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Design and Construction of Gari Sieving Machine

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Abstract

This work is concerned with the design and construction of gari sieving machine. From thesaurus legend [www.google.com], sieves are strainers use for separating lumps from powdered materials or grading particles. Wire mesh or closely perforated metal is used for such straining and sifting. Sieves are generally divided into three categories namely, Riddle – a coarse sieve (for gravels), Sifter – a household sieve (for flour etc.) and Strainer – a filter used to retain larger pieces of materials while the smaller pieces or liquids pass through the holes of the sieve into a container[1].

The first part of the work is the overview about cassava and its processing as well as literature about sampled sieves and finally the methodology of the design and construction of the device. The purpose of this work is to design and construct gari sieving machine which would be used to address the problems associated with the raffia sieve (traditional sieving method). The problems identified with the traditional way of sieving the gari were contamination of the product (gari), low production rate, high labour cost, the raffia sieve not being durable and inability to sieve the fine grains required. The machine is enclosed to prevent the product (gari) from contamination either by hand or dust in the air as a result of exposure of the product to the atmosphere. It can sieve one "olonka" cup in every two minutes as compared to the raffia sieve which can sieve an average of thirty-five (35) "olonka" cups a day. Again, it can sieve an average smaller grain size of $1.14\,mm$ *as compared to the raffia sieve which can sieve an average smaller grain size of* $1.53\,mm$. *The labour cost could be reduced since only one person is required for the operation of the machine.*

The methods used in coming out with this device are interviews and observations during field visit and information gathered from library and internet. Although, the raffia sieve is easy to come by and cost been very low, it has its own associated problems which are enumerated above. Besides, it needs to be changed after it has been used a few number of times because the holes become large and outlive its usefulness. With the advent of this machine, even though the capital cost is high, the problems associated with the raffia sieve would be thing of the past. This machine can be used for a very long time and also has a very low running cost.

Keywords: Gari, Raffia Sieve

1.0 INTRODUCTION

Gari is one of the most popular cassava foods in West Africa especially Nigeria, Ghana and many more. Gari is solely prepared from cassava and can be used to prepare different delicacies such as "Eba" a popular Nigeria food and gari soakings, a Ghanaian food. As a result of its ready market, a lot of people have gone into its production and it has been a source of livelihood for many Africans especially, the rural folks. A finished (fried) gari product needs to be sieved into grains of different sizes (coarse and fine grains) to make it more appealing for human consumption.This important sieving stage which attracts consumers is at the moment done by raffia sieve (traditional method of sieving) made from raffia sticks. The raffia sieve has many associated problems which have been identified as follows; *Contamination of product* – since the sieving is done in an open space, there is the possibility of dust entering the product, *Low production rate* – as the demand for consumption increases so must the production also increases but the traditional method of sieving solely depends on human strength and therefore takes a longer time for small quantity of gari to be sieved.

This inconvenience results in low production rate. *High labour cost* – the traditional method been used at the moment comes with low production rate. In order to meet the demand of the consumers which is very high means employing more labourers and this results in high labour cost. Also, *the raffia sieve is not durable* – although the raffia sieve is cheap and easily available, it has to be changed after it has been used for a few months because the holes become large and outlive its usefulness.As a result of the above enumerated problems associated with raffia sieve, it is therefore necessary to embark on a project which will be used to address the above mentioned problems, hence "*Design and construction of Gari sieving machine*". In order to make the machine last longer it was made of metals. Also, the machine works under a mechanism of vibration and belt drive. The vibrating spring will enhance the sieving process.The purpose of this work is to address the problems enumerated above. Enclosing the machine will help to reduce the contamination of the product (gari). The labour cost would be reduced since one person is required to operate the machine. With this machine the rate of production would be high and also the efficiency would be increased since it can sieve one "olonka" cup (olonka - a container/cup for measuring gari) in every minute as compared to the raffia sieve which can sieve an average of thirty-five "olonka" cups a day.

Again, it can sieve an average smaller grain size of $1.14\,mm$ as compared to the raffia sieve which can sieve an average smaller grain size of $1.53\,mm$. Other objectives of this project will include the improvement upon the traditional sieving process and high income generation.

1.1. Cassava Plant And Its Production

According to Philips T. P. (1984), Cassava (*Manihot esculenta*), also called yucca or manioc, a woody shrub by the native of South Americans is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root, and a major source of carbohydrates. Cassava is the third largest source of carbohydrates for meals in the world. Nigeria is considered to be the world largest producer of cassava. It is classified as sweet or bitter depending on the level of toxic cyanogenic glucosides in it[2]. However, bitter taste is not always a reliable measure but improper preparation of cassava can leave enough residual cyanide to cause acute cyanide intoxication and goitres, and has been linked to partial paralysis. Nevertheless, farmers often prefer the bitter varieties because they deter pests, animals and thieves. In some locations the more toxic varieties serve as a fall-back resource (a "food security crop") in times of famine[3].

The cassava root/tuber is long and tapered with a firm homogeneous flesh encased in a detachable rind about $1\,mm$ thick, rough and brown on the outside. Commercial varieties can be $5\,cm$ to $10\,cm$ in diameter at the top and around $15\,cm$ to $30\,cm$ long. A woody cordon runs through the root's axis. The flesh could be chalk-white or yellowish in colour. Wild population of domesticated cassava are centred in west-central Brazil, where later appeared in the Gulf of Mexico lowlands at the San Andrés archaeological site. The oldest direct evidence of cassava cultivation comes from a Maya site, Joya de Cerén, in El Salvador. Although the species *Manihot esculenta* likely originated from further south in Brazil and Paraguay, with its high food potential it had become a staple food of the native population of southern Mesoamerica and the Caribbean. However, as a result of it high demands its cultivation was continued by the colonial Portuguese and Spanish.

Since the introduction of cassava in Africa of which Ghana is no exception by the Portuguese traders from Brazil in the 16th century, cassava have replaced traditional African crops as the continent's most important staple food crop. Cassava is sometimes described as the 'bread of the tropics' **Error! Reference source not found.** Cassava is propagated by cutting the stem into sections of approximately $15\,cm$, these being planted prior to the wet season and allowed to grow for at most a year. It is then harvested by hand by raising the lower part of the stem and pulling the roots out of the ground, then plucking the tubers from the base of the plant. The uppermost part of the stem with the leaves is plucked off before harvest. A sample cassava plant and its tuberous root are shown in figure 1 below.

Figure 1. Typical cassava plant and tuberous root [5].

