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EFFECTS OF THE INITIAL MOISTURE CONTENT VARIATION OF BEECH (*FAGUS SYLVATICA* L.) VENEER ON ITS WAVINESS AND THE MOISTURE CONTENT DISTRIBUTION AFTER DRYING

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ABSTRACT

The investigations aim to determine the relationship between beech (*Fagus sylvatica* L.) veneer properties before drying (the initial moisture content and its distribution in the plane of a sheet), drying intensity and selected quality factors (waviness and the final moisture content distribution). The obtained results show that the relationship exists between the magnitude of veneer waviness after drying and variation of veneer initial moisture content in the plane of a sheet.

KEY WORDS: beech veneer, waviness, moisture content, drying intensity

INTRODUCTION

The usefulness of veneer for plywood production depends on original and secondary diversification of properties of the raw material, curse of the heating process of logs and the peeling process (Perkitny and Stefaniak 1970). However, the final quality of veneer is developed during drying. The main aim of veneer drying from relatively high and diversified initial moisture content is to obtain the low and uniform final moisture content with preserving the requirements of flatness of veneer. The need of the application of high drying temperatures as well as short drying times causes the extreme high intensity of the drying process (Kollmann et al. 1975).

One of the basic properties of veneer before drying is its uniform moisture content within a sheet as well as similar moisture content level of a veneer batch, which guarantees the same drying intensity. However, the level and diversification of the initial moisture content of a batch of rotary-peeled veneer depends on position of a log in a tree stem (logs from but end, center and top of a tree stem etc.) as well as on the position of the peeling zone in the cross section (Fig. 1).

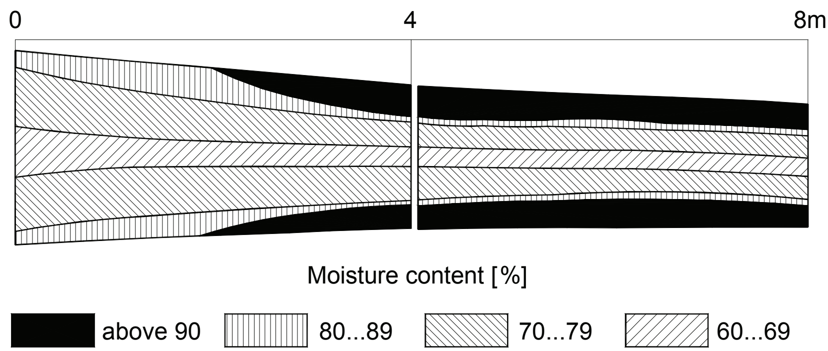

Fig. 1: Distribution of moisture content in a beech stem cut into two sections after pelling in March (Mayer-Wegelin 1932 cited in Kollmann et al. 1975)

In the case of veneer convective drying with constant air parameters, i.e. temperature, absolute humidity and air velocity, the diversification of the initial moisture content within a veneer sheet leads to the diversification of drying intensity defined as the moisture content decrease in time. In regions of a veneer sheet with high initial moisture content the flux of evaporated water is higher as compared to regions of low moisture content. It may result in differences of shrinkage rate in the plane of a veneer sheet. The restriction of desorption shrinkage in faster drying regions of a veneer sheet causes development of tensile stress. The stress development is accompanied with desorption checks, which develop faster due to the fact that during rotary-peeling of veneer the tangential direction is dominating in the plane of a veneer sheet (the highest desorption shrinkage) as well as the tendency of checks propagation in the plane of wood rays.

The usefulness of veneer for plywood production depends also on its failures such as diversification of the final moisture content and deviation from flatness (waviness). The only effective method for the reduction of deformations (in the shape of waviness) is veneer plasticization by heating to temperature corresponding to the drying temperature Kollmann *et al.* 1975). During pressing of batches of wavy veneer it has to be take into account that sheets may be straighten out with possible risk of veneer cracking. Moreover, pressing of wavy veneer is also related to the risk of adhesive flowing off and therefore, formation of adhesive layer of diversified thickness. When the adhesive joint of higher thickness is curing the joint shrinks intensively causing additional stress development in a plywood sheet. For that reasons determination of the relationship between the mean initial moisture content, its distribution and the curse of the drying process, i.e. drying intensity as well as the magnitude of veneer waviness after drying has practical significance.

