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Design, Analysis and Development of Rotary Rotor Bagasse Dryer for Smart Jaggery Plant

Satish Yadav[1], Dr. Pramod Magade[2], Dr. B.M. Shinde[3]

[1]*PG Student, Department of Mechanical Engineering, Zeal College of Engineering and Research,Pune, Maharashtra,India.*

[2]*Professor, Department of Mechanical Engineering, Zeal College of Engineering andResearch, Pune, Maharashtra, India.*

[3]*Professor, Dhole Patil College of Engineering, Pune, Maharashtra, India.*

ABSTRACT

Bagasse, a by-product of sugar industry and jaggery plant is utilized as a fuel for boilers. The price of crude oil is touching to the sky and being a non-renewable resource, its availability will decrease, and its cost will steeply rise with time. Improving the use of bagasse in furnaces is currently an important strategy. If moisture content of bagasse is reduced, it will help in increasing its calorific value (Cv) and will improve the boiler efficiency.

In this project work, focus is on increasing the efficiency of bagasse. Major steps involved in the process are mechanical crushing of sugarcane, evaporation, juice clarification and cooling. The bagasse generated on site is completely consumed for juice heating and evaporation. Here, bagasse dryer (Rotary Rotor Type) has been designed, analysed the design for optimization, developed its prototype. For testing and validation of this system, three samples are taken into consideration i.e. average weight of the wet bagasse is kept the same i.e. 5.2 kg. Sample A loses its weight by 0.67kg at 85°C temperature. Sample B loses its weight by 0.4kg at 75°C temperature. Sample C loses its weight by 0.2kg at 65°C temperature. With increasing temperature, moisture gets reduced i.e. Temperature is inversely proportional to the moisture. Here, achieved efficiency is 81.7%.

***Keywords**: Bagasse,Baffles,Boiler, Dryer, Flue gas, Jaggery,moisture, Rotor, Sugarcane*

1.Introduction

Thermal energy for evaporation of juice is provided by combustion of bagasse, which is a biomass generated after cane crushing. The dry bagasse is excellent solid fuel with less than 2% ash and heating value equivalent to B-grade coal (about 4500 kcal /kg). Material flow diagram for jaggery making process is presented in figure 1.

Bagasse is the residual fiber that remains after the crushing of cane. It consists of water (moisture), fiber and small amount of soluble solids. Bagasse represents 12% of the total sugarcane mass. The cane, after being cut, crushed in conventional and non-conventional mills in a sugar industry leaves moist bagasse. The bagasse is sometimes post-processed for other industrial applications like paper industries and bagasse is even used as a reinforcement fiber in composites. In some sugar industries around the world, the bagasse is used for power production.

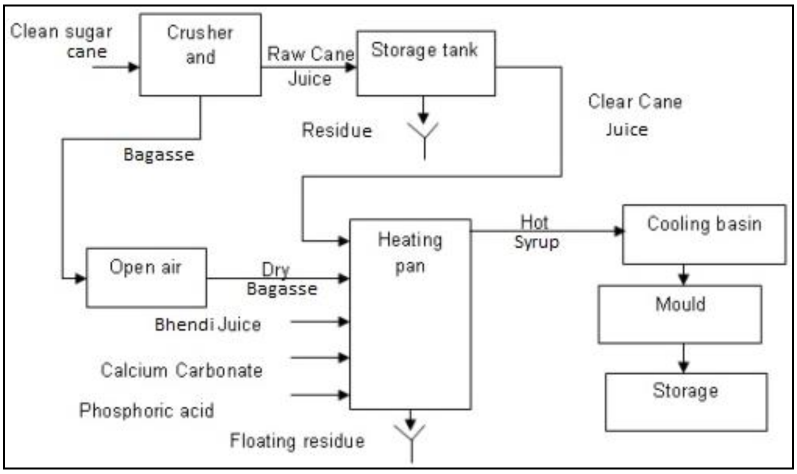

Fig. 1 process flow diagram for jaggery plant [9]

1.1Objectives

- To design& analysis of bagasse dryer.
- To develop the model of sugarcane bagasse dryer using CAD software.
- To Increase efficiency of boiler.
- To Design and Modification of Mechanism.

