Similarly, in coffee, different sizes of coffee grounds are required for different types of work. For sorting, a fine husk is used, coffee grounds are used in the aromatic industry. Similarly, the size of coffee beans ranging from 5mm to 10mm is used to refine the coffee، Hence the coffee needs to be sifted accordingly. To date, coffee is sieved mainly by hand. The process of sifting coffee by hand takes longer to filter out the finer coffee. To sift coffee of different sizes, different types of sieves are used, and it is a bit tedious work to deal with two or five types of sifters that are manually operated on site،. If fine coffee is required for this task, then sifting the coffee becomes a time-consuming work due to the manual operation that is done for many times to get the finer coffee grade from the coarser coffee. To inculcate this problem, we have designed and manufactured a multi sieve coffee sifting machine which can be used in any industry that requires sifting, just by changing the sieve plate or mesh plate.

Multiple sieves can be used to sift the coffee to the desired size. Just by changing the sieves, different kinds of items can also be sifted. This machine can be used other than sifting coffee, sieving sand, sifting millet, etc. to sift materials just by changing the sieve plate accordingly**.**

1.1 Problem statement:

One of the major issues facing the coffee industry is the need to ensure consistent quality of coffee beans. Coffee beans come in different sizes, shapes, and colors, and their quality can vary depending on a number of factors, such as maturity level, growing conditions, and processing methods.

Coffee sorting machines were developed to address this problem by sorting coffee beans based on their size, shape, color, and density. However, there are still some challenges that need to be addressed.

One challenge is the cost of equipment, which can be a significant investment for a small coffee grower or processor.

1.2 Project scope and limitations:

Project Scope:

The project scope for a coffee sorting machine would involve designing and developing an efficient and accurate machine that can sort coffee beans based on their size and shape. This would include identifying the necessary components such as screens, sieves, or air jets, and determining the optimal configuration for the machine.

Additionally, the scope would involve developing a user-friendly interface and control system for the machine, as well as testing the machine for accuracy and consistency. The project would need to ensure that the machine can sort coffee beans to the desired level of precision and quality, while also being cost-effective and environmentally sustainable.

Limitations:

One limitation of a coffee sorting machine project would be the cost of the equipment, which can be a significant investment for small-scale coffee growers or processors. Additionally, the accuracy and consistency of the sorting process may be limited by the quality of the coffee beans or the conditions of the environment in which the machine is used.

The project would also need to consider the environmental impact of the machine, such as energy consumption and waste generation. The use of sustainable materials and energy-efficient components could help reduce the environmental impact of the machine.

Overall, the project scope for a coffee sorting machine would be to develop a machine that can accurately sort coffee beans based on predetermined criteria, while also being cost-effective and environmentally sustainable. The limitations would include cost, technical expertise, and environmental considerations.

1.3 Project objectives:

The project objectives for a coffee sorting machine would be to:

1. Providing the machine to consumers at prices that are competitive with import prices.
2. Breaking the monopoly.
3. Supporting national production and industries.
4. Entrepreneurship aspect.
5. Design and develop a machine that can accurately sort coffee beans based on their size, shape, and density.
6. Develop a user-friendly interface and control system for the machine.
7. Test the machine for accuracy and consistency in sorting coffee beans.

By achieving these objectives, the coffee sorting machine can help improve the quality and consistency of coffee beans, which can benefit coffee growers, processors, and consumers. The machine can also help reduce labor costs and increase productivity, which can benefit the coffee industry as a whole. Additionally, by incorporating sustainable materials and energy-efficient components, the machine can help reduce the environmental impact of coffee production.

1.4 Project methodology:

This project consists of two branches, electrical and mechanical:

- The electrical one includes the motor and the electrical source.
- The mechanical design is the outer structure and bearings.

And there is a possibility to add a control system in the project, such as controlling the source of electricity so that no problems occur with an increase in electricity or when a malfunction occurs or overload for the motor to perform the cutting process, and also the possibility of adding gates to open and close at the coffee exit Chan.

1.5 project Organization

This report is organization as follows:

- **Chapter 2** The competition works, the history and types of coffee and its machines.
- **Chapter 3** Design stages and parts used, in addition to equations.
- **Chapter 4** Implementation, in addition to the stages and steps of installation.
- **Chapter 5** Mechanism of action and analytics .
- **Chapter 6** summarizer the conclusion and future works.

Chapter 2
BACKGROUND AND LITERATURE REVIEW

2.1 Background

Pre-harvest stage, proper nutrition and good water are provided and then, after harvesting, the red flower is harvested from the coffee and then It is dried on boards that are supervised by specialists that.

They are designated with clean packages and transferred to a laboratory for excellence and industry for peeling and preparation, and then they sort manually by size through a manual sifter that can be equipped for transportation and the amount of production with this thing very weak.

2.2 Literature Review

2.2.1Overview

Coffee sifting machine is currently served in many logistics processes, such as manufacturing and refining coffees and spices. The coffee sifter machine and their advanced electrical and control devices enable independent operations in mechanical environments. Compared to a Danish automated system of machine (SCM) where a central unit assumes control of the machine and steering by means of a pivot shaft driven by a motor gearbox for all sieves, the SCM can sift coffee and produce per hour up to four tons independently with other resources such as hulling machines Thus achieving decentralization in the decision-making process. Decentralized decision making allows the system to react dynamically to changes in the state of the system and the environment. The traditional method can only sift in the old days by manually sorting it into flat edges for pre-drying and then manually sorting it according to size show in (Fig. 2-1) [1].

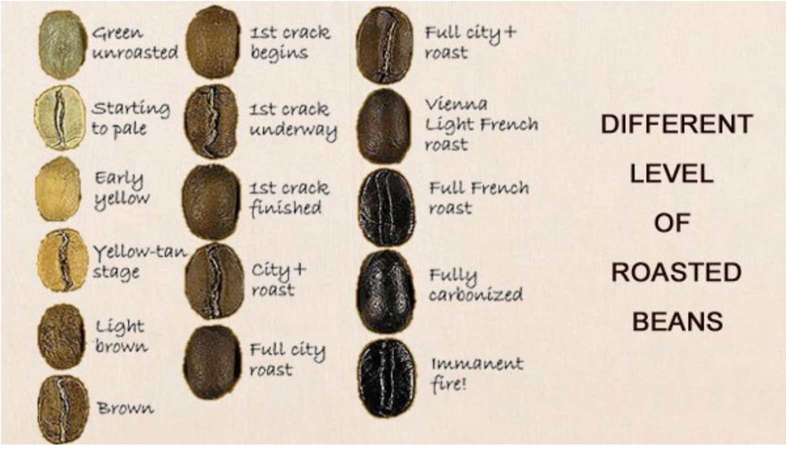


Figure 2-1 Coffee Color

In contrast, the tub can be changed into a drip pan and become a coffee ground machine with the same sieves used[2].

2.2.2 SCM Application

- Coffee Beans Color Sorter show in (Fig. 2-2):

Figure 2-2 Coffee Beans Sorter

A machine that sorts coffee beans with an accuracy of 99.9%, the color of the coffee beans, the place of manufacture, China, the electric voltage is 220v, 50Hz, the weight of the machine is 1360 kg, the power is 3 kilowatts, it contains 5 sliders, the price is 10,000 dollars, Model 6SXM-192JM5 the productivity per hour is 4 tons [3].

