DESIGN AND CONSTRUCTION OF ACHA MECHANICAL SEPARATOR

BY

AGBELUSI TEMITOPE O. CARLOS

2000/9482EA

DEPARTMENT OF AGRICULTURAL ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY,

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BEING A FINAL YEAR PROJECT SUBMITTED IN
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DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree, diploma or certificate at any University or Institution. Information derived from personal communication, published and unpublished works of others were duly referenced in the text.

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Agbelusi Temitope O. Carlos

22/11/2006
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Date

ABSTRACT

This project was aimed at designing and constructing an acha (*Digitaria spp)* mechanical separator to be powered by an electric motor. It was observed that ancient or traditional method of grain separation is not effective, labour intensive and time wasting. This however, results in insufficiency in acha grain produced and also of low quality after processing due to the presence of impurities like stones, dust and chaffs. Hence, the development of acha mechanical separator based on the above listed problems associated with traditional method of grain separation. In the design, necessary equations were used to determine the dimension of parts and forces involved as required. The mechanical separator is capable of separating about 200 kg of acha per hour, and all the assembled components were procured locally at moderate prices. The power required to drive the machine is 2128.8W using a 3 hp electric motor. The machine was tested and 82.34 % efficiency was arrived at, by removing dust and smaller stones than acha.

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INTRODUCTION

1.1 . General Introduction

Acha, *Digitaria spp* also known as Hungary rice is the oldest indigenous African cereal that is identified with early crop domestication in the Western Sudan zone. It is a small grain cereal of ancient cultivation widely grown in West Africa and dry savanna zones of Mali, Burkina Faso and Guinea. It is widely grown in Nigerian in the cool region of Plateau state, part of Bauchi, Kebbi, Taraba, Kaduna and Niger states.

The husked grain contains approximately 6.0% Water, 8.7 % Protein, 1.1% Fat, 81.0% Carbohydrate, 1.1% Fiber and 2.1% of Ash. Each year about 300,000 hectares of land is devoted by farmers to the cultivation of acha every year in West African sub region. It supplies the food need of about 4 million people. It is the staple food for many tribes in Plateau and Nasarawa state of Nigeria. At present about 20,000 tonnes of the crop is produced in Plateau state alone which is about 25% of the total need of the state.

Among the cultivated types two species are prominent; white acha (*Digitaria exilis)*, which is the most widely cultivated, is found in Senegal to Chad, and is very popular around the upland plateau of central Nigeria. The other species, the black acha *(Digitaria iburua)* is restricted to Jos – Bauchi plateau of Nigeria as well as to Northern regions of Togo and Benin republic. The crop is a little bigger when compared to *D. exilis,* in terms of stature and even grain size. It can tolerate poor soils and will grow where little else succeeds.

Acha is used in a variety of ways; it can be eaten raw, use for the preparation of porridge and cous cous, or solid food dough like 'tuwo', 'kunu-acha', grounded and mixed with other flours to make breads. A family of 7-10 will consume between 2-

3kg/day. It has been described as good substitute for semolina-the wheat product used to make spaghetti and other pastas. Also, acha is useful in the brewery industry. The straw and chaff are used as animal feeds, in mattresses, as bedding for livestock, production of potash, block-making and as source of fuel for cooking. It is used as a reliever for diabetic patient in medicine.

1.2. Justification

Africa has the fastest population growth in the world currently increasing at approximately 3% a year and this rate has been sustained for the last two decades. In contrast, food production increased by 1.8% between 1998 and 2002 which indicates a clearly divergent trend (Merenah, 2004). According to Merenah (2004), growth of food production has consistently fallen behind population growth for the past three decades. Consequently, many African countries that were self-sufficient in food 20 or 30 years ago are now importing food (Okigbo, 2004). Unfortunately, most African countries are poor and depts. Through importing food are exacerbating the African food crisis.

It is estimated that the number of the people dying from starvation and malnutrition related disease is between 20,000 and 70,000 daily. More than half of these victims are children under the age of five. In addition, FAO (1984) estimated that 400 to 500 million children living in the 60 poorest countries suffer from severe chronic starvation and malnutrition which result in poor physical and mental development.

Acha is one of the most nutritious of all grains. Its seed is rich in *methionine* and *cystine*, *amino* acids vital to human health and deficient in major cereals. Apart from the benefits of the combination of *amino* acids and taste, the revenue generated by small scale-farmers as well as the large-scale or estate farmers in acha has continued to increase.

Harvesting and post-harvest of acha are however done manually. This resulted in insufficiency of grain produced and also of low quality after processing due to the presence of impurities like stones, dust and chaffs. Separation of the grain from these impurities require the modern technology of cleaning, sorting, grading and destoning to encourage more production acceptable to the consumers.

1.3 . Aims and Objectives

The objectives of this project are:

1 To design and fabricate an acha mechanical separator with a productive capacity of not less than 150kg/hr.

2 To reduce the drudgery associated with manual processing of acha,

3 To separate acha based on size alone.

1.4 Scope of Project

The scope of the project is to design, construct and test an a mechanical separator that can be used separate acha from foreign materials based on size alone, in an environmentally friendly manner before it is later moved to a pneumatic separator that cleans the acha based on difference in aerodynamic properties.

CHAPTER TWO

LITERATURE REVIEW

2.1. Historical Background to Grain Separation

Grain separation is a preparatory unit operation performed on agro-allied materials in to remove organic and inorganic impurities or to separate poly shape and multi-size grains into their constituents. Screening as form of separation operation is based on the principle of employing the mechanical and physical properties of the particular grain in question.

In the olden days, screening/sieving operation was limited to the manual sieving by the use of hand to separate grains into different sizes. In the nineteenth century, sieving was modified by P.B Andrews, by the introduction of shallow cylindrical frame work. Not withstanding, the efficiency of this sieve is still very low.