2.Literature Survey

L. Praveen Raj and B. Stalin have discussed about the use of pneumatic dryer in which hot steam is used as the medium for drying. The work shows that 5% reduction of moisture in bagasse leads to 7% increase in boiler efficiency and 5% increase in power output. [1]

Sankalp Shrivastav, Ibrahim Hussain have discussed about drying bagasse by using flue gas (at 190°C) is an optimum solution to enhance efficiency of boiler in sugar factory. A bagasse-dryer placed in between the air preheater and chimney and flue gas passed from dryer's one end and bagasse from another end. This increases boiler efficiency from 79% to 81% in sugar industries. [2]

S. I. Anwar has discussed about jaggery making furnaces in which sugarcane bagasse is used as a fuel. An attempt has been made to use microwave oven for drying of bagasse. It took about 20 to 25 minutes for the determination as compared to 8-10 hours in conventional air-drying method. [3]

Mr. Godfrey has discussed about furnace design and bagasse conditions considering the burning of bagasse. The furnace design should be such that the gaseous products from the three zones should firstly be mixed by passing through a narrow passage and impinged on the opposite wall of a relatively large internal chamber and by reverberation, the walls of this chamber become incandescent; thus completing the combustion. [4]

Mr. B P Edwards has discussed about drying methods, dryer characteristics and its cost. The drying of bagasse has become the subject of great interest in order to increase the production rate, system efficiency and profit. [5]

Opere Joel Akomohas discussed about power generation internally in the factories and also exported to the grid. The main stages of the study included the design of the drier, determination of the Cv of dried bagasse and its effect on combustion. [6]

B. P. Edwardshas also discussed on disposal of mud and ash, particularly in wet weather conditions, is a significant expense for mills. The performance of a pilot flue gas dryer for drying mud and ash was evaluated. The mud and ash mixture was found to dry much faster than final bagasse.[7]

J. Sudhakar, P. Vijay have discussed about Sugar mill wet bagasse used as a fuel in sugar industry. This paper discusses about the bagasse dryer installation and operation. [8]

2.1 Research Gap:

A short lead time in process of Jaggery output is highly demanded to satisfy the increasing consumption needs of Jaggery in the Indian market. In India, the tea business is booming nowadays. Our ancestors used to use

Jaggery for preparing tea as Jaggery is always good for health. In order to bring this Jaggery tea to the forefront of the modern age, many tea franchises are working on their authentic recipes of Jaggery Tea and coffee variants. They are deriving the various jaggery products like Cubes, Cream Roll, Shashi barfi etc.

With increasing demand of jaggery, it is immensely necessary to shorten the lead time in jaggery production. Drying of Bagasse is important process to shorten the lead time in Jaggery production.Over 400 types of dryers have been reported in the literature and more than 100 distinct types,few are commonly available. There are many methods available for bagasse drying but the rotary dryer is one of the most economical and simple design. In this mechanism, there are two main types:

i. Drum is stationary and rotor is rotating

ii. Drum rotating method.

3. Calculations and Analysis of Design

In this section, calculations of design are done by referring the standards, catalogues and reference books. During this work, designfinalization, dimensions of the parts and material selection are determinedwith reference to the function and loading conditions of the parts. Thermal analysis is additionally checked to confirm thermal sustainability of the system.

3.1 Motor Selection

Choosing a motor that runs at max efficiency at load pointof the application whichallows the designer to optimize the performance.

Load of bagasse to feed in the rotary drum = 30kg = 300N [3]

3.2 Design of Rotor Baffle

Baffles are assembled on the rotary shaft which is powered by a motor. Assembly of Shaft and Baffles is fitted in the stationary drumas shown in Fig.2.

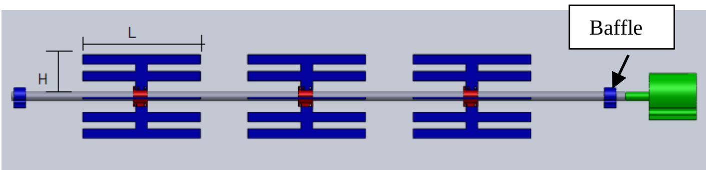

Fig.2 design of shaft-baffleassembly

Considered Design load = 300 x1.5 = 450N→500N (considered more than the calculated).

Here, drum diameterconsidered is D = 200mm, Baffle height H = 90mm

So Max Torque T = Effort x Radius of rotary shaft-baffle assembly

Total torque on crank = 500 x90 = 45000N-mm, Max Speed of drum = 10rpm

By considering application and extra jerk and safe design; power considered = 0.5 hp

σ = 193N/ mm2 considering factor of safety = 3.

As per Design data book, shaft material selected is Carbon steel C40.

