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Design & Analysis Of Waste Heat Recovery System For Open Pan Jaggary Plant

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Abstract: Jaggery making from the sugarcane is a traditional process which creates local employments and entrepreneurship opportunities. Jaggery making plants are generally small units fabricated by local artisans on the basis of age-old expertise without any technical support. Bagasse is used as fuel to boil the sugarcane juice.In traditional single pan jaggery furnace due to incomplete combustion of bagasse energy losses are high resulting into higher fuel consumption and low thermal efficiency of the plat. In order to reduce the losses and cut down the consumption of bagasse, exhaust heat is utilized for preheating of sugarcane juice in pre-heater. The improved plant and the conventional plant are compared on the basis of thermal efficiency and bagasse consumption per Kg jaggery production. Resulted that thermal efficiency is improved and bagasse consumption is reduced.

Keywords: Bagasse, Boiling Pan, Pre-heating, Single pan jaggery

I. INTRODUCTION

The design and analysis of a waste heat recovery system for an open pan jaggery plant aims to efficiently utilize the waste heat generated during the production process. Jaggery, a traditional and widely consumed sweetener, is made by evaporating sugarcane juice in open pans. This process often leads to significant energy wastage in the form of hot flue gases that are released into the atmosphere. To address this issue and promote sustainability, a waste heat recovery system can be employed to capture and reuse the waste heat. This system involves the collection, extraction, and utilization of the waste heat for various purposes, such as preheating the shugercane juice. By recovering this waste heat, the overall energy efficiency of the jaggery plant can be greatly improved.

The design and analysis of such a waste heat recovery system require careful consideration of various factors, including the temperature and flow rate of the waste heat, the available technologies for heat recovery, and the specific requirements and limitations of the jaggery production process. Thorough analysis of these factors will help in selecting the most suitable heat recovery technologies and designing an efficient system that maximizes the utilization of waste heat.

In addition, economic and environmental aspects also play a crucial role in the design and analysis of the waste heat recovery system. The cost-effectiveness of implementing the system, as well as the potential carbon footprint reduction, are important factors to consider. Proper economic and environmental assessments can help justify the investment in a waste heat recovery system and ensure its long-term sustainability. Overall, the design and analysis of a waste heat recovery system for an open pan jaggery plant is a multidisciplinary task that requires expertise in thermal engineering, process optimization, and environmental sustainability. By successfully implementing such a system, the jaggery plant can not only reduce its energy consumption and operational costs but also contribute towards mitigating the environmental impact associated with its operations.

The design and analysis of the waste heat recovery system involve various aspects, including the identification of potential waste heat sources, selection of appropriate heat transfer fluids, heat exchanger design, and the integration of the recovered heat into the plant's energy system. These aspects require a comprehensive understanding of thermodynamics, heat transfer, fluid dynamics, and process engineering.

One of the key challenges in designing the waste heat recovery system is to ensure its compatibility and optimal integration with the existing jaggery plant infrastructure. This requires a thorough analysis of the plant's energy requirements and heat transfer pathways, as well as the consideration of practical constraints such as space availability and cost- effectiveness.

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II. LITERATURE SURVEY

Agalave, G. B. (2015). Performance improvement of a single pan traditional jaggery making furnace by using fins and baffle. International Journal of Advance Research in Science and Engineering, 4(4), 85–89.

The jaggery is obtained from sugarcane juice after crushing it and remaining material is called bagasse. Bagasse may be used in jaggery furnaces, sugar industry, manufacturing bricks, chemical industries, textile industries for steam generation, etc. It is a traditional process industry in India, which provides rural employment. Bagasse is used as a fuel, which saves the other fuel. Heat generated in the combustion of the bagasse is utilized for evaporation of the water in the juice. Any efficiency improvement in the thermal performance of a jaggery furnace saves the bagasse fuel and the atmosphere. At village level jaggery making is done using juice obtained after crushing sugarcane at the site with a crusher. The bagasse left after crushing is sun dried in open yard for reducing the moisture content and used as fuel in the furnace for jaggery making. A study was conducted to evaluate the overall heat utilization efficiency of these furnaces. A typical jaggery making furnace consists of fuel feeding, opening, grate, fire place, chimney, and ash chamber. At rural place, it is constructed with brick and mud below the ground level as the revenue is less with farmers. The smoke produced during combustion is made to go out through a chimney of the furnace. Manually the bagasse is continuously fed through the fuel feed opening at regular interval of time. The sugarcane juice is kept in a GI vessel placed over the fire place and boiled. The study revealed that 650 kg of juice and 350 kg of bagasse were obtained from one tons of sugarcane crushed. The crushed bagasse has 50% moisture content and after sun drying it.

