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ANALYSIS OF THE SHAPE STABILITY OF WATER-RESISTANT PLYWOODS

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Abstract

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The paper analyses causes of disorders of the shape stability of water-resistant plywoods produced by an important producer in the CR. Deformations of plywoods are caused by many reasons, such as wood structure (the course of wood fibres), plywood construction (the construction balance as for size and material regularity), the moisture of processed veneers and boards, glue spread, actual pressing process, the storage and climatization of finished plywoods. Basic technological parameters affecting the shape stability of plywoods were analysed, such as parameters of the hydrothermic preparation of raw material, parameters of veneer drying and the moisture of peeled veneers after drying as well as pressing parameters. At the conclusion, recommendations to improve the shape stability of plywood sheets are presented.

veneer, plywood, plywood construction, moisture, thickness, longitudinal and cross deformation, shape stability

Generally, deformations of plywoods occur as the result of disturbances in the symmetrical arrangement of sheets. Deformations mean the abnormal curvature of a plywood sheet. The potential disturbance of the symmetrical construction of plywoods can occur virtually already in all technological operations where a basic construction element is produced or processed, ie peeled (rotary-cut) veneer. The symmetry can be disturbed by the various thicknesses of veneer, plywood construction, different moisture of veneers, sheet moisture, uneven glue spread, uneven pressing etc. There are several causes and it is possible to carry out gradual testing the decisive technological operations (SOINÉ, 1995).

Deformations mean very serious damage to a plywood sheet and according to the degree of damage they can result in its total inapplicableness. Deformations are measured by a deviation in mm from an absolute level being expressed in absolute values or in percents per one m diagonal or plywood edge.

Water-resistant plywoods are produced for building industry. Their dimensions are 1200 x 1200 mm and thickness 15 mm, surface treatment is carried out by a phenolic foil. Water-resistant plywoods are produced with a beech or birch face veneer. A large number of water-resistant plywoods are produced of coniferous species. For the production of water-resistant plywoods of coniferous species, spruce veneers 1.8, 2.4 and 2.6 mm thick are used. Abroad, veneers of higher thickness are used, particularly 3.2, 4.2 and 4.8 mm. The technological process of production is identical with the production of joiner's plywoods up to glue spread. For gluing water-resistant all-beech plywoods particularly phenol-formaldehyde adhesives are used. Various types of foamers and extenders are added to gluing mixtures.

The gluing mixture is applied on cylindrical glue spreaders in quantities 145 g/m^2. Cold prepressing is carried out using 1 N/mm^2 pressure for a period of 10 minutes. The respective pressing is carried out at a temperature of 140 to 145 °C and the period of pressing is derived similarly as in other plywoods, ie 3 min. + 1 min. per every mm plywood thickness up to the last glue line to the central axis. The pressing schedule is dependent on the plywood thickness (MAHÚT, RÉH; 1996).

The hydrothermical treatment of wood is a physico-mechanical process when the plasticity of wood is increased at preserving its integrity under the simultaneous change of main components of wood. The hydrotheric treatment has to be carried out for a sufficiently long period and at a scheduled temperature. Similarly as insufficiently carried out hydrothermic treatment also the excessively sharp way and regime of hydrotheric treatment are harmful. Due to excessively high temperatures and the excessively long period of hydrothermic treatment partial release of wood structure occurs, which becomes evident by the removal of early and late wood boundary-lines and also by fissures beside and along wood rays.

At the production of veneers, the highest importance is shown by a condition when wood is most plastic and particular components of wood are least degraded. When physical factors (temperature and moisture) predominate at the hydrothermic treatment (plastification) such a condition can be achieved just at the moment of completing the hydrothermic treatment. Plasticity can be expressed by total plastic deformation, which can be achieved without the permanent disturbance of wood structure. It becomes evident by the decrease of some quality indicators (KRÁL, 2006).

In the technical literature, the view of suitability or unsuitability of the plasification environment is not unambiguous. The choice of vapour or water, according to some authors, follows, eg, the initial moisture of wood, economic aspects etc. According to Kubinsky, water guarantees balanced heating, easy checking the heating and accurate control of the regime.

The strength homogenization, ie balancing the compression strength in tangential and radial direction can be achieved:

- at hard-wooded broadleaved species at a temperature of about 90 °C,
- at coniferous species at a temperature of about 70 °C,
- at soft-wooded broadleaved species at a temperature of about 45 °C.

Veneers have to be peeled at a preset temperature when the hydrothermic preparation of the raw material will be achieved. This temperature ranges in the certain interval of an optimum temperature. For the production of quality veneers keeping the optimum wood temperature during slicing is an important condition (Tab. I.).

