NIPES

Advances in Engineering Design Technology

Journal homepage: www.nipesjournals.org.ng

# Design and Fabrication of a Sawdust Screw Conveyor for a Steam Boiler Power Plant

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**ARTICLE INFORMATION**

*Article history*:
*Received 13 Sept 2023*
*Revised 16 October 2023*
*Accepted 09 November 2023*
*Available online 10 Dec 2023*

*Keywords*:
*screw-conveyor, Hopper, sawdust, blower, Boiler, steam plant*.

*https://doi.org/10.5281/zenodo.10341040*

ISSN-2682-5821/

**ABSTRACT**

*Materials are required to be conveyed to the combustor for combustion so that heat can be released to convert the water to steam for propelling the turbines. As manual feeding of the material into the combustor may be to non-uniform distribution of combustor performance, hence, this study designed and fabricated a simple sawdust screw conveyor with the sole aim material conveyance into the combustor for combustion. The conveyor was fabricated using local materials considering the design and functional requirements of the sawdust screw conveyor The conveyor is powered by an 5Hp electric motor and blower through a direct shaft drive. The produced machine was tested using sawdust and the screw conveyor gave a screw linear velocity of 1.99 m/s and a volumetric capacity of 0.00004m$^3$/min. the machine gave a combined blade and nozzle efficiency of 57.*

## 1. Introduction

The inadequate supply of electricity is Nigeria by the electricity generation companies has grossly affected industrial and manufacturing sectors. This situation has compelled most industries to embark on the use of diesel generators as alternative source of power. High cost of diesel fuel in running diesel generators has forced some companies to close down and others to leave Nigeria for other countries where electricity is stable and affordable. It is in view of the high cost of running diesel generators that motivated this research on an alternative source of generating electricity such as sawdust. Sawdust (solid fuel) can be used to heat up a boiler, so as generate steam to run turbine for generating electricity for use in both industries and homes. This study is mindful of environmental consequences of the use of sawdust. The use of sawdust has a negligible impact on the environment as compare to fossil fuel. Sawdust is in abundance and easily be sourced at the timber saw mills at minimal cost. [1].

It is a known fact that Nigeria is endowed with large deposit of solid fuels such as coal, wood, charcoal. The wood is been processed for different applications ranging from roofing to household

and school furniture. The processing of the wood at sawmill usually leaves a lot of waste product from sawmilling. Presently this waste called sawdust are been disposed off by burning, very few is been used as insulator. In this paper a sawdust screw extruder is been designed and fabricated for generating heat which transforms water to steam for driving turbine use for electricity generation. The grinded sawdust is transported into the combustor via a screw conveyor. Also, a blower is used to introduce the oxygen along with the sawdust into the combustor for optimum burning.
The first screw conveyor was designed by Archimedes in the third century B.C for removing water from ship and for irrigating farmland. The device consisted of a hollow cylinder with a center shaft and a spiral fixed to the inner Wall of the cylinder and center shaft. As the assembly rotated, water was conveyed and lifted from one location to another. The rotating part of the conveyor is simply called as auger, [2]. Other types of screw conveyors includes horizontal screw conveyor, inclined, vertical and shaft less screw conveyors. These screw conveyors can with fitted with different feeders depending on the application or use of the screw conveyor. [3].

## 2.0 Materials and Methodology

This section presents the design and fabrication method used in this study. Appropriate candidate materials are selected for the components design, followed by the design analysis and synthesis for each components. The last stage of the process is the fabrication procedure. This design process seeks to establish the minimum safe design variables (dimensions) for critical components, such as hopper plate thickness, the shaft diameter e.t.c.

### 2.1 Materials Used

The materials used for the fabrication are listed below:

1. The Hopper
2. The stirrer
3. A stirrer motor.
4. A screw conveyor and its barrel
5. Screw Motor
6. The Blower

### 2.2 Description of the Hopper-screw conveyor system

Figure 1, shows the sectional view of the hopper-screw conveyor. This include the hopper, the stirrer, the screw conveyor and its casing, the blower. This design conveys the sawdust into the combustor with the aid of a blower for complete combustion, which in turn releases heat energy into the steam boiler.

