INFLUENCE OF THE INITIAL TEMPERATURE OF FROZED LOGS ON THE DURATION AND ENERGY CONSUMPTION OF REGIMES FOR THEIR DEFROSTING IN BOILING PITS

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ABSTRACT

With the help of our own non-stationary model, the defrosting times of frozed beech logs with a diameter of 0.4 m, initial temperature of −10ºC, −20ºC, −30ºC, and moisture content of 0.6 kg·kg^{-1} were determined at water temperatures in the boiling pit equal to 80ºC. Using the determined logs' defrosting durations, the change in energy required for the entire plasticization process and that for each of the 5 components of the pit's thermal balance was calculated. Computer simulations were performed for a well-insulated concrete pit with working volume of 20 m^3 and degree of filling with logs f equal to 25%, 50%, and 75%. It was found that at f = 75% the total energy consumption of the pit increases from 163.6 kWh.m^{-3} to 177.6 kWh·m^{-3} when the initial temperature of the logs decreases from −10ºC to −30ºC. The thermal efficiency of the studied pit decreases almost proportional to the decreasing of f, mainly due to the increase in the specific energy required to heat the water in the pit.

Key words: concrete pits, heat balance, defrosting of logs, energy consumption.

INTRODUCTION

It is well known that the thermal treatment of logs in boiling pits is carried out for the purpose of plasticizing the wood, in order to reduce the cutting resistance during the formation of quality veneer (Chudinov 1968, Kollmann and Côté 1984, Shubin 1990, Trebula and Klement 2002, Videlov 2003, Deliiski and Dzurenda 2010, Niemz et al. 2023).

The boiling and steaming processes of wood materials in pits are characterized by high energy consumption and low energy efficiency (Sohor and Kadlec 1990, Lawniczak 1995).

The correct and effective control of the considered process is possible only when its physics and the weight of the influence of too much factors for the specific wood materials and equipment are well understood. Estimating the total impact of so many factors on the temperature distribution in the heated materials and on the required energy consumption is a difficult task and its solution is possible only with the help of adequate mathematical models.

In (Dzurenda and Deliiski 2010, 2011), a mathematical model of the heat balance of the shown below in Fig.1 pit is proposed only for the case of boiling in it non-frozed prismatic wood materials. When boiling in the pit beech prisms with dimensions 0.4 × 0.4 x 1.2 m, moisture content of 0.8 kg·kg^{-1}, initial temperature of 10°C at a water temperature of 80°C until reaching a temperature in the center of the prisms of 70°C, the following results were obtained for the individual components of the pit's heat balance: 29.1% for heating of the prisms, 30.0% for heating the pit's construction, 35.2% for warming up of the boiling water, 4.7% for covering the heat losses, and 1.0% for heating of the metal kalorifer of the pit.

Of significant theoretical and practical interest is the study of the heat balance of boiling pits for the case of defrosting in them of frozed logs intended for different purposes. Therefore, the aim of the present work is to further develop the model given in (Dzurenda and Deliiski 2010, 2011) and conduct with it a study of the heat balance of the same pit shown in Fig. 1, for the case of complete defrosting in it of frozed logs with industrial parameters.

MATERIALS AND METHODS

The computer simulation in this study was carried out with frozed beech (*Fagus sylvatica* L.) logs having the following parameters, which influence the heat balance of the boiling pit: diameter D = 0.4 m, length L = 3.0 m, initial temperature $t_{w0} = -10$°C, –20°C, and –30°C, basic density ρ_b = 560 kg·m^{-3}, moisture content u = 0.6 kg·kg^{-1}, and fiber saturation point u_{fsp} = 0.31 kg·kg^{-1} (Videlov 2003). Logs with such initial temperatures contain significant amounts of frozen both free and bound water, the melting of which will favor the increase of the differences between the corresponding energy consumptions of the pit.

