DESIGN AND FABRICATION OF A DUAL-PURPOSE WASTE GLASS PROCESSING MACHINE

BY

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DEPARTMENT OF INDUSTRIAL DESIGN
FACULTY OF ENVIRONMENTAL DESIGN
AHMADU BELLO UNIVERSITY, ZARIA

APRIL, 2017

DECLARATION

I declare that the work in this Dissertation entitled “Design and Fabrication of a Dual-Purpose Waste Glass Processing Machine” has been carried out by me in the Department of Industrial Design. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other Institution.

Stephen Olayemi OLASEHINDE	_____	_____
Name of Student	Signature	Date

CERTIFICATION

This dissertation entitled, "DESIGN AND FABRICATION OF A DUAL-PURPOSE WASTE GLASS PROCESSING MACHINE", by Stephen Olayemi OLASEHINDE, meets the regulation governing the award of the degree of Master of Science in Glass Technology, of the Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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Prof. S.Z. Abubakar Dean, School of Post Graduate Studies	_____ Signature	_____ Date

DEDICATION

This work is dedicated to my caring brothers; Late Leken Olasehinde and Late Damilola Olasehinde continue to rest in the bosom of the Lord.

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ABSTRACT

This research focused on the design and fabrication of a dual-purpose waste glass processing machine, using specific design considerations, design theories and calculations, to improve the efficiency of processing of waste glass. Recycling waste glass plays an important role in the grading and upgrading of waste glass in the environment. The post consumer waste glass pollutes the environment and by processing the waste glass using the dual-purpose waste glass processing machine upgrade the waste glass. The isometric projection and orthographic projection showing the major components of the dual-purpose waste glass processing machine were designed using software known as solid works. The major material used for fabrication was mild steel and other materials used were sourced at Old Panteka, Kaduna State. The hopper has an opening of 420mm by 120mm and a discharge end of 400mm by 100mm. The separator plates have a thickness of 4mm, length of 150mm, height of 150mm and total of 4. The shaft has a length of 530mm, height of 30mm and thickness of 30mm. The eccentric shaft has a length of 650mm and thickness of 30mm. The hammer mill has a length of 140mm, breadth of 35mm, thickness of 2mm and total of 18. The pin has a length of 240mm, thickness of 15mm and total of 2. The spacers have a length of 20mm and are 24 in total. The perforated screen has a length of 450mm, width of 250mm and thickness of 4mm. The sieves have a length of 320mm, height of 35mm, width of 285mm and a total of 3. The front door has a length of 390mm and width of 320mm. The collector has a length of 320mm, height of 35mm and width of 285mm. The housing case has two compartments, the first compartment has a length of 25mm, height of 15mm, width of 30mm; while the second compartment has a length of 250mm, height of 250mm and width of 520mm. Electric motor bed has a length of 450mm, height of 5mm and width of 350mm. The machine has a length of 996mm, height of 700mm and width of 696mm. The assembly of the dual-purpose waste glass processing machine was done by separable (using bolts and nuts) and permanent (by welding) fixed joints. The dual-purpose waste glass processing machine was sprayed with red oxide and an orange colour. The waste glasses were collected from different locations in Ahmadu Bello University Zaria, Samaru main campus. The beneficiation process of the waste glasses involved sorting, soaking, washing and drying. Each of the waste glasses were weighted to 2300g, and were used to test run the dual-purpose waste glass processing machine. The performance of the dual-purpose waste glass processing machine was tested using the sieves of 4mm, 3mm, 2mm and a collector. The results of the processed waste glass were determined by the grain sizes retained on each sieves. The total weight of the flint processed glass retained on the sieves and collector was 2288g, while the total weight of the amber and green processed glasses are 1822g respectively. The grain sizes retained on 4mm and 3mm sieves can be use for glass melting. The grain sizes retained on green, amber and flint glass 2mm sieve can be used for surface texture design. The grain sizes retained on the collector can be for partial replacement of cement, glass paint and glass tiles. The sieve analysis was carried out to determine the grading of the waste glass for use as aggregates.

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DEFINITION OF OPERATIONAL TERMS

Boulder is a rock fragment with size greater than 25.6 centimetres in diameter

Mild steel is the most common form of steel and it's a strong tough steel that contain a low quantity of carbon

Cullet is a recycled broken or waste glass used in glass-making

Machine is an apparatus using mechanical power and having several parts, each with a definite function and together performing a particular task

Commutator is a moving part of a rotary electrical switch in certain types of electric motors and electrical generators that periodically reverses the current direction between the rotor and the external circuit

Design is the creation of a plan or convention for the construction of an object or a system as in engineering drawings

Beneficiated glass is cullet that has been sorted, cleaned, crushed and sized

Solid works is a computer-aided design program used for 2-D and 3-D design and drafting

Recycling is the process of converting waste materials into reusable objects

Contamination is the presence of an unwanted constituent, contaminant or impurity in a material

Electromotive force, also called emf (denoted and measured in volt), is the voltage developed by any source of electrical energy such as a battery

LIST OF NOTATION AND SYMBOLS

% = Percentage

mm = Millimeter

g = Grams

= Naira

l = Length

b = Breadth

rpm = rotation per minute

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Waste glass exists in three forms which are off-specification cullet, pre-consumer cullet and post-consumer cullet. Off-specification cullet is generated as glass producers slowly change the ingredient mix in their giant melting vats, and finished glass that breaks at the manufacturing plant. Pre-consumer cullet is the finished glass that breaks at a bottling or distribution facility. Both of these types of waste glass are reused within the glass plants. Post-consumer cullet consists of the glass bottles or other glass products discarded by consumers after use. Glass is 100 percent recyclable and it can be melted repeatedly to produce the same product, and the technology for recycling glass is relatively simple and well established (McCarthy, 2015).

The glass produced by different manufacturers differs in both form and chemical composition. The form variations are familiar because glass can be pressed and blown into shapes, or in more complicated applications, such as fiberglass or fiber optics. Although glass can be re-melted and changed from one form into another with ease, a problem arises in separating the glass from other materials in a product (for example; separating the glass in a light bulb from other non-glass components). Although all glasses are composed of silica and sodium oxide (soda ash), the type and quantity of other compounds added vary slightly in different types of glasses. These differences frequently cause problems in recycling glass because producers of some types of glass have strict specifications for the chemical make-up of any cullet they might use (McCarthy, 2015).

According to Garkida (2007), waste glass are non-degradable making them even more hazardous when they litter the environment especially to children whose only playgrounds are these refuse areas in a country with poor health care system. The need for safe disposal and the search for utility for unwanted glasses cannot be over emphasized, in order to stimulate a reduction of health risks and the conversion of waste to wealth.

Recycled glass must meet quality standards to ensure it can be marketed and made into new glass products. Contaminants must be kept out of glass recycling articles. Contaminants such as ceramics, glass metal rings, and caps cause problem in the recycling process. Ceramics, for examples, have higher melting temperature than glass, when mixed with recycled glass in the melting furnace; the ceramics pieces get embedded in the new glass, resulting in defective and unacceptable new glass products. Metal contaminants remaining in the molten glass also result in depictive and unacceptable new products (Jekada, 2013).

In Gonah (2001), crushing and grinding machines must be designed to exert either pushes or pulls on individual particles, since there are no other kinds of mechanical forces, and that the solid particles must be so introduced into and maintained in the force zone that the forces available can be applied to them. A crushing machine must not only break the materials but, must provide means for continuous representation of uncrushed materials to the crushing zone and continuous discharges of crushed materials therefrom.

1.2 Research Problem

Waste glass is one of the major sources of problem in waste management in Nigeria. The use of waste glass in free blowing and casting was due to high cost of fluxing and fining raw materials (Gonah, 2001). The waste glass processing machine at the Department of Glass and Silicate Technology uses 3 phase and set of sieves are not incorporated into it. The procedures for upgrading and grading of the glass waste are collection, washing, magnetic separation, crushing and sieving respectively. The particle sizes of the cullet which stemmed from the upgrading and grading are used in different applications like melting, casting, partial replacement of sand in concreting, ceramics glazing, surface texture design, and partial replacement of cement. However, the processes of upgrading and grading require two or more machines, which add to the cost of production. Therefore, a dual-purpose waste glass processing machine is imperative to reduce the cost of production.

1.3 Aim

The aim of this research was to design and fabricate a dual-purpose waste glass processing machine.

1.4 Objectives

Objectives of the research were to:

1. design a dual-purpose waste glass processing machine
2. fabricate the dual-purpose waste glass processing machine
3. test run the dual-purpose waste glass machine using the waste glass

1.5 Significance of the Study

Glass can be processed over and over again without the quality deteriorating. Separating and processing glass could significantly reduce waste management costs. The amount of energy needed to melt recycled glass is considerably less than that needed to melt raw materials to make new bottles and jars. Some companies are realizing cost savings by implementing their own processing programs. Processing all the waste glass we throw away would create new jobs for the unemployed by selling the processed glass. Glass processing machine helps in crushing waste glass properly to save time and energy, instead of using stones.

1.6 Justification of the Study

Department of Glass and Silicate Technology are in need of technological equipment; so the availability of a dual-purpose waste glass processing machine will boost the working processes of the glass industries in the country. Waste glass is useless until when graded by crushing into desired size known as cullet, which is not only added to glass melt, but the cullet as raw materials in other industries, particularly building and construction work (Gonah, 2001). For the manufacture of any glass, a poor sieving of glass making raw materials results in defects in the glass production process and reduces the overall quality. Vibrating sieving machines are widely used for grading and screening materials for fast processing. Magnets can pick up magnetic items such as nails, needles, bottle crowns that are either too small for the eye to see during sorting. Magnets can be used in waste operations to separate magnetic metals such as iron, cobalt, and nickel from non-magnetic metals such as aluminum.

1.7 Scope of the Study

The research covered the design using software known as solid works, fabrication using mild steel in old Panteka, Kaduna and the test running of the dual-purpose processing machine with waste glass that was sourced from different locations in Ahmadu Bello University, Zaria, Samaru Main Campus. This research covers only crushing of waste glass and not complete comminution.

CHAPTER TWO

LITERATURE REVIEW

Waste management methods cannot be uniform across regions and sectors because individual waste management methods cannot deal with all potential waste materials in a sustainable manner. Conditions vary; therefore, procedures must also vary accordingly to ensure that these conditions can be successfully met. Waste management systems must remain flexible in changing economic, environmental and social conditions. A variety of approaches have been developed to tackle waste issues; the economic and environmental performance of the entire system can be impacted by the way the materials are collected and sorted. In many instances, the collection point will be an interface where waste generators and waste collectors that must be carefully managed if the system is to be effective. Waste generators require waste collection with minimal inconvenience, while collectors must be able to collect waste in a way that is compatible with the planned treatment and processing methods if the waste management system is to be sustainable (Gary, 2011).

Contaminants are materials present in waste glass that are unwanted for its further use. Contaminants can be classified in two groups; non-glass material components and glass material components that are detrimental for new glass manufacturing. Non-glass material components are metals (ferro-magnetic and non-ferro-magnetic). Non-metal non-glass inorganic is ceramics, stones and porcelain. Organics are food remains, plastic, wood, textiles and so forth. Hazards are hazardous materials contained in bottles, jars, medical or chemical refuse contained within needles and syringes. Glass material components; glass product quality is severely affected by the presence in glass cullet of glass types different from the main glass cullet type. For example; to

manufacture flint container glass, there is a limit on what percentage of green container glass cullet is used. Above that limit, the green glass cullet is adverse for new flint glass manufacturing. The first phase of treatment upon arrival of waste glass at the reprocessing plant is visual inspection. Visual inspection is undertaken by experienced staff with good knowledge of the processing technology of the plant. If inspection results in acceptance, the material is crushed. Crushing reduces the glass piece size to the size suitable for further sorting or cleaning. Afterwards the organics may be dried at ambient air, or removed by washing, before the material passes sieves to reduce the organic content as well as magnetic separators and Eddy current separators to reduce the metal content. Manual sorting can also be part of the sorting steps, removing by handpicking large pieces of foreign material such as plastics, paper, stone and so forth (Elena *et al.*, 2011).

The literature reviews the design and fabrication of a dual-purpose waste glass processing machine, with emphasis on indigenous technology, comminution, crusher and types of crushers, glass crusher, steel, sieve; sieve analysis, magnet, concept of fabrication; metal fabrication; engineering drawing; sources for raw materials; machining; forming, welding, electric motor, cullet, production and manufacturing processes; bearing; shaft; belt; pulley; hopper, machine frame, general machine design safety condition, design theory, belt drive, spring, mathematical modeling of the vibratory sieve housing, power needed to drive the threshing, drum, equivalent twisting moment and equivalent bending moment.

2.1 Indigenous Technology

Indigenous technology enhances a nation's development and reduces its dependence on importation of equipment and machineries. It addresses the local need and to an extent, meets international standards (Morakinyo, 2012). As with several key concepts like science and technology, innovation and entrepreneurship, there seems to be no single universal definition of indigenous knowledge but the fundamentals are clear. Contrasting indigenous knowledge with globalized knowledge, Warren *et al* (1995), noted that it is the local knowledge that is unique to a given culture or society. Focusing on the sources of indigenous knowledge, it was defined by Grenier (1998), as the unique, tradition, local knowledge existing within and developed around specific conditions of women and men indigenous to a particular geographic area. A particular commonality to be noted is that indigenous knowledge generally refers to the matured long-standing traditions and practices of certain regional, indigenous, or local communities as well as the wisdom, knowledge, and teachings of the communities. At its most basic level, technology is defined as the application of knowledge to provide solutions to problems, mostly of mankind. Some forms of traditional knowledge are expressed through stories, legends, folks-lore, rituals, songs and even laws while other forms are often expressed though different means (Archarya *et al.*, 2008).

