Following of moisture content and temperature in wood chips piles

J. AST*, Y. ROGAUME, E. MOUGEL, A. ZOULALIAN
NANCY UNIVERSITE, LERMAB-ENSTIB, 27, rue du Merle Blanc, BP 1041, F-88051 EPINAL Cedex 9
{johann.ast, yann.rogaume, eric.mougel}@enstib.uhp-nancy.fr

NANCY UNIVERSITE, LERMAB-Faculté des Sciences, Bd des Aiguillettes, BP 239, F-54506 Vandœuvre-lès-Nancy cedex
andre.zoulalian@lermab.uhp-nancy.fr

RESUME
Les plaquettes forestières, lorsqu'elles sont entreposées en tas voient leur température augmenter sans aucun apport de chaleur extérieure. Ces tas de plaquettes forestières s'auto-échauffent à cause de la respiration des cellules contenues dans le bois et l'écorce et des différents micro-organismes présents sur le bois. Afin de suivre l'évolution de la température et de l'humidité dans les tas de plaquettes forestières, un dispositif expérimental a été mis au point. Le dispositif a été optimisé pour différentes conditions opératoires (fortes humidités). Ce dispositif a été utilisé dans le cas décrit dans cette communication, la température dans le tas fut par moment 65°c supérieur à la température ambiante et l'humidité a fortement diminué au cours du séchage pour atteindre 20-25% d'humidité sur brut.

ABSTRACT
Wood chips' temperature increase in pile without heat input from the outside. These piles of wood chips self-heat due to respiration of still living wood and bark cells and the different micro-organisms inhabiting wood. To follow temperature and moisture content evolution in wood chips piles, an experimental device was created. The device was optimised for different operative conditions (high moisture content). This device was used in the case described in this paper; temperature in the pile was, by moment, 65°C upper than ambient temperature and moisture content decreased during the drying to reach 20-25% moisture content on wet basis.

1 INTRODUCTION

Nowadays, with the constant increasing price of oil, wood use as energy is an answer more and more pertinent economically and technically. Wood chips are natural resources more and more used, these wood chips are obtained by crushing of forest residues. Moisture content of this resource is very important, indeed, thermo-chemical plants need precise and stable wood moisture to get a better output. To answer this constraint, it is necessary to control wood chips drying without increasing too much their cost. So, wood chips natural drying in pile seems to be a good solution but not well known and empiric.

2 WOOD CHIPS PILES SELF-HEATING

2.1 Generalties [1] to [4]

When wood chips are freshly chipped and piled, self-heating occurs and allows reaching temperatures more than 80°C in the pile. This heating is due to some actions: wood respiration, mushrooms and bacteria development.

The quantity of heat produced and the temperature inside the pile depend on the following characteristics: the quantity of wood chips piled, particle size distribution, pile compactions, wood moisture content …

Heat stagnation in the pile is very influenced by size distribution and compaction. Indeed, more the pile is compact; more the space between the wood chips is low, so the convection exchanges decrease, heat released stagnates and self-ignition risks increase. At the same time, more wood chips are small, more wood surface is in contact with air and more the heat production is important.

Size distribution is a characteristic more important concerning heat production and stagnation than pile height.

For wood chips, 10 meters pile height seems to be reasonable.

2.2 Reactions [1][5][6]

Cells respiration produces heat if they are always living. This respiration seems to be the origin of 1% dry matter loss so be it 160 kJ/kg dry matter. Moreover, over 40°C cells respiration increase. If we consider a latent energy vaporization of 2500 kJ/kg, this represent 0.064 kg of water evaporated per kg of dry matter. So, for wood chips at 50% moisture content wet basis, moisture should decrease of 1,7% dry basis.

Bacteria development in the pile causes its fermentation. More there are leaves, bark and nutrients in the pile, more the fermentation is fast and important. Fermentation produces lactic acid which appear early in the drying, this kind of fermentation seems to be the one which produce the more heat even if other kind of fermentation occurs.

Nitrogen in bark and cambium is the main organic nitrogen source for mushrooms development. Furthermore, there is 3 to 8 times more nitrogen in bark than in wood, so more the tree is young, more there is bark and nitrogen and more mushrooms develop. Among mushrooms developing in wood chips piles, there are mesophilic and thermotolerant mushrooms. So during all the drying process, mushrooms are present. The kind of mushroom the more present at the last of drying is *Aspergillus fumigatus*. Compaction rate have no influence on mushrooms development, however, stock area have an impact: if the pile is stocked outdoor, there will be less mushrooms than if the pile is indoor. Moreover, mushroom development will be easier in hardwood than in softwood, indeed, in softwood resins and terpenes increase pH and reduce its growing. Inside a wood chips pile, mushrooms action will produce acetic acid.

