3D-Moldability of Veneers Plasticized with Water and Ammonia

Jozef Fekiač,[a] Ján Zemiar,[a] Milan Gaff,[a,b,*] Jozef Gáborík,[a] Miroslav Gašparík, [b] and Róbert Marušák [c]

The 3D-moldability of veneers, as opposed to the moldability of plastic or other materials, is limited because of the characteristics of wood. Veneers can be modified by physical, chemical, or mechanical treatment. We chose water and ammonia-water solutions. After treatment for an established time, the moldability of veneers was examined. The level of concave deflection of a test piece of punch-molded veneer was assessed. Three sets of test pieces were tested by dipping in cold water (20 °C), hot water (95 °C), or a 25% solution of ammonia, for different durations of time. The results showed that the 3D-moldability of veneers increased by 66 to 119% after plasticization by a 25% solution of ammonia, unlike the unmodified veneers with a moisture content of 7.65%. The increase in moldability was significantly higher in comparison to the veneers modified by dipping in cold water (20 °C) and hot water (95 °C). Futhermore, the relationship between the moisture content of the veneers after their modification/plasticization, the level of concave deflection, and the molding force in relation to the level of concave deflection were examined.

Keywords: 3D-molding; Wood; Veneer; Concave deflection; Plasticization

Contact information: a: Department of Furniture and Wood Products, Technical University in Zvolen, T. G. Masaryka 24, Zvolen, 96053, Slovakia; b: Department of Wood Processing, Czech University of Life Sciences in Prague, Kamýcká 1176, Praha 6 - Suchdol, 16521, Czech Republic; c: Department of Forest Management, Czech University of Life Sciences in Prague, Kamýcká 1176, Praha 6 - Suchdol, 16521, Czech Republic;
** Corresponding author: gaffmilan@gmail.com*

INTRODUCTION

Veneers belong to a group of materials that are used both for decoration and for construction. They are a component used for creating planar, bended (2D-molded), or 3D-molded products. The application of 3D-molding is limited significantly because of the characteristics of wood, primarily its small tensile deformations, small ratio of plastic deformations, and anisotropic characteristics (Požgaj *et al*. 1997; Buchelt *et al*. 2009). It is possible to adjust or modify the aforementioned characteristics to some extent, and therefore increase the moldability of the wood.

The interest in three-dimensional wood molding (veneer) is long-term. As early as 1949, Vorreiter (1949) mentions some options for increasing the moldability of veneer by means of creating multi-layered material, producing veneer from comprimed wood, or modifying veneers by chemical plasticization. Previously, the issue of moldability and modification of veneers was mentioned in several works, including Wagenführ and Buchelt (2005), Wagenführ *et al*. (2006), Huber and Reinhard (2007), Buchelt and Wagenführ (2008), Yamashita *et al*. (2009), and Schulz *et al*. (2012).

Plasticization is a traditional type of wood-modification carried out mainly for the purpose of bending (2D-molding). There are several known methods of plasticization, *i.e.*, hydrothermic, electromagnetic, and chemical (Zemiar *et al*. 1999). While hydrothermic and electromagnetic are used in practice for the given purpose, chemical methods are mainly applied in the compression (press molding) of wood, carried out to compensate for the deficiency of hard wood species or for the purpose of surface relieving (Lábsky 1974).

Water is a traditional agent used in hydrothermic wood modification. Among the chemical agents used in plasticization, the various modifications of ammonia are important, such as the liquified and gaseous forms, or in solution with water (as ammonia-water) (Bariska 1969; Oniško and Mateják 1971; Solár and Melcer 1980). The modification of wood by liquified or gaseous ammonia is technically difficult and requires special equipment. A simpler means is the treatment of wood with a water solution of ammonia; however, this is accompanied by an unwanted increase in the moisture content of the wood. As far as practical application is concerned, the increased amount of water is not ideal because the veneer molding process is usually followed by glueing. If the level of veneer moisture content is higher than the level of moisture content suitable for glueing, then it is only possible to use molding for the purposes of pre-molding. The process of glueing can only be realised after an adjustment of humidity.

The aim of this research was to test the effect of plasticization by water and a water solution of ammonia on the 3D-moldability of beech veneers, based on a method developed by the authors (Zemiar and Fekiač 2014).