1.2. Applications of Cassava Plant

Cassava plant has a lot of uses for the various parts of which the root tuber is no exception. Cassava roots are very rich in starch and contain significant amounts of calcium ($50mg/100g$), phosphorus ($40mg/100g$), and vitamin C ($25mg/100g$). However, they are poor in protein and other nutrients. In contrast, cassava leaves are good source of protein and are rich in amino acid lysine[6]. Some of the uses of the cassava roots tuber include but not limited to the following; it is used in preparing medicine and animal feed. Tapioca or fecula, essential flavourless starchy ingredient produced from treated and dried cassava (manioc) root is used in cooking and is commonly used to make a milky pudding similar to rice pudding. Boba tapioca pearls are made from cassava root. Cassava is also used in making cassava cake, a popular pastry. In Indonesia, cassava is an important food material. It can be cooked by frying or boiling or processed by fermentation to make tapai and getuk cake, while the starch is made into krupuk crackers[7][8].

The cassava flour is also used to make cassava bread by boiling flour until it is thick and rubbery ball (called bukari in Swahili or luku in Kikongo). The cassava bread is often affectionately, called la boule nationale (the national ball) in french. The flour is also made into a paste and fermented before boiling after wrapping in banana or other forest leaves. This fermented state is called chikwangue in French or kwanga or nkwanga in Lingala and Kikongo. Again, cassava is used to make alcoholic beverages. The English explorer and naturalist Charles Waterton reported in Wanderings in South America (1836) that the natives of Guyana used cassava to make liqour, which they later abandoned when rum became available[9][10].

1.2.1. Gari Processing

Cassava is not only used for making the above mentioned products but also used in preparing gari. This gari is used in making "eba" and gari soakings, popular delicacies in Ghana and Nigeria. One can simply make gari soakings by soaking the gari in cold water, add a bit of sugar, groundnut and sometimes milk which cost less than US$1.00. In fact gari is not a delicacy for only Ghanaians and Nigerians but also for many Africans so its demand for consumption is high.The processes of preparing Gari are as follows; cassava is peeled, washed and then either grated or milled into cassava dough. The dough is kept in a sack and the end of the sack is tied. The sack containing the cassava dough is placed under a pressing machine or heavy weights such as stones, rocks and woods. The essence of this is to squeeze as much as possible more water from the dough so as to make sieving easier, reduce heat energy in frying and make frying easier. The dough under compression is allowed to stay for about two days for fermentation to take place. After much water has been removed and the dough has fermented, it is then sieved to remove unwanted particles such as ungrated cassava and cassava cordon. The sieved dough is now ready for frying. After the dough has been fried, it is then sieved to grains of different sizes (coarse and fine grains) to make it more appealing for human consumption.

Figure 2. Sample fried gari in a container

1.3. Review on Sample Sieves

From thesaurus legend [www.google.com], sieves are strainers for separating lumps from powdered materials or grading particles. Wire mesh or closely perforated metal is used for such straining and sifting. The three(3) main types of sieves are *Riddle* – a coarse sieve (for gravels), *Sifter* – a household sieve (for flour, etc.) and *Strainer* – a filter used to retain larger pieces of materials while the smaller piece and liquids pass through the holes of the sieve into a container[1]. This machine will operate similarly, to that of standard test sieves for testing bituminous materials; vibrating conveyor sieves; and more especially rotary sand siever and Raffia sieve (the traditional method of sieving) [11][12][13].

1.3.1. RAFFIA SIEVE (Traditional Method of Sieving)

In general, Raffia palms (Raphia) are genus of twenty species of palms native to tropical regions of Africa especially in Madagascar. They are mostly found in muddy areas and grow up to $16\,m$ tall and are remarkable for their compound pinnate leaves, the longest in the plant kingdom has a leave up to $25.11\,m$ long and $3\,m$ wide [14]. The raffia which is a fibre obtain from the raffia palm is used for weaving items such as mat and raffia sieve which is the traditional way of sieving gari. The raffia sieve is made of interwoven strips of raffia in a desired shape (square, circular, etc.) and cane sticks framed around the interwoven strips. It is used by placing it on a container and a measured quantity of gari is poured on the sieve. The gari is then stirred and shaken with the hands and in the process the fine grains pass through the holes in the sieve into the container leaving the coarse ones on the sieve. The picture below illustrate raffia sieve on container for sieving grains of gari into different sizes.

Figure 3. A picture of raffia sieve on container for sieving grains of gari into different sizes.

2.0 REVIEW OF THEORIES AND SOFTWARE RELATING TO THE WORK

In the design of the device, some parameters like the diameter of the shaft as well as that of the bearings were taken into consideration so as to enable easy construction. Also, density of gari, volume and weight of gari to be contained in the sieve drum were considered and the mathematical relations connecting these parameters are shown below.

2.1. Bearing Design

Determination of The Equivalent Bearing Load: In general, loads under radial bearing are made up of radial and axial forces. The equivalent bearing load (P) is therefore given by the equation;

$$\mathrm{P} = \mathrm{xv}F_r + yF_a \quad (1)$$

Where F_r and F_a are radial and axial loads respectively, x and y are radial and thrust factors respectively and v is the rotating factor (1 for inner ring rotary and 1.2 for outer ring rotary).

Relationship Between Load and Life of Bearing: The relations for the Life equations of bearing are given in the equations (2)

$$L = (\mathrm{C}/\mathrm{P})^{\mathrm{r}} \quad \text{and} \quad L = \frac{60nL_h}{1x10^6} \quad (2)$$

Where L is the nominal or desired life in millions of revolution, C is the basic dynamic, P is the equivalent load, r is index ($\mathrm{r} = 3$ for ball bearings and $\mathrm{r} = 10$ for roller bearing), (C/P) is load ratio, L_h is the nominal life in working hours [*service hours*] and n is the speed of shaft in rev/min.