MATERIAL AND METHODS

Beech veneer was selected in this study due to its high structural homogeneity in the normal wood zone as well as high desorption shrinkage (Galewski and Korzeniowski 1958). There is a well-founded speculation that the high desorption shrinkage may be one of causes of beech veneer susceptibility to waviness formation during drying. It has to be emphasized that beech wood is the most common raw material for plywood production.

The investigations were performed in the industrial conditions. Five fresh fallen beech stems of the initial moisture content higher than the Fiber Saturation Point (FSP) were used. Five but end logs were cut from stems after their heating. Length of each log was 2500 mm. Next, the logs were rotary peeled and the 1.5 mm thick veneer strip was obtained. The strip was clipped into sheets of the following dimensions – length of 2450 mm in the longitudinal direction (L) and width of 1400 mm in the tangential direction (T). Because of the diversification of physical and morphological properties of beech wood in the radial direction, i.e. moisture content, density, shrinkage, false heartwood, veneer sheets from different zones of the cross section of the logs were subjected to the investigations. From each log six veneer sheets were selected, i.e. two sheets from the near surface zone (sheets coded as 1a and 1b), two sheets from the middle zone (sheets coded as 2a and 2b) and two sheets from the zone near to peeler cores (sheets coded as 3a and 3b). The sheets coded the letter "a" were used for measurements of waviness and moisture content after drying. The twin sheets coded as "b" were used for measurements of the initial moisture content. The total number of sheets was 30.

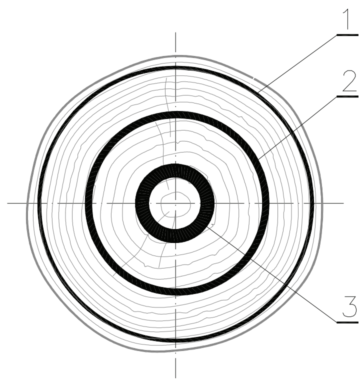

Fig. 2: Log cross-section with the localization of sampling zones of veneer sheets used in the investigations; 1 - near surface zone, 2 - center zone, 3 – inner zone (near to peeler cores)

The research program consisted of the following measurements:

Type "a" sheets

- veneer waviness immediately after peeling,
- veneer moisture content immediately after drying (designated as the final moisture content),
- veneer waviness immediately after drying.

Type "b" sheets

- veneer moisture content immediately after peeling (designated as the initial moisture content),

The deviation from flatness of a veneer sheet was assumed as the measure of waviness. In order to determine the measure, 36 measuring points were set in positions presented in Fig. 3 for each type "a" veneer sheet.