EXPERIMENTAL

Materials

Radially-cut veneers sheets, with annual rings 1.5 mm wide, were sliced from trees harvested in Poľana region, near Zvolen, Slovakia. The veneers were subjected to rigorous selection. The test pieces were cut from veneer sheets and checked to ensure they did not have any faults in the wood, such a cracks, fiber curling and knots, respectively. In preliminary tests the authors verified the effect of veneers variability, and found an influence up to 3%. All test pieces were conditioned on same moisture content 25%. The 3D-moldability of circular pieces with 60-mm diameters, made of radial beech veneers (*Fagus sylvatica* L.), which averaged a thickness of 0.51 mm, were studied. Then, an auxiliary circle was drawn on the right side of the test piece using a template (Fig. 1), which served to center the test piece in an appliance used for 3D-moldability detection.

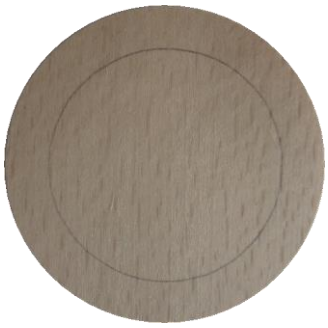

Fig. 1. Test piece with the drawn auxiliary circle

Methods

Currently, unlike with sheet metals, there is no standardized method for testing 3D-moldability of wood veneers. Because veneers lack bendability compared to metallic materials, Erichsen's method (Veles 1989) was modified and used to evaluate the moldability of metal sheets, for the present purposes by doubling the size of the dimensions of the matrix and punch and by applying a peripheral thrust system. The reason for increasing the size of the dimensions was that veneers have significantly lower moldability than do metal sheets. A system of peripheral thrust was developed for the purpose of preventing the formation of waves on the periphery of the circular test piece, which was held up by the peripheral force *F´* (Fig. 2) during molding. The 3D-moldability was evaluated based on the extent of maximal concave deflection (*h*) of the veneer pressed by a punch until breaking.

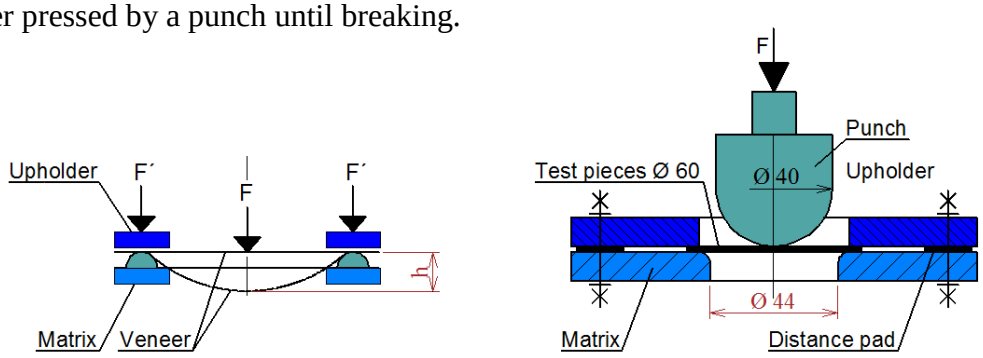

Fig. 2. Schematics of the (a) process and (b) molding arrangement. F, molding force; F´, upholding force (Zemiar and Fekiač 2014)

The molding thrust acting upon the test piece by a hemispheric punch was generated by the testing machine LabTest 4.050 (LaborTech, Czech Republic) at an advancing speed of 10 mm/min. The peripheral thrust force was technically limited by distance pads of the same thickness as the test piece, which were inserted between the matrix and retaining upholder (Fig. 2b). The test piece was inserted between the matrix and upholder in a manner such that the molding force would act on the right side of test piece, and the auxiliary circle was concentric with the opening in the upholder.

The plasticization with water was performed by dipping the veneers in water at a temperature of 20 °C or 95 °C for durations of 1, 2, 5, 15, 30, or 60 min. Plasticization was carried out in a desiccator with a 25% water solution of ammonia for 5, 15, 30, and 60 min, and 24 and 48 h. During the insertion and removal of the test pieces, the dessicator was placed in an evaporator because of the presence of toxic vapors. The effect of plasticization within two different time intervals (1 min through 60 min, or 5 min through 48 h) was determined. The different time intervals were based on the different impact of plasticization media (water *vs.* water solution of ammonia) on moldability and on achieving the highest values of concave deflection within the selected time interval, which characterized 3D-moldability. The concave deflection values were measured for all types of plasticizations/modifications on a set of ten test pieces.

In addition to testing the extent of concave deflection, the veneer moisture content as well as the molding force were determined both before and after plasticization. For the purpose of comparing the changes caused by plasticization of the veneer with water and water solution of ammonia, tests were also performed on untreated veneers. The data were used as reference values for a plasticization effect comparison.

Measured values obtained using the described methods were processed with the program STATISTICA 10 (StatSoft Inc.; Tulsa, OK) and evaluated by the Duncan test, multifactor spread analysis in the form of graphs.

