Performance Evaluation of Two Pan Furnace for Jaggery Making

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Jaggery is produced in cottage industries. About 27.6% of total sugarcane produced is consumed by jaggery and khandsari industries. 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 boiling and concentration of juice is performed in furnaces. 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. Overall efficiency of the furnace was 29.3%, which was higher than the single pan furnace efficiency of 16% to 19.7%. There was a saving of 34.82% in the operating cost of jaggery making in case of two pan furnace as compared to traditional single pan furnace.

Keywords **:** Two pan furnace; Jaggerry making process; Bagasse consumption

INTRODUCTION

In India, 281 Mt sugarcane is produced in an area of 4.2 M-ha (2005-2006)[1]. Jaggery, a product of sugarcane, is produced in cottage industries. Per capita consumption of jaggery and khandsari in our country is estimated as 8.4 kg per annum (2001-2002). About 27.6% of total sugarcane production is diverted to jaggery and khandsari and rest theis used for sugar production, seed and chewing purpose[2]. Jaggery production process involves crushing of cane, boiling and concentration of juice, moulding into standard shapes, sizes and packaging in suitable packages. Crushing of cane is done with the help of bullock operated or power driven crushers to get the juice. The second unit operation in jaggery production is boiling and concentration of juice. It is performed in furnace where bagasse is used as main fuel. An efficient furnace should consume minimum bagasse then only it will be economical to the manufactures directly and sugarcane grower indirectly, as the bagasse is a good raw material for paper and pulp industry, particle/ board industry and animal feed industry. From the above view point, a fuel efficient furnace needs to be operated. In different parts of the country, different types of furnaces are prevalent. Mostly the furnaces are of single pan and having low efficiencies[3]. Therefore, extra fuels are required during operation. To overcome this problem, the present work tried to develop a two pan furnace to cater the need of jaggery producers. In the present study, the performance of the above furnace has been evaluated.

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MATERIALS AND METHODS

Constructional Details of Furnace

Main components of the furnace (Figure 1) are mentioned here.

Boiling Pan

It had the shape of inverted and truncated cone. Top and bottom diameters were 1.65 m and 1.1 m, respectively. The depth of the pan was 0.3 m. It was made of mild steel.

Gutter Pan

It was rectangular in shape. Length, width and depth of the pan were 1.8 m, 0.6 m and 0.3 m, respectively. It was made of mild steel.

Chimney

It had 2.75 m height. Internal opening was 0.3 mm $\times$ 0.3 m and it was made of masonry structure.

