

# Introduction of Wood Chips in Controlled Manner for Improving Thermal Efficiency in Tea Drying Furnaces

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**Abstract:** Firewood is the main thermal energy source in tea industry. But there are certain problems facing when it is using fuelwood such as lack of supply, low combustion efficiency of the existing system and low controllability etc. It has been found that high moisture content and inappropriate sizes are directly related to the low combustion efficiency.

Wood chips, which are produced using wood logs, were introduced instead of wood logs as a fuel to reduce moisture level and physical size. In addition Griricidia pieces, which are produced by sticks, can be used instead of large wood logs.

A pilot scale plant is in operation at Deen Side tea factory in Gampola, incorporation with a wood chipper, new grate and screw feeder(attaching a controller), without applying any modifications for the existing furnace. The screw feeder is equipped with a control system, to control wood chip feeding rate to the furnace maintaining the desirable temperature level inside the dryer. Wood chips were prepared using a chipper.

The saving of fuel wood is about 40% by weight. The other advantages are reduction of warming up period, improvement of quality of made tea and user-friendly nature of the system.

**Keywords:** Tea industry, Biomass, wood logs, wood chips

## 1. Introduction

Tea sector is the biggest agro base industry in Sri Lanka. A large number of families directly depend on this industry especially in up country. A sizeable share of the country's income is generated from this sector. Firewood is the main source of thermal energy used for tea drying. It is the biggest industrial consumer of fuel wood in the country and accounts for about 24% of the total of fuel wood consumption in the industrial sector<sup>[3]</sup> accounting for about 326000 metric tons (1997) of annual consumption of fuel wood<sup>[1]</sup>. At present wood logs is the main form of fuel wood used to generate hot air for tea drying. A small amount of heat is also necessary during the withering.

Presently, there is a scarcity of fuel wood and the industry is affected badly. Some factories converted conventional wood fired air-heating systems to diesel fired air-heating systems. As a result the country's dependency on fossil fuels for its energy needs further increased. Further, the cost of production is increased rapidly due to increase of oil prices in the world market making our product less competitive in the international market. This affects badly the national economy. Also burning large amount of oil annually contributes to environment pollution and health hazards due to emissions of sulfur dioxide and carbon dioxide to the atmosphere.

## 2. Current Systems for Hot Air Generation for Tea Processing

After plucking, withering, rolling and fermentation of tea leaves it has to be dried using hot air at a suitable temperature decided by the type of dryer being used for the operation

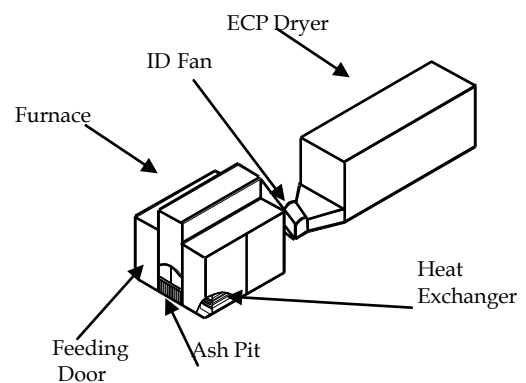


Fig.1. Isometric View of the Existing System

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For example, Endless Chain Pressure ( ECP ) type dryers are operated at a temperature of 102 – 110°C. The hot air for this purpose is generated by fuel wood or oil fired hot air furnace. (fig 1) Furnace cum air heater is coupled to the ECP dryer. Ambient air is sucked through the heat exchanger and delivered to the dryer using an

furnace. Feeding of wood logs is done manually at 20 minutes intervals by labourers. Although provisions are available to control air / fuel ratio, it is difficult to do finer adjustments due to practical constraints. Controlling of air and feeding of logs, is too much operator dependant making it difficult to achieve an efficient operation consistently.

### Nomenclature

$C_p$	Specific heat of air at constant pressure ( $kJkg^{-1}C^{-1}$ )	$t$	time (s)
$C_w$	calorific value of wood chips ( $kJkg^{-1}$ )	$T_a$	Ambient Temperature ( $^{\circ}C$ )
$F$	frequency of the power supply to the screw feeder motor (Hz)	$T_d$	dryer inlet temperature ( $^{\circ}C$ )
$K, k$	constants	$V$	heat exchanger out side volume ( $m^3$ )
$m$	chips weight per resolution (kg)	$\dot{W}_a$	air flow rate ( $kg s^{-1}$ )
$n$	gear box ratio	$\dot{W}_w$	wood chips flow rate ( $kg s^{-1}$ )
$\dot{Q}_d$	heat input to the dryer (kW)	$\eta_{cb}$	combustion efficiency
$\dot{Q}_f$	heat output rate to the dryer (kW)	$\eta_{he}$	heat exchanger efficiency
		$\rho_a$	air density ( $kg m^{-3}$ )

Induced Draught (ID) fan. Required air quantity for the dryer can be changed adjusting the flap position manually. It is difficult to maintain dryer inlet air temperature at a desired level.

