Development, Design and Fabrication of Smoke Drying Cabinet (Prototype) for Ribbed Smoked Rubber Sheet Production

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Citation

Abstract
Value addition is very significant in optimization of agricultural produce production and it is only this that can make the nation’s rubber industry compete with other natural rubber producing countries in the world. Value can be added to natural rubber latex via centrifugation, creaming, sheeting e.t.c. Therefore, the aim of this work is to develop, design, and fabricate a drying cabinet for production of ribbed smoke sheet from natural rubber latex with objectives of reducing production cost but increase productivity in term of quality and quantity. A prototype Drying cabinet was locally fabricated from metal sheet grade GN8-EN which has oven insulator, smoking chamber, insulated wall, and smoke separator base as components. Metal sheet grade GN8-EN use to form a frame that accommodates oven insulator. The furnace has a rectangular shape of 260 mm high, 690 mm long and 915 mm wide. It has a primary combustion chamber measured 500mm wide, 690 mm long and 260 mm high. The secondary section of combustion chamber is half-opened to drift air into the primary section for complete combustion. The side wall has a metal form work of 260 mm high stand, a padded form work with dimension 940 mm high, 125 mm wide, 915 mm long attached to the side frame while padded work of dimension 915 long wide, 75 mm, 940 mm high is attached to the back wall. The metal roof has dimension of 915 mm by 690 mm and has 260 mm diameter chimney attached to it. 75 mm thickness layer of granite is loaded on a perforated metal sheet on the furnace to serve as smoke separator and heat reservoir during firing. Local oven insulator is prepared from termite hill sand with addition of internal fuel and anti-shrinkage.

1. Introduction

Despite the competition of synthetic compounds, natural rubber continues to hold an important place in tyre consumption. In particular, its superior tear strength and excellent resistance to heat up makes it better suited for high-performance tyres used on racing cars, trucks and buses, and aircraft. In these applications, the potential for switching from natural to synthetic rubber is quite limited, given the clear-cut technological advantages to natural rubber [Giroh et. al, 2007]

The demand for tyres increases in tandem, leading to increases in consumption of RSS. Demand in North America, Japan, Europe and Asia – Pacific Region are expected
to drive growth in future. China and India are expected to dominate the market in coming years in term of RSS consumption. Demand for RSS and price are influenced by political stability, macro-economic fundamental, weather conditions, inflation, crude oil prices interest rates and government policies. To meet high demand of RSS, several factors are to be put into consideration, such as production capacity, input and processing costs, price differential with synthetic rubber and technological changes. Currently, China is the largest consumer of RSS in the world, it depends on imports to meet demand with about 70% of demand been met through imports [Global industry analysts, inc., http//www.strategyR.com, 2015; Suttisak and Sirichai, 2015; Prasertsan et. al, 2015; Fasina, 1998; Abolagba et. al, 2003].

In production of bricks from local source of materials, various additives are used such as internal fuel, and anti shrinkage. Internal fuel such as coal dust, boiler ash, sponge iron waste agro-agricultural waste like rice husk, saw dust are added to clay to reduce the external fuel consumption and stack emission. It also upgrades the fire bricks quality. Anti-shrinkage materials are added to clay to transform highly plastic soil for brick making. Materials such as fine river sand, medium sand (less than 2 mm thickness), stone dust and sandy soil are anti-shrinkage materials added to avoid high shrinkage and resultant crack during drying under direct sunlight. Addition of saw dust, rice husk, groundnut husk and agricultural agro-waste into the clay creates pores that reduce the conductive capacity of the refractories and therefore increase their insulating characteristics [John et. al. 2014; Halima et al, 2013].

Therefore, the main objectives of the project is to locally develop an economical smoking cabinet prototype for smoking/drying of rubber sheet with the following sub-objectives: to design and fabricate smoking cabinet, to produce a local oven insulator from termite hill and to evaluate the performance of the system on drying time, fuel consumptions, and quality of the sheet produced.

2. Materials and Methodology

Smoke cabinet design and construction involves metal work and oven insulator production. The metal frame is constructed using metal plate grade GN8-EN, angle bar, and iron rod. Sections of the cabinet were fabricated before assembled together using welding method of production. These sections are sides padded wall, back padded wall, metal door, furnace and chimney. The furnace is fabricated using angle bar, iron rod and metal plate. The entire structure is reinforced with angle bar and iron rod. Oven insulator produced is loaded into the padded wall and allowed to dry.

2.1. Side and Back Wall Frame Work

Side wall frame is made up of 1,020 mm by 690 mm metal plate that accommodates a padded metal frame of a rectangular shape measured 690 mm by 940 mm by 125 mm.

\[
\text{Volume of padded wall} = \text{Lenght} \times \text{Breath} \times \text{Height} = 690 \times 940 \times 125 \text{ (mm)}
\]

\[
\text{Surface area of padded wall} = \text{Lenght} \times \text{Breath} = 690 \times 940 \text{ (mm)}
\]

2.2. Furnace Construction and the Chimney

The furnace is a rectangular structure measured 915 mm by 690 mm by 260 mm. The furnace is segmented into three sections, the centered segment measured 500 mm by 260 mm which accommodates the fire wood and the other two sections are half covered with metal sheet to draft air into the furnace for complete combustion. A perforated metal plate (3 mm thickness) is placed on the furnace to distribute smoke and dissipate heat. Gravel layer of thickness 30 mm is loaded on top of the perforated metal to filter the heavy smoke and also, store heat.
Volume of the furnace = \( [260 \times 500 \times 690] \text{m}^3 \)

Surface area of the heat dissipating plate = \( 915 \times 690 \text{ (mm)}^2 \)

\[ (2) \]

Figure 3. Furnace.

