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Technologies to Reduce Energy Consumption of Lumber Drying Operations

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Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Needs and Objectives

According to the last forecasts released by BC Hydro, in 20 years the demand for electricity in B.C. will increase about 40%. A typical sawmill in Canada has between 4 and 8 kilns which operate on a constant basis throughout the year. Each kiln dries on average about 16 to 20 kiln charges per month and every kiln charge is on average 250 Mfbm of lumber (based on 2-inch thickness). A typical cross-shaft kiln is equipped with fifteen 25 hp motors (approximately 18 kW) so the total installed power per kiln is about 270 kW. Kilns operate an average of 660 hours per month. Thus, mills with drying operations such as in the example above will consume a significant amount of electricity to dry their required production.

Site-specific kiln drying / heat treatment (KD/HT) schedules, which last typically between 3 to 6 hours, have been developed for more than 60 kilns in British Columbia in the last 7 years. Usually initial moisture content (MC) for mountain pine beetle (MPB) lumber (dry sort) before KD/HT varies between 17 to 21%. During a KD/HT moisture movement is primarily governed by diffusion because the MC is well below the fibre saturation point (28%). Under these circumstances the impact of air velocity is not as critical as it is during the early stages of drying when the lumber is green. The same applies for the so-called dry sort for mills processing regular wood stocks (non-infested wood). Thus, using lower air velocities during KD/HT for MPB wood or regular dry sort spruce-pine-fir (SPF) should not have a significant impact on the KD/HT times. If for example typical air velocities between 600 to 800 ft/min are reduced by 50% power requirements will be about 1/8 of the power required to run the fans at full speeds, a significant reduction in electrical consumption.

Although site-specific schedules have been developed primarily for mills processing large amounts of MPB infested wood, they could also be applied for the portion of the production that exhibits lower initial MC. Statistically about 35 to 40% of the volume of lumber produced has initial MCs below 40%. For a typical mill, this could represent a total production volume of about 100 Mfbm per year. Thus, for a considerable production volume, mills could reduce significantly the amount of energy, both electrical and thermal, during their drying operations. In addition to reducing their footprint, mills will attain considerable reduction in their processing costs.

The main goal of this project is to investigate some methods for reducing energy consumption of lumber drying operations, and the specific objectives to reach the goal are as follows:

- Review the recent Swedish development in the area of energy reduction in kilns, the so-called Alent Technology;
- Evaluate the impact of reduced air velocities for sorted lumber with lower initial MC (dry sort).

1.2 Benefits

The main benefits from this project can be summarized as follows: (1) Potential reductions in energy consumption to about 30 to 50% (2) Reduced over-drying and therefore improved quality at the end of the drying process (3) Increase in productivity (faster drying times for the lower initial MC lumber).

2 Materials and Methods

2.1 Alent Technology

An innovative energy-efficient lumber drying process has been developed by Alent Drying AB in Sweden. The new process called “Alentpumpen” is based on the complex wood and water relationship under variable heat and mass transfer conditions. Conventional drying relies on the difference of moisture content between the shell and core of the pieces to act as the main driving force to move the water from the core to the shell layers. So a dryer shell is necessary to bring moisture out of the wetter core of the wood. To maximize moisture flux from the core of the wood, its temperature should be higher than the temperature observed at the shell layers. But in conventional drying the surface is always hotter that the core because the lumber is heated from outside in. The “Alentpumpen” process allows reversing the temperature gradient within the wood for short intervals allowing moisture from the core to migrate at the surface.

A number of three sawmills from Sweden using the Alent technology were evaluated during a visit in 2014 fall. Electrical savings and the potential of implementing this technology in BC mills were assessed.

2.2 Current Drying Times in BC Mills

Typical conservative, accelerated and site-specific drying schedules are illustrated below in Figures 1 and Tables 1, 2 and 3.

