DESIGN AND FABRICATION OF A MINI CENTRIFUGAL SEPARATOR FOR A SMALL SCALE USUAGE

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Certification

This is to certify that this project has been carried out by ANIOGBE CHUKWUKA with Matriculation number: Eng1506638, Department of Production Engineering, University of Benin.

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Dedication

I dedicate this project to the Almighty God, all students in the field of engineering (introduction, manufacturing, mechanical and industrial) and especially to those seeking knowledge in this field or others related to this research.

Acknowledgement

I wish to thank God Almighty for bringing me thus far. I also wish to express my gratitude to Engr. G.F. Aigbanbee for giving me this golden opportunity to carry out the project under his supervision. I am greatly indebted to him for his inspiring guidance, constructive suggestion and criticism from time to time during the course of progress of the work.

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ABSTRACT

This research centers on the design and fabrication of a mini-centrifugal separator for a small scale usage. The machine is made up of various components; capacitor, flexible wire, sieve, bolts, nuts and washers, A.C motor, sheet metal.

The mill corn is fed through the opening at the top and the centrifugation action of the machine coupled with the rotor speed pushes the pap of more concentration to the walls of the centrifuge while the chaff remains in the inner cover.

CHAPTER ONE

INTRODUCTION

1.1 Background of study

A force arising from the body's inertia which appears to act on a body moving in a circular path and is directed away from the center around which the body is moving is known as centrifugal force.

The process of centrifugation can be traced back to the mid-15th century. When hand driven centrifuge systems were used to separate milk. In 1864, this ad hoc system of milk separation was commercialized by Antonin Pradtl who developed the first diary centrifuge for the purpose of separating cream from milk.However, this study deals with the separation of liquid from solid.

Since its invention more than 30 years ago, the centrifugal separator has become an indispensable piece of equipment in the food and beverage industry.Today's cutting edge separation technology gives clear advantages in terms of product quality and safety operational efficiency and production flexibility. Centrifugal separation means separating substances of different specific gravity levels by means of centrifugal force. Nowadays, the local separation techniques involved in most rural areas in Nigeria cannot be over emphasized simply because they are not aware or inclined about the machinery equipment which can aid and relieve the stress of separation or filtration.

According to Richard Paul Evans, the law of centrifugal force seems to be as true for the human condition as it is for the Newtonian mechanics.The faster our lives spin, the more things tend to fly apart.

The need for higher speed was present and in 1925, Theodore Svedberg who wasa colloid chemist invented the first ultracentrifuge as an analytical instrument. One year later, the Nobel prize was awarded to him for his research and the invention of the ultracentrifuge.

As one of the most commonly used Laboratory instrument today, the centrifuge offers an efficient means of preparing and separating sample of different densities often for scientific and medical use. This form of density-driven preparation has been around for centuries, dating as early as the 1400s with simple hand powered milk separators, however a formal commercialized version of his centrifuge did not emerge until the 80s.

In forensic and research Laboratories, it can be used in separation of urine and blood components. It also aid in the separation of protein using purification techniques such as salting out, e.g. ammonium sulfate precipitation. Centrifugation is also an important technique in waste treatment, being one of the common processes used for sludge dewatering. This process also plays a role in cyclonic separation, where particles are separated from airflow without the use of filters. In cyclone collector, air moves in a helical path. Particles with high inertia are separated by centrifugal force while smaller particles continues with an airflow.

1.2 Statement of the Problem

In the making of Pap (Locally known as Akamu) which is made from corn, separation has to take place and over time, conventional means (the use of clothes) has been used. After the maize has been soaked and grinded, the corn starch, the chaff and the water has to be separated in order to get pap. Although there is a local means of separating the starch and water from the maize, it is time consuming and also stressful. This project is tied towards the design and fabrication of a machine that takes care of the separation and makes the process easier and less time consuming.

1.3 Aim and objectives

1.3.1 Aim of the study

The aim of this project is to design and develop a mini centrifugal separator for a small scale usuage.

1.3.2 Objectives of the study

To carry out this study the following objectives will be pursued÷

i. To carry out extensive literature review on the subject matter
ii. To design a concept of a mini Centrifugal separator
iii. To carry out the fabrication of the component parts
iv. To assemble the component parts of the Centrifugal seperator
v. To test the machine prototype

1.4 Relevance of study

Pre-filtration: The Centrifugal separator helps improve the efficiency of filtration as well as minimize liquid loss when it is used for pre-filtration.

Reducing Industrial waste: Centrifugal liquid separators are designed to remove solids from a liquid.

Development of the Centrifuge will reduce the time consumed by small scale users in production of chemical products, as well as improve the quality and homogeneity of chemical products. This will also provide employment for the populace as more people can buy and use the mini centrifugal separator since it is less small and less expensive.

1.5 Scope of study

This project standards and specifications is limited to the design and the fabrication of a mini centrifugal separator for a small scale usuage which will be able to separate the Pap from the charge after the corn has been soaked over a period of time.

CHAPTER TWO

LITERATURE REVIEW

2.1 Theory of Separation of Compounds

The separation of chemical compounds depend on differences in physical properties, differences in melting or boiling point , structures of compounds , to purity of compounds and classes of chemical compounds. All chemical compounds of biochemical interest occur naturally as components of composite mixtures from which they can be isolated only with considerable difficulty. (Burr,2002)

2.2 Types of Separation

There are various forms of separation which are listed below;

2.2.1 Separation by Chromatography

Chromatography is a laboratory technique for the separation of a mixture. The mixture is dissolved in a fluid (gas, solvent, water) called the mobile phase, which carries it through a system (a column, a capillary tube, a plate, or a sheet) on which is fixed a material called the stationary phase. The different constituents of the mixture have different affinities for the stationary phase. The different molecules stay longer or shorter on the stationary phase, depending on their interactions with its surface sites. So, they travel at different apparent velocities in the mobile fluid, causing them to separate. The separation is based on the differential partitioning between the mobile and the stationary phases. Subtle differences in a compound's partition coefficient result in differential retention on the stationary phase and thus affect the separation(McMurry,2011).

2.2.2 Separation By Extraction

Extraction in chemistry is a separation process consisting in the separation of a substance from a matrix. Common examples include liquid-liquid extraction, and solid phase extraction. The distribution of a solute between two phases is an equilibrium condition described by partition theory. This is based on exactly how the analyte moves from the initial solvent into the extracting solvent. The term washing may also be used to refer to an extraction in which impurities are extracted from the solvent containing the desired compound.

*Solid-phase extraction (SPE) is an extractive technique by which compounds that are dissolved or suspended in a liquid mixture are separated from other compounds in the mixture according to their physical and chemical properties. Analytical laboratories use solid phase extraction to concentrate and purify samples for analysis. Solid phase extraction can be used to isolate analytes of interest from a wide variety of matrices, including urine, blood, water, beverages, soil, and animal tissue(Hennion,1999).

2.2.3 Separation By Centrifuge

A centrifuge is a device that uses centrifugal force to separate various components of a fluid. This is achieved by spinning the fluid at high speed within a container, thereby separating fluids of different densities (e.g. cream from milk) or liquids from solids. It works by causing denser substances and particles to move outward in the radial direction. At the same time, objects that are less dense are displaced and move to the centre. In a laboratory centrifuge that uses sample tubes, the radial acceleration causes denser particles to settle to the bottom of the tube, while low-density substances rise to the top(Mikkelsen,2004).

2.2.4 Separation By Filtration

Filtration is a physical or chemical separation process that separates solid matter and fluid from a mixture using a filter medium that has a complex structure through which only the fluid can pass. Solid particles that cannot pass through the filter medium are described as oversize and the fluid that passes through is called the filtrate. Oversize particles may form a filter cake on top of the filter and may also block the filter lattice, preventing the fluid phase from crossing the filter, known as blinding. The size of the largest particles that can successfully pass through a filter is called the effective pore size of that filter. The separation of solid and fluid is imperfect; solids will be contaminated with some fluid and filtrate will contain fine particles (depending on the pore size, filter thickness and biological activity). Filtration occurs both in nature and in engineered systems; there are biological, geological, and industrial forms (Trevor, 2015).

The first scientific studies conducted by Knight in 1806 reported the differences in orientation of roots and stems of seedlings when placed in a rotating wheel. However, it was not until some 60years later that centrifuges were first used in industrial applications. The first continuous centrifuge designed in 1878 by the Swedish Inventor De Laval to separate Cream from milk, opened the door to a broad range of industrial applications. About this same time, the first centrifuge containing small test tubes appeared.These were modest, hand operated units that attained speeds up to 3000rpm (Salim et al, 2013).

