MIND based optimisation and energy analysis of a sawmill production line

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The lumber drying process uses about 80 % of the total heat consumption in sawmills. Efforts to increase energy efficiency in lumber kilns were very restricted due to the low biomass prices between the 80th and 90th. Today with higher production and biomass prices, companies want to decrease their own use of biomass and increase the heating system efficiency. The study proposes alternative ways to reduce the heat consumption at batch kilns by recirculation of the evacuation air and addresses particular problem encountered in sawmills. Which produce their own heat and suffer from bottlenecks in the heating system due to high heat load from the dryers and increased production. The study shows the possibility to recycle the evacuation air from each kiln which reduces the overall heat consumption of the kilns by 12 %. At nationally basis this corresponds to a decrease of heat consumption of 440 GWh annually, among Swedish sawmill. This will decrease the individual heat consumption of the kilns, heat load in the heating system and the bottleneck effect in the drying process. The decreased own use of biomass brings benefits of more available biomass to the market and increased profits for the sawmill.

Introduction

The Swedish sawmill industries produce 16.4 Mm^3 lumbers annually (Staland J., et al. 2002). The drying process uses 78-83 % (Vidlund A., 2004, Stridberg S., et al. 1984) of the total used heat in sawmills. This makes lumber drying the largest heat and time consuming process in the lumber production process. A modern kiln dryer uses about 285 kWh/m^3 (Vidlund A., 2004), which corresponds to a national heat consumption of 4.7 TWh. Normally is heat produced in a furnace by own by-products from the sawmill processes, biomass as bark, woodchips, sawdust. The interests in increased energy efficient kilns were very limited due to the low biomass prices under the 80th and 90th. Reducing drying time and increasing the lumber quality were highly prioritised instead. With larger lumber demand on the market and increased energy prices have led to higher priority of energy efficient kiln and heating system. This study brings solutions to lower the heat consumption in lumber drying by recycling of evacuation air.

Technical description

The drying process is necessary to gain sufficient quality and moisture content of lumber with less structural deformations. The lumber undergoes a specific drying scheme with different temperatures and moisture contents of surrounding air. The appearance of the drying scheme is depending on the end moisture content of the lumber, type of wood and dimensions etc. The outdoor air is heated by firing biomass in a furnace, the air then enters the drying kiln and is circulated beside the lumbers. To maintain a high drying capacity among the circulation air and avoid an equilibrium state between the air and the lumber, it is necessary to evacuate a part flow from the kiln and exchange it with fresh air. The air is evacuated to the outside for a conventional kiln, which results in high drying losses and decreased drying efficiency. The used heat, air humidity and temperature in a kiln during a drying cycle are presented in Figure 1. The two diagrams (see Figure 1 (c)-(d)) show the temperature and humidity inside the kiln over time. As can be seen in Figure 1 (a), the heat consumption in the beginning part of the drying scheme (the first eight drying steps) corresponds to 50 % of the total heat consumption.. This high consumption is related to the large amount of evacuation air, high lumber moisture content and the lumber warm up process which stands for 6 % (Johansson L., et.al. 2000) of the kiln heat consumption.