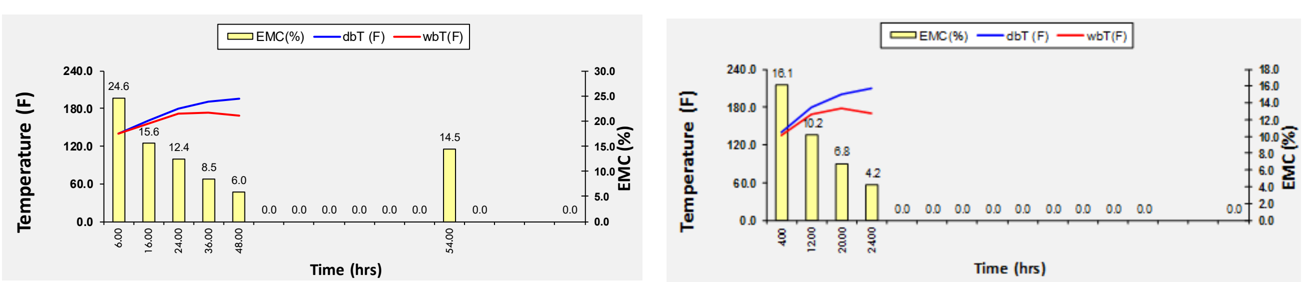

Figure 1 Drying parameters in a conservative (left) and an accelerated drying schedule for SPF

Table 1 Drying parameters in a typical conservative drying schedule

Step #	Description	Elapsed time (h)	DBT* (F)	WBT* (F)	RH* (%)	EMC* (%)	Fan Speed (%)	Fan reversal (h)
1	heat-up	6	140	140	100	24.6	65	2
2	d1	16	160	155	88	15.6	85	2
3	d2	24	180	172	83	12.4	100	4
4	d3	36	190	174	69	8.5	100	4
5	d4	48	195	168	53	6.0	85	4
6	Equalization	54	190	185	89	14.5	85	3

* DBT is dry bulb temperature, WBT is wet bulb temperature, RH is the relative humidity and EMC the equilibrium moisture content

Table 2 Drying parameters in a typical accelerated drying schedule

Step #	Description	Elapsed time (h)	DBT (F)	WBT (F)	RH (%)	EMC (%)	Fan Speed (%)	Fan reversal (h)
1	heat-up	4	140	135	87	16.1	85	2
2	d1	12	180	168	75	10.2	100	4
3	d2	20	200	178	61	6.8	100	4
4	d3	24	210	170	40	4.2	100	4

Table 3 Example of a site-specific drying / heat treatment for 2-inch SPF lumber

Elapsed time (h:min)	DBT (C)	DBT (F)	Fan Speed (%)	Fan reversal (h:min)
1:00	31.8	89.2	100	2:29
2:00	46.3	115.3	100	
3:00	58.7	137.7	100	
4:00	68.1	154.6	100	
4:58	78.0	172.4	100	

In all three drying schedules above, there is the potential of saving electricity by reducing air velocities towards the end of the drying schedules, even for the short site-specific schedule illustrated in Table 3.

2.3 Air Velocity Measurements

The hypothesis of thia study was: “During conventional drying and or drying / heat treatment (HT) of SPF lumber, the air velocity can be reduced to a certain level without affecting productivity and the requirements of treatment schedules”.

The idea was to replicate the exact HT conditions – temperature and air velocity – currently used in a partner mill and reduce gradually the air velocity during the process. At its full capacity, the experimental kiln located at FPInnovations in Vancouver can hold two, 4’ high x 4’ wide x 8’ long wood stickered packages ~2.4 Mfbm (Figure 2). The lumber used in the tests was obtained from a dry-sort population with MCs below 28%. The core temperatures of 24 specimens were monitored throughout the heat treatment process. The HT schedule used for replication consisted of ramping the temperature from 86 to 169F over a period of 5 hours and 42 minutes. During this time frame the core of all specimens should reach and maintain for half an hour a temperature of 56C (133F) or higher.

Figure 2 Front view of the fully loaded kiln before a HT test

A total number of 6 HT runs at different air velocities were tested and analysed: (1) control at 410 feet/min (2),(3),(4) lower air speeds, 300, 250 and 150 feet/min and (5), (6) two replications for the successful HT.