In order to keep given temperatures in the course of the log processing it is necessary to remove only so many logs from a steaming pit what is necessary for their processing during 1.5 to 2 hours. In winter, the period shortens by half. Excessive logs should be returned back to the steaming or tempered pit and heated at given temperatures.

After completing the hydrothermic treatment by means of the environment temperature control, equalizing the logs is carried out from a temperature of 70–90 °C to 20– 25 °C. At this stage, the plasticizing medium affects wood at the closed supply of a heating medium. At equalizing, temperature differences inside a log are balanced.

The period of equalizing is determined, similarly as at steaming, according to the tree species, log diameter and the optimum temperature interval. It ranges from 12 to 16 hours.

Veneer drying is carried out with the aim to decrease the moisture of wet veneers (30 to 150%) to final moisture 8 to 10%, for the manufacture of water-resistant plywoods to 4 to 6%. The reason of decreasing the plywood moisture is an endeavour to prevent the origin of fungi or subsequent twisting.

The final moisture of veneers after drying determines the quality of gluing and the quality of plywood. The final moisture is dependent on the type of plywood and used adhesives. Following limiting values of the final moisture of peeled veneers are recommended:

- peeled veneers for water-resistant plywoods when using phenol-formaldehyde adhesives (birch, beech, spruce) – 4 to 6 %,
- peeled veneers for non-wood-resistant plywoods when using urea-formaldehyde adhesives (birch, older, beech) – 8 to 10 %
- peeled veneers for laminated wood – 3 to 6 %

Due to overdried veneers:

- The wettability of wood decreases by reason of the increased diffusion of a solvent into wood. The transfer of an adhesive to the second surface is made difficult.
- The deformability of wood is decreased and the contact of an adhesive with veneer is worsened.
- The moisture of surface layers of veneers increases through the moisture absorption from the adhesive. It results in the increase of inner stress in the glued joint and thus in the whole plywood sheet.
- The lower plywood moisture causes its deformations.

By reason of the excessively high initial moisture of veneers:

- The viscosity of an adhesive decreases and hardening the adhesive is slowed. The adhesive infiltrates

I: *Optimum wood temperatures at slicing*

Species	Wood density (kg/m³)	According to Möhrat (°C)	According to ŠDVÚ (°C)
Pine	490–520	42–70	60–80
Spruce	430	30–60	60–80

into wood and thus, the poor joint of low strength is created.

- Excessive moisture results in the temperature destruction of an adhesive.
- Additional drying wets finished plywood causing the origin of inner stress in plywood.

Drying peeled coniferous veneers takes place mainly in belt dryers at the environment temperature 180–200 °C. The speed of feed for particular thicknesses of spruce veneers should be:

- 2 mm 16–18 m/min
- 1.8 mm 20–22 m/min
- 3 mm 10–12 m/min

Veneers have to be stored in such a way protection against unfavourable weather conditions to be ensured and the relative air humidity and temperature to ensure the determined moisture of veneers.

Through pressing the contact of glued surfaces is achieved, their fixation until hardening the adhesive and creation the thin layer of adhesives in the joint. Basic parameters of pressing are as follows:

- the time of feeding into a press
- pressing time
- pressing temperature
- working pressure.

These basic physical data are interconnected and their size is given by properties of veneers and adhesives.

The time of feeding to a press is a time, which takes from feeding the first package till inducing the working pressure. If this time is not kept, particularly its extension over a period necessary for hardening the adhesive, it causes premature condensation of the adhesive layer situated near the hot pressing plate. Then, bad fixation of a face veneer occurs. Pressing time is the period of time when the plywood material is closed in a press under the effect of pressure and temperature. During the pressing time, physico–chemical conversions have to take place the required quality of gluing to be achieved. The pressing time is dependent on the tree species, number of layers and the thickness of a glued package, the temperature of pressing plates, the size of working pressure and the size of the gluing mixture layer.

Achieving the necessary technological temperature in the glue line is dependent on the temperature of pressing plates, the type of material, the number of layers and the thickness of a glued package. For the fast warming of veneers and glued joints the highest temperature of pressing plates is used. However, excessive temperatures can result in unfavourable effects. The working pressure is derived from a specific pressure and the plywood area. It is measured by a manometer (KRÁL, HRÁZSKÝ; 2006).

MATERIAL AND METHODS

Within this analysis, all measurements were carried out at an important producer of veneers and water-resistant plywoods in the CR.