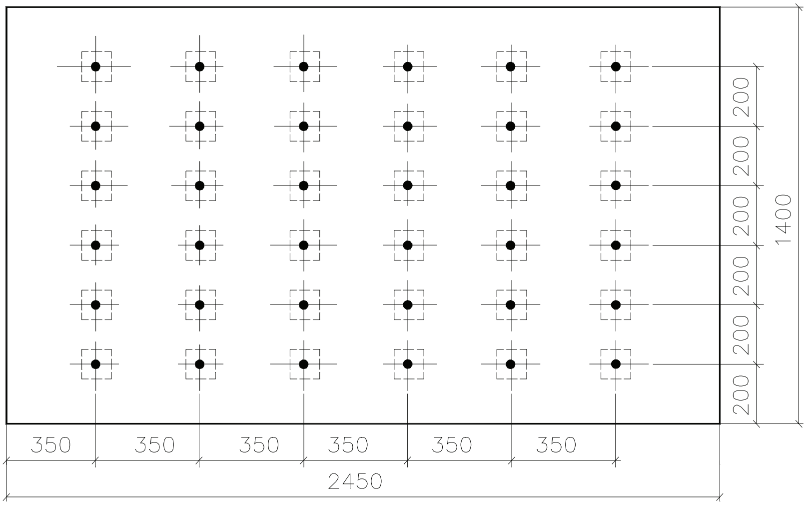

Fig. 3: Veneer sheet with measuring positions of waviness measurements (dots) and sampling for the initial moisture content determination in twin sheets (dashed boxes)

As the veneer waviness may be the result of wrongly performed heating and/or peeling the measurements of waviness were also made before drying, i.e. immediately after peeling. It let to isolate the waviness component related to drying only. As the result of the assumed procedure the waviness, i.e. deviation from flatness (*W*) was defined by the following relationship:

$$W = W_{i(x,y)} - W_{f(x,y)}, \quad (1)$$

where:
$W_{i(x,y)}$ – deviation from flatness measured before drying (mm)
$W_{f(x,y)}$ – deviation from flatness measured immediately after drying (mm)

The measurements of the deviation from flatness were made on the specially prepared table of the dimensions of 2700 · 1700 mm and equipped with a unit letting to move the measurement sensor (slide caliper with analog-to-digital converter VIS E24, measuring accuracy 0.01 mm).

As it was supposed that the waviness of veneer sheets may be related to the drying intensity the drying rate was determined as the ratio of the mean moisture content decrease of veneer to time of veneer staying in a dryer:

$$\frac{MC_i - MC_f}{\tau}, \quad (2)$$

where:
MC_i – mean initial moisture content of veneer (%)
MC_f – mean final moisture content of veneer immediately after drying (%)
τ – drying time (min)

The moisture content measurements before drying (i.e. moisture content above the FSP) were made with the use of the oven dry method. From each twin sheet of veneer (type "b" sheet) there were collected 36 samples of the square shape and the side dimension of 100 mm (Fig. 3). The center of each sample coincided with the location of waviness measurements (deviation from flatness) at surface of the type "a" veneer sheets.

The measurements of moisture content after drying were made for the sheets earlier used for the waviness determination (type "a" sheets of veneer). The final moisture content was determined with the use of a capacitance meter CSA Delta-2000 (measuring accuracy of 0.1%). The locations of measuring points of the final moisture content were the same as for the waviness determination.

The statistical analysis of the measurements as well as plots of the initial and final moisture content as well waviness of veneer were made for the mean values determined for veneer sheets obtained from 5 logs. Tab. 1 presents results of the initial moisture content measurements (moisture content immediately after veneer peeling). The obtained results show distinct differences between moisture content values for veneer sheets coming from different zones of the cross section of logs.

Tab. 1: Initial moisture content of beech veneer peeled from different zones of the cross section of logs (1 - near surface zone, 2 - center zone, 3 – zone near to peeler core)

Zone of veneer peeling	MC_{max}	MC_{mean}	MC_{min}	SD	CV	RD
	%				%	
1	81.5	70.9	59.6	4.33	6.1	3.09
2	72.3	66.6	61.7	2.89	4.3	1.59
3	65.8	62.3	56.2	2.13	3.4	1.54

SD – standard deviation
CV – coefficient of variation – $100(SD/MC_{mean})$, %
RD – relative dispersion of moisture content – $(MC_{max} – MC_{min})/MC_{mean}$

The highest values of the initial moisture content were observed for the veneer sheets obtained from the near surface zone. Moreover, it may be stated from the comparison of the obtained values of the relative variation of moisture content (Tab. 1) that the veneer peeled from the near surface zone has the highest variation of moisture content within a veneer sheet. In the case of the analyzed veneer the observed variation was two times higher as compared to veneer sheets peeled from other zones of logs. The observed higher variation of the initial moisture content is probably caused by uneven moistening of the near surface zone during logs heating (Ławniczak 1995). Moreover, it has to be noticed that the absolute difference in the moisture content of beech veneer peeled from the opposite zones in the cross section of logs was over 25% (Tab. 1). In the context of the assumption that veneer drying was made in a roller dryer at constant drying parameters, i.e. temperature and drying time, the high diversification of the initial moisture content of veneer may be the significant reason for the distinct diversification of drying intensity of veneer sheets peeled from different zones of the cross section of the same log.