2.2. Shaft Design

In the design of the diameter of the shaft,the power in kW transmitted to the shaft by the motor and the speed of the shaft in $\mathrm{rev/min}$ are taken into consideration. Let the power in watts transmitted to the shaft be P_o, the speed of the shaft in $\mathrm{rev/min}$ be n and T be the torque transmitted by the shaft then;

$$P_o = \frac{2\pi nT}{60} \quad (3)$$

Expressing power in kW and making the totque T the subject of the equation (3), then the relation below could be obtained;

$$T = \frac{9549P_o}{n}\ Nm \quad (4)$$

Given that the diameter of the shaft is d/mm, the torsional stress or calculated stress isτ and polar sectional modulus is Z then the torsional stress or calculated stress and the polar sectional modules are given by equations (5);

$$\tau = \frac{T}{Z} \quad \text{and} \quad Z = \frac{\pi d^3}{16} \quad (5)$$

Combining the two equations in equation (5) the relation below could be obtained.

$$\tau = \frac{16T}{\pi d^3} \quad (6)$$

The design stress, σ and the torsional stress, τ are connected by the relation below.

$$\sigma \geq \tau \quad (7)$$

Substituting equation (6) into equation (7) the relation below was obtained

$$d^3 \geq \frac{16T}{\pi\sigma} \quad (8)$$

Again, the design stress σ is given by

$$\sigma = \frac{\sigma_y}{F} \quad (9)$$

Where σ_y is the yield stress and F is the factor of safety. Since the material used for designing the shaft is mild steel (St60) and it will serve normal condition purpose it implies that σ_y is $280\ N/mm^2$ and factor of safety F is 2.0. Combining equations (4), (8) and (9) the diameter of the shaft becomes

$$d \geq 70.2964\ x \sqrt[3]{\frac{P_o}{n}} \quad (10)$$

2.3. Determination of the Density of Gari

In the determination of the density of gari, a box of dimensions l, b and h was fully filled with gari to the brim. The relations connecting the various parameters are given below.

$V_b = V_g = lbh$, and $M_g = M_t - M_b$ (11)

Where $l, b \; and \; h$ are the length, breadth and height respectively of the box which was used in the determination of the volume, V_g and mass, M_g of the gari sample. The volume and mass of the box used in the determination of the density are given as V_b and M_b respectively. The total mass of the box fully filled with gari to the brim is given as M_t. If the mass and volume of the gari are known then the density, ρ of the gari is given by the relation below.

$$\rho = \frac{M_g}{V_g} \quad (12)$$

2.4. Volume of Gari in the Sieve Drum

In order to determine the maximum volume of gari that should be contained in the sieve drum, the volume of the part of the shaft that runs through the sieve drum, the volume of the perforated sieve drum including the part of shaft in the drum as well as the volume of the perforated sieve drum without the shaft were given as V_s, V_{sd} and V respectively. Also, given that the diameter of the shaft is d, the diameter of the end circular disc is D and the length of the sieve drum which is also the length of the part of shaft in the sieve drum is l_s then the following relations could be obtained.

$$V_s = \frac{\pi l_s d^2}{4} \quad \text{and} \quad V_{sd} = \frac{\pi l_s D^2}{4} \quad (13)$$

The volume of the perforated sieve drum without the shaft V can be deduced as the difference in the two volumes in equation (13), thus;

$$V = \frac{\pi l_s}{4}(D^2 - d^2) \quad (14)$$

2.5. Weight of Gari in the Sieve Drum

The maximum weight, W_{max} of gari to be contained in the perforated sieve drum was estimated by considering the volume, V and density,ρ of gari. Given that the weight of a body is $W = mg$, then from the definition of density the maximum weigth of gari to be contained in the sieve drum could be obtained as;

$$W_{max} = \rho g V \quad (15)$$

Hence from equation (15), equation (16) can be wrtten as;

$$W_{max} = \frac{\pi l_s}{4}\rho g(D^2 - d^2) \quad (16)$$

2.6. SOLIDWORKS and Its Significance

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs primarily on Microsoft Windows. SolidWorks is a solid modeller, and utilizes a parametric feature-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies. The software is written on Parasolid-kernel. Building a model in SolidWorks usually starts with a 2D sketch, although 3D sketches are available for power users. The sketch consists of geometry such as points, lines, arcs, conics, and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently or by relationships to other parameters inside or outside of the sketch.

Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, *assembly mates* define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. SolidWorks also includes additional advanced mating features such as gear and cam follower mates, which allow modelled gear assemblies to accurately reproduce the rotational movement of an actual gear train. Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards (ANSI, ISO, DIN, GOST, JIS, BSI and SAC) [15]. SolidWorks software comes with packages such as SOLIDWORKS Premium, SOLIDWORKS Professional, SOLIDWORKS Standard and many more.

SOLIDWORKS Premium is a comprehensive 3D design solution that adds powerful simulation and design validation to the capabilities of SOLIDWORKS Professional, as well as ECAD/MCAD collaboration, reverse engineering, and advanced wire and pipe routing functionality. SOLIDWORKS Professional builds on the capabilities of SOLIDWORKS Standard to increase design productivity, with file management tools, advanced photorealistic rendering, automated cost estimation, eDrawings, Professional collaboration capabilities, automated design and drawing checking, and a sophisticated components and parts library. SOLIDWORKS Standard speed up works and unlock the benefits of powerful 3D design solution for rapid creation of parts, assemblies, and 2D drawings. Application-specific tools for sheet metal, weldments, surfacing, and mold tool and die to make it easy to deliver best-in-class designs. In general, SolidWorks accelerate design, save time and development costs, and boost productivity with 3D solid modelling capabilities in SOLIDWORKS 3D design software. 3D solid modelling is a critical aspect of modern product development and provides the basis for design, simulation, and manufacturing of any part and assembly across a broad range of industries and applications [16].

3.0 RESEARCH METHODOLOGY

3.1. Material Selection

In the design and construction of the unit, engineering books from the library and on internet were used for research on the properties and selection of materials. The various materials to be selected for the various parts and reasons for their selections are discussed below.

3.1.1. Stainless Steel

Stainless steel - Austenitic-ferrite also referred to as duplex stainless steels, combines many of the beneficial properties of ferritic and austenitic steels. Due to their high content of chromium and nitrogen, and often also molybdenum, these steels offer good resistance to local and uniform corrosion. The duplex microstructure contribute to their high strenght and high resistance to stress, corrosion and cracking. Duplex steel also have good weldability. The five (5) broad stainless steel categories possess shared properties which make them a virtually universal material, well suited to the challenges of the present day. Each category and each grade - thanks to its specific composition is distinguished by specific advantages and have the most extensive range on the market. The various properties are corrosion resistance, aesthetics view (a great variety of surface finishes), hygienic to foodstuffs (stianless steel is an inert material that does not alter the characteristics of foodstuffs), resistance to fire and stianless steel items are easy to clean.

Adding elements such as nickel, molybdenum, titanium and niobium give stianlees steel additional advantages such as resistance to corrosion in highly corrosive environment, resistance to oxidation and creep resistance at high temperatures, strength and ductility at low temperatures, good mechanical properties and ease of working (stamping, bending, hydro forming, welding, brazing) [17]. These properties make it more convenient for stainless steel to be selected for the receiver (chamber), the cover of the sieve drum and the two(2) circular ends of the sieve drum.