However, with industrial revolution of twentieth century, industrial screening machine were designed. The machines were operated mechanically by vibration caused by either electromagnetic device. In most screens the grains drop through the opening by gravity. Coarse grains drop quickly and easily through large opening in a stationary surface. With finer particles, the screening surface agitated in some way. The common ways are;

1 Revolving a cylindrical screen about a horizontal axis and

2 Shaking, gyrating or vibrating the flat screens.

2.2 Separation Operation

Separation is a post-harvest operation undertaken to remove foreign and undesirable materials from threshed crops/grains and to separate the grain/product into various fraction. This is done to enhance their economic value by increasing their nutritional value and availability overtime and space and therefore, their price or market value. A mixture of seeds can be separated on the basis of difference in length, width/thickness, specific gravity, surface texture, drag in moving air, color, shape, electrical conductivity and magnetic properties. Separation operation includes such activities as cleaning, sorting and grading.

Cleaning in agricultural processing means the removal of foreign and undesirable matters from the desired grains/product and may be accomplished by washing, screening, hand picking etc. Grading refers to the classification of cleaned products into various quality fractions depending upon the various commercial values and other usage. Sorting refers to the separation of cleaned product into various quality fractions that may be defined on the basis of size, shape, density, texture, and color.

Screening is a method of separating grain/seed into two or more fractions according to size alone. For cleaning and separation of seeds, the most widely used device is screen. When solid participles are dropped over a screen, the particles smaller than the size of screen openings pass through it, whereas larger particles are retained over the screen or sieve. A single screen can thus make separation into two fractions. When the feed is passed through a set of sieves, it separates into different fractions according to sieves. Screens along with an air blast (air screen) can satisfactorily clean and sort most of the granular materials.

According to Singh and Kashyab (1987), the basic purpose of any screen is to separate the feed consisting of a mixture of particles of different sizes into two distinct fractions. These fractions are;

1 the underflow :- the particles which pass through the screen, and

2 the overflow or oversize:- the materials that are retained over the screen.

A screen can be termed as ideal screen which separates the feed in such a way that the largest particle of underflow is just smaller than screen opening, while the smallest particle of overflow is just larger than the screen opening. But in practice no screen gives perfect separation as stated above, and is called actual screen. The underflow may contain material coarser than screen size, whereas the overflow may contain smaller particles than screen size.

An effective cleaning operation of grain must;

1 separate the contaminants effectively

2 remove the cleaned surfaces in the desired condition and

3 Limit recontamination of the cleaned grains.

Inefficient removal and disposal of the contaminants once it is separated from the grain result in product recontamination.

Separation operations such as cleaning, grading and sorting of products are performed by exploiting the differences in engineering properties of the materials. Various forms of separation equipments have been designed and developed on the basis of properties of the product to be handled. Thus, these equipments can be classified based on the characteristics of the materials namely; size, shape, specific gravity or weight and aerodynamics properties (Kaul, 1967).

2.3 Classification of separation operation

2.3.1 The Traditional Separation Operation

The separation of foreign and undesired matters from grains starts as early as the origination of the grains thousands of years ago. The threshed grain is thrown into the air in the direction of the wind to remove contaminants but stones which are slightly heavier cannot be completely removed by this method.

2.3.2 Separation Based on Specific Gravity

The specific gravity separator makes the separation according to differences in densities or specific gravity of products. This separator works on two principles;

1 The characteristics of grains to flow down over an inclined surface

2 The floatation of the particles due to upward movement of air.

The main part of the device is a perforated deck. The deck is properly baffled underneath to ensure uniform distribution of air over it. The pressure or terminal velocity of the air rising through the deck is controllable very close wide range.

When grain mixture is fed into feed box. Air is blown up through the porous deck surface and the bed of grain by a fan at a rate that the material is partially lifted from contact with the deck surface. The air coming through the deck from bottom stratifies the. materials while the vibrating action of the deck separates the heavy materials from lighter materials. The heavier materials more towards the top end of the deck where as the higher materials are discharged from the low end of the deck (Ahuja and Pathak, 1971).

2.3.3 Separation Based on Aerodynamic Properties

The separation is performed based on the difference in aerodynamic properties of various constituents of the mixture. Examples of equipments that separate based on aerodynamic properties are the pneumatic separator and the aspirator. Both the aspirator and the pneumatic separator use terminal velocity of grains to separate different fractions. This refers to the air required to suspend particles in a rising air current (Uhl and Lamp, 1966).

2.3.4 Separation Based on Fluidisation Technique

The fluidised bed cleaner/separator makes the classification of seed due to difference in density and size. When an air current is passed through a perforated deck containing a bed of granular materials, various phenomenon occur.

At low air flow rate the bed remains inert, causing pressure drop in the air flowing through the bed. As air flow rate increases, a stage is reached called the quiescent stage when the bed begins to expand to the extent of 10% volume increase. The mobility of the bed depends on the shape of the particles but the external vibration is applied to produce a mobile fluid bed (Clarke, 1985).

2.3.5 Separation Based on Size

The separation is performed according to size alone. According to Sahay and Singh (1999) the mixture of grain and foreign matter is dropped on a screening surface which is vibrated either manually or mechanically. A screen is used to separate into two fractions. The screening unit may be composed of two or more screens per the cleaning requirement. Grain is fed on the screening surface in batches.

2.4 Design Consideration of a Mechanical Separator

The factors which influence the design of the mechanical separator can be classified into two categories:

Machine and operational factors.

Material factors

2.4.1 _Machine and Operational Factors

Capacity and efficiency in screening operations are closely related to each other. In cleaning operation, when the rated capacity is increased, its capacity is decreased. Some of the machine factors which should be taken into account while designing the mechanical separator are described below:

2.4.1.1 The Feeding Mechanism

The feeding mechanism should be designed properly in order to obtain the maximum capacity and efficiency. The hopper should be positioned in such a way that the material would be able to spread uniformly over the full width of the screen surface.

It should approach the screen surface in the direction parallel to the longitudinal axis of the screen and at as low practical velocity as possible.

2.4.1.2 The Angle of Inclination

The screen should be adjusted to a certain degree of inclination to the horizontal. In a precision grain cleaner, 4 to 12° of pitch gives adequate cleaning capacity. High capacity grain separators have should have a steep pitch to move grain over the screen rapidly and flattened pitch while cleaning round grain like to prevent them from gaining too much momentum and bouncing over the screen without properly graded. The angle of inclination is also a function of many other variables such as material to be handled, width, length of screen etc. If the angle is too high, material moves too fast and efficiency drops. However there is steep loss of efficiency at steep angles, but sharper drop in capacity at low angles.

