

Design and Fabrication of Glass Powdering and Grading Machine for Various Industrial Applications

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ABSTRACT: The design and fabrication of glass powdering and grading machine was completed. As glass is widely used throughout the world used in almost all the things we see and use in our life. About million tons of waste glass, which is generated every year and large portion of it, ends into landfill. Pollution resulting from hazardous glass is widespread across the world, thus finding uses for waste glass becomes important for us. This machine crushes waste glass, which includes tubelight glass to large bottles, windowpanes etc. The machine has an impact rotor, which crushes the glass to finer powder. The crushed glass size is be controlled via modular perforated sheets. The glass once crushed has to be segregated based on the particle size, this happens within the machine structure and via a system of inclined sieves. The glass powder collected can be used for further applications in areas like civil industry, decorative fields, and mechanical engineer or can be reused or recycled later. The machine was conceptualized & modelled using SolidWorks and was fabricated successfully

KEYWORDS: Waste glass, Reusing, crushing, fine powder, machine, impact rotor, grading, fluorescent tubelight

I. INTRODUCTION

Solid waste management is a major problem in developing countries. Solid waste includes organic waste (food waste) and inorganic waste (glass waste, plastic waste etc.). Unlike the inorganic waste, the organic waste is biodegradable and easy to decompose. Glass waste such as glass bottles, glass cups, tubelight, which are mass-produced through the world every year. Glass is recyclable if it is properly segregated, but even though a vast majority of it still ends up being dumped all over the world. The percentage of glass being recycled over the world stands at approx. 21 percent while it is 45percent in India. Rest of the glass ends up in the landfills. Since glass waste is non-biodegradable, the waste is accumulated in the landfills for years and is not easily decomposed. This can get hazardous to the environment at later stage. Thus crushing of glass into fine particle will enable it to be used for further application in the industries. This will result in environmental friendly use of the waste glass. Being non-biodegradable in nature, glass disposal as landfill has environmental impacts and also could be expensive. Sustainable construction practice means creation and responsible management of a healthy built environment considering resource efficiency and ecology. As we know, the prime material used all over the world for construction is concrete as it is widely versatile and economical; however, it has impacts on the environment. Manufacturing of cement (key ingredient used for the production of concrete) is a major source of greenhouse gas emissions. The use of supplementary cementitious materials (SCMs) to offset a portion of the cement in concrete is a promising method for reducing the environmental impact from the industry. Several industrial by-products have been successfully used as SCMs, including silica fume, ground granulated blast furnace slag and fly ash. These materials are used to create blended cements which can improve concrete durability, early and long term strength, workability and economy. Apart from the above material, there is another material which has potential as a SCM, however, has not yet achieved the same commercial success is Waste Glass. Researches indicated that glass has a chemical composition and phase comparable to traditional SCMs. It is abundant, can be of low economic value and is often land filled. Crushing of glass to micro-meter scale particle size, for enhancing the reactions between glass and cement hydrates, can bring major energy, environmental and economic benefits when cement is partially replaced with crushed waste glass for production of concrete. Various Studies also focused on use of waste glass as aggregate in concrete production. Study on durability of concrete with waste glass pointed better performance against chloride permeability in long term but there is concern about alkali-silica reaction.