RESULTS AND DISCUSSION

Table 1 shows that in comparison to control test pieces, *i.e.*, the pieces made of beech veneers with a moisture content of 7.65%, all the applied variants and modifications were statistically significant. Based on the statistical evaluation included in Table 1, statistically significant values are those with a confidence level greater than 0.05.

The most basic indicator of 3D-moldability, concave deflection, is shown in Fig. 3. The graph shows the relationship between concave deflection and test piece plasticization type and time. The graph also shows that with each type of plasticization, the concave deflection is altered depending on plasticization duration. The optimal duration, corresponding to the maximal concave deflection, was 1 min with cold water (20 °C), 15 min with hot water (90 °C), and 24 h with water solution of ammonia. The corresponding concave deflection values were 5.02, 4.34, and 5.73 mm. These results suggest that with cold water, the maximal concave deflection was achieved in the shortest selected time. With other modifications, hot water and a water solution of ammonia, this time was prolonged significantly ($p<0.05$). Futhermore, the data show that the greatest concave deflection was achieved by plasticization with the water solution of ammonia and the smallest with hot water, which is considered a surprising discovery.

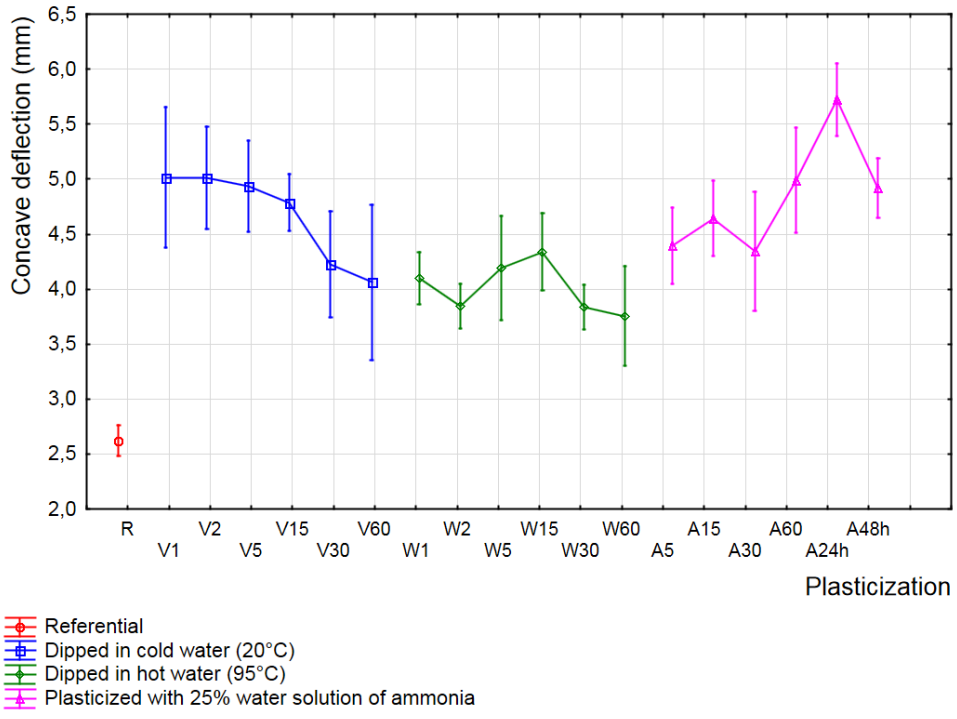

Fig. 3. Concave deflection extent in relation to the type and duration of plasticization; modifications of test pieces. Data provided as the mean ± standard deviation
R, control pieces; V1 through V60, dipped in cold water (20 °C) for 1, 2, 5, 15, 30, and 60 min; W1 through W60, dipped in hot water (95 °C) for 1, 2, 5, 15, 30, and 60 min; A5 through A48h, plastified with 25% water solution of ammonia for 5, 15, 30, and 60 min, and 24 and 48 h

Table 1. Comparison of the Effects of Distinct Modifications of Test Pieces to Match the Concave Deflection using Duncan Test