- Coreprogram coffee bean color sorter 5400-pixel belt type :

Figure 2-3 Coreprogram Coffee Bean color Sorter

Coreprogram Coffee Bean Color Sorter 5400 Pixel Belt Type Cherry Sorting Machine SMC Filter

Highlight

SMC Filter Coffee Bean Color Sorter. 5400 Pixel Coffee Bean Color Sorter. SMC Filter Cherry Sorting Machine 5400 Pixel Coffee Bean Color Sorter, SMC Filter Cherry Sorting Machine

- place of origin
- Hefei, Anhui, China
- Brand name

- Coreprogram
- Model number
- BL-30
- minimum quantity
- 1 Negotiable set
- Energizing
- Go to
- the prices
- Accessibility limit: not available.

The coffee cherry sorting machine is of elastic belt type for bottom damage removal

Main characteristics:
Full color CCD camera:
The captured images are converted into a Coreprogram vision system and then transmits the signals to the system, CCD signals through a dedicated image processing camera with a resolution of up to CCD 5400 color pixel 0.02mm camera can identify subtle differences and defects in color successfully advanced image processing system customized specific algorithm according to different sorting materials can adjust excellent color sorting performance and sensitivity ratio low damage rate through a-type structure design Belt Horizontal conveying by uniform and stable conveyor makes less collision of materials so that the light ratio is much lower than that of traditional lubricant type color sorter.

Remote interconnection system:
Remote diagnosis of the sorting machine and assistance with operation are available Equipment after getting authorization from clients Precise aiming technique Accurately locate material defects and impurities, and blast out defects and CCD target program by combining the latest camera target positioning, which can increase accuracy screening reduces the much improved migration ratio high quality dedicated valves With high frequency and strong force, they can accurately blast some high density materials such as metal, quartz and many kinds of stones show in (Fig. 2-5). [4]

اسم المنتج	ز نوع المرحلة الحكيمة
الجهد االكهربى	220 فولت
قوة	400 واط
انتاج |	600 كجم / ساعة
وزن	85 كجم
أبعاد الآلة	1570 * 780 * 1520
حجم التعبئة	1570 * 780 * 1160
أجزاء إضافية بما في ذلك	2 ات شاشات التصنيف
مادة	ستانلس ستيل

Figure 2-4 Semi Coffee Machine

[5]

Figure 2-5 Principle of Work for coffee sorter

2.2.3 previous work:

Table 2-1 Comparison between Local and Broad Machine Price

Name	***Brazilian made***	***Chinese made***	***Yemeni made***
Company & Model	PXZE	DAYONG DZSF-1020	H-N
Date of production	2019	2019	2023
Advantage	High productivity	Cheap	Cheap & low maintenance
Disadvantage	Very expensive	High maintenance	Not much Technology
Price	20000$	6000$	4400$

Chapter 3

PROJECT DESIGN

3.1 Introduction:

Generally, during coffee preparation, the sifting process of the coffee is done manually. The coffee is screened using panels, purified and divided manually. In the current coffee sifting method, the sample is subjected to horizontal movement according to the method chosen. This results in a relative motion between the kernels and the strainer. Depending on their size, the individual grains pass through the sieve mesh or are retained on the surface of the sieve. There are different machines that are used in sifting coffee that have been made, but we offer the design and manufacture of a coffee sifting machine that is automatically operated, which is characterized by low cost, easy to operate, and easy to disassemble and install.

This project focuses on the design and manufacture of the mechanical part of the machine and the sieve machine system.

To achieve this project goal, this sieve machine body structure and mechanical system need to take care of some other parameters such as strength, safety and ergonomic design. [6] This project flow must start from design, analysis and manufacturing process finally before the sieve machine is developed, it must be compared with other product in the market from Brazilian. This is due to studying the customer's need and creating a new design with a new feature and a lower cost.[7]

3.2 Suggested Designs:

3.2.1 Version 1:

In this Version we considered the design from Brazilian machine, which depends on one sieve and many outputs, so the production process will be few with low quality, As show in (Fig. 3-1).

Figure 3-1 Design of Version 1

3.2.2 Version 2:

We solved the problem of the previous design by putting 5 sieves instead of one the increase the production process and increase the quality of the output as show in (Fig. 3-2).

Figure 3-2 Design of Version 2

3.3 Components:

Components used in screening coffee machines:

1- Motor gear box 81N.
2- Two bearings 35 Ø.
3- Axial column 75 Ø.
4- Three Galvanized rectangular iron tube thickness 1.5.
5- Two Galvanized angle iron 0.5.
6- Two H 12.
7- One U 14 .
8- Four bearings side.
9- Two sheets 2,5 mm.
10- Five sieve (10,8,6,5).

3.3.1 Motor with gear box 81N:

The motor used to move the machine works in a smooth motion show in (Fig. 3-3).

Figure 3-3 Motor with Gear Box

3.3.2 Bearings 35°:

Plain bearings use surfaces in frictional contact, often in the presence of a lubricant such as oil or graphite. A simple loader may be a separate or non-separate device. It may not be more than a surface in contact with a hole with an axis passing through it, or a flat surface bearing another surface (in this case it does not form a device), and it may be a layer of molten metal on the material or in the form of a separate metal tubular part. With the proper lubrication, plain bearings offer acceptable accuracy, life, and friction at small costs. This is why simple bearings are commonly used.

There are many applications in which using more suitable bearings can improve effectiveness, accuracy, speed, reliability, size and weight، Therefore, there are many types of bearings, with different shapes, materials, lubricants, and working principles. [8] For example, roller bearings use balls or rollers that roll between parts to reduce friction, allowing for lower tolerances and greater accuracy than plain bearings, and reduced wear increasing the machine's working life. Plain bearings are generally made of various types of metals or plastics depending on loads, dirtiness and wear in the working environment. In addition, the friction in the bearings may be significantly modified according to the type and method of use of the lubricant. For example, the lubricant may improve the friction in the bearing and its life span show in (Fig. 3-4) [9].

Figure 3-4 Bearing

3.3.3 Axial column 75 °:

It is to carry out the axial rotation process, as it works to shake the part responsible for moving it، the flywheel is installed on the crankshaft to reduce the pulse characteristic in four-stroke engines, and sometimes as a damper for vibrations and rolling along the crankshaft resulting from most of the cylinders and some from the outlet show in (Fig. 3-5).

Figure 33–5- Axial Shaft (CAM)

3.3.4 Galvanized rectangular iron tube thickness 1.5:

Galvanized rectangular iron tube, size 40 x 20 mm, thickness 1.50 mm, hollow stainless-steel tube, used in a variety of applications, including industrial maintenance, transportation tools and equipment.

It was used to install the screen mesh show in (Fig. 3-6) [10].

.

Figure 3-6 Galvanized rectangular iron tube thickness 1.5

3.3.5 Galvanized angle iron 0.5:

Galvanized angle iron tube, size0.5x 0.5 mm, thickness 1.50 mm, hollow stainless-steel tube, used in a variety of applications, including industrial maintenance, transportation tools and equipment.

It was used to install the screen mesh show in (Fig. 3-7) [11].

.

Figure 3-7 Galvanized angle iron 0.5

3.3.6 Galvanized H 12:

Galvanized (H) iron tube, size12x 15 mm, thickness 5.50 mm, hollow stainless-steel tube, used in a variety of applications, including industrial maintenance, transportation tools and equipment.

It was used to install the screen mesh show in (Fig. 3-8) [12].

.

Figure 3-8 Galvanized H 12

3.3.7 Galvanized U 14:

Galvanized (U) iron tube, size10x 15 mm, thickness 5.50 mm, hollow stainless iron tube, used in a variety of applications, including industrial maintenance, transportation tools and equipment. It was used to install the screen mesh show in (Fig. 3-8) [13].