When indigenous knowledge finds applications in tools, techniques, processes and methods that help in solving problems, indigenous technologies arise. Notable examples include the making of talking drums in Oyo (South-Western Nigeria), the fabrication of aluminium pottery in Saki (South-Western Nigeria), the production of beads in Bida (North-Central Nigeria). Nigeria is greatly blessed with gifted hands that are laboriously engaged in various types of indigenous technologies. There is hardly any part of the country that does not have a remarkable indigenous technology to show for its

existence. The indigenous industries among others include the production of pots from clay and aluminium metal scraps, textile making, cloth weaving, bronze casting, leather tanning, and the like, in various parts of the country. The indigenous knowledge supporting these industries is generally passed on from generation to generation and hence it is a tradition in specific locations to produce specific products. The method of indigenous knowledge transmission and skills acquisition is largely through observation and apprenticeship. In today's industrial world man's innovative ideas has taken him towards all directions concerning the production and safety in industrial establishments. Some instruments are of shear excellence whereas others are the result of long research and persistent work, but it is not the amount of time and money spent in the invention of device or the sophistication of it operation, but its convenience, utility and operational efficiency that are important in considering the device (Anant *et al*, 2014).

2.2 Comminution

Comminution is normally the first step in beneficiation of solid materials and waste glass. It is usually a stage process, utilizing in the successive steps machines especially suitable for reduction of particular size. Comminution is a term used to describe all phases of size reduction from the crushing of very large boulders to the grinding of smaller sizes to the very finest particles. Size reduction entails three main methods cutting, shearing and crushing of the materials. Cutting is accomplished by forcing a thin blade through the materials while shearing is by shaving with a dull edged blade. The crushing is the processing of rupturing the materials into particles of irregular shapes and sizes (Gonah, 2001).

2.3 Crusher

Crusher is a machine designed to reduce large materials, for example, rocks, into smaller rocks, gravel, or rock dust so that they can be more easily disposed of or recycled. Crushing is the process of transferring a force amplified by mechanical advantage through a material made of molecules that bond together more strongly, and resist deformation more, than those in the material being crushed. Crushing devices hold material between two parallel or tangent solid surfaces, and apply sufficient force to bring the surfaces together to generate enough energy within the material being crushed so that its molecules separate from (fracturing), or change alignment in relation to (deformation), each other. The earliest crushers were hand-held stones, where the weight of the stone provided a boost to muscle power, used against a stone anvil (Chesner, 1992).

In industry, crushers are machines which use a metal surface to break or compress materials into small fractional chunks or denser masses. Throughout most of industrial history, the greater part of crushing and mining part of the process occurred under muscle power as the application of force concentrated in the tip of the miners pick or sledge hammer driven drill bit. Before explosives came into widespread use in bulk mining in the mid-nineteenth century, most initial ore crushing and sizing was by hand and hammers at the mine or by water powered trip hammers in the small charcoal fired smithies and iron works typical of the Renaissance through the early-to-middle industrial revolution. It was only after explosives, and later early powerful steam shovels produced large chunks of materials, chunks originally reduced by hammering in the mine before being loaded into sacks for a trip to the surface, chunks that were eventually also to lead to rails and mine railways transporting bulk aggregations that post-mine face crushing became widely necessary (Mahaja, 2009).

Mining operations use crushers, commonly classified by the degree to which they fragment the starting material, with primary and secondary crushers handling coarse materials, and tertiary and quaternary crushers reducing ore particles to finer gradations. Each crusher is designed to work with a certain maximum size of raw material, and often delivers its output to a screening machine which sorts and directs the product for further processing. Typically, crushing stages are followed by milling stages if the materials need to be further reduced. Additionally rock breakers are typically located next to a crusher to reduce oversize material too large for a crusher. Crushers are used to reduce particle size enough so that the material can be processed into finer particles in a grinder (Clark, 1985). The types of crushers are; jaw crusher, gyratory crusher, cone crusher and impact crusher.

2.3.1 Jaw crusher

According to Arora (2007), jaw crusher is a machine for breaking rock between two steel jaws, are fixed and the other swinging. A jaw crusher uses compressive force for breaking of particles. This mechanical pressure is achieved by the two jaws of the crusher of which one is fixed while the other reciprocates. A jaw crusher consists of a set of vertical jaws, one jaw is kept stationary and is called a fixed jaw while the other jaw, called a swing jaw, moves back and forth relative to it, by a pitman mechanism, acting like a nutcracker. The volume or cavity between the two jaws is called the crushing chamber. The movement of the swing jaw can be quite small, since complete crushing is not performed in one stroke. The inertia required to crush the material is provided by a weighted flywheel that moves a shaft creating an eccentric motion that causes the closing of the gap. Jaw crushers are heavy duty machines and hence need to be robustly constructed. The outer frame is generally made of cast iron or steel. The jaws themselves are usually constructed from cast steel. They are fitted with replaceable

liners which are made of manganese steel. Jaw crushers are usually constructed in sections to ease the process transportation if they are to be taken underground for carrying out the operations (Ibrahim, 2012).

2.3.2 Gyratory crusher

A gyratory crusher consists of a concave surface and a conical head; both surfaces are typically lined with manganese steel surfaces. The inner cone has a slight circular movement, but does not rotate; the movement is generated by an eccentric arrangement (Gulma, 2012). According to Arora (2007), gyratory crusher is a primary breaking machine in the form of two cones, an outer fixed cone and a solid inner erect cone mounted on an eccentric bearing.

2.3.3 Cone crusher

A cone crusher breaks rock by squeezing the rock between an eccentrically gyrating spindle, which is covered by a wear resistant mantle, and the enclosing concave hopper, covered by a manganese concave or a bowl liner (Gulma, 2012).

2.3.4 Impact crusher

According to Arora (2007), impact crusher is a machine for crushing large chunks of solid materials by sharp blows imposed by rotating hammers or steel places or bars. According to Ibrahim (2012), impact crushers involve the use of impact rather than pressure to crush material. The material is contained within a cage, with openings on the bottom, end, or side of the desired size to allow pulverized material to escape. There are two types of impact crushers: horizontal shaft impactor and vertical shaft impactor. The horizontal shaft impactor crushers break rock by impacting the rock with hammers that are fixed upon the outer edge of a spinning rotor. HSI machines are sold in Stationary, trailer mounted and crawler mounted configurations. HSI's are used in recycling, hard

rock and soft materials. In earlier years the practical use of HSI crushers is limited to soft materials and non-abrasive materials, such as limestone, phosphate, gypsum (Gulma, 2012).

According to Arora (2007), hammer mill is a type of impact mill or crusher by which materials are reduced in size by hammers revolving rapidly in a vertical plane within a steel casing. Hammer mill is also known as beater mill, a grinding machine which pulverizes feed and other products by several rows of thin hammers revolving at high speed. Hammer mills are used to shatter or pulverize materials. The most common configuration is a chamber containing a rotary drum with swiveling hammers of hardened bar or chain. The chamber is typically gravity-fed, and output screens control the size of particle produced. Hammer material, configuration and distribution, and rotation speed are a few of the factors that determine the type of material that can be processed.

The vertical shaft impactor crushers utilize velocity rather than surface force as the predominant force to break rock. In its natural state, rock has a jagged and uneven surface. Applying surface force (pressure) results in unpredictable and typically non-cubical shape resulting particles. Utilizing velocity rather than surface force allows the breaking force to be applied evenly both across the surface of the rock as well as through the mass of the rock. Rock, regardless of size, has natural fissures (faults) throughout its structure. As rock is 'thrown' by a VSI Rotor against a solid anvil, it fractures and breaks along these fissures. The product resulting from VSI Crushing is generally of a consistent cubical shape such as that required by modern applications. Using this method also allows materials with much higher abrasiveness to be crushed than is capable with an HSI and most other crushing methods.VSI crushers generally

utilize a high speed spinning rotor at the center of the crushing chamber and an outer impact surface of either abrasive resistant metal anvils or crushed rock (Gulma, 2012).

2.4 Glass Crusher

The processes used in glass crushing for recycling involves the same methods used by the aggregate industry for crushing rock into sand. The glass crushing begins when a user drop a glass jar, bottles and other waste glass into the feeder, the waste glass travel down into the glass crusher itself, which contains an integral conveyor belt to transport the glass. Steel hammers pulverize the glass into smaller pieces and the glass exists into storage containers or bin at the opposite end. The pulverizing action will not only break the glass, but tumbles it around within the machine to eliminate sharp edges and give the cullet a smooth texture. The crushing machine will help reclaim valuable space, minimize noise pollution and reduce occupational health and safety risks (Mark, 2001).

2.5 Steel

According to Khurmi (2005), Steel is an alloy of iron and carbon, with carbon content up to maximum of 1.5%. The carbon occurs in the form of iron carbide, because of its ability to increase the hardness and strength of the steel. Steel is used widely in the construction of roads, railways, other infrastructure, appliances, and buildings. Steel is used in a variety of other construction materials such as bolts, nails and screws (Rajput, 2008).

2.5.1 Properties of steel

The properties of steel are: ductility, tensile strength, durability, conductivity, luster and rust resistance. Ductility material can be reduced in cross-section without breaking. In wire-drawing, for instance, the materials are reduced in diameter by pulling it through a circular die. The material must be capable of flowing through the reduced diameter of

the die and at the same time withstand the pulling force (Black, 1997). Tensile stress of steel is comparatively high, making it resistant to failure or deformation. Durability is the hardness of steel is high hence resisting strain once formed. It is long lasting and greatly resistant to external wear and tear. Conductivity in steel is a good conductor of both heat and electricity. This property makes it useful in the making of cooking wares as well as electric wirings. Lustre is the property that gives steel, especially stainless an attractive outer appearance; it is silvery in colour with shiny outer surfaces. Rust resistance simply means addition of some elements makes some kinds of steel resistant to rust. Stainless steel for instance, contains nickel, molybdenum and chromium which improve its ability to resist rusting (Ibrahim, 2012).

2.6 Sieve

Sieve is a device for separating wanted elements from unwanted material or for characterizing the particle size distribution of a sample, typically by using a woven screen such as a mesh or net. Hand sieving is a simple technique for separating particles of different sizes. Coarse particles are separated or broken up by grinding against one-another and screen openings. Depending upon the types of particles to be separated, sieves with different types of holes are used. Sieves are also used to separate stones from sand (Ibrahim, 2012). According to Arora (2007), sieving is the operation of shaking loose materials in a sieve so that the smaller particles can pass through the mesh. Sieve diameter is the size of a sieve opening through which some given particles pass through.

2.6.1 Sieve analysis

Sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution (also called gradation) of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic granular materials including sands, crushed rock, clays, granite, feldspars and coal, to get the size of grains depending on the exact method of application. Being such a simple technique of particle sizing, it is probably the most common (Abubakar, 2012). According to Arora (2007), sieve analysis is the size distribution of solid particles on a series of standard size, expressed as a weight percent. Mesh material is often used in determining the particle size distribution of a granular material.

2.7 Magnet

Magnet is a material or object that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet: a force that pulls on other ferromagnetic materials, such as iron, and attracts or repels other magnets. The term magnet is typically reserved for objects that produce their own persistent magnetic field even in the absence of an applied magnetic field. Most materials, however, produce a magnetic field in response to an applied magnetic field; a phenomenon known as magnetism (Ibrahim, 2012). The space around the poles of a magnet is called the magnetic field and is represented by magnetic lines of force. The space around a needle or a permanent magnet is examples of magnetic fields. Magnetic force is the force exerted on one magnet by another on, either of attraction or of repulsion (Gupta, 2012).

Magnetic materials can be used to constrain and direct magnetic fields in well-defined paths. In electric machinery, magnetic materials are used to shape the fields to obtain desired torque-production and electrical terminal characteristics. Ferro-magnetic materials typically composed of iron and alloys of iron with cobalt, tungsten, nickel, aluminium and other metals, are by far the most common magnetic materials. Although these materials are characterized by wide range of properties, the basic phenomena responsible for their properties are common to them all (Fitzgerald *et al,* 2003). According to Gupta (2009), ferro-magnetic materials are of two types; those easily magnetized called the soft magnetic material and those retaining their magnetism with great tenacity designated as hard magnetic materials. The soft ferro-magnetic materials have high relative permeability, easily magnetized and demagnetized, low coercive force and have extremely small hysteresis. Soft ferro-magnetic materials are iron and its alloys with nickel, cobalt, tungsten and aluminium. Hard ferro-magnetic materials have relatively low permeability, and very high coercive force. These are difficult to magnetize and demagnetize. Typically hard ferro-magnetic materials include cobalt, steel, and various ferro-magnetic alloys of nickel, aluminium and cobalt.

2.8 Concept of Fabrication

The concepts of fabrication are procedure in fabrication which are; metal fabrication, engineering drawing, sourcing for raw materials, forming, machining and welding.

2.8.1 Metal fabrication

Metal fabrication is the building of metal structures by cutting, bending and assembling process. Cutting is done by sawing, shearing or chiseling. Bending is done by hammering (manual or powered) or via press brake and similar tools. Modern metal fabricators utilize press brake to either coin or air-bend metal sheet into form.

Assembling (joining of the pieces) is done by welding, binding with adhesives, riveting, threaded fastens, or even yet none bending in form of a crimped seam (Gudmundsson, 2007). According to Callister (1994), metal fabrication techniques are the methods by which metals and alloys are formed or manufactured into useful products. They are alloys with the desired characteristics. The classifications of fabrication techniques include various metal forming methods which are casting, powder metallurgy, welding and machining; often two or more of them must be used before a piece is finished. The fabrication of machine is done, usually on the engineering drawings specification. The raw materials used by metal fabricators are plate metal, formed metal, expanded metal, welding wire or welding rod casting (Rajput, 2008).

2.8.2 Engineering drawing

An engineering drawing is a type of drawing that is technical in nature, used to fully and clearly define requirements for engineered items, and is usually corrected in accordance with standardized conventions for layout, nomenclature, interpretation, appearance (such as typefaces and line styles) size, and so forth (Morakinyo, 2012).

2.9.3 Source for raw material

When the engineering drawing of the dual-purpose waste glass processing machine was drawn, the materials for fabrication can be purchased using the standard raw materials such as welding wire, square stock, metal plate and so forth.

2.8.4 Machining

The tools for machining include; metal lathes, mills, magnetic based drills along with other portable metal making tool. The three principle machining processes are trimming, drilling and milling. Other operations fall into miscellaneous such as shaping, planning, boring, sawing and so forth (Morakinyo, 2012).

2.8.5 Forming

Forming is a process of material deformation. Forming is typically applied to metals. To define the process, a raw materials piece is formed by applying force to an object. The force must be great enough to change the shape of the object from its initial shape. The process of forming can be controlled with use of tools, and machinery can also be used to regulate force magnitude and direction (Binggeli, 2003). Forming operation are in which the shape of a metal piece is changed by plastic deformation, for example forging, rolling, extrusion and drawing are common forming techniques (Callister, 1994).