Type and duration of modification	R	V1	V2	V5	V15	V30	V60	W1	W2	W5	W15	W30	W60	A5	A15	A30	A60	A24h	A48h
R		0.000010	0.000011	0.000011	0.000011	0.000017	0.000031	0.000025	0.000049	0.000021	0.000017	0.000055	0.000114	0.000017	0.000011	0.000018	0.000010	0.000009	0.000011
V1	0.000010		0.985508	0.742456	0.350153	0.001514	0.000138	0.000230	0.000013	0.000912	0.006571	0.000012	0.000011	0.011778	0.134323	0.006574	0.913564	0.001301	0.688914
V2	0.000011	0.985508		0.745023	0.349231	0.001496	0.000138	0.000230	0.000013	0.000907	0.006473	0.000012	0.000011	0.011417	0.132827	0.006418	0.921540	0.001628	0.692658
V5	0.000011	0.742456	0.745023		0.501478	0.003647	0.000395	0.000630	0.000019	0.002316	0.013972	0.000018	0.000012	0.022454	0.210926	0.013561	0.802828	0.000825	0.926538
V15	0.000011	0.350153	0.349231	0.501478		0.020766	0.003269	0.004848	0.000132	0.014470	0.061408	0.000121	0.000039	0.084511	0.505271	0.058307	0.383391	0.000108	0.531271
V30	0.000017	0.001514	0.001496	0.003647	0.020766		0.480920	0.562433	0.108628	0.856342	0.600485	0.106141	0.053956	0.475629	0.081788	0.608618	0.001878	0.000011	0.004342
V60	0.000031	0.000138	0.000138	0.000395	0.003269	0.480920		0.869456	0.304075	0.573018	0.250216	0.313464	0.188830	0.178629	0.018242	0.250508	0.000184	0.000011	0.000498
W1	0.000025	0.000230	0.000230	0.000630	0.004848	0.562433	0.869456		0.263085	0.661035	0.302793	0.263043	0.153285	0.222376	0.025212	0.305332	0.000299	0.000011	0.000783
W2	0.000049	0.000013	0.000013	0.000019	0.000132	0.108628	0.304075	0.263085		0.139382	0.040818	0.963287	0.692010	0.025481	0.001073	0.041540	0.000014	0.000010	0.000028
W5	0.000021	0.000912	0.000907	0.002316	0.014470	0.856342	0.573018	0.661035	0.139382		0.509792	0.138162	0.073160	0.392976	0.061331	0.512420	0.001156	0.000011	0.002810
W15	0.000017	0.006571	0.006473	0.013972	0.061408	0.600485	0.250216	0.302793	0.040818	0.509792		0.039588	0.017636	0.801349	0.193132	0.980995	0.007868	0.000017	0.016123
W30	0.000055	0.000012	0.000012	0.000018	0.000121	0.106141	0.313464	0.263043	0.963287	0.138162	0.039588		0.705598	0.024215	0.001004	0.039823	0.000013	0.000011	0.000021
W60	0.000114	0.000011	0.000011	0.000012	0.000039	0.053956	0.188830	0.153285	0.692010	0.073160	0.017636	0.705598		0.010090	0.000315	0.017687	0.000011	0.000010	0.000013
A5	0.000017	0.011778	0.011417	0.022454	0.084511	0.475629	0.178629	0.222376	0.025481	0.392976	0.801349	0.024215	0.010090		0.243310	0.805994	0.013420	0.000017	0.024637
A15	0.000011	0.134323	0.132827	0.210926	0.505271	0.081788	0.018242	0.025212	0.001073	0.061331	0.193132	0.001004	0.000315	0.243310		0.184221	0.149095	0.000024	0.225634
A30	0.000018	0.006574	0.006418	0.013561	0.058307	0.608618	0.250508	0.305332	0.041540	0.512420	0.980995	0.039823	0.017687	0.805994	0.184221		0.007717	0.000018	0.015354
A60	0.000010	0.913564	0.92154	0.802828	0.383391	0.001878	0.000184	0.000299	0.000014	0.001156	0.007868	0.000013	0.000011	0.013420	0.149095	0.007717		0.001508	0.749479
A24h	0.000009	0.001301	0.001628	0.000825	0.000108	0.000011	0.000011	0.000011	0.000010	0.000011	0.000017	0.000011	0.000010	0.000017	0.000024	0.000018	0.001508		0.000704
A48h	0.000011	0.688914	0.692658	0.926538	0.531271	0.004342	0.000498	0.000783	0.000028	0.002810	0.016123	0.000021	0.000013	0.024637	0.225634	0.015354	0.749479	0.000704	

Red font indicates statistically significant data.
Legend: R, control pieces; V1 through V60, dipped in cold water (20 °C) for 1, 2, 5, 15, 30, and 60 min; W1 through W60, dipped in hot water (95 °C) for 1, 2, 5, 15, 30, and 60 min; A5 through A48h, plasticized with 25% water solution of ammonia for 5, 15, 30, and 60 min, and 24 and 48 h