The first electrically driven centrifuges were introduced in 1910 further accelerating centrifuge development.

Svedberg's invention of the analytical ultracentrifuge in 1923, operating at 10000rpm and equipped with transparent observations, windows, marked another milestone in centrifuge technology.

Although temporarily abandoned in 1943 in favor of a gaseous diffusion process, industrial scale-gas centrifuges were rapidly developed during World War II in an effort to enrich or separate Uranium Isotopes.

2.3 Basics of Centrifugation

The earth's gravitational force is sufficient to separate many types of particles over time. A tube of anticoagulated whole blood left standing on a bench top will eventually separate into plasma, red blood cell and white blood cell fractions.However, the length of time required precludes this manner of separation for most applications. In practice, centrifugal force is necessary to separate most particles. In addition, the potential degradation of biological compounds during prolonged storage means faster separation techniques are needed(Hinds, 1999.). The rate of separation in a suspension of particles by way of gravitational force mainly depends on the particle size and density.Particles of higher density or larger size typically travel at a faster rate and at some point will be separated from particles less dense or smaller.

A centrifuge is a piece of equipment that puts an object in rotation around a fixed axis (spins it in a circle), applying a potentially strong force perpendicular to the axis of spin (outward). The centrifuge works using the sedimentation principle, where the centripetal acceleration causes denser substances and particles to move outward in the radial direction. At the same time, objects that are less dense are displaced and move to the center. Hence, a centrifuge uses centrifugal force to separate two or more substances of different densities or masses from each other (Susan ,2004).

Centrifugation is a powerful method for solid-liquid separation.It can be applied in numerous ways to simplify solid phase synthetic procedures. At the same time, centrifugation is the only totally parallel technique which can be scaled up for processing volume or number of simultaneously run reactions, without the limitation of overpressure or vacuum-driven filtration-based systems. We have developed synthesizers based on the power of centrifugation — peptide and small organic molecule synthesizers utilizing cotton as the synthetic substrate and inclusion volume chemistry, synthesizers for automation of “tea bag” synthesis, and synthesizers based on “tilted plate centrifugation”. The last technique was employed in an oligonucleotide production facility with the capacity of more than 10 million compounds per year (Cargill et al, 1997)

Centrifugation employs rotation at high speed to expedite settling.It is equivalent to spontaneous sedimentation, but occurs within minutes, rather than months.It often replaces multiple racking’s when early bottling is desired.Centrifugation is also useful when the wine is heavily laden with particulate matter. Highly turbid musts and wine are prone to off-odor development if they are permitted to clarify spontaneously. Centrifugation is much more efficient in removing large amounts of particulates than plate filters.Centrifugation also avoids potential health problems (dust and worker allergy) associated with the use and disposal of diatomaceous earth and other filter aids.

Blanketing the wine with an inert gas has minimized a former liability of centrifugation – oxidation. Automation, combined with continuous centrifugation, has improved the efficiency and economy of the process to such an extent that centrifugation is often the preferred clarification technique.

(Ronald, 2014). Centrifugation is a very common technique to separate solid particles dispersed in liquid medium, e.g., blood cells and plasma. The liquid sample is placed in a special vial or holder, which is rotated very fast. Sample components are separated due to the centrifugal force, based on their density difference.Centrifugation is commonly used in combination with a variety of samplete separation techniques.Centrifugation can also be used to separate emulsions (such as milk) and immiscible solvents (e.g., in combination with LLE). Laboratory centrifuges usually work with 20–40 cm diameter rotors holding 10–100 sample vials or two to four micro titer plates. Efficiency depends on rotational velocity; typical laboratory centrifuges work with 100–20,000 rotations per minute, allowing separations in a few minutes time.

Ultracentrifuges are different specialized equipment, working at higher velocities.These are mostly used to separate macromolecules based on molecular mass.Vacuum centrifuges are also common; their purpose is evaporating solvents—centrifugation is used to help in keeping the solution at the bottom of the vial (Gyorgy, 2008).

Effective separation of mixtures is a common challenge experienced in many industrial processes.These mixtures could be two immiscible liquids or solid suspension in liquid. The oldest and easiest way of separating such mixture is by allowing it to settle into two distinct layers with the denser liquid/solid at the bottom while the lighter liquid stays on top (sedimentation) before decanting. Unfortunately, this sedimentation process for most mixtures is time consuming (consuming several hours and in some cases, may run into days) causing a consequent stagnation in production. To achieve continuous production for such systems and reduce overall production time, there is need for a faster means of separating such mixtures.

Centrifuges achieve separation by means of accelerated gravitational force achieved by a rapid rotation (Salim et al, 2013). This replaces the normal gravitational force required for settling. Hence, sedimentation can be achieved in less time by replacing the sedimentation tank/vessel with a centrifuge.

Centrifuges are used in a variety of medical and industrial applications (Piero, 1997). There are 4 basic types of centrifuges designed for different applications: Industrial scale centrifuges, very high speed centrifuges (ultracentrifuges), large centrifuges and gas centrifuges.

Although different centrifuge designs and capacities are already in existence, most of these centrifuges are complex to operate and costly to maintain by small and medium scale producers, especially in developing countries. Hence, the need to develop a simple and cost effective centrifuge for small and medium scaled industries using locally sourced materials.

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2.4 Uses of Centrifuge

- **Laboratory separations**

A wide variety of laboratory-scale centrifuges are used in chemistry, biology, biochemistry and clinical medicine for isolating and separating suspensions and immiscible liquids. They vary widely in speed, capacity, temperature control, and other characteristics. Laboratory centrifuges often can accept a range of different fixed-angle and swinging bucket rotors able to carry different numbers of centrifuge tubes and rated for specific maximum speeds. Controls vary from simple electrical timers to programmable models able to control acceleration and deceleration rates, running speeds, and temperature regimes. Ultracentrifuges spin the rotors under vacuum, eliminating air resistance and enabling exact temperature control. Zonal rotors and continuous flow systems are capable of handing bulk and larger sample volumes, respectively, in a laboratory-scale instrument(Mikkelsen et al, 2004).

Another application in laboratories is blood separation. Blood separates into cells and proteins (RBC, WBC, platelets, etc.) and serum. DNA preparation is another common application for pharmacogenetics and clinical diagnosis. DNA samples are purified and the DNA is prepped for separation by adding buffers and then centrifuging it for a certain amount of time. The blood waste is then removed and another buffer is added and spun inside the centrifuge again. Once the blood waste is removed and another buffer is added the pellet can be suspended and cooled. Proteins can then be removed and the entire thing can be centrifuged again and the DNA can be isolated completely. Specialized cytocentrifuges are used in medical and biological laboratories to concentrate cells for microscopic examination(Stokes et al, 2004).

- **Isotope separation**

Other centrifuges, the first being the Zippe-type centrifuge, separate isotopes, and these kinds of centrifuges are in use in nuclear power and nuclear weapon programs(Cordesman et al, 2006).

- **Aeronautics and Astronautics**

Human centrifuges are exceptionally large centrifuges that test the reactions and tolerance of pilots and astronauts to acceleration above those experienced in the Earth's gravity.

The first centrifuges used for human research were used by Erasmus Darwin, the grandfather of Charles Darwin. The first largescale human centrifuge designed for Aeronautical training was created in Germany in 1933(NASA Research, 2012).

The US Air Force at Brooks City Base, Texas operates a human centrifuge while awaiting completion of the new human centrifuge in construction at Wright-Patterson AFB, Ohio. The centrifuge at Brooks City Base is operated by the United States Air Force School of Aerospace Medicine for the purpose of training and evaluating prospective fighter pilots for high-g flight in Air Force fighter aircraft.

The use of large centrifuges to simulate a feeling of gravity has been proposed for future long-duration space missions. Exposure to this simulated gravity would prevent or reduce the bone decalcification and muscle atrophy that affect individuals exposed to long periods of freefall(Jeremy, 2012).

- **Non-Human Centrifuge**

At the European Space Agency (ESA) technology center ESTEC (in Noordwijk, the Netherlands) an 8-meter diameter centrifuge is used to expose samples in both fields of Life Sciences as well as Physical Sciences. This Large Diameter Centrifuge (LDC 19) began operation in 2007(Goncalves et al, 2012). Samples can be exposed to a maximum of 20 times Earth gravity. With its four arms and six freely swing out gondolas it is possible to expose samples with different g-levels at the same time. Gondolas can be fixed at eight different position. Depending on their locations one could e.g. run an experiment at 5 and 10g in the same run. Each gondola can hold an experiment of maximum 80 kg. Experiments performed in this facility ranged from zebra fish, metal alloys, plasma, cells,liquids, Planaria, Drosophila or plants(Souček et al, 2013).