2.8.6 Welding

According to Khurmi (2000), welding is a process of joining together two or more metal parts. It is done by heating the surfaces, to be connected to a high temperature and then adding additional molten metal, which fuses it and combines the two surfaces. The molten or fused metal is deposited between the parent metal parts, which are also fused to a specified depth. When the deposited fused metal gets cooled, the parent metal parts are joined by this new metal. A number of methods are used for the process of fusion, but oxyacetylene gas welding and electric arc welding are most commonly used. The welded joints have proved to be so reliable, that they are replacing the riveted joints in structural and machine joints. Though there are many types of welded joints, yet the following three types are important from the subject point of view: butt weld joint, fillet weld joint and plug or slot weld joint. The butt weld joint is a joint, in which the edges of the two members butt (i.e. touch) against each other, the two members are jointed together by welding. The fillet weld joint is a joint, in which the two members either overlap or meet each other at about 90^{o} and the two members are joined together by welding. It is used for overlap joints and corner joints. While, the plug or slot weld joint

is done by creating a circular hole, and a fillet weld is provided along the circumference of the hole.

Welding is the main focus of steel fabrication; the formed and machined parts are assembled and welded into place then re-checked for accuracy. The welder will always weld according to the engineering drawing (Boothroyd, 2005). Welding metallurgy deals essentially with the interaction of different metals as well as interactions of the metals with gases and other variety of chemicals. Welding pre-requisites are mainly the supply of energy to induce union, removal of surface contaminant from the surfaces to be joined, protection from atmospheric contamination and control of weld physical metallurgy (Umar, 2000).

2.9 Electric Motor

According to Young (2008), in an electric motor, a magnetic torque acts on a current-carrying conductor; an electric energy is converted to mechanical energy. The moving part of the motor is the rotor; a length of wire formed into an open-ended loop and frees to rotate about an axis. The ends of the rotor wires are attached to circular conducting segments that form a commutator. Each of the two commutator segments makes contact with one of the terminals, or brushes, of an external circuit that includes a source of electromotive force, because a motor convert electric energy to mechanical energy or work, it requires electric energy input. Duncan (2012), opined that a direct current motor consists of a coil on an axle, carrying a direct current in a magnetic field. The coil experiences a couple as in a moving-coil galvanometer, which makes it to rotate. The direct current motor may be used on alternating current if the rotor and field coils are in series. The current then reverses simultaneously in each and rotation in the same direction continues.

2.10 Cullet

Cullets are scraps of broken or waste glass gathered for re-melting, especially with new material. Its physical and mechanical properties behave in a very similar way to sand, being a hard granular material with a similar density. In container glass manufacturing, quantities of minerals such as silica, soda ash, limestone and cullet are what makes-up the batch. Silica is the principal raw material; it is the network former. Soda ash acts as a modifier and lowers the melting temperature. Limestone adds to the chemical durability of the glass whereas cullet facilitates melting and lowers down the melting temperature. The mixture is heated to temperature of between 1300^{o}C to 1650^{o}C. During this time, the molten material is fined (allowed to release all gas bubbles within its volume) and homogenized via mechanical stirring and convection mixing. It is then brought to a suitable temperature for forming and released from the furnace (Gate, 2006).

2.11 Production and Manufacturing Processes of Machine

All machines are built up of parts made of different materials and by various manufacturing processes. Some parts are cast from metals; some are forged, while others are produced by machining on different types of machine tools. The process of forging and casting involves machining before they acquire their proper shape, exact dimensions and the surface finishing. Forging processes are extremely important in the machine-building industry. There is no machine whether simple or complicated, that is not built without the use of forging. It is calculated that, in the Soviet Union, from is to 20 percent of all the metals produced are subjected to forging and stamping. Hammer forging and stamping is particularly widespread in the tractor, locomotive, building, automobile, ship-building and other industries (Gonah, 2001). The following are the

consideration in designing and manufacturing a machine; bearing, shaft, belt, pulley, hopper and machine frame.

2.11.1 Bearing

Bearing are mechanical devices for decreasing frictions in a machine in which a moving part bears or rolls while exerting force on another part. Bearing can also be a machine that permits the connected members to rotate or move in a straight line relative to one another. Often, one of the members is fixed and the bearing acts as a support for the moving member. The common bearings are found at the rigid support of rotating shaft, where friction is the greatest. The support is either transverse (radial) or thrust (axial) loads. The connecting surfaces in a bearing may be separated completely or partially by a film of liquid (usually oil) or gas (Morakinyo, 2012).

2.11.2 Shaft

According to Shigley (2004), shaft is a rotating member, usually of circular cross section, used to transmit power or motion. It provides the axis of rotation, or oscillation, of elements such as gears, pulleys, flywheels, cranks, sprockets, and the like and controls the geometry of their motion. A shaft design really begins after much preliminary work. The design of the machine itself will dictate that certain gears, pulleys, bearing and other elements will have at least been partially analyzed and their size and spacing tentatively determined. A shaft does not only support a revolving part, but also transmits torque. As a result the shaft is subjected to bending as well as torsion stresses. A shaft may fail due to fatigue, which arises due to; the presence of cyclic over loads, stress concentration, wrong adjustment of bearing, insufficient clearances.

The desirable properties of the materials for shaft are; sufficient high strength, a low sensitivity to stress concentration and ability to withstand heat and case hardening

treatment to reduce the effects of stress concentration and increase the wear resistance of the journals. The usual methods of shaft manufacturing are; cold rolling, cold drawing and turning or grinding from rough bars (Agarwal, 2007).

2.11.3 Belt

Belt is used for power transmission from one shaft to another shaft. There are four types of belts; flat belt, V-belt, ribbled belt and toothed belt. The features that were considered in the selection of belt are power to be transmitted, center distance, speed of driver and driven shafts, space available, reduction ration positive drive requirements and service conditions (Morakinyo, 2012).

2.11.4 Pulley

Nagpal (2002) and Morakinyo (2012), opined that pulleys are made of cast iron, pressed steel, welded steel and wood in standard sizes. Cast iron steel pulleys are the most used in transmitting power. According to Morakinyo (2012), pulley is a wheel that carries flexible rope, chord, cable, chain or belt on its rim. They are used single or in combination to transmit energy and motion. Belt and pulley arrangement are used basically to transmit power from shaft to driven shaft.

2.11.5 Hopper

According to Gonah (2001), in the design of a hopper, the weigh is also considered using some design parameters in design are utilized throughout, the needed product would be achieved without much difficulty. Hopper was made of mild steel. It was processed by cutting, welding and polishing with the appropriate instruments like industrial cutting machine, welding machine.

2.11.6 Machine frame

Machine frame is a supporting structure i.e. an underlying structure that consists of solid parts such as struts (bar) which spaces between them and carries the weight of what is built around or on top of it (Morakinyo, 2012).

2.12 General Machine Design Safety Conditions

Some health, safety and welfare regulations at the workshop, while operating the machine are;

The fuse should be connected to the wire attached to the electric motor for easy connection by any user; the case housing where the crushing was carried out is for the purpose of reducing dust generated during the processing of waste glass. Safety spectacle and nose mask should be worn to serve as a guild against the hazard of dust; the flat slit should be used to cover the hopper to avoid splashing of waste glass during the machine operation. Top cover should be used to gain access into the crushing chamber for any repair or to lubricate any part inside the case housing. Safety boots or shoes with strong sole should be worn to avoid injuries from the waste glass, hand gloves should be worn to provide protection against any range of hazards including cuts from waste glass.

2.13 Design Theory

2.13.1 Belt drive

1. Velocity ratio of a belt:

This is the ratio between the velocity of the driver and the driven. It is given by (Khurmi, 2005) as:

$$\frac{N_2}{N_1} = \frac{d_1}{d_2}; also\ v = \frac{\pi dN}{60} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

Also, if there is no slip of the belt, the length of belt passing over each pulley will be equal at every instance, $\pi d_1 N_1 = \pi d_2 N_2$ ……2.2

Where;

v = speed of pulley in m/s

d_1 = diameter of driver pulley in meters

d_2 = diameter of driven pulley in meters

N_1 = speed of driver pulley in r.p.m

N_2 = speed of driven pulley in r.p.m

2. Power transmitted by a belt:

When a belt drive system in set into motion, the driver pulley pulls the belt one side one delivers at the other side, from this analogy, both sides of the belt will be in tension. Hence the power transmitted by the belt drive is given by (Khurmi, 2005) as:

$$P = (T_1 - T_2)v \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.3$$

$$T_{max} = T_1 = \sigma bt \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.4$$

Where:

T_1 = tension (N) in the tight side (always the max. tension in the belt)

T_2 = tension (N) in the slack side

v = speed of belt in m/s

P = power transmitted in Watts

σ = maximum stress in the belt (in N/mm^2)

b = breadth of the belt (in mm)

t = thickness of the belt (in mm)

Also, the relationship between the both tensions can be expressed as

$$\frac{T_1}{T_2} = e^{\mu\theta} \ OR \ 2.3 log \frac{T_1}{T_2} = \mu\theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.5$$

Where

μ = coefficient of friction (approximately always 0.3)

θ = angle of contact in radians

3. Determination of angle of contact:

It is actually derived by using

$$\theta = (180 - 2\alpha)\frac{180}{\pi} rad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .2.6$$

$$\sin\alpha = \frac{r_1 - r_2}{x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .2.7$$

Where:

θ = angle of contact in radians

α = angle of lap in degrees

r_1 = radius of driver pulley in meters

r_2 = radius of driven pulley in meters

x = distance between centres of the pulleys

2.14.2 Spring

1. Spring index

This is defined as the ratio of the mean diameter of the coil to the diameter of the wire, mathematically; it's given by (Khurmi, 2005) as:

$$C = \frac{D}{d} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . . 2.8$$

Where

C = spring index

D = mean diameter of the coil (in mm)

d = diameter of the wire (in mm)

2. Spring rate

This is defined as the amount of load required for a unit deflection of the spring. Mathematically, it's given by (Khurmi, 2005) as:

$$k = \frac{W}{\delta} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . . 2.9$$

Where:

k = spring rate (in N/mm)

W = axial load on spring (in N)

δ = deflection of spring (in mm)

3. Stresses developed in the spring

The maximum stress induced in the spring, neglecting the effect of wire curvature (for a small spring) is given by (Khurmi, 2005) as:

$$\tau_{max} = \tau_1 + \tau_2 = \frac{8WD}{\pi d^3} + \frac{4W}{\pi d^2} = \frac{8WD}{\pi d^3}\left(1 + \frac{d}{2D}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.10$$

Where:

τ_{max} = maximum shear stress (in N/mm^2)

τ_1 = torsional shear stress (in N/mm^2)

τ_2 = direct shear stress (in N/mm^2)

$K_s = \left(1 + \frac{d}{2D}\right) = \left(1 + \frac{1}{2C}\right)$ = shear stress factor

2.13.3 Mathematical modelling of the vibratory sieve housing

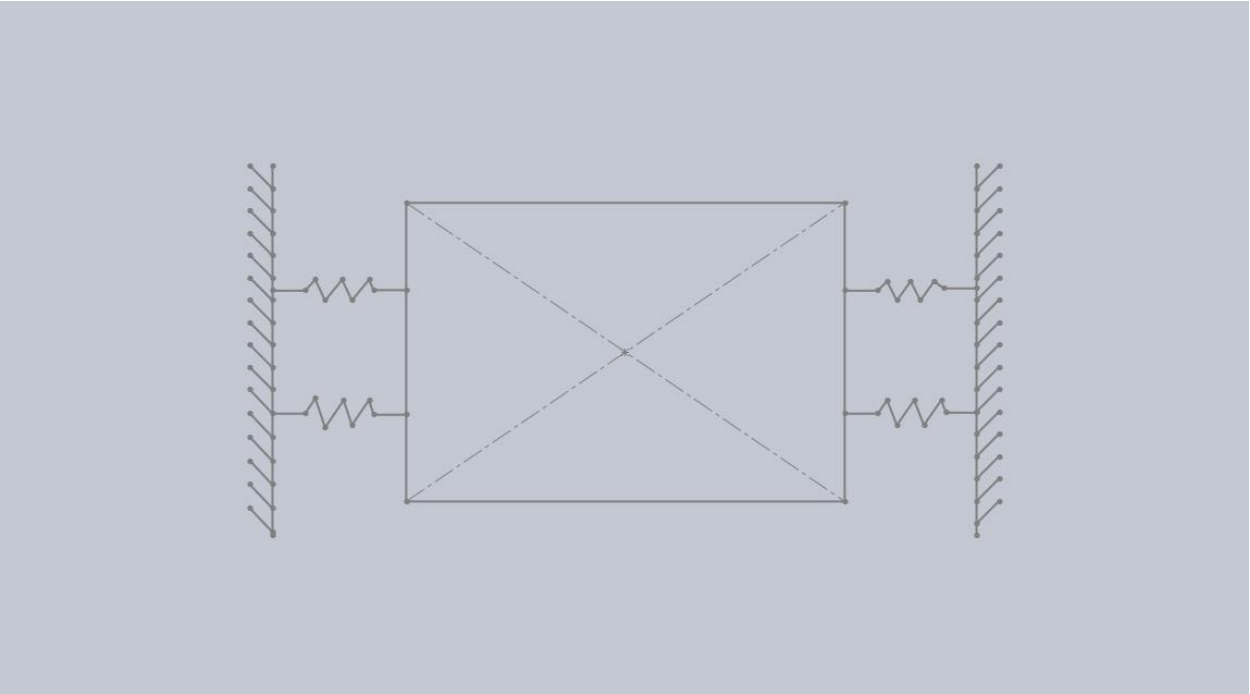


Figure 2.1 Mathematical Model of the Sieve Housing. Source: Khurmi (2005).

