Study of the Consumption of Electric Energy in the Kiln Drying of Wood Using a Converter of Frequency

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Abstract

The aim of this study was to evaluate the influence of the converter of frequency use on the reduction of the electric energy consumption during the fans work in kiln drying operations. The study was carried out in a conventional kiln, masonry made, truck loaded, with nominal capacity of 200 m³, used for drying *Pinus taeda* wood. The kiln ventilation system was superior, provided by 7 fans with engines of 25 HP each one, totalizing 175 HP of installed potency. It was utilized *Pinus taeda* wood with 40mm of thickness, which was dried until 10% of final moisture content. Initially, it was done an analysis of the air velocity distribution inside the loaded kiln at the lowest and highest fans potency (36 and 60 Hz). The fans velocities were controlled by a converter of frequency. To evaluate the influence of the converter of frequency in the consumption of electric energy, there were kiln dried two loads: one at constant and other at changeable air velocity, but with the same drying schedule. The results showed a significant saving of electric energy of around 35%. The costs of electric energy were reduced from US$ 4.49 to US$ 2.92 per cubical meter of dried wood, which resulted in an annual economy of approximately US$ 32,950,00. The economic analysis demonstrated that the pay back of the investment applied with the acquisition of the converter of frequency occurs in less than 12 months, making the investment feasible.

Keywords: converter of frequency, consumption of electric energy, kiln drying.

Introduction

The principal factors which affect the efficiency of the sector of wood drying are the equipments used, the control system, the process operation and the drying schedule used. Regarding to the equipments, the air velocity and its distribution through the stacks are very important for the operation success. It is considered that air velocities between 1.5 and 2.5 m/s are useful for the great majority of wood species (Hildebrand, 1970). Even operating at proper velocities, if the air flow is not uniform in the whole transversal section of the kiln, part of the load will dry faster, leading to drying time problems and low quality of the dried wood.

According to Tomaselli (1981), the amount of energy spent in wood drying is shared in thermal and electric. Thermal energy is used for warming up and maintenance of the system (doors, walls, wood, etc.) while the electric one is to move the kiln fans.

A drying schedule with changeable air velocity, got by a device which adjusts the velocity (converter of frequency), may represent a liquid reduction on the electric energy consumption and ventilation costs in approximately 50%. The converter of frequency permits to change the air flow velocity during the drying operation (Garrahan et al., 1993).

When the electric energy supply decreases and its cost increases, saving energy becomes the most important variable to be controlled in the drying process (Corder, 1980). According to Wengert and Denig (1995), the energy costs in wood drying represent about 50% of the total amount of operational costs.

Due to the fans characteristics, little reductions in air velocity cause great saving in electric energy. For example, an air velocity reduction of 25% results in even 50% of electric energy saving (Simpson, 1997).

Vrazinan and Wohlgemuth (1988) got 30 to 50% of electric energy saving in their work. In general, the electric energy costs represent 14 to 20% of the drying costs. The current computer systems permit to control changes in air flow velocity during drying (Brunner and Hildebrand, 1987).

According to Goggans (1964) the wood of *Pinus taeda* has average specific gravity of 0.47 g/cm^3, where the earlywood is 0.29 g/cm^3 while the latewood is 0.63 g/cm^3. According to Muñiz (1993) the apparent specific gravity of *Pinus taeda* increases with aging, until the adult age, where it is kept constant. According to this same author, the average specific gravity of *Pinus taeda* is 0.51 g/cm^3.

Zaderenko (2000) studied the influence of diffusion on the kiln drying time of *Pinus taeda* and got an average moisture content of 125.7% for this wood. Milota and

Tschernitz (1990) studied the drying tax of *Pinus taeda* and found initial moisture content values ranging from 90 to 180%, with an average of 130%, while Muñiz (1993) got an average of 147.83%.

The aim of this work was to evaluate the influence of the converter of frequency use on the reduction of the electric energy consumption during kiln drying operations.

Material and Methods

This study was carried out in an industrial conventional dry kiln, masonry made, kiln truck loaded, with nominal capacity of 200 m³. The kiln ventilation system was superior, provided by 7 fans, with engines of 25 HP, totalizing 175 HP of installed potency. The kiln was provided with automated computerized controls and a converter of frequency for air velocity control during the drying operation.

