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EFFECT OF EXTERNAL TEMPERATURE AND CONDITIONS OF STEAMING KILN TO THE HEAT LOSS

In wood technology the steaming is one of the most energy demanding process. The shortage of the treatment and the extra high temperature results that this technology has the highest specific energy consumption. The reduction of processing costs needs the reduction of energy consumption and on the other side this intention has an environment protecting effect too. Steaming of wood takes place in practice in steaming chambers. The heat loss of the chamber's wall can be measured with heat flow sensor and thermos vision camera. The sensors were fixed in different position on the wall and the fundation of the kiln. The foundation made of concrete and the walls is sandwich-structured composite with PUR and aluminum sandwich panel. Heat flow was measured 71.3 W/m^2 and 415.5 W/m^2 in average on the wall and the foundation respectively. The energy loss of the chamber was calculated by means of a Win Watt energy simulation software. The rate of heat loss varies by 40% as a function of insulation and the outside temperature, where 10 and 20 cm of thermal insulation and the temperature range of –5 °C to +10 °C with 5 °C steps were calculated. The possibility of using a heat exchanger to reduce the waste energy was studied also.
Keywords: *steaming, energy consumption, steaming chamber insulation/*

Introduction

Steaming is most often used to change the unfavorable properties and color of wood (Majka and Olek 2007; Tolvaj et al. 2006, 2009; Taghiyari et al. 2011; Barański et al. 2017). Beside aesthetical result the steaming can decrease the shrinkage and dwelling of the wood as the effect of moisture change. On the steaming process the wood is warmed up in hot steam and keep in high temperature around 100 °C for 24 to 48 hours pending on the desired strength of steaming. Consequently, steaming has a large energy demand in a very short time, which means specific high energy demand, and expenses. The amount of energy used for steaming is influenced by several factors such as time of schedule, lumber's thickness, species, and density of wood, external temperature, type of steaming, and the condition of the chamber (Németh et al. 2013), and also the initial moisture content of the wood. In case of higher moisture content, the water has to be heated up to the steaming temperature which is very energy consuming taking into consideration the high specific heat of the water. It is almost three a half time higher than specific heat of wood, so to warm up energy amount of one kg water is equal to three and a half of wood. The steaming energy demand of drier wood is lower than wet wood.

Energy amount can be separated to three main part, 1) warming up the wood-water, and the chamber; 2) causing thermochemical changes in the wood structure in cell wall level; 3) heat loss. The ratio between this three main part is important from the aspects of energy efficiency. Only thermomechanical changes is the goal of the treatment; energies turned to heat up the materials and the heat loss are undesirable but necessary that is why reduction is needed.

The used energy is mainly thermal energy, which results high amount of CO_2 emissions. On the other hand, the transportation loss of steam in the pipe usually high, because of the high temperature difference of steam and the ambient. The heat loss can be separated to the heat loss of the chamber during the treatment and the heat loss of steam transportation. From this aspect the distance of steam source from the chamber is highly relevant.

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The energy used for warming up the wood-water and the chamber and changing the cell structure is needed for having the result it cannot be decreased. The heat loss of the chamber can be significant and would be advantageous to decrease as low as possible. This is the energy amount which disappear in the environment without any useful effect completed by the energy released by the cooling down of the wood and the chamber.

In this study was examined the heat loss of an industrially used steaming chamber and was seeking the possibilities of heat loss reduction.

Material and methods

The chosen steaming chamber located in the saw mill in a forest company in the mount of Bakony in Hungary. The chamber is used for thermal modification of beech wood. The capacity of the chamber is 12 cubic meter; the heating fuel is overheated steam produced in a high capacity furnace. The fuel of the furnace is the waste materials of the saw mill. Despite of the name "waste" the company can sell the fuel material on the market, and to minimize the usage for own consumption is desirable.

The chamber heat loss measurements were performed during the treatment of the steam chamber. Fluke TiR3FT infrared camera with the resolution of 0.1 Celsius, and Ahlborn Almemo 2590 data collecting, thermal flux sensor, calibrated temperature sensor was used for thermo vision and thermal flux measurement respectively. During the measurement wasn't any significant wind and air temperature change. The wind could increase the heat loss on the external surface of the chamber. Background temperature was set to the measured air temperature and the emission value of the surface was set 0.25 which fits to the dirty rough aluminum surface. The thermal imiger was verified by tactile thermometer. The photos were analyzed by the Smart View software. For measuring heat flow flux meter was fixed on the surface of the chamber in different places. Inner and external air temperature were also measured. The measurement points were selected to be far away from the corners and inlet points. Because of the fluctuation of the surface temperature number of the measurement was increased to 30 and the average value was considered.

