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INTERNAL HEAT EXCHANGE IN PROGRESSIVE KILNS

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Abstract

In this work possible energy savings were investigated by introducing a new layout of a 2-zone progressive kiln. The layout consisted of installing a door between the first and second zone, thereby allowing the two zones to be run at different temperature levels -making internal heat recovery possible. An Optimized Two Stage continuous kiln is dimensioned for drying sideboard of Norway spruce (Picea abies L. Karst) with the aid of a commercial simulation program. Temperature levels of 75/55°C (dry bulb/wet bulb) were chosen at the pressure side of zone 1 and 45/25°C (dry bulb/wet bulb) at the pressure side of zone 2. The capacity of the heat exchanger was assumed to be sufficient to make the suggested design functional and no consideration was given to the increased air flow resistance the introduction of the heat exchanger would cause. The results indicated that roughly 30% of the heat is possible to recover in comparison to a traditional kiln. It was finally concluded that the influence of ingoing process parameters needs to be implemented in the kiln control system to fully utilize the kilns potential.

Keywords: *wood drying; energy efficiency; kiln design; simulation tools; kiln ventilation.*

INTRODUCTION

The single largest consumer of heat at a sawmill is the drying process where the heat is used for heating the air in air circulating kilns. Since planks and boards with rectangular cross section are sawn out of logs the volume yield is quite low, normally around 50% (Ikonen *et al.* 2003, Pinto *et al.* 2006). This leaves a great amount of residuals which is partly used as fuel in boilers to produce the heat demanded in the drying process. Due to an increased price on biofuels in the last decades the sawmills has become more keen on reducing their own consumption, - leaving a larger share to be sold to external customers and thereby increase the profit of the sawmill. To limit the waste of heat, it is important to keep the drying kilns in good condition in terms of limited air leakage and good insulation. As an additional act, it is often possible to decrease the amount of heat in the drying process by increasing the drying temperature and make sure to stop the drying when the target moisture content is reached. Since the value loss of poor drying quality is high, a drying simulation software is useful in this context (Hukka 1996, Salin 2001, Salin 2002, Salin and Wamming 2008). Finally, the used amount of heat can also be limited by installing a heat recovery system. The most common one is the air to air heat exchanger between the warm humid air that is vented out from the kiln and the cold dry air that is let in whereas other solutions is to use condensations panels, heat pumps, open absorption systems, running several kilns as clusters etc. (Johansson and Westerlund 2000, Chua *et al.* 2002, Elustondo and Oliveira 2006, Anderson and Westerlund 2014).

There exist mainly two types of drying kilns in the sawmill industry; the batch kiln and the progressive kiln. In the batch kiln the whole kiln is filled with green timber before the door is closed and the drying starts. The drying then proceeds untill the whole batch is dried and the kiln can be unloaded and ready to be filled up with the next batch of green timber. In the progressive kiln the kiln is always full of timber in different stages of drying. The loading-unloading is done by loading one stack of green timber at the entry of the kiln and simultaneously take out one stack of dried timber at the exit end of the kiln. The three most common types of progressive kilns are the 1-zone progressive kiln, the 2-zone feed-back kiln and the Optimized Two stage Continuous, OTC-kiln (http://www.valutec.se/assets/documents/kanaltorkar/Progressive_kilns.pdf, http://www.muehlboeck.co.at/uploads/media/Kanaltrockner_EN_NEU2011.pdf).

Due to the continuous drying process in a progressive kiln as well as its higher annual drying capacity, a heat recovery system has shorter payback time for a progressive kiln than for a batch kiln (Esping 1982).

OBJECTIVE

In this work possible energy savings are investigated by introducing a new layout of a 2-zone progressive kiln. The layout consists of installing a door between the first and second zone, thereby allowing the two zones to be run at different temperature levels, making internal heat recovery possible.

MATERIAL AND METHODS

A new design of an OTC-kiln is suggested by adding a door between the two zones. By introducing the door the opportunity raises to run the two different zones at very different temperature levels. With one of the zones acting like a heat sink for the other, the amount of heat recovered in the total system can be increased considerably. A schematic sketch of the suggested system is shown in Fig. 1.