.

Figure 3-9 Galvanized U 14

3.3.8 Bearings side:

bearings side Plain bearings use surfaces in frictional contact, often in the presence of a lubricant such as oil or graphite. A simple loader may be a separate or non-separate device. It may not be more than a surface in contact with a hole with an axis passing through it, [14]. or a flat surface bearing another surface (in this case it does not form a device), and it may be a layer of molten metal on the material or in the form of a separate metal tubular part. With the proper lubrication, plain bearings offer acceptable accuracy, life, and friction at small costs. This is why simple bearings are commonly used[15].

There are many applications in which using more suitable bearings can improve effectiveness, accuracy, speed, reliability, size and weight، Therefore, there are many types of bearings, with different shapes, materials, lubricants, and working principles. For example, roller bearings use balls or rollers that roll between parts to reduce friction, allowing for lower tolerances and greater accuracy than plain bearings, and reduced wear increasing the machine's working life. Plain bearings are generally made of various types of metals or plastics depending on loads, dirtiness and wear in the working environment. In addition, the friction in the bearings may be significantly modified according to the type and method of use of the lubricant. For example, the lubricant may improve the friction in the bearing and its life span show in (Fig. 3-9) [16].

.

Figure 3-10 bearings side

3.3.9 Sheets 2,5 mm:

It is a flat sheet of galvanized iron that was used in the sifting edges to contain the grains entering from it, as its thickness reached 2.5 mm show in (Fig. 3-10) [17].

Figure 3-10 sheets 2,5 mm

3.3.10 sieve (10,8,6,5 mm):

It is a perforated slab that uses sifter plates to sort coffee sizes during sifting.

Figure 3–11 sieve (10,8,6,5)

3.4 SINR and data rate calculation:

Table 3-1*Condition of Sand & Density*

CONDITION OF SAND & DENSITY (Density of Building Materials As Per IS 875 Part-1)		
SR NO	CONDITION OF SAND	DENSITY (kg/m^3)
1.	Dry	1540-1600
2.	Wet	1760-2000

[18]

$$Density\ (\rho) = \frac{Mass\ (m)}{Volume\ (V)}\quad (kg/m^3)$$ ……………. (3-1)

$Case\ 1 : Condition\ of\ sand = Dry$

$\therefore Mass\ of\ sand = 1600 \times 0.03$

$= 48\ kg \sim 50 kg$

$Case\ 2 : Condition\ of\ sand = Wet$

$\therefore Mass\ of\ sand = 2000 \times 0.03$

$= 60\ kg$

2) *Calculation of lift on sling*

$$Tension\ in\ each\ sling\ = \frac{Weight}{Number\ of\ legs} \times L.A.F$$ ……………. (3-2)

$Considering\ weight\ of\ sand\ poured\ at\ a\ time = 50 kg$

L.A.F for 90° sling angle = 1

$\therefore$ Tension in each sling = $\frac{50}{2} \times 1$

$Tension\ in\ each\ sling = 25\ kg$

3) *Torque calculation*

$Taking\ motor\ of\ specification\ 960\ rpm\ , 1\ HP$

$1\ HP = 750W$

$$Torque\ (T) = \frac{Power}{\omega}$$ ……………. (3-3)

$$T = \frac{60 \times P}{2\pi N}$$

$$T = \frac{60 \times 750}{2\pi \times 960}$$

$$T = 7.46\ N.m$$

4) *Machine efficiency* $(\eta_{Machine})$

$Power\ of\ motor = 750 Watt = 0.75 KW$

$Power\ for\ 1\ hr = 0.75 \times 1 = 0.75\ KWhr$

$Unit\ Consumption = 0.75\ units$

$Working\ for\ 6\ hours\ a\ day = 0.75 \times 6 = units\ per\ day$

$One\ month\ consumption = 4.5 \times 30 = 135\ units$

$Approx\ bill\ for\ a\ month = 135 \times 10 =$ ₹1350

5) Manpower efficiency $(\eta_{Manpower})$

$(Considering\ same\ amount\ of\ work\ done\ by\ the\ man\ power\ as\ compared\ to\ the\ machine)$

$Daily\ wages =$ ₹200

$Monthly\ wages =$ ₹ $200 \times 30 =$ ₹6000

(*Note : Even the sand will be sieved by machine but the labour will be required to pour the sand into the machine , but at the same time labour can do another work at the site. This is how the efficiency at the work site will be increased at the same wages.)

[8]

6) *Power Calculation (P)*

$Power = Force \times Velocity$ .... (3-4)

$Considering\ velocity = 0.5\ m\ per\ sec$

$\therefore Power = mass \times accleration\ due\ to\ gravity \times veloctiy$ .... (3-5)

$\therefore P = 50 \times 9.81 \times 0.5$ $\cdots (When\ mass = 50\ kg)$

$\therefore P = 245.25\ watt$

$Taking\ factor\ of\ safety = 3$

$*\ (As\ the\ conditation\ sand\ will\ change\ as\ per\ the\ atmosphere)$

$P = 150 \times 9.81 \times 0.5$ $\cdots (When\ mass = 150\ kg)$

$\therefore P = 735\ watt$

$\therefore 750\ watt\ motor\ is\ suitable\ for\ the\ power\ transmission$

7) *Torsional Force in Shaft*

(Material of shaft → Mild steel)

$Maximum\ tensile\ stress\ of\ mild\ steel\ (\sigma_{Tensile}) = 525MPa$

$Maximum\ shear\ stress\ of\ mild\ steel\ (\sigma_{shear}) = \frac{525}{1.75} = 300MPa$

$Diameter\ of\ shaft\ (D) = 30mm = 0.0.3m$

$Maximum\ Torque\ transmitted\ by\ circular\ shaft\ (T_{max}) = \frac{60 \times P \times K_l}{2\pi N}$ (3-6)

$(Taking\ K_l = 1.5)$

$\therefore T_{max} = \frac{60 \times 750 \times 1.5}{2\pi N}$

$\therefore T_{max} = 11.2\ N.m$

8) *Torsional Vibration*

$E = 200\ GN/m^2 = 200 \times 10^9\ N/m^2$

$D = 30mm = 0.03m\ ,\ L = 1.5m$

$Moment\ of\ Inertia\ (I) = \frac{\pi}{64} D^4$ .... (3-7)

$I = \frac{\pi}{64} \times 0.03^4 = 3.97 \times 10^{-8}\ m^4$

$Static\ deflection\ (\delta)$

$\delta = \frac{Wa^2b^2}{3EIL}$ .... (3-8)

$\delta = \frac{50 \times 9.81 \times 0.2^2 \times 1.3^2}{3 \times 200 \times 10^9 \times 3.97 \times 10^{-8} \times 1.5}$

$\therefore \delta = 9.256 \times 10^{-4}\ m^4$

$Natural\ frequency\ of\ torsional\ vibrations\ (f_n)$

$f_n = \frac{0.4985}{\sqrt{\delta}}$ .... (3-9)

$f_n = \frac{0.4985}{\sqrt{9.256 \times 10^{-4}}}$

$f_n = 16.385\ Hz$

[9]The parameters measured included classifier work capacity, power, specific energy, [19] classification distribution, classification effectiveness, and classifier efficiency.