Flue Gas Passage

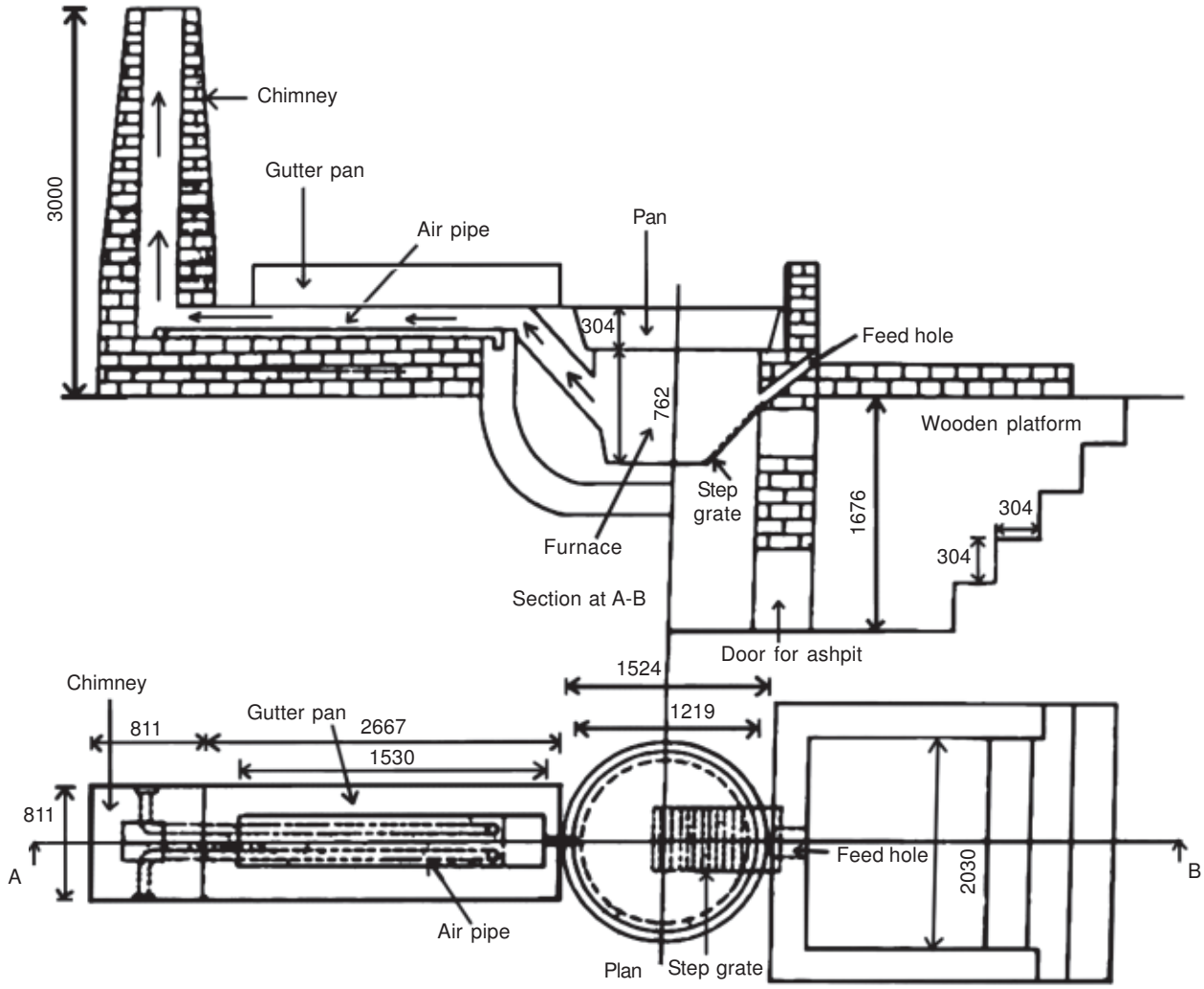
It was the space between gutter pan and chimney. It had the length of 2.85 m and 0.3 mm $\times$ 0.3 m in cross-section.

Combustion Chamber

It was the place where combustion of bagasse takes place. The boiling pan was kept over it.

Step Grate

It was fitted near the feeding mouth. It was made of mild steel flats. The bagasse was fed on the step grate that leads to the combustion chamber. Proper combustion was offered with this arrangement. .



All dimensions are in mm

Figure 1 Constructional details of two pan furnace

METHODOLOGY OF TESTING

A test proforma was developed for recording the observations of various parameters. The weighed cane was crushed with a power crusher. The quantity of juice obtained was weighed. The juice was poured in the boiling and gutter pans. Ambient temperature, initial juice temperature, relative humidity of air, moisture content of bagasse were measured properly. Then, feeding to the furnace was started. When the juice of the boiling pan reached to the desired consistency (striking temperature) it was taken out for cooling and moulding. The juice of gutter pan was then transferred to boiling pan for the second batch and gutter pan is refilled with fresh juice. Transferred juice was concentrated till it reaches the striking point. Again, the juice was cooled and moulded. The weight of the jaggery produced was recorded. The process flow chart of jaggery making is presented in Figure 2. Calculations were done as shown here.