C40 =>σ_{ut} = 580 N/mm^2, σ_y = Yield = 435 N/ mm^2, Length = 900 mm

Max. bending moment BM = 250 x900 = 225000N-mm

Here,

M= $(\pi/32) \times d^3 \times \sigma$…………….(Eq.1)

σ = 193 N/ mm2 considering factor of safety = 3

By using above equation drive shaft diameter d= 22.81 mm

Hence, diameter of shaft = 25mm is selected considering extra jerk and for safe design.

3.3Heat load calculations

Purpose of these calculations is to know the amount of heat that needs to be supplied in order to remove the moisture from wet bagasse.

Assumptions:

Total mass of Bagasse = 5.2 Kg, Mass of water content in total Bagasse = m_i= 2.5 Kg.

(Assuming moisture content in Bagasse = 48%)

Temperature of air in drying chamber = 60^0 C, Specific heat of water = C_{pw}= 4.18 KJ/Kg K

Water in bagasse is at atmospheric temperature which is 27^0 C.

Amountof heat required is calculated as follows,

Q = $mi \times Cpw \times \Delta T$= 2.5 x 4.18 x (60-27) = 345KJ ………..(Eq.2)

"Q" amount of heat is being given to the water content in bagasse with the help of the collector.

For daytime, the heat required per hour is as below,

Q/hr = 345KJ/24hr = 14.38KJ/hr.

3.4Quantity of moisture to be removed

Need of this calculation is to decide the amount of moisture to remove from wet bagasse using below formula [8].

$m_w = m_p \frac{(mi-mf)}{(100-mf)}$= 2.5 x (48-25) / (100-30) = 0.82 kg ……….. (Eq.3)

Where m_w= amount of moisture to be removed, m_p= total quantity of moisture in Kg,m_i = initial qty. of moisture %in bagasseand m_f = qty. of moisture%in dried bagasse.

This quantity of moisture has to be removed from bagasse.

3.5Quantity of air required

Need of this calculation is to decide the input quantity of air to remove 0.82kg of moisturefrom wet bagasse.

Below Formula is used [8],

$Qair = \frac{mw}{wo-wi}$ = 0.82 / (0.030 – 0.0221) = 103.8 kg …….. (Eq.4)

Where mw = Quantity of moisture to remove in Kg, w_o = air humidity at outlet of heater&w_i = humidity of air at inlet to heater.

This quantity of air is required to remove considered quantity of moisture.

From SKF bearing catalogue, the bearing static capacityis selected for shaft diameter25mm = 2.32 KN

From above equation = C = 285 N

Hence, dynamic capacity Ccalculated< dynamic capacity C mentioned in bearing catalogue = 4.32KN

Hence from catalogue bearing chosenis = 61804

3.6 Analysis

Fig. 3 exhibits the Thermal analysis of Stationary Drum and Baffles assembly using Solidworks. Purpose of this Thermal Analysis is to check thermal sustainability of a system at 2.67xMax. temperature used for the trials i.e. 2.67 x 85°C = 227°C = 500 K.

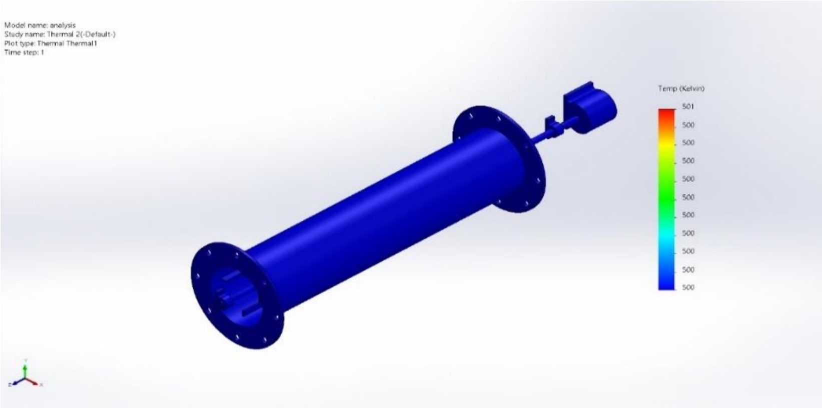

Fig.3thermal analysis of drum &baffles

The outline of this project is to remove moisture from wet bagasse to dry bagasse. The main parts related to bagasse are thestationary drum, shaft and baffles hence thermal analysis has been done on these parts. The minimum temperature at 15884 node and maximum temperature is at the node number 2706. Conclusion of this analysis is that the system under consideration is being shown in blue meaning it is very safe to use at elevated temperature.