Test pieces plastified with 25% water solution of ammonia showed the highest value of concave deflection among tested modifications for the plasticization duration of 24 h. Compared to the control pieces, 3D-moldability increased by up to 119% with this modification. By increasing the duration of plasticization to 48 h, the concave deflection decreased and corresponded to the plasticization duration of 60 min. By increasing the duration of plasticization, the molding force decreased, which did not have a positive effect on concave deflection. The reason for this is over-plasticization of the test pieces, thus excessively disrupting the bonds between of the individual components of wood, *i.e.*, cellulose, hemicellulose, and lignin. Bond disrupting due to plasticization with a water solution of ammonia was a cause of changes in the physical-mechanical characteristics of wood, as also mentioned by Solár and Melcer (1980).

The extent of concave deflection after plasticization with water solution of ammonia for 60 min and 48 h was similiar to the amount of concave deflection observed after dipping test pieces in cold water (20 °C) for 5 min. Hence, plasticization with a water solution of ammonia for 60 min and 48 h was found to be disadvantageous when compared to dipping in water for 5 min, including a long duration, difficult process, high final moisture content, harmfulness to the environment, and economic aspect. As a result of a long exposure of water solution of ammonia, there are undesirable changes in the properties of wood and the excessive weakening of the wood as a whole.

During soaking in water, the 3D-moldability also increased compared to the control samples. This increase in water was 55 to 89%, and in hot water 43 to 66%.

The graph in Fig. 3 also shows that after the plasticization/modifications of veneers by dipping in cold water, the concave deflection decreased with increasing duration. Similarly, during the modification by hot water (95 °C), there was a decrease in concave deflection with an increase in duration in some but not in all cases.

Plasticization with selected methods, *i.e.*, water and water solution of ammonia, caused two changes in the wood relevant to molding: (1) the moisture content of the wood increased, and (2) the mechanical characteristics varied. Both types of changes strongly affected the process of molding. From the perspective of molding, it is desirable that the wood does not contain loose water and the amount of molding force decreases in the plasticization process.

Based on the requirements of the wood characteristics regarding molding, our testing was broadened by determining the wood moisture content after plasticization and by determining the amount of molding force.

While testing the impact of moisture content, it was assumed that the concave deflection of the test pieces also depended on their moisture content. The veneer moisture content was determined by the weight method on the control test pieces and on the pieces plastificated with water and with water solution of ammonia. The moisture content values are shown in Fig. 4. In this graph, one can clearly see that moisture content increased with the plasticization media exposure time; the moisture content increased more with modification in water of 95 °C, as opposed to other types of plasticization. From this it can be concluded that an increased temperature of the plasticization media during plasticization of the test pieces had a big influence on change in humidity, *i.e.*, it significantly increased water absorption. This is also confirmed by the graph in Fig. 4, which shows that dipping in hot water for 1 min resulted in a moisture content consistent with dipping in cold water for 60 min.