The hydrothermic treatment of wood is carried out in pits by direct steaming when water vapour is blown through a warming pipe into the steaming pit. To control the hydrothermic treatment regime a manual way is used. The environment temperature is taken by a sensor placed on the side wall of a steaming pit. Regimes of the raw material hydrothermic preparation are prepared for the winter and summer season. According to available data, following regimes are used for coniferous species in the studied plant:

- spruce – summer season 12 to 18 hours, winter season 24 to 30 hours
- pine – summer season 16 to 24 hours, winter season 30 to 36 hours

According to technological regulations the steaming of logs should be carried out at a temperature of 90 to 95°C. The period of emptying the pit takes about 3.5 hours. A night hours, steam is not supplied to the heating system of steaming pits.

Within the analysis, following steps were gradually carried out:

- temperature measurement of the plasticization environment
- determination of the moisture of logs intended for peeled veneers before plasticizing
- moisture measurement of veneers after peeling
- thickness measurement of produced veneers
- moisture measurement of veneers after drying in a kiln and on a veneer yard.

RESULTS AND DISCUSSION

Within the analysis, check reading the temperature of the steaming pit thermometer was carried out. An actual temperature 50 and 60 °C was found out.

The moisture of logs for rotary-cut veneers was also determined. The sample was taken from the stem half after barking in a cross-cutting station. Moisture was determined by a weight method from the sapwood and heartwood part of a stem. Mean values of the measurement in 3 samplings ranged from 32.27 to 37.15% in the heartwood part and from 114.54 to 140.99% in the sapwood part.

In connection with lower temperatures of the plasticizing medium compared to technological instructions it was found that the temperature of a rotary-cut veneer beside a peeler was low (lower than the human body temperature). Therefore, check measurements of the log temperature were carried out on a residual cylinder before peeling and after peeling. Following temperatures were determined:

- the log surface temperature 24–26 °C
- temperatures on the residual cylinder surface after peeling 28–29 °C

- temperatures on the butt end 24–26 °C

Therefore, temperature measurements were also carried out by a laboratory thermometer (used for the temperature measurement of pressing plates of a laboratory press). The length of a bored hole for the thermometer was about half of the diameter of a residual cylinder and the cylinder temperature

- (cylinder length = 2.5 m) ranged from 50–51 to 55 °C
- (cylinder length = 1.3 m) ranged from 50–56 to 60 °C

Substantially different temperatures from 25 to 30 °C were determined.

In addition, check measurements were carried out of the veneer moisture behind the peeler. The moisture of veneers ranged within the limits 30–31–34%.

The moisture of veneers after steaming (plasticizing) at peeling was determined both from the heartwood and sapwood parts. In veneers produced from the heartwood part, the moisture ranged from 25.85 to 30.89%, in veneers produced from the sapwood part from 113.64 to 148.54%.

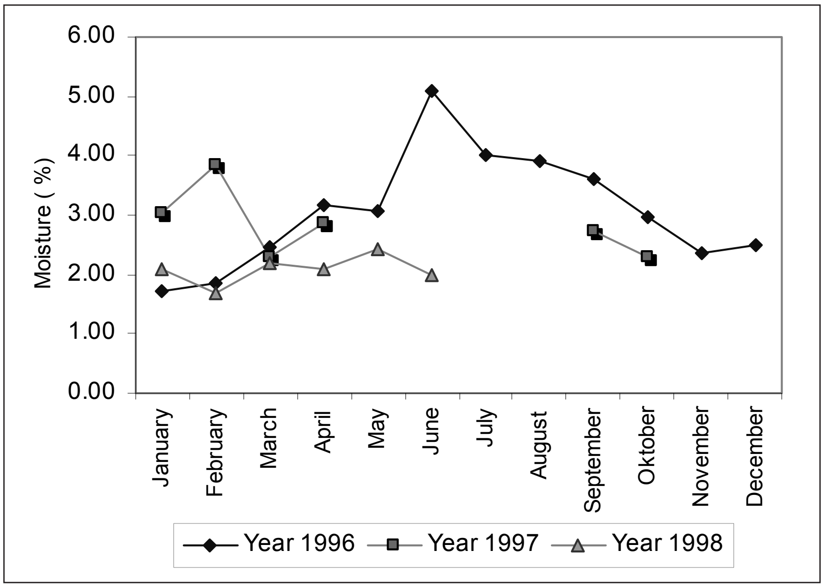
Check measurements were also carried out of the veneer thickness behind the peeler. The veneer thickness (spruce 2 mm) ranged behind the peeler within the limits 1.95–2.20–2.45 mm.

Finally, check measurements of the veneer moisture were carried out. Behind a drier (Raute), the veneer moisture (spruce 2 mm) ranged within the limits 0.55–1.0–1.4%, in the yard of dry veneers moisture ranged from 1.80 to 5.7%. The veneer moisture ranged markedly below the usual value 5–7%.

