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INFLUENCE OF VARIOUS OPTIONS TO BAFFLES SETUP ON AIR VELOCITY AND ITS UNIFORMITY IN A DRYING KILN

Bogdan BEDELEAN
Transilvania University of Brasov, Faculty of Wood Engineering
Str. Universitatii nr. 1, 500068 Brasov, Romania
Tel: 0040 268 419581, Fax: 0040 268 415315, E-mail: bedelean@unitbv.ro

Abstract
In this study, an experimental-based comparative analysis among different options to the baffles settup in a drying kiln was carried. The experiments consisted in measuring the air velocity in different points located at the outlet face of stacks. The results showed that the position of baffles inside a drying kiln plays an important role on mean air velocity and its uniformity withing the wood stacks. In the analyzed case the best option to place the baffles was in the middle of the stacks.

Key words: *drying kiln; air flow; top baffles; side baffles; air velocity and uniformity.*

INTRODUCTION

Conventional heat-and-vent drying kilns are used by the industry to season wood to a desired moisture content, which is a function of the intended use of wood product. The rate at which the hot air transfers heat to the wood and removes the evaporated water depends not only on the temperature and relative humidity of the air, but also on its velocity (Vikberg et al. 2015). According to Incropera et al. (2007) cited by Vikberg et al. (2015), an rise in the air velocity increases the convective heat and mass transfer coefficients, especially when the flow turns from laminar to turbulent. Moreover, an increased air velocity reduces the temperature drop across the load thereby creating a more homogenous drying climate throughout the load (Elustondo et al. 2009).

The most common solution applied to improve air flow in a drying kiln is the use of baffles. Their role is to minimize the value of bypass, which is defined as volume of air that flows around the stacks, divided by the volume of air passing through the stack (Nijdam and Keey 1996; Rilley 2006). According to Langrish and Keey (1996), the energy penalty of flow bypass derives more from a loss of capacity (or extension of drying time) than the direct energy loss in the bypass itself. In addition, the bypass can cause non-uniform drying and moreover, it could reduce the potential of air velocity reducing strategy in order to save electric energy below fiber saturation point (FSP ≈ 30%). This limitation is due to the fact that air velocity reducing should be adapted to the lowest air velocity in the kiln (Steiner et al. 2011). Therefore, a lower air velocity variation will lead to a high potential of reducing air velocity.

The bypass is caused by the gaps generated around the stacks (Fig. 1). These gaps are classified in:

- top gap (CPS), which is the space between the top of the stacks and the false ceiling;
- side gaps (CPL), which are the two spaces between the stacks and the kiln walls along the kiln's length;
- the vertical gap (CPV), which is the space in-between the stacks, equal to the stacks height;
- the horizontal gaps (CPO), which are the spaces created by the bolsters between the lower stacks and the floor and between the lower and upper stacks (Fig. 1).

Since these gaps have a lower aerodynamic resistance than the stacks, a part of the volumetric flow rate generated by the fans will bypass the lumber stacks.

As an alternative to the recommendation that all gaps around the stack should be blocked (Ledig et al. 2007), most of the drying kilns are equipped with top baffles or top and side baffles. For example, the survey performed by Ermurachi (2013) showed that 32% of companies reported that their kilns do not have baffles, 44% of companies communicated that their kilns are equipped with top baffles made of plastic or aluminum and only 24% mentioned that their kilns have both top and side (end) baffles; the study was done based on response received from 25 sawmills located in different parts of Romania.

The influence of baffles on air velocity in a drying kiln has been studied by different scholars (Culpeper 2000; Keey et al. 2000; Riley 2006; Steiner et al. 2011; Bedelean and Sova 2012; Bedelean 2014). The suitable option is to use both top and side baffles in order to obtain a better performance from mean air velocity and its uniformity point of view. These advantages could lead to a short kiln-residence time and energy consumption. Also, it leads to a low final moisture content variation of dried boards. However, there is a lack of research on the optimal position of baffles in a drying kiln. Knowing the suitable position of baffles an increase of air velocity and its uniformity in a drying kiln could be achieved. Also, it could lead to a lower investment and maintenance cost of baffles.