Anwar, S. I. (2014). Improving thermal efficiency of open pan jaggery furnaces—a novel concept. Indian Journal of Sugarcane Technology, 29(1), 32– 34.

Thermal efficiency of open pan furnaces used in jaggery making is low. Lots of heat energy goes as waste through flue gases. Tapping part of this energy for other useful purposes would improve overall efficiency of the furnace. A waste heat recovery system (WHRS) has been developed for this purpose. It consists of a counter current type of heat exchanging system installed in flue gas channel of IISR furnace. Fresh air is sucked through it with the help of an electric blower and heated air is obtained at the outlet. A temperature rise of 30°C was obtained at mass flow rate of 160 kg/h with net energy gain of about 27 MJ in the span of 8 hours under steady-state conditions. This heated air can be used for bagasse drying, which is normally done under open sun and becomes difficult under overcast sky conditions. Jaggery drying and space heating may also be the area of usage of recovered heat.

Abhijeet, N., & Kore, S. S. L. (2020). Review on the overall Development of jaggery plantto enhance thermal efficiency. Psychology and Education Journal, 58, 2172–2180.

Jaggery is an essential ingredient in the food. Due to its medicinal properties, it keeps humans away from diseases. So, it is imperative to make good quality jaggery. Mechanical and thermal energy are used to manufacture jaggery. Effective utilization of these energies is essential for better efficiency of jaggery plant. Current single-pan jaggery plants are 14.75%–24.36%. efficient. Due to its low efficiency, jaggery traders suffer losses, and the quality of jaggery also differs. To solve this problem, it is necessary to use a new operating system. In the modified plant, a conventional single pan with the open-hearth furnace is replaced by a single open pan heat exchanger and thermic fluid heater to cope up with above mentioned losses. First batch of modified plant has an efficiency of 74.84%, whereas it has been improved to 96.49% for the second batch due to the removal of stack losses. Process time for this plant.

Appasaheb Manjare and Jitendra Hole, —Exhaust Heat Recovery and Performance Improvement of Jaggery Making Furnace‖, International Journal of Current Engineering and Technology 2106.

Jaggery processing is one of the traditional agro-based industries mainly found in rural parts of India. Most of jaggery processing units employ open earth pan furnaces for juice concentration with sugarcane bagasse as a primary fuel. In conventional jaggery plants, wet bagasse is spread over the ground and dried under sunlight. This bagasse drying technique is time-consuming, space consuming and labour intensive. In the rainy season, conventional bagasse drying is impracticable due to unavailability of intense sunlight. Also, use of alternative fuels such as wood, automotive tyres, petroleum products etc. for the operation of jaggery plant is uneconomical and non-eco-friendly. The paper deals with the design and development of modern jaggery plant with bagasse drying mechanism using waste heat recovered from walls of the combustion furnace. The paper presents an experimental performance evaluation of jaggery plant and results validated with CFD simulation. The experimental results show that heat utilized for jaggery preparation is 24%, heat loss during the jaggery preparation is 72 % and the amount of heat recovered by wet bagasse from the furnace walls is 4 %. It is observed that 54.54 % of moisture is removed from the wet bagasse using waste heat recovery from surrounding walls of the combustion chamber.

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III. METHODOLOGY

3.1 Working Principal:

1. In the clarifier tank, the heat coming out of the traditional jaggery plant is flowed from the clarifier tank by installing an ID fan at the back of the clarifier tank.
2. Initially, hot air enters the clarifier tank and enters the front chamber. Divide the hot air from it into 8 pipes and take the tank from that pipe comes into the posterior chamber.
3. 3 ducts are made at the bottom of the clarifier tank. The air again goes forward through the 2 ducts on the sides of the tank and from them the air flows out through the middle duct.
4. Because of this, sugarcane juice which is at room temperature is heated with the help of waste heat before making jaggery and the heat required for heating the sugarcane juice is obtained from the pipe and lower surface.

