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REGIMES FOR THE PRODUCTION OF CURVED BEECH DETAILS BY HIGH FREQUENCY HEATING

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ABSTRACT

The manufacture of curved wooden details is a technological process with long duration. Repeatedly reducing the time needed for plasticizing and drying the wood may be performed by its high-frequency heating. The basic regime parameters that control the production of curved detail in high frequency electromagnetic field are: the frequency of the electricity (respectively of the field power), the water content in the material, the duration of the process (plasticizing, bending and stabilization), the relationship between the anode and grid current (Ip/Ia). Drawing up a regime for faultless performance of the operation is a difficult task with multiple alternatives. However, there are insufficient data and research upon that issue, especially for a comprehensive regime including consistent implementation of the phases of plastification, bending and drying of wood. In this connection, some regimes of high frequency plasticizing, bending and drying were carried based on beech details. The conducted regimes were assessed by the duration of the production cycle and the final production waste.

Key words: regimes for bending solid wood, beech wood, high-frequency electromagnetic field, the frequency of the electricity

INTRODUCTION

Nowadays several ways for plasticization of beech timber are used in order the details to be curved afterwards. The particular choice of production technology for bending of wooden details depends on their shape as specified preliminary in documents and on the values of *h/R* ration (where *R* is curvature radius, *h* is the size of the cross section parallel to the bending plane). High-frequency heating can be used for plasticizing and drying beech wood in a single sequence high-speed solid wood bending process [5]. In this case the most reasonable is the plasticization and drying of wood to be accomplished at positive temperature gradient through radio-frequency heating.

For ratios h/R bigger than 20, most frequently it is used the same pressure-heating equipment for contiguous accomplishment of bending phases (plasticizing, bending and stabilization of detail's shape).

The theoretical approach to wood heating via electromagnetic field is well documented by Torgovnikov (1993). Water is a quite ideal substance in term of heating, because its absorption and loss of energy is big [1]. As a result, high-intensity heating could be achieved and the production cycle is considerably shortened. As it is well-known, at high-frequency warming of wood inside is generated some heat. It is result of the friction between wooden substance and dipole water molecules, as well as among them at multiple spinning in the alternative high-frequency filed. The inside heat accumulation creates circumstances for unidirectional movement of water and increase of the temperature in the stuff volume from center outside to surface.

This is the major difference and advantage of this method against the traditional ways for heat transfer (contact, convention) towards wood, where a negative temperature gradient exists.

The principal scheme of high-frequency wood heating includes the following processes: creating high-frequency waves in magnetron; creation of high-frequency waves in magnetron; irradiation of wood; absorption of high-frequency waves; internal heating of wood and phase transformation of containing water; water movement towards the materials surface; surface evaporation.

In high-frequency heating of wood its moisture is essential. A good control over the moisture content of the raw material is needed and the equipment for bending must be designed to prevent flash-over in the electromagnetic field and to prevent steam in the wood from rupturing the cell walls [5]. It is very important that the timber details subject to bending to have the same equally distributed humidity. Otherwise, the filed influences with all its power only in the details areas that are with higher humidity, which results in internal timber breaks, so called hydraulic cracks. In this regard, the humidity of the wood should not be higher than 20 %. In case of water absence in the timber, the wood heating from its field is suspended.

To reach a low rejection level in the bending process, the process parameters, i.e. input energy and time for the different processing stages, have to be well controlled since the time-span for optimal bending is very small [5]. The basic parameters that control the production of bent wooden details in high-frequency field are: current frequency, water content in materials, the duration of the processes of plasticizing, bending and stabilization, the ration between grid current (I_g) and anode current (I_a) I_p/I_a.

The following relation exists between the material' heating speed and the specific power (P, W/cm^3) of the high-frequency field [2]:

$$P= (\Delta t/\Delta \tau). (\rho.c/\eta t) \qquad \textbf{(1)}$$

ρ – density of heated wooden material (beech- 0,68 kg/m^3);

c – specific heat capacity of heated timber (0,52 at W – 18% and t v 20°);

ηt – thermal key indicator, accounting the heat losses in the environment (0,5–0,7);

Δt/Δτ – temperature gradient.