2.4.1.3 Vibration Amplitude and Frequency

The speed and amplitude of vibration should be designed to convey the material properly and to prevent the blind of screen. These are more or less dependent upon the size and weight of the material being handled and are related to the angle of installation and type of screen surface. The fast shake causes the grains to turn and tumble and present all their sides to the screen openings. However, when the shake speed is too fast, rounds or heavy grains tend to bounce over the screen and are not sift properly. Slow shake speeds are used to obtain accurate separation. However the grain will be dead on the screen if the shake is too slow.

The frequency of oscillation has a very significant effect on the grain losses in combines. An increase in frequency of vibration to a maximum limit gives better, but decrease in effectiveness sets in with higher frequencies.

2.4.1.4 Number of Screens

It is generally agreed that the most efficient screening results when a series of single deck screens are used. This is because lower decks of multiple-deck screens are not fed so that their entire area is used and because each separation requires a different combination of angle, speed and amplitude of vibration for maximum performance.

2.4.1.5 Rate of Forward Travel

The rate of forward travel is completely an empirical factor that does not lend itself to generalization because it depends upon both machines and material characteristics. This indicates the travel of speed in m/min. If the length of screen (in m) is multiplied by 60 and divided by the product rate travel in m/min, then the result is the retention time in seconds. This is useful in determining the capacity of screen.

2.4.2 Material Factors

The various material factors which are taken into account while designing a mechanical separator are described below:

2.4.2.1 Distribution of Various Fraction Sizes

The distribution of various fractions of grains in the mixture greatly influences the separation.

2.4.2.2 Stickiness and Abrasiveness

If the particles tend to stick together these must separated. Material abrasiveness affects the selection of screen. Electrostatic charges built up by mechanical action of sifting will cause the particles to coat or blind the screen. Such particles can not be dislodged by mechanical action. Besides the above, the moisture content and crop species also affect the design of the separator.

2.4.2.3 Compaction or Bed Density

The freedom of flow of material over the screen is greatly affected by compaction or bed density. If the bed of material over the screen is more compact, its normal flow over screen is restricted. The normal flow does not occur without constant changes in the relative position of a particle with respect to its adjacent particles. At the same time materials having low density also pose problem in screening due to fluffy nature.

2.4.2.4 Particle Size and Shape

There are two ways in which particle shape is related to its size that passed or retained on a particular sieve. First, if all the openings in the sieve are square and having exactly the same size, the flattened grains would pass diagonally through the opening. Secondly, some variation in size and shape of opening is unavoidable in the manufacturing. Consequently, the size and shape of grain passed or retained would depend upon the number, size and shape of the off-size openings.

2.5 Description of the Acha Mechanical Separator

The acha mechanical separator is made up of a working deck comprising of a single screen. The single screen in the working deck serves to separate dust and the fine particles smaller in size to the grains. The screen tray is a special wire cloth selected for separation purposes. The screen is inclined at 12° to the horizontal. The sieving unit is held in place by four flexible suspension reeds (hanger) by means of bolts and nuts on the lower side of the machine frame. At one end of the sieving unit is mounted a vibrating exciter which consist of a shaft rotating to generate the required vibration. This is driven by an electric motor via belt drive

. On the top of the working deck is fitted a hopper that feeds the machine with the material to be separated. Towards the lower end of the machine on the either side, there are two outlets for selected grains and stones as shown on the diagram (DRG NO 1)

2.6 Operation of the Machine

The acha to be cleaned is supplied into the hopper. Gradually, it passes through the throat and falls on the first screen of the sieving unit. The rate of the acha feed is controlled manually.

The working deck (sieving unit) is vibrated by the action of the exciter. The material move down as the screen performs the task of removing the cleaner acha and the larger impurities on the screen, while the smaller stones and dust are dropped off from the screen.

The cleaned acha is then collected through the selected material outlet on one side of the machine, while the smaller impurities are collected through the stones outlet on the other side.

CHAPTER THREE

DESIGN CALCULATIONS

3.1 Design Parameters and Assumption

In this design

The mass of steel framing for the sieve unit = 108kg

The mass of wooden framing for the sieve unit = 55kg

The total mass of sieve unit = (108 + 55) kg = 163kg

Assuming the total weight of Acha and sieve unit attachment to be 15%

$$W = 163 \times 0.15 \times 9.81 = 1838.8845 \text{ N}$$

3.2 Determination of Sieve Support Bar Dimension

Since there are four support bars carrying the sieving unit, and calculation for load per support.

$$W_s = \frac{W}{4} = \frac{1838.8845}{4} = 459.72\text{N}$$

The maximum bending moment due to sieving unit is

$$M_s = I_f \times W_s \times 1 \qquad (3.1)$$

Where

I_f = dynamic load factor, and for the purpose of this design, it is assumed to be 3

I = distance from upper frame to the lower connection of the working deck is 1.1m

$$M_s = 3 \times 459.72 \times 1.1 = 1517.076\text{Nm}$$

For bending load, the yield strength is given as

$$\delta_y = \frac{M_S}{Z} \qquad (3.2)$$

From which the section modulus

$$Z = \frac{M}{\delta_y}$$

Using a grade II steel (δ_y = 48 Mpa)

$$Z = \frac{1517.076}{48 \times 10^6} = 3.16 \times 10^{-5}\,m^3$$

Assuming a cross-sectional proper of d = $h/9$ {3.3}

$$Z = \frac{bd^2}{6} = \frac{9d^3}{6}$$

$$d = \left[\frac{6Z}{9}\right]^{\frac{1}{3}} = \left[\frac{6 \times 3.16 \times 10^{5}}{9}\right]^{\frac{1}{3}}$$

$$d = 0.028m$$

For the purpose of this design d = 0.03 m will be used and from equation (3.3)

b = 0.27m

The deflection is given as

$$\gamma_{max} = \frac{W_s l^2}{3EI} \qquad (3.4)$$

Where E = 200×10^9 = modulus of elasticity

I = Moment of inertia

$$I = \frac{bd^3}{12} = \frac{0.27 \times (0.028)^3}{12} = 4.9392 \times 10^{-7} m^4$$