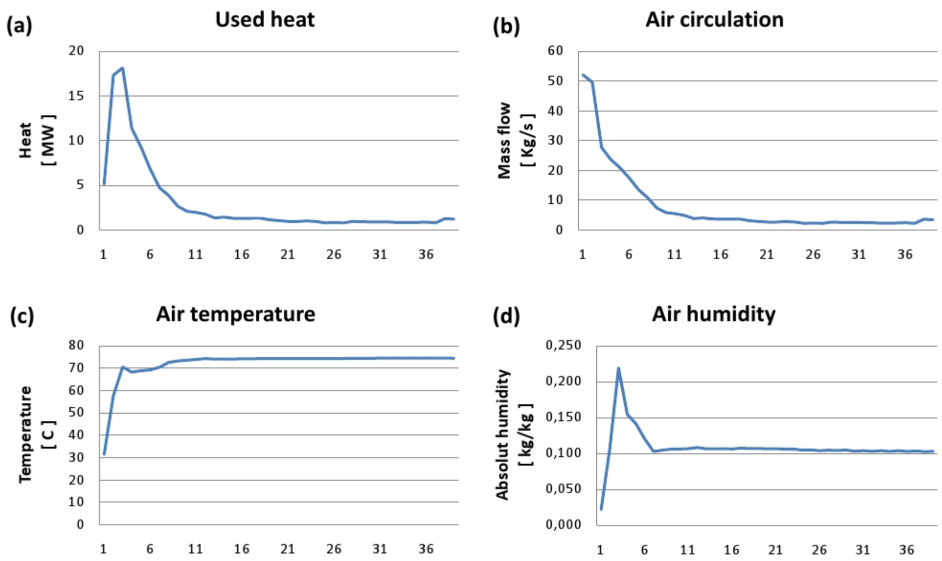

Figure 1: Lumber drying cycle in kiln dryers

The extend of this high heat load in the beginning of the drying cycle can cause problems in form of bottlenecks in the heating system, particularly if several kilns are started simultaneously. The evacuated air humidity is largest at drying steps 2-8 where the mass flow of evacuated air is highest, shown in Figure 1(b) and (d). It renders possible to recycle some of the evacuated air from kilns which no longer is in the same drying step and have lower moisture content in the evacuated air, to kilns which is in the beginning part of the drying cycle. This can be achieved if some of the dryers are displaced in starting time between each other.

Methodology

The energy demand at kilns was determined by experimental measurements in a batch kiln and from former published research. The measurements were made in Tunadal sawmill, located in Sundsvall, Sweden. The sawmill was chosen due to their use of drying technology which represents the most common used, with new heating system and kiln facilities and accurate control system. Those correspond to the latest drying facilities at the market. The experiments were performed in February on batch kilns, with Norwegian spruce with a dimension of 50 x 175 mm and an end moisture content of 12 %. The experimental data were collected by the kiln control-system. Sampled variables were dry and wet temperature at both sides of the timbers package (marked (C) and (D) in Figure 2), air mass flow and the heat supply from the heating coil. The conditions of the outside air marked (A) in Figure 2, temperature and relative humidity, were measured in a nearby control station by the Swedish road department. Mark (B) refers to a theoretical calculated point which corresponds to the air condition at the heating battery, where an adiabatic process is obtained due to pure heating of the entering air towards point (C). The air enthalpy between point (C) and (D) have been considered as constant. Hence, only moister absorbing without heat reduction occurs, after the lumber heat up process. When the air passed the lumber package, at point (D), has the air been considered as saturated.

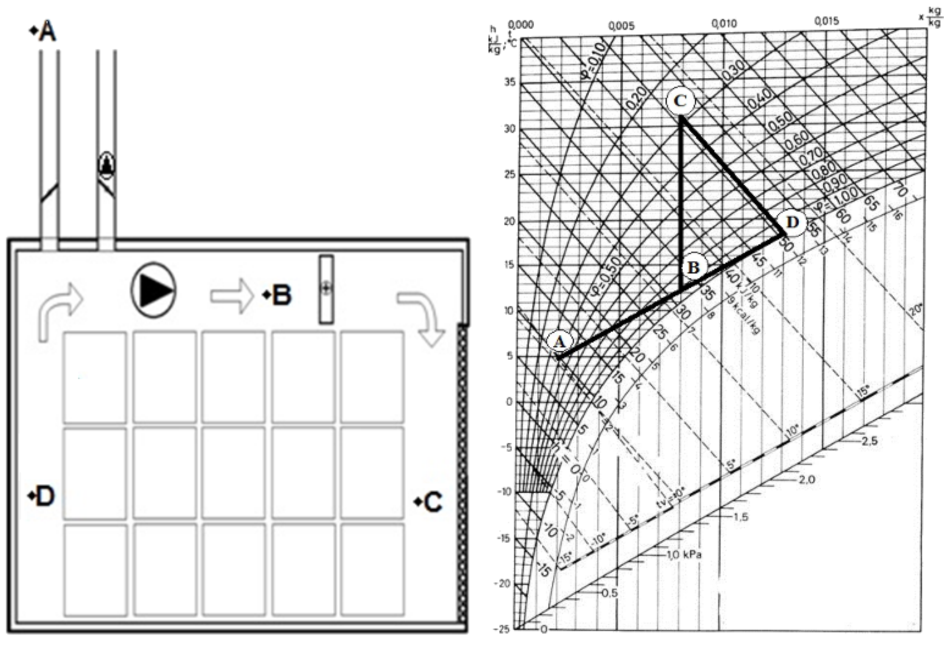

Figure 2, Measurement points of air cycle in kiln and mollier diagram

The air enthalpy, evaporated water and heat consumption can be established through well known thermodynamic and psychometric relationship. The experimental values of one drying scheme were sampled each minute and turned into 39 drying steps with arithmetic average of the sampled experimental values. The overall load at the heating system was analyzed by studying five kilns which had the same drying cycle and drying conditions. A comparison over time was then established between the mass flow and the outside and entering air enthalpy. A kiln with lower air humidity in the evacuation air was accepted to recycle air into a kiln with higher air humidity. To obtain this condition, the kiln needs to be displaced in starting time compared with the other kilns. The heat consumption was calculated with the air mass flow and the enthalpy difference between the evacuated air, the air outside and inside of the kiln.