The simulations were carried out on the heat balance of the shown in Fig. 1 pit having the following overall dimensions: length L_p = 8.0 m, width B_p = 2.6 m, depth H_p = 2.5 m, and working volume $V_{pit} = l{\cdot}b{\cdot}h_w$ = 20 m^3. The name and values of all the others marked in Fig. 1 parameters of the pit are, as follows: length of the working volume of the pit l = 6.6 m; width of the working volume of the pit b = 2.0 m; depth of the working volume of the pit h_w = 1.52 m; depth of the pit's walls h = 2.0 m; depth of the upper (above-ground) part of the pit h_u = 0.8 m; distance of the drainage channel of the pit to its upper edge d_d = 0.13 m; thickness of the pit's concrete walls d_c = 0.3 m; thickness of the pit's concrete bottom d_b = 0.3 m; thickness of the insulating layers of the pit's walls and pit's steel lid d_i = 0.1 m.

During the process of thermal treatment of wood materials, the pit is closed with a removable well insulated metal lid. The walls are finished with a groove filled with water, into which the protruding edge of the lid is immersed, creating a perfect water seal.

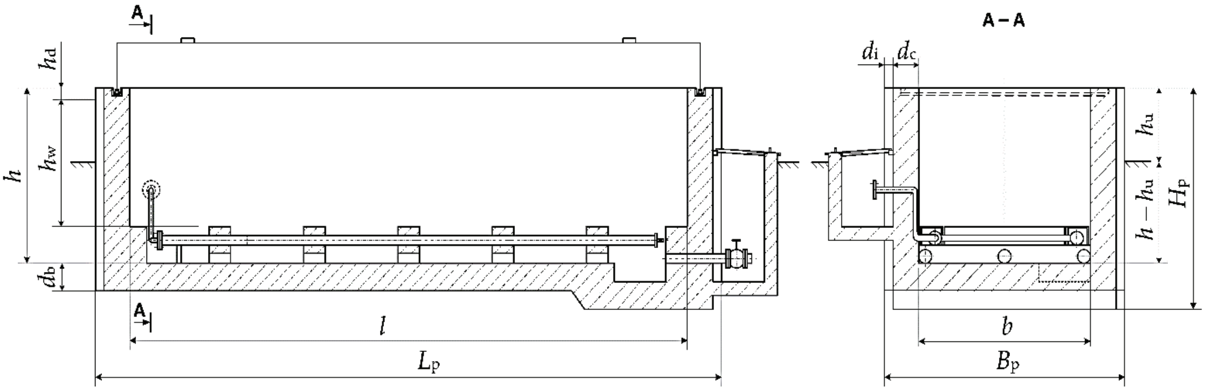

Figure 1: A longitudinal and transverse section of pit for boiling wood materials used during the computer simulations on complete defrosting of frozed beech logs

The heating of the water in the pit to the required operating temperature is carried out indirectly by means of metal calorifier located at the lower end of the pit. The calorifier connected to the plant's heating system is heated by steam or hot water under pressure with a temperature of 120 – 140°C.

To calculate the heat balance of the pit for the case of defrosting in it of frozed logs, it is necessary to know the duration of their defrosting process, τ_{defr}, depending on the influencing factors. Since the heating of frozed logs is a multifactorial process, the duration τ_{defr} is most suitable to be determined with the help of a non-stationary mathematical model adequate to the real process. When the length of the logs, L, is at least 4 times their diameter, D, their defrosting duration can be determined using the following experimentally verified 1D model (Deliiski 2003, 2011):

$$c_{\text{eff-defr1,2,3}} \cdot \rho_{\text{w}} \frac{\partial T(r,z,\tau)}{\partial \tau} = \operatorname{div}(\lambda_{\text{eff-defr}} \operatorname{grad} T) \quad \textbf{(1)}$$

at

$$T(r,0) = T_{\text{w0}} \quad \textbf{(2)}$$

and boundary condition for conductive heat transfer:

$$T(0,\tau) = T_{\text{m}}(\tau) \quad \textbf{(3)}$$

where $c_{\text{eff-defr1,2}}$ are the effective specific heat capacities of the logs during 1st, 2nd, and 3rd temperature ranges of the mutually connected defrosting and heating processes respectively (Deliiski and Tumbarkova 2019, Tumbarkova 2019), $\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$; $\lambda_{\text{eff-defr}}$ – effective thermal conductivities of the logs during their defrosting and heating, $\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$; ρ_{w} – density of the wood, $\text{kg}\cdot\text{m}^{-3}$; r – coordinate along the log's radius; T – temperature, K; T_{w0} – initial temperature of the wood, K; T_{m} – temperature of the boiling water in the pit, K; τ – time, s.