### 3.1 Performance of Existing Furnaces Cum Hot Air Generators

According to the study carried out by Energy and Environmental Management Centre of the National Engineering Research and Development Centre (NERDC), there is a wide variation of fuel wood consumption among the tea factories. Some tea factories, especially in up country, use diesel fired air heaters in addition to fuel wood heaters. Fuel wood consumption for tea processing in three parts of Sri Lanka is summarized in Table 1.

Table 1. Biomass Requirement for Processing of Tea

Region	Fuel wood consumption (kg/kg of made tea)
Up country	1.75
Mid country	1.80
Low country	1.81

Almost all the wood burning furnaces in the tea factories are designed for the burning of wood logs. Normally, wood logs are split into 75mm x 75mm x 1000mm before they are fed in to the



Fig. 2. Manual feeding of wood logs

The major findings of an energy audit carried out by the NERDC at the DEEN SIDE tea factory are as follows

- \* The current overall efficiency of hot air generation system is around 40%
- \* Temperature of the flue gas is comparatively high and it is around 275°C.
- \* The excess air level in the flue gasses is more than 100%, whereas the expected level is 40%
- \* The Moisture Content in Wet Basis (MCWB) of wood logs is more than 43%.

\* Range of fluctuation of hot air temperature is almost  $\pm 20\%$  affecting the quality of the Made Tea (MT).

According to the above information, flue gas temperature is comparatively high. Introducing fins externally (increasing area) and screws internally (increasing resident period) for the tubes of heat exchanger, it's efficiency can be improved some extend.

In addition, flue gas loss due to excess air can be reduced by introducing an automatic air controller for the furnace. In such a system, O<sub>2</sub> & CO levels are detected by a sensor attached to the chimney and air requirement will be corrected accordingly.

Furthermore, recuperator can be used to absorb some of the heat from the exhaust gas and it can be utilised to preheat combustion air or dehydrate wood chips, increasing the overall thermal efficiency of the system.

In this study, wood chips are used instead of wood logs with controlled feeding, in order to improve the efficiency of combustion, to minimize the fluctuation of hot air temperature and also to minimize the moisture content of fuel wood.

#### 4. Objective

The objective of this project is to improve the efficiency of biomass combustion technology in tea industry introducing chipped fuel wood instead of wood logs.

#### 5. Experimental Methodology

Instead of wood logs, wood chips were used. A special screw conveyer was designed and fabricated for this purpose. After several modifications, conveyer system was developed to have a smooth operation. Then a modified grate was introduced replacing the existing grate. The replaced grate has a special feature of having an inclination across the grate & along the grate

in order to spread wood chips properly. In addition, an agitator is attached to the end of the screw to enhance the spreading of wood chips. Then wood feeding controller system was designed, constructed & coupled to the system.

##### 5.1 Wood Chipper

A wood chipper was designed and developed to cut required size of wood chips using wood logs.

Table 2. Specifications of the NERDC Wood Chipper

Parameter	Designed Value
Capacity	300 kg/h, 40% moisture in wet basis
Motor power	15 kW
Maximum wood diameter	50mm
Wood chips size	40mm x 40mm x 7mm



Fig.3. Wood Chipper Developed by NERDC

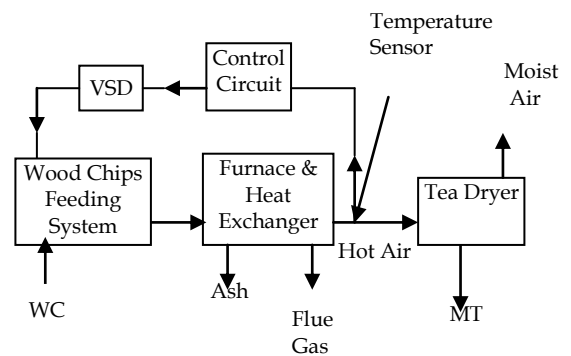


Fig.4. Schematic Diagram of the Process

After manufacturing all accessories for the system, it was coupled to the existing wood log furnace. Then the system was tested for wood chips which were produced by the chipper & Gliricidia pieces which were produced by manually.