It was used *Pinus taeda* lumber, 40 mm thick. The final moisture content was 10%. Table 1 presents the drying schedule used in this work.

PHASE	DRY BULB (°C)	WET BULB (°C)	TIME (HOURS)	CONSTANT VELOCITY (%)	CHANGEABLE VELOCITY (%)
WARMUP	80	80	8	100	85
1	80	75	7		100
2	80	74	7		100
3	80	73	7		95
4	80	72	7		90
5	81	71	6		86
6	81	70	5		82
7	81	68	5		78
8	82	66	4		75
9	82	65	4		72
10	84	64	15		70
EQUALIZING	80	78	2		80
CONDITIONING	80	80	2		80
COOLING	45	37	2		80

Table 1 – Drying Schedule

Kiln Drying Electric Energy Consumption

In this work there were kiln dried and evaluated two loads: one for the constant velocity drying schedule and other for the changeable velocity.

The evaluation of the electric energy consumption (kWh) was carried out first at constant air velocity, at 60 Hz of frequency or 100% of the fans engines potency. The second test was carried out with changeable air velocities along the drying (Table 1). Both of the tests had the electric energy consumption registered by an electric meter.

Measurement of the Electrical Energy Consumption at Different Frequencies

It was also measured the consumption of electric energy (kWh) at different fan engine frequencies in order to get a graphic of consumption.

These were the frequencies in which the electric consumption was measured: 60 Hz (100%), 54 Hz (90%), 48 Hz (80%), 42 Hz (70%) and 36 Hz (60%).

Distribution of the Air Velocity

The “x” (Fig. 1) represent the air measurement points in and outside the stacks.

The air velocity was measured using a “hot wire” thermo-anemometer in m/s in both of the sides of the kiln (front and back door). There were done measurements of the air velocity in the highest (60 Hz) and in the lowest (36 Hz) frequency, in order to get a graphic of the air velocity distribution inside the kiln.

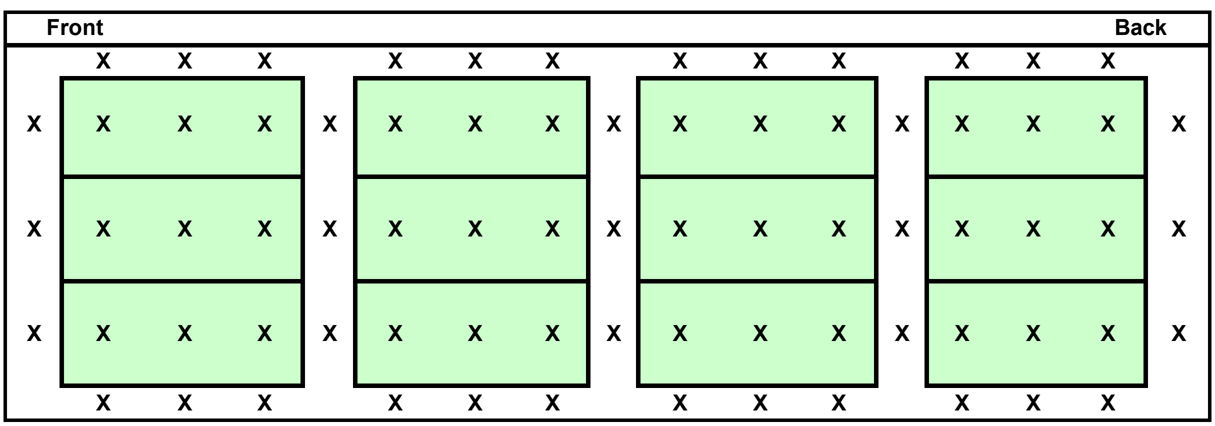

Figure 1 – Air Velocity Measurement Points

Results and Discussions

Kiln Drying Electric Energy Consumption

Figure 2 presents one of the graphics of the drying operation of this study. The red line represents the dry bulb temperature (°C), the blue one represents the wet bulb temperature (°C) and the green one represents the moisture content of wood. The x axis represents the time of drying, in hours.

