Study of Jaggery Processing Plant to Improve the Thermal Performance
Kalyani Haribhau Nikam1 Balaji D. Nelge2 Vishal A. Meshram3
1,2,3 Department of Mechanical Engineering
Indira College of Engineering and Management Pune, India

Abstract— Jaggery industry is one of the most important cottage industries in India. Jaggery is prepared mostly by small and marginal farmers. The production process of jaggery involves crushing of cane, boiling and concentration of juice, moulding into the standard shapes and sizes and packaging in suitable packages. The thermal performance of jaggery processing plant will be improved by parameters like design of furnace, drying process of jaggery, freeze concentration of sugarcane juice, heat transfer and mass transfer from sugarcane juice for evaporation, moisture content of bagasse. In this review paper focus is on the effect of number of boiling pans used in design of furnace, and several methods used in available literatures are discussed. The improved plant and the conventional plant are compared on the basis of four parameters viz. jaggery production, bagasse consumption, emissions and temperature of exhaust.

Key words: Jaggery, Furnace, Drying Process of Jaggery, Bagasse

I. INTRODUCTION
Jaggery is produced by evaporating water from sugarcane juice. The solid and semi-solid mass that we get after boiling sugarcane juice is called gur in north India and jaggery in south India. Jaggery is a traditional, unrefined, non-centrifugal, whole cane-sugar consumed in Asia, Africa, Latin America and the Caribbean. It contains the natural goodness of minerals and vitamins inherently present in sugarcane juice & this crowns it as one of the most wholesome and healthy sugars in the world. [1]

Jaggery contains approximately 60-85% sucrose, 5-15% glucose and fructose, 0.4% of protein, 0.1 g of fat, 0.6 to 1.0 g of minerals (8 mg of calcium, 4 mg of phosphorus, and 11.4 mg of iron), traces of vitamins and amino acids, 100 g of jaggery gives 383 kcal of energy [1]. The jaggery plant owners are also working in unorganized way and as such there is no forum through which they can put their problems to the Government. Therefore a strong need is required to look into this activity in a scientific way and made effort to implement all possible and cost effective improvements to suit rural environment of INDIA. The gur industry, more than any other cottage industry, stands in great need of assistance on government level for its proper and effective development [2].

A manufacturing process for jaggery requires mechanical and thermal energy. Mechanical energy is used for juice extraction by passing the sugarcane stalks through a 3 or 5 roller crusher drawn by animal power or by electric motor or by an oil engine. The thermal energy for condensation of juice is provided by combustion of bagasse [3]. The juice should be boiled immediately after extraction in open pan by using bagasse as fuel which is a biomass generated during sugarcane crushing. During boiling vegetable clarificants are added to remove the suspended impurities as scum. After the boiling mass has reached the striking point at which the boiling is regarded as complete and it is fit to be taken out of the pan for cooling. The boiling mass is transferred from the boiling pan to cooling pan. It is left in the cooling pan to cool further. After stirring the semi solid mass is given the desired shape by hand or by transferring the mass to suitable moulds [2].

II. OBJECTIVE
In this paper following points has been looked from literatures and field survey
- Improve production of jaggery.
- Increase in plant safety.
- Reduction in fuel (bagasse) consumption. 
- Reduction in chimney smoke.

III. FIELD SURVEY
Temperatures of sugarcane juice during jaggery making process with respect to time are studied practically by Prof. G.S. Nevekar [5].

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Temp (Degree)</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>28</td>
<td>Normal Temp. use of Calcium oxides (lime)</td>
</tr>
<tr>
<td>30</td>
<td>86</td>
<td>Removal of first black Scum</td>
</tr>
<tr>
<td>35</td>
<td>92</td>
<td>Boiling Continue</td>
</tr>
<tr>
<td>100</td>
<td>99</td>
<td>Start formation of Second</td>
</tr>
</tbody>
</table>

Fig. 1: Flow chart for process of jaggery making plant [4]

Fig. 2: Graph of temperature of sugarcane during making of jaggery vs. time
Table 1: Temperature, time and processes in jaggery

