CAMOUFLAGED REALITIES AND FACTS IN A SMOKE HOUSE FOR DRYING RSS

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Abstract

More than ninety percent of the latex produced in India is converted into ribbed smoked sheets (RSS) which is the oldest method of processing, widely adopted by rubber growers due to its simplicity and minimal cost of processing. The country has established over 500 group processing centers under rubber producer's society with an aim of producing quality rubber sheets. Sheet rubber processing involves various stages viz. sieving, bulking, standardization, coagulation of latex, sheeting, dripping and drying in a smoke house. Firewood is used as fuel in the biomass furnace attached to the smoke house, which is a traditional practice of drying in the rubber processing industry. Bioenergy generated during the treatment of latex processing effluent is also used in smoke houses as alternative energy. In order to monitor the energy efficiency in a conventional smoke house, heat balance and pollution level were studied. The smoke house (5.46 x 3.35 x 4.64 m) temperature at different points was monitored for heat loss assessment and heat distribution pattern in upper, middle and lower convective zones. The temperature was found to vary between 43 to 63^{o}C during the entire smoke drying process. It was observed that drying RSS of 750 kg per batch in the smoke house consumed 3550 MJ for the required moisture content of 0.5 % within 70 h (4 days) during non-rainy hours. Out of the total heat energy supplied, only 858.5 MJ (24.2 %) of the input heat was utilized and the rest was lost in stored energy, 420 MJ (12%) walls and door loss, 881 MJ (25.1%) exhaust loss, 1240 MJ (34.5%) moisture in fuel, 106.5 MJ (3.0%) and the rest 42.6 MJ (1.2%) being unaccountable. Isothermal contour was drawn for the temperature distribution inside the smoke house at different altitude points. Higher temperature was maintained at the upper convective zone, which led to maximum heat loss through chimneys. Average daily biogas generated was 10 cum from 5000 liters of effluent processed and the biogas fuel was retrofitted in the smoke furnace for an average of 4 hours as heat supplement (703 MJ). Firewood reduction of 26 kg (19.8%) was achieved with alternate biogas fuel for the drying process. The composition of exhaust gas emission was found to be CO_2 (5.5 %), CO (8.5 %), O_2 (14 %) and SOx and NOx (<1 %), the greenhouse gases leading to global warming. Altering air supply and providing proper insulation in the smoke house are recommended for considerable reduction of heat loss and greenhouse gases. Switching over to cleaner, renewable energy sources for drying RSS is also recommended for environmental sustainability in rubber processing industries.

Keywords: biogas, emission, heat balance, RSS, rubber processing, smoke house, temperature

INTRODUCTION

More than ninety percent of the natural rubber latex produced in India is converted into ribbed smoked sheets (RSS) which is the oldest method of processing, widely adopted by rubber growers due to its simplicity and minimal cost of processing. Homestead processing of sheets was the practice till 1980's in the country. Later, Rubber Board India started promoting group processing centers and established over 500 group processing centers under Rubber Producer's Society (RPS) with an aim of producing quality rubber sheets. Sheet rubber processing involves various stages *viz.* sieving, bulking, standardization, coagulation of latex, sheeting, dripping and drying in a smoke house. Firewood is used as fuel in the biomass furnace attached to the smoke house, which is a traditional practice of drying rubber in the processing industry.

Firewood is the usual fuel used to generate heat and smoke in the smoke house. In addition, bioenergy generated during the treatment of latex processing effluent is also used as alternative energy. Wood logs having assorted size with various levels of moisture are being used for the combustion and therefore the heat buildup in the drying chamber always varies, leading to non-uniform drying of sheets. Loss of heat from the drying chamber is yet another drawback of the traditional smoke house which always takes 3 to 4 days for the sheets to be dried to the required grade. Over and above, due to the uncontrolled combustion of the firewood, various toxic gases like CO, CO_2, NOx etc. are generated and pushed into the drying chamber making it unsafe for personal engaged in the sheet making. Therefore, indiscriminate use and burning of firewood in the smoke house is not environment friendly. In order to monitor the energy efficiency, heat balance and pollution level in a conventional smoke house, a detailed investigation was carried out.