Figure 2 shows the change of the water temperature t_{m} in the pit in the commonly applied regimes for boiling non-frozed and frozed wood materials. These regimes consist of 2 stages, during which t_{m} changes as follows:

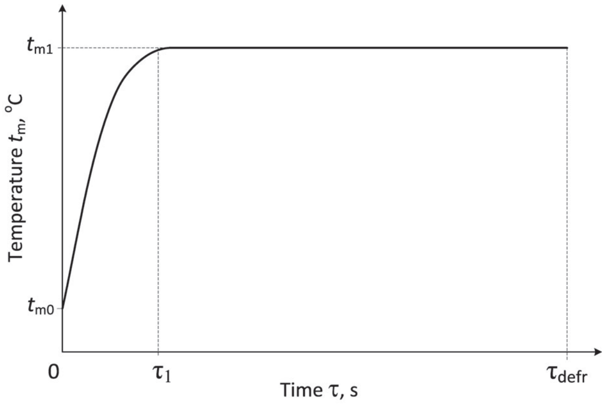

Figure 2: Change of water temperature t_{m} in regimes for defrosting of wood materials in boiling pits

- During the I. stage, in the course of time $0 - \tau_1$, an increase in t_{m} from t_{m0} to t_{m1} takes place by fully or partially opening the valve to introduce steam or hot water into the metal pipe calorifer located at the lower end of the pit, providing indirect heating of the water;
- ▪ During the II. stage of the regime, in the course of time $\tau_1 - \tau_{\text{defr}}$, dosed introduction of steam or hot water into the calorifer is carried out in order to maintain a constant technologically permissible value of t_{m} of the water, equal to t_{m1}. When τ_{defr} is reached, a complete defrosting of the logs occurs.

Mathematical descriptions of all thermo-physical characteristics of frozed and non-frozed wood, which are involved in the model (1) − (3), have been made and verified with foreign experimentally obtained dissertation data in (Deliiski 2003, 2011) as a function of the temperature and wood moisture content.

MATHEMATEICAL MODEL OF THE HEAT BALANCE OF BOILING PITS DURING DEFROSTING OF LOGS

The heat balance of the pit during defrosting of logs can be represented by the following model in a general form:

$$Q_{\text{Pit-defr}} = Q_{\text{Wood}} + Q_{\text{Constr.}} + Q_{\text{Water}} + Q_{\text{Calorif.}} + Q_{\text{Losses}} \tag{4}$$

where $Q_{\text{Pit-defr}}$ is the total amount of the specific (for 1 m^3 wood) heat energy, required for complete defrosting of the logs; Q_{Wood} – energy required for warming up of the logs themselves subjected to defrosting; $Q_{\text{Constr.}}$ – energy required for heating of the pit's construction materials; Q_{Water} – energy required to heat the water in the pit to the set operating temperature; $Q_{\text{Calorif.}}$ – energy required to heat the metal caloriifer of the pit itself; Q_{Losses} – energy required to cover heat losses of the pit during the entire logs' defrosting process. The dimension of all variables Q in equation (4), and also everywhere below, is $\text{kWh}\cdot\text{m}^{-3}$.