$$\text{Juice boiling rate (Jbr)} = \frac{W_j}{t} \quad (1)$$

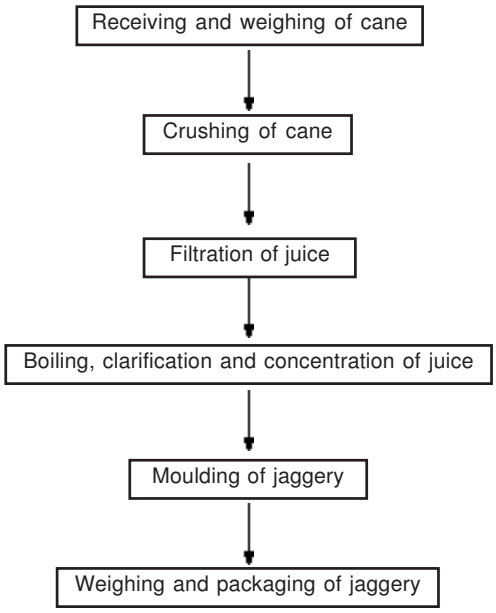


Figure 2 Process flow chart of jaggery making

$$\text{Bagasse consumption rate (Bcr)} = \frac{B_c}{t} \quad (2)$$

$$\text{Water evaporation rate (Wer)} = \frac{W_{we}}{t} \quad (3)$$

$$\text{Jaggery producing rate (Jpr)} = \frac{W_{jp}}{t} \quad (4)$$

$$\text{Juice boiling per kg of bagasse consumed} = \frac{\text{Jbr}}{\text{Bcr}} \quad (5)$$

$$\text{Water evaporated per kg of bagasse consumed} = \frac{\text{Wer}}{\text{Bcr}} \quad (6)$$

where B_c is the weight of bagasse consumed, kg; W_j, the weight of juice, kg; W_{we}, the weight of water evaporated during the concentration process, kg; W_{jp}, the weight of jaggery produced, kg; and t, the time consumed in the concentration of juice, h.

Energy utilized in the juice concentration was calculated by using following mathematical relationship.

$$HU = W_{js}T + W_{we}L \quad (7)$$

Energy supplied through bagasse

$$HI = B_cC \quad (8)$$

$$\text{Overall furnace efficiency}^7 = \frac{HU}{HI} \quad (9)$$

where HU is the heat utilized for juice concetration, kcal; C, the calorific value of bagasse, kcal/kg; s, the specific heat of juice, kcal/°C-kg (3.76 kJ/°C-kg); T, the temperature difference between boiling point and initial temperature of juice, °C; and L, the latent heat of vaporization, kcal/kg (2157 kJ/kg).

Initial parameters recorded were ambient atmospheric temperature, average relative humidity, initial juice temperature, calorific value of bagasse and quantity of fresh sugarcane juice in boiling as well as in gutter pan.

Economics of jaggery making in two pan furnace was compared with the traditional single pan furnace. The operating cost of jaggery making was calculated by analyzing the fixed as well as variable costs as per BIS procedure.

RESULTS AND DISCUSSION

Initial test parameters; ambient temperature, initial juice temperature, relative humidity and calorific value of bagasse were measured as 26°C, 22°C, 58.5% and 16510 kJ/kg,