- **Geotechnical Centrifuge Modeling**

Geotechnical centrifuge modeling is used for physical testing of models involving soils. Centrifuge acceleration is applied to scale models to scale the gravitational acceleration and enable prototype scale stresses to be obtained in scale models. Problems such as building and bridge foundations, earth dams, tunnels, and slope stability, including effects such as blast loading and earthquake shaking(Zhang, 2006).

- **Synthesis of materials**

High gravity conditions generated by centrifuge are applied in the chemical industry, casting, and material synthesis (Yoshiyuki, 2001).

The convection and mass transfer are greatly affected by the gravitational condition. Researchers reported that the high-gravity level can effectively affect the phase composition and morphology of the products (Pramodn, 2010).

- **Industrial Centrifugal Separator**

Industrial centrifugal separator is a coolant filtration system for separating particles from liquid like, grinding machining coolant. It is usually used for non-ferrous particles separation such as, silicon, glass, ceramic, and graphite etc. The filtering process does not require any consumption parts like filter bags, which saves the earth from harm (Chinminn, 2020).

Commercial Applications

i. Sugar centrifugal machines for separating sugar crystals

ii. Standalone centrifuges for drying (hand-washed) clothes – usually with a water outlet.

iii. Washing machines are designed to act as centrifuges to get rid of excess water in laundry loads.

iv. Centrifuges are used in the attraction Mission: SPACE, located at Epcot in Walt Disney World, which propels riders using a combination of a centrifuge and a motion simulator to simulate the feeling of going into space.

v. In soil mechanics, centrifuges utilize centrifugal acceleration to match soil stresses in a scale model to those found in reality.

vi. Large industrial centrifuges are commonly used in water and wastewater treatment to dry sludges. The resulting dry product is often termed cake, and the water leaving a centrifuge after most of the solids have been removed is called centrate.

vii. Large industrial centrifuges are also used in the oil industry to remove solids from the drilling fluid.

viii. Disc-stack centrifuges used by some companies in the oil sands industry to separate small amounts of water and solids from bitumen

ix. Centrifuges are used to separate cream (remove fat) from milk; see Separator (milk).

2.5 Classification of Centrifugal Separator

Centrifuges may be classified based on maximum speeds, measured as revolutions per minute (RPM). Speeds range from 0-7,500 RPM for low-speed centrifuges, all the way to 20,000 RPM or higher.

Centrifuge rotor speed is often expressed as RCF in units of gravity (x g) for various procedures.However, many centrifuges display speed as revolutions per minute (RPM), necessitating conversion to ensure the correct experimental conditions.

In a solution, particles whose density is higher than that of the solvent sink (sediment), and particles that are lighter than it float to the top.The greater the difference in density, the faster they move.If there is no difference in density (isopyknic conditions), the particles stay steady.

To take advantage of even tiny differences in density to separate various particles in a solution, gravity can be replaced with the much more powerful “centrifugal force” provided by a centrifuge which is a device for separating particles from a solution according to their size, shape, density, viscosity of the medium and rotor speed. (Biochemistry and Molecular Biology (BMB) 2017).

The sedimentation (separation) process which is induced by centrifugal-Coriolis forces in a mixture of buoyant particles (droplets, bubbles) in a suspending fluid, remains very much on the frontier of fluid flow research. The motivations are:

2.6 Centrifugal Separator Working Principle

The centrifugal separator features an inlet, outlet, and separator.The liquid-solid, solid-liquid, or gas-solid mixture is pumped into a cone-shaped working apparatus in the separator. The separator produces a spinning vortex, which leads to the filtration of solids from liquids. The separated solids are collected at the bottom of the separator, and they are purged from there.High-density liquid flows out of the separator, along with the contaminant, and low-density component will remain inside.Water is one of the denser liquids, so it flows outside, and is removed through a discharged outlet.However, lower density fluids such as oil will remain at the center of the vortex. Segregated oil can be easily recovered from the suction orifice of the separato

2.7 Types Of Centrifugal Separation

Centrifugal separators are mainly used for liquid-based applications. They are widely used to separate

- Liquid-Solid Suspensions
- Liquid-Liquid Mixtures
- Solid/Gas-Liquid Mixtures

2.8 Advantages of Centrifugal Separators

Centrifugal separators are used in a variety of industrial applications, owing to various advantages they offer. They have a few moving parts than other separators and have no filters, bags, screens, as well as cartridges, which makes them an ideal choice for various industrial applications. In addition to their design advantages, these separators provide the following benefits:

• **Maintenance Free:** The centrifugal separator is largely maintenance-free owing to the absence of moving parts or other components. It is fitted with an automatic purge valve designed to flush the debris and contaminants automatically.

• **Minimal or No Downtime:** This is another major advantage of centrifugal separator water filters or centrifugal separators used in the industrial process. As the filtration is performed by the spinning of a vortex, there are no real filters involved. This means there will no accumulation of debris in filters, and there will no breakdown due to this accumulation. Also, there will no need to change the filters more often, as in the case of other liquid separators.

• **Minimal Liquid Loss:** Do you know there is a little liquid loss by purging while using centrifugal separators than other filters! Typically, the users have to bear major liquid loses when cleaning sand media filters or automatic strainers.

• **High Efficiency:** The efficiency of centrifugal separation is 98% of 40 microns in a single pass. However, for centrifugal separator, this is 44 microns.This stands valid for solids at the gravity of 2.6 and water at 1.0.

The centrifugation method has a wide variety of industrial and laboratorial applications; not only is this process used to separate two miscible substances, but also to analyze the hydrodynamic properties of macromolecules (Grisham et al, 2013).

Centrifugation in biological research

- **Microcentrifuges**

Microcentrifuges are specially designed table-top models with light, small-volume rotors capable of very fast acceleration up to approximately 17,000 rpm. They are lightweight devices which are primarily used for short-time centrifugation of samples up to around 0.2–2.0 mL. However, due to their small scale, they are readily transportable and if necessary, can be operated in a cold room(Rickwood, 2001)

They can be refrigerated or not. The microcentrifuge is normally used in research laboratories where small samples of biological molecules, cells, or nuclei are required to be subjected to high RCF for relatively short time intervals(Rickwood, 2001). Microcentrifuges designed for high speed operation can reach up to 35000 rpm, giving RCF up to 30000×g, and are called high-speed microcentrifuges(Khandpur, 2020).

Low-speed centrifuges

Low-speed centrifuges are used to harvest chemical precipitates, intact cells (animal, plant and some microorganisms), nuclei, chloroplasts, large mitochondria and the larger plasma-membrane fragments. Density gradients for purifying cells are also run in these centrifuges. Swinging-bucket rotors tend to be used very widely because of the huge flexibility of sample size through the use of adaptors(Rickwood, 2001).

These machines have maximum rotor speeds of less than 10 000 rpm and vary from small, bench-top to large, floor-standing centrifuges(Graham et al, 1991).

High-speed Centrifuges

High-speed centrifuges are typically used to harvest microorganisms, viruses, mitochondria, lysosomes, peroxisomes and intact tubular Golgi membranes. The majority of the simple pelleting tasks are carried out in fixed angle rotors. Some density-gradient work for purifying cells and organelles can be carried out in swinging-bucket rotors, or in the case of Percoll gradients in fixed-angle rotors. High-speed or superspeed centrifuges can handle larger sample volumes, from a few tens of millilitres to several litres. Additionally, larger centrifuges can also reach higher angular velocities (around 30,000 rpm). The rotors may come with different adapters to hold various sizes of test tubes, bottles, or microtiter plates(Rickwood, 2001).

Ultracentrifugations

Ultracentrifugation makes use of high centrifugal force for studying properties of biological particles at exceptionally high speeds. Current ultracentrifuges can spin to as much as 150,000 rpm (equivalent to 1,000,000 x g).They are used to harvest all membrane vesicles derived from the plasma membrane, endoplasmic reticulum (ER) and Golgi membrane, endosomes, ribosomes, ribosomal subunits, plasmids, DNA, RNA and proteins in fixed-angle rotors. Compared to microcentrifuges or high-speed centrifuges, ultracentrifuges can isolate much smaller particles and, additionally, while microcentrifuges and supercentrifuges separate particles in batches (limited volumes of samples must be handled manually in test tubes or bottles), ultracentrifuges can separate molecules in batch or continuous flow systems.

Ultracentrifugation is employed for separation of macromolecules/ligand binding kinetic studies, separation of various lipoprotein fractions from plasma and deprotonisation of physiological fluids for amino acid ananlysis.

