Research Journal of Applied Sciences, Engineering and Technology 9(4): 282-287, 2015
DOI:10.19026/rjaset.9.1406
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: August 13, 2014 Accepted: September 14, 2014 Published: February 05, 2015

Research Article

Biomass Powered Natural Convection Kiln for Timber Drying

[1]N.V. Ogueke, [1]P.C. Nwaizu, [1]O. Nwufo, [2]K. Nwaigwe and [1]E.E. Anyanwu
[1]Department of Mechanical Engineering,
[2]Department of Agricultural Engineering, Federal University of Technology, PMB 1526, Owerri, Nigeria

Abstract: The design and test performance of a biomass powered natural convection kiln for timber drying is presented. It consists of two sections: the heating section where biomass combustion for inlet air heating occurs and the drying section where the timber is loaded for drying. Inlet air heating is achieved in a heat exchanger of dimension 0.5 m by 0.165 m while temperature stratification in the drying chamber is reduced by letting flue gas from the combustion chamber flow through a space between the side walls of the drying section and the outer housing of the kiln before being expelled. The kiln performance test was carried out for 40 day. Results obtained show that air temperature within the drying section stabilized at 55 -59°C with a minimum relative humidity of 31% (when unloaded) and 45% (when loaded). Timber moisture content reduction from 65 to 30% was achieved in 30 days. Thus it has potential for improved timber drying.

Keywords: Biomass, drying, kiln, timber

INTRODUCTION

The importance of wood to man is enormous. However, its major applications are seen in the building industry for building construction and furniture making. In the rural areas of the developing world, they serve as fuel for cooking purpose in homes and sometimes hotels. Wood is mostly useful in its dry state. Unfortunately freshly cut wood contains a lot of moisture; about 50% (Desch and Dimwoodie, 1996) which must be removed before the wood is put to proper use. The moisture removal in wood (i.e., drying) can be achieved either by air drying or drying in a kiln. In air drying, the wood is exposed to ambient air. The ambient humidity in most localities prevents the wood from reaching the moisture content necessary for dimensional stability and use, especially for interior use (Bond *et al*., 2011) while in kiln drying, the processes are controlled for optimal performance, thus it is better and often preferred.

Different types of kilns for wood drying exist. However, the most extensively studied are the solar powered kilns. This may be associated to the running cost and energy demand of conventional kiln where air heating comes mostly from steam. The use of solar as an energy source in kiln for wood drying dates back to the beginning of last century and it is currently applied the world over in various kilns design (Bauer, 2003). A review of 31 different solar kiln designs classified them as solar kilns with external collectors and greenhouse type solar kilns (Wengert and Oliviera, 2010). Some of the resent works on solar kiln include the works of Bond *et al*. (2011) on design and operation of a solar heated dry kiln; Kassem *et al*. (2013) on the development of the solar kilns used in drying the palm trees waste in Saudi Arabia; Müller (2011) on operation and performance of a solar hardwood drying kiln utilizing natural dehumidification; Bergman (2008) on operation and cost of a small dehumidification dry kiln; Haque and Langrish (2006) on assessment of the actual performance of an industrial solar kiln for drying timber and MacDonald (2009) on drying lumber-with solar energy. Unfortunately these systems suffer from low drying rate with little or no drying occurring at night and heavily overcast periods of the day. Furthermore, fans are employed for effective drying operation thus introducing complexities that increase cost of the system and also make it difficult to use in remote regions without grid connected electricity.

Biomass is a form of renewable energy and very easily accessible. Dry leaves and wood shavings are some common examples. Its appropriate use to power kiln will significantly reduce the problem of night time drying or drying during overcast days associated with solar kilns. Furthermore, since its energy source is biomass, it can come from the tree being processed. Unfortunately, no record of this type of dryer has been reported in the literatures. Therefore in this study, a biomass powered natural convection kiln for wood drying is investigated. This kiln tries to solve most of the identified problem associated solar kiln.