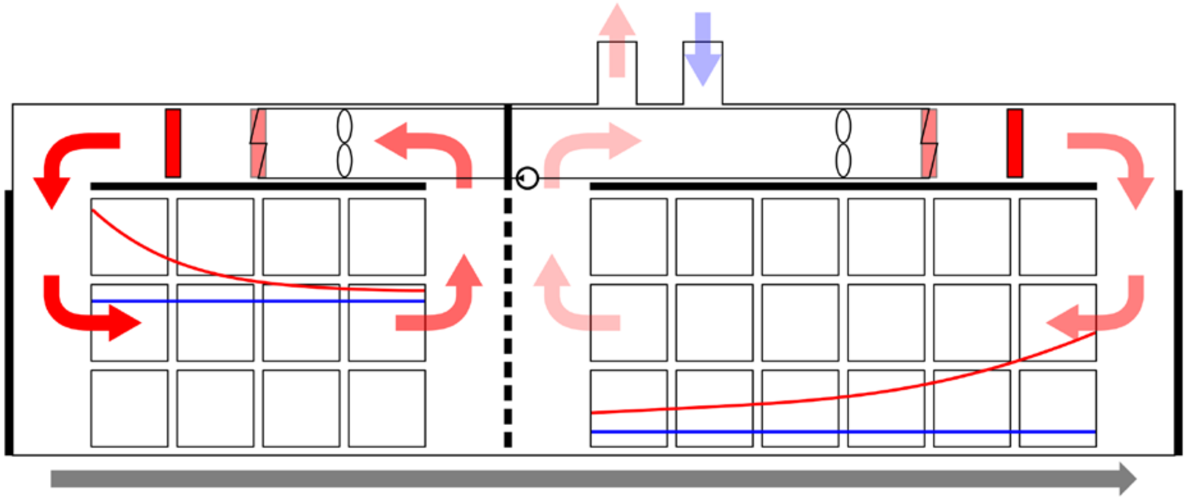

Fig. 1.
Optimized Two stage Continuous, OTC, kiln with heat exchanger and door between the two zones. In each zone, the dark red battery is showing a regular heat battery whereas the faded red battery, schematically connected with pipes, is showing the heat exchangers. The door between the two zones is presented by a dashed line and the directions of airflow in the two zones are illustrated by arrows. The feeding direction through the kiln is illustrated by the gray arrow in the bottom of the figure

Due to the expense of constructing a kiln and run drying trials in full scale, the drying process was simulated using the commercial software Valusim. A drying schedule for drying Norway spruce *(Picea abies L. Karst)* sideboards from an initial moisture content of 110% to a final moisture content of 17.4% was created with parameters according to Table 1. The dimensioning of the kiln was chosen as to keep the possibility to run it without the door between the two zones.

Table 1

Ingoing parameters to wood drying simulations

Parameter	Zone 1	Zone 2
Dry bulb temperature when entering the wood stack [°C]	75	45
Wet bulb temperature when entering the wood stack [°C]	55	25
Circulating air [$kg_{dry\ air}/s$]	56	66
Nr. of trolley positions	3	12
Air leakage [% of $kg_{dry\ air}/s$]	25	25
Air speed in sticker space [m/s]	4.0	3.8
Sticker thickness [mm]	25	
Board thickness (nominal) [mm]	22	
Board average length [m]	4.5	
Package height [m]	1.5	
Package width [m]	6	
Package depth [m]	1.5	
Nr. of packages on each trolley	3	
Bolster thickness [mm]	90	
Specie	Norway spruce	
Wood basic density [kg/m^3]	380	
Drying time [h]	36	
Initial moisture content [%]	110	

With a possible kiln layout and temperature levels of the drying stated, a model determining the conditions of the air was developed by implementing the basic thermodynamic equations of humid air. An amount of air passing the timber without actively taking part in the drying was chosen to represent air going through bolster spaces and around the timber packages.

Throughout the work, it was assumed that a heat exchanger able to transfer the heat from zone 1 to zone 2 could be constructed. Also, no consideration was given to the additional pressure drop over the air circulating fans that would be caused by the introduction of a heat exchanger. The power consumption of fans running the ventilation was also excluded from the calculations.

RESULT AND DISCUSSION

The resulting temperatures, moisture content and heat demand of the drying simulation is summarized in Table 2. Although the heat demand of zone 1 became 1.5 [MW], only 1.4 [MW] was available for zone 2. The difference is explained by the air passing the timber and not taking part in the drying.

Table 2

Results from wood drying simulations. The temperatures after mixing the drying air with the air passing the wood and not taking part in the actual drying are reported.

Parameter	Zone 1	Zone 2
Dry bulb temperature after passing the wood stack [°C]	63	34
Wet bulb temperature after passing the wood stack [°C]	55	25
Moisture content when exiting the zone [%]	65	17.4
Heat demand [MW]	1.5	See Fig. 3.