Hence,

$$\gamma_{max} = \frac{459.72 \times (1.1)^2}{3 \times 200 \times 10^9 \times 4.9392 \times 10^{7}}$$

$$\gamma_{max} = 1.877 \times 10^{-3} m$$

The stiffness is given as

$$K = \frac{W_s}{\gamma_{max}} = \frac{459.72}{1.877 \times 10^{3}} = 24.49 \times 10^4\ N/m$$

Where

K_T = Total stiffness of the support bars

$$= 4 \times K = 4 \times 24.49 \times 10^4$$

$$= 97.969 \times 10^4 \text{ N/m}$$

3.3 Determination of Power Transmission

For the purpose of the design, the mass of each support bar is 1.82kg

The total weight of the support bars is

$$W_s = 4 \times 1.82 \times 9.81 = 71.4168\text{N}$$

Hence, the total weight to be accelerated is

$$W_a = W + W_b$$

$$= 1838.8847 + 71.4168$$

$$= 1910.3015 \text{ N}$$

The dynamic load on the shaft is obtained from the relation

$$F_d = W_d = \frac{W_a \times 2(a + \delta)}{\delta}$$

For a zero load displacement, a = 0

$$W_a = 2W_a = 2 \times 1910.3015 = 3820.603\text{N}$$

The torque required to accelerate the load is

$$T = I_p\alpha = MK^2\frac{\Delta n}{t} = \frac{Wd}{g}K^2\frac{\Delta N}{60t} \qquad (3.5)$$

For the purpose of the design, a sieve shaft speed N = 360rpm is adopted.

If assumed that the system is to come to full operational speed in 5 seconds, then the developed torque from equation (3.5) is

$$T = \frac{3820.603}{9.81} \times (0.3476)^2 \times \frac{360}{5 \times 60} = 56.468\text{Nm}$$

Hence, the power required to accelerate the load will be

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

$$P = 56.468 \times \frac{2 \times \pi \times 360}{60} = 2128.799\text{W}$$

$$P = \frac{2128.7997}{746} = 2.8536 \text{ hp}$$

For motor tables, a single-phase integral has a power motor of 3hp at 1440rpm is adopted, with a motor pulley of 100mm (0.1m).

3.4 Determination of Amplitude and Frequency of Vibration

For a system of force vibration with single degree of freedom, the amplitude is obtained from the relation

$$\gamma = \frac{F_d / K_T}{\left[\left[1 - \left[\frac{\omega}{\omega_n}\right]^2\right]^2 + \left[2\xi\left[\frac{\omega}{\omega_n}\right]\right]^2\right]^{1/2}} \quad (3.6)$$

Where ω = frequency of excitation force

$$\omega = \frac{2\pi N_2}{60} = \frac{2\pi \times 360}{60} = 37.7 \text{ rad/s}$$

ω_n = Natural frequency of vibration of the system

$$\omega_n = \sqrt{\frac{K_T}{M}} = \sqrt{\frac{K_T g}{F_d}} = \sqrt{\frac{97.969 \times 10^4 \times 9.81}{3820.603}}$$

ω_n = 50.16 rads/s

Assuming a coefficient of dampness, ξ of 0.2 the equation (3.6) becomes

$$\gamma = \frac{3820.603 / 97.969 \times 10^4}{\left[\left[1 - \left[\frac{37.7}{50.16}\right]^2\right]^2 + \left[2(0.2)\left[\frac{37.7}{50.16}\right]\right]^2\right]^{1/2}}$$

$$\gamma = 7.734 \times 10^{-3} \text{ m}$$

The frequency of vibration of the system is given as

$$f = \frac{\omega}{2\pi} = \frac{37.7}{2\pi} = 5.9365\text{Hz}$$

3.5 Determination of Belt Size and Belt Selection

The transmitted power $P_t = 2238\text{W}$ (3hp)

Since the length of belt that passes over the driving pulley is equal to the length that passes over the driven pulley in one minute,

Therefore $\pi d_1 N_1 = \pi d_2 N_2$.

Hence, the velocity ratio is,

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} = \frac{360}{1440} = \frac{1}{4}$$

$d_2 = 4 \times d_1 = 0.4\text{m}$

Where, d_1 = diameter of driving pulley

d_2 = diameter of driven pulley.

For a machine operating at 8 hours per day, the belt safety factor of 1.1 is pulley

$P_d = 1.1 \times P_t = 1.1 \times 3 \quad 3.3$ hp

At 360 rpm of the drive motor and a power of 3.3 hp, a 3 v- belt section is adopted.

The belt speed is,

$$V = \frac{\pi dN}{60} = \frac{0.1\pi \times 1440}{60} = 7.5398 \text{ m/s}$$

With a velocity ratio of 4, the added power from charts is 2.0hp. Hence the required belt power is now.

$3.3 + 2.0 = 5.3$hp

Using the centre distance range of

$d_2 < C > 3(d_2 + d_1)$

$0.4 < C > 3(0.4 + 0.1)$

$0.4 < C > 1.5$

Assuming a centre distance C = 0.8m, the required belt length is obtained as

$$L = 2C + \frac{\pi}{2}(d_2 + d_1) + \frac{(d_2 - d_1)^2}{4C}$$

$$L = 2(0.8)+\frac{\pi}{2}(0.4 \ +0.1\ )+\frac{(0.4-0.1)^2}{4\times 0.8} = 2.41313m$$

From tables, a standard belt length of 2.413m is adopted. Hence,

$$B = 4L - 2\pi(d_1 + d_2)$$

$$B = 4 \times 2.413 - 2\pi(0.4+0.1)$$

$$B = 6.51m$$

The actual centre distance is

$$C = \frac{B+\sqrt{B^2-32(d_2-d_1)^2}}{16}$$

$$C = \frac{6.51+\sqrt{(6.51)-32(0.4-0.1\ )^2}}{16}$$

$$C = 0.7997m$$

$$C \approx 0.8m$$

The angle of wrap on the smaller pulley is

$$\theta_1 = 180^0 - 2\sin^{-1}\left(\frac{d_2-d_1}{2C}\right)$$

$$\theta_1 = 180^0 - 2\sin^{-1}\left(\frac{0.4-0.1}{2\times 0.8}\right)$$

$$= 158.386^0 = 2.76 \text{ rads}$$

From charts, for $\theta_1 = 186.14^0$, the service factors C_0 = 0.95 and C_1 = 1.06.