The energy required for defrosting of the logs themselves, Q_{Wood}, can be expressed by the following model:

$$Q_{\text{Wood}} = Q_{\text{w-fr}} + Q_{\text{bw}} + Q_{\text{fw}} + Q_{\text{w-nfr}} \tag{5}$$

where $Q_{\text{w-fr}}$ is the energy required for the heating of the frozed wood to a condition necessary to melt the frozen bound water in it; Q_{bw} – energy required to melt the frozen bound water in the wood; Q_{fw} – energy required to melt the entire amount of frozen free water in the wood; $Q_{\text{w-nfr}}$ – energy required to heat the wood in the absence of ice in it until complete defrosting of the logs at 0 °C in their central points. Mathematical descriptions of each of the 4 members of the right-hand side of equation (5) depending on the set of influencing factors are made and verified in (Deliiski and Tumbarkova 2019, Tumbarkova 2019).

The specific heat energy required for warming up of the construction materials of the pit, $Q_{\text{Constr.}}$, can be expressed by the following model:

$$Q_{\text{Constr.}} = Q_{\text{Constr.1}} + Q_{\text{Constr.2}} + Q_{\text{Constr.3}} + Q_{\text{Constr.4}} \tag{6}$$

where $Q_{\text{Constr.1}}$ and $Q_{\text{Constr.2}}$ are the energies, required for heating of the walls of the above-ground part and those located in the ground part, respectively, of the pit's construction; $Q_{\text{Constr.3}}$ and $Q_{\text{Constr.4}}$ – energies required for heating of the pit's bottom and pit's lid, respectively. In (Dzurenda and Deliiski 2010, 2011) are given equations for calculation of each of the components $Q_{\text{Constr.1}}$, $Q_{\text{Constr.2}}$, $Q_{\text{Constr.3}}$, and $Q_{\text{Constr.4}}$ depending on specified there influencing constructive and thermo-physical factors, namely: $Q_{\text{Constr.1}}$ as a function of 16 factors, $Q_{\text{Constr.2}}$ – of 17 factors, $Q_{\text{Constr.3}}$ – of 10 factors, and $Q_{\text{Constr.4}}$ – of 12 factors.

The specific heat energies required for heating of the technological water in the pit, Q_{Water}, and for warming up of the metal calorifer of the pit itself at the beginning of the logs' defrosting process, $Q_{\text{Calorif.}}$, can be calculated with the help of the models given in (Dzurenda and Deliiski 2011), depending on a total of 9 and 7 factors respectively specified there.

The specific heat energy required to cover the losses of the pit, Q_{Losses}, can be expressed by the following model:

$$Q_{\text{Losses}} = Q_{\text{Losses1}} + Q_{\text{Losses2}} + Q_{\text{Losses3}} + Q_{\text{Losses4}} \tag{7}$$

where Q_{Losses1} and Q_{Losses2} are the energies, required to cover the heat losses caused by the heat emission through the walls of the above-ground part and those located in the ground part, respectively, of the pit's construction; Q_{Losses3} and Q_{Losses4} – energies required to cover the heat losses caused by the heat emission through the pit's bottom and pit's lid, respectively.

In (Dzurenda and Deliiski 2011) are given equations for the calculation of Q_{Losses1}, Q_{Losses2}, Q_{Losses3}, and Q_{Losses4} depending on specified there influencing constructive and thermo-physical factors, namely: Q_{Losses1} as a function of 14 factors, Q_{Losses2} – of 15 factors, Q_{Losses3} – of 11 factors, and Q_{Losses4} – of 8 factors.

SOLVING THE MODELS (1) – (3) AND (4) – (7)

The mathematical descriptions of t_m and the thermo-physical characteristics of wood given in (Deliiski 2003, 2011, Deliiski and Dzurenda 2010, Hadjiski et al. 2021) were entered into the model (1) – (3) and it was solved with the help of the finite difference method using own software program in Visual FORTRAN platform created by Microsoft.

From the obtained change of the temperature field along the radius of the logs, and in particular from that of the temperature in their center, the duration of the defrosting process of the logs, τ_{defr}, at water temperature t_{m1} = 80 °C was determined for the three investigated values of the initial temperature of the logs t_{w0}, equal to -10°C, -20°C, and -30°C.

