International Journal of Engineering Innovation & Research
Volume 4, Issue 5, ISSN: 2277 – 5668

The Effect of Fraction Size on Thermal Stability of Wood Dust

Peter Rantuch, Zuzana Szabová, Veronika Kňažková

Abstract **– The article deals with thermal decomposition of wood dust in dependence on the size of its particles. The samples of waste formed in the wood processing industry were divided into 7 fractions in the range from 0 to 2 500 µm. Each fraction was subsequently heated in the air flow in the air-heating oven with heating rate of 5 °C/min, while its weight loss was recorded in 10 s intervals. The dependence of initiation temperature of thermo-oxidation, its maximum rate and termination were assessed on the basis of thermo-gravimetric curves. It seems from the measured results that the particle size of the tested samples does not exert significant effect upon the initiation temperature of thermal degradation, which was determined within the temperature range from 245 °C - 248 °C**

Keywords **– Fire Initiation, Thermal Degradation, Thermogravimetry, Wood.**

I. INTRODUCTION

Wood is a renewable natural resource. It has been the most versatile material for building, construction, decoration or furniture, due to its superior properties like aesthetically pleasing characters, high strength to mass ratio, low thermal conductance and low economic cost [1]. Wood is a polymeric material which essentially contains hemicelluloses, cellulose, lignin and extractives [2, 3, 4]. Hemicelluloses, the most reactive compounds, decompose at temperature in the range of 225–325 °C, cellulose at 305–375 °C and lignin gradually over the temperature range of 250–500 °C [2, 5]. Many authors deal with description of thermal decomposition of the wood, for example Martinka [5] and Zachar [7].

At the repairs requiring welding operations in the premises of wood processing industry there occurs the risk of ignition of the wood mass. Mainly the fine wood waste deposited on the surrounding surfaces may be often disregarded. In case of its whirling a cloud is formed which may attain its volume concentration higher than the lower explosion limit. The impact of spruce wood particle size on the ignition temperature of dust clouds was described by Martinka, Rantuch and Balog [8].

This work is aimed to the study of effect of particle size on thermal stability of wood dust in the case when its whirling does not occur and it exists in the loosed form.

II. EXPERIMENTAL

The samples of wood dust, composed of a mixture of the fine beech and oak wood waste, formed at industrial processing of the sawn timber, were tested. Individual fractions were obtained by the aid of a sieving device type Resch AS 200. The air was used as a screening medium. 7 sieves were used with openings in the size of 2.5 mm, 1 mm, 500 µm, 250 µm, 200 µm, 150 µm and 71 µm. The fraction with the size of particles over2.5 mm was not used at testing since it did not attain sufficient homogeneity. Individual attained fractions are shown in Figure 1. Each of them has got a letter designation from "a" to "g". The weight of tested samples is given in Table 1.