MATERIALS AND METHODS

Drying is one of the major energy consuming processes in sheet production. In traditional methods, natural rubber is dried using flue gas which is produced by direct biomass combustion. The conventional smoke house dryer at the Group Processing Centre under Elevampadam Rubber Producers' Society (EMRPS) in Kerala, India was selected for the study. The smoke house consists of a furnace and drying chamber, rubber wood is used as fuel for generating heat for drying rubber.

Traditional Smoke house

The smoke house (5.46 x 3.35 x 4.64 m) is made up of brick masonry and a door made up of teak wood with the furnace located below the drying chamber. The rubber sheets are hung on the wooden reapers which are rested on the wooden frame fixed inside the drying chamber (Fig.1). The furnace is 0.8 m in diameter and 1.21m in length. Firewood is fed into the furnace and burnt. The wood gets fired slowly in the furnace by allowing a limited supply of air. Ultimately wood turns to char which provides hot air in the smoke house. The total capacity of the smoke house is 750 kg and the firewood requirement is 450 kg per batch. Drying time required for rubber sheet in the smoke house is 3 days. Fig. 2 shown the isometric view of smoke house and temperature measuring points inside the drying chamber.

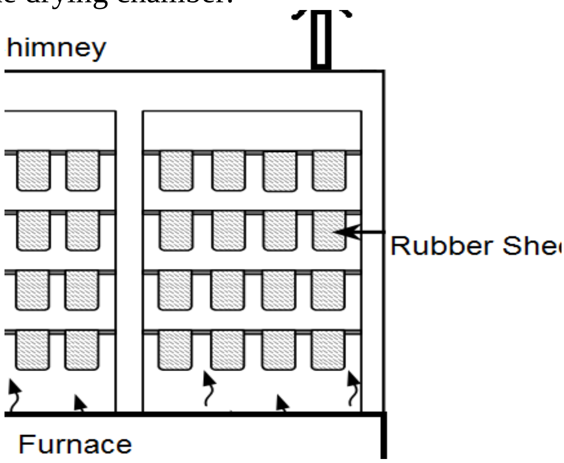

Figure 1. Conventional smoke house

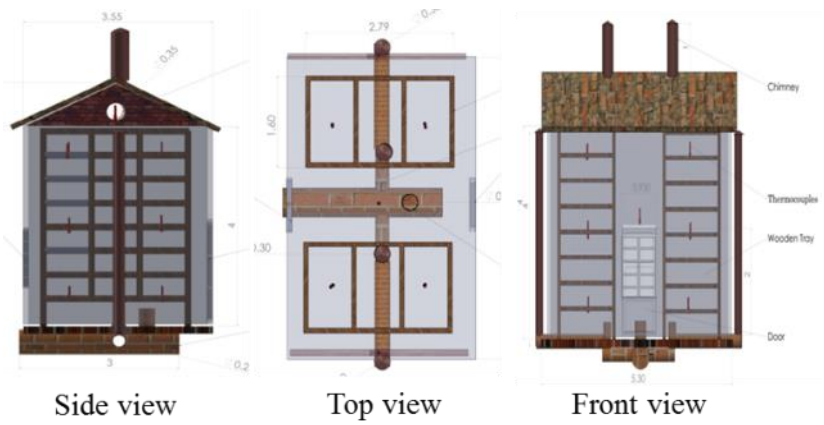

Figure 2. Isometric view of smoke house and temperature measuring points inside the drying chamber.

Performance of a Conventional Smoke House

In order to analyze the heat distribution pattern and heat loss in the smoke house, the temperature measurements were taken at various points during drying under load and no load conditions. The smoke house temperature was measured at different altitudes at hourly intervals. The smoke house temperature was monitored throughout the drying period. Twelve sensors (k-type thermocouples) were installed in the smoke house at an altitude of 1.16, 2.32 and 3.48 m for measuring the inner temperature. A sensor was also installed in the middle of the smoke house to measure the average room temperature. A portable exhaust gas analyzer was used to measure the exhaust gas compositions with the time span of 1 hour throughout the drying period. Two sensors were used to measure the exhaust temperature at chimney level. Four sensors were used to measure the wall temperature which includes left, right, back and front from the door.