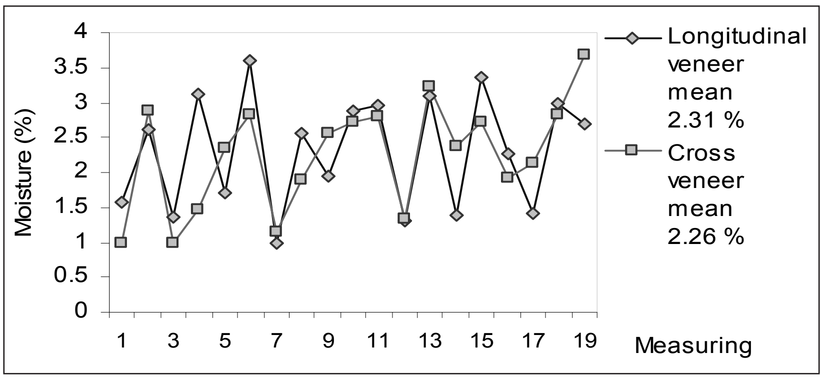
Therefore, we requested records of an operational laboratory on the moisture of dried veneers in the past, namely in 1996–1998. These data are given in Fig. 1.

The moisture of longitudinal and cross veneers behind the drier Raute in the period 10/2007 is given in Fig. 2.

Values of moisture given in Figs. 1 and 2 show that the moisture of rotary-cut veneers behind the drier Raute ranged in 1996–1998 and also in the course of the analysis in 2007 (but some exceptions)) from 0.97 to 3.5%. Thus, it is possible to conclude that



1: *The moisture of veneers behind the drier Raute (1996–1998)*



2: *The moisture of veneers after drying in the Raute driver (10/2007)* the moisture of veneers ranges deep below the usual value 5–7%.

Within the analysis, check measurements were carried out of the veneer moisture before a glue spreader. Before the gluer, the moisture of veneers (spruce 2 mm) ranged within the limits 1.40–1.80%. In Figs. 3 and 4, the moisture of veneers is displayed. It was measured before Pagnoni presses, hornbeam (HBR) 6 and hornbeam (HBR) 8 in months 10–11/2007.

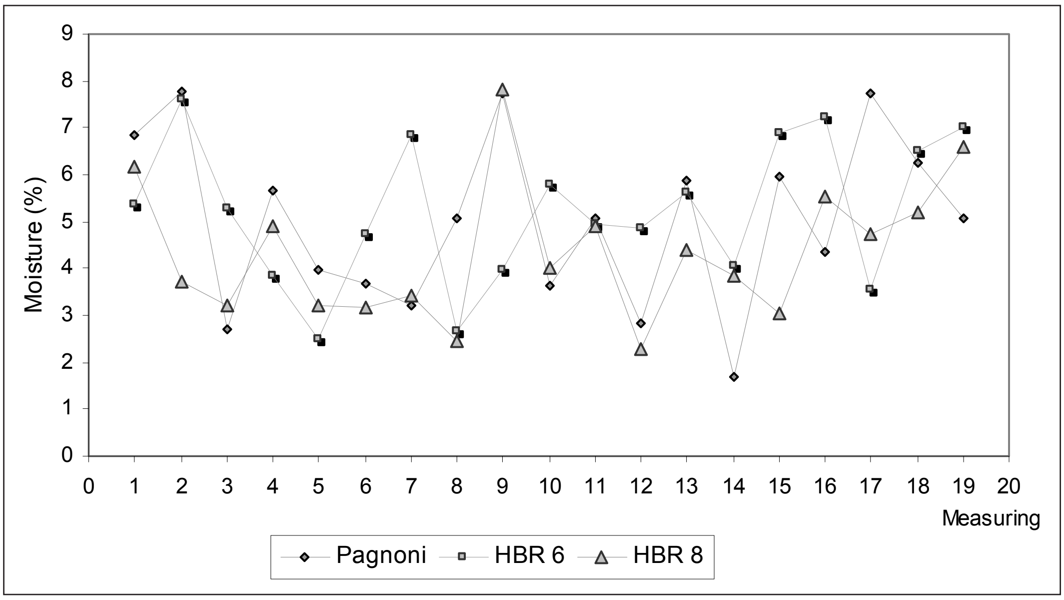
Values of moisture given in Figs. 3 and 4 showed that the moisture of peeled veneers before presses ranged within the limits 1.02 to 8.46% during the period 10/2007 to 11/2007. The moisture fluctuated within a considerable interval (differences reached even 7.44%). Fluctuation of the mean moisture of veneers ranged within the limits 1.68 to 7.82% in October 2007.

