A MODELING OF THE SOLAR-ASSISTED FOR RUBBER SMOKED SHEETS (RSS) SYSTEM

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Abstract: *This research used finite element method (FEM) to design for development of the solar- assisted rubber smoking system. In order to decrease fuel usage while increase performance. And revise structure design of the smoking room in accordance to cover with greenhouse.*

From finite element method it has been observed that the air flow characteristics are the best in the smoking room of 2 x 2.5 x 2.5 m^3, cover greenhouse of 4 x 6.5 x 3 m^3, each collector zone width of 1 m. and a channel width for rubber wheelbarrow of 2 m. This system is able to conduct heat lose from smoking room for reduce moisture of rubber sheet.

Key Word*: CFD/ Solar/ Rubber smoking system/Finite element method.*

1. INTRODUCTION

70% of natural rubber has been produced by sources in the region of Thailand, Indonesia and Malaysia. During these three countries, Thailand is the highest natural rubber producer focusing on smoked rubber sheets and extract rubber latex. Smoked rubber sheets that Thailand can produce most are the 3rd grade. Main markets of smoked rubber sheets and extract rubber latex produced by Thailand is Japan and China. These countries prefer Thai smoked rubber sheets for making tires of automobile (one of main products made out of natural rubber) because of its high quality and flexibility at the reasonable price.

Unfortunately, in Thailand, various problems in production process of smoked rubber sheets have been left undue; for instance, high production cost due to increasing price of fuel, transportation and salary while productivity still be the same. Many researchers used to solve such a problem in the past. Breymayer, Pass, Amir and Mulato, 1993 [1] invented and tested the rubber sheet smoking system using solar air heater as an auxiliary unit. The test result could reduce time for smoking and reduce wood fuel consumption as compared to the previous system.

The survey of smoking sheet rubber manufactures in provinces of southern finds that in each ton of the smoking sheet rubber production, the 0.36 m^3 of rubber lumber will have to be used to be consumed fuel for the drying room. To calculate in quantity of lumber, which is used throughout the year, will be used about 229,994 m^3 or equals to 137,996.5 tons. (the firewood 1 m^3 = 600 kg) and energy value is 2.14×10^6 GJ comparatively. And the research finds that the efficiency of the rubber smoking room, where uses in present, is rather low due to the demand of the combustive fuel that will be utilized only 31%, while the 57% of the remaining heat will be lost through wall of smoking room and the 12% of the other will be lost by ventilation and the duration for smoking of sheet rubber in each set will be spent about 5-7 days.

Hence, to decrease fuel usage and duration of smoking process becomes the first priority. To increase rubber humid elimination capability of the smoking room by improving its structure is also important.

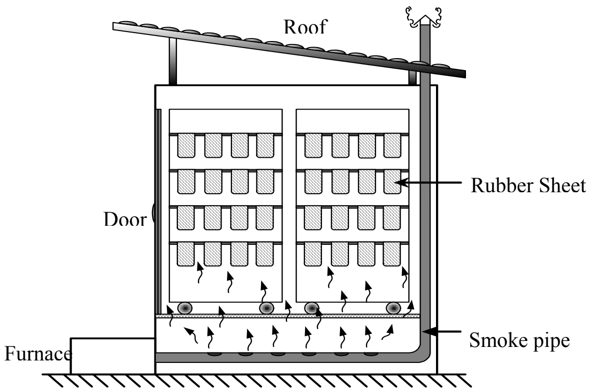


Fig. 1 Natural rubber sheet smoking room (old system).

2. EXPERIMENTATION

The design of new smoking room will have to be considered from the old smoking system (Fig. 1). It will indicate that the most of obtained heat from wooden fuel will be transferred to outside and lost to outside through wall and room door (Fig. 2), consequently, if the loss heat can be utilized for rubber moisture reduction with the solar energy consumption, it will be able to reduce wooden fuel consumption.