From the configuration of the vibratory sieving housing, it could be deduced mathematically that:

$$2kx + ma + 2kx = F \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.11$$

Where:

k = stiffness of each spring (in N/m)

x = maximum allowable horizontal movement of the sieve housing (in m)

m = mass of sieve housing (in kg)

a = linear horizontal acceleration of the sieve housing (in m/s^2)

F = external force generated into to the sieve housing to make it move (in N)

2.13.4 Power needed to drive the threshing drum (P)

It is expressed by Khurmi (2005) as:

$$P = \frac{2\pi NT}{60} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.12$$

Where

$$N = speed\ of\ the\ auger\ shaft\ (rpm)$$

$$T_s = torque\ on\ the\ auger\ shaft\ (Nm)$$

2.13.5 Equivalent twisting moment (T_e)

It is expressed mathematically by Khurmi (2005) as:

$$M_e = \sqrt{(M^2 + T^2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.13$$

Where

$$M = maximmum\ bending\ moment\ on\ the\ auger\ (Nm)$$

$$M = maximmum\ bending\ moment\ on\ the\ auger\ (Nm)$$

2.13.6 Equivalent bending moment (M_e)

It is expressed mathematically by Khurmi (2005) as:

$$M_e = \frac{1}{2}\left(M + \sqrt{(M^2 + T^2)}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.14$$

CHAPTER THREE

MATERIALS AND METHOD

For this research, experimental method was adopted. The research covered the design using software known as solid works, fabrication using mild steel collected from old Panteka, Kaduna and the test running of the dual-purpose processing machine with the waste glass that was sourced from different locations in Ahmadu Bello University, Zaria, Samaru Main Campus. The methodology encompasses materials and equipment, design consideration, designing of components in the machine, sourcing for the materials used for the fabrication, fabrication processes of the components of the dual-purpose waste glass processing machine; hopper; separator plate; shaft; eccentric shaft; hammer mill; revolving beaters; spacers; perforated screen; sieves; top cover; front door; collector; housing case; electric motor bed; machine frame, assembly of the dual-purpose waste glass processing machine, painting of the dual-purpose waste glass processing machine, cost estimate, sourcing and beneficiation process of the waste glass.

3.1 Materials and Equipment

The engineering materials are mainly classified as: metal and their alloys, such as iron, steel, aluminium and so forth, while non-metals such as glass, rubber, plastics and so forth. The metals may be further classified as: ferrous metals and non-metals. The ferrous metals are those which have the iron as their main constituent, such as cast iron,

wrought iron and steel. The non-metals are those which have a metal other than iron as their main constituent, such as aluminium, brass, tin, zinc and so forth. The mechanical properties of the materials are strength, stiffness and corrosion resistance (Khurmi, 2005).

The materials used for fabrication were readily available and the cost was affordable. The magnets attached behind the hopper. In fabrication of the major components of the dual-purpose waste glass processing machine, mild steel was used because, it is relatively cheap and easily machined. It was used for components like the shaft, electric motor bed, spacers, perforated screen, sieves, hammers, separator plates, case housing, sieve stray, collector, front door, top cover, pin and machine frame cover. Other materials used were pulleys of different sizes, electrodes, spring, tyres, 2 inch angular bar, 3 quarter pipe, filling wire, hinges, concrete nail, waste glasses; green, amber and flint.

The equipment that were used for this study are hand and industrial drilling machine; for drilling holes on some of the machine component part, measuring tape; for taking measurement of length, breadth and width of machine components, hammer; for flattening the mild steel sheet, grinding machine; used cutting metals and for smoothing any part that was welded, industrial cutting machine; for cutting mild steel sheets, electric welding machine; for joining metal parts and making angular joints, square; for measuring the length of mild steel, saw; for ruling line on the mild steel; to ease cutting, turn; for holding the electrode used for welding, industrial folding machine; for bending mild steel, pliers; for holding mild steel parts during welding, dark safety goggle; for reducing the ray of light to the eyes during welding, spraying machine; for painting the machine, vice; for holding angular bar to ease cutting and machining, spanners; to tight

bolts and nuts together and scissors; for cutting mild steel. The processed waste glass was poured into the 12 containers. A piece of cloth, bowl, water, detergent, hand gloves, nose mask; for preventing inhaling of dust through the nose were also used during beneficiation. Equipment like digital weighing scale was used to weigh the waste glass after beneficiation and after processing the waste glass.

3.2 Design Considerations

The appropriate electric motor for the machine based on its capacity was 3 horse power (Hp). For the purpose of the design; 1740 rpm was chosen as the speed of the hammer mill in the dual-purpose waste glass processing machine. Sometimes the strength required of an element in a system is an important factor in the determination of the geometry and the dimension of the element. In such situation, strength is said to be an important design consideration. Design consideration refers to some characteristics that influence the design of the element or perhaps, the entire system. Usually quite a number of such characteristics must be considered in a given design situation. Some of the important ones are functionality, strength or stress, wear, safety, manufacturability, cost, size, maintenance and reliability. Some of these have to do directly with the dimensions, the materials, the processing, and the joining of the elements of the system (Shigley, 2004).

Design is an activity, concerned with devising a plan or an original solution to problem by which materials are converted into a system or machine to satisfy human need. They may be clearly defined or it may be vague and this need maybe referred into a clearly statement problem which requires a solution (Abba, 2010).

3.3 Design of Components in t he Machine

The dual-purpose waste glass processing machine has a hammer mill for the crushing, because it is not easily damaged. The isometric projection and orthographic projection showing the major components hopper, beater shaft, eccentric shaft, beater, sieve stray, door, lower crushing, upper crushing chamber, machine frame and assembly drawing of the dual-purpose waste glass processing machine were designed.