Mean values of the moisture of veneers before presses are given in Tab. II.

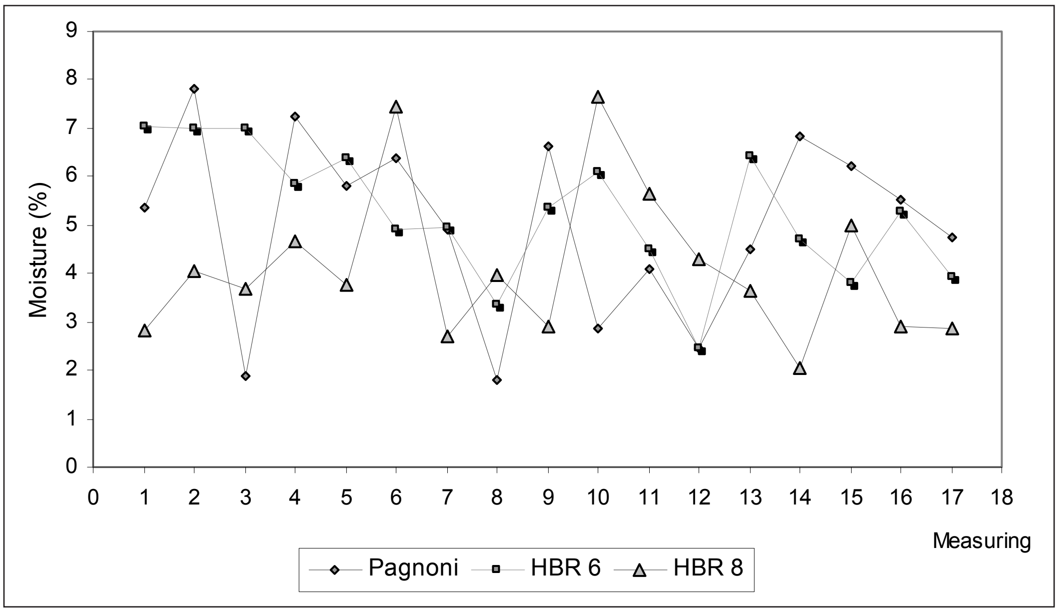
II: *Mean values of the moisture of veneers before Pagnoni presses*

Month	Veneer moisture %		
	Pagnoni	HBR 6	HBR 8
09/2007	4.98	5.05	5.65
10/2007	5.00	5.22	4.35
11/2007	5.00	5.23	4.12