II. RELATED WORK

- A. Studies on glass powder as partial replacement of cement in concrete [2]
In this study, finely powdered waste glasses are used as a partial replacement of cement in concrete and compared it with conventional concrete. This work examines the possibility of using Glass powder as a partial replacement of cement for new concrete. Glass powder was partially replaced as 10%, 20%, 30% and 40% and tested for its compressive, Tensile and flexural strength up to 60 days of age and were compared with those of conventional concrete. Based on the results, it was found that glass powder can be used as cement replacement material up to particle size less than 75 μ m to prevent alkali silica reaction. Compressive strength is found to increase with the addition of waste glass to the mix up until the optimum level of replacement. This can be attributed to the angular nature of the glass particles facilitating increased bonding with the cement paste.
- B. Use of recycled glass as coarse aggregate in concrete [6]
Concrete is a composite material composed of sand and gravel, chemically bound together by hydrated Portland cement. As a result, the concrete industry is also one of the biggest consumers of natural resources specifically sand, gravel, rock and water. From their experiment, it is found that Architectural glass concrete slabs strength checked by applying 50kg weight for 24 hours and no deformation occurred. Concrete cubes, 150mm in size, supposed to test in order to determine compression and flexural strength, absorption. Concrete cubes expecting to make using 100% natural aggregate as well as with 10%, 20%, 40% and 60% aggregate replacement by glass cullet are subjected to test. These levels of replacement were used for concrete made with Portland cement. The proportioning used for all concrete mixes was the same. All batching, including glass cullet replacement, was by volume. The free water content, cement content and aggregate content were 180, 350 and 1820 kg/m³ respectively. There is great potential for the utilization waste glass in concrete in several forms, including coarse aggregate and architectural forms with concrete. It is considered that the latter form would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for expensive materials such as granite, marble and terrazzo.
- C. Strength and durability properties of concrete by using fluorescent light tube waste replacing as fine aggregate [3]
The following conclusions are drawn from the study on fluorescent tube light waste fine aggregate sand and they are applicable for the range of can be formed into useful fine aggregate. It is observed that there is a strength increase with addition of fluorescent tube light waste of 10% and beyond which there appears to be no specific enhancement in strength. This strength increase appears to be true for compressive and flexural strength. A measurable increase in durability of the concrete with fluorescent tube light waste is observed. The experimental study in total revealed a better performance of the concrete with respect to strength, acid resistance, alkali attack and sustainability under fire. The compressive strength of fluorescent tube light waste concrete with 10% replacement of fine aggregate is 22.20% higher than control concrete. The split tensile strength of fluorescent tube light waste concrete with 10% replacement of fine aggregate is 0.3% higher than control concrete. The flexural strength of fluorescent tube light waste concrete with 10% replacement of fine aggregate is 3.70% higher than control concrete.
- D. Design of Hammer Mill for Crushing of Glass Waste [7]
This research work focus on design of cost effective and affordable glass waste recycling machine in developing countries which can be used in crushing of glass waste into some useful products. The machine was successfully designed. The design calculation showed that the machine required minimum crushing force and crushing power for its operation. A physical model of the machine was analysed using SolidWorks and the outcome proved that the machine is efficient and when fabricated for use, it should be able to crush glass waste successfully into some useful products.

III. ADVANTAGES OF REUSING OF GLASS

Even though glass items can be recycled, there are a few exceptions. For example, glass from light bulbs and window panes cannot be recycled because they contain ceramics and other impurities that would contaminate the entire recycling process. Thus in some cases it is advisable to Reuse the glass for protecting the environment which is an alternative to recycling. Also, it has been argued that glass recycling has a significant impact on employment within the glass manufacturing industry. There is high cost which is associated with Recycling for glass to be properly recycled, since it needs to be separated by colour. This process is quite labour intensive and rather complicated. Also in most countries Recycling is also done overseas due to a lack of proper facilities locally, making it very costly



IV. OBJECTIVES

- To reduce the amount of waste glass being dumped into the landfills.
- To promote use of glass waste in effective and environment friendly manner.
- To crush glass to fine particle size as per the requirement.
- To effectively crush tubelight along with the separation of its caps.
- To promote the reuse of waste glass and reduce overall waste being dumped in the landfills.

IV. APPLICATIONS OF CRUSHED GLASS

- i. Crushed Glass Powder used as a Concrete / construction aggregate in construction sites as a replacement to natural sand.
- ii. Crushed Glass used in the construction of roads.
- iii. Glass crushed into particles can act as an abrasive media.
- iv. Crushed Glass used as Pipe Bedding by replacing natural sand.
- v. Glass powder used for Landscaping and water filtration.
- vi. Crushed glass contains absorbing properties and hence used as Leachate drainage layer material in landfills (replacing gravel)
- vii. For partial replacement of concrete as a binder.

V. DESIGN PROCESS

1) Design Considerations

- i. The glass crushing machine will be consisting of hoppers connected to the crushing chamber
- ii. The crushing rotor is expected to operate within a rotating speed of 1300rpm
- iii. It must not deliver a crushing force greater than 300N
- iv. The crushing power will be 3HP
- v. Determination of bearing based on loads
- vi. Estimation of angle of repose for sieve arrangement
- vii. Determination of shaft diameter

2) Components of Machine

The components of machine are one hopper each for tubelight and bottles, crushing chamber, eccentric rotor with two blades, ball bearings, jaw coupling, crushed glass collection boxes, induction motor, and shaft and machine structure.