They are the most commonly used centrifuge for the density-gradient purification of all particles except cells, and while swinging buckets have been traditionally used for this purpose, fixed-angle rotors and vertical rotors are also used, particularly for self-generated gradients and can improve the efficiency of separation greatly. There are two kinds of ultracentrifuges: the analytical and the preparative(Fischer, 2018).

Analytical ultracentrifugation

Analytical ultracentrifugation (AUC) can be used for determination of the properties of macromolecules such as shape, mass, composition, and conformation. It is a commonly used biomolecular analysis technique used to evaluate sample purity, to characterize the assembly and disassembly mechanisms of biomolecular complexes, to determine subunit stoichiometries, to identify and characterize macromolecular conformational changes, and to calculate equilibrium constants and thermodynamic parameters for self-associating and hetero-associating systems. Analytical ultracentrifuges incorporate a scanning visible/ultraviolet light-based optical detection system for real-time monitoring of the sample's progress during a spin.

Samples are centrifuged with a high-density solution such as sucrose, caesium chloride, or iodixanol. The high-density solution may be at a uniform concentration throughout the test tube ("cushion") or a varying concentration ("gradient"). Molecular properties can be modeled through sedimentation velocity analysis or sedimentation equilibrium analysis. During the run, the particle or molecules will migrate through the test tube at different speeds depending on their physical properties and the properties of the solution, and eventually form a pellet at the bottom of the tube, or bands at various heights(Hansen, 1999).

Preparative ultracentrifugation

Preparative ultracentrifuges are often used for separating particles according to their densities, isolating and/or harvesting denser particles for collection in the pellet, and clarifying suspensions containing particles. Sometimes researchers also use preparative ultracentrifuges if they need the flexibility to change the type of rotor in the instrument. Preparative ultracentrifuges can be equipped with a wide range of different rotor types, which can spin samples of different numbers, at different angles, and at different speeds(Analytical & preparative ultracentrifuges).

Fractionation process

In biological research, cell fractionation typically includes the isolation of cellular components while retaining the individual roles of each component. Generally, the cell sample is stored in a suspension which is:

- Buffered - neutral pH, preventing damage to the structure of proteins including enzymes (which could affect ionic bonds)
- Isotonic (of equal water potential) - this prevents water gain or loss by the organelles
- Cool - reducing the overall activity of enzyme released later in the procedure

Centrifugation is the first step in most fractionations. Through low-speed centrifugation, cell debris may be removed, leaving a supernatant preserving the contents of the cell. Repeated centrifugation at progressively higher speeds will fractionate homogenates of cells into their components. In general, the smaller the subcellular component, the greater is the centrifugal force required to sediment it. The soluble fraction of any lysate can then be further separated into its constituents using a variety of methods(Bruce et al, 2002).

Differential centrifugation

Differential centrifugation is the simplest method of fractionation by centrifugation, commonly used to separate organelles and membranes found in cells. Organelles generally differ from each other in density in size, making the use of differential centrifugation, and centrifugation in general, possible. The organelles can then be identified by testing for indicators that are unique to the specific organelles. The most widely used application of this technique is to produce crude subcellular fractions from a tissue homogenate such as that from rat liver. Particles of different densities or sizes in a suspension are sedimented at different rates, with the larger and denser particles sedimenting faster. These sedimentation rates can be increased by using centrifugal force(Marielle, et Al, 2002).

A suspension of cells is subjected to a series of increasing centrifugal force cycles to produce a series of pellets comprising cells with a declining sedimentation rate. Homogenate includes nuclei, mitochondria, lysosomes, peroxisomes, plasma membrane sheets and a broad range of vesicles derived from a number of intracellular membrane compartments and also from the plasma membrane, typically in a buffered medium(Rickwood,2001)

Density gradient centrifugation

Density gradient centrifugation is known to be one of the most efficient methods for separating suspended particles, and is used both as a separation technique and as a method for measuring the density of particles or molecules in a mixture.

It is used to separate particles on the basis of size, shape, and density by using a medium of graded densities. During a relatively short or slow centrifugation, the particles are separated by size, with larger particles sedimenting farther than smaller ones. Over a long or fast centrifugation, particles travel to locations in the gradient where the density of the medium is the same as that of the particle. Therefore is a small, dense particle initially sediments less readily than a large, low density particle. The large particles reach their equilibrium density position early, while the small particles slowly migrate across the large particle zone and ultimately take up an equilibrium position deeper into the gradient.

A tube, after being centrifuged by this method, has particles in order of density based on height. The object or particle of interest will reside in the position within the tube corresponding to its density. Nevertheless, some non-ideal sedimentations are still possible when using this method. The first potential issue is the unwanted aggregation of particles, but this can occur in any centrifugation. The second possibility occurs when droplets of solution that contain particles sediment. This is more likely to occur when working with a solution that has a layer of suspension floating on a dense liquid, which in fact have little to no density gradient (Price, 1982)

A centrifuge can be used to isolate small quantities of solids retained in suspension from liquids, such as in the separation of chalk powder from water. In biological research, it can be used in the purification of mammalian cells, fractionation of subcellular organelles, fractionation of membrane vesicles, fractionation of macromolecules and macromolecular complexes, etc. Centrifugation is used in many different ways in the food industry. For example, in the dairy industry, it is typically used in the clarification and skimming of milk, extraction of cream, production and recovery of casein, cheese production, removing bacterial contaminants, etc. This processing technique is also used in the production of beverages, juices, coffee, tea, beer, wine, soy milk, oil and fat processing/recovery, cocoa butter, sugar production, etc. It is also used in the clarification and stabilization of wine(Rickwood, 2001)

In forensic and research laboratories, it can be used in the separation of urine and blood components. It also aids in separation of proteins using purification techniques such as salting out, e.g. ammonium sulfate precipitation(Marielle, et al, 2008). Centrifugation is also an important technique in waste treatment, being one of most common processes used for sludge dewatering(Ludovico, et al, 2019). This process also plays a role in cyclonic separation, where particles are separated from an air-flow without the use of filters. In a cyclone collector, air moves in a helical path. Particles with high inertia are separated by the centrifugal force whilst smaller particles continue with the air-flow(Ming, et al, 2000)

Centrifuges have also been used to a small degree to isolate lighter-than-water compounds, such as oil. In such situations, the aqueous discharge is obtained at the opposite outlet from which solids with a specific gravity greater than one are the target substances for separation(Woodard, 2006).

Maize

Maize (/meɪz/ MAYZ; Zeamays subsp. mays,from Spanish: maíz after Taino: mahiz), also known as corn (North American and Australian English), is a cereal grain first domesticated by indigenous peoples in southern Mexico about 10,000 years ago(Benz, 2001). The leafy stalk of the plant produces pollen inflorescences andseparate ovuliferous inflorescences called ears that yield kernels or seeds, which are fruits(USDA, 2018).

Maize has become a staple food in many parts of the world, with the total production of maize surpassing that of wheat or rice. In addition to being consumed directly by humans (often in the form of masa), maize is also used for corn ethanol, animal feed and other maize products, such as corn starch and corn syrup(Foley, 2019). The six major types of maize are dent corn, flint corn, pod corn, popcorn, flour corn, and sweet corn(Franklin, 2013). Sugar-rich varieties called sweet corn are usually grown for human consumption as kernels, while field corn varieties are used for animal feed, various corn-based human food uses (including grinding into cornmeal or masa, pressing into corn oil, and fermentation and distillation into alcoholic beverages like bourbon whiskey), and as chemical feedstocks. Maize is also used in making ethanol and other biofuels.

Maize is widely cultivated throughout the world, and a greater weight of maize is produced each year than any other grain(International grain council market report 2013). In 2014, total world production was 1.04 billion tonnes. Maize is the most widely grown grain crop throughout the Americas, with 361 million metric tons grown in the United States alone in 2014. Genetically modified maize made up 85% of the maize planted in the United States in 2009(New york times, 2011).

Maize and cornmeal (ground dried maize) constitute a staple food in many regions of the world. Maize is used to produce cornstarch, a common ingredient in home cooking and many industrialized food products. Maize starch can be hydrolyzed and enzymatically treated to produce syrups, particularly high fructose corn syrup, a sweetener; and also fermented and distilled to produce grain alcohol. Grain alcohol from maize is traditionally the source of Bourbon whiskey. Corn flour is used to make cornbread and other baked products.