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Time</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>115</td>
<td>100</td>
<td>Boiling of Juice with bubble cream layer</td>
</tr>
<tr>
<td>130</td>
<td>101</td>
<td>Breaking of upper cream layer</td>
</tr>
<tr>
<td>150</td>
<td>105</td>
<td>Juice ready for liquid Jaggery</td>
</tr>
<tr>
<td>155</td>
<td>107</td>
<td>Use of Hydrous or Cooking Oil</td>
</tr>
<tr>
<td>170</td>
<td>118</td>
<td>Formation of Jaggery</td>
</tr>
<tr>
<td>175</td>
<td>118</td>
<td>Transfer of Juice to cooling pan</td>
</tr>
<tr>
<td>180</td>
<td>96</td>
<td>Stirring of hot Juice first pattern</td>
</tr>
<tr>
<td>190</td>
<td>91</td>
<td>Stirring of hot Juice Second pattern</td>
</tr>
<tr>
<td>195</td>
<td>89</td>
<td>Start collection and pouring concentrated Juice</td>
</tr>
<tr>
<td>200</td>
<td>85</td>
<td>Moulding Jaggery</td>
</tr>
<tr>
<td>205</td>
<td>81</td>
<td>Moulding Jaggery</td>
</tr>
<tr>
<td>210</td>
<td>78</td>
<td>Moulding Jaggery</td>
</tr>
<tr>
<td>215</td>
<td>76</td>
<td>Stop Moulding of Jaggery</td>
</tr>
</tbody>
</table>

IV. METHODOLOGY

The performance of jaggery processing plant depends upon parameters like number of boiling pans used in design of furnace, drying process of jaggery, freez concentration of sugarcane juice, heat transfer and mass transfer from sugarcane juice for evaporation, moisture content of bagasse. In this paper effect of number of boiling pans used in design of furnace, drying process of jaggery and freezing concentration of sugarcane juice are discussed.

A. Design of Furnace

The existing furnaces have low fuel efficiency and require more fuels during the operation. To overcome the above problem, an improved furnace has been developed. A simple juice boiling furnace consists of a burning chamber, with or without grate, and a flue channel at the end of which a chimney is provided for taking out flue gases. In single pan furnace the juice boiling pan is placed on the burning chamber, while in multiple furnace pans are also placed on the flue channel as well to utilize the effect fuel economy. Now a day single pan furnace, double pan furnace, three pan furnace and four pan furnace is available in jaggery processing plant of India. The big multiple pan furnaces are generally more efficient than single pan furnaces and have rather lower fuel consumption per unit of juice processed. Selection of the desired type of furnace mainly depends on the holding of cane acreage to be disposed each day. The Poona double, triple or multiple pan furnaces are generally used for large scale manufacture of jaggery, as capacity of the boiling pans of these furnaces are 730 to 820 kg. [1]

Madan et al. [3] conducted performance trials for traditional and improved jaggery three pan furnaces. The traditional furnace included ordinary masonry bricks cemented with earth clay and a vertical chimney of rectangular cross section without any brickwork at the bottom or fire grate. Improved furnace was designed with use of fire brickwork at the bottom or fire grate. Improved furnace was designed with use of fire brick with refractory cement and a chimney of circular cross-section of optimum height to create sufficient draft. Improved chimney also included sliding dampers for draft control, firing platform for easy feeding of bagasse, fire grate for mixing of air with fuel. The specific bagasse consumption in traditional furnace was about 2.24 kg/kg jaggery which was improved to 1.96 kg/kg jaggery.

Anwar [7] conducted performance trials with evaporation of water in a two pan furnace with and without external fins on flue gas heating side. His study reports increase in the efficiency from 20% to about 29% with inclusion of fins.

Dr. R. D. Singh et al. [4] report the performance evaluation of improved two-pan furnace in comparison with single pan furnace. The second pan (termed as gutter pan) in the improved furnace is installed in the flue gas path of the first pan (termed as boiling pan). Other improvements were air preheating and installation of stepped grate. The study reports an improvement of furnace efficiency from 16% for single pan traditional furnace to 29% for improved furnace.

Pankaj K Arya et al. [8] studied on improved plant of three pan furnace which compared with conventional plant on the basis of four parameters viz. jaggery production, bagasse consumption, emissions and temperature of exhaust. The Improved unit resulted in about 12% reductions in bagasse consumption, about 23% increases in jaggery production capacity, lesser emissions and comparatively lower exhaust gas temperature.

Vishal R. Sardeshpande et al. [3] studied the procedure of four pan jaggery processing furnace including of four pan jaggery processing furnace including mass and energy balance. A controlled fuel feeding based on the oxygen percentage in the fuel gases is proposed and demonstrated. Fuel feeding rate reduced in specific fuel consumption from 2.73 kg bagasse/kg jaggery to 1.73 kg bagasse/kg jaggery. That means the rate of bagasse addition has a strong impact on efficiency.

