PERFORMANCE EVALUATION OF A FORCED CONVECTION SOLAR BAGASSE DRYER TO INCREASE THE BOILER EFFICIENCY.

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Abstract*-Conservation of energy in the boiler have need of drying bagasse ,because there are more than 600 sugar factories in India and each sugar factory must have boiler for the production of steam for generation of electricity.. Bagasse drying is one of the best solution of energy conservation in boiler. Objective of this work is to reduce the moisture contents of bagasse by using solar energy. Efficiency of boiler increases by 1-2 % by reducing bagasse moisture 1-2%. Sugar cane bagasse have high GCV but due to 40- 50% moisture, it is not possible to achieve its full heat. So for improve the boiler efficiency by using solar energy is the work of experiment. Experimental setup is designed at least reduced the bagasse moisture by 2% and after drying of bagasse it is proven that moisture is reduced by 2%. Reduction of bagasse moisture from 50% to 48% and improved the boiler efficiency by 1.075%.*

Keywords*-Bagasse Dryer, GCV, Boiler Efficiency, Moisture content of bagasse, Sugar Factory.*

1. INTRODUCTION

Bagasse is a byproduct of sugarcane after crushing into the mills. This bagasse are used in factory for boiler as a burning fuel. So this bagasse having moisture contents are 40-50%. This moisture contents are effects on the boiler efficiency due to low calorific value of wet bagasse. So here try to minimize the moisture of bagasse and increase the boiler efficiency and for that we design, fabricate solar bagasse dryer. The objective of this work is to reduce the moisture of bagasse at least 2%. As the gross calorific value of bagasse increases the requirement of bagasse i.e. fuel reduces for same output. Hence the boiler efficiency increases by 1 %. As the bagasse requirement of particular output reduced the bagasse energy can be saved, it is nothing but the energy conservation. Bagasse costs rupees 2 per kg in current market. If the sugar factories having cogeneration plants then bagasse dryer definitely considerable cost can be saved with low payback periods.

Mr. Avesahemadet al [1]Experimentally it is proved that solar drying technology is economical viable and possible in this review paper we reviewed direct mode, indirect mode and mixed mode solar dryer for various agricultural crop. From paper select the indirect type forced convection solar dryer for remove the moisture and increase the boiler efficiency.

Chetan T. Patel et al [2] Inthis research paper from the data related to the boiler, if higher GCV coal is used, then the efficiency should be increased.Moisture content and ash inside the fuel which affects on the efficiency. In this paper using semi bituminous coal having efficiency is 80.30% because it's high heating value and less moisture. WhileIndian lignite coal gives 78.21% efficiency on the same boiler because of it has more moisture contents than the semi bituminous coal.

Lakshmi PathiJakkamputi et al [3] This paper present analytical calculations done to study the performance improvement ofthe jagerry making unit using solar collector and solar dryer. In the conventional process of jaggery preparation, dry bagasse is used as raw material for the combustion process. Around 45% of total energy produced in the combustion process is effectively utilized for jaggery preparation and remaining 55% of total energy is lost through flue gases, ash and walls.

SankalpShrivastav et al [4] In this research paper study of Bagasse drying by using flue gases comes from air preheater to chimney is a best solution to improve efficiency of boiler in sugar factory as bagasse has high calorific value but due to because its moisture about 50 % not able to use its all heat. Improved GCV of bagasse about 790 KJ/Kg which improves boiler efficiency from 79 % to 81 % in sugar factory.

1.1 Problem Statement

Bagasse having moisture contents is 40-50%, this moisture are effects on the efficiency of boiler due to lower calorific value of wet bagasse. This effects on consumption of bagasse are required more quantity & its affects on other cogeneration plant for shortage of bagasse in sugar factory.For solution on this problem we "Design and Fabricate Forced Convection Solar Bagasse Dryer".