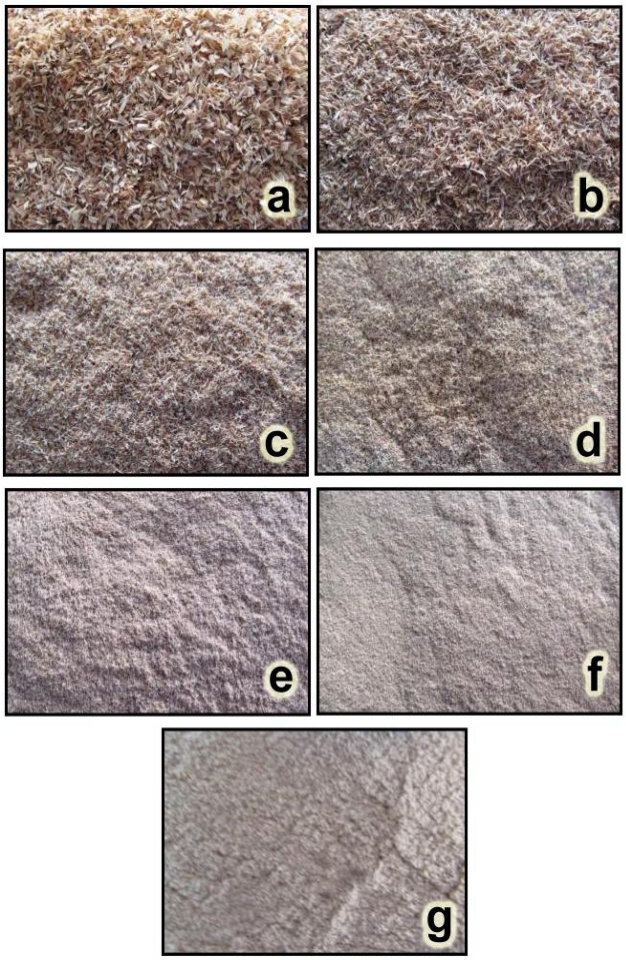

Fig.1. Samples of individual fractions of the wood dust: a = 1 000 µm – 2 500 µm; b = 500 µm – 1 000 µm; c = 250 µm – 500 µm; d = 200 µm – 250 µm; e = 150 µm – 200 µm; f = 71 µm – 150 µm; g = 0 µm – 71 µm

The diagram of testing device is illustrated in Figure 2. In order to achieve uniform heating of the sample, a hot-air oven (2) was used, which is described in more detail in ISO 871:2010 [9]. The mentioned oven was adjusted for the purpose of thermal gravimetric analysis. The sample was placed into a metal crucible (3) having an inner volume of 15 cm^3, which was mechanically interconnected with digital scales (5). Every 10 seconds, the sample weight was recorded using a computer (6) [10].

Table 1: Weight of tested samples

Sample designation	Mean particle size (μm)	Weight (g)
a	1750	1.006
b	750	1.008
c	375	0.999
d	225	1.000
e	175	0.997
f	110.5	1.002
g	35.5	1.002

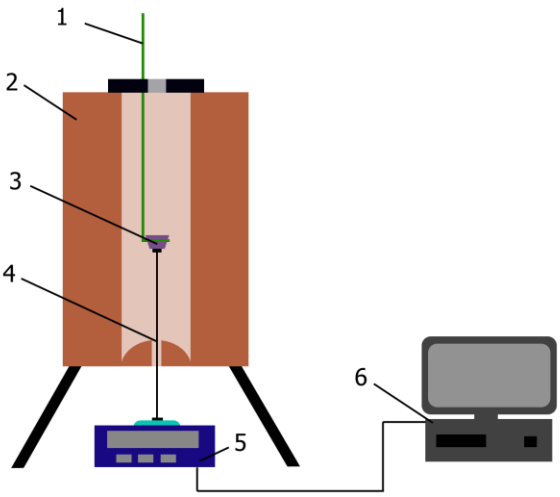

Fig.2. Schematic chart of measuring device: 1 – holder for inserted sample; 2 – hot-air oven; 3 – crucible with tested sample, 4 – interconnecting rod; 5 – scales; 6 – computer [10, 11]

Tested samples were heated by uniform heating with heating rate of 5 °C/min., maximum temperature was set to 550 °C, whereas the initial temperature of measurement was 20 °C ± 2 °C. Heating was realised by hot air with the flow rate of 6 l/min.

III. Results

The dependence of weight of individual samples on temperature in their vicinity is shown in Figure 3. According to the shape of mentioned curves the course of experiments may be divided into four distinct phases.

The first phase represents heating of the wood dust up to temperature of 110 °C – 140 °C. Drying of samples occurs during it, whereas their weight loss takes place due to water evaporation. Drying time of sample "a" was the longest, which was completed at temperature of 136 °C, whereas the shortest drying times were observed with the samples "d" and "g".

The thermal phase between 130 °C and 245 °C may be considered as the second one. From the course of gravimetric curves it is obvious that the weight of samples in that phase was almost constant. Therefore it may be supposed that at these temperatures none significant decomposition of wood dust occurs and it may be considered for stable from the short-time aspect.

At temperatures higher than 245 °C the weight of samples begins to decrease again. Significant weight loss occurs, caused mainly by thermal decomposition of individual components of the wood. In the case of samples "c" and "e" the decomposition started already at the mentioned temperature, whereas the sample "b" was stable up to temperature of 258°C. Termination of the main decomposition occurred at temperatures from 327 °C (sample "g") to 354 °C (sample "b"). Branca, Albano and Di Blasi report at the same heating rate of wood in the air flow the value of initial degradation temperature of 250 °C and the temperature of decomposition termination of 373 °C [12]. As obvious, the initiation temperature is similar to values of tested samples, however, the thermal range of their decomposition is significantly wider. This fact may be caused by different weight of samples and different value of the air flow rate.