Hence the corrected power is,

$$P_C = C_0C_1P$$

$$P_C = 0.95 \times 1.06 \times 5.3$$

$$= 5.3371 \text{ hp}$$

From charts, the power rating for 3 v-belt is 3.8 hp, hence the required number of belt is

$$n = \frac{P_c}{P_r} = \frac{5.3371}{3.8} = 1.4045$$

$$n = 2 \text{ will be used}$$

3.6 Shaft Design

3.6.1 Determination of Pulley Load

The pulley load is given as

$$Fp = \frac{2M_1}{d_2} = \frac{2 \times 79.16}{0.4} = 395.8N$$

In this design, the angle of inclination of the belt to the pulley $\alpha = 30$

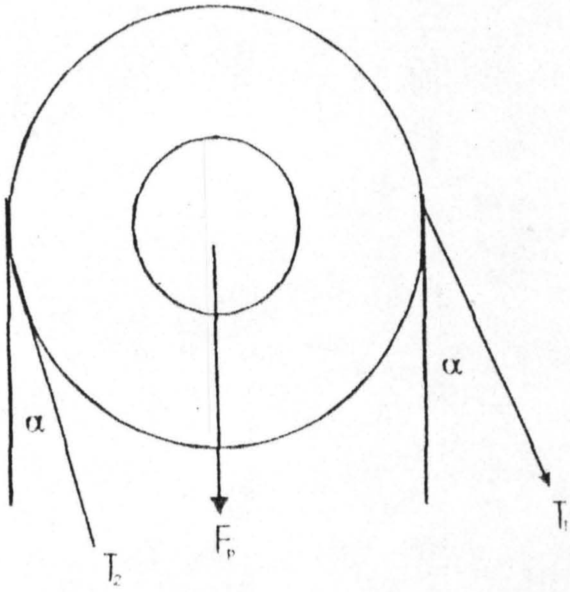

Figure 3.1: Pulley Configuration

From Figure 3.1, the various components of load are obtained as

$$F_{vp} = F_P\cos\alpha = 395.8\cos30 = 342.77N$$

$$F_{hp} = F_P\sin\alpha = 395.8\sin30 = 197.9N$$

3.6.2 Determination of Shaft Loads

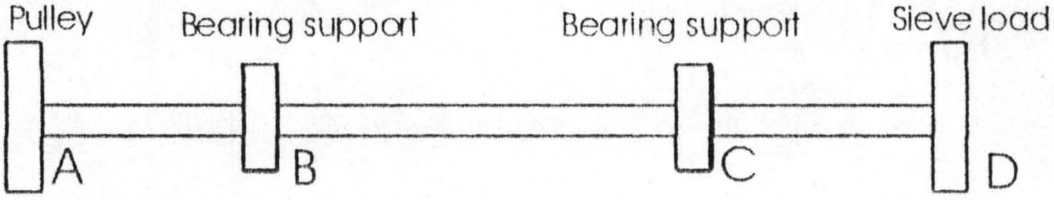

Figure3.2: Shaft Configuration

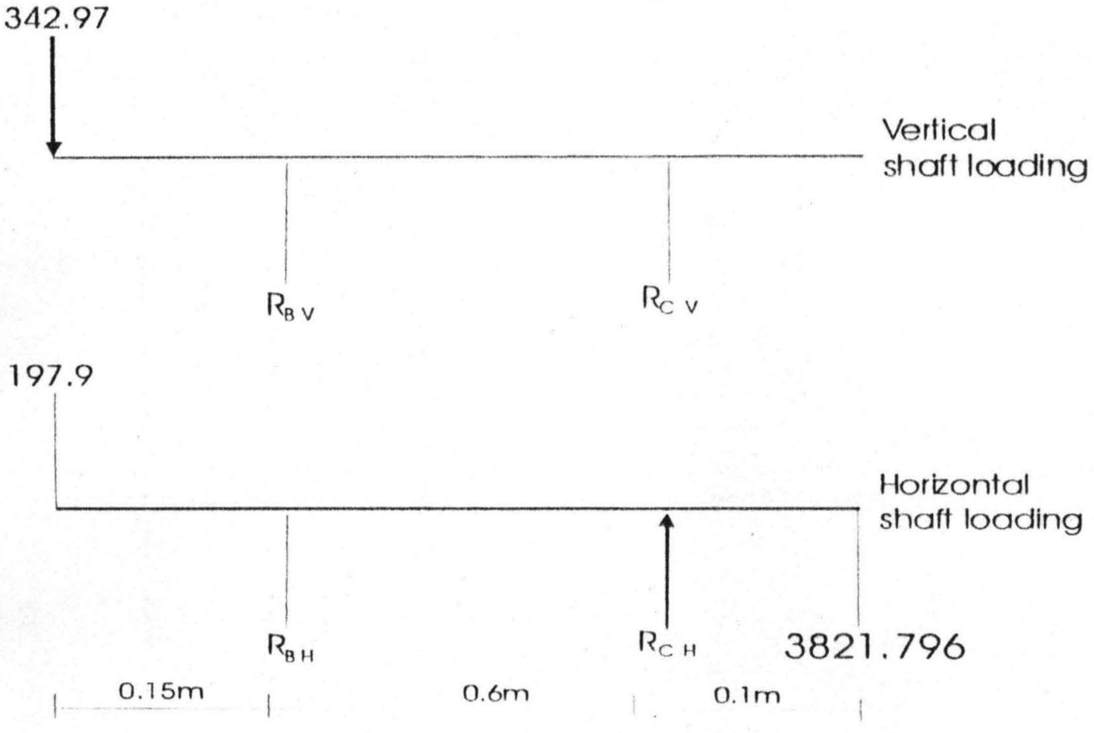

Figure 3.3: Shaft loading

Vertical shaft loading

In figure 3.3 (a), summing forces in vertical direction gives

$$+\uparrow \Sigma F_V = 0 = -342.77 + R_{BV} + R_{CV}$$

Therefore, $R_{BV} + R_{CV} = 342.77$ N (3.7)

