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# Thermogravimetric studies of exotic woods in oxidative environment

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**Abstract:** *Thermogravimetric studies of exotic woods in oxidative atmospheres.* The aim of this studies is to gain the knowledge on thermal decomposition of exotic woods (lapacho, teak, bintangor) and comparing it to domestic species (pine). This paper described experimental research with the use of thermogravimeter for thermal analysis. The measurements were made in polithermal conditions with heating rates: 2,5°C/min, 10°C/min and 20°C/min, under air atmosphere. The TGA experiments confirms the previous report that the process thermal decomposition of wood under an oxidative atmosphere is divided into two phases. Obtained results show higher thermal resistance of exotic woods. It should be noted that these are slight differences.

*Keywords:* exotic wood, wood, thermogravimetry, thermal decomposition,

## INTRODUCTION

Wood, wood based materials are one of the most important materials in the building and construction industries of its renewability, and appropriate characteristics. From the chemical point of view, wood is composite material consist of cellulose, hemicelluloses and lignin, and also with smaller quantities of extractives and inorganic matter (Pofit-Szczepańska et al. 2014, Bryden et al. 2002, Poletto et al. 2013)). From the physical point of view, wood is natural materials and has got a complex structure with anisotropic properties. Nevertheless, wood is inherently flammable. Well-known, that the chemical and physical properties of wood such as moisture content, chemical composition, density are key factors that affect the characteristics of combustion of wood. The burning of a solid is essentially a three-stage process consisting of heating, thermal decomposition and ignition (Pofit – Szczepańska et al. 2014, Hrabaly, Jelemensky 2014). Thermal decomposition is the first thermochemical conversion of wood and connected with pyrolysis is the first step in any gasification or combustion process and thus understanding of thermal decomposition is essential to well-known mechanism of combustion of wood. The pyrolysis of solid fuels plays an important role in both the ignition and growth stages of fires. Thermal decomposition of wood is a very complicated process which proceeds in hetero phase configuration and is a complex interplay of chemistry, heat, and mass transfer (Jaskółowski et al. 2010, Jin at al. 2013)). Most reported studies about the thermal decomposition of woods focus on pyrolyzing cellulosic materials under inert atmospheres using either experimental or theoretical methods and refers to European woods (Shen at al. 2009). The knowledge in this space is comprehensive. In the last few years we can observe a rising interest in exotic wood (Wesselik, Ravenshorst 2008, Jaskółowski at al. 2010). Exotic woods show major advantages with regard to strength and stiffness as compared to European woods. Due to their high characteristic densities, modulus of elasticity values can be between 60 and 80 % higher than that of softwoods from European region at a reference moisture content of 12 % (van de Kuilen 2013).

The aim of this study is to obtain a good knowledge on thermal decomposition of exotic woods under oxidative atmospheres, mainly examining the effects of heating rate to different species.

MATERIALS AND METHODS

Thermal decomposition of solid wood is performed using a TA Instruments, model Q 500 thermogravimeter (Fig. 1) under oxidative atmosphere. Four different wood samples, namely pine, lapacho, teak and bintangor. Every kind of wood used for research was of natural origin. Prior to thermogravimetric experiments, the particles were reduced to less than 0,5 mm (500 µm) to ensure the heat transfer rate within the kinetic regime of the decomposition. to small chips (1 mm). Masses of the samples oscillated between 20 mg and 30 mg. The samples were heated from 20 to 600$^0$C at heating rates of 2,5, 10 and 20$^0$C/min. During the experiment the furnace of TGA was flashed with 90 ml/min air to maintain an oxidative atmosphere for the decomposition of the particles. For each experiment, weight loss of the samples was determined as a function of temperature. TG curves as well as the derivative curves (DTG) of the sample were obtained as an output of the experiment.

**Figure 1.** Thermogravimeter for the thermal analysis

RESULTS AND CONCLUSSIONS

Obtained results are summarized in table 1.

**Table 1.** The characteristic values of TG and DTG curves for the different species under 2,5, 10 and 20$^0$C/min heating rate.

| Kind of wood | Φ (˚C/min) | $T_{Pap}$ (˚C) | $T_{50\%}$ (˚C) | $T_{I\ maks}$ (˚C) | $T_{II\ maks.}$ ($^0$C) | $m_{poz.}$ (%) |
|---|---|---|---|---|---|---|
| pine | 2,5 | 234,5 | 315,4 | 314,4 | 443,7 | 0,9 |
| | 10 | 238,8 | 323,4 | 325,9 | 454,9 | 0,8 |
| | 20 | 239,2 | 336,4 | 338,9 | 469,7 | 0,6 |
| lapacho | 2,5 | 254,1 | 309,3 | 293,8 | 426,6 | 0,9 |
| | 10 | 259,2 | 339,4 | 324,4 | 433,3 | 1,1 |
| | 20 | 262,4 | 341,9 | 330,8 | 443,1 | 0,7 |
| teak | 2,5 | 248,9 | 314,9 | 303,7 | 438,7 | 1,2 |
| | 10 | 251,8 | 335,3 | 326,8 | 461,2 | 0,9 |
| | 20 | 259,5 | 342,3 | 339,1 | 471,9 | 0,8 |
| bintangor | 2,5 | 263,3 | 324,1 | 293,1 | 424,9 | 0,6 |
| | 10 | 268,0 | 342,7 | 320,4 | 478,1 | 0,9 |
| | 20 | 271,7 | 342,7 | 331,8 | 499,5 | 0,6 |