3.1.2. Mild Steel

Mild steel is a type of steel alloy that contains a high amount of carbon as a major constituent and iron alloy with 0.3% carbon. It is malleable and ductile, and therefore bends fairly easily. Mild steel is the cheapest and most versatile form of steel and serves every application which requires a bulk amount of steel. Mild steel is especially desirable for construction due to its good wedability and machinability. Because of its high strenght and malleability, it is quite soft. This means that it can be easily machined compared to harder steels. It takes on a nice finish and it is polishable. However, it cannot be hardened through heat treatment processes as that of higher carbon steel can be done. As a result of these properties mild steel was selected for the construction of the table stand and the shaft.

3.1.3. Cast Iron

Cast iron is an alloy of iron and carbon, and it is popular because of its low cost and ability to make complex structures. The carbon content in cast iron is 3% to 4.5% by weight. Silicon, Sulfur, Phosphorus and small amount of Manganese are also present in it. The products of cast iron exhibit resonable resistance against corrosion. The cast iron is neither malleable nor ductile and it cannot be hardened like steel. It melts at about $2100°\mathrm{F}$ and has either a crystalline or a granular fracture. The mechanical properties of cast iron are very much dependent on the morphology of its carbon content. Carbon is present in the form of plates in gray cast iron,whereas it incorporated in compound Fe_3C (cementite) in white cast iron. Nodular cast iron, which shows better tensile strength and strain than gray cast iron carries carbon in the form of sphere shaped graphite particles. Some of the properties of cast iron are good tensile strenght, high compressive strenght, low melting point, resistance to deformation and resistance to oxidation[18]. As a result of these properties cast iron was selected for the pulleys.

3.1.4. Aluminium

Aluminium is the most modern of the common engineering metals. In its pure state aluminium is soft, silvery, ductile and has good thermal conductivity and affinity to oxygen. The affinity of aluminium to oxygen readily provides it with a tenacious oxide film that protects its from further corrosion attacks [19]. As a result of these properties aluminium was selected for the perforated sieve.

3.2. Research Methodology

This section provides all the information used in manufacturing the device, collection of data and analysis in consultation with gari processing sectors. Some of these methods include; interview from field visit, laboratory experimental work and methods used in design, modeling and construction.

3.2.1. Field Visit

A number of visits were done to some selected Gari Processing Communities in order to obtain firsthand information on existing Gari sieves, the process of sieving, limitations on the current way of sieving gari and whether there is the need to invent a new machine or the existed one is preferable. Some of these commmunities which were visited are Egyambra in the Ahanta West Municipal and Avilebo in the Nzema East Municipal, all in the Western Region of Ghana.

A Visit to Egyambra and Avilebo: Three (3) gari processing groups were selected at Egyambra for interview. After the introduction and the purpose of the visit made known to them some interviewed questions were asked. The questions and their responses could be found in appendix I. During the visit to Avilebo, five (5) gari processing groups were selected for the interview. It was realised that the responses were not different from that of Egyambra.

Observations: The responses of the interview among all the groups during the field visits show that, the sieving was done in an open atmosphere. Some of the workers do not wash their hands before sieving is done. Again, the size of the holes of the raffia sieve enlarges after sieving for some time and this allows some of the coarse grains to mix with the fine grains. The raffia sieve can last for at most five (5) months when used continousely. From the responses of the interviews it was observed that on an average, thirty-five (35) olonka cups of gari were sieved per day. The raffia sieve is not durable; thus it does not last long and therefore needs to be changed in every five (5) months. As a result, people were recommending for a new machine to be designed instead of the raffia sieve.

3.2.2. Design Methods

Determination of the Diameter of Bearing and Shaft

Specimen Calculation

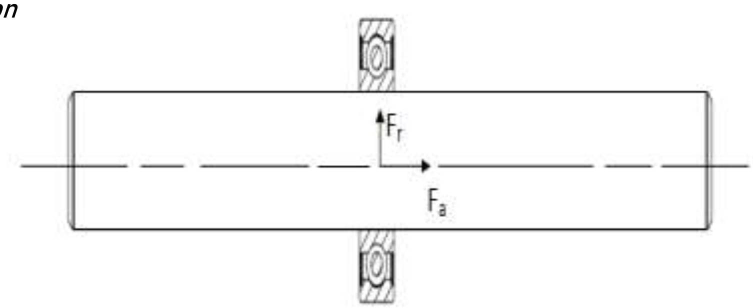

Figure 4.Diagram of bearing and shaft acted upon by axial and radial loads.

For proper design, loads acting on the bearing were taken into consideration as shown in figure 4. Given that the radial force, F_r acting on the bearing is $53\ \mathrm{N}$ and there is no axial load, F_a on the bearing then F_a is zero (0). Again, when the nominal life in working hours L_h and speed of the shaft n were taken to be $8\,x\,10^5\ in\ working\ hours$ and $60\ rpm$ respectively then using equations (1) and (2), the basic dynamic rating, C could be estimated as $754.06kg \approx 1660Ib$. From the table in appendix II if $C = 1660\ Ib$ then, the diameters and width of the bearing can be estimated from the table in appendix II. Since the material used for the design of the shaft is mild steel (St60) and it will serve normal condition purpose it implies that the yield stress σ_y and factor of safety F are $280\ \mathrm{N/mm^2}$ and 2.0 respectively. Therefore using equations (8), (9) and (10) if the power transmitted is $0.8486\ kW$ then the diameter of the shaft can be determined. The results are shown in table (1).

Determination of the Density of Gari: The density of the gari must be known in order to help determine the maximum weight of gari in the sieve drum. A box of dimensions, $l\ x\ b\ x\ h$ were measured and the volume of the box, V_b was calculated using equation (1). This volume, V_b is equal to the volume of the gari, V_g in the box. The mass of the box, M_b was measured. The box was fully filled with gari to the brim and the total mass, M_t was measured and the mass of the gari, M_g was determined as the difference between the two masses M_t and M_b. Finally, the density ρ of gari was calculated using equation (12). This result could be found in table (2).

Determination of the Volume and Maximum Weight of Gari in the Sieve Drum: In designing and construction of the machine, the diameter of the shaft, d, diameter of the sieve drum, D and length or height of the sieve drum, l_s which is also the length of the shaft in the sieve drum were taken into consideration. If d, D, l_s and density ρ are taken to be $17\ \mathrm{mm}$, $168\ \mathrm{mm}$, $297\ \mathrm{mm}$ and $7.05\,x\,10^{-4}\ \mathrm{g/mm^3}$ respectively (values taken from the table of results) then using equations (14) and (16) the maximum volume and weight of gari to be contained in the sieve drum can be determined and the results are found in table (3).