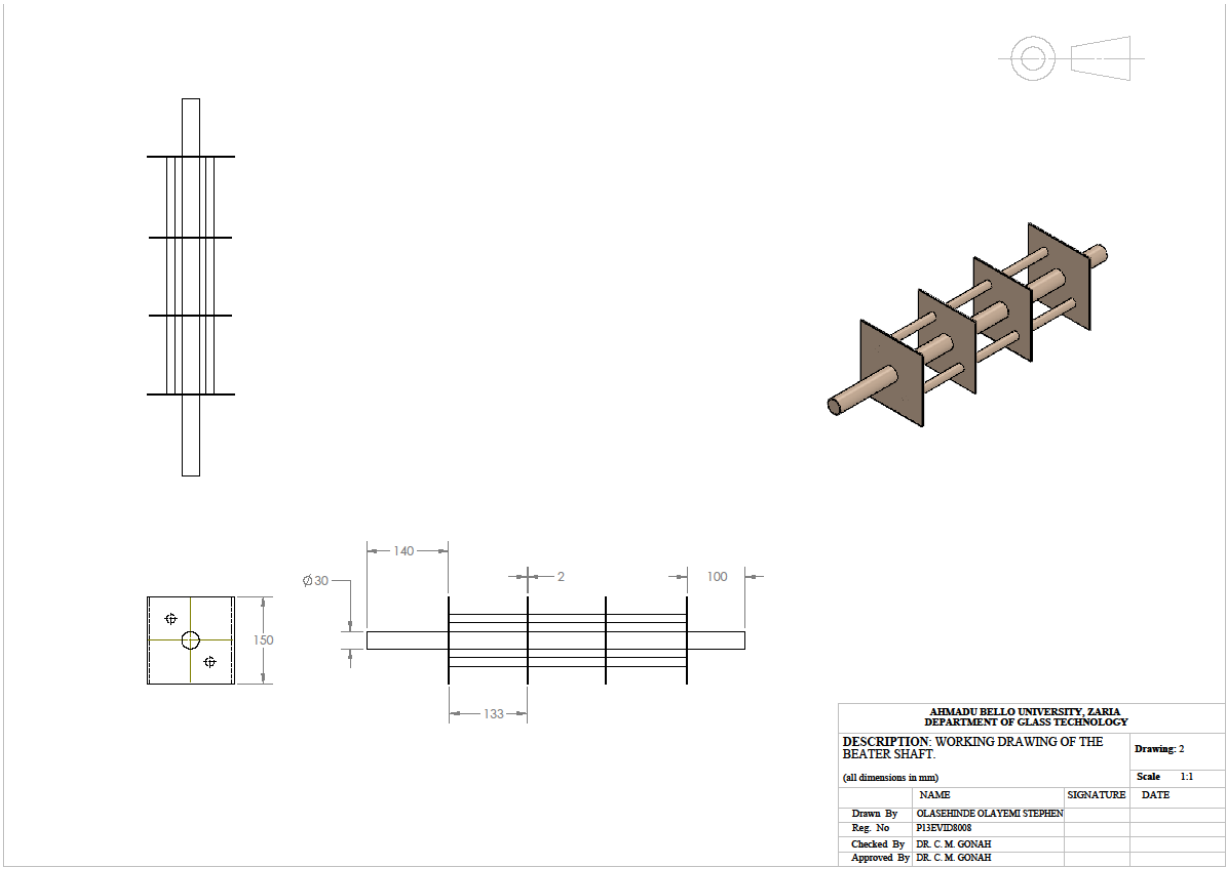


Figure 3.1 The Beater Shaft

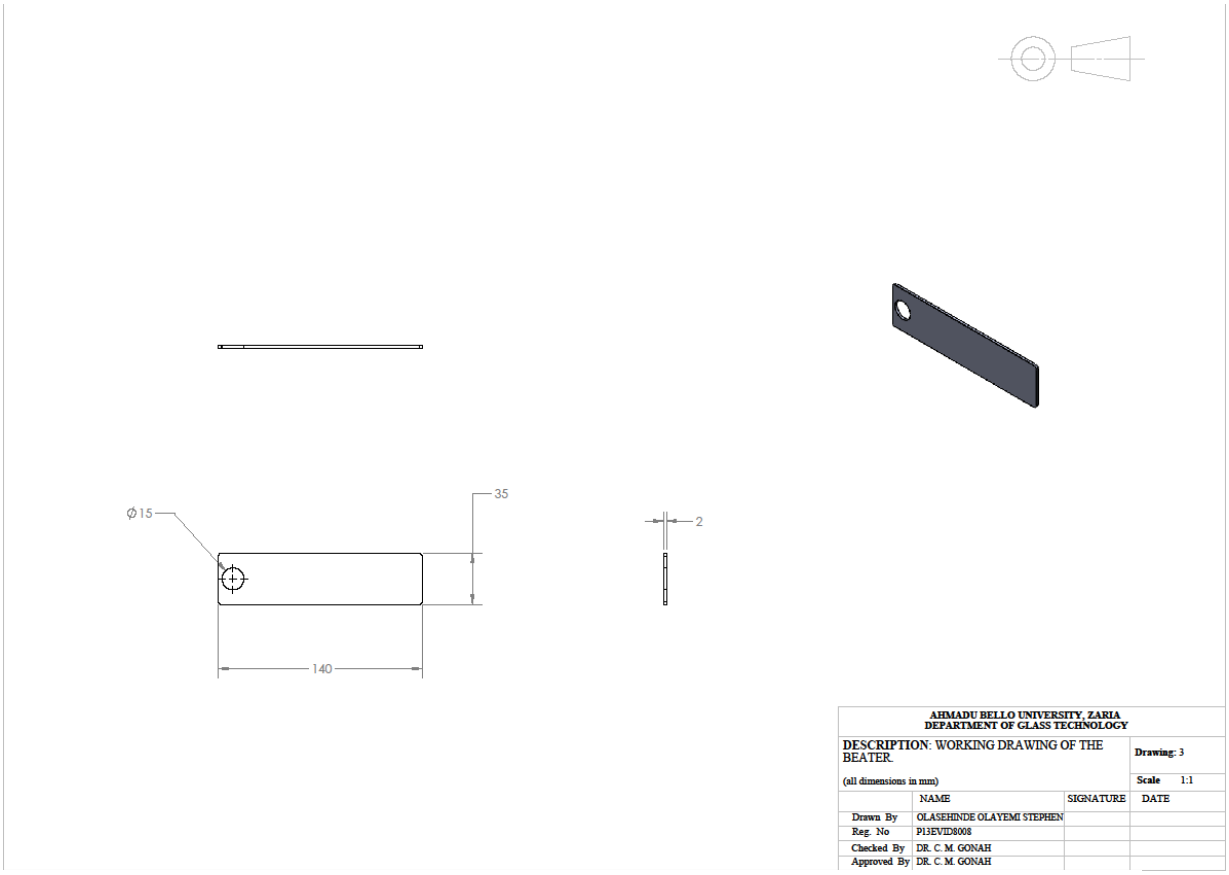


Figure 3.2 The Beater

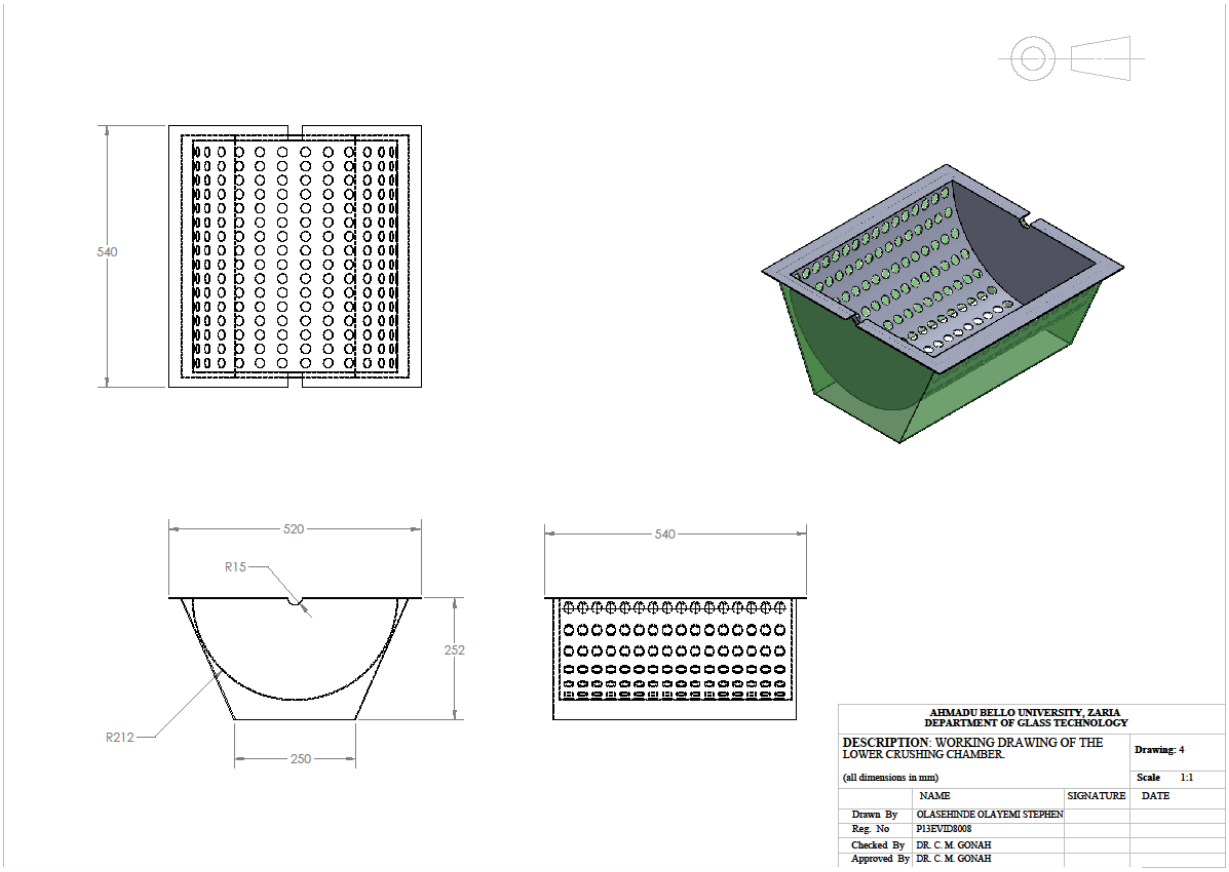


Figure 3.3 The Lower Crushing Chamber

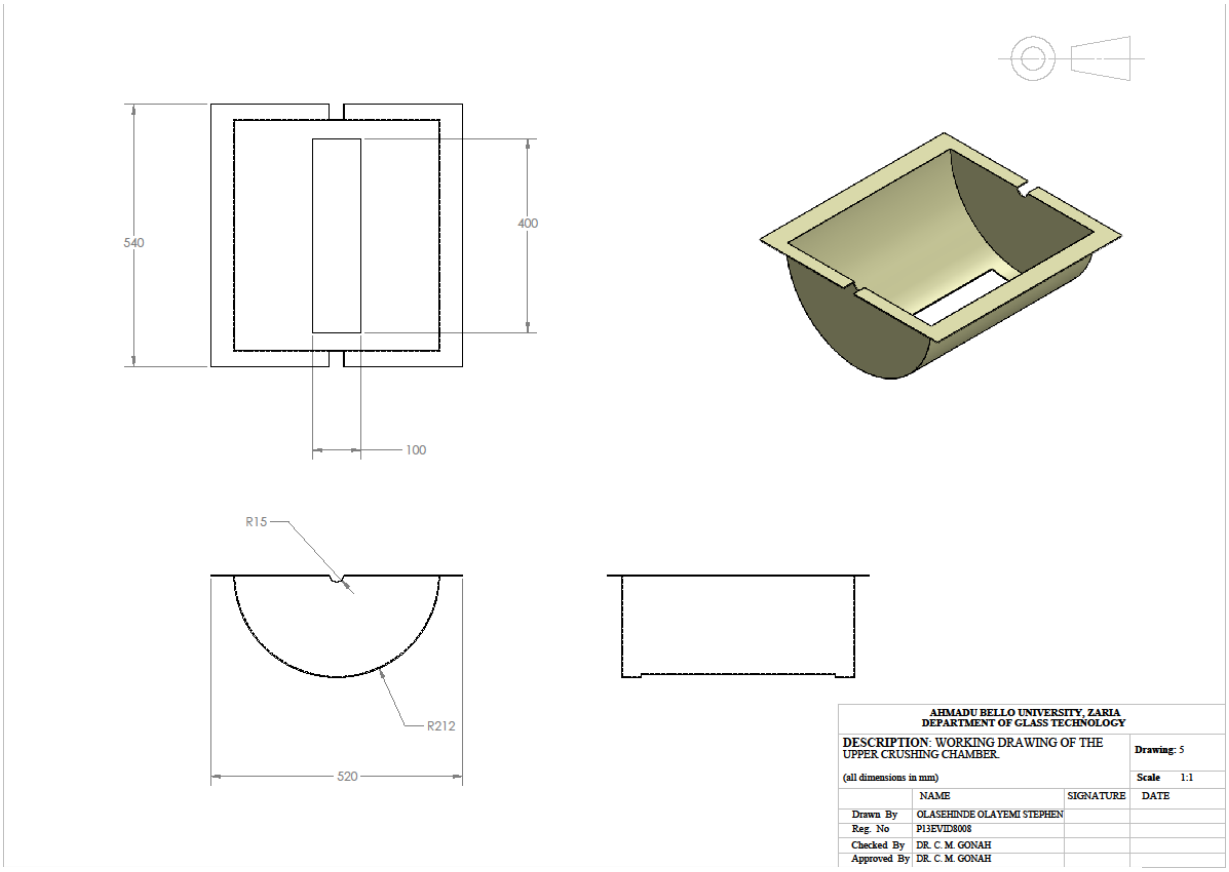


Figure 3.4 The Upper Crushing Chamber

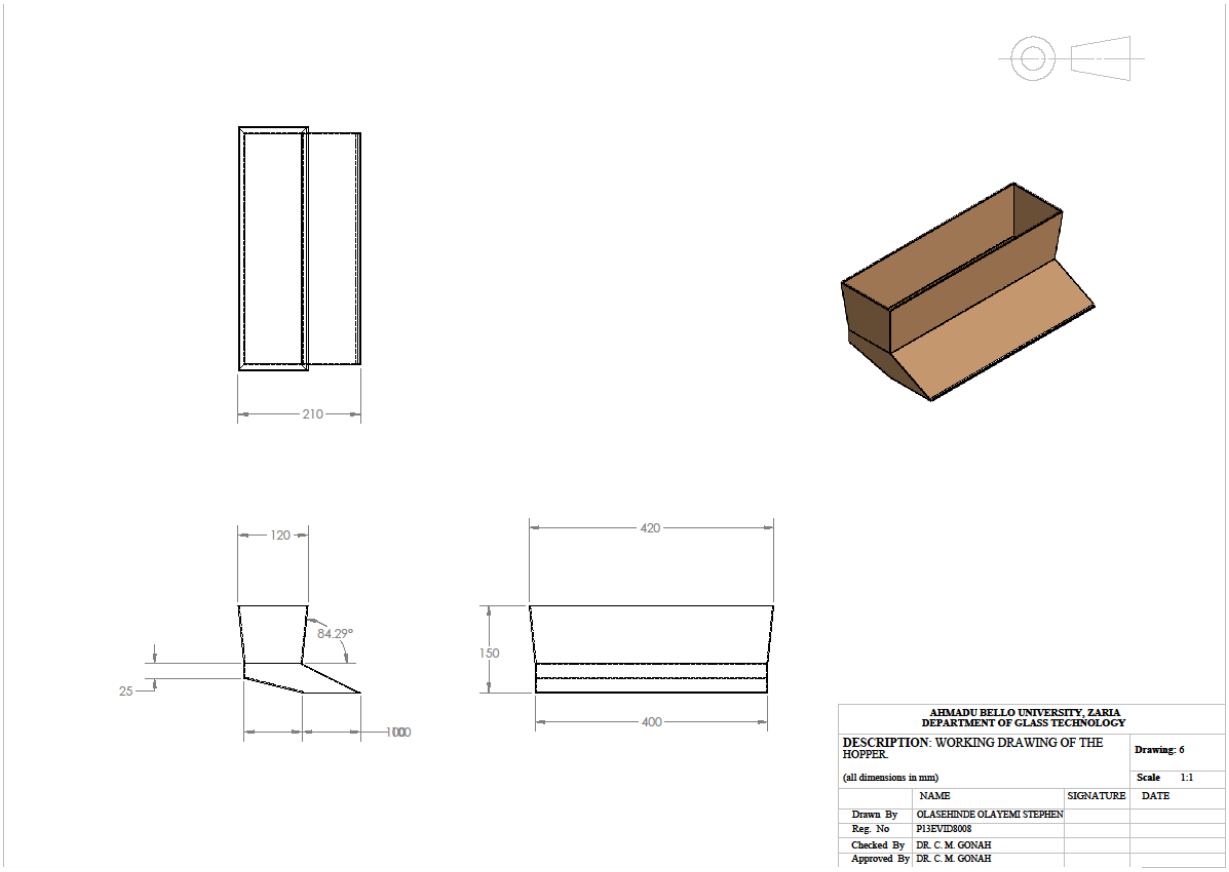


Figure 3.5 The Hopper

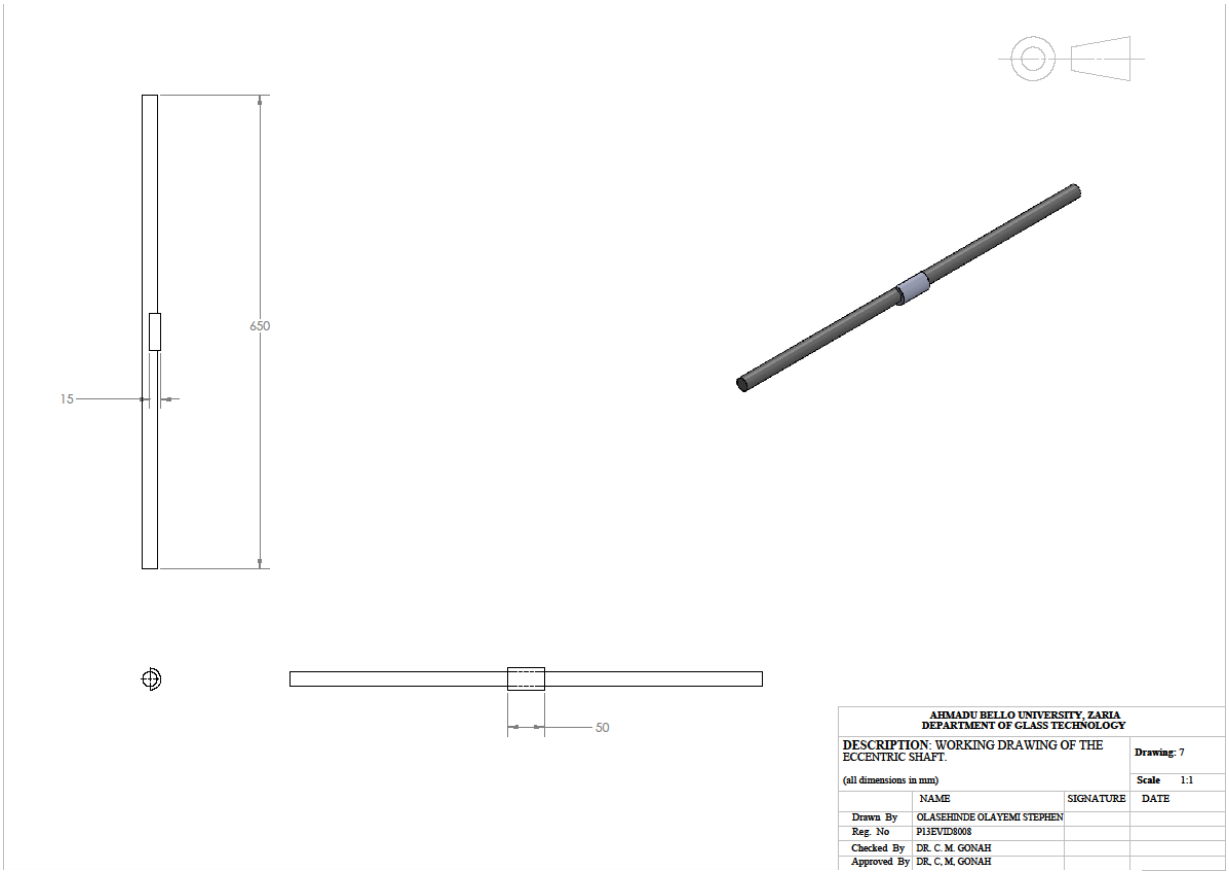


Figure 3.6 The Eccentric Shaft

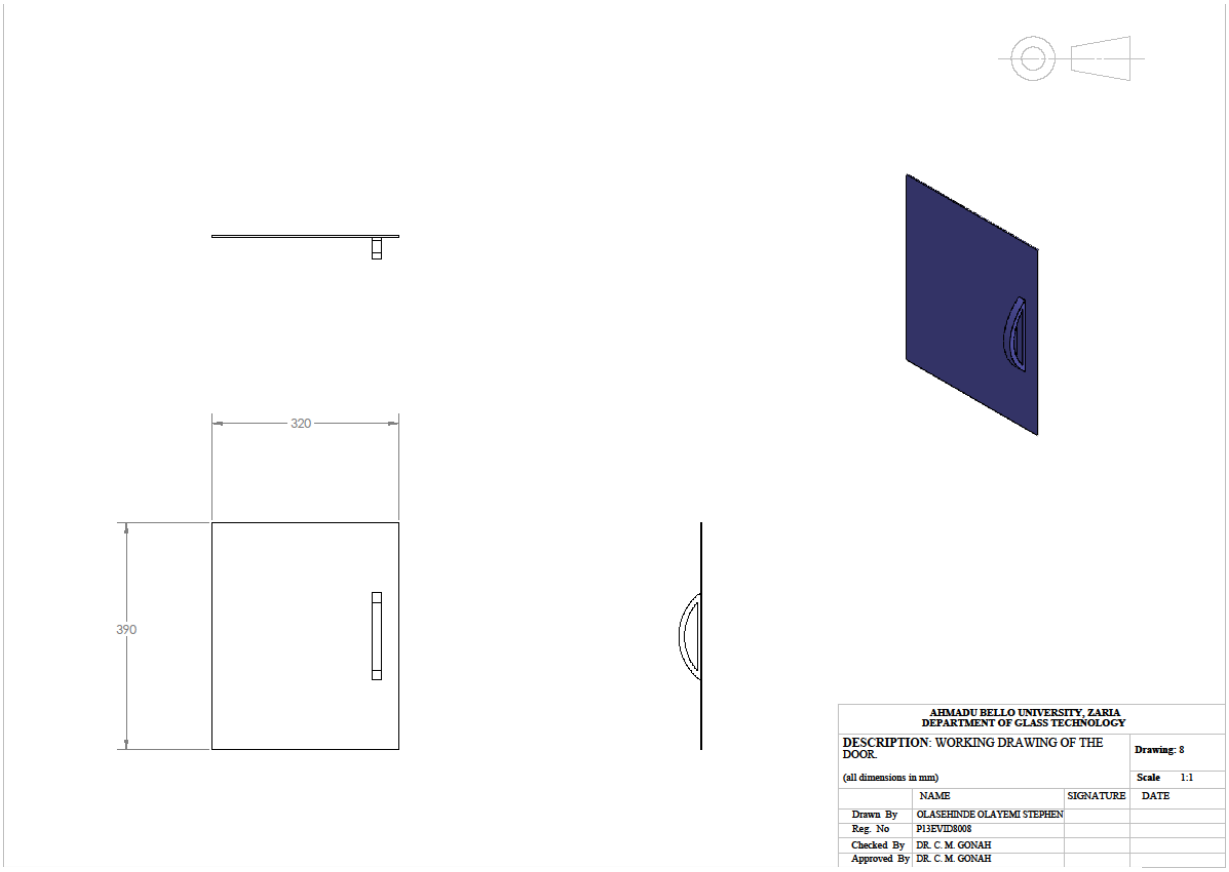


Figure 3.7 The Door

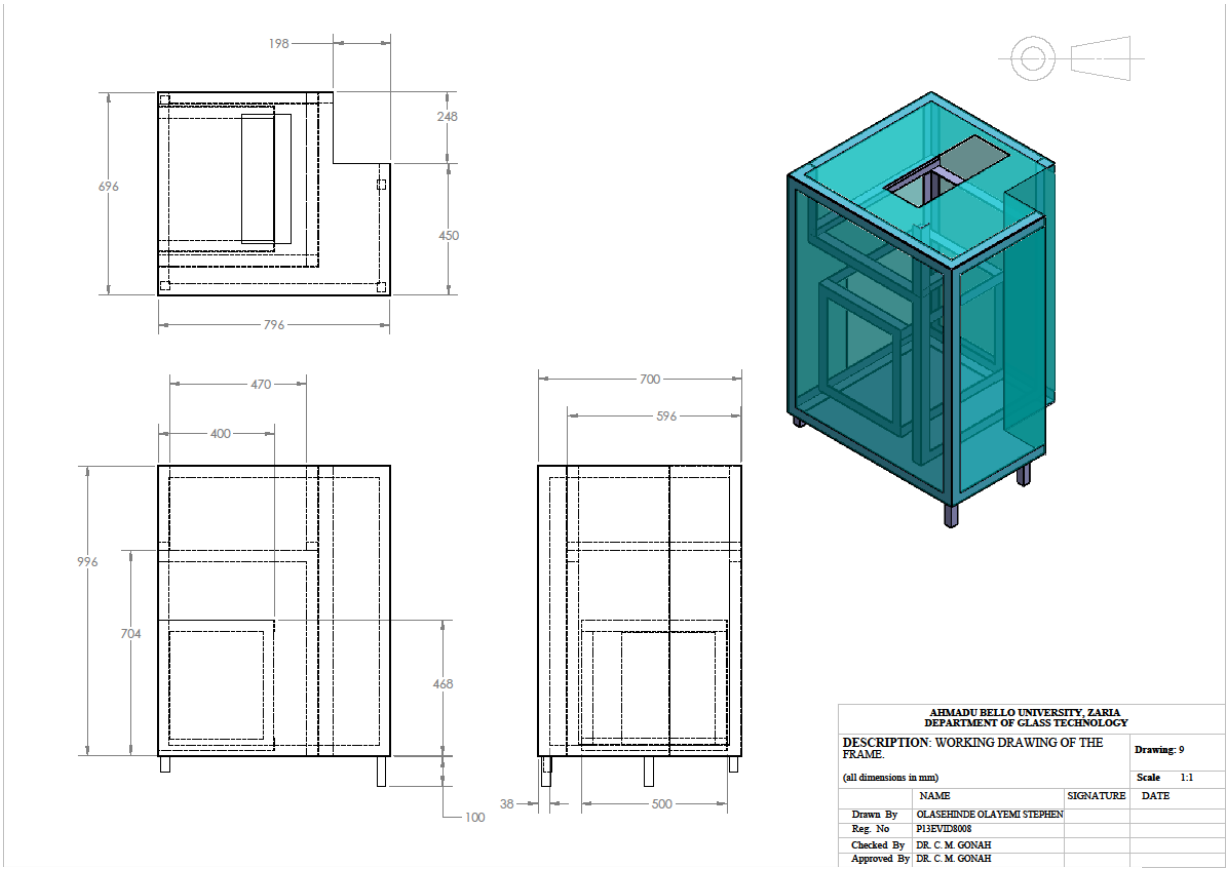
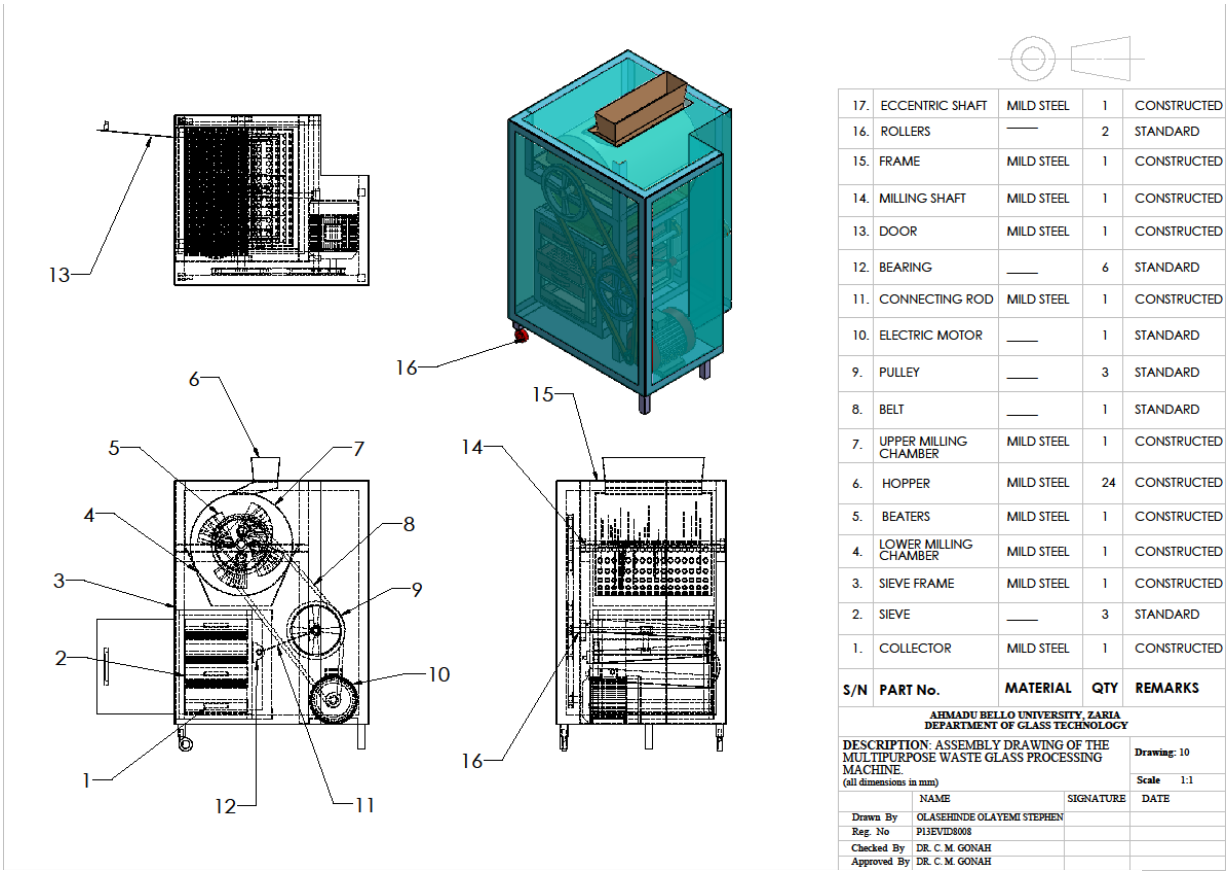


Figure 3.8 The Machine Frame



S/N	PART No.	MATERIAL	QTY	REMARKS
17.	ECCENTRIC SHAFT	MILD STEEL	1	CONSTRUCTED
16.	ROLLERS	——	2	STANDARD
15.	FRAME	MILD STEEL	1	CONSTRUCTED
14.	MILLING SHAFT	MILD STEEL	1	CONSTRUCTED
13.	DOOR	MILD STEEL	1	CONSTRUCTED
12.	BEARING	——	6	STANDARD
11.	CONNECTING ROD	MILD STEEL	1	CONSTRUCTED
10.	ELECTRIC MOTOR	——	1	STANDARD
9.	PULLEY	——	3	STANDARD
8.	BELT	——	1	STANDARD
7.	UPPER MILLING CHAMBER	MILD STEEL	1	CONSTRUCTED
6.	HOPPER	MILD STEEL	24	CONSTRUCTED
5.	BEATERS	MILD STEEL	1	CONSTRUCTED