The selection of the appropriate material for design is key to the success of the design process, [4]. The factors used for the selection of the candidate materials are presented in Table 1, as explained by [5] and [6].

### 2.3 Design of Hopper and Conveyor Screw

A frustum hopper is chosen to store the sawdust before being conveyed by the screw conveyor. A stirrer driven by and AC electric motor were attached to the stirrer, (see Figure 2), the hopper temporarily stores the sawdust before it moves into the screw conveyor. Therefore it is important that thickness of the frustum can bear the load due to the weight of the sawdust. The volume of the hopper and the thickness of the hopper plate are estimated using equations 1-3.

The volume of the hopper in Figure 3, is computed using equation 1.

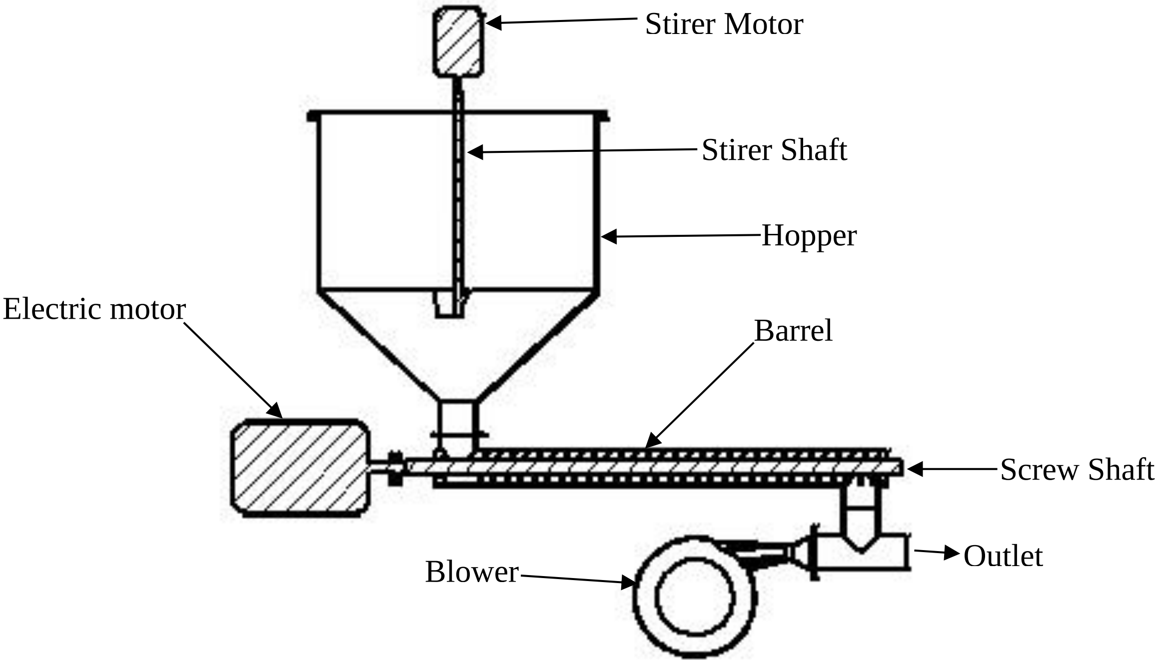


Figure 1: Schematic Diagram of the Hopper-screw conveyor.

Table 1: Material selection criteria.

| S/no | Component | functions | Objective | Constraints | Candidate material | Cost/ Availability |
|---|---|---|---|---|---|---|
| 1. | Hopper | To contain the sawdust | Minimize failure | Strength and Rigidity | -Mild steel<br>- stainless steel | - Cheap and easy to fabricate. |
| 2. | Screw conveyor | To transport the sawdust | To minimize torque loss | High rigidity and Fatigue | High carbon steel | Expensive and easy to turn |
| 3. | Screw Conveyor Barrel | To house the screw and material | Moderate strength | Rigidity | - Mild steel | - Cheap and available |
| 4. | Blower | Supply oxygen and to convey the sawdust | Continues air supply | Speed | Nill | - cheap |