Determination of Heat Loss

Energy flow into the drying chamber was calculated from the heating value of the fire wood. Energy flowing out of the system was calculated from the heat conducted through the walls and exhaust gas. The smoke house temperature used in heat loss calculation was obtained from the averages of 10 consecutive measurements. SURFER 10 software was used to draw the isothermal contour of smoke house to find out the heat distribution pattern inside the drying chamber. Elemental constituents of the rubber wood was determined.

a. Input energy

$$Q_{in} = HV\, m_w\, (1 - \varphi)$$

Q_{in} Heat input to the system
HV Heating value of rubber wood, 13.6MJ
$_w$ Mass of fire wood
Φ Moisture of fire wood, 0.42

b. Energy loss

1. Conduction through walls

$$Q_{lC} = \sum(\boldsymbol{kA}\,\frac{\boldsymbol{\Delta T}}{\boldsymbol{\Delta x}}, \Delta \boldsymbol{t})$$

Q_{lC} Conduction loss through walls
K Thermal conductivity, w/mk
A Wall area, m^2
ΔT Temperature difference, °C
X Wall thickness, m
T Time, s

2. Door and window loss

$$Radiation \qquad Q = \sum \in \sigma A(T_O 4 - T_a 4).\Delta t)$$

ε	0.80
σ	5.67 x 10^{-8} W/m^2 K^4
A	Door area or window area, m^2
T_{in}	Inner wall temperature, °C
T_o	Outer wall temperature, °C

3. Exhaust loss (with reference to surroundings)

$$Q_{le} = \{[m_a + (1-a)(1-\varphi)\, m_w]\Delta T\}\{C_{pa} + \omega_e C_{pv}\}$$

m_a	Mass of dry air, kg
A	Ash content of the rubber wood
C_{pa}	Specific heat of room structure material, kJ/ kg K
ω_e	Humidity ratio

4. Heat loss due to Moisture present in the fuel

$$\frac{M\, x \left\{584 + C_p(T_f - T_a)\right\}}{GCV\ of\ fuel}$$

5. Latent heat that vapories the water in rubber

$$Q_{vp} = \lambda\, m_{wr}$$

λ - Latent heat of water
m_{wr} - Mass of water present in the rubber sheet

6. Heat stored in rubber

$$Q_{sr} = \Delta T C_{pw} + \Delta T C_{pr}\, m_r + m_{wr}$$

C_{pw}	Specific heat of water
C_{pr}	Specific heat of rubber
m_r	Mass of dry rubber

7. Heat stored in room structure

$$Q_{ss} = \sum(\Delta T\, C_{ps}\, m_s)$$

m_s - Mass of room structure materials
C_{ps} - Specific heat of structure material

RESULTS AND DISCUSSION

Effect of Temperature in the Smoke House

The conventional smoke house temperature was recorded and varied from 43°C to 63°C for a drying period of 96 h in a typical drying batch. Figure 3 shows the average smoke house temperature. Initially the temperature rose up to 55°C then it gradually reduced to 46°C due to the high moisture in the rubber sheets at 32 h of drying and then increased to 63°C during 40 h. The optimum drying temperature recorded was between 55-60°C after 70 h of drying.

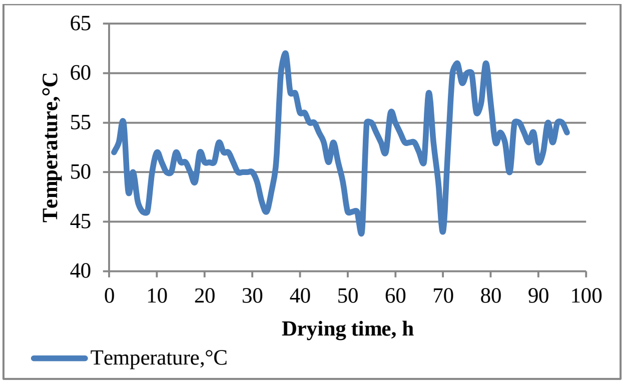

Figure 3. Average smoke house temperature

Figure 4. shows the temperature distribution up inside the smoke house with different altitudes during drying. The chimney temperature was measured at a height of 4 m and distance about 0, 4.9 m. The smoke house temperature varied from 49-55°C at the end of the drying process. Density of the hot air was less since a higher temperature was maintained in the upper convective zone of the smoke house. The contour explains the exhaust temperature of the smoke house which was higher than the average room temperature. A uniform temperature was not reached in the smoke house throughout the drying period. Even though the drying chamber reached the desired temperature for rubber sheet drying, the heat loss was more.