In prehistoric times Mesoamerican women used a metate to process maize into ground cornmeal, allowing the preparation of foods that were more calorie dense than popcorn. After ceramic vessels were invented the Olmec people began to cook maize together with beans, improving the nutritional value of the staple meal. Although maize naturally contains niacin, an important nutrient, it was not bioavailable without the process of nixtamalization. The Maya used nixtamal meal to make varieties of porridges and tamales. The process was later used in the cuisine of the American South to prepare corn for grits and hominy(pilcher, 2013).

Ogi (or Akamu)

This is a fermented cereal pudding from Nigeria, typically made from maize, sorghum, or millet. Traditionally, the grains are soaked in water for up to three days, before wet-milling and sieving to remove husks. The filtered cereal is then allowed to ferment for up to three days until sour. It is then boiled into a pap, or cooked to make a creamy pudding. It may be eaten with moin moin or akara.

In Kenya the porridge is known as uji (not to be confused with ugali) and is generally made with millet and sorghum. It is commonly served for breakfast and dinner. But often has a thinner gravy-like consistency.

The fermentation of ogi is performed by various lactic acid bacteria including Lactobacillus spp and various yeasts including Saccharomyces and Candida spp (Mathurin, 1998).

CHAPTER 3

DESIGN METHODOLOGY

3.1 Material Selection Used

The component of the machine – mini centrifugal separation used for fabrication and assembly are listed in Table 3.1

Table 3.1: Component Parts

S/N	Materials	Number of Units
1.	1mm sheet metal	1
2.	750W A.C driven induction motor	1
3.	6mm bolts, nuts and washers	6 each
4.	Fabric (1.5mmsq)	1
5.	4μF Capacitor	1
6.	Truncated Cone	3
7.	Flat bar 5mm x 10mm	8
8.	Flexible wire	3m

Some of the component part for the machine were bought from the market.

3.2. The Working of the Centrifugal separator

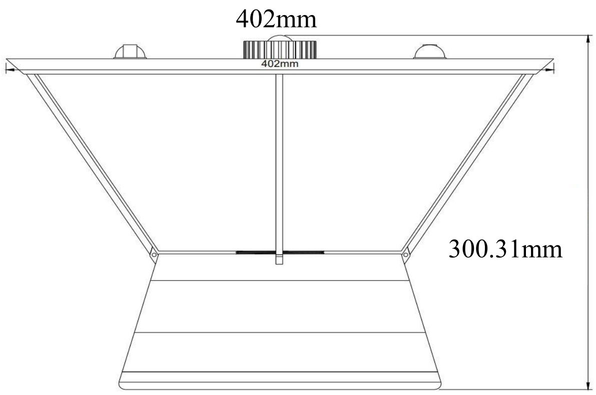


Fig. 1. A Side view of the designin 2D representation

A simplification of the stages of separation A-D that the mixture undergoes.

As in fig.3.2, the feed via the stationary inlet enters the cylindrical vessel A where, separation occurs partly to separate the mixture into two distinctive layers of which by eqn (vii) the particle with the greater mass attracted by a greater centrifugal force relative to the other moves closer to its walls and forms a layer while the less dense particles form next to it.

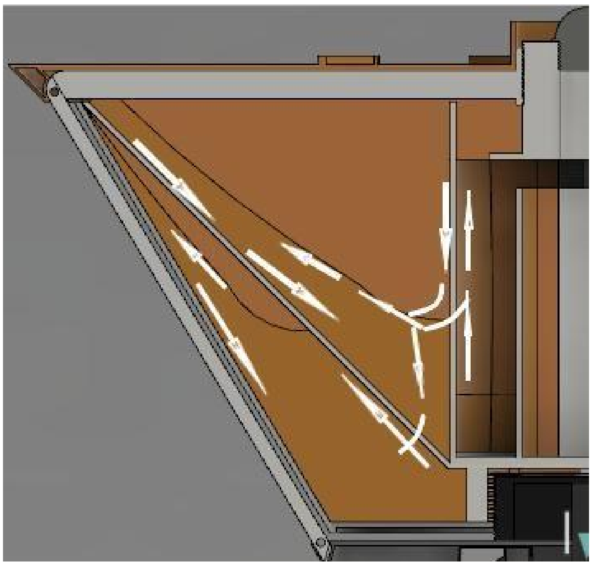


Fig. 2. Flow of solid particles in one-half sectional view of the vessel.

In the above illustration, we can see the distinctive layers indicated by colors in Section A.

Referring to fig.3.2, moving from A, the flow goes into the section B where separation occurs again but here, the compartment is netted to allow for our desired ogi particles in feed mixture to flow to C while preventing any corn chaff that may be present from A to remain in B.

As shown above in the primary separation stage as well as the secondary stage C and D viewed from fig.3.2 and fig.3.3, the particles of the solid in the mixture move in such a way that while the machine is turned on and spinning, the particles travel to the upper part of the vessel in any stage of separation. For separation to proceed once they reach the topmost portion, they settle; the velocity of the mixture at the settling surface is negligible and so the ogi particle is no longer carried along with the liquid. At this point, it slides along the slant height of the vessel influenced by the centrifugal force and is deposited at the lower portion of the vessel compartment.

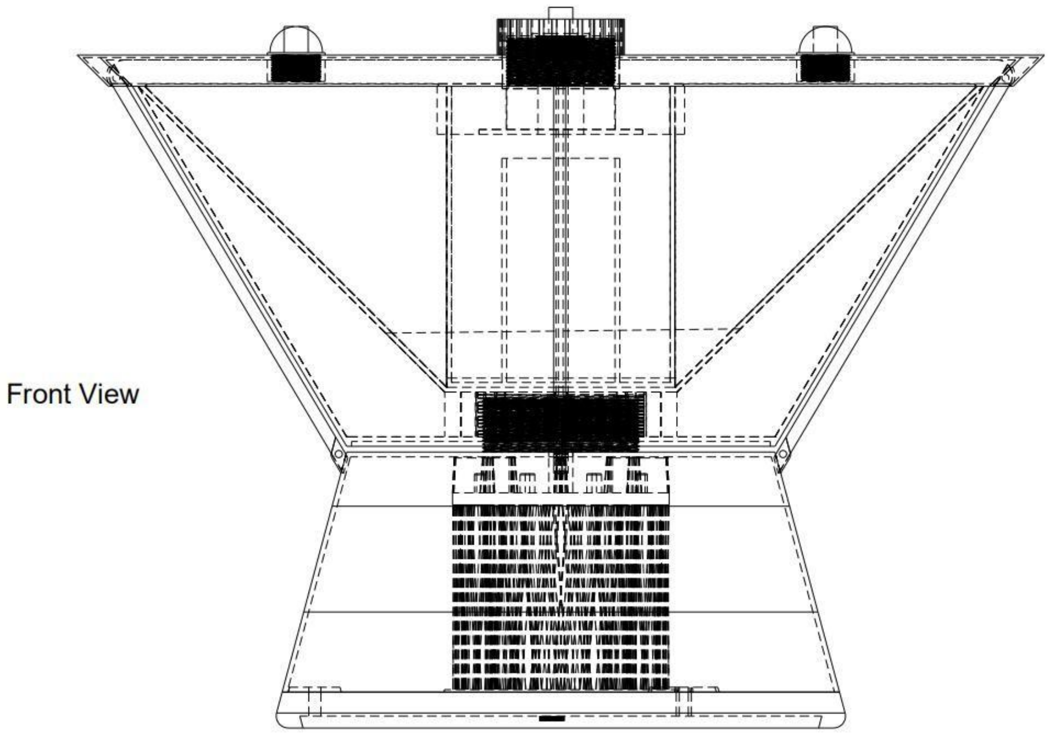
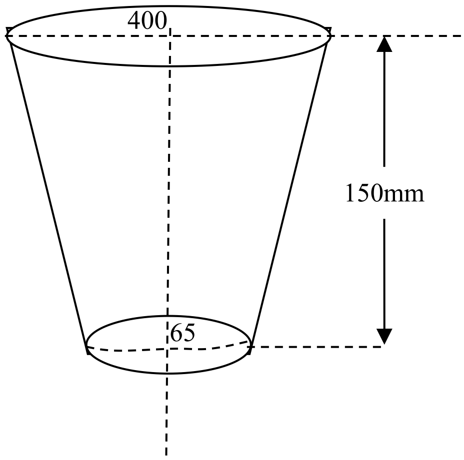


Fig. 3. A front view of the design in 2-D representation

The approach intended here, seeks to exploit the density difference between the particles of the Ogi(Akamu) and the fluid in which it is in a mixture with the intent of the application of the basic knowledge of centrifugal force which acts on a body in circular motion relative to an axis of rotation.