3.2.3. Modelling and Construction

The machine is categorized into five (5) main parts. These parts include the table stand, the perforated sieve drum and shaft, the receiver (chamber), the cover of the receiver and some purchased parts. In order to obtain the device, the various parts were first modelled to get firsthand view of the device. These parts were later manufactured at workshop. The methods used in modeling and manufacturing of the various parts as well as the assembling of the whole machine are described in the following sections.

Tool/Equipment/Machine/Software Used: In the construction of the gari sieving machine a SOLIDWORKS software was used for the modelling so as to enable the designer to obtain the firsthand information about the unit whereas in the manufacturing of the unit the following devices and machines were used and they are measuring tape, ruler, try square, scriber, trammel, mallet, hacksaw, grinding, welding, drilling and lathe machines.

The Table Stand: The table stand is solely made of mild steel angled iron. The procedures involved in the manufacturing are described as follows; four stands were measured and cut. Two out of the four stands are of dimension $640\,mm$ and the other two $700\,mm$ long. Another five angled iron bar of dimensions $270\,mm$ were measured and cut to obtain the front and back sides as well as a support for the motor. Again, four ends side $380\,mm$ and $375\,mm$ of two each long were measured and cut to obtain four ends sides of the table stand using measuring tape, scriber/try square and hacksaw. The various part were assembled and joined together using arc welding or bolts and nuts to form the table stands. However, the table stand was modelled before construction. The modelled table stand is shown in figure 5 below.

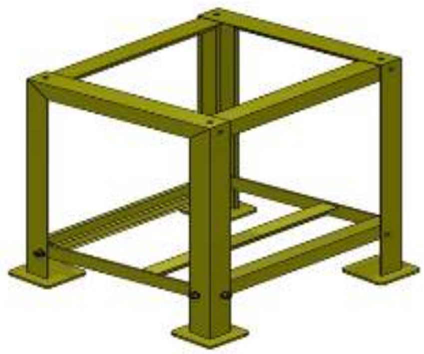

Figure 5.A modelled table stand

The Sieve Drum and Shaft: The sieve drum was constructed with perforated aluminium mesh and the shaft also made of mild steel. The processes involved in the manufacturing are described below. Two circular discs of diameter $168\,mm$ were cut from stainless steel using trammel, chisel and mallet. Holes of diameter $18\,mm$ were drilled at the center of each disc using drilling machine. Also, a chord of $60\,mm$ were measured and cut from one of the dics and the two segmented plates were joined with hinges to provide gate for the sieve drum. A shaft of diameter $17\,mm$ and length $500\,mm$ was turned and cut and passed through the holes of the two discs separated $297\,mm$ apart. Number of fins of dimensions $5\,mm\,x\,10\,mm$ each were welded onto the shaft. Again, a metallic mesh of length $297\,mm$ and breadth $530\,mm$ was cut, folded and riveted on the ends of the circular discs to obtain an enclosed cylindrical sieve drum after assembling of different parts were done. The modelled sieve drum and shaft as well as handle before construction are shown in figure 6 below.

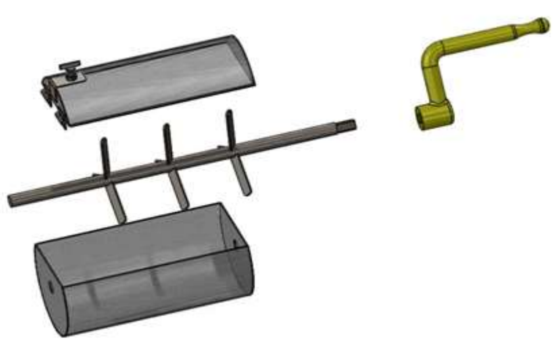

Figure 6.Model of the sieve drum, shaft and handle

The Receiver and Cover of the receiver: The receiver (chamber) was made from stainless steel. Two semi circular discs of diameter $175\,mm$ was cut from stainless steel plate for the ends of the receiver using trammel, chisel and mallet. Holes of diameters $25\,mm$ was drilled at the center of the diameter of each disc. A stainless steel plate of length $330\,mm$ and breadth of $280\,mm$ in dimensions was measured and cut using measuring tape, try square, scriber and shears. The stainless steel plate was folded and welded onto the two semi circular discs separated $330\,mm$ apart to obtain the receiver. An opening was made at one end of the receiver and a spout of lenght $25\,mm$ and width $25\,mm$ was welded at the opening to aid in the collection of the sieved gari. The cover of the receiver was also made of stainless steel. The processes used in manufacturing the receiver were repeated to manufacture the cover. The receiver and its cover were later joined together using hinges. The receiver and its cover were first of all modelled and the modelled parts are shown in figure 7 below.

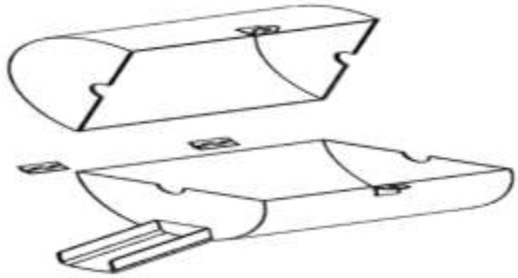

Figure 7.A modelled receiver and its cover

Other Items: In the manufacturing of the machine, other necessary parts with specifications were purchased from shops in the market and these items include, bolts and nuts, bearings, springs, hinges, V-belt, an electric motor, driving and driven pulleys of diameters $50\,mm$ and $100\,mm$ respectively.

3.2.4. Assembling of the Device

After all the modelling techniques and requirements have been fulfilled and other components such as motor, v-belt, hinges etc. have been purchased, subassemblies were done to assemble the various parts. Finally, a general assembling was done to obtain the modelled device as shown in figure 8 and the technical drawing of the device is shown in appendix III.

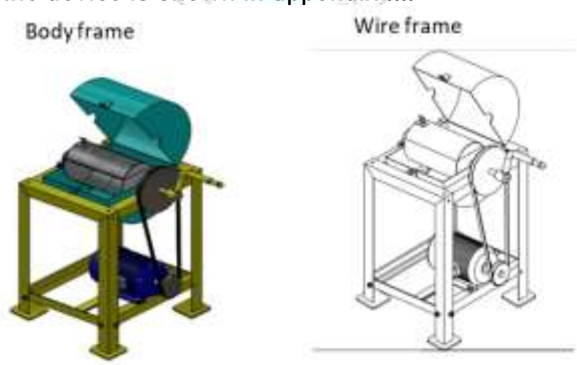

Figure 8.Model of Gari Sieving Machine

The modelled machine was fabricated in order to obtain the real gari sieving machine. Since in engineering, the aesthetic quality of a component or an engineering product has a psychological effect on an individual, thus the better the finishing, the higher the demand. In view of this, after all the design requirements have been fulfill and the device manufactured, rough edges were removed and the device was painted with anti-corrosive paint to protect it from environmental effect such as rust, corrosion and oxidation. The fabricated gari sieving machine is shown in figure 9.

