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THE INFLUENCE OF HEAT TREATMENT ON GRANULARITY OF SAND WOOD DUST

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Abstract

The paper deals with the granular analysis of the sand dust of heat-treated wood from red meranti, depending on the treatment temperature of 160 °C, 180 °C, 200 °C and 220 °C. The proportion of dust fractions with a particle size ≤ 0.08 mm was determined by sieving. The percentage shares of these fractions are similar for natural wood 84.17 % and temperature of treatment at 160 °C (87.18 %), 180 °C (86.23 %) and 200 °C (80.79 %). A significantly lower proportion of dust fractions with a particle size ≤ 0.08 mm occurred at a temperature of 220 °C, only 74.48 %. We assume that the main factor that caused the decrease of the dust fraction with a particle size ≤ 0.08 mm at 220 °C is the reduction of wood density.

Key words: *thermowood, sanding, wood dust, granular analysis*

INTRODUCTION

Wood is one of the most interesting natural materials that has many uses. Despite its many positive attributes, it also has certain negative properties - dimensional instability due to swelling, shrinking or attack by pests or rot. And therefore, users of this natural material are constantly striving to minimize the negative properties of wood in a variety of ways. One of them is the treatment by increased temperature, thermowood. The basis of heat, steam and water treatment is that no harmful chemicals are used to change the properties of the wood, resulting in wood, with new physicochemical properties that increase its utility properties similar to those of tropical woods (Thermowood 2016). Thermowood has two standards for treatment. Thermo-S is an increase in wood stability and Thermo-D is an increase in its durability (ThermoWood Handbook 2003). Each type of wood can be heat-treated, but each wood has its own characteristics, so the thermal treatment parameters are modified for each type of wood (or similar species) in terms of optimizing the resulting quality (Kminiak, Kubš 2016).
The advantages of thermowood include: reduction of moisture absorption, dimensional stability, biological resistance, attractive appearance of heat treated wood, application of material without surface treatment, high durability of heat treated wood, removal of resin from the material, reduction of thermal conductivity, increase of hardness of the wood surface, increase of crack resistance. Heat treated wood has a higher static load in terms of mechanical properties, but the disadvantage is that its dynamic strength values are reduced – reducing both bending and toughness, which results in the wood being more brittle.

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The change of physical-mechanical properties results mainly from the change in chemical properties of wood. The high temperatures degrade some wood building polymers to form of new water-insoluble substances, as well as substances with toxic or repellent effects. Wood treated in this way is more resistant to biological pests and its hygroscopicity decreases. Strength and some other mechanical properties of the heat treated wood are reduced due to chemical changes in the anatomical structure of the wood, where cracks in the cell walls are created and wood becoming more fragile. Fragility and cracks cause a reduction in wood strength and toughness (Reinprecht, Vidholdová 2008, Kačíková, Kačík 2011, Kminiak, Gaff 2015, ThermoWood Handbook, 2003). In general, as the temperature is higher and the duration of the action longer, the reactions and the changes in wood are more intense, the deciduous species of wood with a lower proportion of lignin are thermally modified more intensively than the coniferous species of wood.
Thermowood is the subject of many researches. The aims of these researches are the changes in the physical-mechanical properties (Gunduz *et al*. 2009), the chemical properties (Reinprecht, Vidholdová 2008, Kačíková, Kačík 2011, ThermoWood Handbook 2003, Čabalová *et al*. 2016), the quality of the obtained surface (Budakci *et al*. 2013, Kvietková *et al*. 2015, Vančo *et al*. 2017, Kaplan *et al*. 2018) the colour of the wood, the woodworking (Sandak *et al*. 2017, Reinprecht, Vidholdová 2008, Král, Hrázský 2005), the workability in the context of energy consumption (Kubš, Gaff, Barcík 2016), the stability against the impact of weather (Panayot, Jivko 2008, Yildiz *et al*. 2011), the granularity of the chips (Barcík, Gašparík 2014), or sawdust (Dzurenda, Orlowski, Grzeskiewicz 2010).

The aim of the present paper is to determine the granularity of sand wood dust obtained from the sanding of heat-treated wood (red meranti) along the wood grains on a vertical belt sander with a manual pressure of samples on the sanding belt, depending on the heat treatment of samples (of 160 °C, 180 °C, 200 °C and 220 °C), focusing in particular on the percentage share of particles measuring ≤ 0.08 mm, which does not settle or sediment in the working environment, and is a source of both health and safety risks.

MATERIAL AND METHODS

Experimental samples: Red meranti (*Shorea acuminata*). The red meranti was purchased in a subcontracting company and processed in test samples measuring 20 x 100 mm with a length of approximately 700 mm. The samples were then dried to a moisture content of 8 %. The entire process was performed in the Research and Development Workshops of the Technical University in Zvolen.