9) Critical speed of shaft (N_c)

$$N_c = f_n \times 60 \qquad \text{................ (3-10)}$$
$$N_c = 16.385 \times 60$$
$$\therefore N_c = 983.07\ rpm$$

10) Range of speed (N)

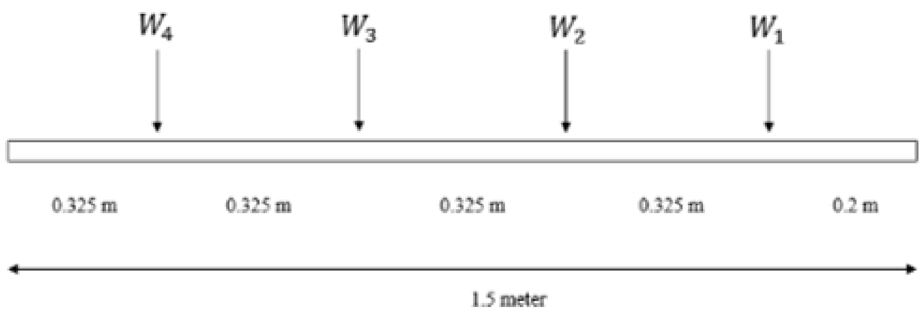
$$N = \frac{N_c}{\sqrt{1.16}} \quad or \quad \frac{N_c}{\sqrt{0.84}}$$

$$N = \frac{983.07}{\sqrt{1.16}} \quad or \quad \frac{983.07}{\sqrt{0.84}}$$

$$\therefore N = 912.76 rpm \ \& \ N = 1072.617 rpm$$

$$\therefore Range\ of\ speed\ is\ from\ 912.76\ rpm\ to\ 1072.617\ rpm$$
$$\therefore The\ selected\ speed\ of\ motor\ is\ sufficient\ to\ drive\ the\ load.$$

11) Natural frequency of transverse vibrations for a shaft subjected to number of point load (f_n)



Considering,

$$W_1 = 50kg = 50 \times 9.81 = 490.5\ N$$
$$W_2 = 35kg = 35 \times 9.81 = 343.4\ N$$
$$W_3 = 20kg = 20 \times 9.81 = 196.2\ N$$
$$W_4 = 10kg = 50 \times 9.81 = 98.1\ N$$

By Dunkerley's Method,

$$\frac{1}{f_n^2} = \frac{1}{f_1^2} + \frac{1}{f_2^2} + \frac{1}{f_3^2} + \frac{1}{f_4^2} + \cdots + \frac{1}{f_s^2} \qquad \text{................ (3-11)}$$

$$f_n = \frac{0.4985}{\sqrt{\delta_1 + \delta_2 + \delta_3 + \delta_4 + \cdots + \delta_s}}$$

$$\delta_s = Static\ point\ deflection$$

There are two types of engine working capacity, namely theoretical and actual. The theoretical capacity was calculated by the equation:

$$\delta = \frac{Wa^2b^2}{3EIL}$$ .... (3-12)

$$\delta_1 = \frac{490.5 \times 0.2^2 \times 1.3^2}{3 \times 200 \times 10^9 \times 3.97 \times 10^{-8} \times 1.5}$$

$$\delta_1 = 9.2801 \times 10^{-4}\ m$$

Similarly,

$$\delta_2 = 2.5178 \times 10^{-3}\ m$$

$$\delta_3 = 1.676 \times 10^{-3}\ m$$

$$\delta_4 = 4 \times 10^{-4}\ m$$

Transverse vibration at each point ,

$$f_n = \frac{0.4985}{\sqrt{\delta}}$$ .... (3-13)

$$f_1 = \frac{0.4985}{\sqrt{9.2801 \times 10^{-4}}}$$

$$f_1 = 16.364\ Hz$$

$$f_2 = 9.934\ Hz$$

$$f_3 = 12.18\ Hz$$

$$f_4 = 25\ Hz$$

According to Dunkerley'sempirical formula, natural frequency of whole system is given by;

$$f_n = \frac{0.4985}{\sqrt{\delta_1 + \delta_2 + \delta_3 + \delta_4 + \cdots + \delta_s}}$$

$$f_n = \frac{0.4985}{\sqrt{9.2801 \times 10^{-4} + 2.5178 \times 10^{-3} + 1.676 \times 10^{-3} + 4 \times 10^{-4}}}$$

$$f_n = 6.7085\ Hz$$

$\therefore$ *Natural frequency of transverse vibration of whole system* $(f_n) = 6.7085\ Hz$

$McT=60\ V\ \rho\ n$ ------------- (3-14)

where Mc_T = classifier capacity of theoretic (kg/h), V = volume classification (m^3), ρ = beans densities (kg/m^3), n = rotational speed of the driving force (rpm).

The actual capacity was calculated by the equation:

$McA=Wst$ ---------------(3-15)

where Mc_A = classifier capacity of actual (kg/h), Ws = seeds weight (kg), and t = time (h).

Power was calculated by the equation:

$P=2\pi\omega n60$ --------------- (3-16)

where P = Power (W), ω = torque moment (Nm), n = rotational speed of the driving force (rpm).

Classification specific energy consumption was calculated by the equation:

$GSEC=PMcA$ ------------ (3-17)

where GSEC = Classification specific energy consumption (kJ/kg), P = Power (W), Mc_A = classifier capacity of actual (kg/h).

The distribution of classification results was calculated by the equation:

$Dis=GsMt\times100\%$ -------------- (3-18)

where Dis = classification distribution (%), Gs = classification sieve (kg),

Mt = total material (kg).

The effectiveness of classification was calculated by the equation:

$Eff=McgMng$ -------------- (3-19)

where E_{ff} = effectiveness (%), Mcg = classifier classification (kg), manual classification (kg).

The efficiency of the classifier was calculated by comparing theoretical capacity with actual capacity, or with the equation [20]:

$\eta=McTMcA$ -------------------- (3-20)

where η = classifier efficiency (%), Mc_T = classifier capacity of theoretic (kg/h), Mc_A = classifier capacity of actual (kg/h)

Chapter 4

IMPLEMENTATION AND TESTING

4.1 Implementation:

A 172rpm, 81N/m three-phase motor is used to drive the shaft. The rotary motion provided by the motor to the main shaft is then connected to the other offset shaft which will drive the main screen frame. The displacement is given for the shaft attached to the sieves. This displacement will create torsional vibration and transverse vibration as it will move back and forth/alternate. As a result of this back-and-forth movement on the sieve, the coffee will be sifted in the required volume of coffee mixture show in (Fig. 4-1).

Figure 4–1-Motor 3 Phase with gearbox

4.1.1 Implementing the Coffee Box:

The coffee is poured into this box, and it is poured on its way to the sieves. It’s controlled by gate located in the bottom of it show in (Fig. 4-2).

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Figure 4-2 Coffee Box

4.1.2 Implementing The Body:

the sieve structure contains sieve tracks so that it keeps stable when the machine vibrates, in show in (Fig. 4-3).

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Figure 4-3 Body

4.1.3The Axial Shaft

The axial shaft contains an asymmetric bearing and acronical shaft, and is installed on the sieve frame.

Figure 4-4 Axial Shaft

4.1.4The Connected Shaft:

This shaft is used for connecting the motor and the axial shaft.

Figure 4-5 Connected Shaft

Assembly of the Project:

Step 1 The external structure of the machine, in show in (Fig. 4-6).

Step 2 After designing the exterior structure, the fill tank was placed, in show in (Fig. 4-7).

Step 3 Bering has been placed on the outer structure, in show in (Fig. 4-8).

