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Determination of the wettability of gaboon wood (*Aucoumea klaineana* Pierre)

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Abstract: *Determination of the wettability of gaboon wood (Aucoumea klaineana Pierre).* The examined gaboon wood is used in European countries mostly for the production of plywood, windows and elevations. In this work, the wettability of gaboon wood was determined on the basis of the sessile drop method, using wood contact angle measurement with water and diiodomethane. The characteristics determined were the surface free energy for wood, wetting energy, spreading coefficient, work of adhesion and surface tension for the wood - water and wood - diiodomethane structure. The course of the wettability process, particularly in case of polar liquid (water), demonstrates significant dynamics. Satisfactory stabilization of the process occurs after about 30 sec from placing a droplet, and this time should be considered optimal. The presence of striped and irregular grain translates into an increase of the changeability of the tested surface wettability indicators.

Key words: gaboon, wettability, contact angle, wetting energy, work of adhesion, surface tension

INTRODUCTION

Gaboon wood (also known as okume or okoumé, according to EN 13556:2003) comes from Central Africa, with main area of acquisition in Gabon (i.e. 90% of the gaboon wood available on the market). Due to its high dimensional stability, gaboon wood is commonly used in European countries for the production of plywood, window joinery and elements of elevations (Galewski and Korzeniowski 1958, Bartowski 2005, Kozakiewicz 2007), but also for veneer cutting (BN-74/7112-05:1974, PN-D-97004:1999).

In case of the use of gaboon wood, not only basic characteristics such as density and natural durability (provided in EN 350-2:1994) or shrinkage and mechanical properties (described by Wagenführ 2007) are important but also its surface characteristics, especially wettability. Physicochemical parameters of the surface directly affect its interaction with water and the dynamics of the soaking process, thus determining significant usability characteristics. Moreover, wood surface characteristics influence the process of gluing, impregnation and finishing.

One of the fundamental tools for describing physico-chemical properties of a solid object surface is the wetting angle, formed by the surface of the object and the line tangent to a droplet surface at the point of contact of the phases (e.g. water droplet surface). A smaller value of the wetting angle points to a better surface wettability. According to the research carried out so far, if the wetting angle is greater than 90°, the liquid does not wet the surface of a solid object; and if the angle is less than 90°, intensive wetting of the surface by the liquid occurs. Also a change of the wetting angle value within a predetermined time is important (Owens and Wendt 1969, Liptakova and Kúdela 1994, Huang et al. 2012, Kúdela 2014).

The purpose of these tests was to determine selected parameters (i.e. wetting angle, surface free energy, wetting energy, spreading coefficient, work of adhesion and surface tension) and physico-chemical properties of gaboon wood (*Aucoumea klaineana* Pierre).

MATERIAL AND METHODS

Gaboon wood (*Aucoumea klaineana* Pierre) was used in the tests. Wood samples (dimensions of 135x135x15 mm) were cut along the main anatomic sections so that tangential section (i.e. the section most commonly used in finished products) was on the broad surfaces. The samples surfaces were finished by slicing. After conditioning of the samples to air-dried state, wood moisture content was determined in accordance with ISO 13061-1:2014, and its density was determined in accordance with ISO 13061-2:2014.

Using the sessile drop method, the contact angles of wood wetted with reference liquids were tested in a Phoenix 300 goniometer manufactured by Surface Electro Optics. Water and diiodomethane were used in the tests as reference liquids. Wetting energy was determined, as well as the spreading coefficient, work of adhesion and surface tension for the structure of wood - water and wood - diiodomethane. On the basis of tests carried out using the Owens-Wendt method (Owens and Wendt 1969), wood surface free energy was determined. The values of the parameters characterising wood wettability were determined after 1, 2, 3, 10, 20, 30, 40, 50 and 60 sec from placing a droplet of a reference liquid onto wood surface.

RESULTS AND DISCUSSION

Gaboon wood was characterised with an average density of 378 $kg \cdot m^{-3}$ (standard deviation of 3 $kg \cdot m^{-3}$) and moisture content of 9.6% (standard deviation of 0.4%). The obtained density of the tested wood is relatively low, close to the bottom value of the scope of density variability for this wood species in air-dried state given in the literature, i.e. 380 – 440 – 530 $kg \cdot m^{-3}$ (Galewski and Korzeniowski 1958, Kozakiewicz 2007, Wagenführ 2007). Table 1 and picture 1 present the results of the wettability tests.