1.2 Objectives:

- To use solar energy for drying bagasse.
- To develop a forced convection solar bagasse dryer. Forced convection of air is to be used for efficient bagasse drying.
- To reduce bagasse moisture at least 2 %.
- To improve calorific value of bagasse and hence to decrease the losses associated with the moisture of bagasse.
- To improve boiler efficiency. As the losses decreases the efficiency of boiler increases.

1.3 Scope of the Project:

- Today in this world of skyrocketing technology, it has become very difficult to have a hand on the control knob of worlds increasing pollution level every year.
- Thus keeping a proper balance of present as well as sustainable development in mind, we have to take steps to reserve our natural resource.
- This project has tremendous scope in future to avoid or at least reduce the use of coal (non-renewable resource) in boilers by using the effective concept of cogeneration.
- The bagasse (renewable source) availability is very high in India. Most of it goes in waste. Thus by using it in boilers instead of coal is a great idea.
- We can reserve a lot of renewable source by using such alternate energy source if treated properly.
- Bagasse being cheaper than any other source is most economical alternative fuel.
- This solar dryer has large scope as it can be used to dry any of the other material for example chilies, tapioca, grains, fruits, bagasse etc.

2. DESIGNING OF EXPERIMENTAION

2.1 Mass of Water to be Evaporated from Bagasse

Here we design the setup by assuming rate of 3 Kg/hr. of bagasse feed rate and for that how much percentage of water to be evaporated for reducing moisture to 48% will be calculate.

$$M_w = M_b \times \frac{(M_i - M_f)}{(100 - M_f)} \qquad (2.1)$$

Where,

M_b= initial mass of bagasse= 0.05 (kg)

As required bagasse feed rate is 3 kg/hr

M_i= initial moisture of bagasse= 50 (%)

M_f= final moisture of bagasse= 48 (%)

As required bagasse moisture is 48 %

Therefore

$M_w = 0.05 \times \frac{50-48}{100-48}$

M_w = 0.00192 kg

Here we design the setup by assuming rate of 3 Kg/hr of bagasse. For this feed rate how much heat energy are required for drying of bagasse to 48% and Heat energy required to dry bagasse at rate of 3 kg/hr to 48 % moisture is ,
$H_a = M_w \times L$
Where,
L= Latent heat of evaporation of water= 2256 kJ/kg
H_a= 0.00192 × 2256
H_a= 0.07219 kW

2.2 Solar Collector Area

Solar collector is blackened MS plate with 45 % collector efficiency. Considering sugar factory seasonal months i.e. from October to May.The average global solar radiation in Pune from month October to May is 0.2873 kW/m^2(This is taken from Journal of Metrological Department of India).We get the heat collected at solar collector plate by 45 % collection efficiency is,
H_c= 0.1293 kW
For the requirement of 0.07219 kW heat energy, the minimum area of solar collector required is
A_c= 0.558 m^2

2.3 The Mass Flow Rate of Drying Air

The mass flow rate of drying air is expressed as

$$M_a = \left[\frac{M_w \times L}{C_p \times \rho_a} \times \frac{1}{(T_i - T_f)}\right] (2.3)$$

Where,
L= Latent heat of vaporization= 2256 kJ/kg
ρ_a= Density of air= 1.005 (kg/m^3)
C_p= Specific heat of air at constant pressure = 1.005 (kJ/kgK)

$$M_a = \left[\frac{0.00192 \times 2256}{1.005 \times 1.225} \times \frac{1}{(51.5 - 44.5)}\right]$$

M_a= 0.5026 kg/min
M_a= 0.0084 kg/sec

2.4 Volume Flow Rate of Air

Volume flow rate of air is

$Q_a = \frac{M_a}{\rho_a}$ (2.4)

$Q_a = \frac{0.0084}{1.005}$

Q_a= 0.4 m^3/min

Q_a= 0.0067 m^3/sec

2.5 Air Velocity Calculation

Air velocity is,

$V_a = \frac{Q_a}{A}$ (2.5)