By using SURFER10 software the isothermal contour of the smoke house could be drawn. Figure 5. shows the temperature distribution inside the smoke house at different altitudes during the drying process. The chimney temperature was measured at a height of 4 m and distance about 0, 4.9 m. The smoke house temperature ranged from 49-55°C throughout a particular time period. The density of hot air was high hence, higher temperature was maintained in the upper portion of the smoke house. The contour explains the exhaust temperature of the smoke house which is higher than the average room temperature. Uniform temperature throughout the smoke house was not obtained by this system.

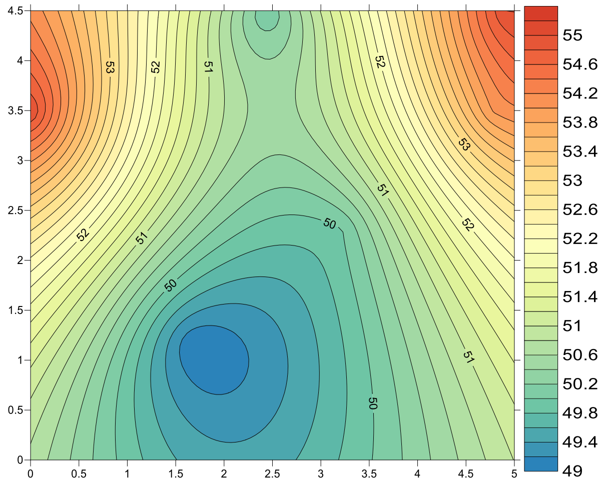

Figure 4. Isothermal contour of smoke house

The efficiency of the combustion system depends upon the amount of air supplied to facilitate combustion. The amount of air required for complete combustion of its fuel wood depends on elemental constituents that is carbon, hydrogen, nitrogen, oxygen and sulphur.

Table 1. Ultimate analysis of rubber wood

Elemental constituents, % (ASTM-D 5373)				
C	H	N	S	O_2
53.4	6.7	3.1	0.1	36.7

The combustion products are primarily carbon dioxide (CO_2), water vapor (H_2O), nitrogen oxide (NO_2) and sulphur dioxide (SO_2) along with nitrogen in the air. Exhaust gas composition production was dependent on the chemical composition of the fuel wood (*Hevea brasiliensis)*. The exhaust gas contained CO_2, CO, Sox, NOx and $O_{2,}$ as shown in Figure 5. Oxygen content in the exhaust gas was observed to be 14%, Carbon dioxide content as 5.5% and carbon monoxide as 8.5%. SOx and NOx levels were less than 1%.

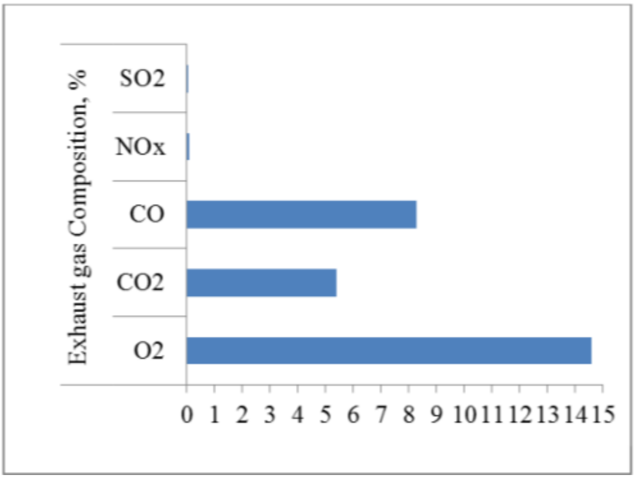

Figure 5. Exhaust gas compositions

Effect of Flue-Gas Constituents in the Smoke House

Oxygen is the indicator of the quality of the combustion process. Hot gas and smoke obtained from wood burning were used to dry the rubber sheets in the smoke house. Smoke acts as a disinfectant which makes the rubber sheets less susceptible to mould growth. CO_2 composition is comparatively less than CO in the drying system as shown in Figure 6. The combustion process was incomplete, as sufficient oxygen was not supplied to the system, which led to the generation of smoke. Smoke contains creosote materials that act as preservative for the rubber sheets, preventing the mould growth. Smoke is always recommended to reduce the mould growth in the rubber sheets.