4.	LOWER MILLING CHAMBER	MILD STEEL	1	CONSTRUCTED
3.	SIEVE FRAME	MILD STEEL	1	CONSTRUCTED
2.	SIEVE	——	3	STANDARD
1.	COLLECTOR	MILD STEEL	1	CONSTRUCTED

AHMADU BELLO UNIVERSITY, ZARIA
DEPARTMENT OF GLASS TECHNOLOGY

DESCRIPTION: ASSEMBLY DRAWING OF THE MULTIPURPOSE WASTE GLASS PROCESSING MACHINE.
(all dimensions in mm)

Drawing: 10
Scale 1:1

	NAME	SIGNATURE	DATE
Drawn By	OLASEHINDE OLAYEMI STEPHEN		
Reg. No	P13EVID8008		
Checked By	DR. C. M. GONAH		
Approved By	DR. C. M. GONAH		

Figure 3.9 The Assembly Drawing of the Dual-purpose Waste Glass Processing Machine

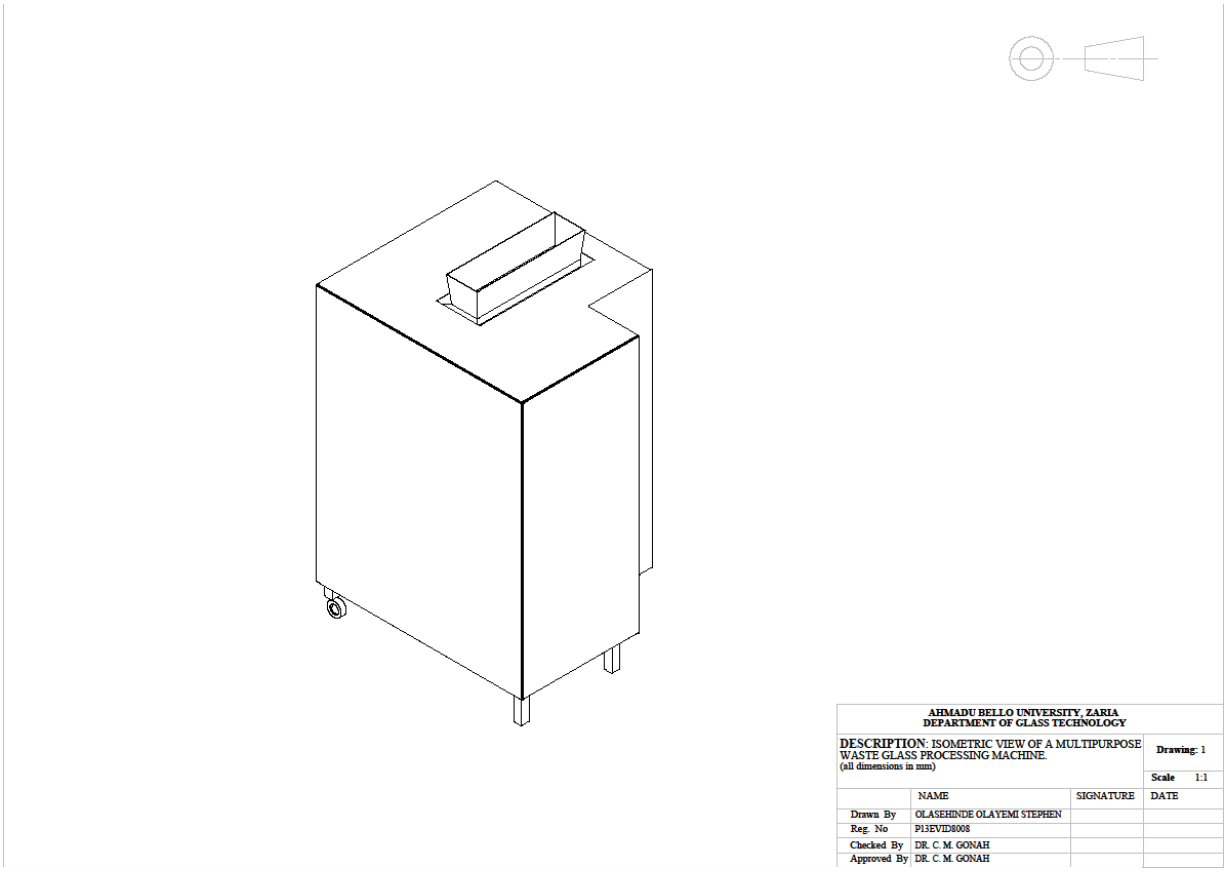


Figure 3.10 The Isometric View of the Dual-Purpose Waste Glass Processing Machine

3.4 Materials used for the Fabrication

The materials that were used for the fabrication are mild steel, 2 inch angular bar, 3 quarter pipe, hinges, filling wire, electric motor, pulleys, springs, V-belt, bolts and nuts, magnets, wire, electric fuse and paint was used for the purpose of coating and beautifying the surface of the machine. All the materials were purchased at old Panteka, Kaduna State.