$V_a = \frac{0.067}{0.002784}$

V_a= 2.24 m/s

2.6 The Useful Power of the Motor of Blower

The useful power of the motor of blower is

$P = \frac{1}{2} M_{fa} \times V^2$ kw (2.6)

$P = \frac{1}{2} \times 0.0084 \times (2.24)^2$

P= 21.07 W

Table 2. Design details of experimentation

Sr. No	Component	Specification	Material
1	Solar collector	L=1040 mm W=540 mm H=160 mm	MS
2	Drying Chamber	L=800 mm W=540mm H=160mm	MS
3	Absorber plate	L=1040mm, W=540mm T=2mm	MS Blackened
4	Solar collector glass cover	L=1040mm W=540mm T=5mm	Glass
5	Air Blower	L= 6 inches N=2400rpm (varying) Power -21watt	Fiber
6	Strainer	Various sizes, 5 qty.	Stainless Steel

3. TEST SETUP

Fig 3. Actual experimental setup

Working of Solar Bagasse Dryer

Solar drying refers to a technique that utilizes incident solar radiation to convert it into thermal energy required for drying purposes. Most solar dryers use solar air heaters and the heated air is then passed through the drying chamber (containing material) to be dried. The air transfers its energy to the material causing evaporation of moisture of the material. In the process of drying, heat is necessary to evaporate moisture from the material and a flow of air helps in carrying away the evaporated moisture. There are two basic mechanisms involved in the drying process: the migration of moisture from the interior of an individual material to the surface, and the evaporation of moisture from the surface to the surrounding air.The bagasse and hot air get mix with each other and the moisture content in bagasse get evaporate. The bagasse dryer is so designed that the moisture of bagasse will reduced at least 2 %.The hot air and bagasse mixture leaves dryer box and enters in to the bagasse collector.

4. EFFICIENCY OF BOILER FOR VARYING MOISTURE CONTENT

The efficiency of boiler has been found out analytically for the existing and varying moisture content and calorific value which has been verified with the moisture content and calorific value obtained by experimental setup. This chapter discusses the efficiency of boiler for both the cases.

4.1 Observed Temperature at Various Times in a Day for Experimental Setup

4.1.1 May Month Readings

We taking of reading in two month after preparation of experimental setup but only optimum range readings are taken for calculations (Taken readings of May month). In that time we get the temperature at outlet of solar collector and outlet of bagasse dryer are note down.The maximum temperature of air attained leaving collector is 61 ^{0}C.

Table 4.1.1: Temperature measured in May months at various times in a day

Sr. No.	Time	Temperature of air leaving collector °C	Temperature of air leaving dryer °C
1	8 am	42	38
2	10 am	49	42
3	12 pm	61	52
4	2 pm	59	49
5	4 pm	52	46
6	6 pm	46	40
	Average	**51.5**	**44.5**

4.2 Boiler Efficiency by Indirect Method

Percentage heat loss due to moisture present in fuel (L_3)

$= \frac{Moisure\ in\ Fuel\ [584+C_p\,(T_f-T_a)]\times 100}{GCV\ of\ fuel}$[4.2]

$= \frac{0.50\times[584+0.45(51.5-27)]\times 100}{2276}$

= 13.913 %

Total Heat Loss in %**(L)**= $L_1 + L_2 + L_3 + L_4 + L_5 + L_6$

= 6.01 + 9.917+ 13.913 + 0.198 + 0.492 + 1

= 31.53 %

Boiler Efficiency before Drying of bagasse is,

Here put the initial value of bagasse moisture which is 50% found in laboratory.Then for 50% moisture of bagasse boiler efficiency is,

Boiler Efficiency =100 – Total Heat Loss in %

= 68.47 %

4.3 Experimental Efficiency of Boiler
From May month temperature observation

Improvement efficiency of Boiler after drying of bagasse is,

The reduction on bagasse moisture is got 2 %

Final GCV= 2368 kCl/kg

Initial loss due to moisture $(L_3)_i$= 13.913 %

Final loss due to moisture

$(L_3)_f = \frac{Moisure\ in\ Fuel\ \ [584+C_p\,(T_f-T_a)]\times 100}{GCV\ of\ fuel}$ [4.6]