Based on the measurement results, a virtual model of the chamber was built with Win Watt software, and the effect of ambient temperature and insulation thickness on thermal conductivity was calculated.

After the first measurement the steaming chamber was improved by changing the sealing of the doors. Second measurement was performed with the improved chamber and the thermal images was compared.

Results

The large heat losses determined with the help of thermal images were solved with seals and insulations (Fig. 1).

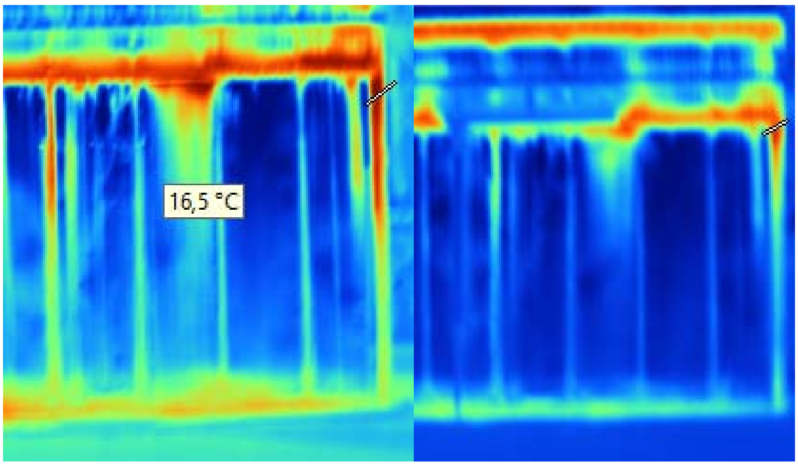

Fig. 1. Chamber door's temperature before and after the change of seal

Beside the surface heat loss, the filtration heat loss is occurring and as the Fig. 1 shows not negligible magnitude. However, the changing of sealing does not affect the surface heat loss, but can reduce considerable the filtration loss.

The measured average heat flow on the chamber surface can be seen in the table.

Table

Measured heat flux in different point of chamber. The point 1 and 2 is on the PUR panel

Surface	Measuring point 1	Measuring point 2	Concrete foundation
Average heat flux [W/m²]	69.7	72.3	415.5

Based on the model of the chamber, 15 °C increase of the external temperature reduces the heat waste about 10 % (Fig. 2).

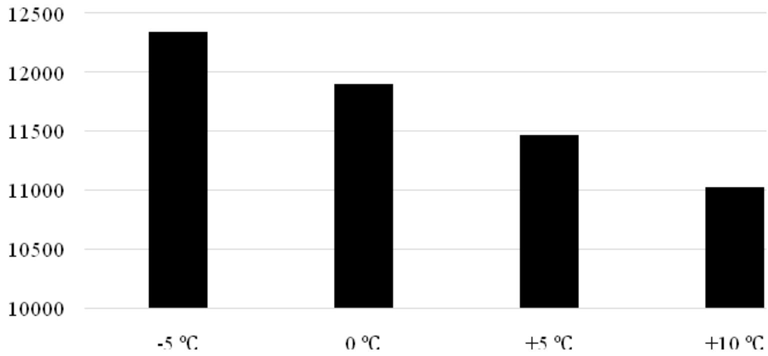

Fig. 2. Heat waste [W] during 1 hour with increasing external temperature

The theoretical insulation of the chamber induced a decreasing heat loss (Fig. 3). The degree of thermal insulation is more important at lower external temperatures: at –5 °C even the weakest insulation caused an extra 18 % loss, while the double insulation and the separate insulation of the fundation almost doubled this (34 %). The difference between the weakest and strongest insulation calculated in percentage point was hardly affected by temperature: it was reduced from 15.7 to 13.4 %. At higher outdoor temperatures, the reduction in heat loss was greater, reaching 40 % with the best thermal insulation. With the best insulation, the outside temperature had little effect on the rate of reduction in heat loss (34.5 to 40 %).