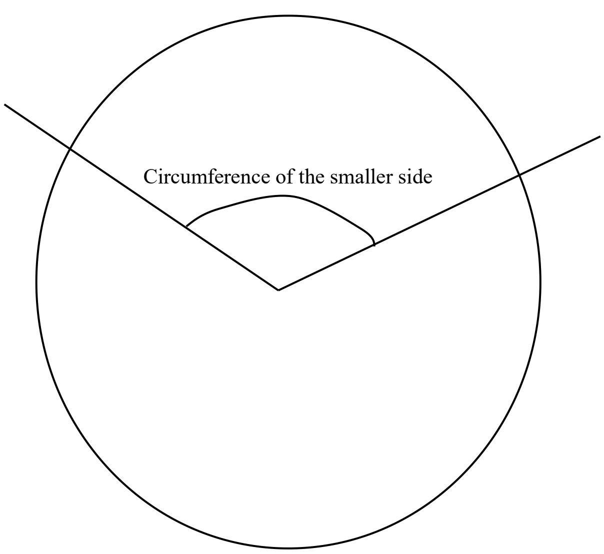
3.3 Design Analysis and Calculations

1. From the diameter of larger side of the cone and the smaller side, we construct the cone between the spentied height. As shown in the figure below.



It is now possible to calculate the slanting height by projection, we condax the apex of the cone. The length of the slanting height from the base to the apex is radius of the required circle.

After the circle is drawn to size on the blank (or work piece), from an arbitrary point, mark off the circumference of the base of the cone. Then mark off the slanting height of the cone.



With Centre at the centre of the main circle, describe and arc equal to the circumference of the top of the cone. The shape thus formal is cut out and folded to form the cone.

Much similar to sedimentation, the use of a centrifuge vessel in separation is advantageous for the fact that gravity still acts but with an added force(centrifugal). Consider a particle in a vessel that is being rotated at some tangential velocity v.

Now,

v r $v = w.r$ …………………………………. (i)

For a body in circular motion, its acceleration is given by

$a = \frac{v^2}{r}$ …………………………………. (ii)

$a = \frac{(w.r)^2}{r} = w^2.\ r$ ………………………… (iii)

The centrifugal force can be expressed thus as

$f = m.a$ ………………………………… (iv)

$f = \frac{m.v^2}{r} = m.w^2.\ r$ ………………………… (v)

If we express this force in terms of the relative speed of the particle and the number of revolutions at which it is in motion.

$F_{cg} = m.(\frac{2.\pi.N}{60})^2.\ r$ ………………………… (vi)

$F_{cg} = 0.011m.r.N^2$ ……………………………………. (vii)

From the above, we see that the centrifugal force is dependent on the mass of the particle, the radius of rotation and the speed of rotation. Thus for a constant radius and speed, the controlling factor is the mass. This is to be exploited in our separation vessel in which the force will be more on the denser relative to the other.

Centrifuge/Flotation velocity is determined by the properties of the particle as its

1. Diameter d_p
2. Density ρ_p
3. Continuous phase density and viscosity p_c and v_c respectively
4. Acceleration a

Armed with this and the idea of stokes equation for sedimentation

$$V_g = \frac{d_p{}^2\ (\rho_{p-}\ \rho_c}{18.V_c}\ .g \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (viii)$$

We can make a suitable substitution for g as the acceleration a leading to

$$V_c = \frac{d_p{}^2\ (\rho_{p-}\ \rho_c}{18.V_c}\ .w^2.r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (ix)$$

$$w = \frac{2\pi N}{60} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (x)$$

3.3 1. Cost Evaluation

In the pursuit of this project, we purchased some materials which assisted us in the success of fabricating the components of the bending machine. These are as shown in the table below.

Table 3.3 Bill of Engineering Materials and Evaluation

S/N	Materials	Number of Units	Cost(Naira)
1	3mm sheet metal	1	10000
2	A.C driven induction motor	1	20000
3	10mm bolts, nuts and washers	6 each	2000
4	Corn		3000
5	Fabric (1.5mmsq)	1	10000
6	Capacitor	1	3000
7	Truncated Cone	3	2000
8	Flat bar	8	15000
9	Flexible wire	5m	5000
10	Miscellaneous (2 Grinding disc, 2 cutting disc, 20litre Gasoline, other expenses)		30000
	Total		100000

The table above details the expenses we incurred in the advancement of this project during the fabrication stage.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Testing of the Machine

Using the machine fabricated, we tested it with some three thousand naira, (₦3000) worth of corn which we had treated with water to make a milky corn-starch and water mixture. With sufficient quantity fed into the rotating vessel, we were able to separate some chaff from the mixture which we had initially fed into the rotating part. Furthermore, when the output from this stage got to the next stage for settling, the product of corn starch particles to be dried sedimented out much quickly than the control model of the same quantity of feed divided away in a bucket for sedimentation without going through the centrifugal machine designed.

All achieved with a greater efficiency of no chaff and an output time perceived less than 10 minutes from our machine outlet flowing from section B(the sedimentation stage).

4.2. Discussion

In contrast to the traditional method of separating out the corn starch from water where the corn starch mixture with water is left in a bowl and waited on for sedimentation to occur naturally, utilizing the centrifugal force acting on a body being rotated in our machine, we were able to efficiently separate more of the milky starch in less time due to the fact that in section A, pre-separation into distinct layers was achieved and by the time the mixture got to section B, each phase settled in layers with the denser of our starch particles at the bottom and water at the top. All that had to be done was collect our product from the outlet outside.

Furthermore, due to the design of section A, a 3 micron netted material attached to its inner surface prevented unwanted particles as chaff from getting to section B and thus, the quality of separation was improved as well as the time for separation to occur.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

From the results and observation, it is thus concluded that the quality and quantity of product that can be obtained from our centrifugal separation machine are much improved than the traditional method given the same working time.

5.2. RECOMMENDATION

In this project, we had considered separation in a vertical rotating cylindrical vessel and due to the design of the vessel A, the perforations started at some height h from the base of the vessel and thus for flow to the next section, the fluid has to rise to height h to pass through the holes made. Based on the particle flow of the rotating fluid, the solid particles tend to make a vertical wall at the sides of the vessel and sufficient feed has to be continuously fed in till the height h is overcome for flow to the next section.

- ✓ For continuous running of the machine, it is recommended that easy access for evacuation of the chaff should be provided.
- ✓ For further studies, a speed regulator will enable the efficiency as well as efficacy of the machine to be determined at various speeds.
- ✓ It is recommended that the machine should be introduced to local palp makers to enhance hygiene and improve productivity.

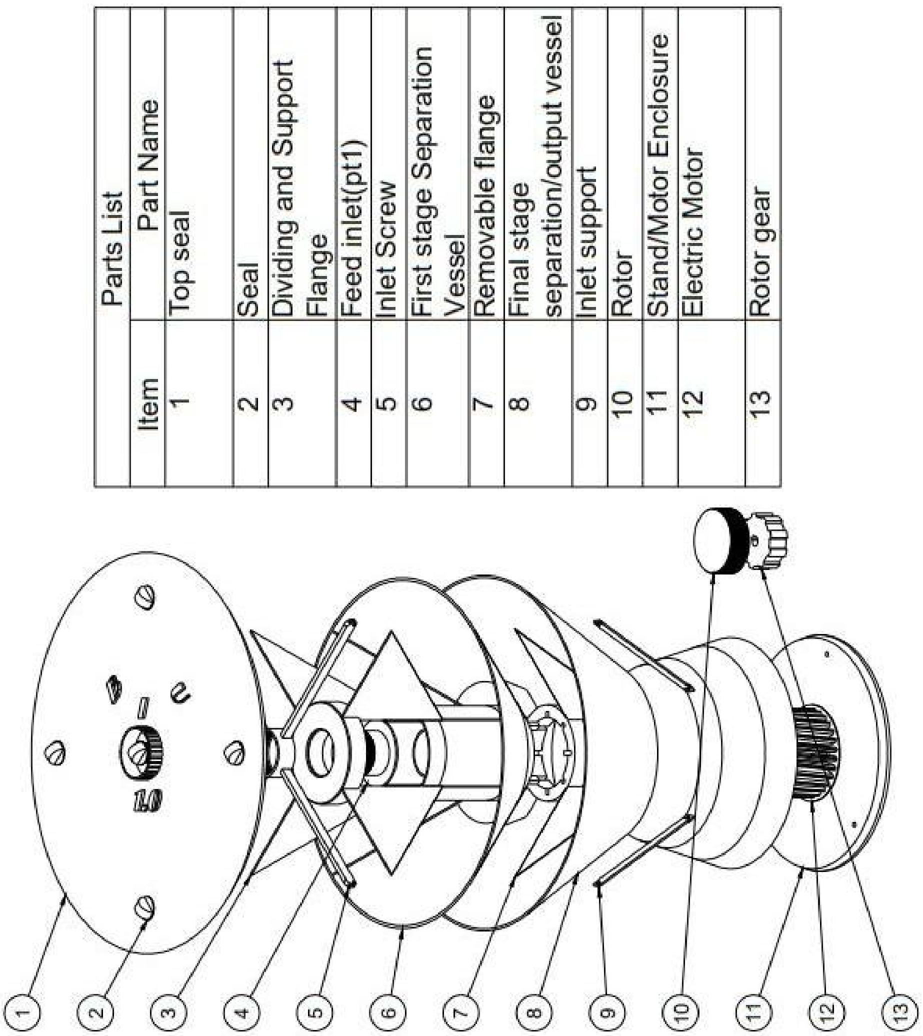


Fig.7. An exploded view of the design showing the different parts that make up the centrifugal separator machine as in the design