Final loss due to moisture $(L_3)_f = \frac{0.48\ \ [584+0.45(51.5-27)]\times 100}{2368}$

Final loss due to moisture $(L_3)_f$= 12.8375 %

Improvement in Boiler efficiency = $(L_3)_i - (L_3)_f$

Improvement in Boiler efficiency =13.913-12.83

The improvement in boiler efficiency= **1.0755**

For 5 April temperature observations

Here calculate the improvement of boiler efficiency by using above (4.6) formulas in which put the temperature values of collector panel found in 5 April days.

The improvement in boiler efficiency= **0.71%**

For 20 April temperature observations

The improvement in boiler efficiency= **0.49%**

4.4 Bagasse Saving Due To 2% Moisture Reduction

Bagasse Required Per Hour is,

Heat of steam required per hour= 68599542.33 kCal/hr

Bagasse required per hour $= \frac{Enthalpy\ of\ steam}{GCV\ of\ fuel\ \times Boiler\ efficiency}$ [4.4]

$= \frac{68599542.33}{2276\ \times 0.6847}$

= 44019.8 kg/hr

Bagasse Saving:

Moisture of dried bagasse= 0.48%

$= \frac{Enthalpy\ of\ steam}{GCV\ of\ dried\ bagasse\ \times Boiler\ efficiency(Improved)}$[4.5]

$= \frac{68599542.33}{2368\ \times 0.6954}$

Dried bagasse requirement= 41655.32 kg/hr

Bagasse saving per hour=44019.8575 – 41655.32

Bagasse saving per hour**=** 2364.5375 kg

5. RESULT AND DISCUSSION

1. Aim of this experiment is reduced the moisture of bagasse.
2. Design the experiment setup for the reduction of bagasse moisture at least 2%.Below are the designed values of setup.

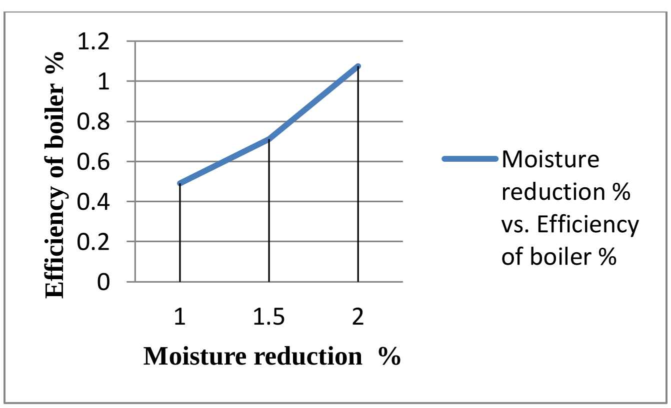
Table 5.2. Design parameter and values

Notation	Parameter	Designed value with SI unit
M_w	Mass of Water to be Evaporated	0.00192 kg
A_c	Solar Collector Area	0.558 m^2
M_a	Mass Flow Rate of Drying Air	0.0084 kg/sec
Q_a	Volume Flow Rate of Air	0.0067 m^3/sec
V_a	Air Velocity	2.24 m/s
P	Power of the Motor of Blower	21.07

3. First calculated analytical and experimental efficiency of boiler at getting moisture reduction values of bagasse. As per moisture reduced from bagasse, efficiency of boiler is increased.