Step 4 Motor to move the machine, in show in (Fig. 4-9).

Step 5 Link between the uniform column and the baring, in show in (Fig. 4-10).

Step 6 Connect belt between motor and column connection, in show in (Fig. 4-11) .

Step 7 The body of the sieves has been placed, in show in (Fig. 4-12).

Step 8 The connection between the uniform and the back, in show in (Fig. 4-13).

Step 9 Bearings between the outer and inner body, in show in (Fig. 4-14).

Step 10 Inserting the sieves into the stream, in show in (Fig. 4-15).

Step 11 After the completion of the introduction of sieves in the tracks, in show in (Fig. 4-16).

Step 12 Introduction of a grain sortion structure, in show in (Fig. 4-17).

Step 13 The final shape of the coffee sifting machine, in show in (Fig. 4-18).

Figure 4-6 Step 1

Figure 4-7 Step 2

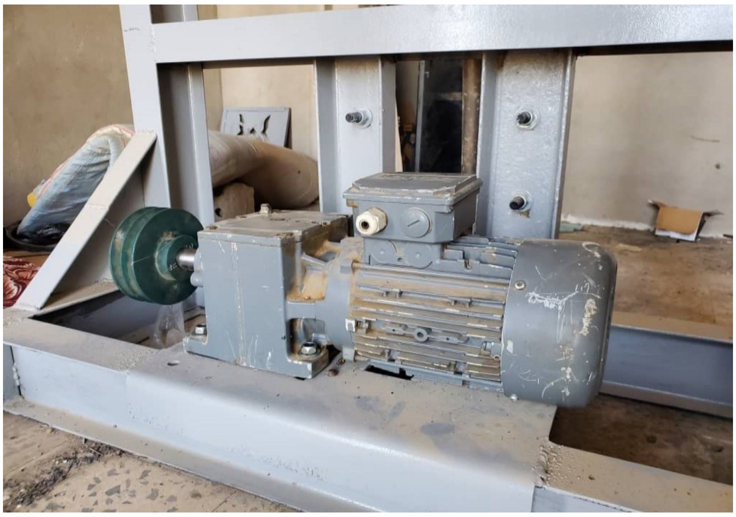


Figure 4-8 Step 4

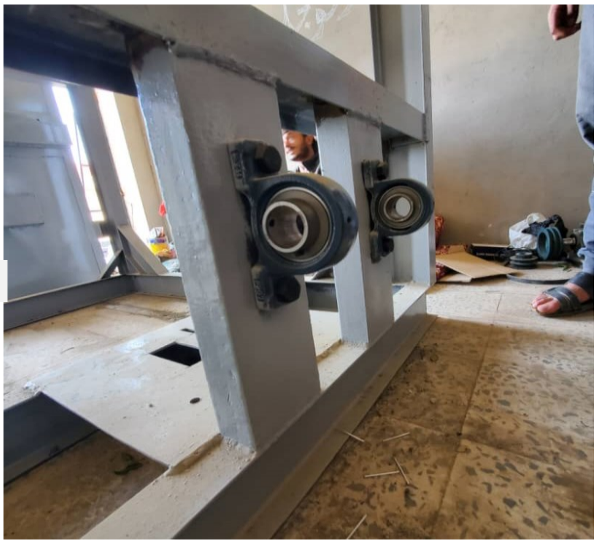


Figure4-9Step 3

Figure 4-10 Step 5

Figure 44-11 Step 6

Figure 44-12 Step 8

Figure44-13 Step 7

Figure 44-14 Step 9

Figure 44-15 Step 10

Figure 44-16 Step 11

Figure 44-17 Step 12

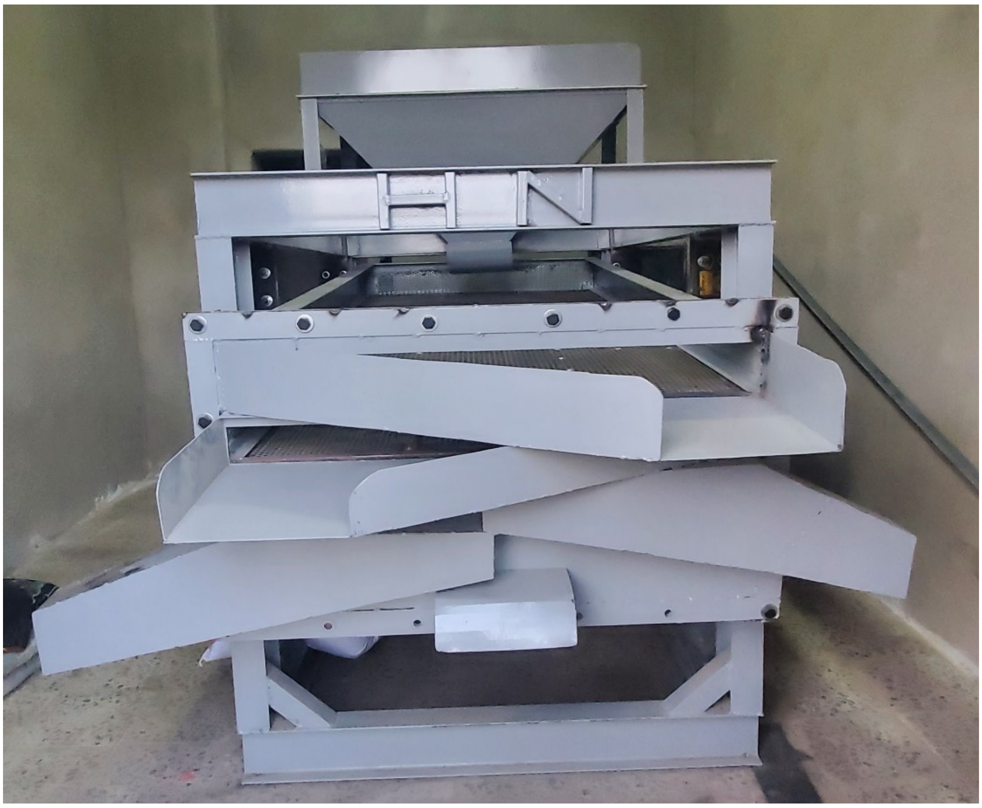


Figure 4-18 Step 13

4.1.5 Control Circuit:

In the control part 5 itineraries will be added to the project. The first route will be to transfer the coffee beans from the main tanks to the upper tank of the machine, which pours the coffee beans into the machine. As for the other 4 conveyor lines, they will be for the output of the machine, after the sorting process is completed for the required sizes, and each line will be of a specific size, with the possibility of adding packaging for the milk or moving it to the storage place designated for each size. Each conveyor belt will use one motor as the conveyor of the production line for tanks or packaging, because the control circuit does not need much control, we will design it with classical control to reduce the cost.

The pieces used and its function in the circuit:

- 1 A main breaker whose function is to turn on and off the circuit.
- 4 conductors that separate and connect the circuit.
- 5 Overload, its function is to protect the motor from damage.
- 5 motors to move the traffic lines.
- 1 emergency stop in order to stop the circuit in the event of anything urgent happening in the machine.
- 5 pushbuttons to operate each line separately, and the contactor point has been connected in parallel in order for the line to remain operational until it is stopped.
- 5 pushbutton to stop each track individually.
- 10 LEDs indicating 5 when each lane is on and 5 when each lane is off.