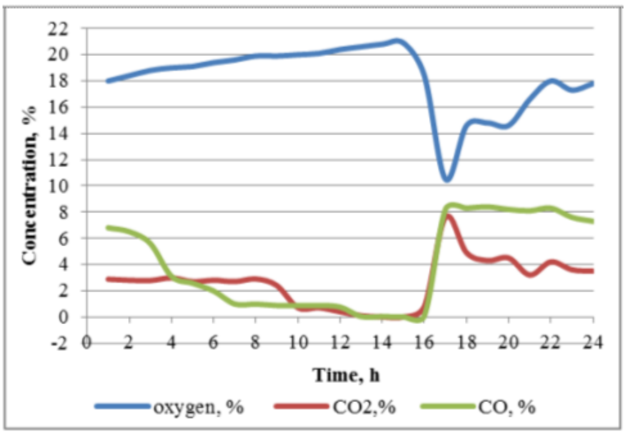

Figure 6. Concentration of exhaust gas in the smoke house

Heat Loss Calculation

Heat loss in the present system was calculated from the observed temperature. The heat balance calculation is shown in Table 3.

Table 3. Heat balance calculation

Energy	Test value	Percentage
Input energy	3550	100%
Useful energy		
a) Sensible heat	291	8.2%
b) Latent heat	567.5	16%
Stored energy		
a) Room structure (walls and door)	420	12%
Energy losses		
a) Left wall	136	3.8%
b) Right wall	109	3 %
c) Back wall	260	7.8%
d) Front wall	376	10.5%
Exhaust loss	1240	34.5%
Moisture in fuel	106.5	3.0 %
Uncountable	42.6	1.2%

It was observed that drying a 750 kg batch of RSS in the smoke house consumed 3550 MJ to reach the required moisture content of 0.5 % within 70 h (4 days) during non-rainy hours. Out of the total heat energy supplied, only 858.5 MJ (24.2 %) of the input heat was utilized and the rest was lost in stored energy, 420 MJ (12%) walls and door loss, 881 MJ (25.1%) exhaust loss, 1240 MJ (34.5%) moisture in fuel, 106.5 MJ (3.0%) and the rest 42.6 MJ (1.2%) being unaccountable. The isothermal contour was drawn for the temperature distribution inside the smoke house at different altitude points. A higher temperature was maintained at the upper convective zone, which led to maximum heat loss through chimneys.

Exhaust loss and wall loss were comparatively higher than other losses. To reduce the exhaust loss room structure could be modified and heat recovery from the chimney would reduce the exhaust loss and increase the system efficiency. Wall and door loss could be reduced by providing thermal insulation which is economically viable. It was not possible to measure the heat lost through the floor and roof. Those losses were accounted for in the unaccountable category.

Biogas Energy

Average daily biogas generated was 10 cum from 5000 liters of effluent processed and the biogas fuel was retrofitted in the smoke furnace for an average of 4 hours a heat supplement of (703 MJ). Firewood reduction of 26 kg (19.8%) was achieved with alternate biogas fuel for the drying process

CONCLUSION

Results of the study indicated that the conventional smoke house where heat is generated by combustion of wood was not efficient in terms of energy utilization. Only 24% of input heat was useful and the remaining was lost through various means. Over and above, due to the uncontrolled combustion of the firewood, various toxic gases like CO, CO_2, NOx etc. were generated and pushed into the drying chamber which is unsafe for personel working in the smoke house. (Above camouflaged realities and facts in the traditional smoke house advocate for its design changes and structural work). R&D on renewable energy drying technology would be highly desirable for environment friendly and sustainable sheet production.

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