
Design and Fabrication of a Dual-Purpose Waste Glass Processing Machine for Small Scale Operations

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ABSTRACT

Processing waste glass plays an important role in the grading and upgrading of waste glass in the environment. The isometric projection and orthographic projection of the machine were designed using software known as solid works. The major material used for fabrication was mild steel and the assembly was done by separable and permanent fixed joints. The machine has a length of 996mm, height of 700mm and width of 696mm. The waste glass were collected in Ahmadu Bello University, Zaria, Samaru main campus. The beneficiation process of the waste glass involved sorting, soaking, washing and drying. Each of the waste glass were weighted to 2300g, and were used to test run the machine. The performance of the machine was tested using the sieves of 4mm, 3mm, 2mm and a collector. The weight of processed flint glass on the sieves and collector were 434g, 528g, 680g and 646g; the weight of processed amber glass were 188g, 602g, 400g and 632g; while the weight of processed green glass were 194g, 508g, 628g and 492g. The grain sizes of 4.9mm-3.0mm can be use for glass melting. The grain sizes of 2.9mm-2mm can be used for surface texture design. The grain sizes on the collector can be used for partial replacement of cement, glass paint and glass tiles. Less than hundred thousand Naira; was used to fabricate the machine and it can be used to process animal feeds. The Small to Medium Enterprise (SME) can adopt this machine for pilot plant.

Keyword: Machine, Sieve Analysis, Waste Glass, Dual-Purpose

INTRODUCTION

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 furnaces 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). According to Garkida (2007), waste glass is non-degradable making it even more hazardous when it litters the environment especially to children whose only playgrounds are these refuse areas in a country with poor health care system. Therefore, the need for alternative use and proper disposal of waste glass to reduce health risks and for conversion of waste to wealth cannot be over emphasized.

Gonah (2001) asserts that 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 from there. The crushing is the processing of rupturing the materials into particles of irregular shapes and sizes. The processes used in glass crushing for recycling involves the same methods used by the aggregate industry for crushing rock into sand (Mark, 2001).

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. 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 end use. Being such a simple technique of particle sizing, it is probably the commonest (Abubakar, 2012).

Metal fabrication techniques according to Callister (1994), are the methods by which metals and alloys are formed or manufactured into useful products. The concepts of fabrication are procedure in fabrication which are; metal fabrication, engineering drawing, sourcing for raw materials, forming, machining and welding. 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. Virtually all the available literatures said little or nothing on grading and upgrading operations by a single machine. This project addressed this very problem.

The objectives of the research were to design a dual-purpose waste glass processing machine for small scale processing, fabricate the dual-purpose waste glass processing machine for small scale processing and test run the dual-purpose waste glass machine using waste glass. Processing all the waste glass we throw away would create new jobs for the unemployed. Separating and processing waste glass could significantly reduce waste management costs.

METHODOLOGY

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.

Materials and Equipment

The materials used for fabrication were readily available and the cost was affordable. In fabrication of the machine, mild steel was used because; it is relatively cheap and easily machined. 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 in this study are hand and industrial drilling machine; measuring tape; hammer; grinding machine; industrial cutting machine; electric welding machine; square; saw; turn; industrial folding machine; pliers; dark safety goggle; spraying machine; vice; spanners; and scissors.

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 due to its efficiency.

Design of the Machine

The isometric projection and orthographic projection showing the major components of the machine and assembly drawing of the dual-purpose waste glass processing machine were designed. Figure 2.1 shows the assembly drawings of the Dual Waste Glass Processing Machine.