The major disadvantage of the high-frequency heating of wood is the necessity of overall humidity and temperature control. Besides, it is not useful for timber specimen with high quantity of cellular barriers (membranes). They prevent the free steam outflow from wood, which results in internal cracks [3]. Analogical is the result of beech bending with false core of high-frequency field [6]. Another limitations and disadvantages are the increased requirements for no defects in specimen, the need for strict compliance with the requirement for applying the same and equally distributed moisture in all processed details, as well as the expensive and hard to maintain equipment.

Drawing a mode for production of curved parts by RF heating is a responsible task with multiple versions. It is relatively difficult to determine the impact of the field frequency factor. Indirectly, it is the bearer of heat in the timber. By increasing the frequency, it is increased also the number of turns at 180° of water molecules per unit of time and thus increases the speed of heating. Specific capacity of the field is proportional to the frequency of the current and field intensity. There is no information about the conduct of complex regimes, including consistent implementation of the phases of plasticizing, bending and drying of wood. The purpose of this work is the preparation of a complex rational mode for faultless production of bent beech details by high frequency heating.

In that relation, some regimes have been conducted aimed at wood bending in high frequency field at variable frequency. The efficiency of the fields is evaluated by the quantity if defected details and the whole duration of the production cycle of bending.

EXPERIMENTAL METHODS

The regimes for bending of beech details in high-frequency field were conducted in production circumstances. Each regime was consisted of 3 main phases: plasticization, bending and drying. The following equipment has been used: one floor press Italpresse (model FHF60) and high quality generator Elettronica Cavallo GAF 40. The generator electrodes have been attached to the working surface of the curvilinear press shapes (matrix and punch) of the press. Via the five-degree switch the power has been regulated (8, 16, 24, 36 and 40 kW) and the field frequency has been roughly controlled (2.8, 5.5, 8.4, 11.2 and 14 MHz).

The fine controlling of the field frequency has been implemented through potentiometers for grid and anode current and respectively the adjustment of the ration between them I_p/I_a. Upon plasticization and bending of timber specimen this ration has been 1:5 i.e. grid current Ip=0.4mA, anode current I_a = 2mA.

The used beech details have been with cross-section (hxb) 52x45mm, and were designed for production of hind chair legs. The radius of curvilinear (R), achieved upon bending, was 1500mm i.e. bending has been conducted are ratio R/h=28,9. The beech details were compliant to the technological requirements of the process of bending, and the water content was 18±1 %.

One cycle for production of curved details included the following processes: the specimens for bending were put in metal strap with end stops. 27 sets of details have been loaded in the press and the high-frequency generator has been switched into work mode. The press board was lifted so thus that the details to attach the punch i.e. the upper electrode. In this position the details stayed for initial plasticization the so called ‘pre-heating’. The duration of this process depends exclusively on the high-frequency field power, the density, the volume and humidity of the wood.

The bending has been conducted for 5 minutes by repeated lifting of the bottom plate of the press until the full contact of the details with punches.

The drying of curved details has been conducted in high-frequency field at the following ratio I_p/I_a =1/4.

After the end of the drying process, the high-frequency filed has been switched off. The details stayed curved in the press for 40 min until the final stabilization of their shape.

RESULTS AND DISCUSSIONS

The data from the conducted regimes for beech timber bending in high-frequency field are presented in table 1. The regimes have been conducted at three levels of field frequency (I, II, and III degree of the generator). Regimes with frequency 11,2/14MHz (IV^{th} и V^{th} degree of the generator) have not been conducted. It has been cleared out in advance that the bending of solid wood at these frequencies is related to numerous hydraulic cracks. The quite intensive process of high-frequency heating is characterized also with wood ignition.