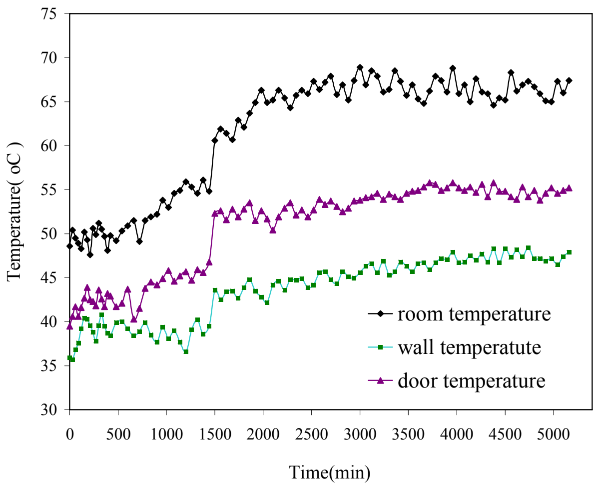
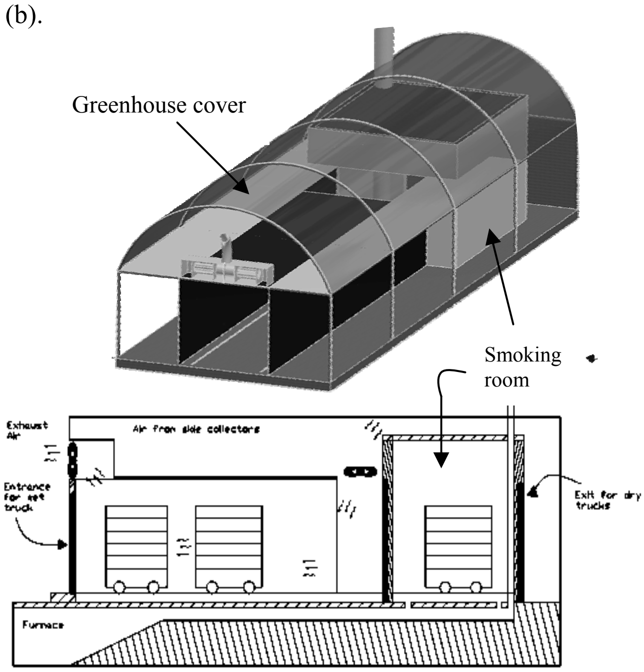
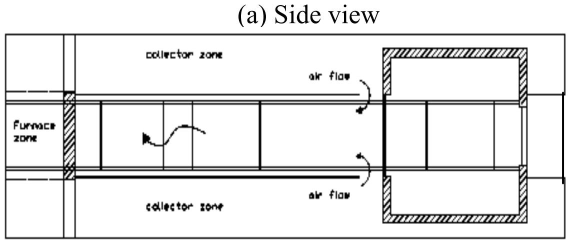


Fig. 2 room, wall and door temperature of smoking room (old system)

The conceptual design initially, the greenhouse portion of drying room is designed to be solar energy receiver and product drying machine simultaneously. Researcher will design structure of greenhouse to be rectangular room with curved roof, it is simple structure, materials are not consumed and it endures to wind force. The inner glass house is divided to 3 portions as figure 3 (b).



(a) Side view



(b) Top view

Fig. 3. Conceptual design initially of the greenhouse drying.

The 2 side portions are east collector zone and west collector zone, and the middle portion is the room for keeping pushcart that rubber is hanged and it is portion that hot air is sucked by fan through inside room to reduce moisture of rubber and it is evacuated to outside house.

But due to drying room design that is mentioned above, we certainly have not known that dimensions of various portions both collector zones and pushcart room, includes optimized length of various cavities. It is necessary to use finite element method that is one of popular method to aid for design.

2.1 Modeling equation for fluid flow

Finite element method provides a greater flexibility to model complex geometries than finite difference and finite volume methods do. It has been widely used in solving structural, mechanical, heat transfer, and fluid dynamics problems as well as problems of other disciplines.