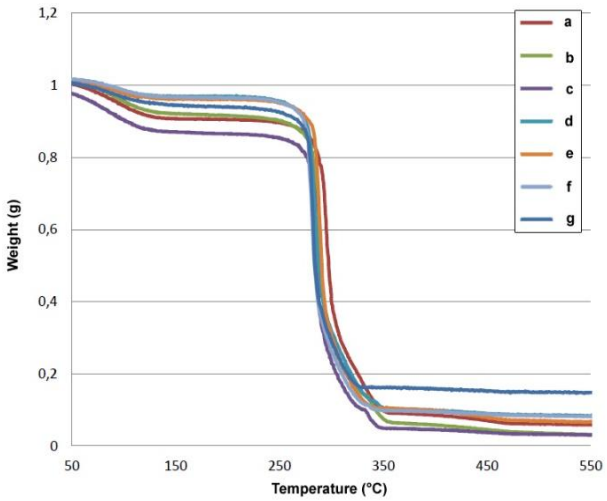

Fig.3. Thermogravimetric curves of measured samples

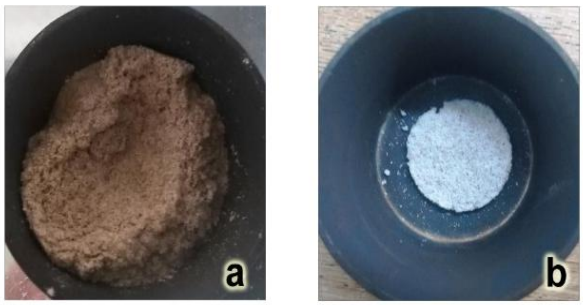

Fig.4. An example of tested sample a = prior to measurement; b = after measurement

From the data obtained by thermo-gravimetric analysis it is possible to determine the initiation temperature, maximum rate and termination of decomposition reactions. Whilst the initiations and terminations may be read directly from the graphs in Figure 5, the rate of chemical reaction attains its maximum at the peak points of its derivation according to the time, which is shown in Figure 5.

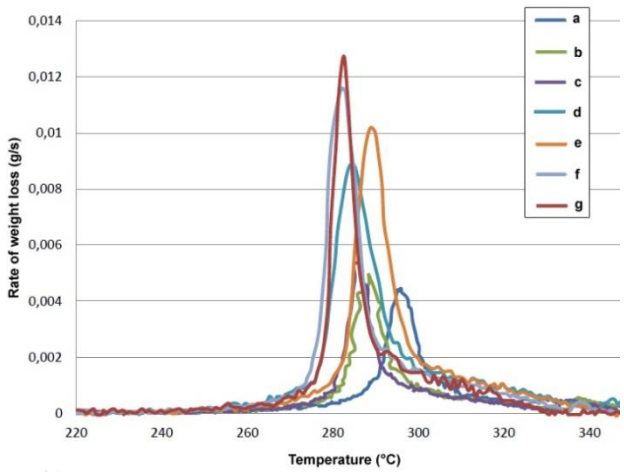

Fig.5. Derivative thermo-gravimetric curves of tested samples

The dependence of thermal characteristic of decomposition of wood dust on the size of its particles is shown in Figure 6. As obvious, the trend of initiation of decomposition reactions seems to be actually constant in the tested range of fractions with their directive approaching zero.

The temperature of peaks of derivative thermo-gravimetric (DTG) curves suggests a slight growth with the growing particle size. The obtained relationship seems to be linear in accordance with the equation:

$$T_p = 0.0074 \times f_A + 282.25 \quad (1)$$

where T_p is peak temperature of DTG and f_A is average fraction size. The square of correlation coefficient attains the value of 0.8729.

Final decomposition temperature $T_f$seems to be in logarithmic dependence on the average fraction size. Form of this equation is:

$$T_f = 6.3839 \times \ln(f_A) + 308.84 \quad (2)$$

with the square of correlation coefficient equal to 0.7906.

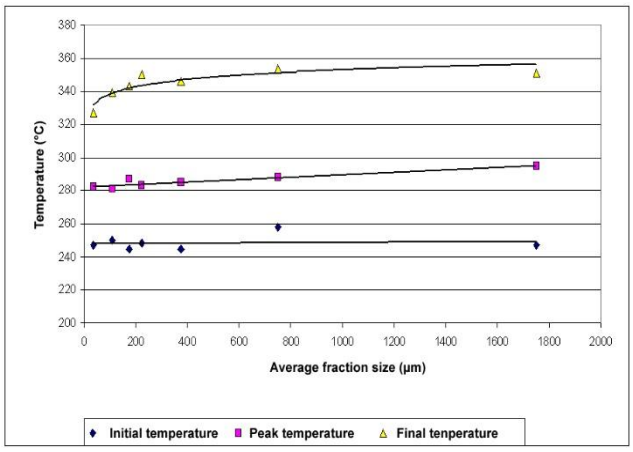

Fig.6. Dependence of initial, peak and final decomposition temperature of wood dust on average fraction size

IV. Conclusion

In the first phase of heating the wood dust mixture (up to 110 °C - °40 °C) mainly its drying has occurred. The main phase of its thermal decomposition occurs in the temperature range from 245 °C to 354 °C with the peak within the range between 281 °C – 295 °C.