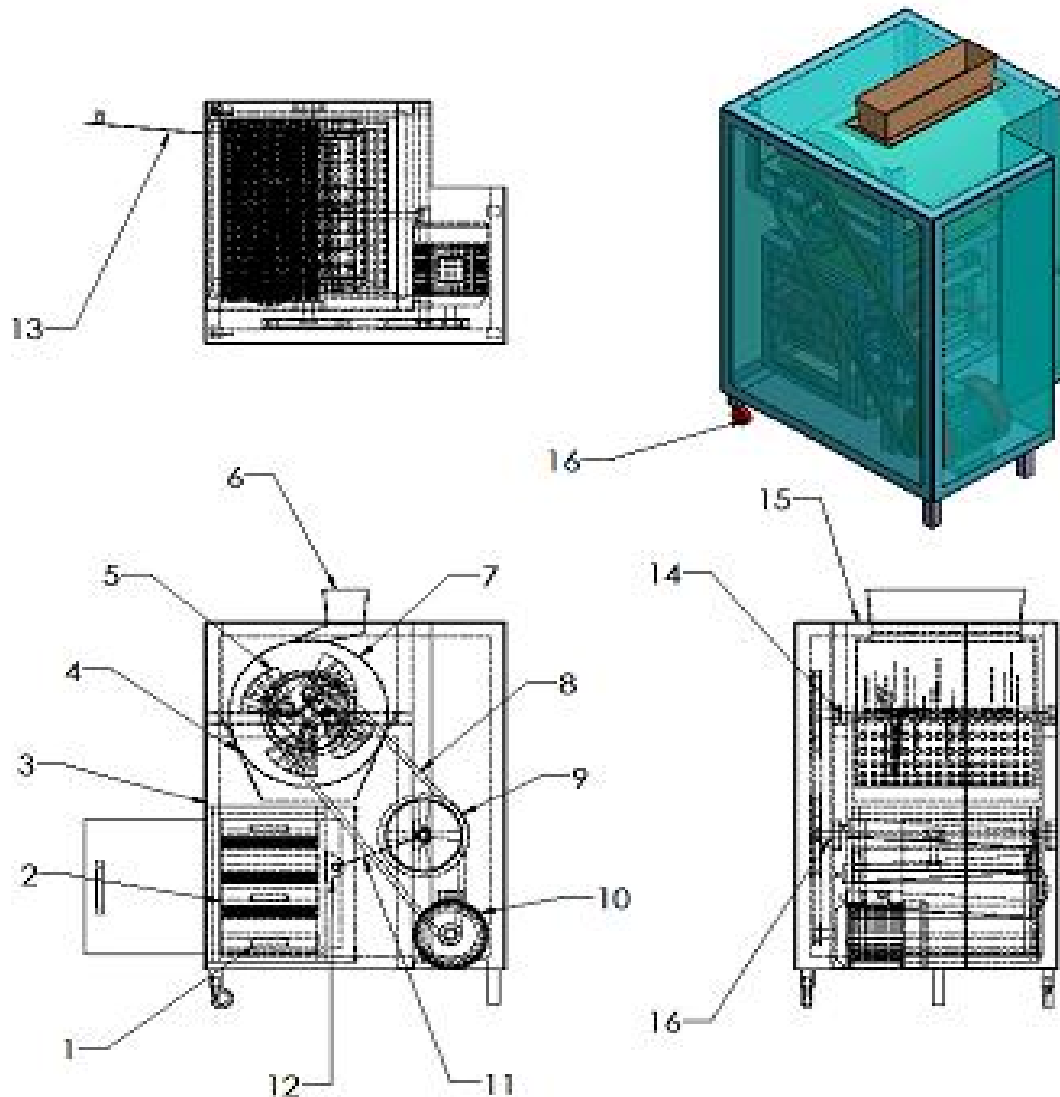


Figure 2.1 The Assembly Drawing of the Dual-purpose Waste Glass Processing Machine.

1. Collector 2. Sieve 3. Sieve Frame
4. Lower Milling Chamber 5. Beaters
6. Hopper 7. Upper Milling Chamber 8. Belt
9. Pulley 10. Electric Motor 11. Connecting Rod
12. Bearing 13. Door
14. Milling Shaft 15. Frame 16. Rollers
17. Electric Shaft

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

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. The separator plates were made using mild steel with a thickness of 4mm. Two holes of 10mm were drilled at the corner on each plate for the passage of pins and another hole of 50mm was also drilled in the middle of each plate for the passage of the shaft. The length of the Dual Waste Glass Processing Machine is 150mm and height 150mm. The total number of the separator plates is 4. The shaft was made using mild steel 530mm in length and a thickness of 30mm. The eccentric shaft was made by machining using mild steel. It is 650mm in length with a thickness of 30mm. 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. The hammers are 9 on each row. The pin was made by cutting and machining the mild steel to a length of 240mm and thickness of 15mm. The revolving beaters are units of assembly consisting of 18 hammers, 24 spacers, 2 pins, 4 separator plates and the shaft. The length of the revolving beaters is 196mm.

The spacers were made of mild steel cut to specified size. The total number of the spacers is 24 of equal sizes 20mm length and 15mm in diameter. The perforated screen was made of mild steel

sheets by drilling and cutting to the appropriate length of 450mm and width of 250mm. It was 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. The sieve was produced using mild steel by cutting and hammering. The sets of sieves are 320mm in length, 35mm high and 285mm wide. Mesh with aperture sizes of 4mm, 3mm and 2mm were attached to the sieves. The total numbers of the sieves are 3.