- governing equation

This is a multiphysics model, meaning that it involves more than one kind of physics. In this case, we have Incompressible Navier-Stokes equations from fluid dynamics, that is, essentially a convection-diffusion equation. There are tree unknown field variables: the velocity field components u and v and the pressure, p. They are all interrelated through bidirectional multiphysics couplings.

The pure Incompressible Navier-Stokes equations consist of a momentum balance (a vector equation) and a mass conservation and incompressibility condition. The equations are

$$\begin{cases} \rho \dfrac{\partial u}{\partial t} + \rho(u \cdot \nabla) p + \eta \nabla^2 u + F \\ \nabla \cdot u = 0 \end{cases} \tag{1}$$

Where F is a volume force, ρ the fluid density and η the dynamic viscosity. We denote the vector differential operator by ∇ (pronounced "del").

Table 1 summarises the boundary conditions values for the tested configurations. Air velocity, direction, and thermal conditions were specified at the fluid inlet.

Table.1 the boundary conditions values for the tested.

Parameter	Value
Density of air (kg/m^3)	1.20
Dynamic viscosity (kg/m.s)	1.88*10^{-5}
Heat capacity (kJ/kg.K)	1.005
Thermal conductivity (W/m. K)	0.024
Acceleration gravity (m/s^2)	9.81
Outlet velocity (m/s)	10
Temperature (K)	303

2.2 Thermal modeling

- Working principle [2]

The working principle of the greenhouse rubber sheet drying under force convection condition is illustrated in Figure 4. The polycarbonate covered greenhouse traps the solar energy in the form of thermal heat within the cover $(\sum I_i A_i \tau_i)$ and reduces the convective heat loss. The fraction of trapped energy (1-F_n)F_j $(\sum I_i A_i \tau_i)$ will be received partly by the rubber sheet and partly (1-F_n)(1-F_j) ($\sum I_iA_i\tau_i$) by the floor and exposed tray area and the remaining solar radiation ((1-F_n)(1-F_j) $(1-\alpha_g)(\sum I_iA_i\tau_i)$) will heat the enclosed air inside the greenhouse. A greenhouse with the forced mode of drying reduces the relative humidity inside the greenhouse and increases the vapor pressure difference, resulting in a faster rate of moisture removal (Fig. 4)

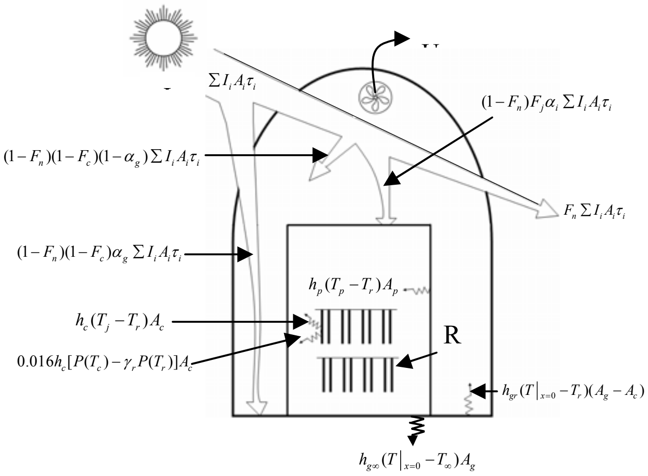


Fig. 4 Principle of solar rubber sheet drying under greenhouse forced convection

- Energy balance [3]

(a) Energy balance equation at rubber sheet surface,

$$(1-F_n)F_C\alpha_C\sum I_iA_i\tau_i = M_CC_C\frac{dT_C}{dt}+hc(T_C-T_r)A_C +0.016hc[P(T_C)-\gamma_rP(T_r)]A_C \qquad (2)$$