3) Specifications and dimensions

Component	Specifications
Main frame	Length=1080mm, Width=500mm, Height=1040mm
Motor	3 HP Single phase 1440RPM AC motor
Crushing chamber	ID=400mm, OD=406mm Width= 150mm
Rotor	260mm Dia. & 130mm Width
Hopper	120*120*800 mm(W*B*L)
Shaft	25mm dia. & 610mm length
Sieves	10mm, 5mm, 2mm perforations
Coupling	L100 Lovejoy Jaw with Buna N insert
Bearing	SKF 6205 with Plummer block
Collection box	GI Sheets Gauge 22

Table 5.3.1 Specifications and dimensions

4) Components design and selection

I. Motor

The motor used here is an AC 3 HP, 3-Phase, 1440rpm Induction Motor. The motor drives the shaft which has the Crushing blade (rotor) mounted on it. Fig 5.4.1



Fig. 5.4.1 Ac Motor

II. Shaft

Considering application of shaft, EN8

Material properties are:

$$\sigma_{ut}=657 \text{ N/mm}^2, k_b=1.5\sigma_{yt}=353 \text{ N/mm}^2, k_t=2.0$$

Take $\sigma_{ut}= 657\text{N/mm}^2$

Using ASME code for Designing Shaft

$$0.3 \sigma_{yt}= 0.3 \times (353) = 105.9\text{N/mm}^2$$

$$0.18 \sigma_{ut}= 0.18 \times (657) = 118\text{N/mm}^2$$

Since the lower value is found to be 105.9N/mm²

$$\tau_{MAX}=105.9 \text{ n/mm}^2$$

In Fig.5.4.2.0

Point A = Motor, Point B= Bearing, Point C(R) = Rotor

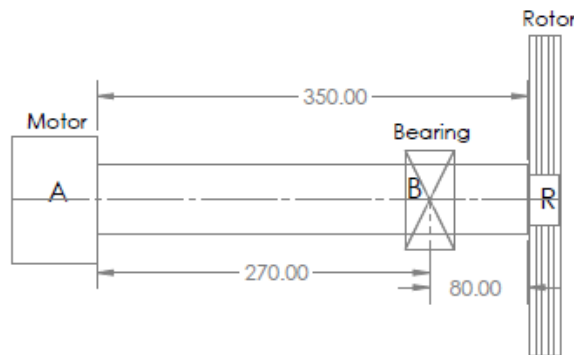


Fig.5.4.2.1 Positions of rotary members

Analysis of vertical forces

The Figure 5.4.2.1 represents the vertical forces acting on the shaft.

Where VA= Vertical forces at point A

VB= Vertical forces at point B VR= Vertical forces due to Rotor

Total weight of the rotor was calculated to be 8.56 kg (approx.10Kg)

$$10\text{kg} \times 9.81= 98.1\text{N}$$

$$F= 98.1\text{N (approx. 100N)}$$

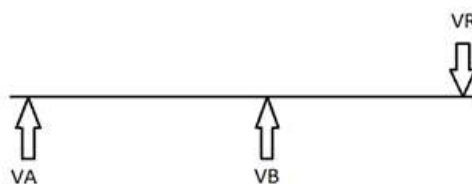


Figure 5.4.2.2: Analysis of Vertical forces

Considering Equilibrium of vertical forces

$$\sum F_v = VA + VB - 100 \text{ ----- (Eqn 1)}$$

Taking moment about A

$$\sum MA = 0$$



$0 = V_B * 270 - 100 * 350$
 $V_B = (350 * 100) / 270$
 $V_B = 129.62 \text{ N}$ thus we get,
 $V_A = -29.62 \text{ N}$

Hence, the direction we assumed is incorrect, thus we have to change Direction of V_A

Analysing Horizontal Forces

Where H_A = Horizontal forces at point A
 H_B = Horizontal forces at point B
 H_R = Horizontal forces due to Rotor



Fig.5.4.2.3 Analysis of Horizontal forces

Consider Equilibrium of Horizontal force

$\sum FH = 0$
 $H_A + H_B - H_R = 0$ ----- (Eqn 2)
 $H_A + H_B = 300 \text{ N}$

Taking moment at point A in Horizontal Direction

$$\sum MA = 0 + HB * 270 - 300 * 350$$

$H_B = (300 * 350) / 270$
 $H_B = 388.88 \text{ N}$

Substitute value of H_B in eqn. (2)

$H_A = -88.88 \text{ N}$

Hence the direction we assumed is incorrect, thus we have to change direction of H_A