An Excel program has been prepared for joint solving of all equations involved in the model (4). Using this program, the heat balance of the pit shown in Fig. 1 was investigated for the case of defrosting in it of frozed beech logs at a degree of filling of the pit with logs equal to 25%, 50%, and 75%. The study was limited only to the moment of complete defrosting of the logs, in which the temperature in their center becomes equal to 0°C.

The heat energy efficiency of the pit, $\eta_{\text{Pit-defr}}$, at the end of the logs' defrosting is equal to

$$\eta_{\text{Pit-defr}} = 100 \frac{Q_{\text{Wood}}}{Q_{\text{Pit-defr}}} \tag{8}$$

where $Q_{\text{Pit-defr}}$ and Q_{Wood} are the calculated by Eqs. (4) and (5) values of the specific energies required for for carrying out the entire defrosting process in the pit and for the heating of the logs themselves respectively, $\text{kWh}\cdot\text{m}^{-3}$.

RESULTS AND DISCUSSION

Figure 3 shows the change of the temperature in the center of the studied logs, t_{wc}, and also of the average mass temperature of the logs, t_{avg}, during their defrosting at temperature t_m of the hot water, which was calculated with the model (1) − (3). The temperature t_m in the pit changes from its initial value t_{m0} = 10 °C to maximum value t_{m1} = 80°C.

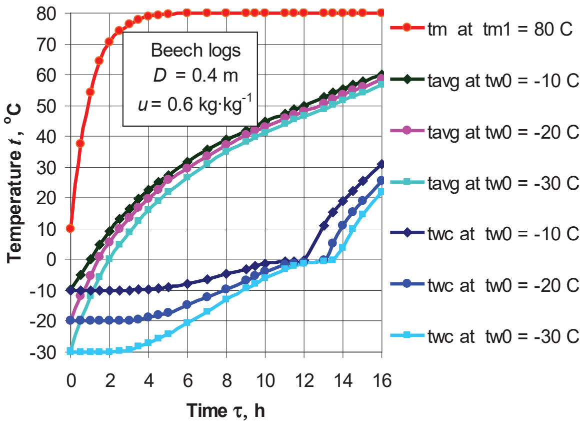

Figure 3: Change in t_m, t_{wc}, and t_{avg} of the studied logs during their defrosting, depending on t_{w0}

In Fig. 3 it can be seen that complete defrosting of the investigated logs occurs as follows: after 12 h at $t_{w0} = -10$°C; after 13 h at $t_{w0} = -20$°C and after 13.5 h at $t_{w0} = -30$°C. At these values of τ_{dfr}, the temperature of the slowest heating central point of the logs reaches 0°C, at which the melting of the entire amount of frozen water in the wood ends.

The specific almost horizontal sections of retention of the temperature t_{wc} for a long period of time in the range from –1°C to 0°C in the center of the logs (and also in all calculation points not shown in Fig. 3 in the inner layers of the logs) are caused by the extremely small temperature conductivity at these points during the prolonged melting of the frozen free water in the wood (Deliiski et al. 2015, Tumbarkova 2019).

Figure 4 presents the change of all individual components of the heat balance of the pit $Q_{\text{pit-defr}}$, as well as the total energy $Q_{\text{pit-total}}$ (in kWh·m^{-3}) required for the complete defrosting of the studied beech logs from their initial temperature t_{wo}, equal to −10°C, −20°C, and −30°C to final temperature of 0°C in their center, depending on t_{w0}.

Figure 5 shows the change of the individual components of the heat balance of the pit in % to the total energy consumption, $Q_{\text{pit-defr}}$, depending on the studied values of t_{w0}.

Figure 6 presents the calculated by Equation (8) change of the heat efficiency of the pit $\eta_{\text{Pit-defr}}$, depending on the studied values of the water temperature t_{w0} and the degree of filling of the pit with logs $f = 25$, 50 and 75%.