Figure 9. Fabricated Gari Sieving Machine

A – Bearing with two springs under it
B – Perforated sieve drum
C – Receiver
D – Cover of receiver
E – Shaft
F – Pulley with belt
G – Table stand

3.2.5. Basic Operation of the Machine

Measure a given amount (at most $6.52\ x10^3 m^3$) of volume of gari to be sieved and pour it into the sieve drum through the opening (gate) of the sieve drum and close the gate. Also, close the receiver with its cover to avoid the gari from spinning out. The device can be operated electrically and manually. If the machine is to be operated electrically then, the motor being connected to an AC source is switched on and as the motor rotates the sieve drum, the spring also vibrates the sieve drum simultaneously for sieving to be done. However, in manual operation the handle is rotated several times with human effort. The sieved grains of gari are collected through the opening (gate) of the receiver and the particles are tested for quality and specification if necessary.

3.2.6. General Maintenance of the Machine

Since every engineering device needs a regular maintenance to operate properly, here are list of enumerated maintenance processes for this device to perform well.

1. Avoid belt from getting contact with oil.
2. Check for stretch belt and replace to avoid slipping.
3. Check for damage bearings or bearings which produce noise and change them.
4. Lubricate the bearings always to avoid bearing damage if necessary.
5. Check for springs which have or about to exceed elastic limit and replace them.
6. Paint the machine with anti-corrosive paint to avoid rusting and corrosion.
7. Regularly clean the machine before and after use.
8. Check for loose bolts and nuts and tighten them if necessary.
9. Gently, close the cover of the receiver to avoid tearing of the hinges.
10. Check for gari which has clogged the holes of the perforated sieve drum and remove them.
11. Always close the receiver with the cover when necessary to avoid dust and other dirts from entering the chamber.

4.0 DATA ANALYSIS & DISCUSSIONS

Results obtained from various measurements and calculations are presented in tabular form and analyses as well as discussion of the obtained results are presented in this section.

Table 1. The diameter and width of the designed bearing and shaft.

ITEM	BEARING			SHAFT
Quantity	Inner diameter, d_B $[mm]$	Outer diameter, D_B $[mm]$	Width, B_B $[mm]$	Diameter, d $[mm]$
Estimated value	17	40	12	17

Base on the forces and stresses that would act on the bearing and the shaft, effective inner diameter of $17\,mm$, outer diameter of $40\,mm$ and width of $12\,mm$ for the bearing were selected. Also, a shaft of at most $17\,mm$ in diameter was used for the manufacturing of the machine.

Table 2. Results of measured and calculated quantities in the determination of the density of gari.

Quantity	Estimated value
Length, l $[mm]$	143
Breadth, b $[mm]$	40
Height, h $[mm]$	60
$V_b = V_g$ $[mm^3]$	343200
M_t $[g]$	252.685
M_b $[g]$	10.613
M_g $[g]$	242.072
ρ $[g/mm^3]$	$7.05\ x\ 10^{-4}$

The density, ρ of gari was estimated to be approximately $705.34\,\mathrm{kg/m^3}$ or $7.05\ x\ 10^{-4}\,\mathrm{g/mm^3}$. This density was used in the determination of the maximum weight and volume of gari to be contained in the sieve drum.

Table 3. Estimated volume and maximum weight of gari to be contained in the sieve drum.

Quantity	Volume, V $[mm^3]$	Maximum weight, W_{max} [N]
Estimated value	6516209.02	45.09

According to equation (16) it could be seen that the weight of an object is proportional to its volume. This means that as the volume increases so does the weight also increases and vice versa. From the calculated values in table 3, it could be seen that the maximum weight and volume of gari to be contained in the sieve drum for sieving to be done (effective performance of the machine) are approximately $45.09\,N$ and $6516209.02\,mm^3$ respectively.

Table 4. A table showing the sizes of particles of gari.

Particle	1	2	3	4	5	6	7	8	9	10
Size [mm]	1.09	1.30	1.16	1.07	1.38	1.10	0.98	1.07	1.05	1.21

In order to test the machine for its performance, samples of some sieved grains of gari by the machine were taken and at least ten (10) largest particles in sizes were randomly selected and their sizes were measured. The results are shown in table 4. From the table it could be observed that, the machine can permit an average grain size of $1.14\,mm$ large to be sieved and also, the machine is capable of sieving one olonka cup of gari in at most every two minutes.

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5.0 SUMMARY

A new machine for sieving gari has been developed in this work. Although problems were encountered during the process of designing and constructing the machine, it has been successful since the expectations of the designer were met. The machine is enclosed to prevent the gari from contamination. It is effective, efficient, reliable, easy to operate and can be used to sieve up to average grain size of 1.14mm large as compared to the raffia sieve which can sieve up to 1.53mm of size. Also, it was found that unlike the raffia sieve which can sieve thirty-five (35) olonka cups of gari a day, the machine is capable of sieving one olonka cup of gari in every two minutes. The machine is electrically or manually operated by one person and so the cost of production and human effort is minimizing. This means that in order to meet the demand of the consumers, the machine is recommendable. Therefore, it is recommended that;

- All gari producers should use the machine to increase productivity.
- Other companies, industries and individuals such as road and building contractors, GRATIS FOUNDATION, etc. whom the machine is applicable to them can use the machine for their sand sieving.
- Series of sieves of diferent mesh sizes should be use in further research on this project in order to sample gari by dividing the sample into sections of different grain sizes according to the size required and
- If the machine is to be operated, then an electric motor of a very low horse power and speed should be used so as to have more effective and efficient running.

The designer of the machine would not hesitate to welcome suggestions from other colleague engineers if necessary to increase the efficiency of the machine.

6.0 ACKNOWLEDGEMENTS

The research reported here was carried out as part of individual social intervention and also to support government and organizations to develop and create employment in the rural areas. I first of all register my sincere gratitude to the Almighty God for giving me the strength, insight and guidance in the preparation of this task successfully.

Secondly, I am indebted to Prof. Moses Jojo Eghan of the University of Cape Coast, Ghana and Mr. Fredrick Coduah for their assistance and time wasted on this project; to them I say a big thank you. The realization of this project is supported by Mr. Denis Asiamah of ASIABRON ENGINEERING SHOP – Accra, GRATIS FOUNDATION – Tema. Finally, I would like to express my appreciation to Mr. George Ackah, Madam Mary Dadzie and Mrs Mercy Ngoah, the owners of *Super A. A., "Nyame ye odo"* and *Peace and Love* Gari processing firms respectively.