Finding Bending Moment

$(M_b)_B = \sqrt{(129.6 * 120)^2 + (388.8 * 120)^2}$
 $= 49189.60 \text{ N-mm}$

$(M_b)_R = \sqrt{(350 * 350)^2 + (300 * 350)^2}$
 $= 110679.71 \text{ N-mm}$

For an induction motor with specification:

Power = 2.25 kW Rpm = 1500

Diameter of Shaft:

$$D^3 = 16 / (\pi T_{Max}) \sqrt{(K_b * M_b)^2 + (K_t * M_t)^2}$$

$D = 23.13 \text{ mm}$

The shaft diameter was taken as 25mm

(Approx. 25mm)

An EN8 shaft was selected of 30mm dia., which was reduced to 25mm dia. by turning on lathe machine. Two dimple holes were drilled on the shaft in order to mount the rotor and to provide a surface for the grub screw to hold firmly.

III. Bearing Selection (plummer block)

Loads to be considered for design- Radially downwards due to blade weight. Tangential due to impact forces

$F_a = 0$ (F_a = axial loads)

$F_r = \sqrt{(F_v)^2 + (F_t)^2}$

We know, $F_t = 300 \text{ N}$, $F_v = 100 \text{ N}$

$\therefore F_r = 316.227 \text{ N}$

Our shaft diameter is 25mm thus suitable bearing will be SKF 6205



Fig.5.4.3.1 (SKF 6205 with Plummer Block)

$d = 25 \text{ mm}$, $D = 52 \text{ mm}$

$C_o = 6965 \text{ N}$, $C = 10690 \text{ N}$

$N_{\max} = 13000 \text{ rpm}$

$P_{\text{equivalent}} = X V F_r + Y F_a$

$\therefore P_{\text{eq}} = V F_r$

Assuming $X = 1$, \therefore only radial loads are present

$V = 1$ \therefore Inner race is rotating

$\therefore P = 1 \times F_r$

$P = 316.227 \text{ N}$

Assuming maximum rpm to be 1440.

Considering the working time of bearing to be for 10000 hrs.

$L_{10} = 60 \eta L_{10h} / 106$

Where, L_{10} = Life in million revolution, L_{10h} = Life in hours

Now to check F the actual dynamic load is within limits

$L_{10} = C^3 / P^3$

$864 = C^3 / (316.227)^3$

$C = 3011.87$

The value of actual C is much less than the permissible value hence our bearing selection is safe

IV. Coupling

The coupling used in the machine is a Lovejoy jaw coupling Series L100 with Buna N spider. It is used to couple the motor output shaft and the rotor shaft. The coupling is selected based on the power transmission capacity using the jaw coupling catalogue



Fig.5.4.4.1 Lovejoy Jaw Coupling

V. Rotor

This is the main part of the entire machine and it does all the glass crushing which is fed to the chamber. The Rotor or the crushing blade has been made of hardened steel plate of thickness 10mm the blades have been welded to a MS Square-pipe, which is fastened onto the shaft by means of grub screw. Fig.5.4.5.1



Fig.5.4.5.1 Crushing Rotor

VI. Crushing Chamber

The chamber houses the rotating crushing blade. The chamber has projections made on its interior circumference so as provide extra rough surface for the crushing activity. The rotor is mounted eccentric to the chamber to provide better crushing. The square hopper is for feeding the glass bottles and large pieces of waste glass. The round hopper adjacent to the square hopper if for feeding of tubelight. Fig.5.4.6.1

1. Square hopper cut
2. Tube hopper cut
3. Cut for the rotating shaft.
4. Bottom cut for the exit of Crushed Glass and placement of the Modular sieve.

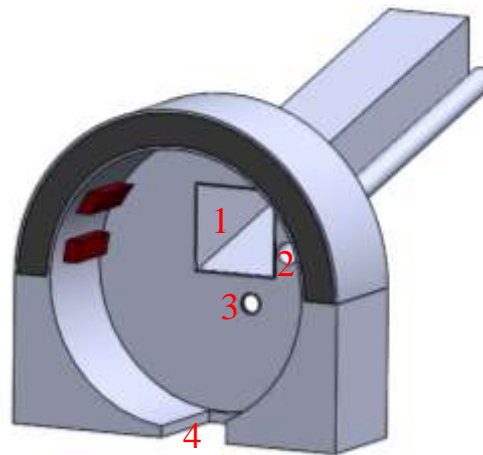


Fig5.4.6.1

VII. The Grading mechanism

This consist of the inclined arrangement of sieves which help in separating of the different grades of the crushed glass produced in the crushing chamber by the action of the rotor. Once the glass exits the crushing chamber it still has a mixture of crushed glass size. This is separated by means of several sieves inclined to the horizontal axis. The sieve size goes on decreasing as we descend to the lower levels. The glass which does not pass through the sieve will slide and get collected in the collection box. Two such inclined sieves are used in this machine. Fig.5.4.7.1