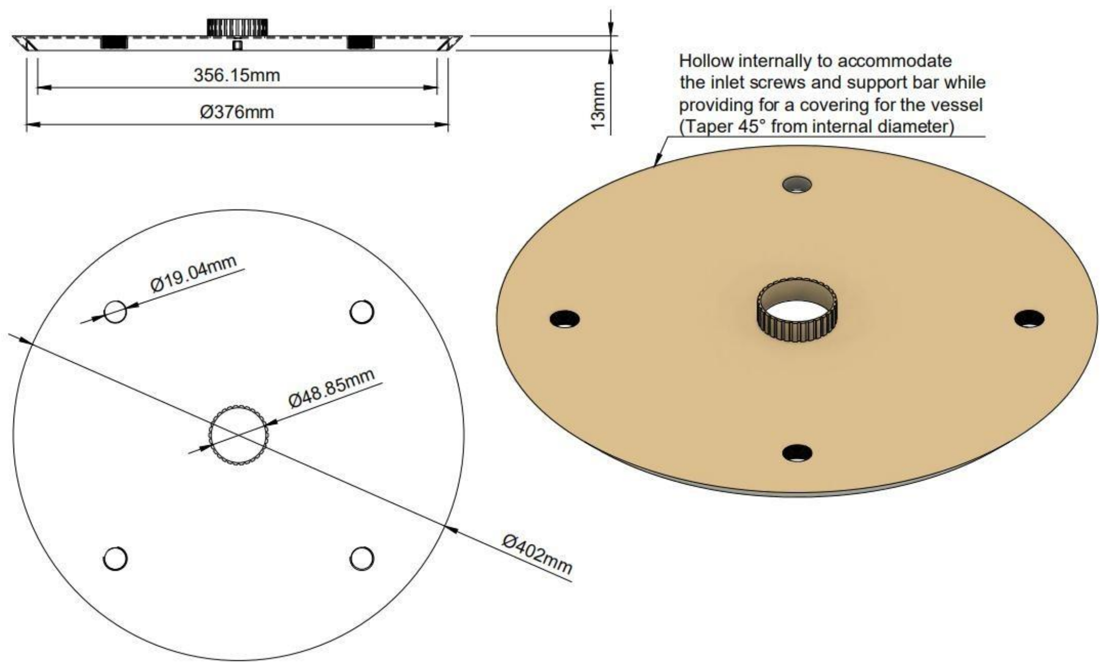


Fig. 8. The Top seal

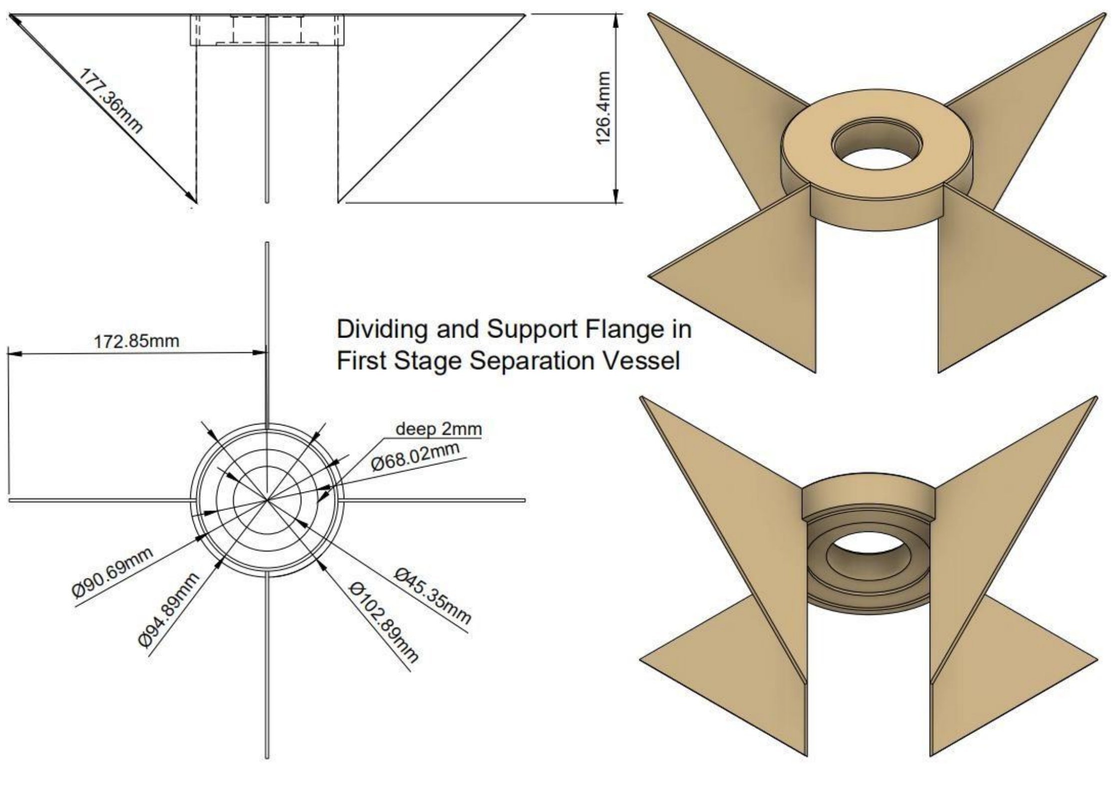


Fig. 9. The dividing and supporting flange

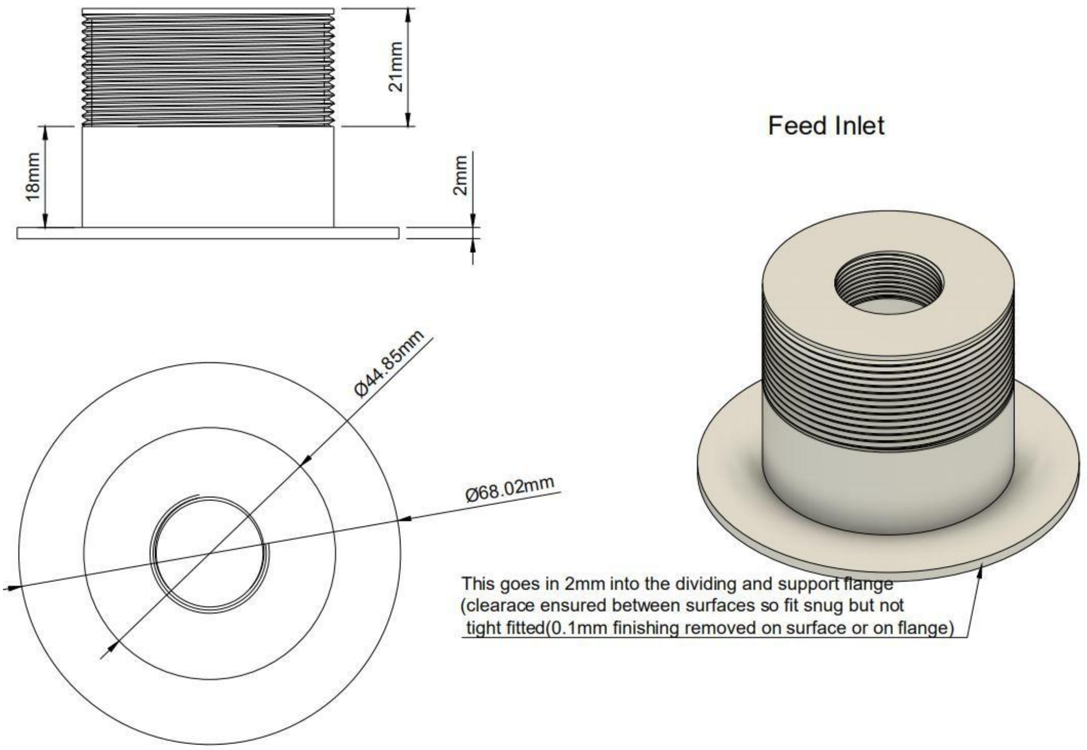


Fig. 10. The Feed inlet

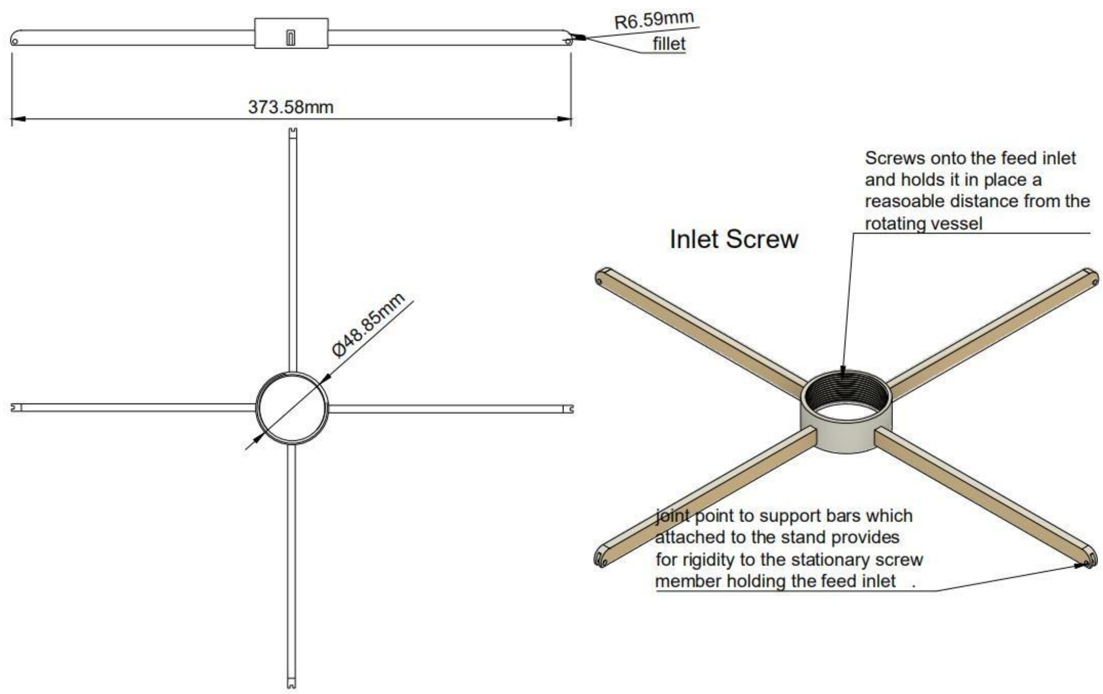