The MC of the selected specimens was measured at the beginning and end of each HT run. The electrical power going into the fans was measured using a digital meter connected to the main transformer of the kiln.

3 Results

3.1 Alent Technology Potential

Electrical savings were easy to demonstrate since fan motors could be easily monitored throughout the drying process. The impact on heating energy consumption and lumber quality are more complicated to confirm at this stage although some mills representative anecdotally suggested savings of about 10% in total heating energy during their drying processes. According to Alent representatives, there are about 200 Alent systems in use in Sweden and the technology was introduced in Germany in 2014. Mills with longer drying schedules, for example coastal BC mills drying hemlock thick products, could potentially benefit from the Alent technology by reducing significantly their electrical energy consumption.

3.2 Reduced Air Velocity Measurements

The distribution of moisture content of the measured specimens is shown in Figure 3. Based on the results, 90% of sample met the dry sort requirement.

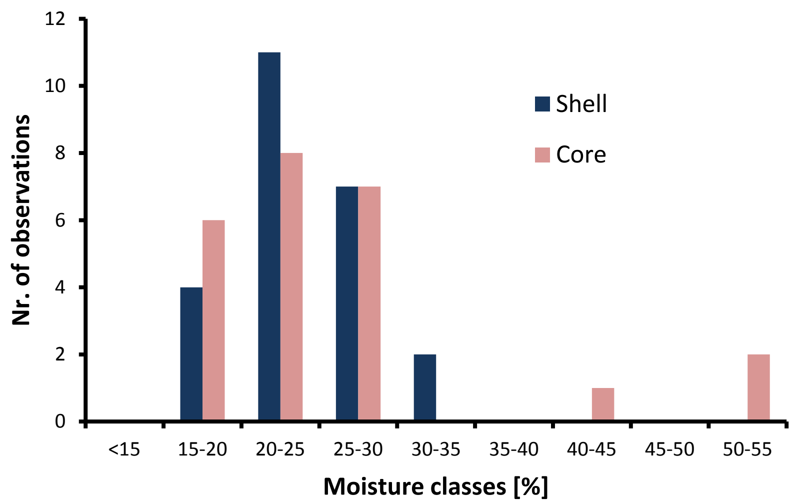

Figure 3 Moisture content distribution prior to HT

There is a linear relationship between fan power and air velocity and a cubic relationship between the consumed electricity and fan power (Figure 4). The cubic relationship underlines the potential importance of reducing air velocity – even a small decrease in fan power can lead to significant drops in consumed electricity. At full power (100%) the RPM for each of the two fans in the experimental kiln is about 575.

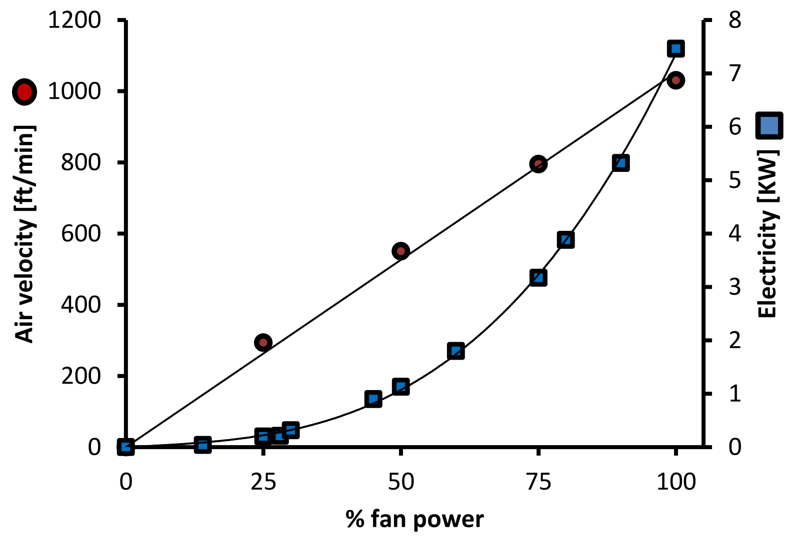

Figure 4 The relationship between air velocity and electricity consumption

A comparison between average temperature increase and different air velocities is shown in Figure 5. The HT requirements, all sensors having reached 56 °C in 5 hours and 12 minutes was met only by the control (410 ft/min) and the 300 ft/min runs. Thus, air velocity values below 300 ft/min will take longer to HT the specific dry sort used in this study. The 300 ft/min experiment was repeated twice.