Heat treatment and sample processing methods

The processed samples were heat-treated in the Arborét FLD (ČZU Praha) in the city of Kostelec nad Černými lesy. The S400/03 (LAC Ltd., Czech Republic) chamber was used for thermal treatment, Fig. 1, designed to heat the wood with ThermoWood technology, with the parameters listed in Tab. 1. Five samples were prepared for experiment.

Fig. 1 Chamber S400/03

Tab. 1 Chamber parameters S400/3

Maximal temperature (°C)	300
Volume (l)	380
External dimensions - w×h×d (mm)	1400×1850×1200
Internal dimensions - w×h×d (mm)	800×800×600
Weight(kg)	350
Fan	1
Input (kW)	6,0

The heat treatment procedure for the individual temperatures was as follows: the application of temperature sensors and a humidity sensor on the samples, the storage of samples in the chamber, the closure and locking of the chamber door, the setting of the heat treatment parameters with a computer program – target temperature, steepness [°C /hr.] for heating and cooling, heat treatment of samples, sample collection from the chamber.

The thermal treatment was realized at 160, 180, 200 and 220 °C in six phases: the 1st – increase of temperature to 40 °C, the 2nd – increase of temperature to 130 °C, drying, the 3rd – heat treatment – heating to working temperature, the 4th – heat treatment – working temperature of 3 hours, the 5th – cooling to 130 °C and humidity treatment, the 6th – cooling to 60 °C with humidity treatment at the level of 4 – 7 %.
The process is completed when the temperature reaches 60 °C.

Due to the space in which the samples were stored, they were placed in the dryer at approximately 10 °C. The samples taken from the dryer after completing the heat treatment process had a temperature of about 40 °C. The heating, conditioning and cooling phases of the wood samples are shown in Fig. 2 and the time intervals are shown in Tab. 2.

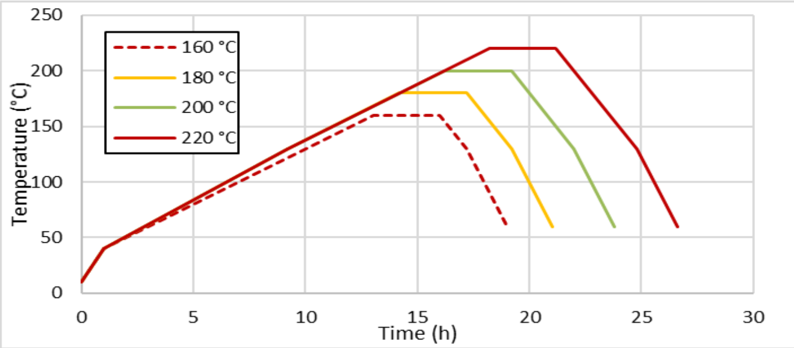

Fig. 2 Phases of heat treatment of red meranti

Tab.2 Time intervals of the thermal modification of the wood – red meranti

Working temperature (°C)	Phase (h)						∑ (h)
	I.	II.	III.	IV.	V.	VI.	
160	1,0	9,0	3,0	3,0	1,2	1,8	19,0
180	1,0	8,2	5,0	3,0	2,0	1,8	21,0
200	1,0	8,2	7,0	3,0	2,8	1,8	23,8
220	1,0	8,2	9,0	3,0	3,6	1,8	26,6

Sanding machine

JET JSG-96 narrow belt sander, cutting speed of 10 $m.s^{-1}$, HIOLIT XO P 80 sanding belt with a grain of 80, individual pressure of wood sample on sanding belt, laboratory experiments. A sharp sanding belt was used for each heat treatment variant.

Granular analysis

Samples for the granular wood dust analysis were taken isokinetically from the suction pipe of the sander in accordance with STN 9096 (83 4610): "The manual determination of the mass concentration of solid pollutants" during the sanding of individual heat-treated wood samples.

The granularity of the wooden sand dust was found by sieving. For this purpose, a special set of superimposed sieves (2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.080 mm, 0.063 mm, 0.032 mm and the bottom) was used on the vibrating stand of the sieving machine (Retsch AS 200c) with an adjustable sieving interruption frequency (20 seconds) and a sieve deflection amplitude (2mm/g), in accordance with STN 153105/STN ISO 3310-1.

The granular composition was obtained by weighing the percentages remaining on the sieves after sieving on a Radwag WPS 510/C/2 electronic weighing scale, with a capacity of 510 g and an accuracy of weighing at 0.001 g. For each variant, three sievings were performed and the results are given as their mean value.

RESULTS AND DISCUSSION

The results of the experiment are presented in the Tab. 3.