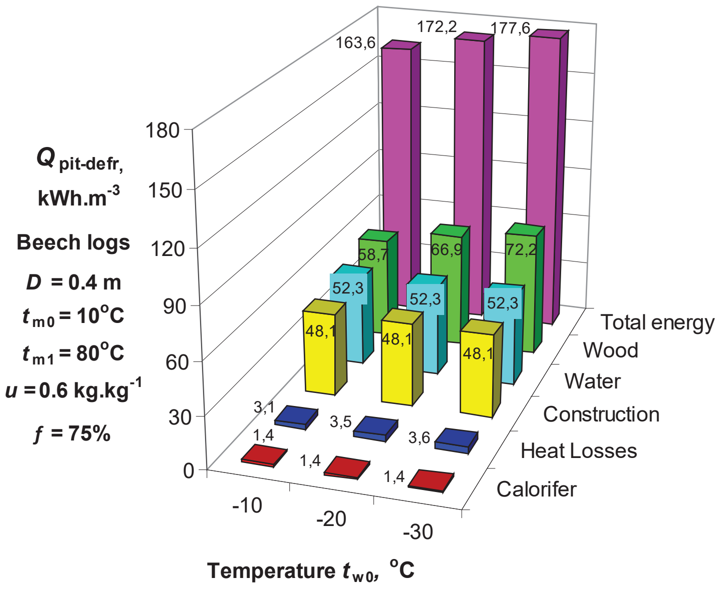

Figure 4: Change in the components of the heat balance (in kWh·m^{-3}) of the pit at the end of logs' defrosting, depending on t_{w0}

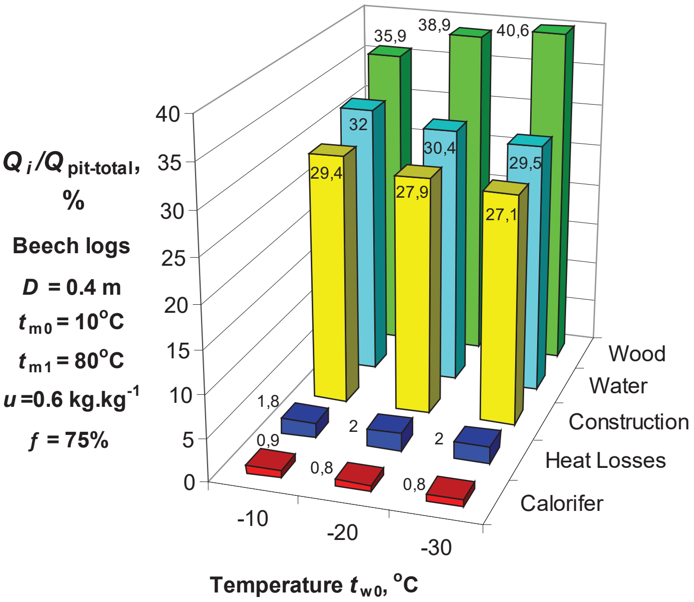

Figure 5: Change in the individual components of the pit's thermal balance in % to the total energy, depending on t_{w0}

When expressing the heat balance of the pit in kWh·m^{-3}, a decrease of t_{w0} from −10 °C to −30 °C causes the following change in the components of the pit's heat balance at t_{m1} = 80 °C and f = 75% (Fig. 4):

– Q_{Wood} increases from 58.7 kWh·m^{-3} to 72.2 kWh·m^{-3};

– Q_{Losses} increases from 3.1 kWh·m^{-3} to 3.6 kWh·m^{-3};

– Q_{Water} remains unchanged with a value of 52.3 kWh·m^{-3};

– $Q_{\text{Constr.}}$ remains unchanged with a value of 48.1 kWh·m^{-3};

– $Q_{\text{Calorif.}}$ remains unchanged with a value of 1.4 kWh·m^{-3}.

