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Calorific value of selected wood species and wood products

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Abstract In a preliminary study, the gross and net calorific values of eleven veneers and engineered wood products having applications in the interior work of yachts were determined. Differences were found among the individual materials amounting to as much as 15 %. The chemical composition regarding lignin content and binder content is thought to be an essential factor of influence.

Heizwerte ausgewählter Holzarten und Holzwerkstoffe

1 Introduction

In the field of top-quality interior work, wood plays an important role. A prerequisite for the use of different wood species and engineered wood products is their respective fire protection certification. In order to calculate fire loads, it is necessary to first ascertain the heat of combustion that is emitted by the materials in the event of fire. The gross-heat of combustion (PCS, formerly H_O) indicates a given material's energy content that is released after complete incineration. The water vapour contained in the off-gas is condensed in this process and is available as condensation heat. The combustion of an object, however, can rarely be considered as a closed system. If off-gases are emitted from the object, part of the water vapour condenses outside the system. Since it is only conditionally possible to describe condensation mechanisms due to the complexity of various fire scenarios, the net-heat of combustion (PCI, formerly: H_U), as opposed to the gross-heat of combustion, serves as the output parameter for the calculation of fire loads (Werner 2004).

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2 Material and methods

Within the context of this study, eight veneers and three engineered wood products were evaluated that are typically utilized by the Deutsche Werkstätten Hellerau GmbH for the interior work of yachts:

- Maple (*Acer platanoides*)
- Birch (*Betula spec.*)
- Spruce (*Picea abies*)
- Sapele (*Entandrophragma cylindricum*)
- Macassar ebony (*Diospyros celebica*)
- Santos rosewood (*Machaerium scleroxylon*)
- Teak (*Tectona grandis*)
- Wenge (*Millettia laurentii*)
- Medium density fibreboard (MDF)
- MDF faced Blockboard
- HPL (60 . . . 70 % paper, 30 . . . 40 % Phenol/Melamine resin).

Analysis of the samples was accomplished on the basis of the standards DIN EN ISO 1716 (2009), DIN 51900-1 (2000) and DIN 51900-3 (2005) at the Chair for Combustion, Heat and Mass Transfer (Technische Universität Dresden) and comprises the following steps:

After sample preparation (milling with a maximum particle size of 25 μm), the moisture of the analysis sample (ω)

was determined by means of a Halogen Moisture Analyzer (HR73, Mettler Toledo Int. Inc.).

Determination of the gross-heat of combustion (PCS) was accomplished in an adiabatic bomb calorimeter (C4000, Janke & Kunkel). Samples with a weight between 0.91 g and 0.99 g were completely incinerated at 30 bar under pure oxygen environment. The heat that was emitted during incineration was transferred to the calorimeter fluid, whereby the heat capacity (C) for each calorimeter is specific. From the difference in temperature (ΔT) between the initial condition and the temperature of the calorimeter fluid after incineration the level of energy released from the sample material as well as its gross-heat of combustion (PCS) can be ascertained (Eq. (1)). At least one repeat determination was carried out for each sample material.

$$PCS = (C \cdot \Delta T - b)/m \quad (1)$$

The correction factor (b) is the sum of the energy released through incineration of the cotton thread and the ignition wire (Q_z), plus the release of energy that occurs through the formation of nitric acid (Q_n) and sulphuric acid (Q_s) from nitrogen and sulphur oxides (Eq. (2)).

$$b = Q_z + Q_n + Q_s \quad (2)$$

In compliance with DIN 5499 (1972) the sulphur contained in the sample after incineration must be present in a gaseous condition as sulphur oxide. Furthermore, oxidation of the nitrogen must not have occurred. Since this cannot be actualized within the bomb calorimeter, a correction value for these reactions has then to be ascertained. For this purpose, the sulphate and nitrate content of the calorimeter solution was determined by means of an ion-exchange chromatography (ICS-1000, Dionex).

In order to calculate the net-heat of combustion (PCI), the latent heat of vaporization of the condensed water (q) must be subtracted from the gross-heat of combustion (Eq. (3)). For this purpose determination of the hydrogen of the samples was necessary, which was accomplished by means of an Elementary-Analyzer (Vario EL, Elementar Analysesystem GmbH).

$$PCI = PCS - q \quad (3)$$

3 Results and discussion

The results from ion chromatography showed that the correction values for the formation of neither nitric acid nor sulphuric acid achieved notable values. At levels of 40.9 J (Q_n) and 3.4 J (Q_s), the largest values were achieved for MDF. With teak wood, the values at 20.2 J (Q_n) and 0.5 J (Q_s) were the lowest.

Table 1 Gross-heat of combustion (PCS) and net-heat of combustion (PCI) of selected wood species and engineered wood products in air-dry state (ω)

Tab. 1 Brenn- (PCS) und Heizwert (PCI) ausgewählter Holzarten und Holzwerkstoffe im lufttrockenen Zustand (ω)

	PCS [MJ/kg]	PCI [MJ/kg]	ω [%]
Birch	17.9	16.6	7.2
Blockboard	18.4	17.1	5.8
Sapele	18.5	17.1	8.1
Maple	18.5	17.1	6.8
Spruce	18.6	17.2	7.7
MDF	18.6	17.2	5.7
Macassar ebony	18.8	17.5	6.9
Wenge	19.3	18.0	7.0
Teak	20.3	18.9	6.7
HPL	20.4	19.1	4.5
Santos rosewood	20.5	19.1	5.6

The hydrogen concentrations for all sample materials span a narrow range. The highest concentrations of elementary hydrogen were found for MDF (5.7 mass percent), while the lowest were measured for Macassar ebony (5.1 mass percent).