3.5 Fabrication Processes of the Components of the Dual-purpose Waste Glass Processing Machine

The methods of joints used for fabricating the components of the dual-purpose waste glass processing machine are discussed. In fabrication, joints with respect to their capability were made by permanent or separable. The permanent fixed joints were obtained by welding, machining, filling the joints with molten metal using filling wire. While separable fixed joints were obtained by using bolts and nuts. The procedures for fabrication of the hopper; separator plate; shaft; eccentric shaft; hammer mill; pin, revolving beaters; spacers; perforated screen; sieves, top cover, front door; collector; housing case, electric motor bed and machine frame are discussed.

3.5.1 Hopper

The hopper was made of mild steel. It was cut and welded into a rectangular shape with a bend at the middle. It has an opening of 420mm by 120mm and a welded discharge end of 400mm by 100mm. After the hopper was welded, the magnet was place behind the hopper.

3.5.2 Separator plate

The separator plates were made using mild steel with a thickness of 4mm. It was processed by cutting and drilling. Two holes of 10mm were drilled at the angle corner

on each plate; for passage of the pins and another hole of 50mm was also drilled at the middle of each plate; for passage of the shaft. At the process of drilling, water was poured on each of the plates; due to the fact that heat was generated when the bit got in contact with the mild steel and a flat wood was place underneath the plate to create a balance while drilling. The separator plates held the hammers in straight position with the aid of a pin passing through them. The length is 150mm; height is 150mm. The total number of the separator plates is 4.

3.5.3 Shaft

The shaft was made using mild steel and it is 530mm in length, 30mm in height and a thickness of 30mm. The mild steel was processed by cutting and machined to the desired shape of a step-shaft, while the bearings were fixed at both ends of the shaft.

3.5.4 Eccentric shaft

The eccentric shaft was made by machining using mild steel. It is 650mm in length with a thickness of 30mm. Two bearings were attached at both sides and a bearing was inserted at the middle of the eccentric shaft. A flat metal was fixed into the space between the bearing at the middle and the shaft to allow warbling of the flat metal that connects the sieve tray to the eccentric shaft together.

3.5.5 Hammer mill

The hammers were fabricated using mild steel by cutting and drilling. The hammer has a length of 140mm, breadth of 35mm and a thickness of 2mm. A hole of 10mm was drilled at the lower part of each hammer for the pin to pass through it. The hammers are 9 on each rows; making it a total of 18 hammers.

3.5.6 Pin

The pin was made by cutting and machining the mild steel to a length of 240mm and thickness of 15mm. The total number of pins is 2.

3.5.7 Revolving beaters

The revolving beaters are a unit assembly consisting of 18 hammers, 24 spacers, 2 pins, 4 separator plates and the shaft. The length of the revolving beaters is 196mm. The unit assembly performs beating action by revolving along the shaft, while in operation.

3.5.8 Spacers

The spacers were made using mild steel by cutting to specified size. The spacers separate the hammers from brushing one another to reduce friction and maintain the life span of the hammers. The total number of the spacers is 24 of equal sizes 20mm length and 15mm in diameter.

3.5.9 Perforated screen

The perforated screen was made using mild steel by drilling and cutting to the appropriate length of 450mm and width of 250mm. It was be perforated by drilling holes of 5mm in diameter and the number of holes on the screen were determined by the diameter of the holes. The thickness of the perforated screen is 4mm.

3.5.10 Sieves

The sieve was produced using mild steel by cutting and hammering. The sets of sieves have 320mm length, 35mm height and 285mm width. Mesh sizes of 4mm, 3mm and 2mm was assembled to the sieves. The total numbers of the sieves are 3.

3.5.11 Top cover

The top cover was fabricated using mild steel. It was cut, machined and screwed with bolts and nuts to the machine frame. It can be opened to access the case housing; for maintaining the interior.

3.5.12 Front door

The front door was made using mild steel. It was cut, machined and welded to the machine frame and the hinges; for easy opening. It has a handle for opening the machine from the front; to assess the sieves in the machine. It has a length of 390mm and width of 320mm.

3.5.13 Collector

The collector was made using mild steel by cutting and welding. It has a length of 320mm and height of 35mm and width of 285mm.

3.5.14 Housing Case

The housing case was made using mild steel by cutting and welding. It is in two compartments; the compartment at the top; has a length of 25mm, height of 15mm and a width of 30mm, while the second compartment; which is incorporated with the perforated screen has a length of 250mm, height of 250mm and 520mm in width.

3.5.15 Electric motor bed

The electric motor bed was made of mild steel by cutting and machining. The length is 450mm, width 350mm and the height is 5mm.

3.5.16 Machine frame

The machine frame was produced by welding angular bar of different lengths together. The angular bar was used to support the bearing of the shaft. The dimension of the machine frame are; length 996mm, height 700mm and width 696mm.

3.5.17 Assembly of the dual-purpose waste glass processing machine

After the fabrication of the components of the machine was done, the general assembly was done by separable or permanent fixed joints. The angular bar was welded to form the frame of the machine; because the fabricated components of the machine were welded to it. The housing case below was welded to the machine frame. The screen was incorporated into the case housing and it was assembled in a way that the screen could be removable; if larger screen opening want to be used by any user. The separator plates were assembled to the shaft; which has bearing at both ends, while the hammers and the spacers were passed through the pins which were channel through the separator plates.

The revolving beaters; was placed in-between the housing case which comprises of separator plates, pins, hammers mill, spacers and a shaft was bolted to the angular bar and was welded to the machine frame. The housing case was fixed to the second case housing below the revolving beaters. The hopper was assembled to the housing case at the top; which has an opening to allow the feeding of the waste glass to the crushing chamber and a magnet was attached behind the hopper by welding a metal sheet to cover the magnet. The motor bed was assembled to the machine frame and the electric motor was assembled to the motor bed with bolts and nuts. The eccentric shaft was assembled to the machine frame and sieve tray was assembled to the eccentric shaft below the crushing chamber and the spring was assembled below the sieve tray. The different sizes of pulleys were connected to the shaft, eccentric shaft and electric motor.

Four springs was attached to the top of the sieve tray and hanged to the machine frame; while two springs were also attached below the sieve tray and hooked to the machine frame to ease the shaking of the sieve tray. The V-belt was connected to the pulleys of the shaft, eccentric shaft and electric motor. The 2mm and 3mm sieves were inserted into the sieve tray according to the size of their mesh opening at an inclined angle of 35°; while the collector was inserted on the flat base below the sieves. The front door was assembled to the machine frame; to allow access to the processed waste glass. The two tyres were assembled under the machine frame; for easy movement, while two metal rods were welded to the machine frame under the machine to support it. The top cover was assembled to the machine frame with bolts and nuts; to ease access to the housing case inside the machine.

The frame cover was assembled to cover the machine and prevent dust; while the machine is in operation. A part of the machine cover was left open; where the electric motor is located using to create air vent, so that the heat generated by the electric motor can pass through the space. The electric fuse was fixed to the wire on the electric motor. A removable flat slit was incorporated at the opening of the hopper to stop any waste glass that may splash from the crushing chamber during the test running of the machine.



Plate III.I: Welding the Machine Frame



Plate III.II: Assembled Screen inside the Lower Crushing Chamber



Plate III.III: Hopper Welded to the Upper Crushing Chamber

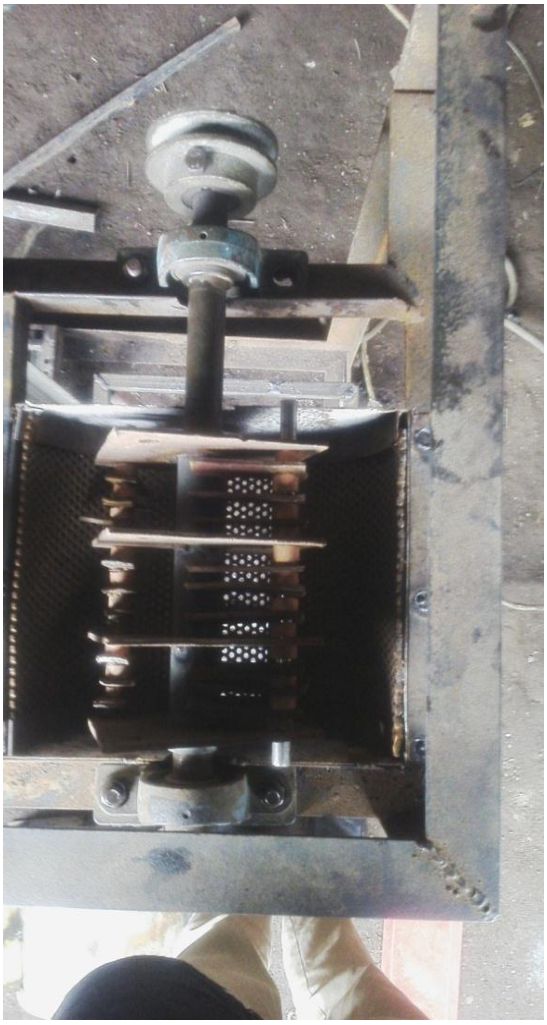


Plate III.IV: Assembled Revolving Beaters in the Crushing Chamber



Plate III.V: Assembled Crushing Chamber, Sieve tray, Electric Motor and Motor Bed to the Machine Frame



Plate III.VI: Covering of the Machine with Mild Steel using Bolts and Nuts



Plate III.VII: Covering of the Machine with Mild Steel by Welding



Plate III.VIII: Assembled Machine

3.5.18 Painting of the finished dual-purpose waste glass processing machine

The spraying machine was connected to the spray gun with the hose and red oxide was poured into the spray gun after which it was powered with electricity. The interior of the machine was sprayed with red oxide to protect the surfaces against corrosive action. The body of the machine was sprayed with a mixture of red oxide and an orange colour. After painting, the machine was allowed to dry for some hours.



Plate III.IX: Painted Assembled Machine

3.6 Cost Estimate

Table 3.1 Cost for each Material for Fabrication

S/No	Description	Types of Materials	Quantity	Price (#)	Total Price (#)
1	Angular bar	Mild steel	2	2500	5000
2	Metal plate	Mild steel	5	1000	5000
3	Pulleys	Standard	3	400	1200
4	Bolt and Nuts	Standard	40	20	800
5	V-Belt	Standard	1	500	500
6	Electric Motor	Standard	1	25000	25000
7	Paint	Standard	1	1500	1500
8	Magnet	Standard	3	200	600
9	Spring	Standard	6	100	600
10	Metal rod	Mild steel	2	1000	2000
11	3 quarter pipe	Mild steel	1	500	500
12	Filling wire	Mild steel	1	500	500
13	Hinges	Standard	2	100	200
14	Wire	Standard	1	200	200
15	Mesh	Standard	3	300	900
16	Tyre	Standard	2	200	400
17	Transportation				6500
18	Workmanship				25000
19	Miscellanous				16000
Total					92400

3.7 Sourcing and Beneficiation Process of the Waste Glass

The waste glass were collected from different locations in Ahmadu Bello University, Zaria, Samaru main campus; at the engineering provision shops, social sciences provision shops, staff club and area A staff quarter. The beneficiation process of the waste glass that was sourced, involved sorting, soaking, washing and drying. The waste glass was sorted into different colours; green, amber and flint. The waste glass was soaked in different bowl of water according to the colours and a detergent was poured into the water; to remove any form of dirt on the surface like paper and clay. After which it was washed using a piece of white cloth to enable the remaining dirt to remove easily and the waste glass was rinsed with clean water before sun drying for some hours in a dust free environment. Each of the waste glasses were weighed to 2300g before using them to test run the dual-purpose waste glass processing machine.

CHAPTER FOUR

RESULTS

This chapter covers the working principle of the dual-purpose waste glass processing machine, test running of the dual-purpose waste glass processing machine, results of the processed waste glass and design calculations.

4.1 Working Principles of the Dual-purpose Waste Glass Processing Machine

After the dual-purpose waste glass processing machine was assembled, it has the length of 600mm, a width of 1000mm and a height of 980mm. A drive pulley fixed on the motor and another driven pulley fixed on both the eccentric shaft and shaft with the aid of a V-belt to make the transmission of power to the machine easy through surface contact. The waste glass was fed into the machine through the hopper, which was fabricated to the top the case housing of the crushing chamber. Magnets were fixed behind the hopper to avoid passage of any magnetic material that may enter into the crushing chamber and to expand the life span of the hammer mill. The crushing chamber which consists of 18 sets of hammers, a shaft, 4 separator plates, 24 spacers, 2 pins which is the assembled revolving beaters to reduce the waste glass. A removable screen was incorporated to the housing case inside the crushing chamber.

The screen retains the large waste glass particles until they have been reduced to the size of 5mm in size. The processed waste glass passes through the discharge from the housing case to the 3 sets of sieves that are inserted into the sieve tray which was hanged to the machine frame with the six springs; four above the sieve tray and two below the sieve tray. The eccentric shaft shakes the sieve tray to allow the proper sieving of waste glass in the sieves and the collector retains the finest particle sizes during the waste glass processing.

4.2 Test Running of the Dual-purpose Waste Glass Processing Machine

After the dual-purpose waste glass processing machine was fabricated and assembled, test running was done by connecting the fuse of the waste glass processing machine to the socket to generate electricity to power the machine due the fact that the machine is a single phase. Each of the beneficiated waste glass was weighed to 2300g and was loaded into the crushing chamber through the hopper. The hopper has magnets behind it to remove any magnetic material in the waste glass before conveying the waste glass into the crushing chamber. The sets of hammers in the crushing chamber pulverized the waste glass which passed through the screen of 5mm to the discharger, for the pulverized waste glass to fall into the 3 sets of sieves from 4mm, 3mm and 2mm and the collector.

The machine was operated for 2 minutes to process the waste glass and was allowed to shake the sieves before the processed waste glass was collected from the 3 sets of sieves and the collector; after which the processed waste glass were poured into the 12 containers and weighed to know their quantity.



Plate IV.I: Test Running the Machine with Flint Waste Glass

4.3 Results of the Processed Waste Glass

The performance of the machine was tested using the three different sieves of 4mm, 3mm, 2mm and a collector. The following results were obtained after the machine was used to process each of the waste glasses.