The top cover was fabricated using mild steel. It was cut and machined. The front door was made of mild steel. It has a length of 390mm and width of 320mm. The collector was made from mild steel by cutting and welding. It has a length of 320mm and height of 35mm and width of 285mm. The housing case was also made of mild steel by cutting to the desired sizes and welding. It is in two compartments. The electric motor bed was made of mild steel. The length is 450mm, width 350mm and a thickness of 5mm. The machine frame was produced by welding angular bar of different lengths together. The dimension of the machine frame is; length 996mm, height 700mm and width 696mm.

Assembly of the dual-purpose waste glass processing machine

After the fabrication of the various components of the machine, the general assembly was done by separable or permanent fixed joints. The angular bar was welded to form the frame of the machine. The housing case 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 easily removed. The separator plates were assembled to the shaft; 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 and a magnet was attached to the back of the hopper. 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. 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 attached to the machine frame. Two tyres were assembled under the machine frame; while two metal rods were welded to the machine frame under the machine to support it. The top cover was attached to the machine frame with bolts and nuts.

The frame cover was assembled to cover the machine. Part of the machine cover where the electric motor is located was left open to create air vent, so that the heat generated by the electric motor can escape 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. The machine was sprayed with red oxide and an orange colour.



Plate 2.1: Assembled Machine

Sourcing and Beneficiation Process of the Waste Glass

The waste glass was collected from different locations at Ahmadu Bello University, Samaru main campus, Zaria. The beneficiation process of the waste glass that was sourced, involved sorting, soaking, washing and drying. The waste glass was sorted into different colours of green, amber and flint. The waste glass was soaked in different bowl with water according to the colours and a detergent was poured into the water to remove all forms of dirt on the surface like paper and clay. After the washing, they were rinsed with water before drying in a dust free environment.

RESULTS AND DISCUSSION

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 loaded into the

crushing chamber through the hopper. The hopper had 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 this the processed waste glass was poured into 12 containers and weighed to know their quantities.

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 2.2: Processed Waste Glass (Green)



Plate 2.3: Processed Waste Glass (Amber)



Plate 2.4: Processed Waste Glass (Flint)

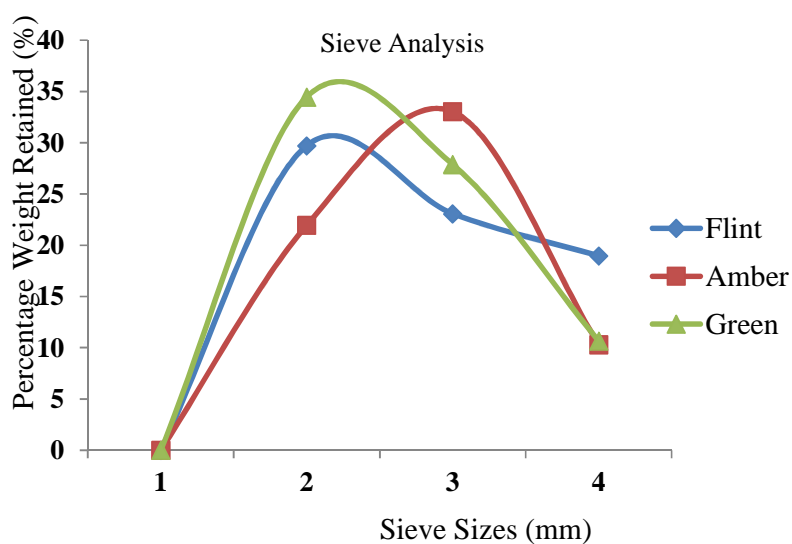


Figure 3.1 Graph of Sieve Analysis of the Processed Waste Glass

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 tested 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 weight of processed flint glass on the sieves and collector were 434g, 528g, 680g and 646g. The weight of processed amber glass were 188g, 602g, 400g and 632g; while the weight of processed green glass were 194g, 508g, 628g and 492g. The flint had more weight retained than the amber and green because it had more silica during the batch formation.

From the graph in Figure 3.1, 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 processed waste glasses were weighed with the digital weighing scale to know the weight retained, weight passing and percentage of weight retained on each sieve and collector of the green, amber and flint 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 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. This sieve analysis was carried out to determine the grading of the waste glass for use as aggregates.

FINDINGS

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.

3. The covering of the waste glass processing machine for safety helped to avoid air pollution during operation.
4. Small scale business can be achieved by using the dual-purpose waste glass processing machine.
5. The machine processes the waste glass properly and simultaneously sieves it into desired particle sizes.

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 for small scale processing, has been achieved.
2. The machine is simple and is made from locally available materials from Old Panteka, 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 accident while operating the machine.
4. The ease of 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.
7. Less than one hundred thousand Naira (₦100, 000.00); was used to fabricate the machine and it could be used to process animal feeds as well.

RECOMMENDATION

Further study is required to improve on grading and upgrading performance of the machine.

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