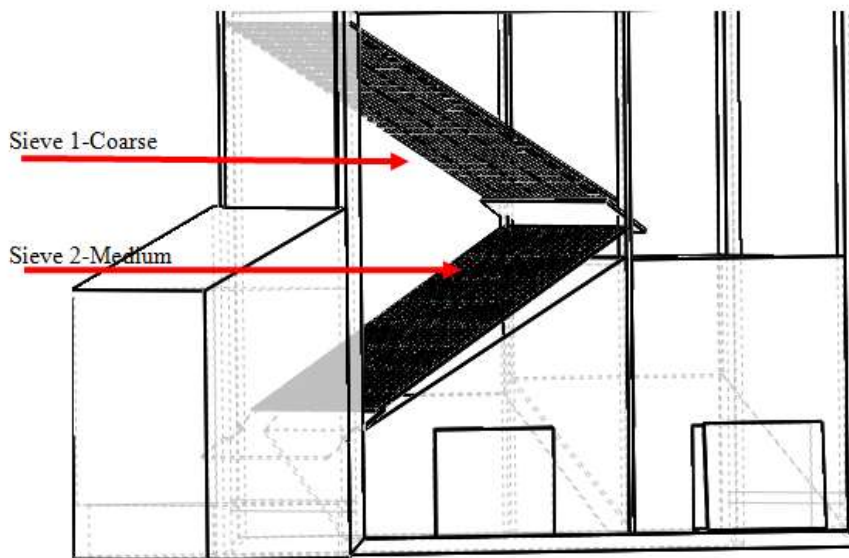


Fig.5.4.7.1 Grading mechanism (Sieve arrangement)

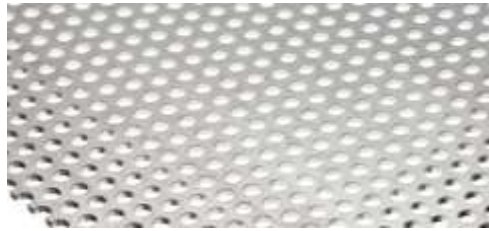


Fig.5.4.7.2 Perforated sheet (Sieve)

VIII. Angle of repose

The angle of repose or critical angle of repose, of a granular material is the steepest angle of descent relative to the horizontal plane to which a material can be piled without sliding. It is calculate by taking Tan inverse of the coefficient of friction between two materials.

In our case, it is glass and metal Coefficient of friction between glass and metal is found to be 0.6 i.e. μ

Angle of repose = a $\tan \Theta = \mu$

I.e. $\Theta = 31^\circ$ (counter clockwise w.r.t. Horizontal)

IX. The Main Seive for grading

The Seive is positioned at the lower part of the crushing chamber. The seive can be Replaced/Changed as per the requirement.

This seive controls the output of the crushed glass size,since the glass will not pass through the seive until and unless the size of crushesd glass is smaller then the seive opening.

This is the reason for the eccentric mounting of the rotor. The rotor will scoope the glass and crush it further untill it can pass through the seive. Fig.5.4.9.