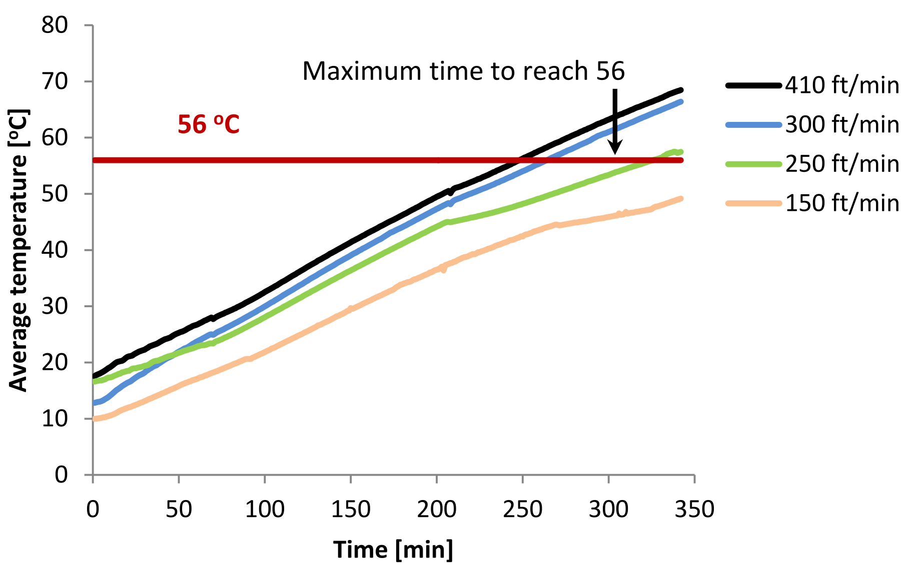

Figure 5 Average temperature increase for different air velocities

In terms of electrical energy consumption, at 410 ft/min the measured fan power was 0.57 kW and at 300 ft/min, it was 0.29 kW (45-50% less). In typical industrial drying installations, mills normally use at least two kilns to dry either its MPB lumber or its dry sort production. Kilns that are 130 feet long equipped with thirteen, 15 hp (11.18 kW) fans are also very common. Most of the mills drying either

MPB lumber or dry sort, use option D of the Canadian Food Inspection Agency (CFIA) generic schedules guidelines which requires a minimum of 12 hours. Thus, for a typical mill from BC the total amount of electricity consumed by fans in one year can be calculated with the following formula:

Q=t*p*A*B*C

where, Q is the power consumed by fans in one year, in kWh/year; t is time of the HT, in hrs; p is the power of the fans, in kW; A is the number of fans, B is the number of kilns, C is the number of treatments per year, numerically

Q=12*11.18*13*2*260= 907367 kWh/year

A reduction of 45 to 50% will result in savings between 408000 and 454000 kWh/year or considering a BC hydro rate for large general service of 9.56 cents/kWh between 39000 and 43000 CAD/year. If the air velocity during the heat treatment is 600 ft/min, a more realistic number for a HT kiln, a reduction to 300 ft/min would save on electricity 82.5% which represents 71600 CAD/year.

4 Conclusions and Recommendations

Based on the experiments the following observations can be made:

- During conventional heat treatment of 2x4 “dry sort” SPF lumber, the air velocity can be reduced to 300 ft/min without affecting productivity and the requirements of treatment schedules;
- The lower air velocity will result in energy reductions for an industrial scenario equivalent with 71600 CAD/year for each mill;
- It opens the opportunity to implement the same strategy during drying operations after the wood has reached moisture contents below 28%.

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