4. Experiment Work

4.1 Fabrication

1. Various componentsaremanufactured using appropriate manufacturing processes.

2. The components are assembled as per the drawing.

3. Operating trials of the project are conducted to validate the system.

4.2 Experimental Investigations (Actual Field Trials)

The fabricated mechanism machine will be tested for the suitability to the intended application. This experimental testing will include the testing of machine at actual site.

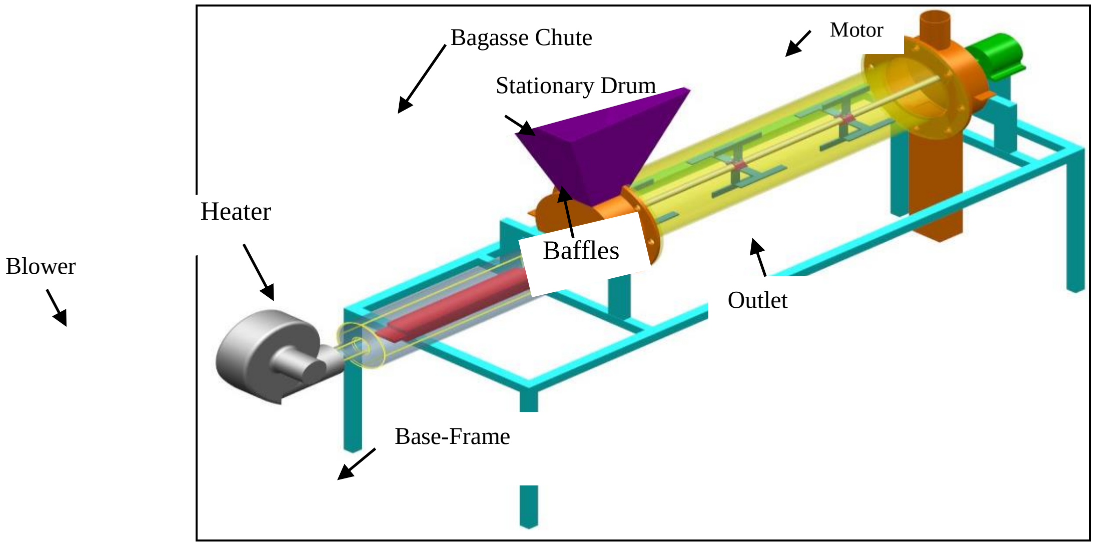

Fig. 4model of rotary rotor bagasse dryer

Fig.4 represents various parts like Base-Frame, Bagasse Chute, Blower, Heater, Motor, Stationary Drum, Outlet etc. of bagasse dryer.Bagasse is burnt directly in jaggery/khandsarimaking furnaces. Efficient burning of bagasse depends on its moisture content. Fresh bagasse has around 50% of moisture and reduction of moisture improves its calorific value. In sugar industries, bagasse is efficiently dried and in some

khandsariunits, counter-current kind of driers used. Whereas in jaggery plants, bagasse is normally sun dried[2]. Varying moisture in sun-dried bagasse affects the performance of the furnaces used in jaggery making. Therefore, it is important to determine the content of moisture in bagasse to know its suitability for using it as a fuel. Calorific value (Cv)gets increased by 10% if bagasse is dried to half of its initial moisture content. Thus a welldried bagasse generates more heat per unit weight.

Table 1 contains composition of bagasse extracted by sugar mill and jaggery units.

Table 1: Composition of Bagasse of Sugar Mill and Jaggery/Khandsari Units.

Composition	**Sugar Mill and Jaggerybagasse***
Fibre	40%
Moisture	48%
Soluble solids	12%

5. MachineTesting

To test and validate the working of developed mechanism for rotary rotor bagasse dryer, to take practical operating trials at various small farms. Also, to gather the feedbacks and enhancement requests in developed model.

5.1Experimental Conditions and Assumption for Various Calculations

Ambient temperature 34°C, Ambient relative humidity (Rh) 35%, Air temperature after air heater 42°C, Rh of air after air heater 25%, Enthalpy of air after air heater 104 KJ/Kg. of dry air, Maximum allowable air temperature in drying chamber 60°C, Enthalpy of air in drying chamber related to 60°C = 138 KJ/Kg.

Testing points and concluded points are as below:

Lot size considered = 25 kg[8]

Results of experiment for moisture content obtained from hot air dryer for the bagasse samples collected from homogenous lot have been summarized in below Table.Bagasse samples were collected at outlet of dryer and were used for moisture content determination.