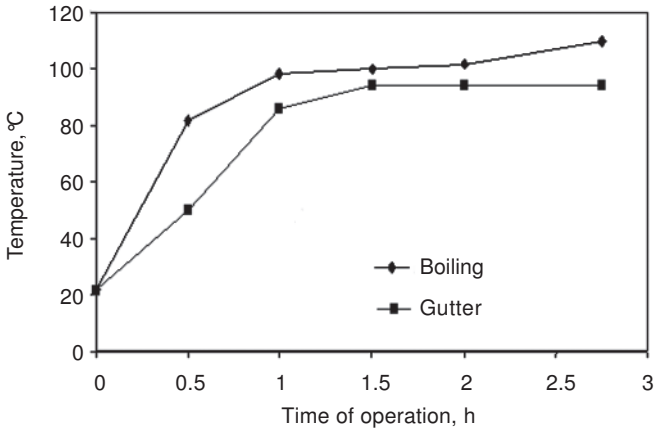


Figure 3 Temperature profile of pans during furnace operation

respectively. The quantity of juice used for testing was 180 kg in boiling pan and 160 kg in the gutter pan. In the boiling pan, the desired consistency (striking point) for jaggery making reached after 2.75 h of bagasse feeding (Figure 3). When combustion occured, boiling pan received heat and flue gases moves through chimney to escape. In this process, gutter pan also received some heat as it was kept over the flue gas passage. This was the advantage of the second pan (gutter pan). The temperature rise in the boiling pan was more than the gutter pan. It was due to the reason that the boiling pan was kept over the combustion chamber where burning of the fuel takes place. As a result, temperature of the boiling pan was higher.

At the striking temperature of juice in the boiling pan, the temperature of the juice in the gutter pan was 94°C. The juice was then transferred from gutter to boiling pan. The transferred juice was received at 84°C due to loss of heat. The transferring time was recorded as 0.16 h. The time consumed to attain the striking point was 2 h. The saving in the time of concentration of juice for jaggery making was due to the fact that initial temperature was higher (84°C). Performance particulars of the furnace have been given in Table 1. The table indicates that juice-boiling rate of the furnace was 71.58 kg juice/h. The rate of water evaporation was found to be 60.4 kg/h. The overall efficiency of the furnace was calculated as 29.3%. The overall efficiency of single pan furnace varied[8] from 16% to 19.7%. It was due to the

Table 1 Overall performance of the furnace

Parameters	Values
Bagasse consumed, kg	155
Time taken, h	4.75
Jaggery made, kg	53
Juice boiling rate, kg/h	71.58
Jaggery making rate, kg/h	11.2
Bagasse consumption rate, kg/h	31.58
Water evaporation rate, kg/h	60.4
Juice boiled per kg of bagasse consumed, kg/kg	2.26
Water evaporated per kg of bagasse consumed, kg/kg	1.92
Overall efficiency, %	29.3

Table 2 Comparative economics of jaggery making

Particulars	Two-pan furnace	Single-pan furnace
Initial cost, Rs	46500	30000
Salvage value (10% of initial cost), Rs	4650	3000
Total life, years	10	10
Working hour in one years	1200	1200
Number of workers engaged	2	2
Fixed cost		
Depreciation, Rs/h	3.87	2.25
Interest on average investment, Rs/h	2.56	1.56
Insurance, Rs/h	0.8	0.5
Repair and maintenance, Rs/h	3.2	2
Housing, Rs/h	0.6	0.37
Total fixed cost, Rs/h	11.03	6.77
Variable cost, Rs/h	20	20
Total operating cost of jaggery making, Rs/h	31.03	26.77
Weight of jaggery made, kg/h	11.2	6.3
Total operating cost of jaggery making, Rs/h	2.77	4.25
Saving in cost of jaggery making, Rs/kg, %	1.48 (34.82)	–

fact that heat of the flue gases were trapped by the gutter pan for preheating of the juice for second and subsequent passes.

It is evident from Table 2 that operating cost of jaggery making was Rs 2.27/kg in case of two pan furnace as against Rs 4.25/kg in case of single pan furnace. Hence, a saving of 34.82% in the operating cost of jaggery making was achieved in case of two pan furnace as compared to traditional single pan furnace.

CONCLUSIONS

Two pan jaggery furnace was able to concentrate the juice at the rate of 71.58 kg/h. It could evaporate 1.92 kg of water with 1 kg of bagasse. Overall efficiency of the furnace was found as 29.3%, which was higher than the single pan furnace efficiency of 16% to 19.7%. There was a saving of 34.82% in the operating cost of jaggery making in case of two pan furnace as compared to the traditional single pan furnace.

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