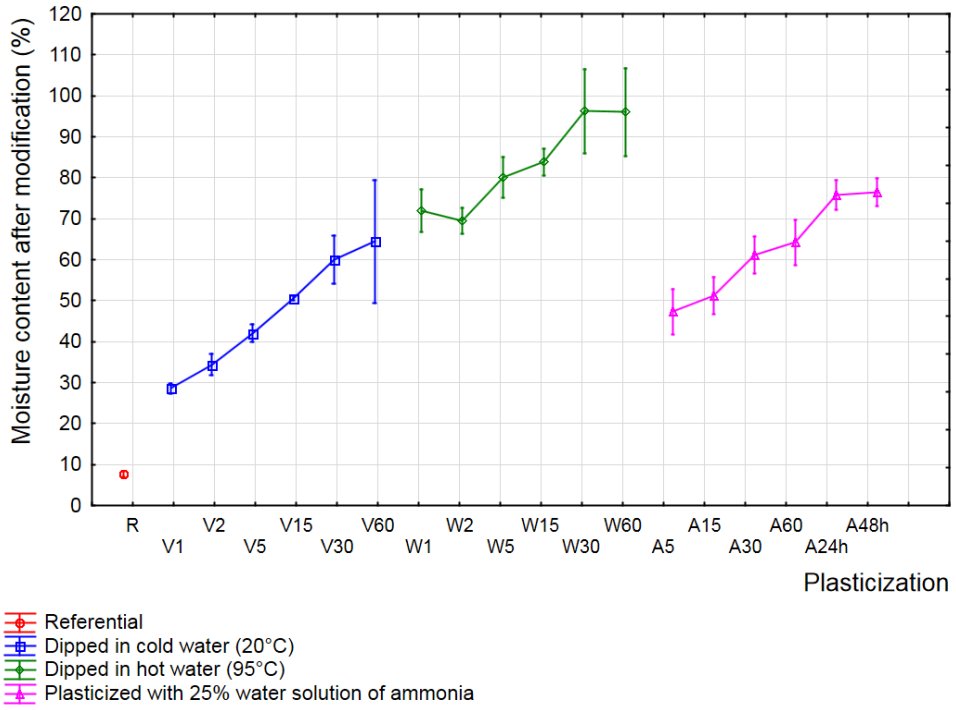

Fig. 4. Moisture content of test pieces in relation to the type and duration of plasticization-modification. Data are provided as the mean ± standard deviation.
R, control pieces; V1 through V60, dipped in cold water (20 °C) for 1, 2, 5, 15, 30, and 60 min; W1 through W60, dipped in hot water (95 °C) for 1, 2, 5, 15, 30, and 60 min; A5 through A48h, plastified with 25% water solution of ammonia for 5, 15, 30, and 60 min, and 24 and 48 h

Likewise, during the plasticization with ammonia, the test pieces were found to have higher moisture content the longer they had undergone plasticization. By comparing the moisture content values at the same durations of plasticization/ modification in cold water and ammonia, no differences were found in the moisture content of the test pieces. Because both processes occurred in cold water, based on their comparison it can be stated that during the modification of 5 min up to 60 min, the water solution of ammonia changed the moisture content in a similiar manner to cold water.

During the plasticization with ammonia, the amount of ammonia-water in test pieces increased with increasing duration of plasticization. At the compared durations of plasticization, a statistically significant increase in the amount of ammonia-water in the test pieces occurred after 30 min and after 24 h, compared to plasticization that lasted 5 min. Furthermore, the diagram shows no extensive increase in the amount of ammonia-water in the test pieces during the 48 h plasticization, compared to the 24 h plasticization. These data suggest that after 24 h plasticization, the test pieces are maximally saturated with the ammonia-water solution, thus making any further increase in duration meaningless as far as the plasticization media absorption is concerned.

If the concave deflection (Fig. 3) and the veneer water content (Fig. 4) are compared, the mechanical characteristics above this point did not change even though in all cases the wood was saturated by water above the anticipated point of saturation of fibers (above 30%). In the case of 3D-molding of thin materials, Požgaj *et al*. (1997) showed that the water content affects the moldability of veneers above this point, too. The moldability decreased with increased moisture content, which was demonstrated during the plasticization/modification with cold and hot water. This can be explained by

the incompressibility of water, which in its intense extrusion disrupts veneer structure. This fact is confirmed by plasticizing with aqueous ammonia solution. Despite higher amounts of humidity, the plasticization effect of ammonia proved to be the crucial factor.

During molding, the test piece changed shape under the molding force action. This, along with the concave deflection, the main indicator of 3D-moldability in this case, is the additional indicator that characterizes the effect of plasticization media on wood characteristics. Considering the different concave deflection distances in relation to the type and duration of plasticization, the molding force was compared to the unit of concave deflection, labelled as "unit molding force."

Comparison of statistical significance ($p<0.05$) of molding force on unit of concave deflection in relation to the type and duration of the plasticization of the test pieces is shown in Table 2.

The amount of unit molding force in relation to the type and duration of plasticization is shown in Fig. 5. Here, in comparison with the control test pieces, lower molding force *per* unit of concave deflection is neccesary in all cases of plasticization. This is related to the lower plasticity of non-plastified pieces, which are frail, and therefore even at relatively high rigidity, they are typified by their low moldability. Dipping or plasticization of the test pieces increased plastic deformation (and therefore an increase in concave deflection during 3D-molding), and the force neccesary for unit of concave deflection decreases.