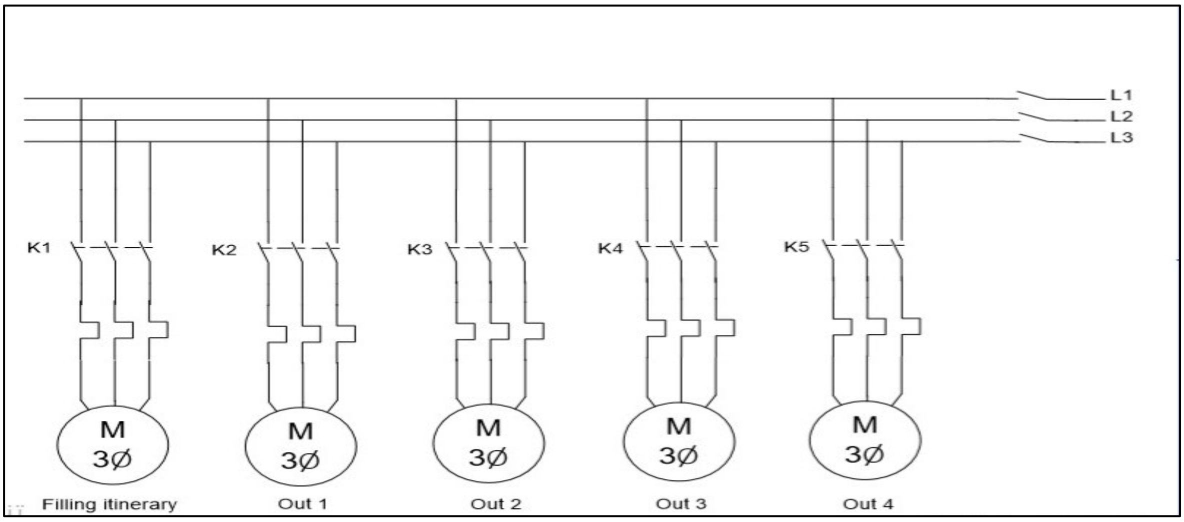


Figure 4-19 Control Circuit 1

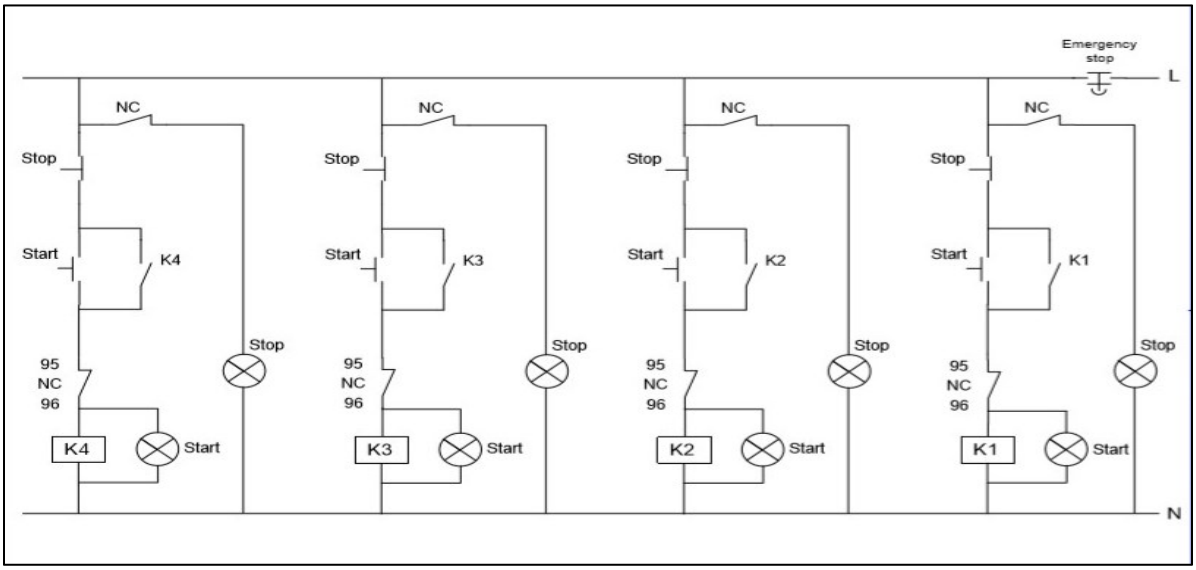


Figure 4-20 Control Circuit 2

Figure 4-21Control Circuit 3

Chapter 5
RESULTS AND DISCUSSION

5.1 Classifier Working Capacity

The results showed that coffee beans that fell from the hopper to the filter were separated based on the diameter of the beans. With a sifting angle of 10°, and with the classifier working capacity at rotary speeds of 91.07, 65.88, and 31.41 rpm, the results of the actual capacity test were 35.51, 26.62, and 22.55 kg/h, respectively

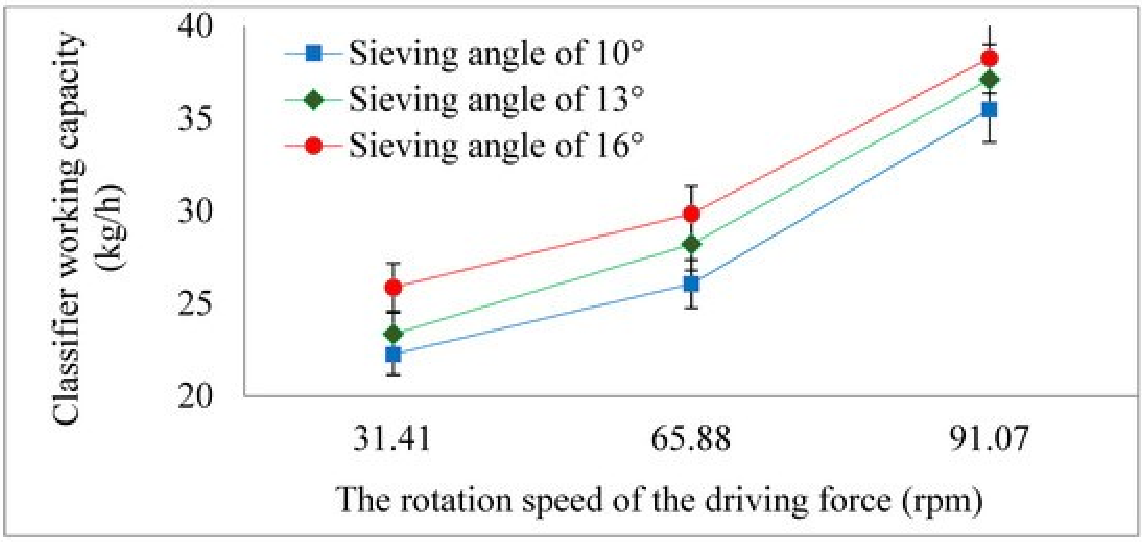


Figure 5-1 Relationship between the sifting angle and the rotational speed.

For a sifting angle of 13°, the classifier working capacity at the rotational speeds of the driving force of 91.07, 65.88, and 31.41 rpm gave results of 37.22, 28.21, and 23.45 kg/h, respectively. As for the sifting angle of 16°, and the classifier working capacity at the rotational speeds of the driving force of 91.07, 65.88, and 31.41 rpm, the results were 38.27, 29.86, and 25.87 kg/h, respectively.

Table 5-1 **Linear Regression Equation**

The linear regression equation of the relationship between the rotational speed of the driving force and the sifting angle of the classifier working capacity .