When temperature reaches nearly 65°C, acetyl groups attached to cellulose leaves it and produce heat and acetic acid.

2.3 Chemical changes and dry matter losses of wood [1][5][7][8]

During drying, reactions producing heat modify also wood. However, only small changes (<3% on mass) were observed concerning structural wood components: cellulose, hemicellulose, and lignin. More important changes were observed for extractables that can be extracted with ethyl alcohol. A 70% decrease of extractables in wood can be observed (for example terpenes).

Usually, dry matter loss is evaluated between 1 and 2% per month. This dry matter loss increase when the wood is young.

3 EXPERIMENTAL DEVICE

To follow temperature and moisture content evolution in wood chip piles, an experimental device was created. Temperature measures are achieved with thermocouples and test samples on which we measure electric resistance are inserted on the pile (Figure 1). The wet samples are put in the pile during its construction and become in hydric equilibrium fastly with wood chips.

Figure 1 : test sample

During the experiments, the samples are positioned in the pile as in Figure 2, this repartition allows to grid half a wood chips pile. So, test samples are on a plan of symmetry which allows evaluating temperature and moisture content on all the pile.

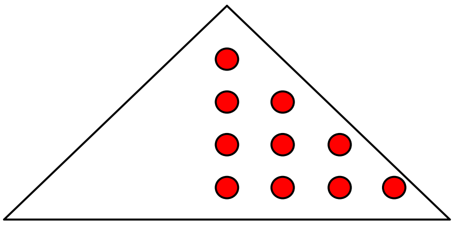

Figure 2 : test samples repartition

4 WOOD ELECTRIC RESISTANCE

To measure wood electric resistance, we use a wheatstone bridge based system. The system is configured to be very precise for high wood moisture. Figure 3 represents fir electric resistance function of moisture content on wet basis from two samples on the same woodcut. For electric measurement, we use 5 cm spaced nails. At important moisture content (>35%), error measurement is nearly 5% and for lower moisture (<27%) error is lower than 2,5%. For electric resistance measurement, nails are attached to be on spring wood and not cross summer wood.

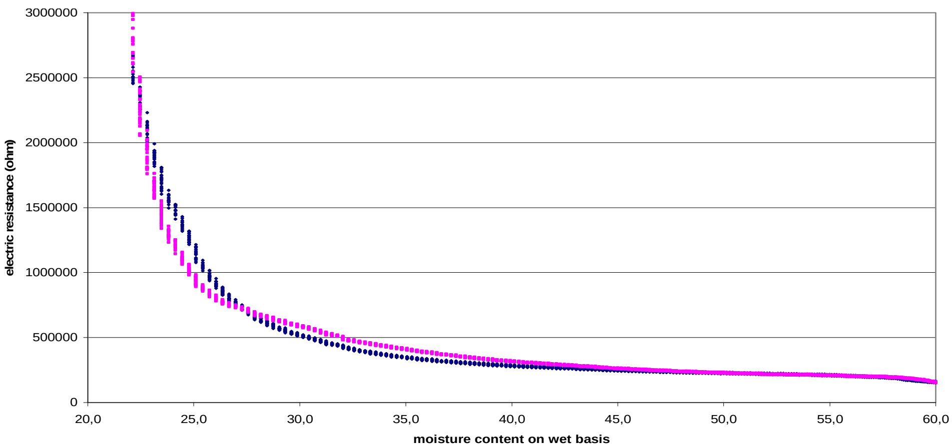

Figure 3 : Fir Electric resistance evolution with moisture content on wet basis

After data treatment, we can trace moisture content on wet basis functions of the inverse of electric resistance. This data treatment is the most efficient to be precise on calculation.