## 5.2 Wood Chips Controlling System

Feed controlling system is one of the major improvement, incorporated into the fuel Wood feeding system of NERDC. The temperature sensor senses the temperature of hot air and is used to control the rotation speed of the feeding motor via the variable speed drive. Thus the rate of feeding of wood chips is controlled according to the hot air temperature so as to maintain it within a close range. Fig.4. shows the schematic diagram of the system. The set temperature range of the controller is 104°C to 110°C for this experiment.

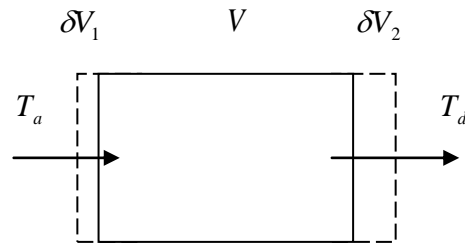
## 5.3 Screw Feeder

The frequency of the input current for the motor of the screw feeder is not changed (50 Hz) up to the temperature 104°C. Then the frequency is gradually decreased according to the dryer inlet temperature up to 25Hz at 110°C. Thereafter frequency does not drop according to the increasing temperature and it maintained at 25Hz level. (see fig.6.). Otherwise frequency decreases further and ultimately the motor is not running. Therefore wood chips are not conveyed to the furnace and combustion is stopped. As a result, dryer inlet air temperature fluctuation is very high, badly affecting the quality of the tea. To avoid this problem, minimum frequency level was set as 25Hz.



Fig.5. Screw Feeder Coupled to the Existing

## 5.4 Mathematical Model Developed for the Developed System



The relationship between **frequency of the power supply to the motor of the screw feeder** & dryer inlet temperature is given by equation (1). This is derived using figure No.6

$$F = f(T_d) = 4.2T_d - 383.3 \quad (1)$$

Wood chips flow rate of the screw feeder is given by equation (2)

$$\dot{w}_w = knmf(T_d) \quad (2)$$

$$\dot{w}_w = Kf(T_d) \text{ where; } K = knm \quad (3)$$

Thermal out put from the furnace is given by equation (4)

$$\dot{Q}_f = \eta_{cb} C_w Kf(T_d) \quad (4)$$

Heat input rate to the dryer is given by equation (5)

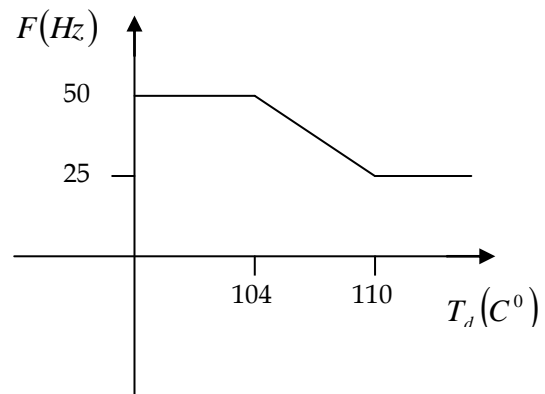


Fig.6. Dryer inlet temperature & screw feeder motor frequency variation

$$\dot{Q}_d = \eta_{he} \eta_{cb} C_w Kf(T_d) \quad (5)$$

Considering  $\delta Q_d$  heat input during  $\delta t$  time period

$$\delta Q_d = \eta_{he} \eta_{cb} C_w K_f (T_d) \cdot \delta t \quad (6)$$

Considering  $\delta T_d$  temperature variation in the heat exchanger during  $\delta t$  time period

$$\delta Q_d = V \rho_a C_p \cdot \delta T_d + \dot{w}_a \cdot \delta t (T_d + \delta T_d - T_a) \quad (7)$$