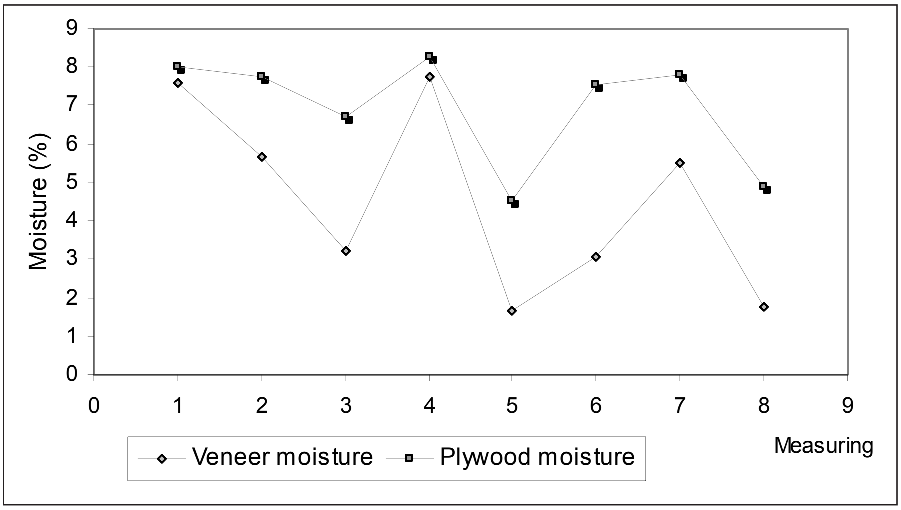
Note: HBR = hornbeam



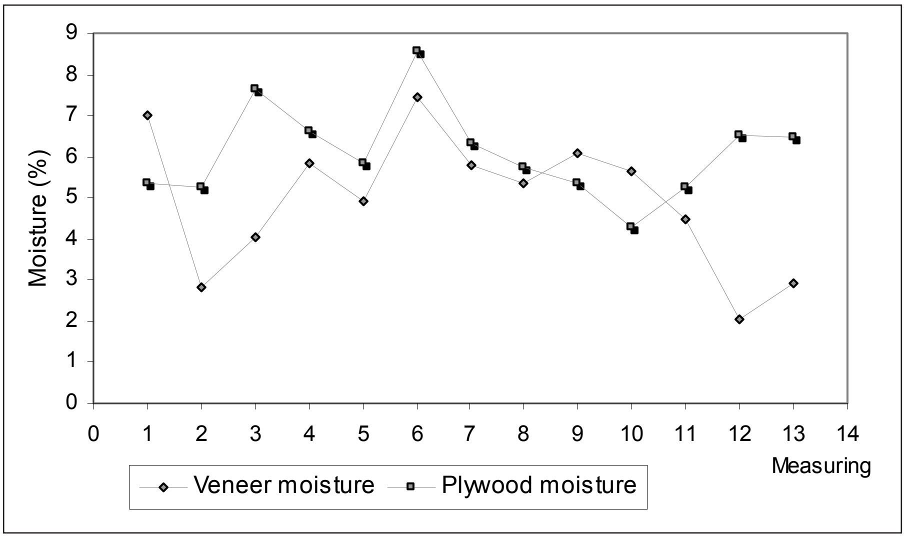
3: *The moisture of veneers at presses in10/2007*



4: *The moisture of veneers at presses in 11/2007*



5: *The moisture of veneers and plywoods in 10/2007*



6: *The moisture of veneers and plywoods in 11/2007*

Figs. 5 and 6 display the moisture of veneers measured before Pagnoni presses, viz. HBR (hornbeam) 6 and HBR (hornbeam) 8 and the moisture of pressed plywoods in months 10–11/2007.

Values of moisture given in Figs. 5 and 6 show that the moisture of peeled veneers before the presses ranges from 1.68 to 7.74% and the moisture of plywood from 4.04 to 8.57%. Comparison of the moisture of veneers and plywoods within the tested months shows that the mean moisture of veneers and plywoods ranges within the following limits (min. – max.):

	Veneer moisture	Plywood moisture
• 10/2007	1.68–7.74%	4.54–8.25%
• 11/2007	2.04–7.46%	4.26–8.57%

Mean values of the moisture of veneers before the presses and the moisture of plywoods are given in Tab. III.

Sorted and marked plywoods are stored in stacks 1.8 to 2 m high. The storage has be carried out in such a way the plywoods not to change their moisture and free access to the stacks to be ensured. Plywoods have to be stored in horizontal position, mustn't be stood on their edge or bear. At quality plywoods, the stack has to be covered and weighted.

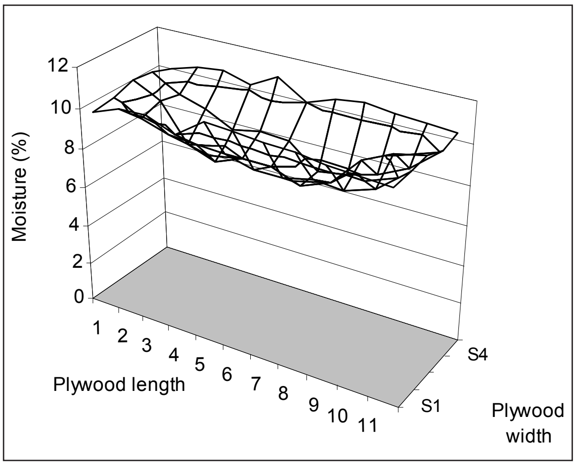
The store mustn't be moist and its size should provide to store at least one-month production, mostly, however, three-month production. Check measurements were carried out of the veneer moisture after pressing and in the store of finished products.

III: *Mean values of the moisture of veneers before Pagnoni presses and of the pressed plywoods*

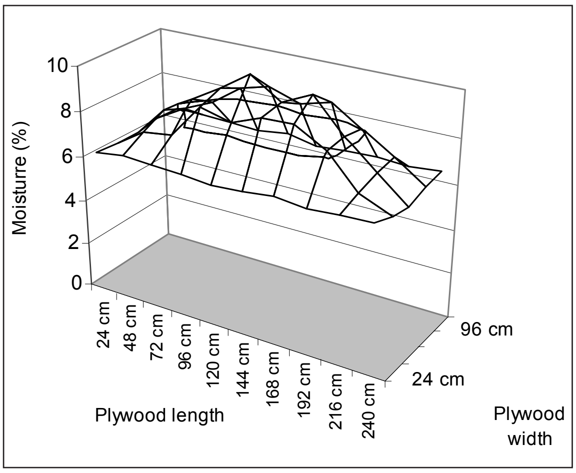
Month	**Moisture (%)**	
	Veneers before the Pagnoni press	**Plywoods**
09/2007	4.80	6.25
10/2007	4.54	6.93
11/2007	4.96	6.09

- After pressing, the moisture of plywoods ranged (spruce 8 mm) within the limits 6.00–10.0 %.
- In the store, the moisture of plywoods (spruce 9.5 mm) ranged within the limits 7.50–11.0 %.