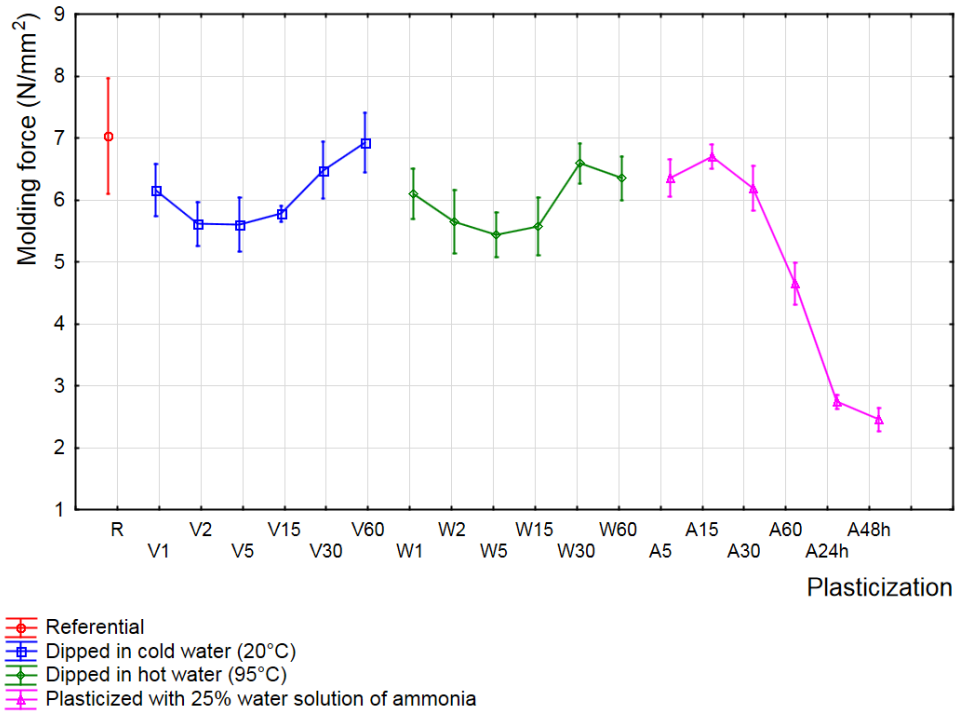

Fig. 5. The amount of unit molding force in relation to the type and duration of plasticization-modification of test pieces. Data are provided as the mean ± standard deviation.
R, control pieces; V1 through V60, dipped in cold water (20 °C) for 1, 2, 5, 15, 30, and 60 min; W1 through W60, dipped in hot water (95 °C) for 1, 2, 5, 15, 30, and 60 min; A5 through A48h, plastified with 25% water solution of ammonia for 5, 15, 30, and 60 min, and 24 and 48 h

Table 2. Comparison of Effects of Various Modifications of Test Pieces on Amount of Unit Molding Force using Duncan Test

Type and duration of modification	R	V1	V2	V5	V15	V30	V60	W1	W2	W5	W15	W30	W60	A5	A15	A30	A60	A24h	A48h
R		0.000324	0.000011	0.000011	0.000018	0.018860	0.628961	0.000140	0.000011	0.000010	0.000011	0.057831	0.004419	0.004414	0.143096	0.000486	0.000011	0.000010	0.000009
V1	0.000324		0.020834	0.019687	0.087778	0.180956	0.001416	0.779026	0.025844	0.002662	0.015200	0.072946	0.402582	0.401841	0.025173	0.880299	0.000017	0.000018	0.000017
V2	0.000011	0.020834		0.947610	0.472302	0.000371	0.000011	0.035669	0.886392	0.434037	0.848084	0.000071	0.002243	0.002211	0.000024	0.015958	0.000062	0.000025	0.000021
V5	0.000011	0.019687	0.947610		0.453088	0.000325	0.000011	0.034565	0.845665	0.452081	0.889024	0.000062	0.002023	0.001967	0.000017	0.014784	0.000082	0.000031	0.000025
V15	0.000018	0.087778	0.472302	0.453088		0.003449	0.000020	0.126600	0.531865	0.156081	0.393284	0.000715	0.015215	0.015462	0.000139	0.073784	0.000023	0.000017	0.000017
V30	0.018860	0.180956	0.000371	0.000325	0.003449		0.051171	0.118563	0.000542	0.000030	0.000220	0.588922	0.559830	0.557615	0.318103	0.216929	0.000011	0.000011	0.000011
V60	0.628961	0.001416	0.000011	0.000011	0.000020	0.051171		0.000631	0.000017	0.000011	0.000011	0.132449	0.014783	0.014541	0.282419	0.002046	0.000010	0.000011	0.000010
W1	0.000140	0.779026	0.035669	0.034565	0.126600	0.118563	0.000631		0.042094	0.005470	0.027556	0.043634	0.289476	0.286967	0.013650	0.687028	0.000017	0.000017	0.000018
W2	0.000011	0.025844	0.886392	0.845665	0.531865	0.000542	0.000017	0.042094		0.374588	0.754990	0.000100	0.003072	0.003077	0.000029	0.020444	0.000047	0.000021	0.000017
W5	0.000010	0.002662	0.434037	0.452081	0.156081	0.000030	0.000011	0.005470	0.374588		0.506837	0.000013	0.000180	0.000170	0.000011	0.001833	0.000443	0.000055	0.000049
W15	0.000011	0.015200	0.848084	0.889024	0.393284	0.000220	0.000011	0.027556	0.754990	0.506837		0.000041	0.001433	0.001379	0.000014	0.011180	0.000097	0.000049	0.000031
W30	0.057831	0.072946	0.000071	0.000062	0.000715	0.588922	0.132449	0.043634	0.000100	0.000013	0.000041		0.293989	0.291178	0.599096	0.091152	0.000011	0.000011	0.000010
W60	0.004419	0.402582	0.002243	0.002023	0.015215	0.559830	0.014783	0.289476	0.003072	0.000180	0.001433	0.293989		0.970566	0.135650	0.457421	0.000017	0.000011	0.000011
A5	0.004414	0.401841	0.002211	0.001967	0.015462	0.557615	0.014541	0.286967	0.003077	0.000170	0.001379	0.291178	0.970566		0.134607	0.465084	0.000011	0.000011	0.000011
A15	0.143096	0.025173	0.000024	0.000017	0.000139	0.318103	0.282419	0.013650	0.000029	0.000011	0.000014	0.599096	0.135650	0.134607		0.032968	0.000011	0.000010	0.000011
A30	0.000486	0.880299	0.015958	0.014784	0.073784	0.216929	0.002046	0.687028	0.020444	0.001833	0.011180	0.091152	0.457421	0.465084	0.032968		0.000018	0.000017	0.000011
A60	0.000011	0.000017	0.000062	0.000082	0.000023	0.000011	0.000010	0.000017	0.000047	0.000443	0.000097	0.000011	0.000017	0.000011	0.000011	0.000018		0.000114	0.000055
A24h	0.000010	0.000018	0.000025	0.000031	0.000017	0.000011	0.000011	0.000017	0.000021	0.000055	0.000049	0.000011	0.000011	0.000011	0.000010	0.000017	0.000114		0.179646
A48h	0.000009	0.000017	0.000021	0.000025	0.000017	0.000011	0.000010	0.000018	0.000017	0.000049	0.000031	0.000010	0.000011	0.000011	0.000011	0.000011	0.000055	0.179646	