No	Sieve Angle	Linear Regression Equation
1	10Ø	y=6.6235x +14.693
2	13Ø	y=6.8885x +15.783
3	16Ø	y=6.1985x +18.939

The equation applies to the driving force rotation range between 31.41 to 91.07 rpm. Based on the consideration of the comfort level of the engine, the maximum driving force rotation that could be used was 91.07 rpm.

The classifier working capacity was largely determined by the rotational speed of the driving force and the sieve angle. The greater the sieve angle and rotational speed of the driving force, the higher the classifier working capacity

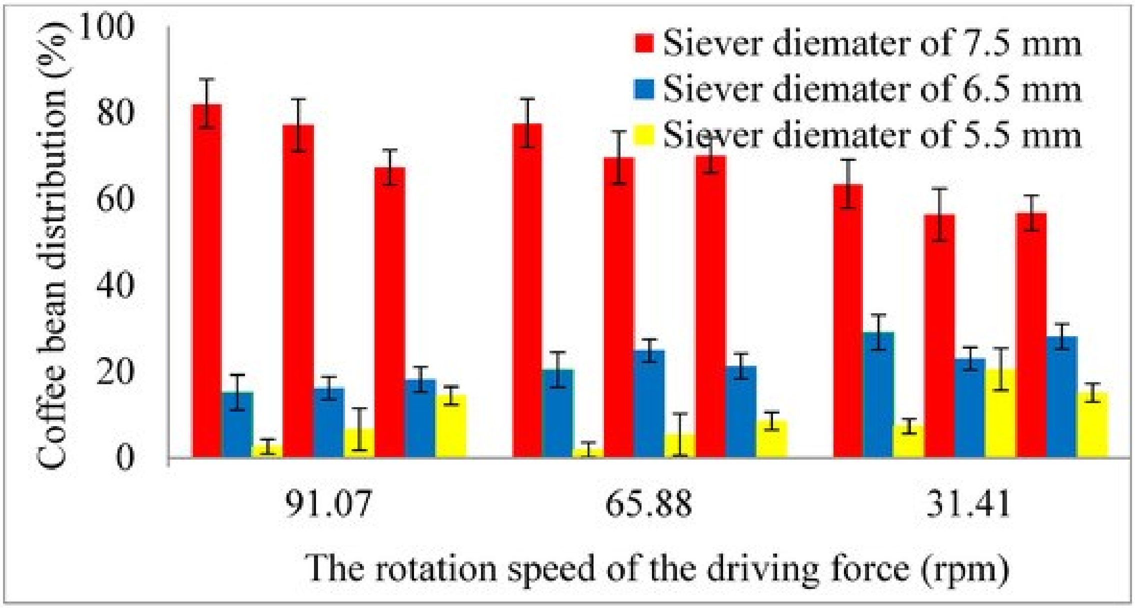


Figure 5-2 Distribution of retained coffee beans in each sieve unit

Conversely, the smaller the sieve angle and rotational speed of the driving force, the lower the classifier working capacity. This is thought to be due to the influence of the coffee bean slip style. A high slip force causes the seeds to slide down faster, so getting into the sieve hole is also faster. This data is in line with the results of the study by Mofolasayo et al, which reported that engine capacity is determined by the rotational speed of the driving force and the sieve angle. However, according to Olukunle and Akinnuli, the use of sifting angles and higher rotational speed of the driving force does not mean that the classifier provides work capacity with the best quality of final product, but depends on the initial uniformity of the coffee beans to be graded.

5.2 Power:

Power measurements are taken when there is a load, using a clamp meter. The actual power at the rotational speed of the driving force 31.41 rpm was an average of 15 Watts, while the rotational speed of the driving force of 65.88 and 91.07 rpm was 17 and 20 Watts, respectively. This data shows that the higher the rotational speed of the driving force, the greater the classifier power. The same data has been reported by Qian et al.

That engine power at a rotational speed of 400 rpm has an average value of 87.5 Watts, while at a speed of 800 rpm the required power was 133.4 Watts.

Linear regression analysis obtained the equation of the relationship between the rotational speed of the driving force with power (y):

y = 6.48x + 15.267

R2 = 0.9559 -------------------------- (8)

The Equation (8) can only be applied to the rotational speed of the driving force between 31.41 and 91.07 rpm. It showed that the higher the rotational speed of the driving force, the greater the power needed. A large classifier working capacity requires a high rotational speed of the driving force as well. The use of electrical energy can be greater with the higher rotational speed of the driving force. To follow the requirements of the International Energy Agency by using less energy input but obtaining the same quality, it is necessary to redesign this classifier.

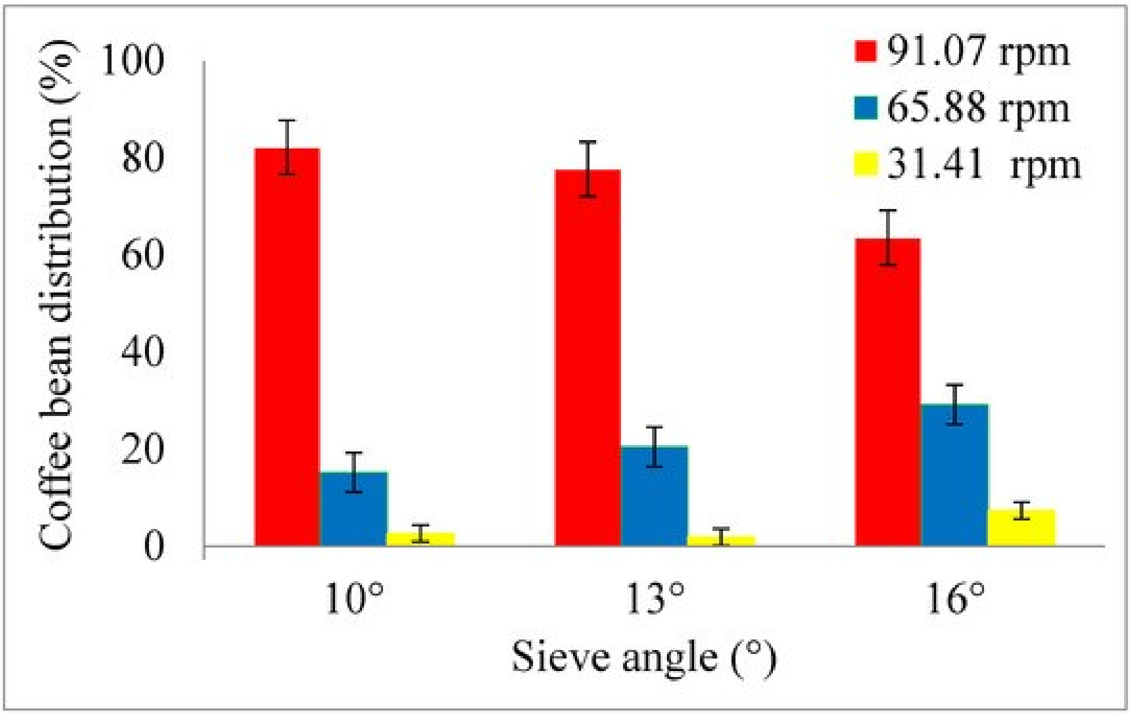
5.3 Specific Energy Consumption

Specific energy consumption (SEC) was the energy needed to do coffee bean classification which can be calculated by dividing the power needed for the classification process by the actual capacity of the classifier. Based on the calculation results obtained, the specific energy classification was 135 kJ/kg. The SEC shows the level of efficiency and effectiveness of classification energy use based on inputs and outputs, and its value is used to estimate energy consumption during the classification process.