Corresponding Author: N.V. Ogueke, Department of Mechanical Engineering, Federal University of Technology, PMB 1526, Owerri, Nigeria, Tel.: +234 805 300 6458

THE KILN

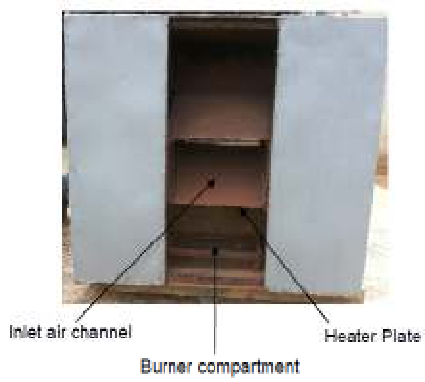
Figure 1 shows the pictorial representation of the kiln. It consists of two sections: the heating and the drying sections. The heating section (Fig. 2) consists of a heat exchanger (air heater) made from a 0.001 m thick galvanized steel plate of dimension 0.5 m by 0.165 m and a burner of depth 0.205 m, length 0.57 m and width 0.2 m capable of holding approximately 3 kg biomass. The bottom plate is perforated for two reasons:

- To allow enough air to be entrained for complete combustion.
- To allow ash fall off while combustion is on.

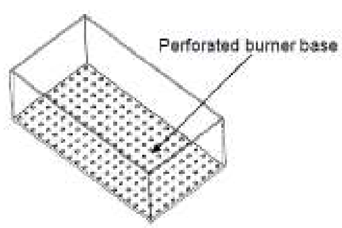
Air heating is achieved by drawing air over the air heater which is inclined at an angle of 30°. The air heater forms part of an inlet air channel with a rectangular cross section. Sustained air movement from the air heater to the combustion chamber is achieved through buoyancy effect.

The drying section (Fig. 3) is a cuboid of volume 0.33 m^3. It is made from 0.001 m thick galvanized steel. An opening at the top of the drying section serves as exit for the moist air from the drying chamber. In order to reduce temperature stratification within the drying section, further air heating is achieved in the drying section by letting flue gas from the combustion chamber flow through a space between the side walls of the drying section and the outer housing of the kiln before being expelled. The outer housing is made of 0.001 m galvanized steel and properly insulated on the outside with wood fibre in order to minimize heat loss to the ambient surroundings. For rigidity, 0.051 m 90° angle iron was used as the frame of the entire assembly.

Fig. 1: Pictorial representation of the kiln



(a)



(b)

Fig. 2: The Kiln showing; (a): The heating section; (b): The burner

Fig. 3: The Kiln showing the drying section

EXPERIMENTAL TEST AND RESULTS

The kiln is fired by charging the burner with dry leaves (which served as the fuel) and returned to the burner compartment. Heating was initiated by igniting the dry leaves. Temperatures at three different points in the drying chamber and the heater plate were measured every 10 min with a Supco DVT4 data logger interfaced with a HP laptop. Some of the relevant meteorological conditions were obtained from a Davis® weather station installed close to the test location. Heated air Relative Humidity (RH) at exit from the drying chamber was obtained using an Omega® 4-in-1 digital hand held wind/humidity/light/temperature meter with an accuracy of 4% while the wood temperature at a depth of 0.03 m from the wood surface was obtained using a thermocouple connected to a digital thermometer. A weighing balance was used to determine weight of wood before commencement of drying and after every 24 h of drying. Moisture Content (MC) of the wood is determined using Eq. (1):

$$MC = \frac{m_{wet} - m_{dry}}{m_{dry}} x100 \quad (1)$$

Two logs of wood of diameter 0.10 m and 1.1 m long were used. One of the logs was kept in the drying chamber while the second is left to dry in the open air.