Tab.3 Granularity of sand wood dust – red meranti heat treated

Dimension of sieve mesh [mm]	Percentage of fractions of sand dust [%]				
	Meranti				
	natur	160 [°C]	180 [°C]	200 [°C]	220 [°C]
2	0.00	0.00	0.00	0.00	0.00
1	0.00	0.10	0.00	0.00	0.00
0.5	0.20	0.10	0.35	0.45	0.00
0.25	0.71	0.45	0.80	0.91	1.41
0.125	14.95	11.18	12.64	17.88	24.12
0.08	31.14	23.31	27.82	31.33	35.45
0.063	11.26	14.98	17.91	13.81	10.21
0.032	34.84	34.70	26.47	24.70	22.23
Bottom	6.93	14.19	14.03	10.94	6.59
Particles below 0.1	**84.17**	**87.18**	**86.23**	**80.79**	**74.48**

Meranti is tropical wood and is characterized as a typical deciduous scattered-porous wood with similar physical and mechanical properties as beech. Based on the results of the granular analysis it can be stated that the percentage shares on the individual sieves are characterized by the fact that 2 kinds of particles are produced (Očkajová, Beljaková, Luptáková 2008), with the highest percentage shares on sieve 0.08 mm (from 23.31 % to 35.45 %) and on the sieve 0.032 mm (from 22,23 % to 34,84 %). The percentage shares of fractions ≤ 0.08 mm is similar for natural wood (84.17 %) as well as for temperatures 160° C (87.18 %), 180 ° C (86.23 %). A certain decrease in the percentage share of particles with a dimension of ≤ 0.08 mm is at temperature of 200 °C (80.79 %), which represents a decrease of this fraction by about 4 %, a significant decrease occurs at 220 °C when this percentage share is only 74.48 %, which is about 11% less than at natural wood. At this treatment temperature, the high percentage share of particles is on sieve 0.125 mm (up to 24.12 %) compared to other temperatures of treatment where the value ranges from 11.18 to 17.88 %. For wood treatment to increase its stability to about 180 °C (Thermo-S) it can be stated that the granular composition is similar to that of natural wood. For thermal treatment up to 220 °C to increase its durability (Thermo-D), granularity varies toward larger fractions, which declare the results of particle stratification on individual sieves.

The density of meranti by (Wagenführ, Scheiber 1985) is 670 kg.m^{-3}, but according to previous research by Očkajová, Banski, Rončka (2006) the measured density for meranti was lower, only 496 kg.m^{-3} and therefore the obtained values of percentage shares of particles ≤ 0.08 mm are lower compared to beech, where this value is 87.23 % for the vibrating sander (Marková *et al.* 2016) 91.95 % for narrow-belt sander (Očkajová, Banski 2013) 94.28 % for hand-belt sander for sanding perpendicular to wood grains and 96.29 % for hand disk sander Očkajová *et al.* (2014).

By Reinprecht, Vidholdová (2008), Král, Hrázský (2005) in machining process of the heat treated wood, the problem can be in creation of more fine fraction of dust, what is caused by increasing brittleness and decreasing some mechanical properties. This assumption is confirmed by Dzurenda *et al.* (2010) during sawing and by Barcík, Gašparík (2014) during milling, although a statistically significant difference is not reported.

In the case of sanding, however, it is necessary to mention the change in physical properties of heat-treated wood, mainly the decrease in weight and density. The density of the heat-treated spruce through the Platowood method decreased by 10 %, (ThermoWood Hhandbook, 2003, www.platowood.nl), similar result is for beech (Maulis 2009). Gunduz *et al*. (2009) reporting a decrease in the density of common alder at a treatment temperature of 210 °C for 12 hours by 16.12 %. According to preliminary our results (so far not published), the density of samples decreased approx. from 18 % (spruce) to 21.5 % (oak) at a temperature of 220 °C.

Based on many granular analyses of various wood sand dusts, from the longitudinal sanding in previous research, we found that the granularity of sand wood dust significantly changes with density, because when sanding wood with low density, the individual chips are easier to separate than for wood with higher density (Hammilä, Usenius 1999, Očkajová, Banski 2009). With increasing of wood density (cca 42 %) in the tested interval from 450 kg.m^{-3} ÷ 774 kg.m^{-3} (spruce 450 kg.m^{-3}, poplar 487 kg.m^{-3}, alder 527 kg.m^{-3}, pine 551 kg.m^{-3}, maple 619 kg.m^{-3}, beech 624 kg.m^{-3}, oak 774 kg.m^{-3}) for sanding process (hand belt sander GBS 100 AE), there is increased the percentage share of small fractions (particle size < 100 μm) from 4.2 % to 53.06 % (Očkajová, Banski 2009). So we assume that our granular analysis results are substantially influenced by the decreasing density of heat-treated wood.

CONCLUSION

The results of the experimental measurements can be summarized as follows:

- in sanding process of red meranti the assumption that with the increasing temperature of the wood treatment the proportion of dust fractions increases too has not been confirmed,
- the lowest value of dust fractions measuring ≤ 0.08 mm was obtained at treatment temperature of 220 °C; when this percentage share is only 74.48 %, which is about 11 % less than at natural wood,
- we assume that the main factor influencing the granular analysis of heat-treated wood in the sanding process is the decreasing density of heat-treated wood.

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