$$V = \frac{\pi h}{3}(R^2 + Rr + r^2) \quad (m^3) \qquad (1)$$

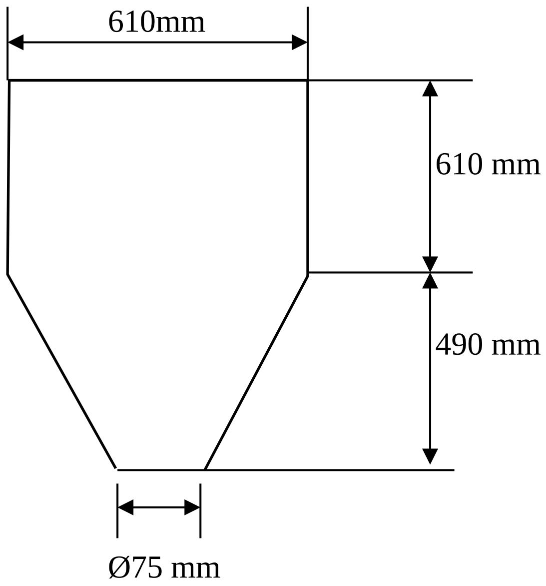

Figure 3: Frustum diagram.

Substituting the values from Figure 3, into Equation 1 gives;

$$V = 0{,}492\ m^3 \approx 0.5m^3$$

The thickness of a steel plate use for the hopper is calculated from equation 2 [7];

$$\sigma = \frac{0.57P^2}{t^2(1.61(a/b)^3+1)} \qquad (2)$$

Where;

$$t = \sqrt{\frac{0.57 \times N \times P^2}{\sigma(1.61(a/b)^3+1)}} \qquad (3)$$

Where

$t_p$ = plate thickness.
P = Load on the Plate, N.
$\sigma$=Hopper material yield stress, 214MN/$m^2$, [4].
a = width, 0.61m, (chosen).
b = length, 1.11m, (chosen).
N= factor of safety, 2, [2].

The load, P (N) acting on the hopper plate is estimated from the sawdust density and the volume of the sawdust, i.e.

$$P = \rho \times v \times g \qquad (4)$$
$$= 716.2 \times 0.5 \times 9.8 = 3.51kN \approx 4kN$$

Therefore;

$$t_p = \sqrt{\frac{0.57 \times 2 \times 3.51e3^2}{214e6(1.61(\cdot{}^{61}/_{1.11})^3 + 1)}} = 0.21mm \approx 0.3mm$$

A 0.3mm thick mild steel plate will be safe to fabricate the hopper.

The main function of the screw conveyor in Figure 3 is to convey sawdust into the combustor with the aid of a blower by rotating and, therefore must possess the required torque, fatigue and safe diameter to be able to perform this function.

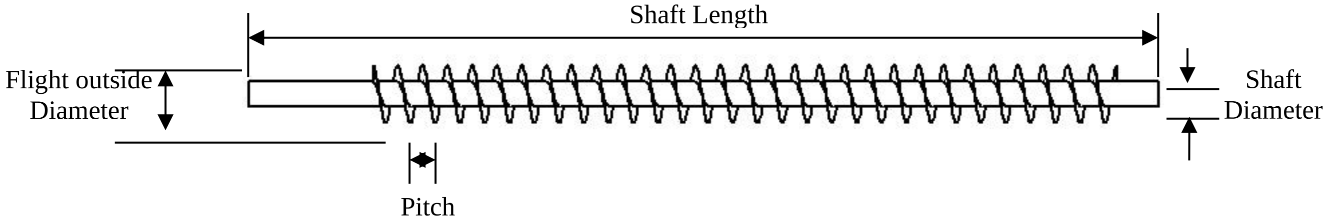


Figure 4: Design of Screw Conveyor.

Theoretical volumetric capacity of sawdust (Qt, $m^3$/min) is expressed by the equation 5, [8];

$$Qt = \frac{\pi}{4}(d_{sf}^2 - d_{ss}^2)\, l_p \qquad 5$$

Data:

Screw flight diameter, dsf, = 0.07m
Screw shaft diameter dss = 0.03m
Pitch length, $l_p$ = 0.05m
Screw rotational speed, N = 0.25 rpm, [9]

Therefore :

$$Qt = \frac{\pi}{4}(d_{sf}^2 - d_{ss}^2)\, l_p n \qquad (6)$$

Qt = 0.7855 (0.004 ) 0.0125
Qt = 0.000039275 $m^3$/min
Sawdust density, $\rho$ =716.2 kg/$m^3$, [2].