Table 1. Selected properties of the structure gaboon wood - water, gaboon wood - diiodomethane (standard deviation in parentheses)

Properties	Time [s]								
	1	2	3	10	20	30	40	50	60
Contact angle [°]									
wood - water	65(4)	61(5)	59(6)	52(6)	47(5)	45(5)	43(5)	40(5)	40(4)
wood - diiodomethane	29(1)	29(1)	29(1)	28(2)	27(1)	26(1)	26(1)	26(1)	26(2)
Wetting energy [$mN \cdot m^{-1}$]									
wood - water	31(5)	35(5)	37(6)	44(6)	49(5)	52(5)	53(4)	54(4)	55(3)
wood - diiodomethane	64(1)	64(1)	64(1)	65(1)	65(1)	65(1)	65(1)	65(1)	66(1)
Spreading coefficient [$mN \cdot m^{-1}$]									
wood - water	42(5)	38(5)	36(6)	28(6)	23(5)	21(5)	19(4)	18(4)	17(3)
wood - diiodomethane	9(1)	9(1)	9(1)	8(1)	8(1)	8(1)	8(1)	7(1)	7(1)
Work of adhesion [$mN \cdot m^{-1}$]									
wood - water	104(5)	108(5)	110(6)	117(6)	122(5)	125(5)	126(4)	127(4)	128(3)
wood - diiodomethane	137(1)	137(1)	137(1)	137(1)	138(1)	138(1)	138(1)	138(1)	138(1)
Surface tension [$mN \cdot m^{-1}$]									
wood - water	-	14(2)	15(2)	18(2)	20(2)	23(2)	22(4)	23(4)	23(4)
wood - diiodomethane	-	10(1)	11(1)	11(1)	12(1)	12(1)	12(1)	12(1)	12(2)

Considering the number of variables which affect wood wettability, the time after which the contact angle should be determined has not been specified. Liptáková and Kúdela (1994) and Kúdela (2014) determined the contact angle after separation of a liquid droplet from a needle (t = 0) and the equilibrium contact angle. Huang et al. (2012) differentiated the time for determining the contact angle for Jack pine (*Pinus banksiana* Lamb.) depending on the type of the reference liquid.

In the case of the tested gaboon wood, the parameters changed substantially within the selected time span of 60 sec, where the changes had the character of an exponential function (the changes were occurring the fastest in the first seconds of the test). Satisfactory stabilization of the tested wettability properties can be observed after about 30 sec from placing a droplet of polar liquid, especially of water. This time should be considered as optimal in case of a single measurement of properties connected with gaboon wood wettability, without observation of the process dynamics. The average wettability parameters 30 sec after placing a droplet of water onto the surface of gaboon wood, were the following: contact angle 45°, wetting energy 52 mN/m^{-1}, spreading coefficient 21 $mN \cdot m^{-1}$, work of adhesion 125 $mN \cdot m^{-1}$ and surface tension 23 $mN \cdot m^{-1}$. In case of dispersive liquid (30 sec after the placement of a diiodomethane droplet) the sizes of the contact angle and the surface tension were about twice smaller, and the spreading coefficient almost three times lower, while the wetting energy and the work of adhesion were greater by about 10 $mN \cdot m^{-1}$. High fibre saturation point of 40% (Kozakiewicz 2007) and easy saturation with protective agents (EN 350-2:1994) points to the open structure and hydrophilic properties of gaboon wood, which was confirmed by the aforementioned results of surface wettability tests.

Gaboon wood has the structure of a diffuse-porous hardwood from the tropical climate zone. The vessels are placed evenly, individually or in commonly short (2-3 vessels) radial rows. The vessels diameter is on average about 0.22 mm. The vessels have poor parenchyma in the form of a single layer of surrounding cells. Also there are radial, fine, 1-cell wide apotracheal parenchyma bands. The elements dominating in the structure are thin-walled, multifaceted fibres (even over 70%). Their average diameter is 0.015 mm and length is 0.9 mm. Rays are narrow and mostly 2- cells wide, less often 1- or 3- cells high. The rays constitute about 12% (Kozakiewicz 2007). These properties show the homogeneity of gaboon wood which is macroscopically disturbed at particular anatomic sections by the presence of striped and irregular grain (Kozakiewicz 2007, Wagenführ 2007). It is the non-linear arrangement of fibres that caused the increase of the standard deviations of the properties recorded during testing.