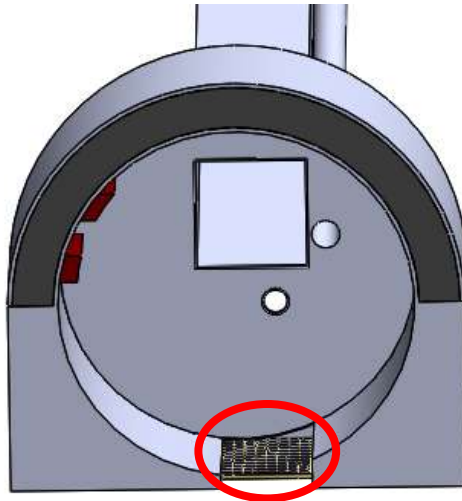


Fig.5.4.9.1 Modular Sieve

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VI. PROCESS FLOWCHART

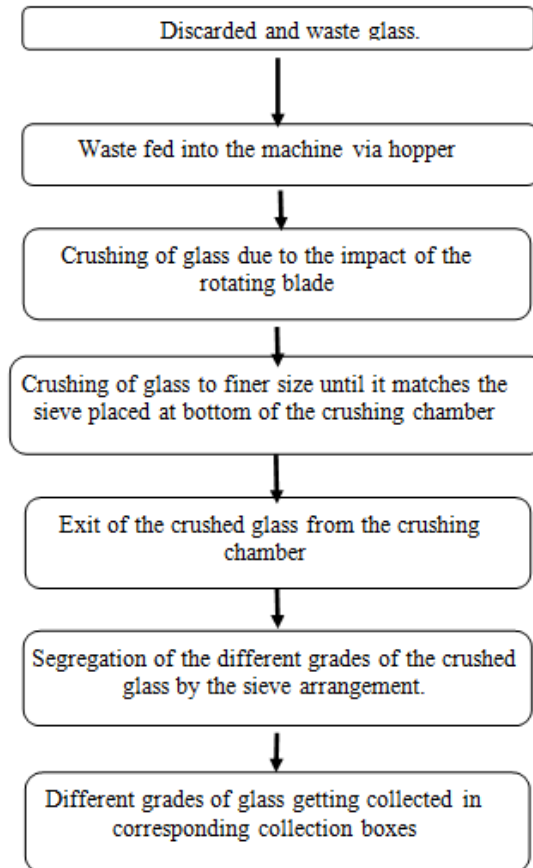


Fig. 6.1 Machine Process flow

VII.MACHINE STRUCTURE / MODEL



Fig.7.1 Fabricated Machine

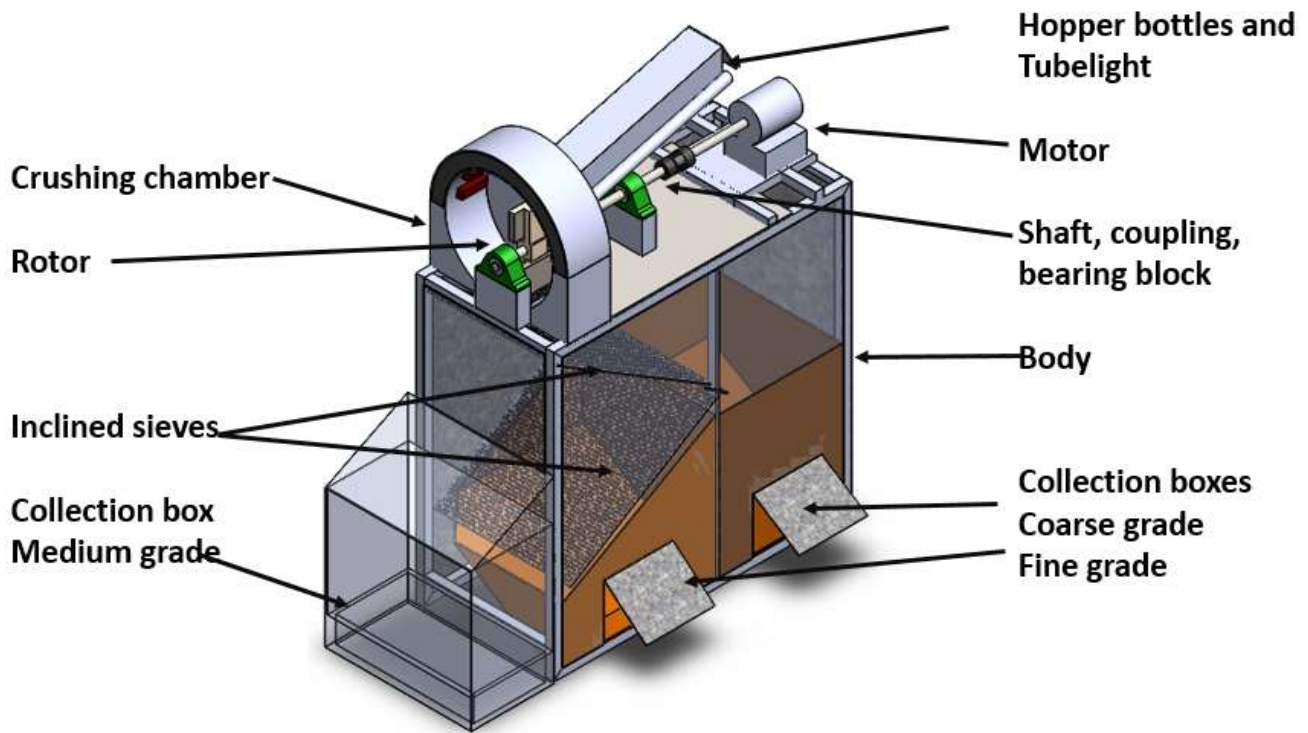


Fig.7.2 3D CAD model of machine n SolidWorks(Showing interior construction)