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APPENDIX

Appendix I

INTERVIEW QUESTIONS AND RESPONSES ON FIELD VISIT

GROUP ONE

Mr. George Ackah, the leader of the group was interviewed. The questions and their responses are as shown in the table below;

QUESTION	*RESPONSE*
What is the name of this group?	*Super A. A. Gari Processing Enterprise.*
How many workers do you have?	*Fifteen (15) workers.*
What type of sieve do you use?	*Raffia Sieve.*
How many workers do the sieving?	*Six (6) workers do the sieving whilst the other nine (9) do the frying and other activities.*
Why is it that six (6) workers do the sieving?	*We need more people to meet the customers demand.*
How many quantity do you sieve a day?	*Forty (40) "olonka" cups*
What is the cost of the raffia sieve?	*Ten Ghana cedis (GH₵10.00) only.*
For how long do you use the raffia sieve before it is changed?	*About five (5) months.*
Will you prefer a new machine to the raffia sieve?	*Yes.*
If you are asked to grade the durability of the raffia sieve from lowest to highest using scale of 1 to 5 what will be your response?	*I'll give it grade 3.*

GROUP TWO

Madam Mary Dadzie, the leader of the group was interviewed. The questions and their responses are as follows;

QUESTION	*RESPONSE*
What is the name of this group?	*"Nyame ye odo" (meaning God is love).*
How many workers do you have?	*Ten (10) workers.*
What type of sieve do you use?	*Raffia Sieve.*
How many workers do the sieving?	*Five (5) workers do the sieving whilst the remaining do the frying and other activities.*
Why is it that five (5) workers do the sieving?	*This will enable us meet the demand of our customers.*
How many quantity do you sieve a day?	*Thirty (30) "olonka" cups.*

What is the cost of the raffia sieve?	*Nine Ghana cedis (GH₵9.00) only.*
For how long do you use the raffia sieve before it is changed?	*About six (6) months.*
Will you prefer a new machine to the raffia sieve?	*Yes.*
If you are asked to grade the durability of the raffia sieve from lowest to highest using scale of 1 to 5 what will be your response?	*Grade 2.*

<u>GROUP THREE</u>

Mrs Mercy Ngoah, the leader of the group was interviewed. The questions and their responses are as follows;

QUESTION	*RESPONSE*
What is the name of this group?	*Peace and Love Gari Processing Firm.*
How many workers do you have?	*Eight (8) workers.*
What type of sieve do you use?	*Raffia Sieve.*
How many workers do the sieving?	*Three (3) workers do the sieving whilst the remaining do the frying and other activities.*
Why is it that three (3) workers do the sieving?	*This will enable us meet the demand of our customers.*
How many quantity do you sieve a day?	*Thirty-five (35) "olonka".*
What is the cost of the raffia sieve?	*Ten Ghana cedis (GH₵10.00) only.*
For how long do you use the raffia sieve before it is changed?	*About four (4) months.*
Will you prefer a new machine to the raffia sieve?	*Yes and I would be very happy.*
If you are asked to grade the durability of the raffia sieve from lowest to highest using scale of 1 to 5 what will be your response?	*The raffia sieve is not durable therefore I'll give it grade 2.*

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Appendix II

SINGLE ROW DEEP GROOVE BALL BEARINGS

Metric Dimension Series 02

Bearing Series 62 | Bearing Series 62-Z | Bearing Series 62-2Z | Bearing Series 62-RS | Bearing Series 62-2RS

Bearings of series 62 with one or two sideplates or synthetic rubber seals are manufactured in a range of sizes which covers the majority of applications requiring these designs. Full details will be advised on request.
Bearings with one or two sideplates have the suffix Z or 2Z respectively, e.g. 6205 Z or 6205-2Z.
Bearings with one or two seals have the suffix RS or 2RS respectively, e.g. 6205 RS or 6205-2RS.
See page 84 for bearings fitted with snap rings.
Numbers in bold type indicate 62 series bearings which are usually more readily available than those in *italics*. Availability of bearings with sideplates or seals will be advised on request.
Follow the directions on pp. 11-26 when determining the bearing size required.

Bearing No.	B.S.* No.	d		D		B		r approx.	Basic capacity, lb		Max. permissible speed r.p.m.
		mm	in.	mm	in.	mm	in.	mm	Static C_o	Dynamic C	
6200	BAL 010	10	0·3937	30	1·1811	9	0·3543	1	430	880	20000
01	BAL 012	12	0·4724	32	1·2598	10	0·3937	1	655	1180	20000
02	BAL 015	15	0·5906	35	1·3780	11	0·4331	1	780	1330	16000
6203	BAL 017	17	0·6693	40	1·5748	12	0·4724	1	965	1660	16000
04	BAL 020	20	0·7874	47	1·8504	14	0·5512	1·5	1430	2100	16000
05	BAL 025	25	0·9843	52	2·0472	15	0·5906	1·5	1560	2400	13000
6206	BAL 030	30	1·1811	62	2·4409	16	0·6299	1·5	2300	3350	13000
07	BAL 035	35	1·3780	72	2·8346	17	0·6693	2	3050	4400	10000
08	BAL 040	40	1·5748	80	3·1496	18	0·7087	2	3450	5000	10000
6209	BAL 045	45	1·7717	85	3·3465	19	0·7480	2	4000	5600	8000
10	BAL 050	50	1·9685	90	3·5433	20	0·7874	2	4650	6100	8000
11	BAL 055	55	2·1654	100	3·9370	21	0·8268	2·5	5700	7500	8000
6212	BAL 060	60	2·3622	110	4·3307	22	0·8661	2·5	7100	9000	6000
13	BAL 065	65	2·5591	120	4·7244	23	0·9055	2·5	7600	9610	6000
14	BAL 070	70	2·7559	125	4·9213	24	0·9449	2·5	8650	10600	5000
6215	BAL 075	75	2·9528	130	5·1181	25	0·9843	2·5	9300	11400	5000
16	BAL 080	80	3·1496	140	5·5118	26	1·0236	3	10000	13100	5000
17	BAL 085	85	3·3465	150	5·9055	28	1·1024	3	12000	14300	4000
6218	BAL 090	90	3·5433	160	6·2992	30	1·1811	3	13700	14600	4000
19	BAL 095	95	3·7402	170	6·6929	32	1·2598	3·5	16000	16600	4000
20	BAL 100	100	3·9370	180	7·0866	34	1·3386	3·5	18000	21300	3000
6221	BAL 105	105	4·1339	190	7·4803	36	1·4173	3·5	20400	22800	3000
22	BAL 110	110	4·3307	200	7·8740	38	1·4961	3·5	22800	24100	3000
24	—	120	4·7244	215	8·4646	40	1·5748	3·5	23900	25000	3000
6226	—	130	5·1181	230	9·0551	40	1·5748	4	25500	27000	2500
28	—	140	5·5118	250	9·8425	42	1·6535	4	28500	28100	2500
30	—	150	5·9055	270	10·6299	45	1·7717	4	31500	33300	2500
6232	—	160	6·2992	290	11·4173	48	1·8898	4	34000	31500	2000
34	—	170	6·6929	310	12·2047	52	2·0472	5	41500	36000	2000
36	—	180	7·0866	320	12·5984	52	2·0472	5	45000	38000	1600
6238	—	190	7·4803	340	13·3858	55	2·1654	5	52000	44000	1600
40	—	200	7·8740	360	14·1732	58	2·2835	5	58500	46300	1600

*B.S. No. refers only to basic design.