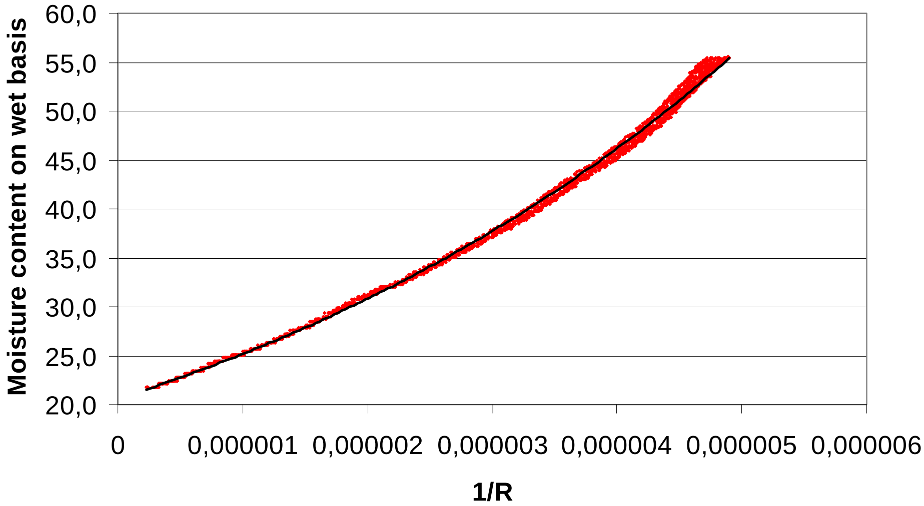

Figure 4 : Inverse of fir Electric resistance evolution with moisture content on wet basis

These measures allow us to know moisture content in the pile by measuring electric resistance.

5 EXPERIMENT OF DRYING IN PILE

For this experiment, the wood chips pile was quite small (4 meters high and 8 meters wide) and its particle size distribution was medium (chips were 4 cm long maximum). During all the drying, le pile was covered with a micro porous layer (Toptex) which allows vapour leaving the pile but avoid remoisturing. Wood used for this pile was freshly cut and chipped, wood composing the pile was young hardwood. Experiment time was 3 monthes and at the last temperature in the pile was uniform and nearly at 25°C.

Figure 5 represents some phases of the temperature of the pile during drying. Dark blue represents a temperature of 20°C and yellow represents 70°C. The first image on the figure show temperature profile in the pile after 14 hours, at that moment wood cells produces heat and temperature in the pile increase quickly until 40-50°C. The second image shows the pile at t = 2 days, temperature in the pile increased a lot thanks to cells activity and bacteria growing, temperature reach 85°C in some points of the pile. At this time, mean temperature in the pile is more than 65°C. After 4 days, wood cells and bacteria decrease their activity, temperature in the pile don’t exceed 65°C and mean temperature decrease slowly during the next 20 days. After, activity in the pile restart and at time t = 25 days we can see biologic activity but this time less important. Temperature in the pile increases in its center and reach 50 - 55°C. After this second heating phase which runs during 15 – 20 days, temperature was quite stable and biologic activity began to decrease. At the 52nd day, temperature in the pile was uniform at 30°C. Until the end of the experiment, temperature in the pile decreased slowly. After 3 months, wood chops were destocked to be burnt in boilers. Temperature at that time was uniform in all the pile at 20°C.

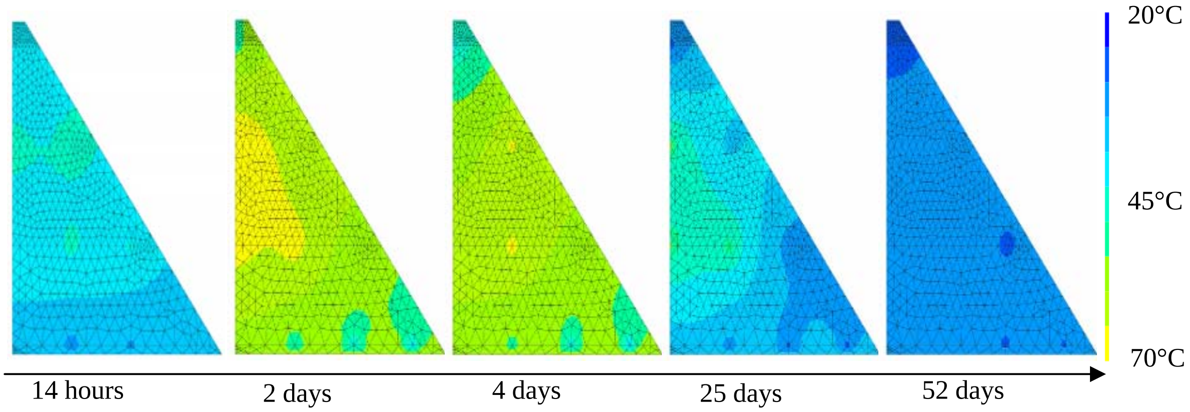

Figure 5 : temperatures evolution in the wood chips pile

Figure 6 represents some phases of moisture content on wet basis evolution in the wood chips pile. Dark blue represent 20% moisture content and yellow 60%.