And summing moments about support about support B gives

$$+\uparrow \Sigma M_B = 0 = -1.15 \times 342.77 - 0.6 R_{CV}$$

$$= R_{CV} = \frac{-0.15 \times 342.77}{0.6} = -85.6925\text{N}$$

Therefore, $R_{CV} = 85.6925\text{N}\downarrow$

From equation 3.7,

$$R_{BV} = 342.77 + 85.67 = 428.46\text{N}$$

Horizontal Shaft Loading

In figure 3.3 (b), summing forces in the vertical direction gives

$$+\uparrow\Sigma F_V = 0 = -197.7 + R_{BH} + R_{CH} + 3821.769$$

Therefore, $R_{BH} + R_{CH} = -3623.869N$ (3.8)

And summing moments about support B gives

$$+\uparrow\Sigma M_B = 0 = -1.15 + 197.7 - 0.6 R_{CH} - 0.7 \times 3821.769$$

$$R_{CH} = \frac{-(0.15)\times 197.7 + 0.7 \times 3821.769}{0.6}$$

$$R_{CH} = -4508.205N$$

Therefore, $R_{CH} = 4508.205N\downarrow$

From equation 3.8,

$$R_{BH} = -3623.869 + 4508.205$$

$$= 884.336 N$$

3.6.3 Determination of Maximum Bending Moment

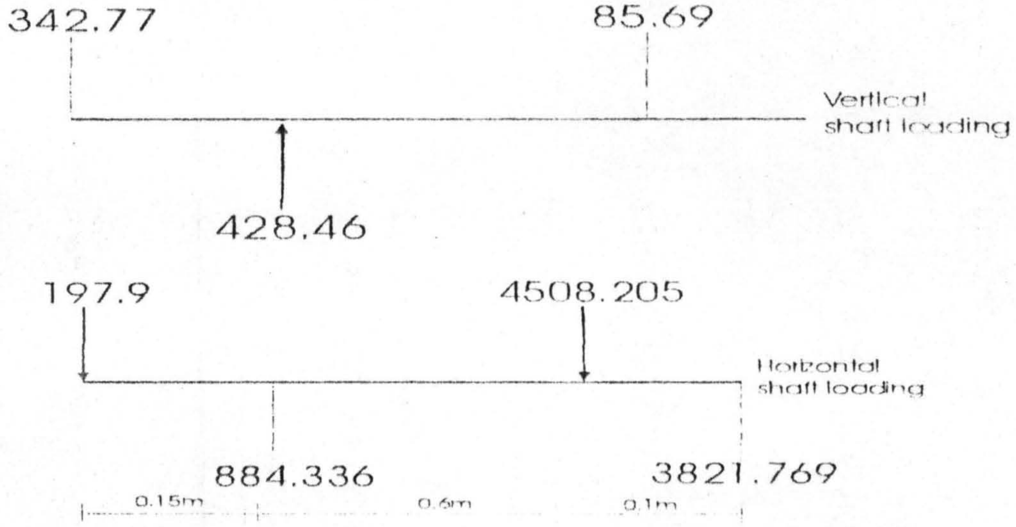

Figure 3.4: Bending Moment Determination

3.6.3.1 Vertical Bending Moment

In figure 3.4 (a) for $0 < x < 0.85$

$$M_{BV} - 342.77x - 428.46(x - 0.15) + 85.69(x - 0.75) = 0$$

$$M_{BV} - 342.77x - 428.46(x - 0.15) + 85.69(x - 0.75)$$

At $x = 0$, $M_{BV} = 0$

At $x = 0.15$, $M_{BV} = 342.77(0.15) = 51.4155$ Nm

At $x = 0.75$, $M_{BV} = 342.77\ (0.75) - 428.46\ (0.6) = 0$

At $x = 0.85$, $M_{BV} = 0$

3.6.3.2 Horizontal Bending Moment

In figure 3.4 (b) for $0 < X < 0.85$

$M_{BV} - 197.9x + 884.33\ (x - 0.15) - 4508.205(x - 0.75) + 3821.769(x - 0.85) = 0$