Fig. 4 and 5 show some of the recorded kiln performances. While Fig. 4 shows the performance without load, Fig. 5 shows the performance when loaded with wood. The figures reveal that temperatures within all parts of the drying chamber are almost uniform both when loaded and unloaded. Therefore the use of a fan for air circulation and maintenance of relatively uniform temperatures may not be necessary. Air temperature within the drying chamber reached a stable operating value of 57°C after 110 min and 60°C after about 280 min for the unloaded and loaded test conditions, respectively. The delay in attaining stable operating temperature when the kiln is loaded compared to when it is unloaded was caused by the increased thermal mass of the space as a result of the log of wood. Inspecting the temperature profile of the wood also points in the same direction.

Comparing the two figures, it is seen that while moisture removal through the moist air removal point was noticeable, the rate of moisture removal was low resulting in the low RH difference of about 14% between the unloaded and loaded systems (Fig. 6). This can be improved by increasing the size of the exit point from its current value of 30 mm. The effect of the moisture accumulation within the drying chamber is seen more clearly in Fig. 6 and 7. Figure 6 shows that drop in the drying chamber was more rapid for the unloaded unit. Comparing the two situations, it can be seen that RH in the drying chamber dropped from an initial value of 76- 40% after 120 min of operation

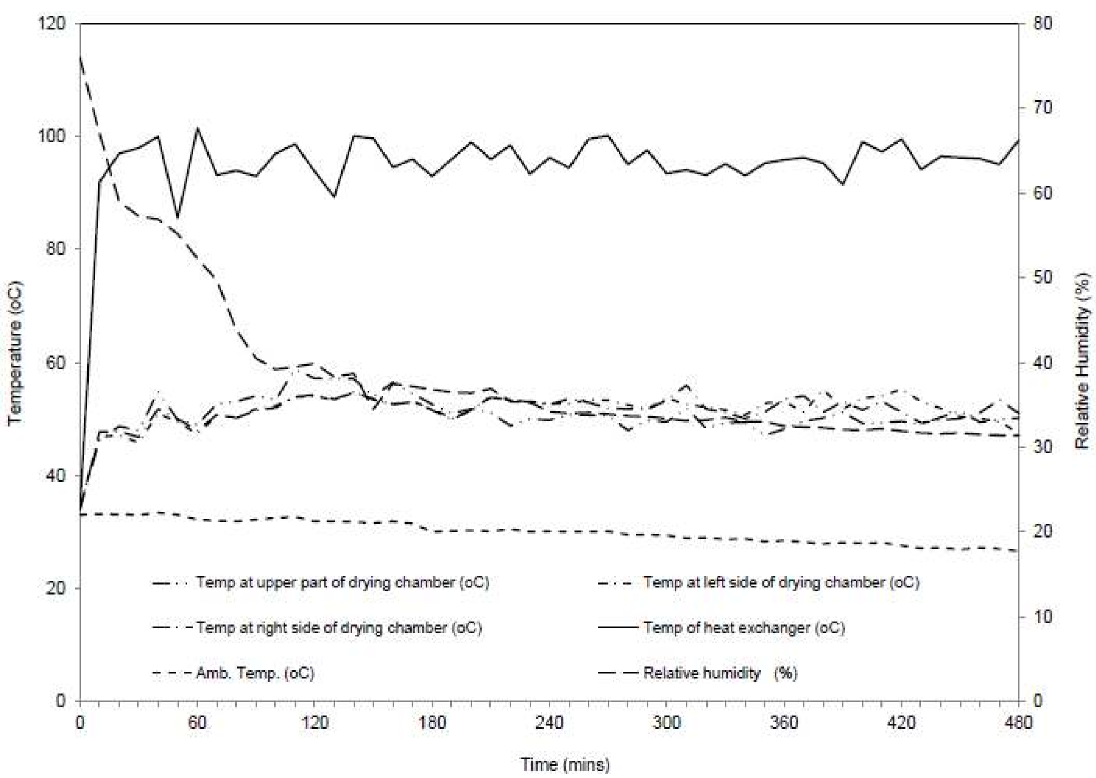


Fig. 4: The dryer performance when unloaded

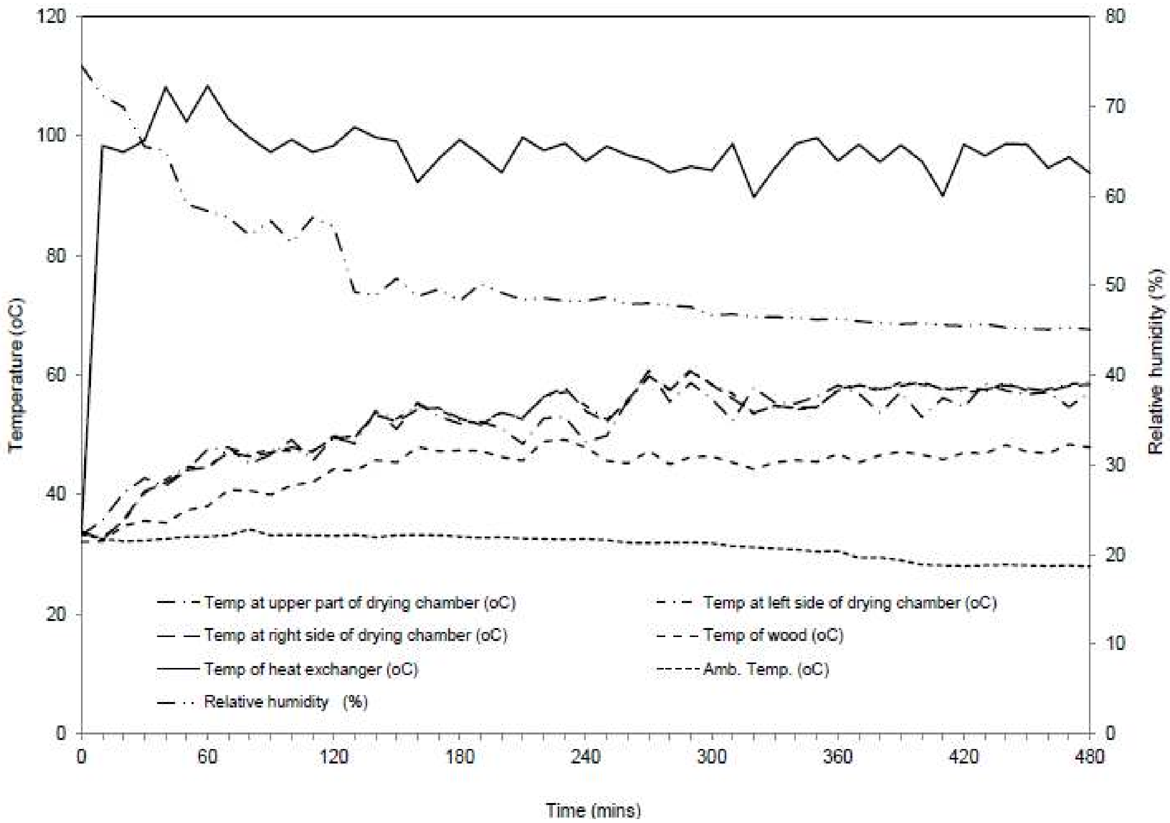


Fig. 5: The dryer performance when loaded

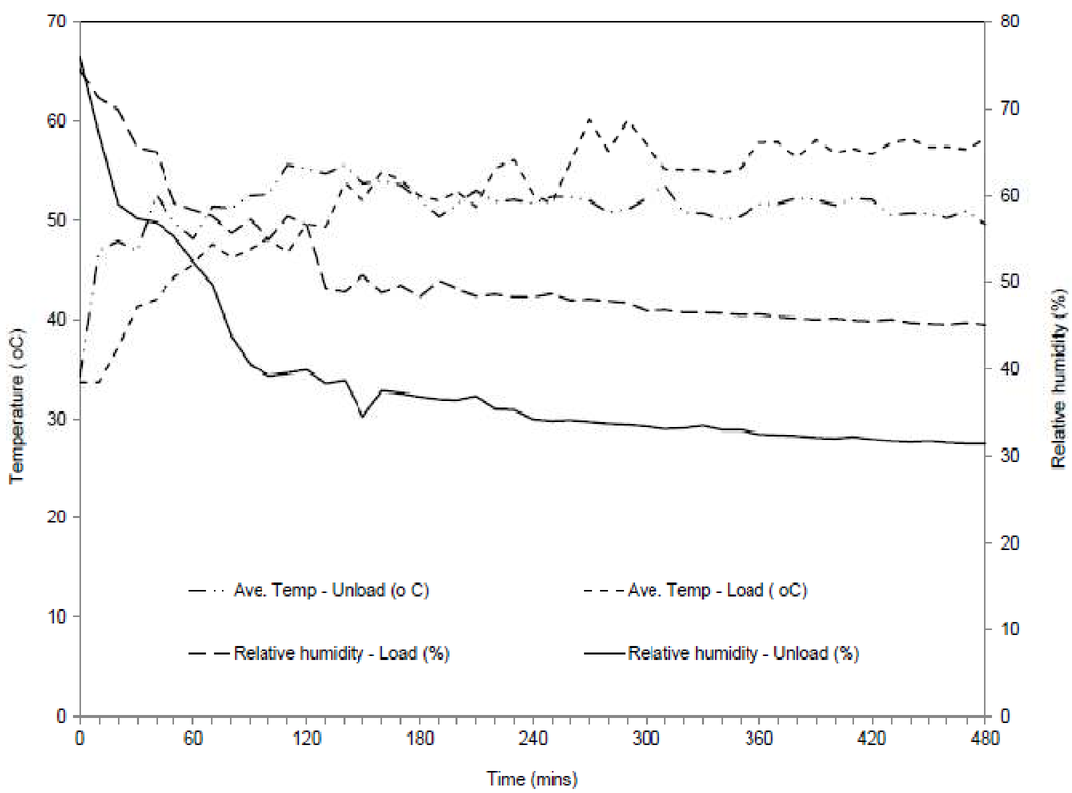


Fig. 6: Comparison of the loaded and unloaded dryer performance

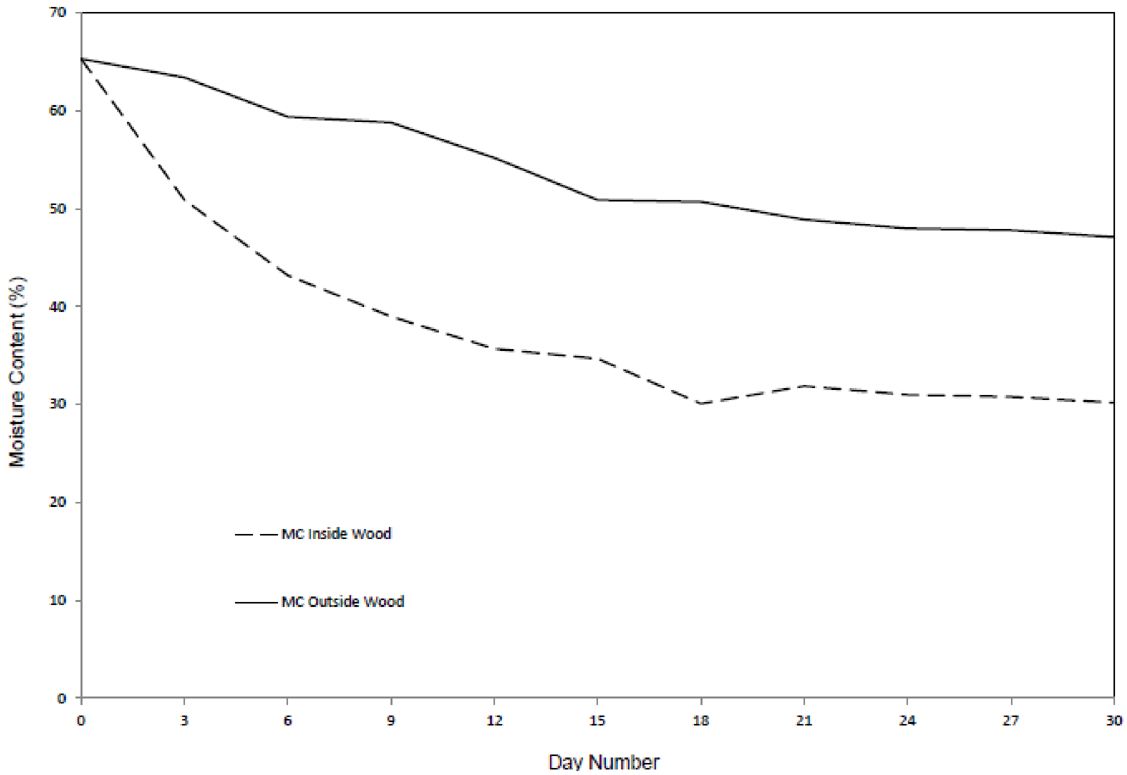


Fig. 7: Comparison of the wood moisture content variation during open air and kiln drying operations

without load while when loaded, it only reduced from an initial value of 75-57% for the same operating time. Similarly, Fig. 7 shows the MC change of the logs of wood after each day of drying. The figure reveals that after 9 days of drying, moisture removal rate from the log of wood inside the drying chamber of the kiln decreased significantly, resulting in a lowest MC of 30% after 30 days of drying.

CONCLUSION