The particle size of the deposited dust did not exert any effect on the temperature of its initiation during testing, however with the growing fraction size also thermal range of thermal decomposition increased. Based on the measured results it may be stated that smaller fractions of the wood dust decompose faster than the greater particles. This phenomenon may be explained by considerably higher proportion of dust particle surface to volume in the case of fraction with smaller grain size.

Acknowledgment

This paper was supported by the Cultural and Educational Grant Agency of the Slovak Republic, grant No. 028STU-4/2013 “E-learning as a Handbook of Health and Safety in Welding”.

References

[1] J. Jiang, “Effect of flame retardant treatment on dimensional stability and thermal degradation of wood”, Construction and building materials, vol. 75, Jan. 2015, pp. 74–81

[2] A. I. Moreno, R. Font, “Pyrolysis of furniture wood waste: Decomposition and gases evolved”, Journal of Analytical and Applied Pyrolysis, vol. 113, May 2015, pp. 464–473

[3] F. Shafizadeh, “Pyrolytic reactions and products of biomass”, in Fundamentals of thermochemical biomass conversion, R. P. Overend, T. A. Milne, L. K. Mudge, Ed. London and New York: Elsevier applied science publishers, 1985, pp. 183-217

[4] M. Poletto, A. J. Zattera, M. M.C. Forte, R. M.C. Santana, “Thermal decomposition of wood: Influence of wood components and cellulose crystallite size”, Bioresource technology, vol. 109, April 2012, pp. 148–153

[5] M. J. Prins, K. J. Ptasinski, F. J.J.G. Janssen, “Torrefaction of wood: Part 1. Weight loss kinetics”, Journal of analytical and applied pyrolysis, vol. 77, issue 1, Aug. 2006, pp 28–34

[6] J. Martinka, T. Chrebet, “Activation energy of teak and oak wood spontaneous ignition”, Advanced materials research, vol. 1001, Aug. 2014, pp. 262-266

[7] M. Zachar, I Mitterová, Q. Xiang, A. Majlingová, J. Cong, Š. Galla, “Determination of fire and burning properties of spruce wood”, Drvna industija, vol. 63, Sep. 2012, pp. 217-223

[8] J. Martinka, P. Rantuch, K. Balog, “Assessment of the impact of spruce wood particle size and water content on the ignition temperature of dust clouds”, Cellulose chemistry and technology, vol. 49, Juli 2015, pp. 549-558

[9] ISO 871: Plastics. Determination of ignition temperature using a hot-air furnace, 2010

[10] P. Rantuch, T. Chrebet, “Thermaldecomposition of cellulose insulation”, Cellulose chemistry and technology, vol. 48, Juli 2014, pp. 461-467

[11] P. Rantuch, D. Kačíková, J. Martinka, K. Balog, “Vplyv rýchlosti ohrevu na termický rozklad izolácie z drevovláknitej hmoty”, Acta facultatis xylologiae Zvolen, vol. 56, 2014, pp. 97-108

[12] C. Branca, A. Albano, C. Di Blasi, “Critical evaluation of global mechanisms of wood devolatilization”, Thermochimica acta, vol. 429, issue 2, May 2005, pp. 133–141

AUTHOR'S PROFILE

Ing. Peter Rantuch, PhD.
was born in Považská Bystrica, Slovakia. He has received his PhD. in fire protection from Faculty of Wood Science and Technology at Technical University in Zvolen. Currently he is researcher at Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislava. His research interests are thermal decomposition of materials and fire protection.

Ing. Zuzana Szabova, PhD. IWE
was born in Bratislava, Slovakia. She has received her PhD. in field of Mechanical Engineering and Materials – Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava. She is currently researcher at Faculty of Materials Science and Technology in Trnava, Department of Safety Engineering. Her research interests are OHS and safety engineering.