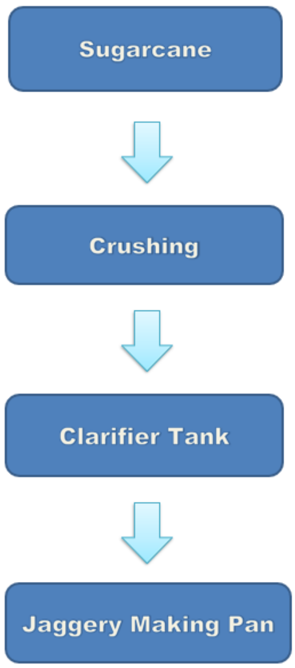

Fig. Block Diagram Of Working Process

3.2 2 D design:

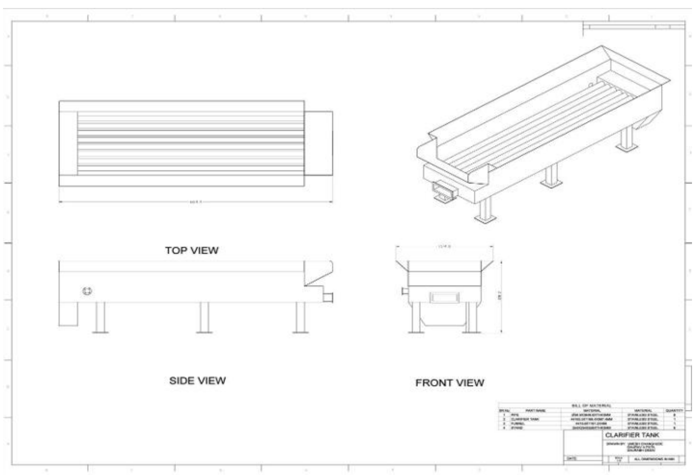

Fig. 2D Design

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3.3 3D design:

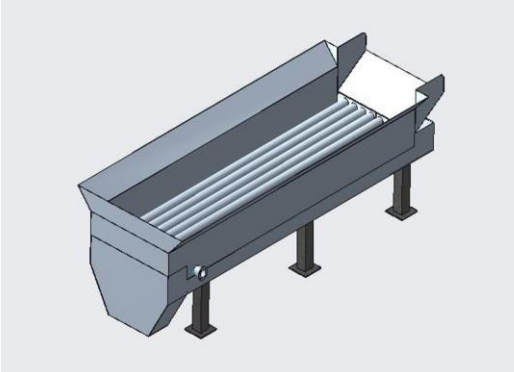

Fig. 3d Model

3.4 Prototype Manufacturing

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IV. CALCULATION

Given Data For Heat Transfer
ṁJuice = ṁc = 1 kg/s
ṁ Flue gas = ṁh = 188.88 kg/sec
c_ph = 1.5 KJ/kg °C c_pc = 4.2 KJ/kg °C t_{h1} = 130 °C
t_{c1} = 30 °C
ε = 0.60
U = 29.424 w/m^2 °C
A = 13.9151 M^2
The Outlet temperature of flue gas and sugarcane juice ($th2$, $tc2$)

$$c_h = \dot{m}\, h\, c_p h$$
$$= 188.88 \times (1.5 \times 1000)$$
$$= 283320 = c_{min}$$

$$c_c = \dot{m}c\, c_p c$$
$$= 1 \times (4.2 \times 1000)$$
$$= 4200 = c_{max}$$

$$\frac{c_{min}}{c_{max}} = \frac{283320}{4200} = 67.4571$$

$$NTU = \frac{UA}{c_{min}} = \frac{29.424 \times 13.9151}{283320} = 1.44514 \times 10^{-3}$$

$$\varepsilon = 0.60$$

$$\varepsilon = \frac{ch(t_{h1} - th2)}{c_{min}(t_{h1} - t_{c1})} = \frac{c_c(t_{c2} - t_{c1})}{c_{min}(t_{h1} - t_{c1})}$$

$$0.60 = \frac{283320(130 - t_{h2})}{283320(130-30)} = \frac{4200(t_{c2} - 30)}{283320(130-30)}$$

$$0.60 = [\frac{130 - t_{h2}}{130-30}] = 0.01482 \; [\frac{t_{c2} - 30}{130-30}]$$
$$t_{h2} = 130 - 0.60(130 - 30)$$

$$t_{h2} = 70°C\ (flue\ gas\ out\ let\ temperatre)$$

$$0.60 = 0.01482\, [\frac{t_{c2} - 30}{130-30}]$$

$$t_{c2} = 88.51°C\ (sugercane\ juice\ temperatre)$$

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V. CONCLUSION & FUTURE SCOPE

4.1 Conclusion

In conclusion, the implementation of a waste heat recovery system in an open pan jaggery plant can yield significant benefits, including improved energy efficiency, reduced fuel consumption, and lower operational costs. The key is to carefully identify and harness the waste heat sources within the production process.

4.2 Future Scope

- In distant future we can improvise our self and this making automation future scope; we can use the hot air coming out of the clarifier tank to dry the bagasse.
- When the temperature of sugarcane juice in the clarifier tank exceeds 70°C, scum forms on top of the juice. We can install automatic scum removal machine to remove this scum

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