

# Experimental Study on the Direct Contact Thermal Screw Drying of Sawdust for Wood-Pellet Fuel\*<sup>1</sup>

Hyoung-Woo Lee\*<sup>2†</sup>

## ABSTRACT

Wood fuel must be dried before combustion to minimize the energy loss. Sawdust of Japanese red pine was dried in a direct contact thermal screw dryer to investigate the drying characteristics of sawdust as a raw material for bio-fuel. Average drying rate and energy efficiency was 1.4%/min and 69.23% at 100 °C, respectively, and those at 120°C was 2.1%/min and 71.03%, respectively.

**Keywords :** sawdust drying, direct contact thermal screw dryer, energy efficiency, bio-energy, wood pellet fuel

## 1. INTRODUCTION

All ligno-cellulosic materials such as wood, straw, paper and many vegetable fibers represent a valuable energy resource. The major problem for these materials is their large volume to weight ratio, making the handling, storage and transport not only difficult but expensive.

This problem can be overcome by refining this material by drying and then compressing it at very high pressure to produce fuel briquettes or pellets. These final products will thus have a higher density and a high heating value.

Wood pellet production started in North America in the second half of the 1970's, and later spread to Europe and other parts of the world. Today, wood pellets are produced and

used on a global scale. The use is concentrated in developed countries (Vinterback, 2004).

Wood fuels, such as wood chips, barks and sawdust, contain water. High moisture levels lead to energy losses. If the wood fuels are burned without being dried, a significant fraction of the heating value of the fuel is used to evaporate the moisture in wood fuels. This results in decreased efficiency and increased emissions in the combustion. There might also be higher risks of mould formation during storage of moist wood fuels. Therefore drying is a key step in the processing of wood fuels.

There have been many studies to determine the most efficient drying method for wood fuels. Hermansson *et al.* (1992) discovered that the inhomogeneity of the wood fuels caused an uneven mass flow distribution through the mate-

\*1 Received on December 26, 2006; accepted on January 30, 2007.

\*2 Inst. of Agri. Sci. & Tech., College of Agriculture, Chonnam Nat'l Univ., Gwangju 500-757, Korea.

† Corresponding author : Hyoung-Woo Lee (hwlee@chonnam.ac.kr)

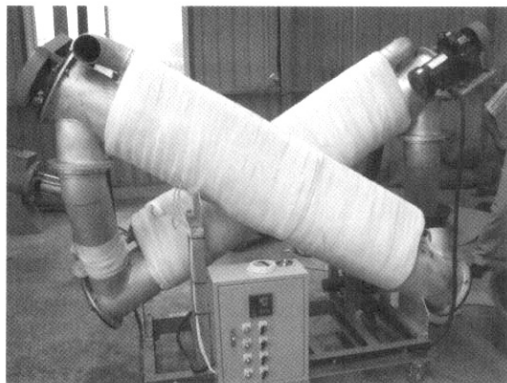


Fig. 1. Lab.-scale direct contact thermal screw dryer.

rial bed which led to a decreased thermal efficiency in their experiments on fixed-bed drying of wood chips and barks with superheated-steam. Johansson and Rasmusson (1997) investigated the effect of drying mediums for wood chips theoretically and showed that shorter periods of constant drying rate, higher maximal drying rates and shorter drying times were obtained with air as drying medium rather than superheated-steam. Fyhr and Rasmuson (1997) studied on the optimal length of pneumatic conveying chip dryer to obtain the desired final moisture content.

Renstrom and Berghel (2002) performed tests on drying sawdust in a spouted bed steam dryer at atmospheric pressure. Their results show that it should be possible to control the outgoing moisture content using the temperature after the dryer as a control parameter.

Yrjola and Saastamoinen (2002) discussed on the practical operation of dryers within the boiler plants through the modelling of drying in fixed and moving bed of wood chips. Recently, Lee (2005) studied on the fluidized-bed drying characteristics of sawdust as a raw materials for wood pellet fuel.