VI. CONCLUSION

The machine was designed and fabricated as per the required objectives t crushes any waste glass including bottles and tubelight.

The tubelight with caps and without the caps were fed into the machine and their crushing was successful. The caps stayed in the crushing chamber while all the glass passed out of the crushing chamber once it was reduced to size less then 10mm.

- i. The said objectives were met.
- ii. The avg. weight of the bottles crushed is 236grams
- iii. The avg. time required to crush one bottle is 25 Sec.
- iv. Crushing time for 1 KG of waste bottles takes approximately 53 Sec.
- v. The avg. weigh of tubelight after cap separation is 137grams.
- vi. The time required for crushing one tubelight is 24sec.
- vii. The avg. time for crushing 1Kg of tubelight is 75Sec
- viii. It was observed that tubelight when crushed, were converted to fine grade in short period of time. Whereas for bottle glass to convert into find grade would take longer time
- ix. While crushing the glass bottles the paper labels would get separated and got collected in the coarse grade collection box
- x. Below fig., show the percentage of different grades of glass when crushed using the machine
 - Blue=fine grade [size less than 2mm]
 - Orange= medium grade [size between 2 to 5mm]
 - Grey=coarse grade [size between 6 to 10mm]

The pie chart depicts the percentage of weights obtained for different sizes of crushed glass.

- Fig. 6.1- percentage of weigh distribution for feeding 1 of glass bottle.
- 6.2- percentage of weight distribution for feeding 1 Kg of glass bottles.
- 6.3- percentage of weight distribution for 1 tube light.
- 6.4- percentage of weight distribution for 1 Kg of tubelight.

i. For one glass bottle.

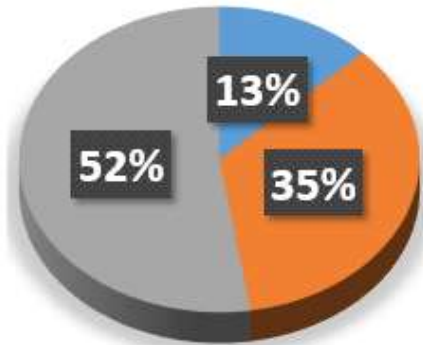


Fig.6.1

ii. For 1 Kg of glass bottle

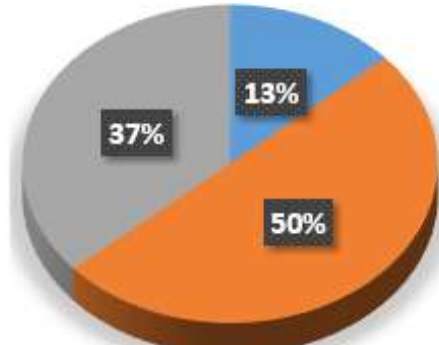


Fig.6.2

iii. For one tubelight

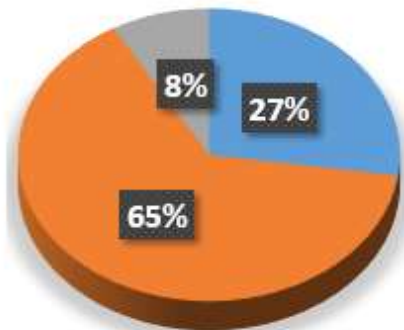


Fig.6.3

For 1 Kg of tubelight

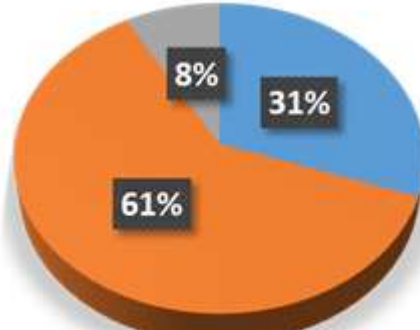


Fig.6.4

Samples obtained as per the grades



Fig 6.5



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