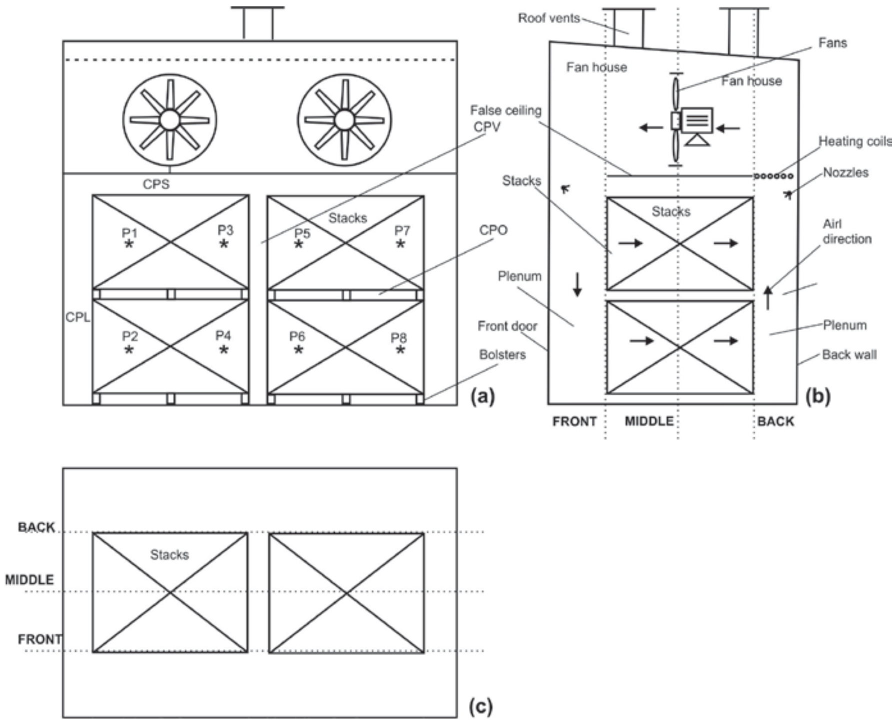

Fig. 1.
Schematic geometry of drying kiln that was used in the study
a – front view; b – side view; c – top view.

OBJECTIVE

The objective of the present research was to figure out the suitable position of baffles inside a drying kiln by taking into account the mean air velocity and its uniformity.

MATERIALS AND METHODS

The experiments were performed in a 4m^3 heat-and-vent laboratory kiln, schematically presented in Fig.1. The kiln is equipped with two reversible overhead fans, a heating coil, two vents and two spray pipes - one on each side of the kiln.

Four stacks were placed inside the kiln as a 2 x 2 matrix (Fig. 1). Each stack contained eighty-eight sticker-stacked spruce (*Picea abies*) boards. Three 24 mm stickers were placed in a row, at the ends and at half the length of the boards. Based on these input data, twenty 1200 x 676 x 24mm sticker spaces arranged as a 2 x 10 matrix were generated in each stack. Three bolsters were placed below each stack (Fig. 1).

The experimental design presented in Table 1 shows the investigated options (sixteen) to setup the baffles in the laboratory kiln.

The test consisted in the air velocity measurement, in the same locations, at the outlet of the airflow from the active channels, as pictured points in Fig. 1. The air velocity was measured at ambient temperature, which is the standard practice in the wood drying industry (Vikberg et al. 2015). The acquisition system composed four components. The first one was a rotating vane air velocity sensor (AHLBORN- FVA915S220), the second was a data-logger (Almemo 2590 – 4S), the third was the AMR Control software, and the last was a laptop computer. To find out more information about the acquisition system used in this study, the reader might consult the research study performed by Bedelean and Sova (2010). During the air velocity measurements the fan speed was equal to 1300 rpm for all investigated options regarding the baffles placement. The top and side gaps was blocked using baffles made of OSB panels (Oriented Strand Board).

Table 1

Various options to setup the baffles in tested drying kiln

Option	Top baffle			Side baffles			Air velocity	
	Front	Middle	Back	Front	Middle	Back	Mean	CV
A	-	X	-	-	-	-	2.42	0.23
B	X	-		X	-	X	3.36	0.05
C	X	-	X	-	X	-	3.64	0.09
D	X	-	-	-	-	-	2.42	0.24
E	-	X	-	X	-	-	3.52	0.06
F	X	-	X	X	-	X	3.62	0.04
G	X	-	-	X	-	-	3.47	0.05
H	-	X	-	X	-	X	3.33	0.07
I	-	-	-	-	X	-	3.26	0.11
J	X	-	X	X	-	-	3.33	0.11
K	-	X	-	-	X	-	3.63	0.05
L	X	-	-	-	X	-	3.38	0.10
M	-	-	-	X	-	-	3.39	0.06
N(control)	-	-	-	-	-	-	3.17	0.05
O	X	-	X	-	-	-	2.27	0.24
P	-	-	-	X	-	X	2.32	0.22

In order to figure out the differences, from mean air velocity point of view, among the candidates solution to place the baffles in a kiln, the same sample of active channels (n=8) was tested in each treatment condition. Consequently, the one-way repeated measure analysis of variance (ANOVA) was used. In addition to, the coefficient of variation, which is used to establish the uniformity of airflow in wood kilns (Ledig et al. 2007), was applied to find out the treatment that improves the uniformity of the air velocity through active channels. The equations 1 and 2 were used to calculate the coefficient of variation and mean air velocity in the drying kiln (Ledig et al. 2007).

$$CV = \frac{1}{v_{am}}\sqrt{\frac{1}{n-1}\sum_{l=1}^{n}(v_l - v_{am})^2} \quad [-] \quad (1)$$

$$v_{am} = \sum_{l=1}^{n}\frac{v_l}{n} \quad [m/s] \quad (2)$$

where:
CV – is variation coeficient of air velocity [-]; v_{am} – is the mean air velocity [m/s]; v_l – is the air velocity at analysed point [m/s]; n – is sthe sample size.