In convective drying, large amount of energy should be consumed to make high velocity air. Average energy efficiency of rotary drum dryer,

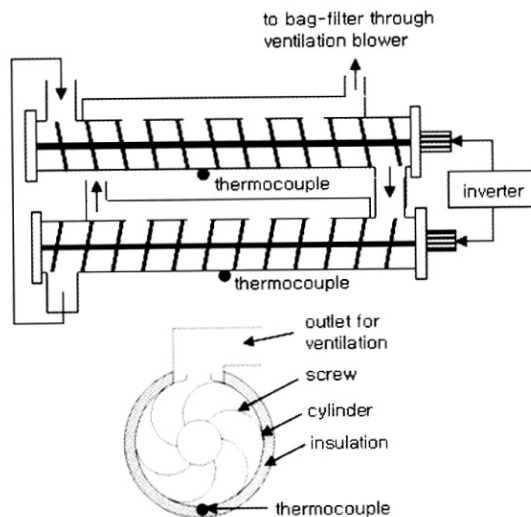


Fig. 2. Schematic diagram of direct contact thermal screw dryer.

which is the most common drying system for sawdust or wood chip, is only about 30% and that of fluidized-bed dryer is 55% (Moreno *et al.*, 1998). About 30% of total production costs in wood pellet plant is spent for drying raw material. Therefore, enhancement of energy efficiency in drying is one of the most important ways to strengthen the competitiveness of wood pellet fuel against other energy resources.

In this study, an experimental analysis of sawdust drying in a direct contact thermal screw dryer was carried out to investigate the drying characteristics of sawdust as a raw material for wood pellet fuel.

## 2. MATERIALS and METHODS

Fig. 1 and Fig. 2 shows the experimental equipment used in this study, which is composed by two 2 m-long cylinders with inner diameter of 254.6 mm. Cylinders were made of 6.4 mm-thick steel plate. Each screw was driven by 0.75 kW geared motor with a frequency converter to regulate conveying speed from 0 to

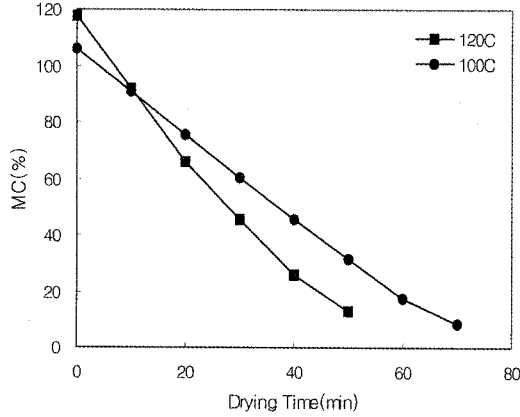


Fig. 3. Drying curves of sawdust during direct contact thermal screw drying at 100°C and 120°C.

5 m/min in cylinder. One of cylinders outlet was connected to the other cylinder's inlet to simulate infinite cylinder. Therefore, retention time could be prolonged as desired.

Water vapor evaporated from sawdust during drying was exhausted by 0.22 kW centrifugal blower and bag filter was connected to the outlet air duct to collect the dust from the dryer.

Eighteen 1.3 kW band type electric heaters wrapped the outer surfaces of cylinders to supply heat energy to maintain the desired drying temperatures. Cylinders were insulated with 50 mm-thick glass wool.

Cylinder wall's temperature was monitored by K-type thermocouple and controlled by PID controller. Total energy consumptions were monitored by watt-hour meter, which included electric energy for heaters, motors and blower. The energy required to heat the sawdust was not included.

The sawdust used in this study was produced from Japanese red pine (*Pinus densiflora* Sieb. et Zucc) with a 3 mm-thick bandsaw of lumber manufacturing plant.

Feed speed was set at 1.3 m/min and drying temperatures of 100°C and 120°C were applied. At each experiment, sample was collected at 10

min interval to monitor the moisture content change during drying. Then energy efficiencies were calculated as follow:

$$\eta = \frac{W_e \times H_L}{E_T \times 860} \times 100 \quad [1]$$

$\eta$  : Energy efficiency (%)

$W_e$  : Weight of water evaporated (kg)

$H_L$  : Latent heat of evaporation (=539 kcal/kg)

$E_T$  : Total electric energy consumption (kWh)

860 : 1 kWh = 860 kcal/hr

### 3. RESULTS and DISCUSSION

#### 3.1. Drying Curves

Fig. 3 shows drying curves at 100°C and 120°C. At drying temperature of 120°C sawdust could be dried from 117.8% to 12.8% moisture content within 50 minutes. At 100°C from 106.1% to 8.6% within 70 minutes. Average drying rate was 1.4%/min and 2.1%/min at 100°C and 120°C, respectively.