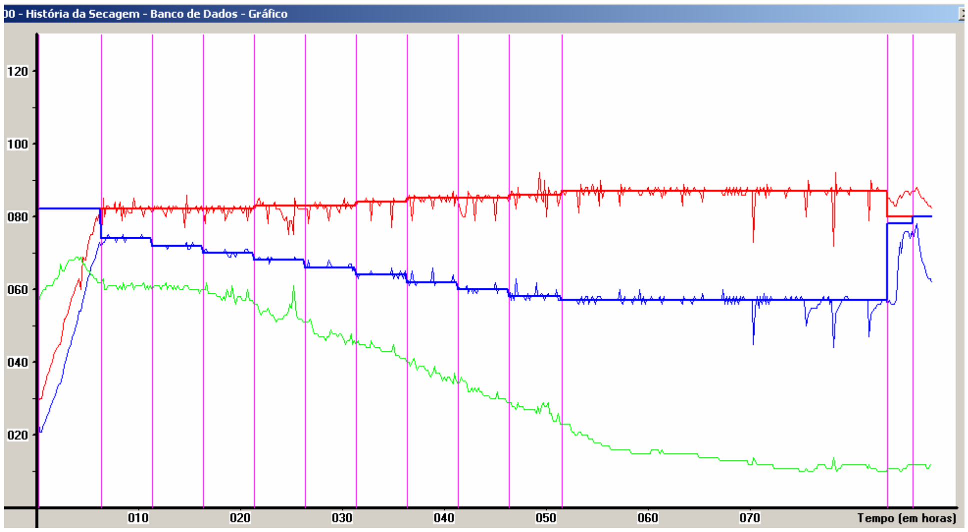

Figure 2 – Control of the Drying Parameters

Figure 3 presents the behavior of the electric energy consumption of the two schedules used.

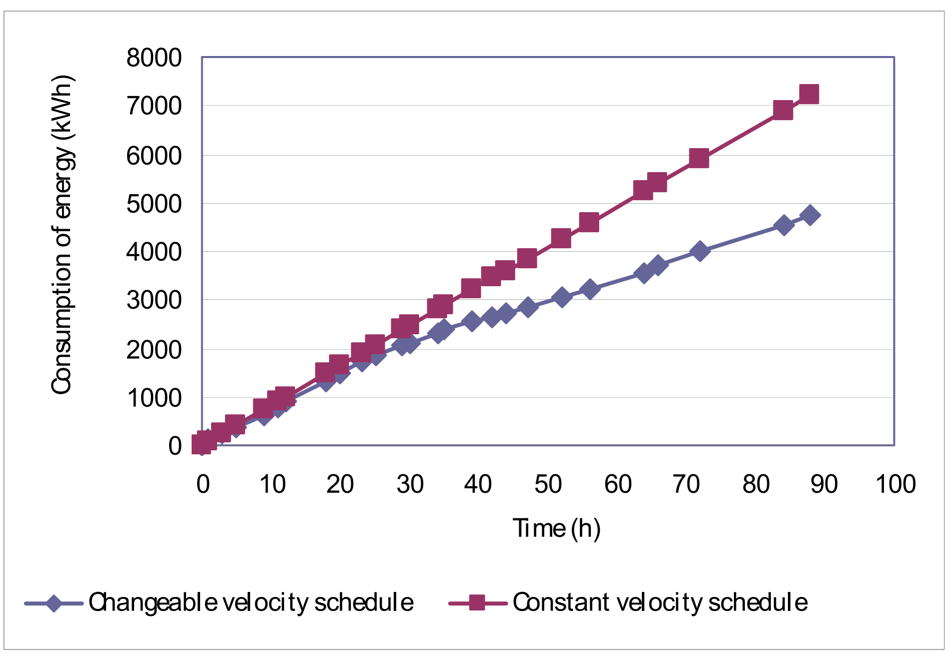

Figure 3 – Electric Energy Consumption at Constant and Changeable Air Velocity

At the beginning of drying the electric energy consumption was the same in both the cases. From the fiber saturation point (30% of moisture content) there was reduction of the consumption in the changeable velocity schedule. The consumption difference between both the drying schedules increased as the drying reached its end. This result is in accordance with those of Brunner and Hildebrand (1987), Vranizan and Wohlgemuth (1988), Culpeper (1990) and Simpson (1997).

Table 2 presents the total electric energy consumption of the drying schedules.