Table 1: Regimes for the production of curved beech details by high frequency heating

Regime / Switch position	Power, kW / Frequency MHz	Ratio I_g/I_a in plasticizing phase, mA	Duration of the plasticizing phase, min	Duration of the bending phase , min	Ratio I_g/I_a in drying phase, mA	Duration of the drying phase, min	Duration of the cooling and stabilization of the shape, min	Quantity of bent details	Technical waste		Notes and reasons for the waste
									pcs	%	
I / 1	8 / 2,8	0,4/2	25	5	0,4/1,5	35	40	27	4	15	Insufficient plasticity of wood
II / 2	16 / 5,6	0,4/2	20	5	0,4/1,5	30	40	27	0	0	No visible defects
III / 2	16 / 5,6	0,4/2	20	5	0,4/2	30	40	27	0	0	No visible defects
IV / 3	24 / 8,4	0,4/2	20	5	0,4/1,5	25	40	27	3	11	cracks in wood, bending wood with moisture under 15%

Analysis of I^{-st} regime

At field frequency of 2,8 MHz, the wood has been slowly heated and respectively plasticized. The slow heating of wood decreases the details humidity, which resulted in worsening of the overall plasticization effect. On the other hand, this brings to details cracking from their concave side. In this case that is the reason to be registered production loss of 15 %.

As result of the prolonged period of plasticization and drying of wood, the regime is characterized with the longest duration (65 min).

Analyses of II^{-nd} and III^{-rd} regime

The curved details at frequency of 5,6 MHz are without visual defects. This means that this frequency is quite suitable for bending of beech wood details. The total duration of the regime is 55 min. Another version of regime II was the conducted regime III. It has been implemented at constant ratio between the grid and anode current (1/5) at all phases of the process. It did not led to change in the overall drying process duration. However, for determining the influence of the ratio I_p/I_a upon the process, it is necessary additional research to be conducted.

Analysis of IV^{-th} regime

At field frequency equal to 8,4 MHz the intensity of the processes of plasticization and drying is the highest among all others. 11 % loss has been registered. Parts of the defects have been a result of the hydraulic cracks. The main reasons for their origin are: the high intensity of the process and unequal distribution of the humidity in wood material. Another part of the cracks are breaks from the concave side of the curves. Here again, as an analogy to the I^{-st} regime, the reason for their occurrence is the low water content in wood (below 15 %), but n this case it is a result of the intense steam vaporization during the plasticization phase. The total regime duration is 50 min and it is the shortest one in the research.

Opportunities for improving the regimes for high-frequency bending of beech

According to Kollmann [2], the temperature gradient at high-frequency filed varies in-between 5÷20 °C/min, depending on the type of wood. Based on data from Turner N., and A.R.Dean [3], the lead time for achieving 100°C is 3-6 min.

Therefore, it is possible the plasticization to be conducted for a shorter period of time. In order to achieve that, it is necessary to provide full contact of the wood detail with both electrodes during the process of plasticization. In this case, the contact zone between the specimen details and the matrix electrodes was relatively small. That leads to decrease of the efficiency coefficient during the plasticization process.

CONCLUSION

Based on the research, the following major conclusions could be made:

- At high-frequency heating of wood the water content in the details is crucial for their faultless bending. Water content in wood under 15 % is not sufficient for its plasticization and leads to breaks in the details from their concave side of the curves;
- Upon unequal distribution of water in wood there is a big chance for hydraulic cracks. In this case it is recommended to work at low frequency of the high-frequency filed (4÷6 MHz);
- Additional research should be conducted for determining the influence of the I_p/I_a ratio over the processes of plasticization and drying of solid wood in high-frequency field;
- Filed frequencies higher that 8,4 MHz are not suitable for solid wood bending. These regimes are characterized with hydraulic cracks and ignition of the details. These occurrences are noticed also at lower field frequencies, but proved to be rarer;
- By increase of the contact zone between the wood and the electrodes it is possible to shorten the durability of the plasticization process;
- For production of curved beech details without any defects it is most efficient to use field frequency at 5,6 MHz.

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