RESULTS AND DISCUSSION

Results showed that two options were the candidates. First is the option that implies to use both top and side baffles and to place them in front and back of stacks (option F). The other is to place the top and side baffles in the middle of stacks (option K). Both selected options ensure a better air circulation in drying kiln than the option to place the baffles in front of stacks (option 7G), which was the anticipated solution. However, it could be observed that the type of baffles used and its position in the kiln can negatively influence airflow within stacks (Fig. 2).

The one way repeated measure analysis of variance ANOVA showed that there was a statistically significant difference among the mean values of the three compared options (the control (N) and candidate options (F and K), Wilks' Lambda = 0.087, $F(2,6) = 31.41$, $p<0.05$, $\eta^2 = 0.913$. The mean and standard deviations are presented in Table 2.

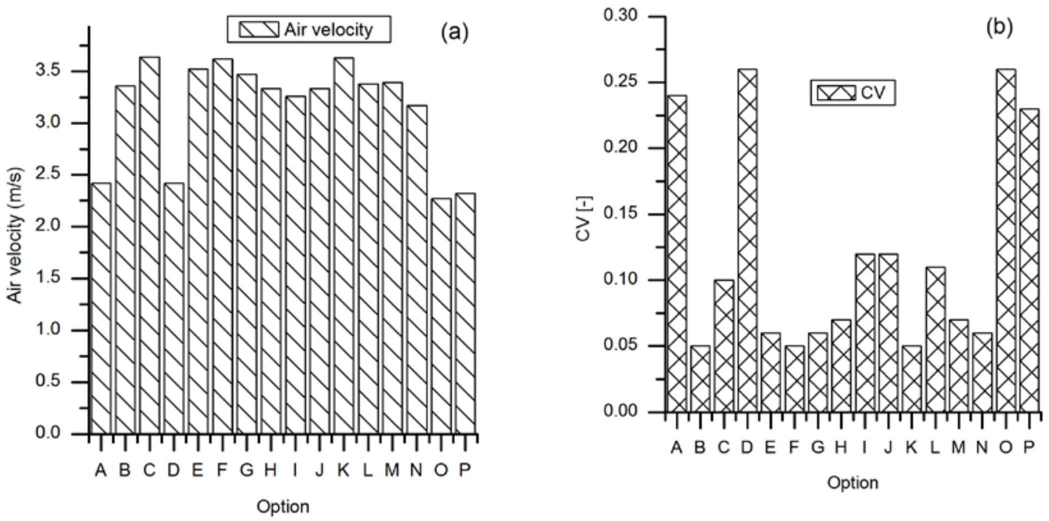

Fig. 2.
Mean air velocity (a) and its uniformity (b) in drying kiln

On the other hand, the pairwise comparison between options F and K showed that the means difference was not statistically significant ($p > 0.05$). Consequently, the null hypothesis, which stated that the means were equal, was not rejected. Therefore, it can be concluded that there is no performance difference, from the mean air velocity through sticker spaces, between option F and K to place the baffles in a drying kiln. Also, there is a small difference between coefficients of variation (Table 1). Since the options to place the baffles in the middle of stacks is cost-effective than to place them in front and back of the stacks, the option K was selected and applied to the investigated kiln and it is presented in Fig. 3.

Table 2

Mean and standard deviation of studied options

Option	Mean air velocity, m/s	Standard deviation, m/s
N (without baffles)	3.17	0.17
F (with top and side baffles placed in front and back of stack)	3.62	0.16
K (with top and side baffles placed in the middle of stack)	3.62	0.19

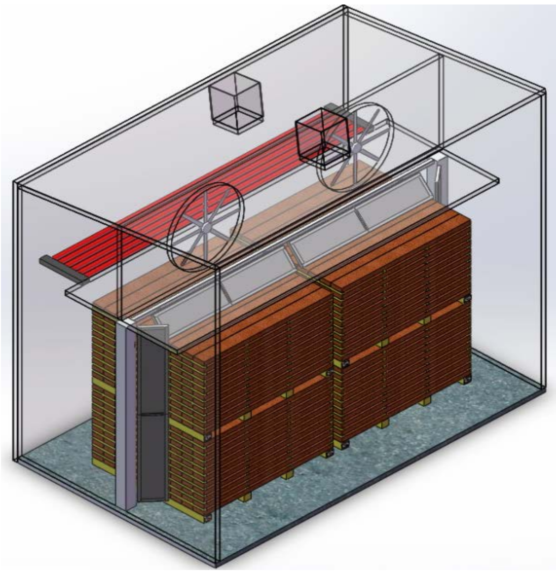

Fig. 3.
The selected configuration to setup the baffles in the analysed kiln

CONCLUSIONS

In this study, different positions to place the baffles in a drying kiln was analyzed. The results obtained within the present research demonstrated that both top and side baffles are needed in order to obtain an increase of mean air velocity and its uniformity though timber stacks. However, special attention should be pay in order to find the suitable position for investigated drying kiln. In the case of analyzed kiln, the suitable position was in the middle of load. In a further study, the suitable position in in an industrial kiln could be analyzed.

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