(b) Energy balance equation at ground surface,

$$(1-F_n)(1-F_C)\alpha_g\sum I_iA_i\tau_i = h_{g\infty}(T|_{x=0}-T_\infty)A_g +h_{gr}(T|_{x=0}-T_r)(A_g-A_C) \qquad (3)$$

(c) Energy balance at greenhouse chamber

$$(1-F_n)(1-F_c)(1-\alpha_g)\sum I_iA_i\tau_i + hc(T_c-T_r)A_c +0.016hc[P(T_c)-\gamma_rP(T_r)]A_c + h_{gr}(T|_{x=0}-T_r)(A_g-A_c) = 0.33NV(T_r-T_a) +\sum U_iA_i(T_r-T_a) \qquad (4)$$

With the help of Eqs. (4), Eq. (4) has been simplified to determine the greenhouse room temperature (T_r) under forced mode for assumed values of rubber sheet temperature and ambient temperature. If the value of room air temperature (Tr) is known, with the help of Eq. (2) the rubber sheet temperature (Tc) can be determined.

Computer program based on Visual Basic (version 6.0) were used to solve mathematical models. The hourly average solar intensity and ambient temperature (from 10 AM to 4 day of continuous drying time). The constant and input values for natural rubber sheet are given in Table 2.

Table. 2 Constant and input values used for modeling

Parameters	values
h_{gr}	8.0
M_c	10
T	3600
α_g	0.60
τ	0.85
A_{co}	0.75x0.45
α_c	0.5
Cc	4200
γ_r	0.55
Tc	24.5
Tr	27.6
N	30

3. RESULT

3.1 fluid flow results

As figure 5, it finds that character of flow is fluent, velocity of air in rubber pushcart portion is high and it finds that average velocity of air in rubber pushcart is 15 m/s approximately that it is high velocity. The design process is considered that the longer distance of rubber pushcart portion effects to the more heat collecting that the heat is from solar that shines to both sides, it is good benefit. If the portion is too short, it makes force to convect less heat from fuming room to outside. So researcher selects length of portion for keeping pushcart, it is 3.75 m, to design glass house.

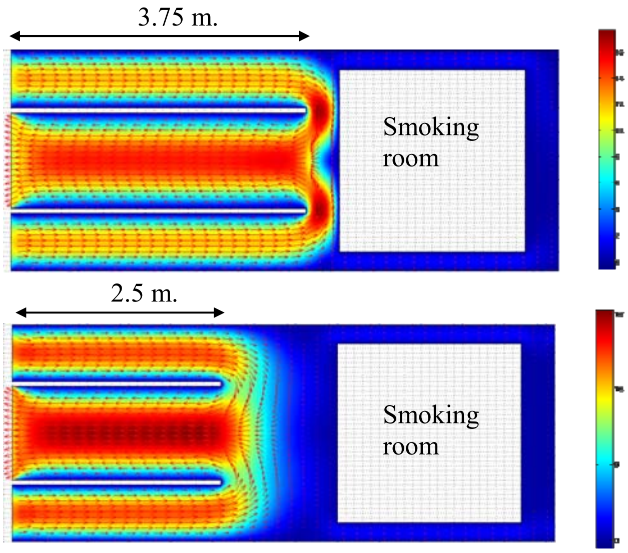
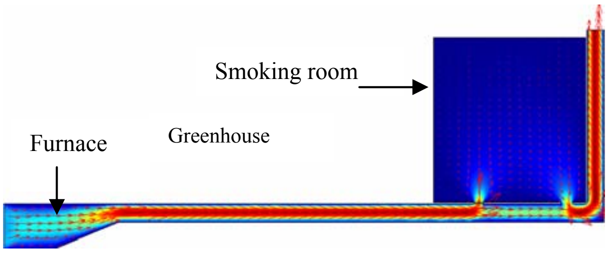


Fig. 5. Air flow character of greenhouse at length of portion for keeping pushcart

The consideration of flow character of hot air inside smoking room, the distribution of air is considered that it is dispersed around room for the most affect to rubber sheet, and optimized ventilating is to adjust optimized temperature of inside room (60 °C approximately). The initial design, researcher determines 100% outlet opening for smoke drainage and 2 upper portions of smoking room are opened. The result is shown as figure 6 (b).