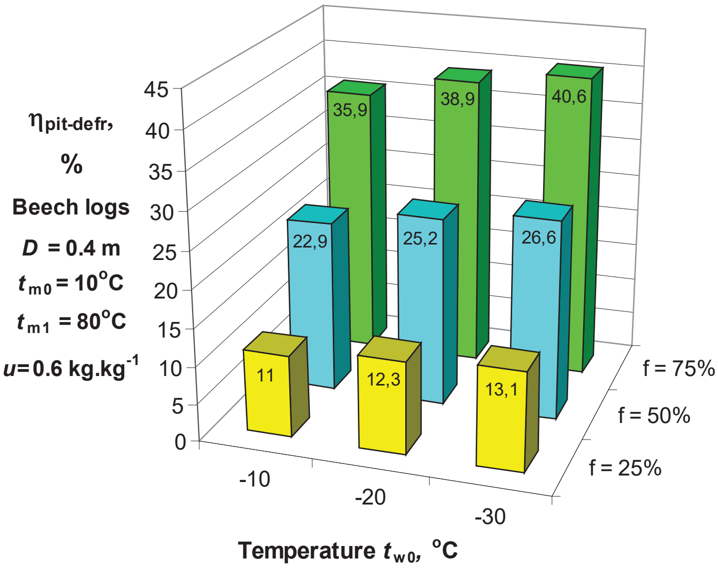

Figure 6: Change in the heat efficiency of the pit, depending on t_{w0} and f

In this case the total specific energy consumption of the pit $Q_{\text{Pit-total}}$ increases from 163.6 kWh.m^{-3} to 177.6 kWh·m^{-3}.

When expressing the individual components of the pit's heat balance Q_i as a % of the total energy $Q_{\text{Pit-total}}$, a decrease of t_{w0} from −10°C to −30°C causes the following change in the fraction of individual components of this balance (Fig. 5):

– Q_{Wood} increases from 35.9% to 40.6%;

– Q_{Water} decreases from 32.0% to 29.5%;

– $Q_{\text{Constr.}}$ decreases from 29.4% to 27.1%;

– $Q_{\text{Calorif.}}$ decreases from 0.9% to 0.8%;

– Q_{Losses} increases from 1.8% to 2.0%.

If the degree of filling of the pit with logs decreases from its maximum possible value of 75% (Sohor and Kadlec 1990) to 25%, the decrease of t_{w0} from −10°C to −30°C causes the following change in heat energy efficiency of the pit $\eta_{\text{Pit-defr}}$ (Fig. 6):

– $\eta_{\text{Pit-defr}}$ decreases from 35.9% to 11.0% at $t_{\text{w0}} = -10$°C;

– $\eta_{\text{Pit-defr}}$ decreases from 38.9% to 12.3% at $t_{\text{w0}} = -20$°C;

– $\eta_{\text{Pit-defr}}$ decreases from 40.6% to 13.1% at $t_{\text{w0}} = -30$°C.

CONCLUSIONS

This paper considers an approach for computing the heat balance and efficiency of concrete boiling pits during defrosting of frozed logs.

With the help of our own non-stationary model, the defrosting times of beech logs with a diameter of 0.4 m, initial temperature of −10, −20, and −30°C, and moisture content of 0.6 kg·kg^{-1} were determined at a water temperature in the pit, t_{m1}, equal to 80°C. Using the determined logs' defrosting durations and the mentioned approach, the total energy required to completely defrost the logs in the pit, $Q_{\text{pit-defr}}$, and that required for each of the individual components of the heat balance were calculated.

It was found that the decrease of t_{w0} from −10°C to −30°C at maximum possible loading level of the pit with logs $f = 75\%$, causes an increase of the energy consumption of the entire pit $Q_{\text{Pit-total}}$ from 163.6 kWh.m^{-3} to 177.6 kWh·m^{-3}, i.e. by 8.6%, which is equivalent to an increase of 0.43% for each degree decrease in t_{w0}.

At the commonly used values of t_{m1} = 80°C and $f = 75\%$, the heat energy efficiency of the pit $\eta_{\text{Pit-defr}}$ is equal to 35.9% at $t_{\text{w0}} = -10$°C, to 38.9% at $t_{\text{w0}} = -20$°C, and to 40.6% at $t_{\text{w0}} = -30$°C. With a decrease in f, this efficiency decreases almost proportional to f, mainly due to the increase in the specific energy required to heat the water in the pit. This shows how important it is for the thermal efficiency of the pits to be well filled with wood materials subjected to defrosting or/and boiling.