Ideally, the heat demand of zone 1, caused by the evaporation of water from the timber to the air will be possible to release in the condenser of zone 1. If this is not possible, some of the moist air also needs to be vented out causing the energy efficiency of the kiln to drop. If, on the other hand, the heat demand in zone 2 is higher than what is available from zone 1 some additional heat needs to be added to zone 2 which also will cause the energy efficiency of the kiln to drop. If no ventilation is installed in zone 1and/or no additional heat sink is available, the ideal case would be to design the kiln with a slightly higher heat demand in zone 2. This design would give a high energy efficiency of the kiln and some safety margin to prevent the process from becoming unstable. It should also be kept in mind that the air circulating fans will add some heat in zone 2 which needs to be taken into account. In practice, some additional heat is also transferred between the two zones, as well as between the kiln and the surroundings when the loading/unloading takes place. The additional heat transfer due to air leakage when the doors are open is not taken into account whereas the heat transfer through the heating of the wood is taken into account in the drying model.

Since air at lower temperature can contain considerably less water vapour, the low temperature in zone 2 implies that a large amount of the circulating air needs to be vented out to keep the assigned drying climate. Of course, the drying air in zone 2 can also be dehumidified by means of other technical solutions but otherwise the functionality of the kiln will be limited by the outdoor climate. The amount of circulating air in zone 2 that needs to be vented as a function of outdoor climate is shown in Fig. 2.

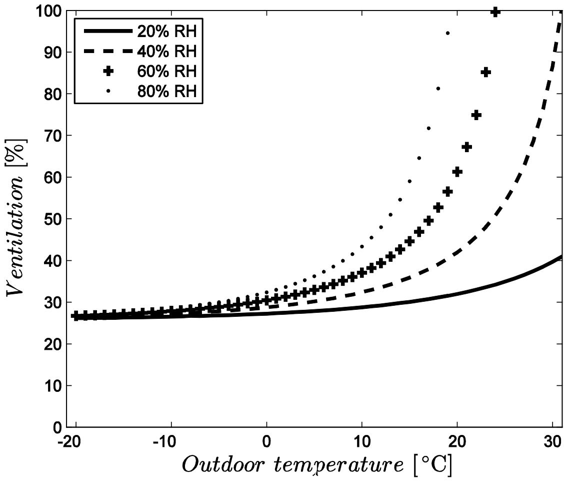

Fig. 2.

Ventilation demand as percentage of the circulating dry air of zone 2 at different outdoor temperatures and relative humidity

From Fig. 2. it can be seen that the high ventilation demand at the suggested drying temperatures of zone 2 will cause the working range of the kiln to be limited. If the outdoor temperature and relative humidity is high the door between the two zones needs to be opened and the kiln operated as a traditional OTC-kiln.

As the amount of ventilation also affects the amount of outdoor air that needs to be heated in zone 2, the heat demand of zone 2 also becomes a function of the outdoor climate, see Fig. 3.

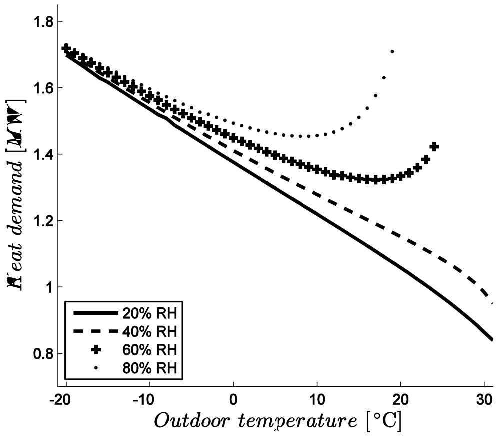

Fig. 3.

Heat demand of zone 2 as function of outdoor temperature and relative humidity.

From Fig. 3. it can be seen that the heat demand of zone 2 decreases approximately linear at low temperatures but as the maximum vapour content increases rapidly at higher temperatures, the heat demand becomes non-linear at higher temperatures. Since the available heat from zone 1 became 1.4 [MW] in our example and the fan power of zone 2 would add an additional power of approximately 0.1 [MW], the suggested kiln design and drying parameters would not work when the heat demand of zone 2 is below 1.5 [MW]. The exact breakpoint when this happens can be moved slightly by dimensioning the kiln different or by changing some of the drying parameters that were reported in Table 1. As to enhance the working range of the kiln at high outdoor temperatures ventilation of zone 1 should be installed. By this, a part of the circulating air of zone 1 could be vented which would decrease the available heat for zone 2. Thereby, the critical minimum heat demand of zone 2 decreases and it would be possible to run the kiln at higher outdoor temperatures. Ventilation of zone 1 will however always decrease the recovered heat. The exact size of the recovered heat is hard to present due to our partly simplified system. Additional heat savings will also be a result from the fact that a condenser in zone 1 will results in a smaller amount of outdoor air than needs to be heated in zone 1 in comparison to when all the circulating air is dehumidified by ventilation. At an outdoor climate of 0°C and 80% RH where the heat demand of zone 2 is approximately what is available from zone 1, the total heat demand of the suggested system is roughly 1.6 [MW]. To run the kiln with the door open between the two zones the total heat demand of the kiln becomes roughly 2.2 [MW]. The total heat savings in our example thereby becomes roughly 30%.The small difference is explained by the fact that the drying in zone 2 becomes more energy efficient at higher temperatures.