Tab. 2 presents the results of the final moisture content measurements. The obtained values show the similar values for all three types of veneer sheets. The difference between the highest and lowest final moisture content was not higher than 0.7%. Also the obtained values of the statistical parameters indicate good quality of drying.

Tab. 2: Final (immediately after drying) moisture content of beech veneer peeled from different zones of the cross section of logs (1 - near surface zone, 2 - center zone, 3 – zone near to peeler core)

Zone of veneer peeling	MC_{max}	MC_{mean}	MC_{min}	SD	CV	RD
	%				%	
1	1.8	1.5	1.2	0.14	9.1	3.93
2	1.9	1.7	1.4	0.11	6.5	2.97
3	1.9	1.7	1.4	0.14	8.3	3.02

Tab. 3: Mean drying intensities of beech veneer sheets peeled from different zones of logs (1 – near surface zone, 2 – center zone, 3 – zone near to peeler core)

Zone of veneer peeling	Drying intensity
	%/min
1	19.3
2	18.0
3	16.8

In order to illustrate surface waviness of different types of veneer contour plots were used. The comparison of the plots presenting waviness of individual types of veneer sheets (Fig. 6) to the results presented in Tab. 3 lets to notice that the highest waviness was found for sheets from the near surface zone, i.e. for the sheets characterized by the highest drying intensity. It may be concluded that high deformations, i.e. waviness of veneer sheets peeled from the near surface zone are caused by high desorption stress and accompanying strain partially having the permanent nature. It is supposed that the degree of fixing the strain increases with the drying rate. Moreover, the analysis of the results clearly shows that the significant reason for the increase of veneer waviness is non-uniform moisture content before drying, which intensifies differences in drying intensity within a veneer sheet.