Figs. 7 and 8 display the moisture of plywood measured behind the presses and in the store of finished products.

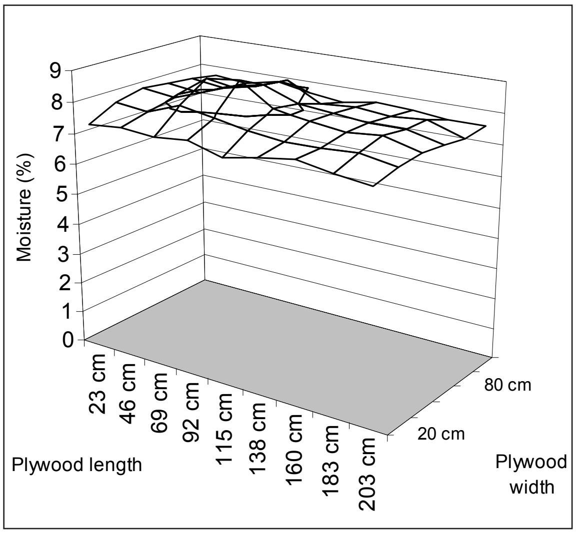


7: *Distribution of moisture in pressed plywood 9.5 mm thick*



8: *Distribution of moisture in pressed plywood 8 mm thick*

Figs. 7 and 8 show that although the mean moisture ranges within the limits 7.5 to 11%, its distribution is, however, markedly uneven. After pressing, moisture in the centre of the plywood surface is 9.2–10% and, on the other hand, along the plywood edge, 6.0–7.6%. The moisture of plywood in the store of finished products shows diametrically different distribution. In the centre of plywood, moisture ranged from 7.5 to 8% and at edges from 10 to 11%. It means the moisture change within the plywood area even by 5%, namely always diametrically: in the centre from 10 to 7.5% and at the plywood edges from 6 to 11%. Plywood, which did not show warping, was characterized by the most even distribution of moisture within the plywood area (Fig. 9).



9: *Distribution of moisture in pressed plywood after a 10-day storage (a board free of warping)*

CONCLUSION

Deformation of plywood is caused by many reasons, such as the structure of wood (the course of fibres), the plywood construction (the construction balance as for size and material regularity), the moisture of processed veneers and plywoods, glue spread, the actual pressing cycle, storage and air-conditioning the finished plywoods. Some technological parameters were tested with following results:

Spruce logs show markedly differentiated moisture zones of the initial moisture. From the aspect of the plywood log processing the proportion of the surface moister zone amounts to 30% and that of the central heartwood zone with lower moisture 70%. The central zone moisture did not exceed 40% in any measurement. The distribution of moisture zones is similar in fresh/green logs and in logs protected by spraying. By the long-term storage of logs on a dry log dump the moisture of both zones is gradually balanced. At checking the parameters of steaming it was found that temperatures ranged within the limits 50–60 °C and the log surface temperature and the cylinder surface temperature between 24 and 29 °C.

Through the temperature measurement by a laboratory thermometer (used to measure the temperature of pressing plates by a laboratory press) the cylinder temperature ranged from 50 to 60 °C. Substantially different temperatures were obtained with a difference 25 to 30 °C.

Check measurements of the veneer moisture was carried out behind a peeling machine with a result 30–34%. The moisture of logs for rotary-cut veneers before steaming determined by a weight method reached 32.27–34.15% in the zone of mature wood and 114.54–130.34% in the sapwood part. Likewise, differences were also determined in the log central and sapwood parts reaching almost 100% (mature wood: 25.85–30.89%, sapwood: 113.64–148.54%).

The veneer thickness (spruce 2 mm) behind a peeler ranged within the limits 1.95–2.45 mm at check measurements. Behind the Raute drying room, the moisture of veneers (spruce 2 mm) ranged from 0.55 to 1.4% and in the yard of dry veneers from 1.80 to 5.7%.

According to long-term measurements (1996–2000), the moisture of rotary-cut veneers behind Raute drying rooms ranged (but some exceptions) within the limits 0.97 to 3.5%. Air conditioning does not take place there at all or most for one exceptionally two days, which is a rather short time to balance the veneer sheet moisture but also the moisture of the whole stack of veneers. At drying spruce veneers from the whole log to the required final maximum moisture 5–7%, as many as about 45% veneer are unproportionally highly overdried. Before spreading the gluing mixture, the moisture of veneers ranged within the limits 1.40–1.80%. On the basis of measurements carried out in September – November, the moisture of rotary-cut veneers before presses ranged from 1.02 to 8.46% and the moisture of plywood from 4.04 to 8.57%.