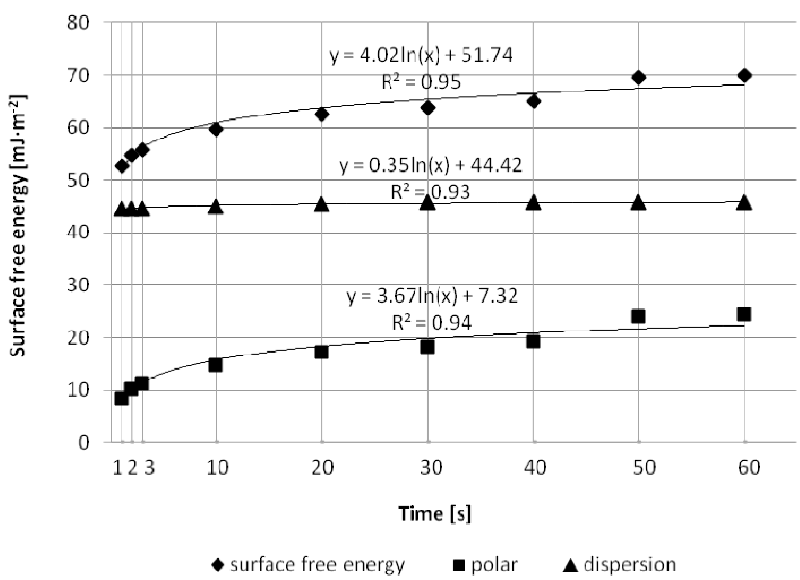

Figure 1. Surface free energy, polar and dispersion components

Figure 1 presents curves which show the variables during the time of surface free energy, also presenting the polar and the dispersion components separately. The obtained results show that the dominating ingredient, and also more changeable in time, is the energy from the polar liquid (water).

CONCLUSIONS

On the basis of the performed tests of surface wettability of gaboon wood (*Aucoumea klaineana* Pierre), the following conclusions were drawn:

1. The course of the wettability process, particularly in case of polar liquid (water), demonstrates significant dynamics. Satisfactory stabilization of the process occurs after about 30 sec from the placing of a droplet and this time should be considered optimal.
2. On the tangential section, 30 sec after the placement of a droplet of polar liquid (water), the average contact angle is 45^{o}, wetting energy is 52 $mN \cdot m^{-1}$ and work of adhesion is 125 $mN \cdot m^{-1}$, and for diiodomethane these are, respectively, 26 ^{o}, 65 $mN \cdot m^{-1}$ and 138 $mN \cdot m^{-1}$.
3. The natural presence of stripped and irregular grain, despite of the homogeneous microscopic structure, translates into an increase of the changeability of the tested surface wettability indicators.
4. The dominating component, and also the more changeable during the time of determining surface free energy, is the energy from the polar liquid (water).

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Streszczenie: *Wyznaczenie zwilżalności drewna okume (Aucoumea klaineana Pierre).* Drewno okume (ang. gaboon wood) stosowane jest w krajach europejskich głównie do produkcji sklejki, okien i elementów elewacyjnych. W pracy określono zwilżalność drewna okume poprzez pomiar kąta zwilżania drewna wodą i dijodometanem na podstawie metody "osadzonej" kropli. Wyznaczono swobodną energię powierzchniową drewna, a także energię zwilżania, współczynnik rozpływu, pracę adhezji i napięcie powierzchniowe dla układu drewno – woda oraz drewno - dijodometan. Przebieg procesu zwilżania, w szczególności cieczą polarną (wodą), wykazuje znaczną dynamikę. Zadawalająca stabilizacja procesu następuje po ok. 30 s od „osadzenia" kropli i czas ten należy uznać za optymalny do dokonania pomiaru. Obecność w drewnie okume pasiastego i gniazdowego układu włókien przekłada się na zwiększenie zmienności badanych wskaźników zwilżalności powierzchni.

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