5.2 Experimental Results for Bagasse Sample

Table2, 3 and 4 exhibit the 3 readings taken for each bagasse Samples A, B and C at heater temperature 65°C, 75°C and 85°C respectively. Relevant moisture removed are mentioned accordingly.

Table 2: Results of Sample A

Sample A	**Heater temp 85**˚C				
Weight of bagasse before drying in kg	Temperature at inlet	Temperature at dryer chamber	Temperature at outlet	Weight of bagasse after drying in kg	Moisture removed in kg
	T1˚C	T2˚C	T3˚C		
5.2	80.4	70.5	55	4.69	0.51
5.3	80.1	70.1	57	4.5	0.8
5.1	80.4	71	53	4.4	0.7

Table 3: Results of Sample B

Sample B	**Heater temp 75°C**				
Weight of bagasse before drying in kg	Temperature at inlet	Temperature at dryer chamber	Temperature at outlet	Weight of bagasse after drying in kg	Moisture removed in kg
	T1°C	T2°C	T3°C		
5.3	70.1	62	45	4.9	0.4
5.1	69	61	42	4.8	0.3
5.2	71	61	46	4.8	0.4

Table 4: Results of Sample C

Sample C	**Heater temp 65**˚C				
Weight of bagasse before drying in kg	Temperature at inlet	Temperature at dryer chamber	Temperature at outlet	Weightof bagasse after drying in kg	Moisture removed in kg
	T1˚C	T2˚C	T3˚C		
5.3	65	58	40	5	0.3
5.2	64.5	55	41.1	4.9	0.3
5.2	64.8	56.5	40.5	5	0.2

6. Results and discussion:

Table 5 exhibits the cumulative results of Table 2, Table 3 and Table 4 readings. It shows comparison between 3 samples considered for testing.Average weight of the wet bagasse is kept the same i.e. 5.2 kg.

Table 5: Comparison of Samples

Description	**Sample A**	**Sample B**	**Sample C**
Average weight of bagasse before drying in kg	5.2	5.2	5.2
Average weight of bagasse after drying in kg	4.53	4.8	5
Heater temperature(°C)	85	75	65
Moisture removed in kg	0.67	0.4	0.2

Sample A loses its weight by 0.67kg at 85°C temperature. Sample B loses its weight by 0.4kg at 75°C temperature. Sample C loses its weight by 0.2kg at 65°C temperature. Fig.5 shows that the moisture gets reduced with increasing temperature.

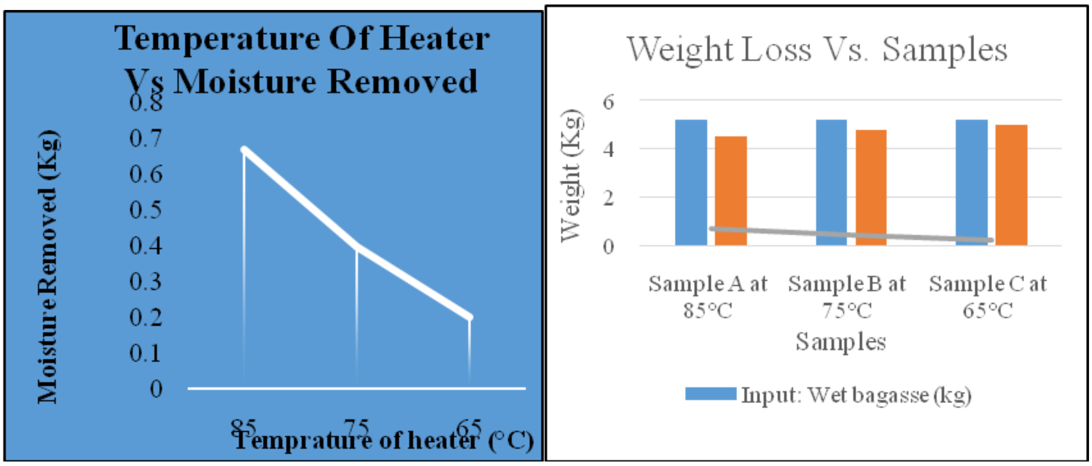

Fig. 5comparison of properties

Conclusions

After studying design calculations and results, the conclusions are as below:

i. Bagasse dryers undoubtedly save the energy and increase the efficiency of the boiler / steam generation system.

ii. 5.2 Kg of wet bagasse has 2.5Kg (48%) of moisture content. Considered moisture reduction target used for calculation is 25%.To reduce moisture from 48% to 25%; 0.82kg of moisture needs to be removed [Ref:3.4].

iii. Actual trials removed 0.67kg of moisture at 85°C. Hence 81.7% efficiency is achieved w.r.t. 0.82 kg of theoretical moisture reduction.

iv. Enlarged system of this prototype with elevated temperature input will further increase the efficiency beyond currently achieved 81.7% efficiency.

v. The main objective to design bagasse dryer to reduce the moisture from wet bagasse, found achieved with greater efficiency.