TABLES OF FACTORS FOR CALCULATION OF EQUIVALENT BEARING LOAD

Table 1. Rotation factor, V.

Bearing type	Rotating inner ring	Rotating outer ring
Self-aligning ball bearings Magneto bearings	1	1
Deep groove ball bearings Angular contact ball bearings Radial roller bearings (incl. taper roller bearings)	1	1·2

Table 2. Factors X and Y.

Bearing type		$\frac{F_a}{VF_r} \leq e$* X	$\frac{F_a}{VF_r} \leq e$* Y	$\frac{F_a}{VF_r} > e$ X	$\frac{F_a}{VF_r} > e$ Y	e
Single row deep groove ball bearings, Series: FL, R, 60, 62, 63, 64, EF, RLS, RMS and FL	$\frac{F_a}{C_o}$ = 0·025 0·04 0·07 0·13 0·18 0·24 0·33 0·56	1	0	0·56	2·0 1·8 1·6 1·4 1·3 1·2 1·1 1·0	0·22 0·24 0·27 0·31 0·34 0·37 0·40 0·44
Magneto bearings Series: EN		1	0	0·50	2·50	0·20
Single row angular contact ball bearings Series: 7B, 73B (α = 40°) S, AMS (α = 30°)		1	0	0·35 0·39	0·57 0·76	1·14 0·80
Taper roller bearings 30203—30204 30205—30208 30209—30222 30224—30230		1	0	0·4	1·75 1·60 1·45 1·35	0·34 0·37 0·41 0·44
32206—32208 32209—32222 32224		1	0	0·4	1·50 1·45 1·35	0·37 0·41 0·44
30302—30303 30304—30307 30308—30324		1	0	0·4	2·10 1·95 1·75	0·28 0·31 0·34
31305—31318		1	0	0·4	0·73	0·82
32304—32307 32308—32324		1	0	0·4	1·95 1·75	0·31 0·34
Double row angular contact ball bearings Series: 32, 33		1	0·73	0·62	1·17	0·86
Double row self-aligning ball bearings 13300—13304		1	1·8	0·65	2·8	0·34
1200 —1203 1204 —1205 1206 —1207 1208 —1209 1210 —1212 1213 —1222		1	2·0 2·3 2·7 2·9 3·4 3·6	0·65	3·1 3·6 4·2 4·5 5·2 5·6	0·31 0·27 0·23 0·21 0·19 0·17

Radial bearings: $P = XVF_r + YF_a$

Spherical roller thrust bearings: $P = F_a + 1{\cdot}2F_r$

Bearing type	$\frac{F_a}{VF_r} \leq e$ X	$\frac{F_a}{VF_r} \leq e$ Y	$\frac{F_a}{VF_r} > e$ X	$\frac{F_a}{VF_r} > e$ Y	e
Double row self-aligning ball bearings (continued) 2200 —2204 2205 —2207 2208 —2209 2210 —2213 2214 —2220 2221 —2222	1	1·3 1·7 2·0 2·3 2·4 2·3	0·65	2·0 2·6 3·1 3·5 3·8 3·5	0·50 0·37 0·31 0·28 0·26 0·28
1300 —1303 1304 —1305 1306 —1309 1310 —1322	1	1·8 2·2 2·5 2·8	0·65	2·8 3·4 3·9 4·3	0·34 0·29 0·25 0·23
2301 2302 —2304 2305 —2310 2311 —2318	1	1·0 1·2 1·5 1·6	0·65	1·6 1·9 2·3 2·5	0·63 0·52 0·43 0·39
RL 4—RL 6 RL 7—RL 8 RL 9—RL11 RL 12—RL14 RL 15—RL18 RL 20—RL36 RL 38—RL48	1	2·1 2·3 2·7 2·9 3·4 3·6 4·2	0·65	3·3 3·6 4·2 4·5 5·2 5·6 6·5	0·29 0·27 0·23 0·21 0·19 0·17 0·15
RM 3—RM 6 RM 7—RM10 RM 11—RM14 RM 15—RM18 RM 20—RM48	1	1·8 2·1 2·4 2·7 2·9	0·65	2·8 3·3 3·8 4·2 4·5	0·34 0·29 0·25 0·23 0·21
Spherical roller bearings 23024 —23088 23092 —230/500	1	2·7 2·9	0·67	4·0 4·4	0·25 0·23
24024C—24072C	1	2·3	0·67	3·5	0·29
23120C—23128C 23130C—23132C 23134 —23184	1	2·4 2·3 2·1	0·67	3·6 3·5 3·1	0·28 0·29 0·32
24122C—24128C 24130C—24160C	1	1·9 1·8	0·67	2·9 2·7	0·35 0·37
22205 —22207 22208 —22209 22210 —22215 22216 —22220 22222 —22264	1	2·5 2·9 3·4 2·6 2·4	0·67	3·7 4·4 5·0 3·9 3·6	0·27 0·23 0·20 0·26 0·28
23218C—23220C 23222C—23232C 23234 —23248	1	2·2 2·0 1·8	0·67	3·3 3·0 2·7	0·31 0·34 0·37
21304 —21305 21306 —21310 21311 —21319 21320 —21322	1	2·8 3·2 3·4 3·7	0·67	4·2 4·8 5·0 5·5	0·24 0·21 0·20 0·18
22308 —22312 22313 —22340 22344 —22356	1	1·6 1·8 1·9	0·67	2·4 2·7 2·9	0·41 0·37 0·35

* For single row bearings, if $\frac{F_a}{VF_r} \leq e$ then $P = VF_r$. The equivalent bearing load P is therefore never less than the radial load VF_r.

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Appendix III

Technical Drawing of theModelled Gari Sieving Machine