Kiran Y. Shiralkar et al. [9] examined comparative study of the energy efficiency of the existing single pan jaggery units and existing four pan jaggery units. Based on the findings authors recommended that four pan units are more productive than single pan units are more productive than single pan units due to their semi-continuous nature.

B. Solidification of Jaggery

Several methods are applied for the drying of the jaggery, such as open sun drying, cabinet drying and greenhouse drying. Jaggery is hygroscopic in nature. That is why open sun drying takes more time due to a lack of humidity control. The drying of jaggery needs moderate temperature hence cabinet drying is not suitable for this either. Solar cabinet dryer gives higher temperature inside the cabinet and it may lead to melting. Therefore, greenhouse drying is the most suitable method for the drying of the jaggery. It is economically more efficient than the cabinet dryer.

Kumar and Tiwari [10] have designed and fabricated the greenhouse for the drying of the jaggery under natural convection. There is fair correlation between the experimental data and the predicted data. They had calculated the convective mass transfer coefficient for three different shapes (0.03×0.03×0.01 m³, 0.03×0.03×0.02 m³ and 0.03×0.03×0.03 m³) during the drying experimentation of jaggery in the roof type greenhouse dryer under active
and passive modes. They concluded that the shape and size of Jaggery pieces plays a significant role in studying the variation of convective mass transfer coefficient. This will be useful in designing efficient greenhouse for Jaggery drying.

Om Prakash and Anil Kumar [11] did experiment to predict the hourly mass of jaggery during the process of drying inside greenhouse dryer under the natural convection mode. Jaggery was dried until the constant variation in the mass of jaggery. Artificial neural network (ANN) is used to predict the mass of the dried jaggery on hourly basis. Solar radiation, ambient temperature and relative humidity are input parameters for the prediction of jaggery mass in each hour in the ANN modeling. Artificial neural network (ANN) methodology is applied in so many fields of energy engineering for the modeling, performance evaluation and prediction of the various systems and parameters. It is successfully applied in forecasting the performance of the systems, such as box-type solar cooker, solar water heater, solar tunnel dryer and flat plate solar collector. The results of the ANN model are also validated with experimental drying data of jaggery mass. It was found that the results of the ANN model and experimental are shown fairly good agreement.

Sugar-cane juice with initial total soluble solids (TSS) of 15° Brix was extracted from blanched sugar-cane stalks and was used for the production of a double strength (30° Brix) sugar-cane juice using a freeze concentration process. The main problem associated with fresh sugar-cane juice is its short shelf life and heat sensitivity of its flavor and components. It is therefore not uncommon for the variation in the total soluble solids (TSS), flavor, color and other sensory attributes of the juice from eatery to eatery. The risk of contracting food poisoning from drinking spoiled sugar-cane juice is also a concern since most of the sugar-cane juice operators are not trained in the area of food safety. The difficulty in preserving sugar-cane juice stems from the nature of the juice itself. In contrast to fruit juice, the pH of fresh sugar-cane juice is normally around 5.0. So it is classified as a low acid product. In addition, the high sugar content of the juice makes it vulnerable to sugar degradation if heated at high temperatures such as during the processes of sterilization, evaporation and drying. Therefore, most of the attempts to preserve the sugar-cane juice have been focusing on the use of heat treatment with refrigeration, and inclusion of preservatives. [12]

Milind V. Rane et al [13] developed mathematical model to calculate total energy consumption of the heat pump based Freeze Concentration System (FCS) by experimental study. Comparison of the conventional process and FCS integrated process concluded that bagasse saving of about 1338 kg per day can be achieved using heat pump based FCS along with bagasse fired pan boiling. Further, hot spots are eliminated resulting in improved jaggery color.

V. CONCLUSION

Indian jaggery industry is the largest unorganized sector which has been one of the most ancient and important rural-based cottage industries. The majority of the sugarcane marginal farmers are manufacturing jaggery with minimum capital investment which provides jobs to the unemployed rural people. Therefore it is essential to improve overall performance of jaggery plant by modification in construction of furnace, chimney which resulted in saving in fuel and energy.

Apart from combustion improvement to increase overall performance, further research may be aimed at design a special type of heat exchanger instead of cooling pan to reduce time for solidification process of jaggery. Also it is helpful to waste heat recovery at the end of drying process of jaggery and to save bagasse.

ACKNOWLEDGMENT

The authors gratefully acknowledge the help got on site of jaggery plant by Mr. Shitole from Nahvi, Pune, which helps to understand jaggery processing methodology. Also I would like to acknowledge Prof. Vishal A. Meshram for his kind help during the review process of this paper.

REFERENCES