Increasing levels of insulation also come with increasing costs. The optimal insulation thickness can be determined by cost and environmental load analysis for the entire life of the chamber, which is the task of the future.

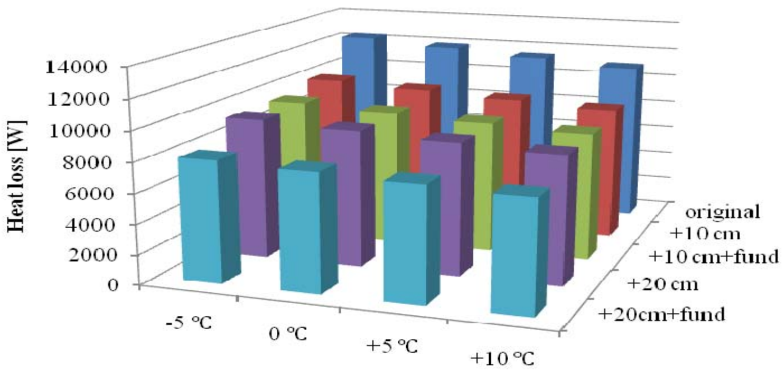

Fig. 3. Heat loss as a function of insulation and outside temperature

A further reduction in the energy consumption can be achieved by recycling the heat leaving the chamber in a controlled manner. According to measurements, through the overpressure outlet the air flow is 84.75 m^3/h at 92 °C.

Fig. 3 show the results matrix of the simulation of different insulation thickness and the different external temperature. Additional 10 or 20 cm wall insulation decreases the heat loss, but the figure shows also the importance of the foundation. Execution of follow up insulation of the chamber surface is not easy to perform and causes higher cost, which returns need economical calculation, but the results help to optimize the wall insulation of a new built chamber. Further

Conclusions

Overall heat loss of steaming exceeds more times of the effective heat energy used for treatment. Reduction of this heat loss is necessary for the fulfilment of sustainable development and circular economy. The study highlighted the importance of chamber conditions and the optimization necessity of the insulation thickness. Furthermore showed the outstanding role of the foundation. High ratio of heat loss evaporate on the foundation and on the leakages of the chamber door. While the sealing can be repaired or changed easily the additional insulation of the foundation is almost impossible. From this reason it is very important the adequate design of the chamber where the concrete and the connection line of concrete foundation and wall is well designed for minimizing the heat loss for the full life cycle of the chamber.

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ОБОСНОВАНИЕ НАПРАВЛЕНИЯ МОДИФИКАЦИИ ФЕНОЛОФОРМАЛЬДЕГИДНЫХ СМОЛ ПРИ ПРОИЗВОДСТВЕ ФАНЕРЫ

Проведен анализ наиболее эффективных российских и зарубежных способов модификации фенолоформальдегидного связующего как на стадии синтеза смолы, так и при введении модификаторов в готовую смолу. Выявлен наиболее удобный и экономичный способ модификации – введение в готовую смолу. Предложен вариант модификации с наиболее возможным снижением энергоемкости производства.

Ключевые слова: *фенолоформальдегидное связующее, модификация, прочность, водостойкость, себестоимость.*

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JUSTIFICATION DIRECTION MODIFICATION OF PHENOL-FORMALDEHYDE RESINS IN PRODUCTION OF PLYWOOD

The analysis of the most effective Russian and foreign methods of modifying the phenol-formaldehyde binder both at the stage of resin synthesis and when introducing modifiers into the finished resin is carried out. The most convenient and economical method of modification – introduction into the finished resin-is revealed. A variant of the modification with the most possible reduction in the energy intensity of production is proposed.

Keywords: *phenol-formaldehyde binder, modification, strength, water resistance, cost price.*

Объемы производства и потребления водостойкой фанеры ФСФ продолжают увеличиваться, растущие требования потребителей ставят новые задачи, поэтому перед производителями фанеры стоит непростая задача совершенствования свойств готовой продукции при возможном снижении себестоимости. Традиционный подход к решению данной задачи – модификация фенолоформальдегидной смолы на стадии синтеза (путем частичной замены фенола), либо готовой смолы различными модификаторами.

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