Red font indicates statistically significant data.

Legend: R, control pieces; V1 through V60, dipped in cold water (20 °C) for 1, 2, 5, 15, 30, and 60 min; W1 through W60, dipped in hot water (95 °C) for 1, 2, 5, 15, 30, and 60 min; A5 through A48h, plasticized with 25% water solution of ammonia for 5, 15, 30, and 60 min, and 24 and 48 h

It is apparent from the graph that when comparing modifications with cold and hot water at the same durations, approximately the same unit molding force was neccesary. The increase of this force after plasticization longer than 15 min was derived from the decrease of concave deflection in both cases, while the overall molding force changed little in relation to the duration of plasticization.

During the plasticization with ammonia, compared to modification by water, the opposite effect occurred; therefore, after plasticization for longer than 15 min, the unit of molding force decreased with the increase of duration. This can be attributed both to the plastifying effect of ammonia and to the aforementioned bond breakage in the wood compounds due to their exposure.

CONCLUSIONS

1. Based upon the results of experimental tests, it was possible to change physical-mechanical characteristics of wood, which increased the dimensional moldability of veneers by means of the suggested plasticization/modification of veneers with cold water (20 °C), hot water (95 °C), and a 25% water solution of ammonia. The effect of plasticization on 3D-moldability was observed based on the comparison of the extent of concave deflection of the plastified/modified and untreated (control) test pieces (with an average moisture content of 7.65%).
2. From the comparison of the concave deflection determined after the plasticization/ modification of veneers, as far as 3D-moldability was concerned, the plasticization with ammonia-water during 24 h was the most efficient, with increased concave deflection up to 119% compared to the control pieces.
3. By dipping the test pieces in cold water, the concave deflection increased by up to 89% compared to the control pieces. Surprisingly, the lowest concave deflection occured after plasticization in hot water (increase of 66%). In this case, a statistically significant increase in wood moisture content occured, which may be the cause of the mentioned fact. Due to the significant increase in moisture content of wood, the extent of concave deflection decreased.
4. The effect of moisture content on the concave deflection of the pieces after plasticization was also examined. It was found that with the moisture content increase after plasticization with water, the concave deflection decreased, and therefore, the 3D-moldability decreased. The plasticization with ammonia water showed the opposite tendency, *i.e.*, the concave deflection increased with increasing moisture content.
5. Molding force is the characteristic additional indicator of the molding process. Here, its size in relation to the unit of concave deflection (N/mm) was expressed. The unit molding force decrease in comparison with the control pieces was caused by the suggested plasticization modifications.

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