The per hour capacity of the screw (C) is estimated as;

$$C = \frac{0.7854\,(DS2 - DP2)\,P\,K\,60}{1728} \qquad (7)$$

Where;

C = Capacity $Cm^3$ / hour, (rpm).
$D_S$ = Diameter of Screw, ( mm).
$D_P$ = Diameter of pipe, (mm).
P = Pitch of Screw, (mm).
K = Percent tough loading.

The screw conveyor diameter, travelling speed, screw power were estimated using equations 8-10;

$$As = \lambda \frac{\pi {D_s}^2}{4} \qquad (8)$$

$$v = \frac{p \times N_s}{60} \qquad (9)$$

$$P_s = \frac{D \times L}{20}\ (kW) \qquad (10)$$

Where;

As = conveyor loading flight area, ($m^2$).
$D_s$= screw shaft outside diameter, (m).
$\lambda$ = type of load factor, (for non-abrasive material $\lambda = 0.4$)
*P*= pitch, 50mm.
V= sawdust travelling speed (m/s).
$N_s$ = rotating speed of the screw in rpm, (for light material N<150 rpm, [10]).
$P_s$=screw power, (kW)

$$As = \frac{\pi {D_{fa}}^2}{4} = \frac{3.142 \times 75^2}{4} = 4418.44mm^2 = 0.0044m^2$$

Therefore, the screw diameter;

$$D_s = \frac{4A_s}{\lambda \times \pi} = \frac{4 \times 0.0044}{0.4 \times 3.142} = 0.014004m \approx 20mm$$

$$v = \frac{50 \times 2.388}{60} = 1.99\frac{m}{s}.$$

$$P = \frac{D \times L}{20} = \frac{0.020 \times 0.5}{20} = 0.005kW.$$

The mass flow rate, $\dot{Q}$ of the sawdust is; $\dot{Q} = A \times V = 1.99 \times 0.0044 = 0.008765\ m^3/s$

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## 2.4 Blower Selection

The proper selection of a blower is highly dependent on system design and the ultimate performance objective. In this research work, it is the piping and discharge system characteristics that are the objective function. For a blower, as the flow rate increases, the blower pressure tends to drop-off, therefore where the system curve meets the blower curve determine operating point for the entire system. The cubic feet per minute (CFM) of the blower is calculated from equation 11 and used to select the an appropriate blower.

$$cfm = \frac{mass\ flow\ rate}{air\ density}, [11]. \quad (11)$$

$$= \frac{0.008754}{1000} = 8.754\ x\ 10^{-6}\ m^3/s$$

## 2.5 Fabrication and Assembly

At the end of the design analysis presented in the previous sections, the fabrication of the screw conveyor for a steam power plant is presented in Table 2 as shown; in Appendix A.

Table 2: Sawdust Hopper and Screw Conveyor Fabrication Method.

| S/No. | Description of Components | Type of material | Dimensions (mm) | Equipment used | Method of fabrication |
|---|---|---|---|---|---|
| 1 | Hopper | Sheet of mild steel iron | Ø 610x1110x100 | Cutting and welding machine | Cutting and welding |
| 2 | Screw conveyor casing | Mild steel iron | Ø 74x500 | Cutting and welding machine | Cutting and welding |

| | | | | | |
|---|---|---|---|---|---|
| 3 | Screw blade | Mild steel iron | Ø 70x500 | Cutting and welding machine | Welding and grinding |
| 4 | Screw shaft | Mild steel iron | Ø 30x500 | Cutting and welding machine | Welding and grinding |

## 3.0 Results and Discussion

The mechanical design results of the screw conveyor is presented in Table 3. The critical components dimension of the screw conveyor were estimated through calculation, such as screw speed, screw diameter, power required e.t.c. this values were used for the fabrication of the screw conveyor.