As an additional heat recover, it would also be possible to install a traditional air to air heat exchanger for the ventilation air of zone 2. It should however be kept in mind that this heat exchanger would only be possible to use when the heat demand of zone 2 is sufficient high.

Also, either zone 1 or zone 2 can in principle be chosen to be the low temperature zone as long as the ventilation is placed in the low temperature zone. The wet bulb depression and air velocity in the low temperature zone should also be kept reasonable high to prevent mould growth (Esping 1987). The flow direction could also be the opposite of what is presented in Fig. 1, i.e. the kiln could be designed as a 2-zone feed-back kiln. The OTC-kiln layout was chosen since a high wet-bulb depression at the exit side of the kiln enhances the possibility to lower the moisture content of the last package in the kiln before the loading/unloading is done. With a small wet-bulb depression in the exit side of the kiln, hardly any drying will take place and delaying the loading/unloading of the kiln will mostly affect the packages early in the drying process.

To maintain a constant airspeed through the stacks, the electrical power consumption of the motors running the air circulating fans will increase by the introduction of the heat exchanger. If the price of heat generated by the air circulating fans (i.e. electric power) is higher than the price of heat generated by burning residuals, the profitability of the suggested system will decrease. Prior to construction of the suggested kiln, more research needs to be done regarding this matter.

CONCLUSION

Installation of ventilation or other additional ways to dehumidify the air of zone 1 is recommended if the presented kiln design and drying parameters are used. This is due to the fact that the heat demand of zone 2 is often lower than the available heat from zone 1. Furthermore, an installation of an air to air heat exchanger on the ventilation is not recommended since its operational time will be limited.

The suggested kiln design represents a great potential in terms of energy savings. Due to the direct interaction between the first and second zone, the behaviour of the kiln however becomes less intuitive. In contradiction to a traditional two zone continuous kiln, the outdoor climate also becomes an important factor for the kiln’s functionality. The influence of ingoing process parameters should therefore be implemented in the kiln control system. This implementation will be a prerequisite to be able to use the full potential of the suggested system.

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REFERENCES

Anderson JO, Westerlund L (2014) Improved energy efficiency in sawmill drying system. Appl Energy 113:891-901.

Chua KJ, Chou SK, Ho JC, Hawlader MNA (2002) Heat Pump Drying: Recent Developments and Future Trends, Drying Technol 20:1579-1610.

Elustondo D, Oliveira L (2006) Opportunities to Reduce Energy Consumption in Softwood Lumber Drying, Drying Technol 24:653-662.

Esping B (1982) Energy Saving in Timber Drying. Wood Technology Report Nr 12. Wood Technology Centre, Stockholm (Sweden).

Esping B (1987) Wood drying 2 Drying defects-actions (in Swedish). TräteknikCentrum, Stockholm.

Hukka A (1996) A Simulation Program for Optimisation of Medium Temperature Drying on an Industrial Scale. Proc of the 5th International IUFRO Wood Drying Conference, Quebec City, (Canada), pp. 41-48.

Ikonen VP, Kellomäki S, Peltola H (2003) Linking tree stem properties of Scots pine (Pinus sylvestris L.) to sawn timber properties through simulated sawing. Forest Ecology and Management 174:251–263.

Johansson L, Westerlund L (2000) An open absorption system installed at a sawmill: Description of pilot plant used for timber and bio-fuel drying. Energy 25:1067-1079.

Pinto I, Knapic S, Pereira H, Usenius A (2006) Simulated and realised industrial yields in sawing of maritime pine (Pinus pinaster Ait.). Holz als Roh- und Werkstoff 64:30–36.

Salin JG (2001) Determination of the most economical drying schedule and air velocity in softwood drying. In 3th COST E15 Workshop, Helsinki, (Finland), pp. 1-10.

Salin JG (2002) Simulation models as an industrial tool for optimizing the drying of timber. In 4th COST E15 Workshop, Santiago de Compostela, (Spain), pp. 1-8.

Salin JG, Wamming T (2008) Drying of timber in progressive kilns: Simulation, quality, energy consumption and drying cost considerations. Wood Material Science & Engineering 3:12-20.