(a) Close upper portions of smoking room (side view)

(b) Open 2 upper portions of smoking room

Fig.6. Air flow character of smoking room

As figure, the dispersion of air is equal for both 2 sides, it may effect to moisture reduction of rubber sheet, there is also the equal rate. But the disadvantage of this method is the more hot air inlet opening to inside smoking room may affect to high inside temperature, it is difficult to control. The method for solving this problem is the determination of hot air inlet quantity by constructing to be damper or the hot air inlet quantity is determined for combusting in furnace supporting.

3.2 Thermal modeling result.

The mathematical model developed for greenhouse drying under forced convection has been solved for the ambient data of February 2007 for natural rubber sheet. The predictions of crop temperature and room temperature are presented in Fig. 7.

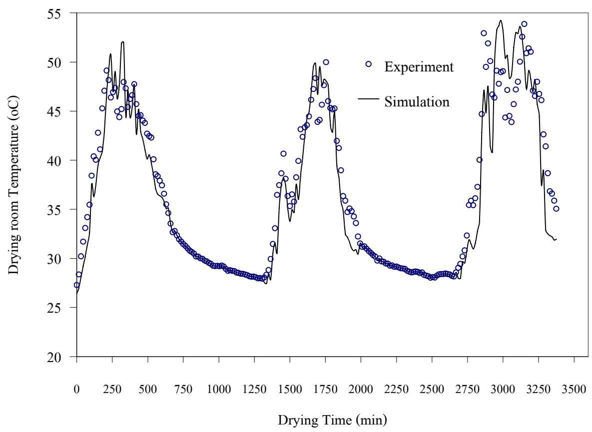


Fig. 7 Rubber sheet and greenhouse air temperature under force convection greenhouse drying.

From Figure. 7, it can be observed that the greenhouse air temperature always exceeded rubber sheet temperature and ambient temperature are 1-2 ^{o}C and 3-4 ^{o}C respectively, due to direct absorption of solar energy.

4. CONCLUSIONS

From finite element method it has been observed that the air flow characteristics are the best in the smoking room of 2 x 2.5 x 2.5 m^3, cover greenhouse of 4 x 6.5 x 3 m3, each collector zone width of 1 m. and a channel width for rubber wheelbarrow of 2 m.

One simple mathematical model was developed to predict the rubber sheet temperature and greenhouse room temperature for greenhouse drying under forced convection. The predicted values were in good agreement, because the greenhouse room temperature always exceeded rubber sheet temperature and ambient temperature.

Nomenclature

A	area, (m^2)
C	specific heat, (J/kg ^{o}C),
h	total heat transfer coefficient (W/m^2 ^{o}C)
h_c	convective heat transfer coefficient of crop, (W/m^2 ^{o}C)
h_r	radiative heat transfer coefficient, (W/m^2 ^{o}C)
I(t)	solar intensity on horizontal surface, (W/m^2)
M	mass (kg)
N	number of air changes per hour
r	coefficient of correlation
t	time (s)
T	temperature (^{o}C)
T_i	average of crop and humid air temperature (^{o}C)
U	over all heat loss (W/m^2 ^{o}C)
v	wind/air velocity (m/s)
V	volume of greenhouse (m^3)
Greek letters	
α	absorptivity of crop surface
γ	relative humidity of air, (dec.)
τ	transmissivity
Subscripts	
0	initial value
a	ambient or air
c	crop
g	ground or greenhouse floor
I	greenhouse wall/roof (i=1,2,..6)
m	mass
r	greenhouse room air
gr	greenhouse floor to room
gα	greenhouse floor to underground
$\left.\right\vert_{x=0}$	surface of floor of greenhouse

5. REFERENCES

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