Reference

[1] L. Praveen Raj and B. Stalin, “Optimized Design of a Bagasse Dryer System for Sugar Industry”, Bonfring International Journal of Industrial Engineering and Management Science, vol. 6, Issue 6, pp. 115-119, 2016.

[2] Sankalp Shrivastav, Ibrahim Hussain, “Design of Bagasse Dryer to Recover Energy of Water Tube Boiler in a Sugar Factory”, International Journal of Science and Research (IJSR), Vol. 2, Issue 8, pp. 2319-7064, 2013.

[3] S.I. Anwar, “Determination of Moisture Content of Bagasse of Jaggery Unit Using Microwave Oven”, Journal of Engineering Science and Technology, Vol. 5, Issue 4, pp472-478, 2010.

[4] Mr. Godfrey “Types And Designs Of Bagasse Furnace” Sub - Committee of Natal Sugar Technologists Association.

[5] Mr B P Edwards “Bagasse drying” Sugar research institute, Mackay. F Plaza, A Booth “Mixing And Drying Mud And Ash At Tully Mill” Queensland University of Technology, Brisbane

[6] Opere Joel Akomo “Open Air Drying Of Bagasse - Potential In Sugar Industries”

[7] B. P. Edwards, “Bagasse Drying”, Proceedings of Australian society of Sugar Cane Technologists, 1981.

[8] J. Sudhakar, P. Vijay, Control of Moisture Content in Bagasse by Using Bagasse Dryer, International Journal of Engineering Trends and Technology (IJETT), Volume-4 Issue-5 Year of Publication: 2013.

[9] Prof. V. V. Patil1, Prof. A.M. Patil, Prof. P. D. Kulkarni, “Design And Development Of Bagasse Dryer For Modern Jaggery House”, International Journal of Advance Research In Science And Engineering, Vol. 3, Issue 1, 2014.

[10] Mr. R. S. Khurmi and J. K. Gupta Machine Design Pub.: Eurasia Publishing House Pvt.Limited.

[11] S. P. Shingare1 and B. N. Thorat1, SUGAR CANE BAGASSE DRYING – A REVIEW 16th International Drying Symposium (IDS 2008) Hyderabad, India 9-12 November 2008.

[12] Juan H. Sosa-Arnao1, Jefferson L. G. Correa2, Maria A. Silva3 and Silvia A. Nebra,Sugar cane bagasse drying - a review, Article in International Sugar Journal · July 2006.

[13] D.Ravichandran1, V. Kavinkumar2, K. Madhan kumar2, M. Prasanth2, T. Ramkumar, Design and analysis of bagasse dryer for boiler, International Journal of Intellectual Advancements and Research in Engineering Computations, Volume-5.

[14] Milkessa Gurmesa1, Mahesh Gopal 2*, Edosa Ketema, Design Of Solar Bagasse Dryer, International Journal On Engineering Technology and Sciences – IJETS ISSN (P): 2349-3968, ISSN (O): 2349-3976 Volume VIII, Issue III, March – 2021.

[15] Greg Wheatley 1, Rong Situ 2, Jarrod Dwyer 3, Alexander Larsen, Dryer design parameters and parts specifications for an industrial scale bagasse drying system,(2020) 69 (4) p 293-305 ISSN 0120-2812 | e-ISSN 2323-0118.

[16] A.A. Tawfik1 , A.K. Abdel-Rahman2 , M.R. Bayoumi3 , And M.G. Morsy, Bagasse Drying: Advantages And Merits (Performance Of A Fluidized-Bed Bagasse Dryer), Egypt-Japan University Of Science And Technology 73 Publications 827 Citations.

[17] Anthony Anukam a,b,n , Sampson Mamphweli a , Prashant Reddy c , Edson Meyer a , Omobola Okoh, Pre-processing of sugarcane bagasse for gasification in a downdraft biomass gasifier system: A comprehensive review.