Table: 5.3 Analytical and Experimental Efficiency of boiler

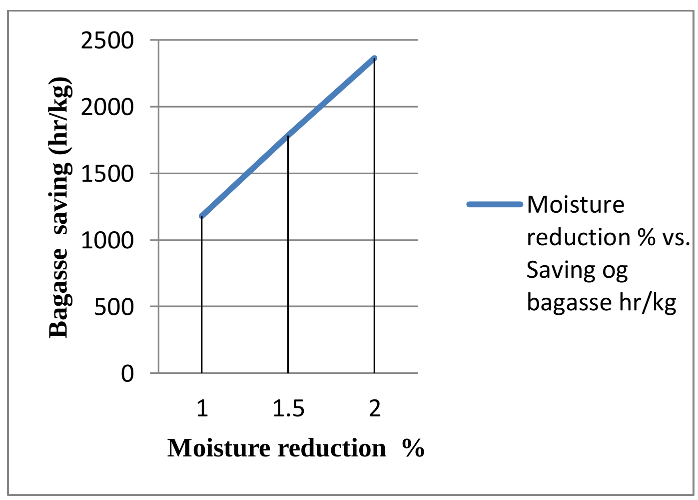
Moisture % in bagasse	Analytical efficiency %	Experimental efficiency after drying of bagasse %	Improved efficiency in %	% of diff. (Error)
47%	69.87	-		
48%	69.55	69.54	1.075	0.01
48.5%	69.18	69.176	0.71	0.011
49	69.00	68.96	0.49	0.01



Graph No.5.3 Moisture reduction Vs Efficiency of boiler

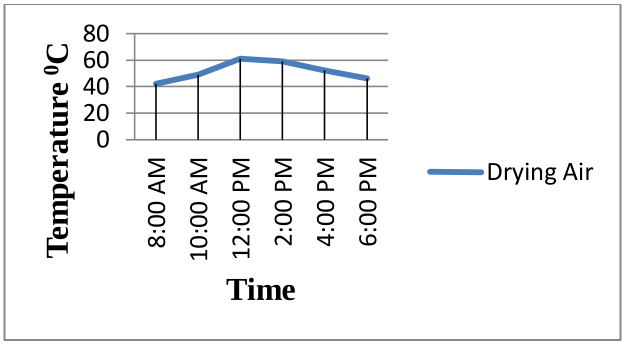
4. Experimental it is proven that bagasse moisture is reduced by 2%.
5. Improved maximum efficiency of boiler is 1.075% (68.47 % to 69.54%) this is achieve due to increase the GCV of bagasse and reduce the losses of fuel.
6. GCV of bagasse is increased from 2276 Kcal/Kg to 2368 Kcal/Kg due to reduction of bagasse moisture.Experimentally it is proven that bagasse saving is 2364.5375 kg/hr. due to reduction of bagasse moisture.Table 5.6 Bagasse saving and efficiency of boiler

Moisture reduction in bagasse (from 50%) %	Increased calorific value of bagasse Kcal/kg(from2276 Kcal/kg)	Improved efficiency of boiler %	Saving of bagasse in Kg/ hour	Cost saving in bagasse per hour in Rs.
1	2320	0.49	1180.65	2361
1.5	2350	0.71	1782.74	3565
2	2368	1.075	2364.53	4729
2.5	2430	1.54%	3031.63	6062



Graph No.5.6 Moisture reduction Vs Bagasse saving

7. The maximum temperature of air attained at leaving collector is 61 ^{0}C.



Graph No.5.7 Variation of air temperature after collector with time.

6. CONCLUSION

Each sugar factory must have boiler for the generation of electricity. Sugar factories combined with co-generation have voluminous potential of energy conservation. Heredesigned and fabricated simple forced convection solar bagasse dryer. The temperature attained by air leaving solar collector is sufficient to dry the bagasse by 2 %. The boiler efficiency improved from 68.47 % to 69.5455 %, ultimately it tends to save bagasse.GCV (Gross calorific value) of bagasse is increased from 2276 Kcal/Kg to 2368 Kcal/Kg due to reduction of bagasse moisture.Due to increase of calorific value, bagasse will be save. Bagasse saving (against the requirement of 44019.8575 kg/hr.) is 2364.5375 kg/hr.

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