Table 3: Results of the Mechanical Design.

| S/no | Description | Value |
|---|---|---|
| **Sawdust Hopper** | | |
| 1 | Sawdust hopper volume | 0.492$m^3$ |
| 2 | Thickness of the hopper plate | 0.3mm |
| 3 | Blower capacity | 22pa, 18kpa, 14kpa, 165$m^3$/hr |
| 4 | Motor capacity | 5kW |
| **Screw conveyor** | | |
| 5 | Diameter of the screw shaft | 0.03m |
| 6 | Screw flight diameter | 0.07m |
| 7 | Screw pitch length | 0.05m |
| 8 | Volumetric capacity of the screw conveyor | 0.00004 $m^3$/min |
| 9 | Sawdust travelling velocity | 0.125m/s |
| 10 | Screw power requirement | 0.005kW |
| 32 | Actual nozzle angle | 23.72° |
| 33 | Velocity coefficient | 0.961880281 |
| 34 | Exit speed | 1007.5 ft/s |
| 35 | Blade work per unit mass | 38.5btu/lb |
| 36 | Actual energy available to the blade | 62.8Btu/lb |
| 37 | Blade efficiency | 61.3% |
| 38 | Ideal entrance/blade velocity | 1843.89 ft/s |
| 39 | Nozzle efficiency | 93% |
| 40 | Combined nozzle and blade efficiency | 57% |

The picture of the fabricated/assembled screw conveyor for the steam power plant is shown in Figure 4.

Figure 4: Fabricated Hopper-Screw Conveyor System

## 4.0 Conclusion

This project presented a successful design analysis and fabrication of a sawdust screw conveyor for a steam power plant. The power plant is used to generate electricity from waste sawdust that liters around the sawmill. The sawdust screw conveyor used a screw shaft to convey the grinded sawdust into the combustor via a blower, this consist of sawdust hopper with stirrer, screw conveyor, electric motors, screw barrel. Most of the components were fabricated using mild steel, because of it is cheaper, available and easier to fabricate. The hopper has a maximum capacity of 0.5 $m^3$. While the screw conveyor has a discharge of 165 $m^3$/hr and velocity coefficient of 0.96 using a 5 kW electric motor.

## References

[1] T. O. Olanrewaju, I. M. Jeremiah and O. P. E., "Design and fabrication of a screw conveyor, AgricEngInt:," *CIGR Journal Open access at http://www.cigrjournal.org,* vol. 19, no. 3, pp. 156-162, October 2017.

[2] M. W. Mayur and K. K. Vijay, "Design and Analysis of Screw Conveyor at Inlet of Ash/Dust Conditioner," *International Journal of Emerging Technology and Advanced Engineering,* vol. 5, no. 5, pp. 291-296, 2015.

[3] S. Conveyors, "KWS Design Engineering Manufacturing," *Screw Conveyor Engineering Guide,* 11 April 2016.

[4] J. Carvill, "Mechanical Engineer’s Data Handbook," Elsevier Science Ltd, Sormerset, London., 2003.

[5] A. Babawuya, "Design and Development of Serial and Parallel Manipulator," A PhD Degree Thesis, Ahmadu Bello University, Zaria, 2015.

[6] I. A. Daniyan, A. O. Adeodu and O. M. Dada, "Design of a Material Handling Equipment: belt Conveoyr System for Crushed Limestone Using 3 Roll Idlers," *Journal of Advanced Engineering and Tecnology,* vol. 1, no. 1, 2012.

[7] R. S. Khurmi and J. K. Gupta, A Textbook of Machine Design, Multicolor Edition ed., New Delhi: Eurasia Publishing House, 2008.