Fig. 11. The inlet screw holding the feed inlet in stationary position

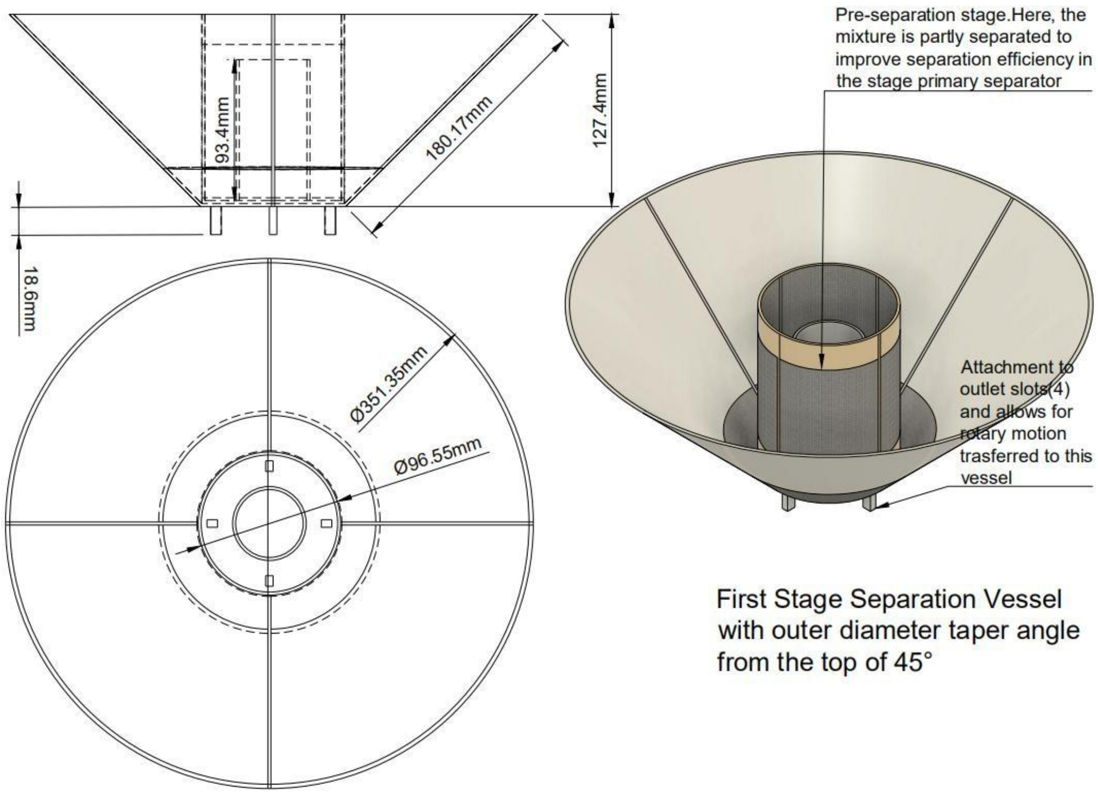


Fig. 12. The first stage separation compartment

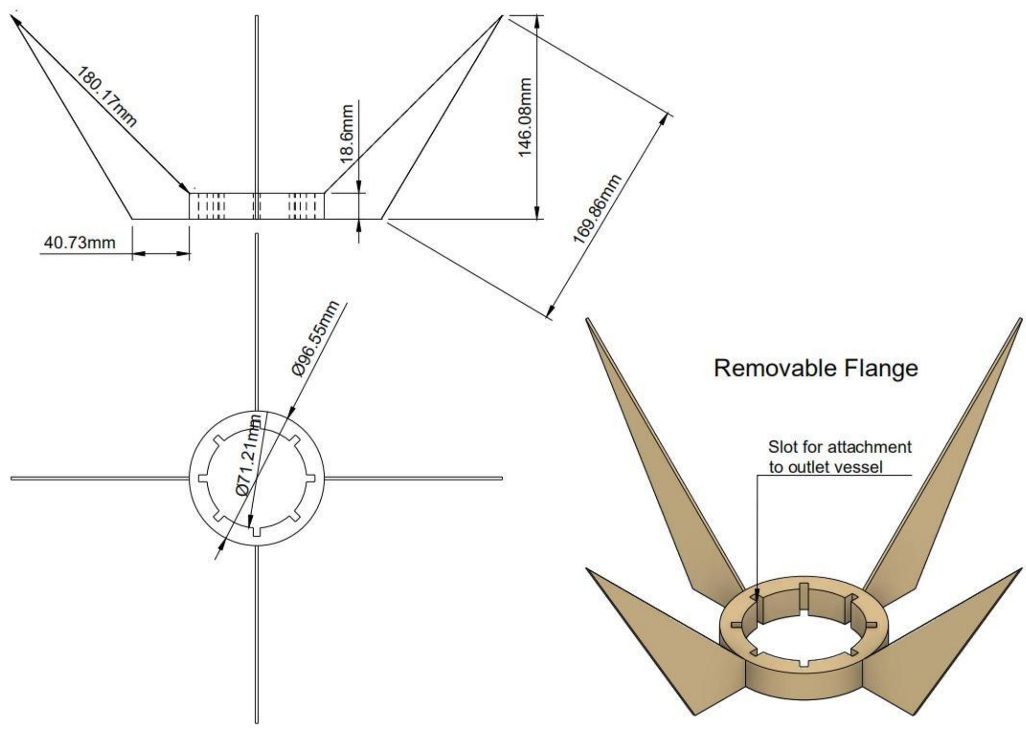


Fig. 13. The removable flange to be placed between the first stage separation compartment and the final stage compartment vessel