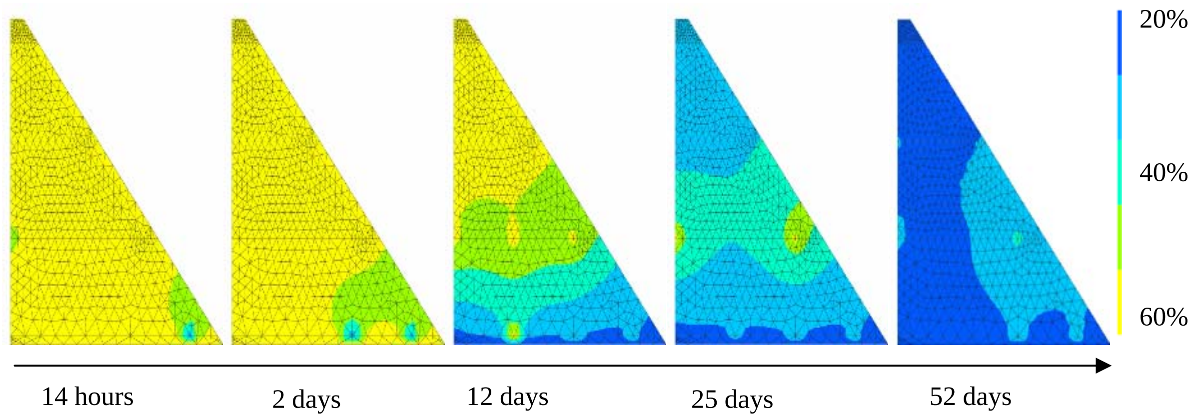

Figure 6 : moisture content on wet basis evolution in the wood chips pile

Moisture content in the pile seems to be high at the beginning, this is due to the test samples which are kept in water until there are inserted in the wood chips pile. After, when temperature increases, moisture content decreases in the pile from the bottom. In this experiment we can see moisture content decreasing from the bottom and the top of the pile. Finally, the part the less dry of the pile is at the periphery near the center. In the rest of the pile, wood moisture content on wet basis is around 20 – 25%.

6 FEEDBACK

At the end of the experiment, some samples were recovered and placed on an air oven. Moisture contents on wet basis were calculated. The results are on the table below (Figure 7). Sample 2 give strange data may be because an error at the beginning of the experiment with the nails. For Sample 9, 21,29% is the lowest moisture content we can measure, the effective moisture content was lower that is in accord with the measures. Error on sample 5 and sample 6 is less than 1%.

	sample2	sample5	sample6	sample9
moisture content from electric resistance measure	21,29	23,81	21,89	21,29
moisture content from measure on recovered samples	33,60	23,00	22,10	18,90
difference	12,31	0,81	0,21	2,39

Figure 7 : Comparison between effective moisture content and calculated moisture content

The measures of electric resistance seem to be trusty but other experiments will be done to limit or avoid errors of measures as for sample 2.

7 CONCLUSION

Other experiments of wood chips natural drying will be drive to have more information on influence of the different parameters affecting self-heating.

These information will be used to create a drying model and at last, a predictive model will be created.

At the same time, a technico-economical model is developed to optimize wood chips drying, compare different solutions of natural drying (wood chips in pile) and artificial drying or a mix.

BIBLIOGRAPHY

[1] J. Garstang.–. identification and characterisation of factors affecting losses in the large-scale, nonventilated bulk storage of wood chips and development of best storage practices. *DTI*

[2] R. Jirjis.–. Effects of particle size and pile height on storage and fuel quality of comminuted Salix viminalis. *Biomass and Bioenergy 28 (2005)*

[3] YOSHIO TSUCHIYA & KIKUO SURINI.–. Combustion spontanée. [online]. Available on : <http://irc.nrc-cnrc.gc.ca/cbd/cbd189f.html> (consulted the 03/04/2007).

[4] J. Ast, Y. Rogaume, E. Mougel, A. Zoulalian.–.Étude de l'évolution des caractéristiques physico-chimiques des plaquettes forestières, Assises de la recherche et de l'innovation dans le bois, 2008

[5] R. Jirjis.–. Storage and drying of wood fuel. *Biomass and Bioenergy, Vol. 9*

[6] R. Jirjis.–. Enumeration and distribution of fungi in stored fuel chip piles. *Material und Organismen*

[7] CH. Idler.–. Loss reduced storage of short rotation coppice. *Research papers of IAg Eng LUA & LU of AG, 2005, vol 37, no 1, 124-134.*

[8] R. Jirjis.–. Storage and drying of woody biomass. *IEA/Bioenergy Agreement*