Some researchers have also previously reported that SEC was a model of energy consumption from a certain perspective. Because the SEC includes a mapping relationship between energy consumption during certain classification work processes, its value can not only compare energy efficiency differences from the same machining process and different processing parameters, but can also reflect energy intensity and productivity differences in different machining processes. Therefore, even though some SEC models are not accurate enough and the relevant parameters are complex, the concept is easy to understand and calculate. Therefore, according to Ma et al., the application is very general.

5.4 Distribution of Classification Results

The distribution of classification results in each sieve was a comparison between the classification results in each sieve and the total weight of the material being fed. The percentage of beans in each sifting was largely determined by the sieve angle and the rotational speed of the driving force



At the same sifting angle, the higher the rotational speed of the driving force, the fewer the number of beans retained. This happened because the coffee beans were slipping more easily into the sieve, so that the number of beans retained was also decreasing.

The observations show that at a sieve angle of 10° and a rotational speed of driving force of 31.41 rpm, the number of beans held in the first sieve was 82.14%, while at a rotational speed of driving force of 65.88 and 91.07 rpm, the number of beans retained was 77.65% and 63.54%, respectively. The same trend occurred at the sieve angle of 13° and 16°). This result is in line with the research report by Gunathilake et al. that states that the best classifier working conditions are those that give the smallest seed size distribution deviation compared to the seed size distribution obtained from manually graded beans.

5.5 Classification Electivity

5.5.1 The First Sieve

The first sieve retained a collection of seeds with a diameter greater than 7.5 mm. The classification results show that the distribution of coffee beans retained in the first sieve, with a rotational speed of 91.07 rpm and a sifting angle of 10°, obtained 82.14% of coffee beans larger than 7.5 mm, whereas at the rotational speed of the driving force of 65.88 and 31.41 rpm, the percentages of coffee beans retained were 77.65% and 63.54%, respectively. This data shows that at the sifting angle of 10° and the rotational speed of the driving force of 91.07 rpm, the percentage of coffee beans that had a diameter smaller than the diameter of the 7.5 mm sieve hole was 17.86%. The higher the rotation speed of the driving force, the higher the percentage of the number of coffee beans with a diameter smaller than 7.5 mm. The same thing was also shown from the test results at the rotational speed of the driving force of 65.88 and 31.41 rpm: 15.21 and 2.65%, respectively.

5.5.2The Second Sieve

The second sieve retained a collection of beans with a diameter smaller than 7.5 and greater than 6.5 mm. The classification results show that the distribution of coffee beans retained in the second sieve at the rotation speed of the driving force of 91.07 rpm and a sieve angle of 10° was 77.14%, while at the rotation speed of the driving force of 65.88 and 31.41 rpm, it was 16.21% and 6.65%, respectively. This data shows that at a sieve angle of 10° and a rotation speed of the driving force of 91.07 rpm, there were 22.86% of coffee beans with a diameter between 6.5 and 7.5 mm.

The faster the rotation of the driving force, the higher the percentage of coffee beans with a diameter smaller than 6.5 mm. The same thing was also obtained from the test results on the rotation speed of the driving force of 65.88 and 31.41 rpm: 16.21% and 6.65%, respectively.

5.6 The Third Sieve

The third sieve retained a collection of beans with a diameter smaller than 5.5 mm. The classification results show that the distribution of coffee beans held in the third sieve at the rotation speed of the driving force of 172 rpm and a sieve angle of 10° was 67.34%, while at the rotation speed of the driving force of 65.88 and 31.41 rpm, it was 18.21% and 14.45%, respectively.

This data shows that at a sieve angle of 10° and a rotation speed of the driving force of 172 rpm, as much as 32.66% of coffee beans had a smaller bean diameter than the sieve hole diameter of 5.5 mm. The faster the rotation speed of the driving force, the higher the percentage of coffee beans with a bean diameter smaller than 5.5 mm. Some previous research results also show the same trend data, as reported by Gunathilake et al.

The rotational speed of 15 rpm and the sieve angle of 3° to the horizontal axis of the cylinder produces the highest performance of 93.46%.

5.7 The Efficiency of Classification

The efficiency of classification was calculated by comparing the actual capacity of the engine with the theoretical capacity of the engine. The actual capacity of the classifier was the ability of the classifier to do classification within a certain time interval. Based on the calculation of the actual capacity of 200 kg/h and the theoretical capacity value of 18 kg/h, the efficiency of the classifier was 91.67%. This value indicates that the efficiency of the classifier was already high, but still needs to be improved. To increase the efficiency of classification, the rotational speed of the driving force needs to be increased based on the Indonesian National Standard (INS).

The energy efficiency was the ratio between performance and energy input. The energy efficiency has a specific application definition for each different condition, but the definition most used is a thermodynamic perspective that uses the ratio of product output to total energy input. Due to the complexity of the function of classifier tools, according to Zhou et al., the definition of energy efficiency is not clear so far and there is an amount of energy efficiency evaluation indicators that can be used for various classifier tools.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

A coffee sorting machine is a valuable tool for the coffee industry that can help improve the quality and consistency of coffee beans while reducing labor costs and increasing productivity. The machine uses a variety of mechanical and electronic components, including screens, sieves, air jets, and optical sensors or cameras, to sort coffee beans based on their size, shape, and density.

The control circuit of the coffee sorting machine is responsible for managing the machine's sorting process, including adjusting the speed and operation of the various components based on the desired criteria. The control circuit designed to be user-friendly and reliable, and can help ensure that the coffee beans are sorted accurately and efficiently.

The project methodology for developing a coffee sorting machine involves several steps, including requirements gathering, design and development, prototyping and testing, manufacturing, installation and training, quality control, and maintenance planning. By following this methodology, the coffee sorting machine can be designed, developed, and implemented in a way that meets the needs and expectations of coffee growers, processors, and consumers.

Overall, a coffee sorting machine is an important investment for the coffee industry that can help improve the quality and consistency of coffee beans, reduce labor costs, and increase productivity, while also being cost-effective and environmentally sustainable.

6.2 Recommendations

There are several areas for future work and development in the field of coffee sorting machines. Here are some potential areas of focus:

1. Artificial intelligence and machine learning: The integration of artificial intelligence (AI) and machine learning (ML) technologies can improve the accuracy and efficiency of coffee sorting machines. These technologies can help the machine learn and adapt to different types of coffee beans and can also help identify and sort defects more accurately.

2. Sustainability: There is a growing interest in sustainability in the coffee industry, and future coffee sorting machines can be designed with sustainability in mind. This can include the use of eco-friendly materials, energy-

efficient components and reducing waste in the sorting process.

3. Integration with other technologies: Coffee sorting machines can be integrated with other technologies such as blockchain, to help track and verify the origin and quality of coffee beans. This can help improve transparency and trust in the coffee supply chain.

4. Improved sorting criteria: Future coffee sorting machines can incorporate more advanced sorting criteria such as moisture content, flavor profile, and aroma. This can help produce more consistent and high-quality coffee beans.

5. Mobile and portable machines: Coffee growers in remote areas may benefit from mobile and portable coffee sorting

machines that can be easily transported to different locations. Future machines can be designed to be lightweight, compact, and easy to set up and operate.

Overall, there is a lot of potential for future work and development in the field of coffee sorting machines. By incorporating new technologies, sustainability practices, and advanced sorting criteria, coffee sorting machines can continue to improve the quality and consistency of coffee beans, reduce labor costs, and increase productivity in the coffee industry.

It is also explained in detail with the control circuits in chapter 4.1.5.

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