At $x = 0$, $M_{BH} = 0$

At $x = 0.15$, $M_{BH} = 197.9\ (0.15) = 29.685$ Nm

At $x = 0.75$, $M_{BH} = 197.9\ (0.75) - 884.336\ (0.6) = -382.1786$Nm

At $x = 0.85$, $M_{BH} = 0$

3.6.3.3 Point of Contra Flexure

Since the bending moment changed sign between the two bearing supports, then

$197.9x - 884.336\ (x - 0.15) = 0$

$197.9x - 884.336x + 132.6504 = 0$

$686.436x = 132.6504$

$x = 0.1933$m

3.6.3.4 Resultant Bending Moment

$$M_{BR} = \sqrt{M^2{}_{BV} + M^2{}_{BH}}$$

At $x = 0$, $M_{BR} = 0$

At $x = 0.15$, $M_{BR} = \sqrt{51.4155^2 + 29.685^2} = 59.37$ Nm

At $x = 0.75$, $M_{BR} = \sqrt{0^2 + (-382.1786)^2} = 382.1786$ Nm

At $x = 0.85$, $M_{BR} = 0$

3.6.3.5 Bending Moment Diagrams

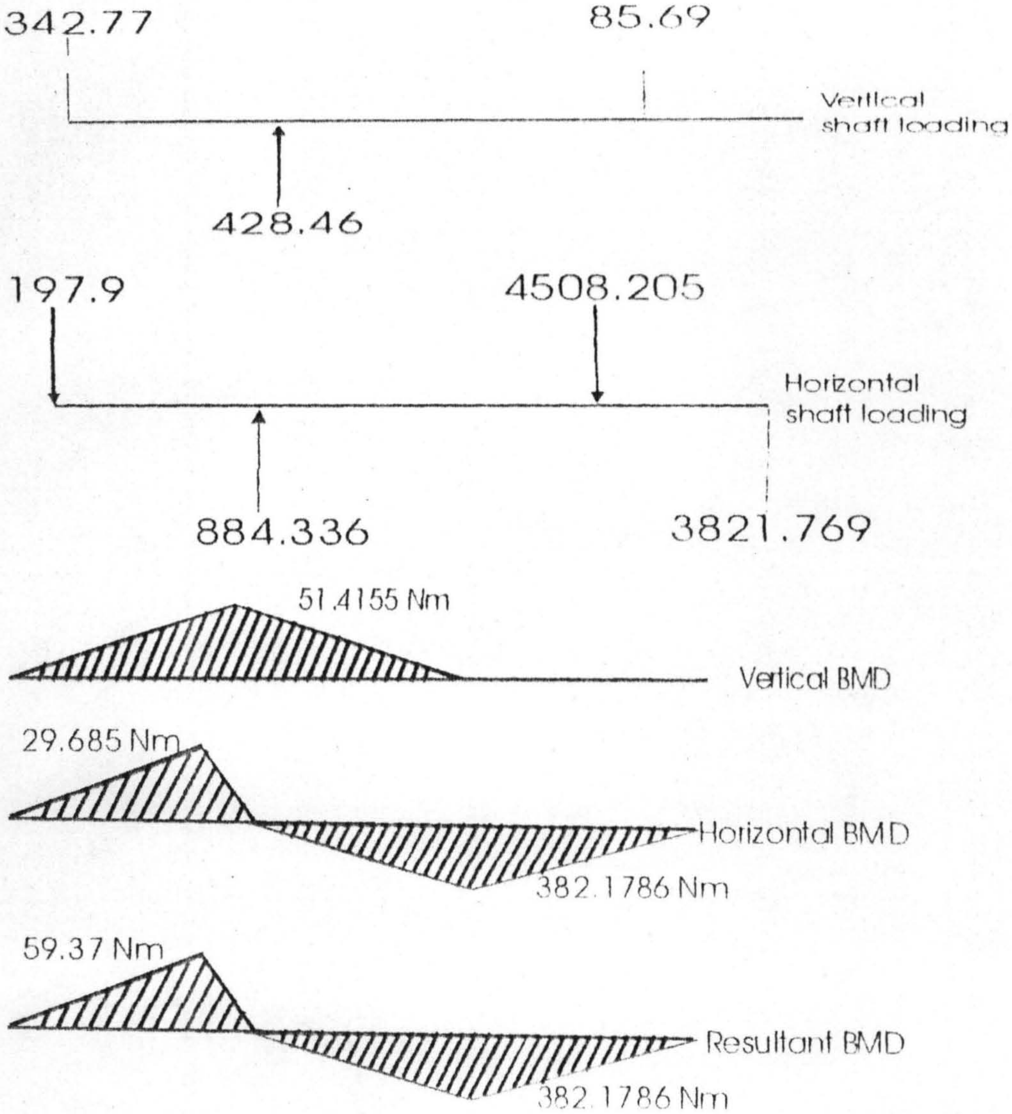

Figure 3.5: Bending Moment Diagrams

3.6.4 Determination of Shaft Size

Assuming a combined bending and torsional moment factor of 1.5 for fatigue, the diameter of the shaft is obtained as

$$d = \frac{16}{\pi Sy}\left(\sqrt{(M_b K_b)^2 + (M_t K_t)^2}\right)^{1/3}$$

$$d = \frac{16}{\pi \times 48 \times 10^{6}}\left(\sqrt{(384.789 \times 1.5)^{2} + (79.16 \times 1.5)^{2}}\right)^{1/3}$$

$$d = 0.0396\text{m}$$

Therefore, a shaft diameter of 0.04m will be used.

3.7 Determination of Bearing Size and Bearing Selection

The reaction of bearing at each support is

$$H = \sqrt{R^{2}_{H} + R^{2}_{V}} \tag{3.9}$$

At support B

$$H = \sqrt{(884.336)^{2} + (428.46)^{2}} = 982.664\text{ N}$$

At support C

$$H = \sqrt{(4508.205)^{2} + (85.67)^{2}} = 4509.019\text{ N}$$

Hence, bearing C guides the design.

Assuming a reliability of 99% and a rated life of 30,000 hours before failure from the relation.

$$R = \exp\left(-\left(\frac{L_{4}}{6.84L_{10}}\right)^{1.17}\right)$$

$$\text{In } 0.99 = -\left(\frac{30 \times 10^{3}}{(6.84)^{1.17} \times (L_{10})^{1.17}}\right)$$

$$L_{10} = -\left(\frac{18248.0402}{In 0.99}\right)^{1/1.17}$$

$$= 223667.6234\text{ hours}$$

The magnitude bearing capacity is obtained from the relation

$$C_{r} = \frac{H(L_{10}n_{2})^{1/k}}{Z} \tag{3.10}$$

For ball bearing, $k = 3$ and $Z = 25.6$

$$C_r = \frac{4509.019\left(223667.6234 \times {}^{450}\!/_{60}\right)^{1/3}}{25.6}$$

$$= 20928.12058 \text{ N}$$

$$= 20.928 \text{ KN}$$

But from bearing tables, a 03 series deep groove ball bearing with basic rating of 21.6KN is adopted.

CHAPTER FOUR

DESIGN SPECIFICATION, MATERIAL SELECTION, COST ANALYSIS AND TESTING

4.1 Design Specification

The design specifications of any machine involve the various requirements, which the design must meet. It is usually the basis on which the design analysis and fabrication are based. The specifications provide more specific and qualitative information about the machine to be described.

Therefore, for the purpose of this project work the design specifications are as follows:

4.1.1. Stroke Length

The stroke length of the screen affects the separation efficiency. The optimum value of stroke length for acha grain has been adopted as 15mm to give maximum efficiency.

4.1.2. Number of Screens

A single deck screen was chosen for the purpose of this project. This is due to the fact that the most efficient screen results when a series of single deck screens are used. Moreover each deck in a multiple-deck screen requires a different combination of angles, speed, and amplitude of vibration for maximum performance.

4.1.3. Angle of Inclination

The angle of inclination was adjusted to 12° to move the grain over the screen rapidly and to have adequate cleaning capacity. A steep pitch should be given to make chaffy grain move down the screen and should be flattened while cleaning round grain to prevent them from gaining too much momentum and bouncing over the screen without properly graded. But because a wire mesh screens was used, it was allowed to be steep since their surface retards seed movement enough to give thorough sifting.