#### 3.2. Energy Efficiency

Energy efficiency changes in direct contact thermal screw drying of sawdust were shown in Fig. 4. Total electric energy consumption was 8.8kW and 9.0 kW at 100°C and 120°C. At 100°C the maximum energy efficiency was 75.21% and then decreased to 52.12% as moisture content of sawdust decreased. The maximum energy efficiency of 78.34% also decreased to 55.65% at 120°C.

Somewhat lower energy efficiencies than the maximum in the early stage of drying were mainly due to the energy consumption for heating up the sawdust. In this study the energy for heating up was not considered in calculating the energy efficiency. In final drying stage enough

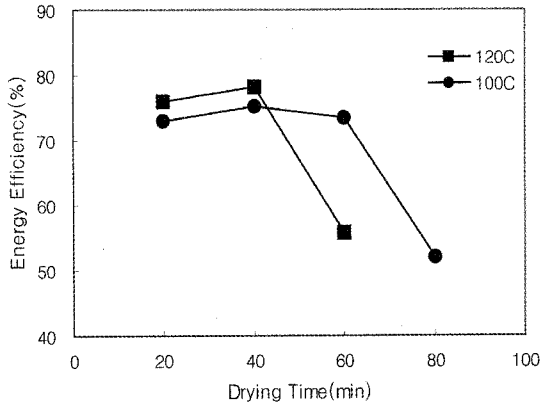


Fig. 4. Energy efficiency of direct contact thermal screw drying of sawdust at 100°C and 120°C

moisture did not remain in sawdust and large amount of energy should be spent for heating up sawdust itself. Consequently, energy efficiencies decreased dramatically in final drying stage.

Average energy efficiency was 69.23% and 71.03% at 100°C and 120°C, respectively. Therefore, there was no significant difference in energy efficiency according to drying temperature.

Average energy efficiency of about 70% in direct contact thermal screw drying is much higher than conventional convective rotary kiln drying and better even than fluidized-bed drying as mentioned in introduction of this study.

### 3.3. Design of Commercial Drying System

For the commercialization of this drying system proper final moisture content of sawdust should be guaranteed for efficient wood pellet manufacturing process. In general, the proper moisture content of sawdust as a raw material for wood pellet is known as about 10%.

If the initial moisture content of sawdust which will be fed into dryer can be monitored precisely, exact retention time in dryer or exact

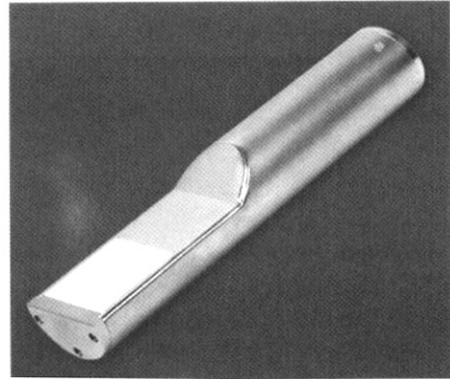


Fig. 5. Microwave type moisture sensor.

conveying speed can be estimated as far as the energy efficiency of dryer is known and the dryer is long enough.

In this study the preliminary test for moisture sensor was performed to commercialize this dryer in the near future. There is no moisture sensor developed specially for sawdust. Therefore, microwave type moisture sensor (Hydro-Probe II, Hydronix Co. Ltd., England) for cement industry was selected for this test (Fig. 5).

Calibration tests were performed with plastic box (300 mm × 400 mm × 570 mm) which filled with sawdust. Microwave moisture sensor was inserted into one of walls on plastic box.

Then outputs (mV) from this sensor was monitored at different sawdust moisture content. As a result good correlation between sawdust moisture content and sensor output could be obtained as shown in Fig. 6.

With this sensor direct contact thermal screw dryer can be automated as Fig. 7. Moisture sensor determine the initial moisture content of sawdust being fed into dryer at predetermined time interval. The output signal is sent to PLC (programmable logical controller) and PLC determines the proper conveying speed with respect to target moisture content and energy input rate. Then the order from the PLC is transferred to inverter to maintain proper conveying

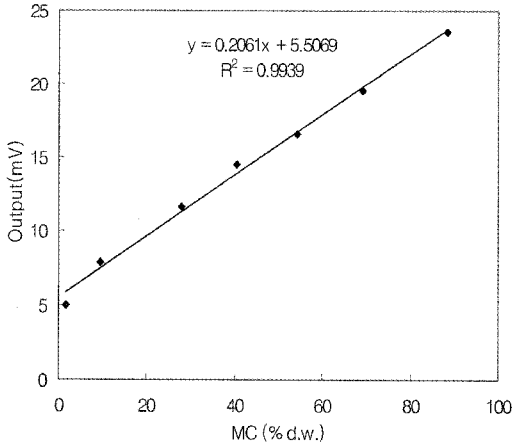


Fig. 6. Calibration between sawdust moisture content and sensor output.

speed.