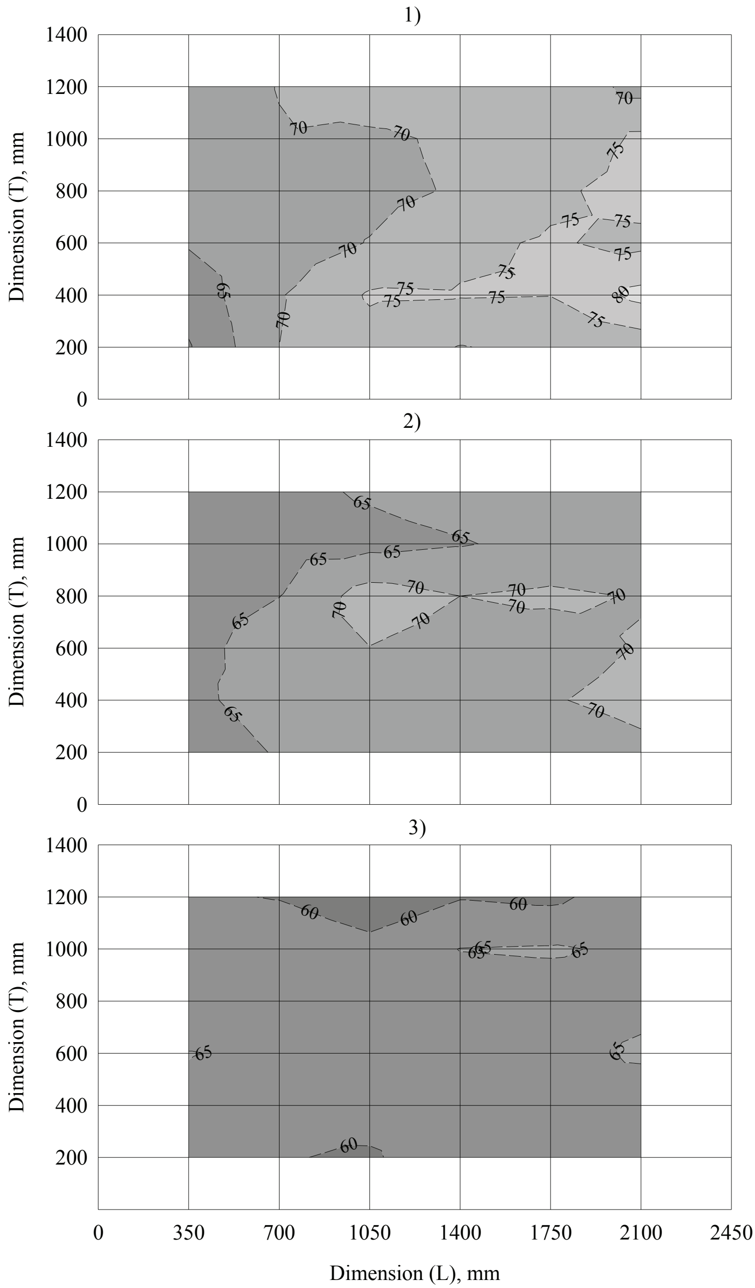

Fig. 4: Initial moisture content (MCi; %) distribution of beech veneer peeled from different zones of the cross section of logs (1 - near surface zone, 2 - center zone, 3 – zone near to peeler core)