DRYING SCHEDULE	TOTAL CONSUMPTION OF ELECTRIC ENERGY	TIME	CONSUMED ENERGY	REDUCTION
	(kWh)	(HOURS)	(kWh/h)	(%)
CONSTANT VELOCITY	7216	88	82.03	34.28
CHANGEABLE VELOCITY	4712		53.88	

Table 2 – Total Electric Energy Consumption

The use of the converter of frequency reduced the electric energy consumption during drying operation in an average of 34.28%. According to Ramos (2001), the converters of frequency have great potential of saving energy, mostly when applied on fans and pumps engines. The saving may range from 30 to 50%.

Vranizan and Wohlgemuth (1988) got an average saving of 39.2%. Culpeper (1990) applied the converters of frequency on fans of dry kilns and got an electric energy saving of 45%. Simpson (1990) cites that little reductions in air velocity result great savings in electric energy, reaching even 50%. Brunner and Hildebrand (1987) studied this same reduction in air velocity and got a saving of 51% for softwoods kiln drying.

The advantages presented in this study prove that the converter of frequency is a necessary device in the lumber industry, mostly in kiln drying, where the installed potency is high. The conservation of the energy can be optimized if the reduction of the air flux was implemented along the process and not in the way it was done in this work (slope way). The electric energy costs were reduced from US$ 4.49 to US$ 2.92 per cubic meter of dry wood, resulting in an annual saving of around US$ 32,950. The economic analysis proved that the pay back of the applied investment on the acquisition of the converter of frequency occurs in less than 12 months, making it feasible.

Measurement of the Electrical Energy Consumption at Different Frequencies

The average electric energy consumption was reduced with the reducing of the fan engines potency. The converter of frequency controlled automatically the frequency changes. It was built a graphic with these data, which are presented in Figure 4.

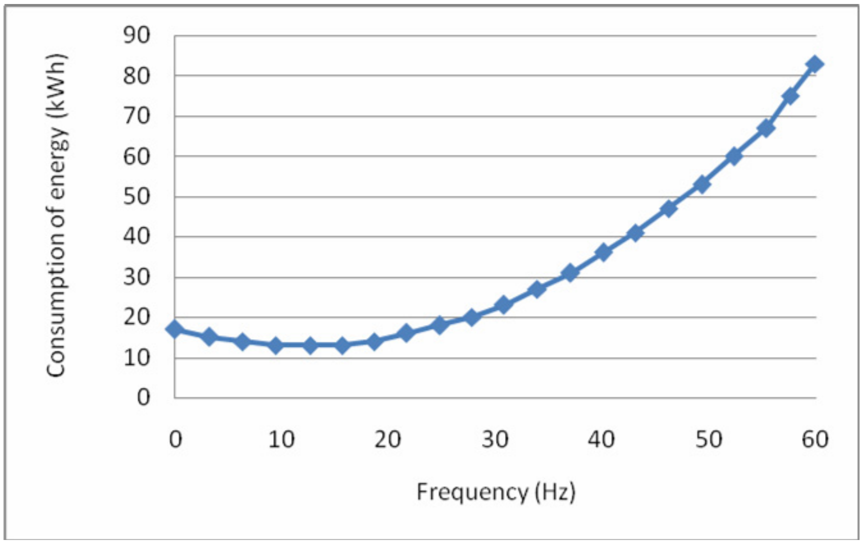

Figure 4 – Electric Energy Consumption at Different Fan Engine Frequencies

It can be seen the exponential design of the graphic according to the frequency used, where a little reduction of the frequency results in a great saving of electric energy. Below 50% of frequency (30 Hz) the consumption of electric energy is almost the same, increasing almost linearly from it to 100% (60 Hz). Such results were also found by Vranizan and Wohlgemuth (1988) and Siemens (1998), and this graphic tendency is considered the standard regarding to electric consumption *versus* air velocity or frequency.

Distribution of the Air Velocity

Figures 5 and 6 present the distribution of the air velocity (m/s) in the kiln at, respectively, 60Hz (100%) and 36Hz (60%) of frequency.