Time required to dry sawdust from initial to target moisture content can be estimated by Equation [2]:

$$t = \frac{W_0 \times (M_i - M_t) \times V_s \times 539}{\eta \times E_i \times 100} \quad [2]$$

$t$  : time required to dry sawdust to target moisture content (hr)

$W_0$  : basic density of sawdust ( $\text{kg/m}^3$ )

$M_i$  : initial moisture content of sawdust (%)

$M_t$  : target moisture content of sawdust (%)

$V_s$  : volume of sawdust filling the whole dryer ( $\text{m}^3$ )

$E_i$  : energy input per hour (kcal/hr)

Therefore, conveying speed optimized for target moisture content can be calculated as follow:

$$S_c = \frac{L_s}{t \times 60} \quad [3]$$

$S_c$  : proper conveying speed (m/min)

$L_s$  : total length of screw dryer (m)

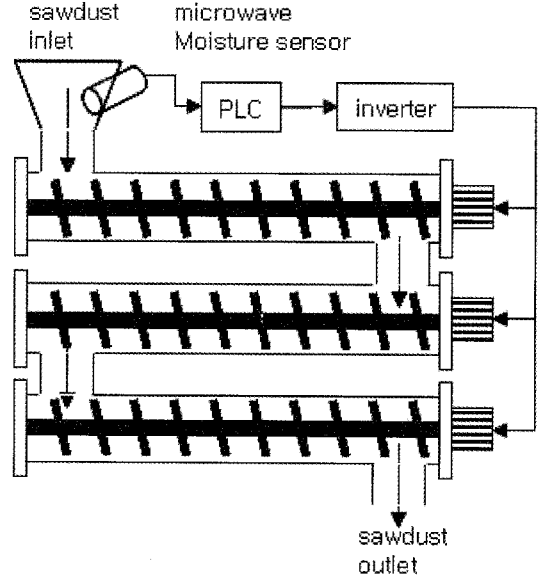


Fig. 7. Schematic diagram of commercial direct contact thermal screw drying system with moisture sensor.

## 4. CONCLUSIONS

An experimental analysis of sawdust drying in a continuous type direct contact thermal screw dryer was carried out to investigate the drying characteristics of sawdust as a raw material for wood-pellet fuel.

Average energy efficiency in direct contact thermal screw drying was about 70%, which is much higher than conventional convective rotary kiln drying and better even than fluidized-bed drying.

## ACKNOWLEDGEMENTS

This work was (in part) supported by the Korea Energy Management Corporation.

## REFERENCES

1. Fyhr, C. and A. Rasmuson. 1997. Steam drying of wood chips in pneumatic conveying dryers. Dry-

- ing Technology 15(6&8): 1775~1785.
2. Hermansson, M., P. Andersson, and R. Wimmerstedt. 1992. Steam drying of wood fuels. *Drying Technology* 10(5): 1267~1286.
3. Johansson, A. and A. Rasmuson. 1997. The influence of the drying medium on high temperature convective drying of single wood chips. *Drying Technology* 15 (6&8): 1801~1813.
4. Lee, H. Y. 2006. Study on the fluidized-bed drying characteristics of sawdust as a raw-material for wood pellet fuel. *Journal of the Wood Science and Technology* 34(2): 30~36.
5. Moreno, R. and J. Oyarzo. 1998. Sawdust fluid-bed drying with heating tubes. *Drying Technology* 16(1&2): 351~367.
6. Renstrom, R. and J. Berghel. 2002. Drying of sawdust in an atmospheric pressure spouted bed steam dryer. *Drying Technology* 20(2): 449~464.
7. Yrjola, J. and J. J. Saastamoinen. 2002. Modelling and practical operation results of a dryer for wood chips. *Drying Technology* 20(6): 1077~1099.
8. Vinterback, J. 2004. Pellets 2002: the first world conference on pellets. *Biomass & Bioenergy* (in press).