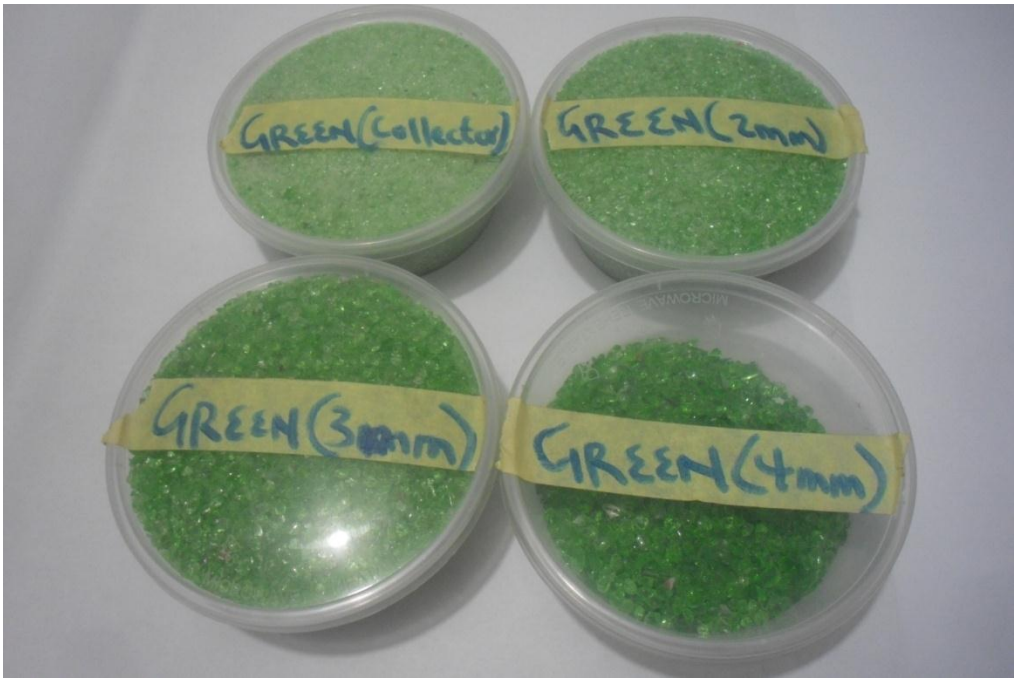


Plate IV.II: Processed Waste Glass (Green)



Plate IV.III: Processed Waste Glass (Amber)



Plate IV.IV: Processed Waste Glass (Flint)

4.4 Design Calculations

Table 4.1: Showing Design Calculations

INITIAL DATA	CALCULATIONS/SKETCHES	RESULTS
	BEATERS	
	Velocity of the beater shaft:	
$l = 270mm$ $N_1 = 1470\ rpm$ $d_2 = 100\ rpm$ $d_1 = 30\ rpm$	$\frac{N_2}{N_1} = \frac{d_1}{d_2}$ $N_2 = \frac{N_1 d_1}{d_2} = \frac{1470 \times 0.03}{0.1}$	$N_b = 441\ rpm$
	Linear velocity of the beater shaft:	
	$v_{bs} = \frac{\pi d_{bs} N_{bs}}{60} = \frac{\pi \times 0.1 \times 441}{60}$	$v_{ls} = 2.31\ m/s$
	CRUSHING CHAMBER	
	Pressure (force) produced of the glass:	
$v_{ls} = 2.31\ m/s$	$f = \dot{m} \times g = 2 \times 9.81$	$f = 19.62\ N$
	$A = lb = 0.27 \times 0.05$	$A = 0.0135\ N$
	$p = \frac{f}{A} \times F.O.S = \frac{19.62}{0.0135} \times 7$	p $= 1077.33\ kN/m^2$
$\sigma_{t1} = 42\ MPa$ $\sigma_{t2} = 28\ MPa$ $p = 1.38\ MN/m^2$ $d = 180mm$	**Thickness of the plate based on hoop stress:** $t_h = \frac{pd}{2\sigma_{t1}} = \frac{1.38 \times 10^6 \times 0.18}{2 \times 42 \times 10^6}$	$t_h = 2.96\ mm$

Thickness of the plate based on longitudinal stress:

$$t_l = \frac{pd}{4\sigma_{t1}} = \frac{1.38 \times 10^6 \times 0.18}{4 \times 28 \times 10^6}$$

$t_l = 2.22\ mm$

Hence, the larger diameter will be adopted (Khurmi, 2005), which is approximately equal to **3mm**

TRANSMISSION SHAFTS DESIGN

For beaters:

$l = 80\ mm$

$b = 30\ mm$

$t = 3\ mm$

$n = 24$

Beater Shaft analysis:

$$Volume\ of\ beaters = lbtn$$

$$= 0.08 \times 0.03 \times 0.003 \times 24$$

$V_b = 0.000173 m^3$

For separator plate:

$l = 180\ mm$

$b = 180\ mm$

$t = 3\ mm$

$n = 4$

$$Volume\ of\ seprator\ plate = lbtn$$

$$= 0.15 \times 0.15 \times 0.003 \times 4$$

$V_{sp} = 0.00027 m^3$

$$Volume\ of\ seprator\ shaft$$

$$= \pi \frac{0.015^2}{4} \times 2$$

$V_{ss} = 0.000353 m^3$

$\rho = 7800\ kg/m^3$

$g = 9.81\ m/s^2$

$l = 600\ mm$

$$Weight\ on\ the\ crushing\ shaft$$

$$= \rho(V_b + V_{sp})g$$

$$= 7800(0.000173 + 0.00027 + 0.000353)9.81$$

$W_{cs} = 60.91N$

$\sigma_b = 100\ MN/m^2$

$\tau = 42\ MN/m^2$

Bending Moment:

$M = 18.27\ Nm$

$$M = \frac{W_c l}{2} = \frac{60.91 \times 0.6}{2}$$

Torque generated by the crushing mill:

$$T = W_{cs} r = 60.91 \times 0.08 \qquad T = 4.87\ Nm$$

Diameter due to bending:

$$\frac{M}{I} = \frac{\sigma_b}{d/2}$$

$$\frac{64 \times 18.27}{\pi d^4} = \frac{2 \times 100 \times 10^6}{d} \qquad d = 26.38\ mm$$

Diameter due to Torque:

$$\frac{T}{J} = \frac{\tau}{d/2}$$

$$\frac{32 \times 4.87}{\pi d^4} = \frac{2 \times 42 \times 10^6}{d} \qquad d = 17.99\ mm$$

Hence 30 mm is adopted

VIBRATION

$W = 105N$

$\delta = 30mm$

$x = 30mm$

$f = 4Hz$

$x = 30mm$

Hence, horizontal velocity $u = 0.024\ m/s$

From equation 2.9,

$$k = \frac{W}{\delta}$$

$$= \frac{105}{0.03} \qquad k = 3500\ N/m$$

From equation 2.11

$$2kx + ma + 2kx = F$$

Assuming $a = 0$,

Then $F = 4kx$

$$= 4 \times 3500 \times 0.03 \qquad F = 420N$$

Torque needed to move the sieve:

$$T = F \times u$$

$$= 420 \times 0.024 \qquad T = 10.08\ Nm$$

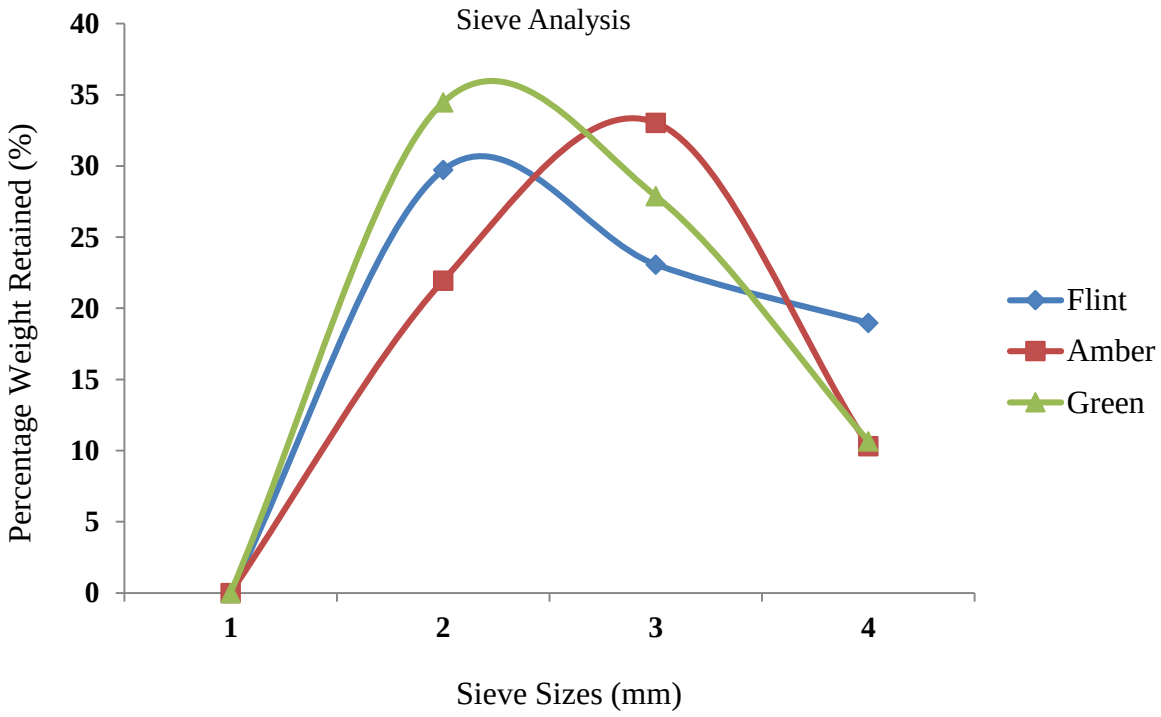


Figure 4.1 Graph of Sieve Analysis of the Processed Waste Glass

4.5 Findings

1. After fabrication, the machine was found to be easy to operate and the parts were coupled in such a way that they can be easily dismantled for quick and easy maintenance.

2. The dual-purpose waste glass processing machine was properly covered to avoid air pollution during operation.

3. Small scale business can be achieved by using the dual-purpose waste glass processing machine.

4. The machine processes the waste glass properly and simultaneously sieves it into desired particle sizes.

CHAPTER FIVE

DISCUSSION

5.0 Discussion

The dual-purpose waste glass processing machine was designed using software known as solid works and each components of the machine was fabricated using mild steel sourced at Old Panteka, Kaduna. The assembly of the components of the machine was

done by separable and permanent fixed joint. The machine was test run using waste glass that was sourced and beneficiated. During the test running of the machine 2300g of each of the waste glass; green, amber and flint were loaded into the machine and the sieves and collector retained some grain particle sizes. The total weight of the flint glass retained on the sieves and collector is 2288g, while the total weight retained on amber and green glasses are 1822g respectively. The flint had more weight retained than the amber and green because it has more silica during the batch formation.

From the graph in Figure 4.1, green glass has the highest grain sizes retained on 2mm sieve. The results of the processed waste glass were determined by the grain sizes retained on each sieves. The grain sizes of green, amber and flint retained on the 4mm sieve are lesser than the 3mm and 2mm sizes; showing that the hammer mill processed the waste glass properly before discharging into the sieves and collector. The grain sizes retained on 4mm and 3mm sieves can be use for glass melting. The grain sizes retained on green, amber and flint glasses 2mm sieve can be used for surface texture design. The grain sizes retained on the collector can be for partial replacement of cement, glass paint and glass tiles. The sieve analysis was carried out to determine the grading of the waste glass for use as aggregates.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

In summary, the waste glasses were sourced at Ahmadu Bello University Zaria, Samaru main campus and were beneficiated by sorting, soaking, washing and drying. 2300g of

beneficiated waste glasses were weighed before using them to test run the dual-purpose waste glass processing machine. A dual-purpose waste glass processing machine was designed with a software known as Solid Works and has been fabricated using mild steel in Old Panteka, Kaduna. The crushing of the waste glass was carried out by hammer mill, while the magnetic separation did not retain any magnetic material, due to the fact that the researcher beneficiated the waste glasses properly before feeding through the hopper into the machine. The vibration motion generated by the spring from the eccentric shaft was used to shake the sieves of 4mm, 3mm, 2mm and the collector.

The processed waste glasses were weighed with the digital weighing scale and the sieve analysis was done to know the weight retained, weight passing and percentage of weight retained on each sieve and collector of the green, amber and flint respectively.

6.2 Conclusion

Based on the design, fabrication and test results, the following conclusions can be deduced;

1. The aim of this research, which was to design and fabricate a dual-purpose waste glass processing machine, has been achieved.

2. The machine is simple and is made from locally available materials from Old Panteke, Kaduna State. The parts are coupled in such a way that they can be easily dismantle for quick and easy maintenance.

3. The safety precautions for operating the waste glass processing machine was provided to avoid any form of hazards it may cause while operating the machine.

4. The automatic operation saves time and does not require high skilled labour.

5. The dual-purpose waste glass processing machine can be used for glass recycling in any recycling workshop or industries.

6. The Post-consumer waste glass was used to test run the dual-purpose processing waste glass machine; because they are waste glass bottles or other waste glass products discarded by consumers after use.

6.3 Recommendation

In view of the advancing technology in engineering, the following is recommended for modification and improvement of the dual-purpose waste glass processing machine.

1. Waste glass bins should be provided by the University management, to the departments, faculties, hostels, sick bay, markets, provision shops, staff quarters and Senate buildings to help in separating waste glass from other wastes on Campus.

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APPENDIX 1: RESULTS OF SIEVE ANALYSIS

Table 4.2 showing sieve analysis of the processed green waste glass

Sieve No	Sieve sizes (mm)	Weight Retained (g)	Weight Passing (g)	% Retained
1	4	194	1628	10.65
2	3	508	1120	27.88
3	2	628	492	34.47

Collector		492	0	27.00

Table 4.3 showing sieve analysis of the processed amber waste glass

Sieve No	Sieve sizes (mm)	Weight Retained (g)	Weight Passing (g)	% Retained
1	4	188	1634	10.32
2	3	602	1032	33.04
3	2	400	632	21.95
Collector		632	0	34.69

Table 4.4 showing sieve analysis of the processed flint waste glass

Sieve No	Sieve sizes (mm)	Weight Retained (g)	Weight Passing (g)	% Retained
1	4	434	1854	18.97
2	3	528	1326	23.08
3	2	680	646	29.72
Collector		646	0	28.23