The presented approach can be applied to compute heat balances of pits both during defrosting only and during complete boiling of frozed logs to a desired final average mass temperature required for the subsequent mechanical processing of the logs.

REFERENCES

CHUDINOV, B. S. 1968. Theory of the Thermal Treatment of Wood, Nauka, Moscow, USSR, 255 p. (in Russian).

DELIISKI, N. 2003. Modelling and Technologies for Steaming Wood Materials in Autoclaves. Dissertation for DSc., University of Forestry, Sofia, 358 p. (in Bulgarian).

DELIISKI, N. 2011. Transient Heat Conduction in Capillary Porous Bodies. In Convection and Conduction Heat Transfer; Ahsan A., Ed.; InTech Publishing House: Rieka, Croatia, pp. 149–176.

DELIISKI, N., DZURENDA, L. 2010. Modelling of the Thermal Processes in the Technologies for Wood Thermal Treatment. TU Zvolen, Slovakia, 224 p. (in Russian).

DELIISKI, N., DZURENDA, L., TUMBARKOVA, N., ANGELSKI, D. 2015. Computation of Temperature Conductivity of Frozen Wood during its Defrosting. Drvna Industrija, 66(2), 87–96.

DELIISKI, N., TUMBARKOVA, N., 2019. Numerical Solution to Two-Dimensional Freezing and Subsequent Defrosting of Logs. In: A. Iranzo, ed. Heat and Mass Transfer − Advances in Science and Technology Applications. IntechOpen, London, 20 p.

DZURENDA, L., DELIISKI, N. 2010. Thermal Processes in the Woodworking Technologies. TU Zvolen, Slovakia, 268 p. (in Slovak).

DZURENDA L., DELIISKI, N. 2011. Mathematical Model for Calculation Standard Values for Heat Energy Consumption during Plasticization Process of Wooden Prisms by Hot Water in Pits. Acta Facultatis Xilologie, 53(2), 25–36 (in Slovak).

HADJISKI, M., DELIISKI, N., ANGELSKI, D. 2021. Computing the Processing Medium Temperature and Heat Fluxes in the Beginning of Regimes for Autoclave Steaming of Frozen Wood Materials. Proceedings of the International Conference Automatics and Informatics (ICAI), 30th September – 3rd October 2021, Varna, Bulgaria, 6 p.

KOLLMANN, F. F., CÔTÉ, W. A. JR. 1984. Principles of Wood Science and Technology. I. Solid Wood. Springer-Verlag, New York. 592 p.

LAWNICZAK, M. 1995. Hydrothermal and Plasticizing Treatment of Wood. Part I. Boiling and Steaming of Wood, Agricultural Academy, Poznan, Poland, 149 p. (in Polish).

NIEMZ, P., TEISCHINGER A., SANDBERG, D. (Eds.). 2023. Springer Handbook for Wood Science and Technology. Springer Nature Switzerland AG, Cham, 2069 p.

SHUBIN, G. S. 1990. Drying and Thermal Treatment of Wood. Lesnaya Promyshlennost, Moscow, URSS, 337 p. (in Russian).

SOHOR, M., KADLEC, P.1990. Hydrothermal Treatment of Wood for Production of Veneer. Drevo, № 2 (in Slovak).

TREBULA, P., KLEMENT, I. 2002. Drying and Hydrothermal Treatment of Wood. TU Zvolen, Slovakia, 449 p. (in Slovak).

TUMBARKOVA, N. 2019. Modelling of the Freezing and Defrosting Processes of Logs and their Energy Consumption. Thesis (PhD). University of Forestry, Sofia, 198 p. (in Bulgarian).

VIDELOV, H. 2003. Drying and Thermal Treatment of Wood. University of Forestry, Sofia, 335 p. (in Bulgarian).

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CONTENTS