Chimney is made of circular pipe of diameter 300 \( \text{mm} \) and 280 \( 	ext{mm} \) high. This is mounted on the topmost wall of the smoke cabinet.

The components or members are assembled together by welding method. Binding wire of diameter 50 \( 	ext{mm} \) is used to fill the joint to make it more sturdy and easy workability at site.

2.3. Preparation of Oven Insulator

The materials used for production of oven insulator (mortar) are termite hill sand, sawdust and common salt. This process of oven insulator production or making includes sand securing, beneficiation, mixing, and forming. Addition of sawdust will reduce cracking during drying and also reduces fuel usage during firing. Salt is an anti-caking agent that allows slow/even curing of the oven insulator. The composition of the oven insulator is 1.2% Salt by Volume, 11% Sawdust by Volume, 88% Termite Hill Sand by Volume.

i. Securing

Termite hill was dug and filtered at RRIN location. Three wheel barrow were imported from the site, filtered to remove unwanted materials such as stone, wood etc.

ii. Beneficiation

10 kg of saw dust was mixed with 0.72 ton of termite hill sand, appropriate quantity of water was added and blended to obtain mine uniform consistency. The mixture was matched for 20 minutes and 3 kg of salt was added and further matched to plasticity and left for 2 – days (48 hrs) to ferment.

iii. Forming

After matching to plasticity, the insulator which is mixture of termite hill sand (saw dust and salt) was loaded intermitently into the padded wall on the fabricated smoke cabinet and rammed for perfect compaction.

2.4. Description and Operation of the Rubber Sheet Drier

The developed drier for rubber sheet smoking consists mainly of three major parts namely; drying chamber, chimney and the fire port (or furnace). The components were fabricated, built and assembled according to the design.

The Drying Chamber: The drying chamber measuring 1020 mm (length), 125 mm (width) and 690 mm (depth) is a unit where the rubber sheets are exposed to heat and it is an enclosure of a brick wall that operates within the temperature range of 40°C – 60°C. The insulated wall reduces rate at which heat is lost to the surroundings, it is therefore increases the efficiency. Inside the drying chamber is located a hanger of 12 - sheets capacity. The outside layer of the drying chamber is made of mild steel, a middle layer properly insulated with brick as lagging material and inner layer is made of mild steel metal sheet. The distance between the ribs stick on the hanger is 3 inches, the spacing is necessary for even drying of the smoked rubber sheets.

The Chimney: This serves as a vent through which the moisture from the rubber sheet escapes to the atmosphere and also to remove excess smoke. The chimney was built of 2
mm galvanized sheet metal of length 500 mm and 140 mm diameter. It has a total area of 0.61 m$^2$. It has a mushroom-like head that reduces heat lost to the surrounding from the chimney.

The Fire Port (or Furnace): This is a rectangular space measured 260 mm by 915 mm. It is divided into three sections, a section to accommodate solid fuel (fire wood) and compartments to drift air into the furnace to support combustion.

3. Result and Findings

Inside and Outside Temperatures with Time

When the system was fired for 30 minutes using 8 kg of rubber wood that has heating value of 13,000 KJ/Kg, the inside temperature was found to be 150°C, the door of the system is opened to allow the temperature to drop to 80°C. The result for the inside temperature along with the outside temperature of the wall is summarized in table 1.

<table>
<thead>
<tr>
<th>Hour</th>
<th>Inside Temperature</th>
<th>Outside Temperature of the Side Wall</th>
<th>Outside Temperature of the Back Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:05 am</td>
<td>80</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>11:20 am</td>
<td>80</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>11:30 am</td>
<td>78</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>11:40 am</td>
<td>75</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>11:50 am</td>
<td>78</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>12:10 pm</td>
<td>75</td>
<td>43</td>
<td>44</td>
</tr>
<tr>
<td>12:20 pm</td>
<td>75</td>
<td>43</td>
<td>46</td>
</tr>
<tr>
<td>12:40 pm</td>
<td>70</td>
<td>43</td>
<td>46</td>
</tr>
<tr>
<td>01:00 pm</td>
<td>68</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>01:20 pm</td>
<td>68</td>
<td>49</td>
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<tr>
<td>01:40 pm</td>
<td>68</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>02:00 pm</td>
<td>68</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>02:40 pm</td>
<td>68</td>
<td>50</td>
<td>53</td>
</tr>
<tr>
<td>3:00 pm</td>
<td>68</td>
<td>50</td>
<td>54</td>
</tr>
</tbody>
</table>

Source: Data Analysis

From the table above, the outside atmospheric temperature was constant for up to a hour before experiencing infinitesimal change after about a hour plus. The temperatures increase linearly but gently along the slope. The chart below shows inverse proportionality between inside temperature and the outside temperatures. This implies the greater efficiency of the system for smoking of rubber sheet.
Generally from figure 3, the temperature of back wall is either equal or greater than side wall temperature. The equality in temperature is as result of the unequal surface area while variation is as a result of difference in thickness of the wall.

4. Conclusion and Recommendation

To diversify to agriculture, value needs to be added to our agricultural produce. Value addition makes us compete with other natural rubber producing nations globally. Value addition has been our priority in term of research development and innovations. This project established the average drying temperature to be 60°C and drying time of 36 hours average. The system is locally powered using renewable energy (biomass) and reduce drying time thereby increase the profit.

References