In the superior part of the kiln (between the fan deck and the stack) occur the highest air velocities, representing loss of air flux in drying. This air was supposed to pass through the stacks. However, the air velocity distribution through the stacks was homogeneous in both the frequencies used. Even at 60%, the average air velocity was around 2.0 m/s, considered satisfactory for conventional kiln drying (Hildebrand, 1970). So, it is possible to use the converter of frequency during the drying operation without reducing the productivity.

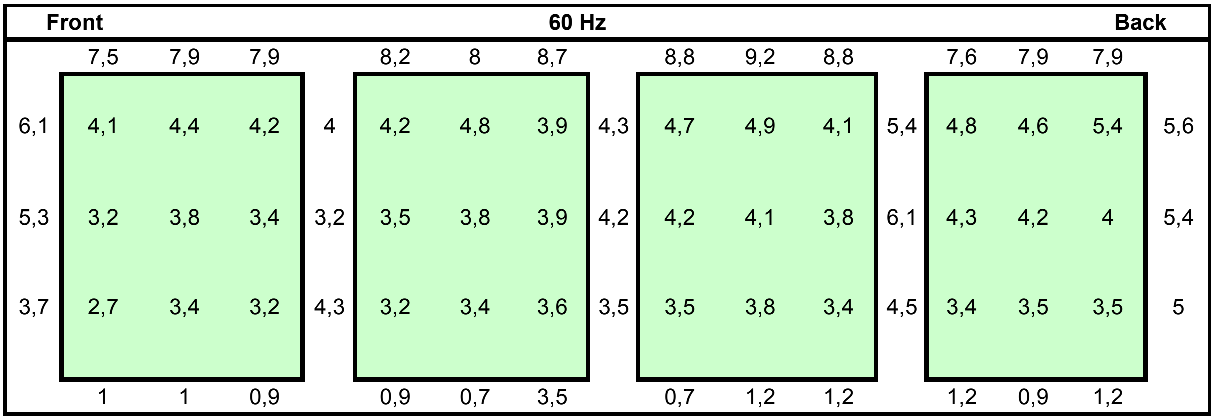

Figure 5 – Air Velocity at 100% of Frequency – 60Hz

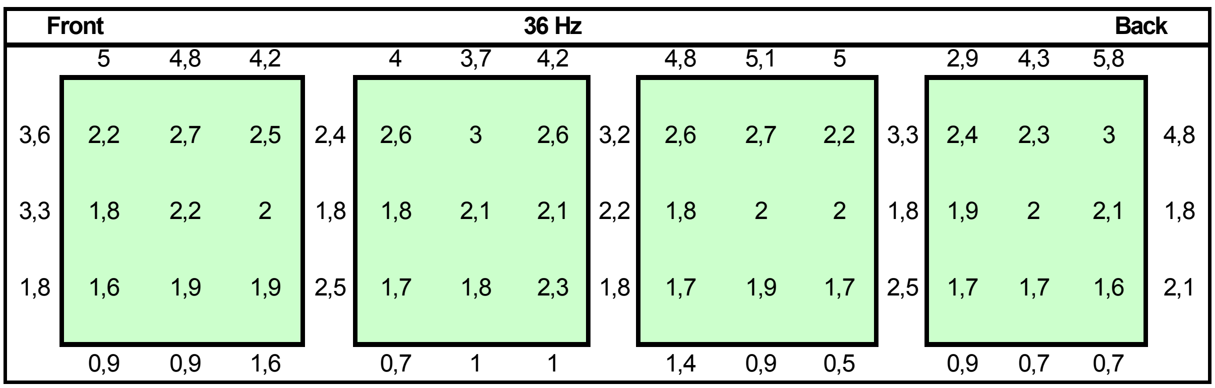

Figure 6 – Air Velocity at 60% of Frequency – 36Hz

Conclusions

The control of the frequency of the fans engines using the converter of frequency represented a saving of around 35% of electric energy.

The electric energy costs was reduced from US$ 4.49 to US$ 2.92 per cubic meter of dried wood, resulting in an annual saving of US$ 32,950,00 for each kiln. Considering the 8 kilns of the factory this annual saving can reach the amount of US$ 263,600,00.

The pay back of the investment on the acquisition of the frequency converter happens in less than 12 months in this study.

The distribution of the air velocity in the kiln, even at the lowest frequency used (60%) was considered satisfactory for conventional kiln drying.

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