Result

The following results are established with 8 drying step displacement in starting time between each of the five kilns. Figure 3 shows the individual heat consumption for the kilns. The solid lines represent the consumption without heat recycling between the kilns and the dashed line represent the consumption with recycling. When comparing the dashed and the solid line, in Figure 3, it can be seen that there is more efficient use of heat in drying step nr 2-7 when recycling the evacuation air. The individual consumption was reduced with 9 %, 6 %, 13 %, 15 %, and 17 % respectively. This results in an overall decreased heat consumption of 12 %. The experimental measurements were repeated three times for identical kilns, the data was then analysed in the same way as previously. This resulted in a maximum variation of 3 % between the measurements.

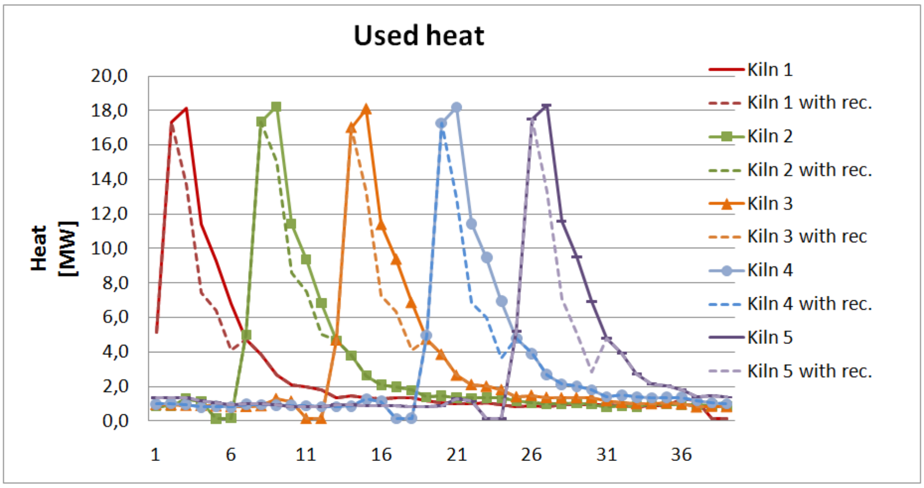

Figure 3, Heat consumption for five identical kilns

Among Swedish sawmills this represents a reduction of 440 GWh in heat consumption annually. For a specific sawmill this will lead to increase the production capacity due the reduced and more even heatload at the heating system and thus, with a result of less drying bottlenecks. The use of heat which are produced from own biomass will decrease, resulting in benefits for the biomass market and the sawmill profit.

Conclusion

The investigation points out that it is possible to decrease the overall heat consumption by 12 %, for heating the entering air into the kiln. This is possible if each of the kilns is displaced in starting time with about eight drying step, to be able to recycle the evacuation air from one kiln with low humidity into another. This will result in more uniform load at the heating system and less bottlenecks at the drying processes. If implement this into larger heating system which embrace larger amount of kiln it is possible to achieve higher efficiency and a heating system which is less sensitive of fluctuations of the drying scheme.

Discussion

The high variation of reduced heat consumption, between kiln 1 – 5 (9 %, 6 %, 13 %, 15 %, and 17 %), can be explained by the specific displacement in time between the specific kiln and the other kilns. This demonstrates how important the displacement in time is between the different kilns, considering the heat recycling. In general, many dryers are started simultaneously, often due to simplicity, which renders effect in an unnecessary peak load at the heating system. The heat recovery system, explain in this paper, can be used among small drying systems in sawmills but will serve best for larger systems, with at least 10 kilns. I.e., sawmills with a production capacity of about 70 000 m^3 lumbers. At these sawmills a heat recycling scheme between the kilns can be made with less sensitiveness of a specific kiln malfunction.

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