The gross-heat of combustion as calculated lies between 17.9 MJ/kg (Birch) and 20.5 MJ/kg (Santos rosewood). The respective net-heat of combustion is on average 7.1 % lower. Birch and Santos rosewood in turn exhibit the smallest and largest values with 16.6 MJ/kg and 19.1 MJ/kg.

Responsibility for the variance in calorific values can be attributed to the chemical composition of the sample materials. Lignin and extractive content have a considerable influence. According to Kaltschmitt et al. (2009), lignin, cellulose and hemicelluloses have a net-heat of combustion of 27.0, 17.3 and 16.2 MJ/kg, respectively. The gross-heat of combustion of cellulose, lignin and extractives isolated from *Gmelina arborea* (Roxb) have been determined by Fuwape (1989) with 19.7, 25.4, 25.1 MJ/kg, respectively.

Therefore, the higher the lignin and extractive content of a material, the higher the respective calorific value (White 1987; Demirbaş 2001; Kataki and Konwer 2001). As regards Birch and Santos rosewood, this should be substantiated exemplarily: Birch has a lignin content of 19.3 to 27.4 %, while Santos rosewood exhibits a lignin content of approximately 31.2 %; the content of substances soluble in an alcohol-benzene mixture is 1.7 to 2.5 % for Birch and approximately 15.6 % for Santos rosewood (Wagenführ 2007; Krauss et al. 2011). As can be derived from Table 1, these differences are clearly reflected in the calorific values.

The energy-related characteristics of the engineered wood products are influenced by the use of adhesives. They feature for the most part a higher calorific value than the wooden components that are to be glued together: The net-heat of combustions of urea-, melamine- and phenol-formaldehyde resins according to Menges et al. (2002) amount to 18, 28 and 32 MJ/kg, respectively. Very probably this is the reason for the high calorific value of the HPL that has a binder content of 30 to 40 %. According to the binder content of 6 to 12 % (Deppe and Ernst 1996), MDF shows a lower calorific value than HPL (see Table 1).

Combustible materials on ships "shall have a calorific value not exceeding 45 MJ/m^2" (IMO 2004). Veneers and engineered wood products that are installed contribute, to varying degrees, to the fire load. In the context of this preliminary study, the net-heat of combustion showed differences of up to 15 %. As regards the interior work of yachts, these results allow leeway for optimization of both the material composition as well as possibilities for configuration.

References

Demirbaş A (2001) Relationships between lignin contents and heating values of biomass. Energy Convers Manag 42(2):183–188

Deppe H, Ernst K (1996) MDF–mitteldichte faserplatte. DRW-Verlag Weinbrenner & Co, Leinfelden-Echterdingen

DIN EN ISO 1716 (2009) Prüfungen zum Brandverhalten von Bauprodukten – Bestimmung der Verbrennungswärme. Deutsches Institut für Normung, Beuth Verlag GmbH, Berlin

DIN 51900-1 (2000) Bestimmung des brennwertes mit dem Bomben-Kalorimeter und berechnung des heizwertes. Teil 1: allgemeine angaben, grundgeräte, grundverfahren. Deutsches Institut für Normung, Beuth Verlag GmbH, Berlin

DIN 51900-3 (2005) Bestimmung des Brennwertes mit dem Bomben-Kalorimeter und Berechnung des Heizwertes. Teil 3: Verfahren mit adiabatischem Mantel. Deutsches Institut für Normung, Beuth Verlag GmbH, Berlin

DIN 5499 (1972) Brennwert und Heizwert – Begriffe. Deutsches Institut für Normung, Beuth Verlag GmbH, Berlin

Fuwape JA (1989) Gross heat of combustion of Gmelina (*Gmelina arborea* (Roxb)) chemical components. Biomass 19(4):281–287

IMO (2004) Consolidated text of the International Convention for the Safety of Life at Sea, 1974, and its Protocol of 1988. Annex II.2—Fire protection, fire detection and fire extinction (Reg 5). URL: http://dtechwx.com/pdf/SOLAS2004.pdf

Kaltschmitt M, Hartmann H, Hofbauer H (2009) Energie aus Biomasse. Grundlagen, Techniken und Verfahren, 2nd edn. Springer, Berlin

Kataki R, Konwer D (2001) Fuelwood characteristics of some indigenous woody species of north-east India. Biomass Bioenergy 20(1):17–23

Krauss A, Krauss H, Waliszewska B, Piątek J (2011) Selected environmental aspects of the introduction into the polish market of exotic wood species on the example of caviuna (*Machaerium scleroxylon Tul*). Ann Agric Environ Med 18(2):345–349

Menges G, Haberstroh E, Michaeli W, Schmachtenberg E (2002) Werkstoffkunde Kunststoffe, 5th edn. Carl Hanser Verlag, München

Wagenführ R (2007) Holzatlas, 6th edn. Fachbuchverlag Leipzig im Carl Hanser Verlag, München

Werner UJ (2004) Bautechnischer Brandschutz. Planung, Bemessung, Ausführung. Birkhäuser, Basel

White RH (1987) Effect of lignin content and extractives on the higher heating value of wood. Wood Fiber Sci 19(4):446–452