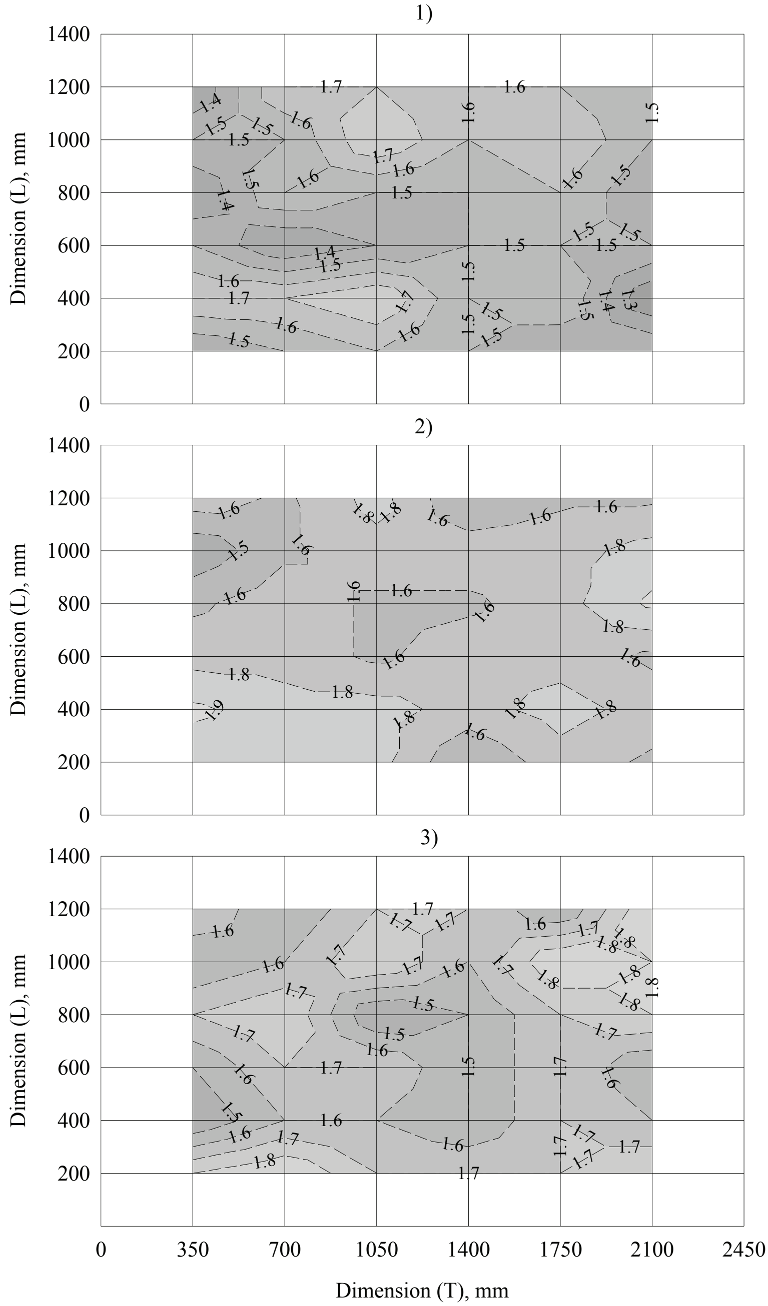

Fig. 5: Final (immediately after drying) moisture content (MCf; %) distribution of beech veneer peeled from different zones of the cross section of logs (1 – near surface zone, 2 – center zone, 3 – zone near to peeler core)