The mean moisture of plywoods ranges from 7.5 to 11% the distribution within the plywood area being uneven. Plywood, which was not warped, showed most evenly the distributed moisture within an area out of all analysed plywoods (Fig. 9).

To improve the shape stability of produced plywoods we propose to realize following measures:

- It is not suitable to use logs stored under different storage conditions (in one batch of logs given for processing /one steaming pit, one shift batch etc./).
- Because of the short-term character of experimental operations all factors affecting processes of drying and distribution of moisture in peeled veneers could not be comprehensively involved and evaluated. It would be desirable to specify these effects. These factors include: felling locality, felling time, log diameter, time and method of storage, thermal processing etc.
- To reevaluate regimes of steaming and to test keeping a temperature in relation to the determined regime.
- With reference to different results we recommend to carry out measurements of the log and cylinder temperature by a digital thermometer, which is intended for the measurement of temperatures from –50 °C to 150 °C. Resolution 0.1 °C.
- To carry out checking the cutting geometry on peeling machines in relation to the uniformity of the peeled veneer thickness.
- To carry out determination of the final moisture of veneers both on the surface and in the centre of the veneer stack aiming at the veneer moisture from the central and sapwood parts (distribution of moisture). It is necessary to test the method of moisture determination and moisture distribution.
- Through the division of a veneer according to moisture even before drying (if it is enabled by the line organization) it is possible to double the capacity of veneer drying at the central drier part.
- At the air-conditioning of veneers on the basis of monitoring the veneer moisture to determine the veneer moisture dependence on the time of veneer air conditioning and on equilibrium moisture.
- At the preparation of packages for pressing to determine the moisture of veneers both on the surface and in the centre of a stack. To monitor the use of whole sizes of veneers for particular layers of plywood. To determine if it is possible to use separately veneers from the zone of mature wood and sapwood. At the operation of glue spread to test the method of determining the size of a layer with an aim to achieve a constant layer. To check the composition of an adhesive mixture.
- At pressing, to reevaluate pressing parameters. To carry out the measurement of plywood thickness and plywood moisture. To change the method of plywood stacking.
- To assess a possibility to use prepressed plywoods because through placing this operation it is also possible to eliminate the lack of the irregular distribution of moisture within the plywood area.
- To carry out air conditioning the finished plywood in the tempered environment on 4 piling sticks by a prescribed method.
- At air-conditioning the finished plywoods on the basis of monitoring the plywood moisture to determine the dependence of plywood moisture on the time of air conditioning and equilibrium moisture.

SOUHRN

Analýza tvarové stálosti vodovzdorných překližek

Předmětem článku je analýza příčin poruch tvarové stabilty vodovzdorných překližek vyráběných významným výrobcem v ČR. Deformace překližovaných desek mají mnoho příčin, může to být například struktura dřeva (průběh vláken), konstrukce desky (vyváženost konstrukce vzhledem k rozměrové i materiálové pravidelnosti), vlhkost zpracovávaných dýh i desek, nános lepidla, vlastní lisovací cyklus, skladování a klimatizace hotových desek. Byly analyzovány zásadní technologické parametry ovlivňující tvarovou stabilitu překližek, jako například parametry hydrotermické přípravy suroviny, parametry sušení dýh, vlhkost loupaných dýh po sušení, lisovací parametry. V závěru článku jsou prezentována doporučení ke zlepšení tvarové stálosti překližovaných desek.

dýha, překližka, konstrukce překližky, vlhkost, tloušťka, podélné a příčné zborcení, tvarová stabilita

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REFERENCES

KRÁL, P., 2006: Assessing the effects of the thickness of beech veneers on compressibility of plywoods. Drvna industria 57 (1): 26–32 pp. ISSN 0012-6772.

KRÁL, P., HRÁZSKÝ, J., 2006: Effects of different pressing conditions on properties of spruce plywoods, Journal of Forest Science 52 (6): 285–292 pp. ISSN 1212-4834.

MAHÚT, J., RÉH, R., 1996: Technológia spracovania dreva II. Metódy zisťovania fyzikálnych, mechanických a technologických vlastností dýh a preglejovaných materiálov. Zvolen. TU: 86.

SOINÉ, H., 1995: Holzwerkstoffe. Herstellung und Verarbeitung. 1. vyd. Stuttgart: DRW Verlag. 368 pp. ISBN 3-87181-340-0.

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