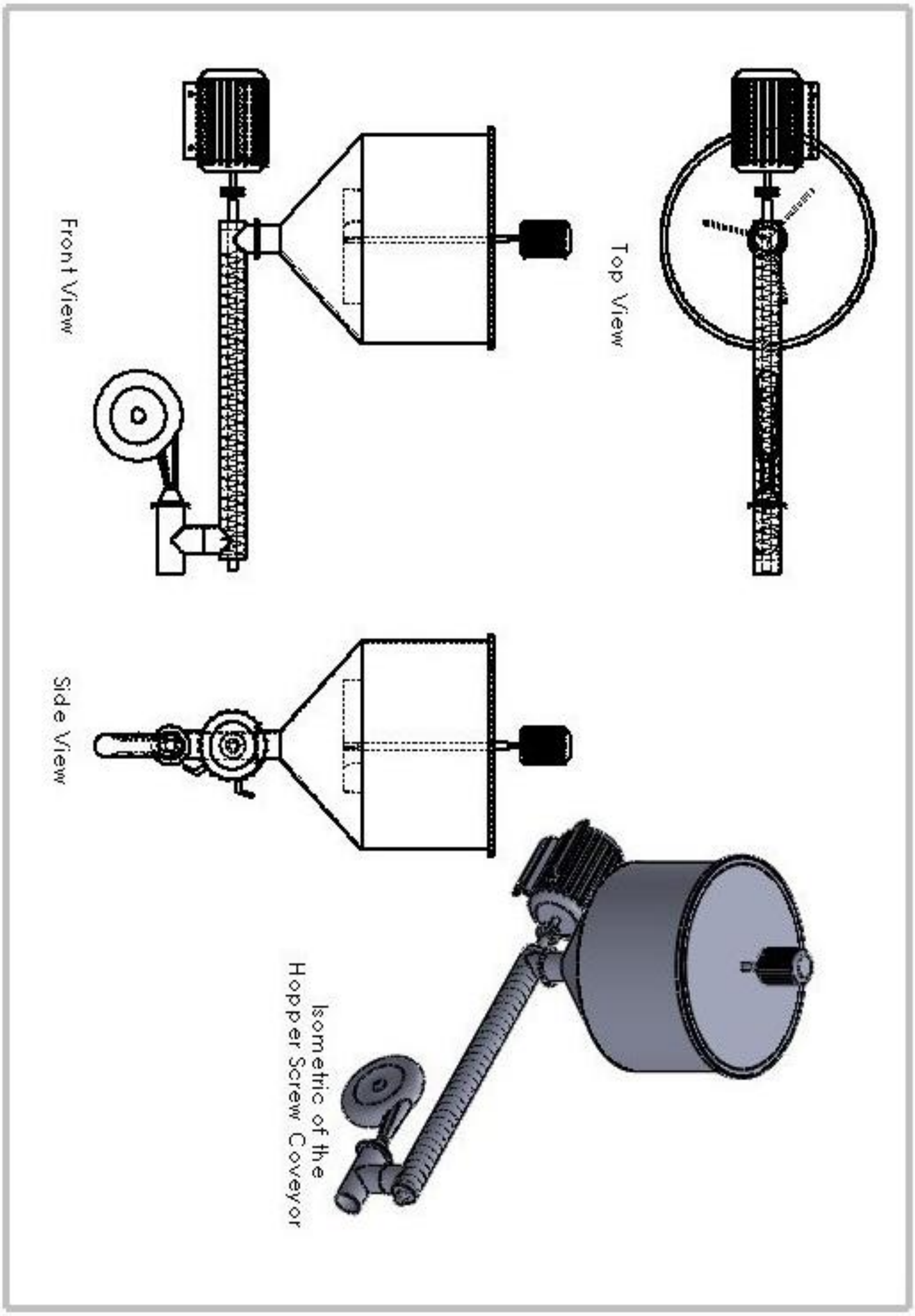
[8] G. M. Pratima, A. D. Lokhande, T. M. Savita and A. S. Sangita, "Peanut Sheller using Screw Conveyor," *International Journal of Current Engineering and Technology,* vol. Special, no. 4, 2016.