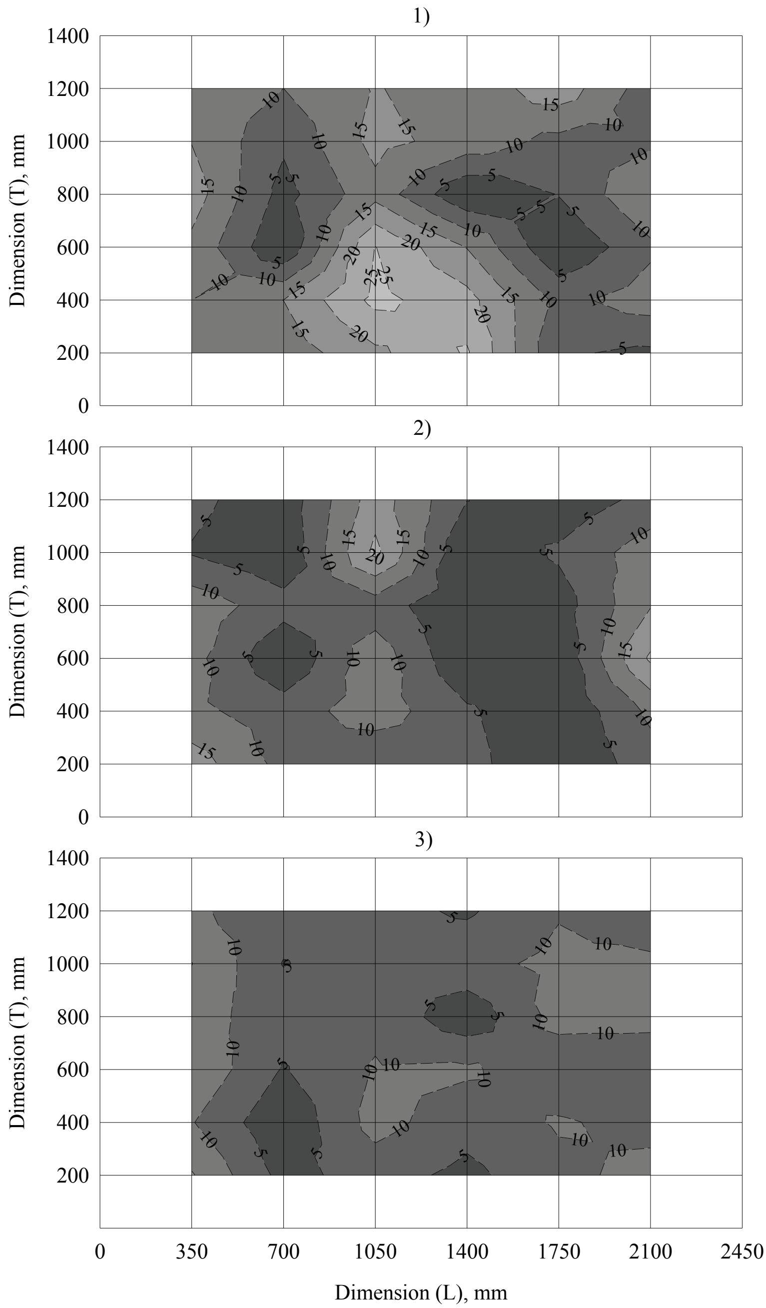

Fig. 6: Waviness (W; mm) of beech veneer sheets peeled from different zones of logs (1 - near surface zone, 2 - center zone, 3 – zone near to peeler core)

The bitmaps were generated from the contour plots presented in Figure 6. The image processing analysis was used to obtain histograms of veneer waviness from the generated bitmaps (Russ 2002).

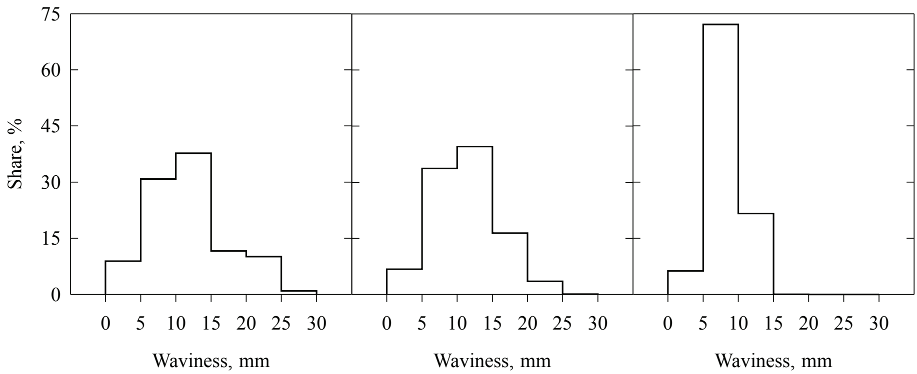

Fig. 7: Histograms of veneer waviness for different zones of veneer peeling (1 - near surface zone, 2 - center zone, 3 – zone near to peeler core)

The comparison of the obtained histograms of veneer waviness (*Fig. 7*) let to state that drying of beech veneer of the lowest diversification of the initial moisture content (sheets peeled from the zone near to the peeler core) is related to the increase of homogeneity of deformations within a sheet. The dominating content of ca. 70% of small deformations of the size of 5-10 mm was found in sheets peeled from the zone near to the peeler core. The high content of the component was due to the reduction of the content of the highest deformations (15-30 mm). It has to be emphasized that drying of sheets with the smallest waviness was characterized with the smallest rates. The obtained values of deformations (waviness) of the sheets from the near surface zone let to suppose that the uncontrolled increase of the drying rate due to the high moisture content of the zone and the high moisture content diversification within a sheet is the main reason for the waviness increase.

CONCLUSIONS

1. The initial moisture content of sheets of beech veneer significantly depends on the position in the cross section of peeled logs. However, veneer obtained from the near surface zone is characterized by the highest moisture content.
2. The beech veneer peeled from the near surface zone showed the highest diversification of moisture content within a sheet. It was found that the moisture content diversification was two times higher as compared to veneer peeled from other zones of the cross section of a log. The observed increase of the diversification was caused by uneven moistening of the near surface zone during heating.
3. The obtained results show that the increase of beech veneer waviness is caused by the increase of the drying rate, which probably influences fixation of strain caused by desorption stress in dried veneer.
4. The relation was observed between the general decrease of surface waviness and values of coefficients characterizing uniformity of the initial moisture content of beech veneer.

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