Φ – heating rate (˚C/min),
$T_{I\ maks}$ – pyrolysis temperature of the beginning of an active phase I (˚C),
$T_{II\ maks}$ – pyrolysis temperature of the beginning of an active phase II (˚C),
$T_{50\%}$ - temperature of 50% mass loss (˚C),
$m_{poz.}$ – mass of pyrolytic residue (%).

The fig. 2 (example) shows the mass loss (TG) (%) and the derivative of mass loss (DTG) (-dX/dt) curves obtained during the pyrolysis of bintangor wood under oxidative ($N_2/O_2$) atmosphere at a heating rate of $20^0$C/min.

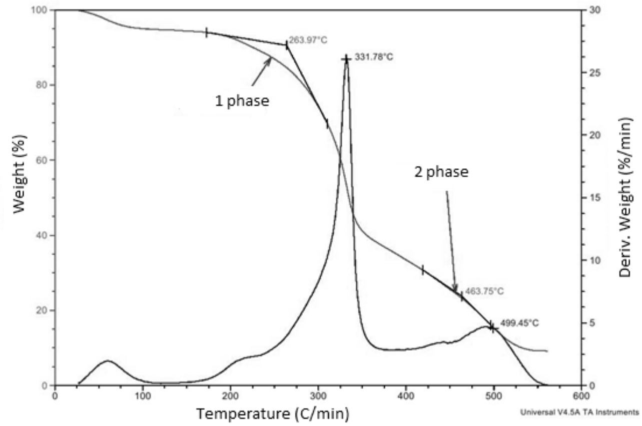


**Figure 2.** The TG and DTG curves of bintangor wood under heating rate of $20^0$C/min

According to this figure, pyrolysis curves of wood the represenative shape for domestic (pine) and exotic woods. The thermal process describes two main phases independently of kind of wood (Jeguirim, Trouve 2009). Two phases of thermal decomposition are also visible in the DTG curves. The first most important phase started from 234,$5^0$C (for pine, 2,$5^0$C/min) to 262,$4^0$C (for lapacho, $20^0$C/min). The second phase started from 424,$9^0$C (for bintangor, 2,$5^0$C/min) to 499,$5^0$C (for bintangor, $20^0$C/min).

During the studies of thermal decomposition was observed implications of heating rate on this process. An increase of the heating rate tended to delay thermal degradation processes towards higher temperatures.

The TGA experiments confirms the previous report that the process thermal decomposition of wood under an oxidative atmosphere is divided into two phases: the first phase is considered to be voltizilation of the constituents and the second stage is contributed to combustion of char formed in the initial stage.

A summary of findings are as follow:

1. Analyzing given curves we can say, that thermal degradation of a sample begins fastest at heating rate of 2,$5^o$C/min. Together with the growth of heating rate grows temperature of the beginning of thermal decomposition – the highest at $20^o$C/min.
2. Obtained results show higher thermal resistance of exotic woods. The difference is clearly visible when the heating rate is low. However with higher heating rates this difference blurs. We can also observe that temperatures of partial mass decrease do not show the superiority of exotic woods over domestic wood.
3. Density of the wood is one of the dominant parameters influencing thermal decomposition. We can observe that woods with higher densities thermally decompose later (in higher temperatures) than woods with lower densities
4. Temperature values of partial mass decrease of examined wood samples were decreasing with the decrease in heating rate. This shows that examined woods decomposed earlier while heated with lower rate. The higher the rate of heating the later the decomposition can be observed.

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**Streszczenie:** *Badania termograwimetryczne egzotycznych gatunków drewna.* Zakres pracy objął badania eksperymentalne z wykorzystaniem termograwimetru do analizy termicznej. Materiał badawczy stanowiły próbki krajowego drewna sosnowego oraz następujących gatunków drewna egzotycznego: lapacho, teak i bintangor. Pomiary zrealizowano w warunkach politermicznych z zastosowaniem szybkości ogrzewania: $2{,}5^0$ C/min, $10^0$ C/min i $20^0$ C/min, w atmosferze powietrza. Wyniki badań wskazują, że temperatura początku rozkładu termicznego drewna egzotycznego jest wyższa. Zależność ta jest szczególnie widoczna dla najniższej szybkości ogrzewania ($2{,}5^0$C/min). Ponadto badania wykazały, że niezależnie od gatunku drewna można zaobserwować dwu fazowy rozkład termiczny drewna.

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