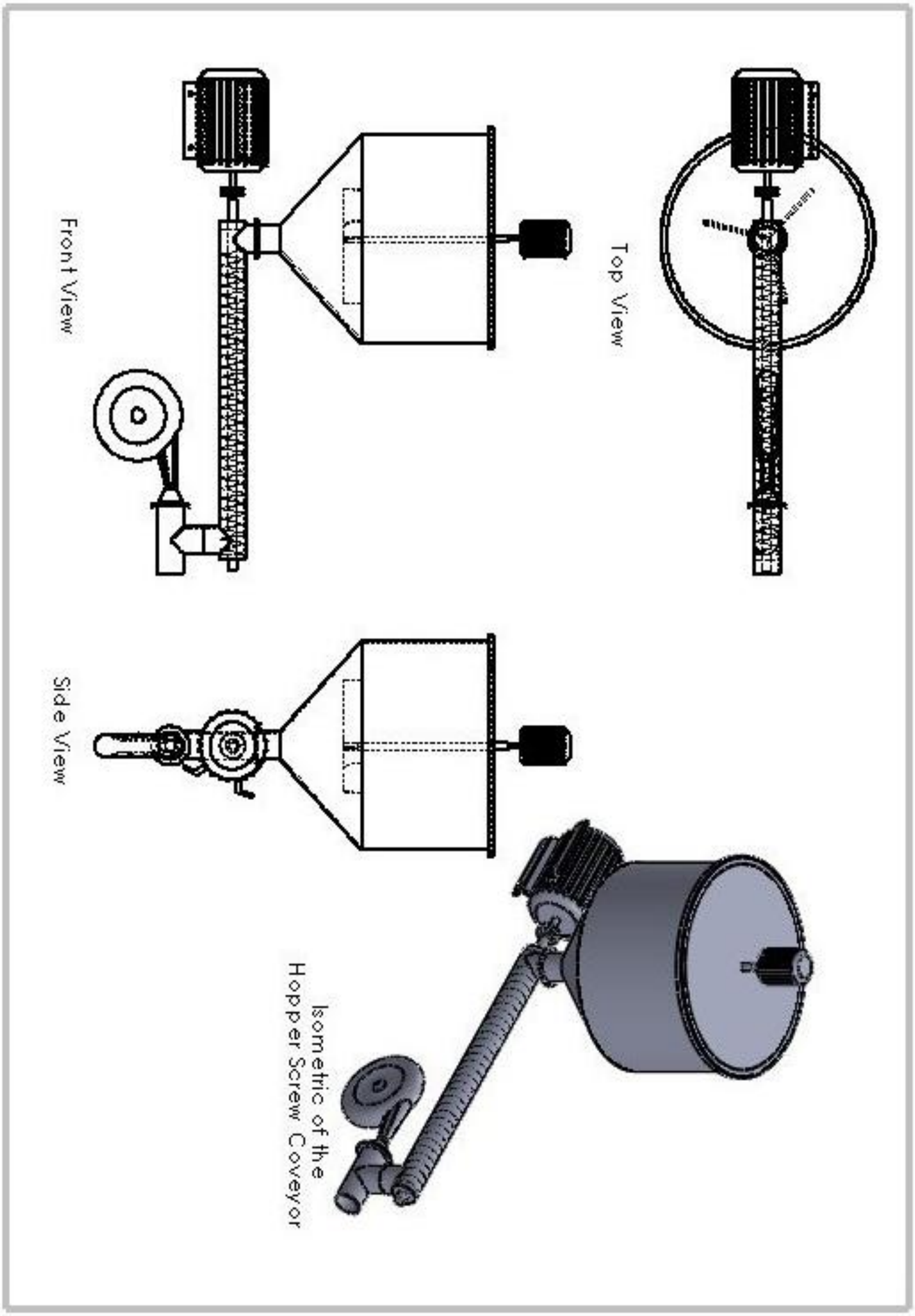
[9] A. Ramesh, P. Karunaker and L. Ramesh, "Design and Analysis of Discharging of Dust in Pneumatic Conveying System by a Screw Conveyor Shafts , Advanc," in *e Research and Innovations in Mechanical, Material Science, Industrial Engineering and Management - ICARMMIE*, Bonfring, 2014.

[10] CEMC, "Screw conveyor componentS & design Version 2.20," Conveyor Engineeing and Manufacturing Co., 2012.

[11] N. L. Rakesh, D. G. Bhavin and H. J. Hameed, "Design & Fabrication of Conveyor Mechanism for High Temperature Molten Chocolate," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 4, no. 7, pp. 6056-6064, 2015.

## Appendix A: Drawings




Front View
Top View
Side View
Isometric of the
Hopper Screw Coveyor