From equation (6) & (7)

$$\delta Q_d = \eta_{he} \eta_{cb} C_w K_f (T_d) \cdot \delta t = V \rho_a C_p \cdot \delta T_d + \dot{w}_a \cdot \delta t (T_d - T_a)$$

$$\eta_{he} \eta_{cb} C_w K_f (T_d) = V \rho_a C_p \cdot \frac{\delta T_d}{\delta t} + \dot{w}_a (T_d - T_a)$$

$$\frac{\delta T_d}{\delta t} = \frac{\eta_{he} \eta_{cb} C_w K_f (T_d)}{V \rho_a C_p} - \frac{\dot{w}_a (T_d - T_a)}{V \rho_a C_p} \quad (9)$$

$$\frac{\delta T_d}{\delta t} = \frac{\eta_{he} \eta_{cb} C_w K (4.2 T_d - 383.3)}{V \rho_a C_p} - \frac{\dot{w}_a (T_d - T_a)}{V \rho_a C_p}$$

$$\frac{\delta T_d}{\delta t} = \frac{T_d (4.2 \eta_{he} \eta_{cb} C_w K - \dot{w}_a)}{V \rho_a C_p} - \frac{(383 \eta_{he} \eta_{cb} C_w K + \dot{w}_a T_a)}{V \rho_a C_p}$$

According to the above equation dryer inlet temperature ( $T_d$ ) variation with time ( $t$ ) is illustrated.

## 6. Results and Discussion

Three types of fuel woods were taken for the experiment and one type was used for two trials.

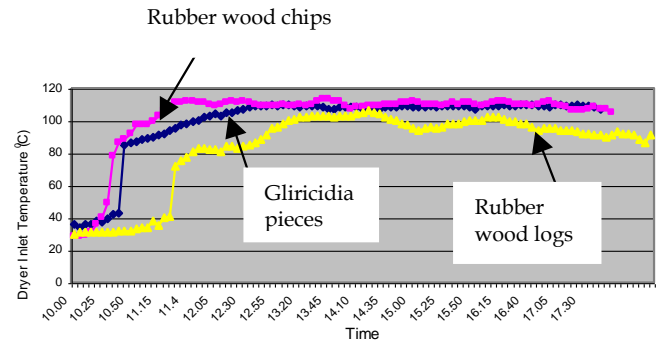
Trial no	Type of wood	Fuel wood consumption @ 15% MCWB (Kg)	Quantity of Made tea (Kg)	Fuel wood consumption Kg/ Kg of made tea
1	RWC	796	618	1.29
2	RWL	1051	435	2.42
3	GP	776	583	1.33
4	RWC	883	687	1.28
5	RWL	1085	454	2.39
6	GP	730	558	1.31

Table 3. Summarised results of the trials

Only one trial was conducted per day and the period of the trial was 8 hours. All trials were started at 10.00 a.m and stopped it at 6.00p.m. Temperatures at different **locations of the dryer** were recorded using temperature data logger in 10 minutes intervals.

According to the figures in the above table, almost same weights of Rubber Wood Chips (RWC) and Gliricidia Pieces (GP) are consumed (around 1.3 kg) to produce 1 kg of made tea. But with the Rubber Wood Logs (RWL), it is consumed around 2.4 kg of biomass.

The **graph below** illustrates actual dryer inlet temperature variation with the time. According to the graph, warming up period is higher when wood logs are used. As well as temperature fluctuation is comparatively greater for wood logs.



Graph 1. Dryer inlet temperature variation with time

Rubber wood chips and Gliricidia pieces were fed using developed system and as a result, almost constant temperature (at dryer inlet) profile was obtained.

## 7. Cost Benefit

Since the cost of one cubic yard of RWL at factory is Rs. 850/= (year 2005), fuel wood cost for 1 Kg of made tea is Rs. 9.22 for the dryer used for the experiment.

The cost involvements for the usage of RWC & GP are different. There is a preparation process before use RWC including splitting, chipping etc. Including all expenses, 1 Kg of RWC is Rs. 4.93 and cost of new feeding system is around Rs. 1.2 million. Considering all factors pay back period for the use of RWC is about 11 months. There is no preparation cost when use Gliricidia and cost of 1 kg of GP (20% moisture content in wet basis) is Rs. 3.50 at the factory. Wood chipper is not needed for GP used system and cost of the system is Rs. 1 million. The Pay back period of this system is about 6 months.

## 8. Conclusion

Introducing the developed system for furnaces in tea industry, 35% to 40% saving can be archived. The fuel wood saving is depending on the dryer type, geographical situation and the weather condition.

Total consumption of fuel wood in tea industry is around 330,000 MT per annum. Introducing this developed system for all tea furnaces, it can be saved about 115,500 MT of fuel wood (minimum) per year and hence it help to reduce the release of CO<sub>2</sub> to environment by 423,500 MT per year.

The developed mathematical model has to be validated. There after the system will be optimised.

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