4.1.4. Vibration Amplitude and Frequency

The vibration amplitude and frequency was designed to convey the material properly and to prevent the blinding of the screen. The vibration amplitude and frequency estimated for this work are and respectively to give better effectiveness.

4.1.5. Aperture Size

The size of screen openings depends upon the size and shape of the grain. The shape and size of a particle are the deciding factors towards identification of proper sieve configuration.

For the round openings, the size of grading screen is decided kept small enough to retain the smallest desirable grain. The following laboratory analyses were performed to determine some of the physical-mechanical properties of acha as shown in the Table 1. in order select the required screen aperture.

Table 4.1: Sieve Analysis for Acha Seed

Sieve size (μm)	Number of seed that passed	Percentage (%)
1000	0.02	0.10
850	10.20	5.60
710	149.80	82.50
500	16.10	8.50
250	4.10	2.25
<250	1.10	0.61

Average diameter of grain	0.85×10^{-3}m
Density	0.888g/cm^3
Pressure required for fluidization	1 Bar
Acha Grain Weight	0.0036g (3.6×10^{3}g)

Based on the result of the sieve analysis shown in Table 1 above, screen aperture of 250μm was therefore selected.\

4.2. Material Selection

The choice of materials for the construction of the mechanical separator is specified based on the following factors:

1 Mechanical, chemical and physical properties (such as strength, density, color, resistance to wear and corrosion)

2 Material availability

3 Cost manufacturing and maintenance

4 Conditions of loading

5 Service life of product, aesthetics and economic consideration.

Based on the above factors, mild steel angle bar (40×40) mm was selected for frame, mild steel angle bar (25×25) mm for the working deck, mild steel flat bar (5×50) mm for the sieve stands and gauge 24 mild steel for the hopper due to strength. Aluminum was selected for the pulley and 0.5 inch plywood for the sieve unit case due to light weight. Also, the painting of the machine was carried out for aesthetic aspect and to prevent rusting or parts.

4.3. Cost Analysis

The cost required to construct a machine is not complete until a good idea of the engineering materials are evaluated. An understanding of the elements that make up the cost is also very important. Hence, the cost estimate for a product is usually considered for following reasons:

(i) To determine the most economical method, process or material for fabricating a particular product.

(ii) To be used as a basis for a cost reduction programme.

(iii) To provide information to be used in establishing the selling price of the constructed project

(iv) To determine standards of production performance that may be used to control costs.

The cost analysis for this project is broken down into three elements namely:

1 Material cost
  (a). Direct material cost
  (b). Indirect material cost
2 Labour cost
  (a). Direct labour cost
  (b). Indirect labour cost
3 Overhead cost

4.3.1. Direct Material Cost

Direct material cost deals with actual market price of the materials used in the construction of this project. Although market prices are dynamic, the latest local price in the market for the year 2006 is used.

4.3.2. Indirect Material Cost

Indirect material cost is incurred as a result of the materials that are used indirectly during construction process. Examples of the materials considered for indirect cost in this project are; hacksaw blades, grinding disc, drill bit etc. and the cost of these items is difficult to trace out. The cost is therefore spread across the estimate in the prices of materials listed in Table 2.

Table 4.2: Material Specification and Costing

S/N	Components	Materials	Specifications	Quantity	Unit Price (#)	Total Amount (#)
1	Shaft and hopper stands	Mild steel	Angle bar (40×40)mm	2 length	1100	2200
2	Working deck frame	Mild steel	Angle bar (25×25)mm	2 length	600	1200
3	Sieve stands	Mild steel	Flat bar (5×50)mm	2 length	800	1600
4	Hopper	Mild steel	Gauge 24	½ sheet	1400	700
5	Sieve	Wire mesh		1 yard	400	400
6	Sieve unit case	Plywood	½ inch	¾ sheet	2000	1500
7	Pulley	Aluminum	F 400 mm	1 nos	800	800
8	Ball bearings	Silicon steel	6305	2 nos	300	600
9	Shaft	Mild steel	Φ 40 mm	1 nos	500	500
10	Belt		A36	2 nos	100	200
11	Bolts and nuts		M13	15 pieces	30	450
12	Welding materials	Electrodes	G1O & G12	½ packet	550	275
13	Base	Concrete	Cement	1 bag	1200	1200
14	Painting	Gloss paints	Red oxide	3 liters	110	330
15	Sieve frame	Wood	1"×1"×12'	1 length	110	110
	Total Material Cost					12,065

4.3.6. Total Cost of Production

The total cost of production is therefore calculated from the sum of these three costs.

i.e. Total = Material cost + Labour cost + Overhead cost.

= #12,065 + #4,222.75 + #3,619.50

= #19,907.25

4.4 Testing

Testing involves running of the unit in order to be able to make observations and rectify any irregularities, to see how the system works and conforms to expected output results.

The entire machine was successfully assembled and the electric motor mounted. The machine was first tested on no load, which is without any acha. The vibration was set to the correct speed and sample of the acha mixture was fed into the hopper. The reciprocating motion produces a vibration on the sieving unit which enables the materials to be separated. The vibration causes the falling of undersize to pass through the sieve. Below is the result of the test analysis carried out on the machine.

Table 3: Performance Analysis of Machine

Sample fraction	Feed, kg	Oversize outlet, kg	Undersize outlet, kg
Clean grain, kg	2.3125	2.0336	0.0136
Impurities, kg	0.1875	0.0289	0.4239
Total grain, kg	2.5	2.0625	0.4375

Fraction of clean grain in feed = 2.3125/2.5 = 0.925

Fraction of clean grain in oversize outlet = 2.0336/2.0625 = 0.986

Fraction of clean grain in undersize outlet = 0.0136/0.4375 = 0.31

Fraction of clean grain in oversize outlet $m_o = 0.0136/0.4375 = 0.31$

$$\text{Cleaning efficiency} = E = \frac{(m_f - m_u)(m_o - m_f)m_o(1 - m_o)}{(m_o - m_u)(1 - m_f)m_f} \times 100\%$$

$$= \frac{0.986\ (0.925 - 0.031)\ (0.986 - 0.925)\ (1 - 0.031)}{0.925\ (0.986 - 0.031)^2\ (1 - 0.925)}$$

$$= 82.34\ \%$$

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