The design, construction and test performance of a biomass powered natural convection kiln has been undertaken. From the results obtained, the following conclusions may be deduced:

- Maximum air temperature within the drying section stabilized at 55-59°C with a minimum relative humidity of 31% (when unloaded) and 45% (when loaded).
- With the kiln, a moisture content reduction of the wood from an initial value of 65 to 30% can be achieved in 30 days. For a similar wood sample dried in open air, a moisture content drop from 65 to 47% was achieved during the same time period.
- There is the need for better means of moist air removal from the drying chamber for improved dryer performance.

ACKNOWLEDGMENT

The authors gracefully acknowledge the contributions of Mr. Okechukwu J. Nwaogu, Mr. Emeka Charles Nwanna and Mr. Chimaobi Nwachukwu in the initial data collection.

REFERENCES

Bauer, K., 2003. Development and optimisation of a low-temperature drying schedule for *Eucalyptus grandis* (hill) ex maiden in a solar-assisted timber dryer. Unpublished Ph.D. Thesis, University of Höhenheim, Hohenheim.

Bergman, R.D., 2008. Operation and cost of a small dehumidification dry kiln. Research Note FPL-RN-0310, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI, pp: 20.

Bond, B., O. Espinoza and P. Araman, 2011. Design and operation of a solarheated dry kiln for tropical latitudes. Gen. Tech. Rep. SRS-134, U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC, pp: 14.

Desch, H.E. and J.M. Dinwoodie, 1996. Timber: Structure, Properties, Conversion and Use. 7th Edn., Macmillan Press Ltd., London, pp: 306.

Haque, M.N. and T.A.G. Langrish, 2006. Assessment of the actual performance of an industrial solar kiln for drying timber. Dry. Technol., 23: 1541-1553.

Kassem, T.K., A.S. Alosaimy, M. Fazian and A.M. Hamed, 2013. Development of the solar kilns used in drying the palm trees waste in Saudi Arabia. Int. J. Mech. Eng., 2(2): 43-50.

MacDonald, P., 2009. Drying lumber-with solar energy. Log. Sawmill. J., pp: 4.

Müller, R.B., 2011. Operation and performance of a solar hardwood drying kiln utilizing natural dehumidification. M.Sc. Thesis, Department of Forest and Wood Science, University of Stellenbosch, South Africa.

Wengert, E.G. and L.C. Oliviera, 2010. Solar Heated, Lumber Dry Kiln Designs. Retrieved form: http://www.woodweb.com. (Accessed on: June 15, 2014)