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Development and testing of apparatus for wooden chips voids measurement

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Abstract. The interparticle porosity of wooden chips (commonly called voids) is a very important factor which significantly affects properties of wooden chips, i.e. bulk density, combustion speed or dielectric properties. Dielectric properties can be used for the measurement of its moisture content and it is the moisture content which is one of the most important factors that affect wooden chips calorific value. This paper is focusing on the development of measuring apparatus for wooden chips voids measurement. The principle of measuring apparatus is based on a gas displacement method. Measuring apparatus is composed from two chambers; both with the same volume. One from chambers is comparative one and second is experimental one. The pressure operating range was from 1,000 to 1,500 Pa. Results showed nontrivial behaviour of wooden material with the change of moisture content which was probably caused by different structures of tested materials.

Key words: wooden chips, porosity, gas displacement method.

INTRODUCTION

Wood chips are typically used as a fuel in various facilities. Common use cases include home boilers for individual family housesor sophisticated heating apparatuses capable of supplying a large number of households with energy.

The moisture content is very important property of wood chips because the water contained within a fuel significantly influences its calorific value (Nyström & Dahlquist, 2004), which is a crucial factor in this case. The moisture content of wood chips can differ significantly, usually between 20% and 55%. From this point of view, autonomous measurement of wood chips moisture content just before this fuel enters a boiler could make the combustion control much more effective.

It is a well-established fact that the dielectric properties of materials are significantly influenced by the water content. Nelson (2005) has published many important articles in this area. James (1975) has focused directly on wood and has published the measurement statistics in the frequency voltage from 20 Hz to 50 MHz for various moisture contents and temperatures. Another important parameter affecting the dielectric properties is the bulk density (Nelson, 1991; Nelson, 2015). Paz et al. (2011) tested dielectric mixing models for the purpose to determine the dielectric constant of

woody biomass at different water contents. An important component of their model was the air volumetric content. Another possibility for wood chips moisture measurement is x-ray. X-radiation is absorbed by material in relation to the total mass in the radiation beam. It is clear that this method is significantly influenced by the material bulk density as well (Nyström & Dahlquist, 2004).

The knowledge of material porosity is crucial for development of universal method for wood chips moisture contend measurement. Several methods for material porosity measurement are available. One of them is the gas displacement method – GDM (Karathanos & Saravacos, 1993; Rahman, 2003; Sahin & Sumnu, 2006). This method can be fast and effective. Several researches used this method for volume/density measurement of seeds (Thompson & Isaacs, 1967; Fang & Campbell, 2000). Authors reported that their measurements were influenced by material internal pores. Another similar experimental methods are liquid and solid displacement method. However, the usage of the liquid displacement method is problematic in case a material that quickly absorbs the liquid (Rahman, 2005; Sahin & Sumnu, 2006). The solid displacement method is similar to liquid displacement method but instead of liquid it uses fine particulate material (sand, glass bead, seed, etc.). The disadvantage of this method is its duration and labour intensity (Sahin & Sumnu, 2006). The bulk density of the agricultural materials can be estimated based on the acoustic measurement (Adamchuk et al., 2004). However, this method is affected by a material modulus of elasticity and material structure.

As it follows from previous text, fast determination of wood chips voids could be a way to better use its calorific value by better combustion control. That is why the main aim of the work presented in this article was to apply GDM for wooden chips voids measurements.

MATERIALS AND METHODS

A new apparatus for wooden chips voids measurement was developed. The measuring apparatus for measurement of voids of wooden chips (Fig. 1) is composed from two chambers with the same volume. Chambers are attached to bearing frame together with connecting line (Fig. 2), which the aim to haul the medium (in our case the air). The connecting line is divided into two parts with the help of three closing valves when digital pressure meter is attached to the first part. Basically, this design is well-known as it was described eg. by authors Sahin & Summu (2006).

Samples from three kinds of wood were (pine, beech, oak) prepared for our experiment. All samples had a cubic shape with 20 mm edge length (see Fig. 3). Samples were measured and weighed before each measurement to determine its volume and moisture. The fault of determining the samples volume did not exceed 3%. At the beginning of the measurement, the samples were dried to the dry matter in the hot-air oven under the temperature of 105 °C (ASABE Standard S358.2, 2006). After taking samples out, their weighing and proportions measurement was done. Then, the samples were inserted into the measuring chamber and the chamber was together with the samples inserted into the pressure mechanism of the measuring chamber.

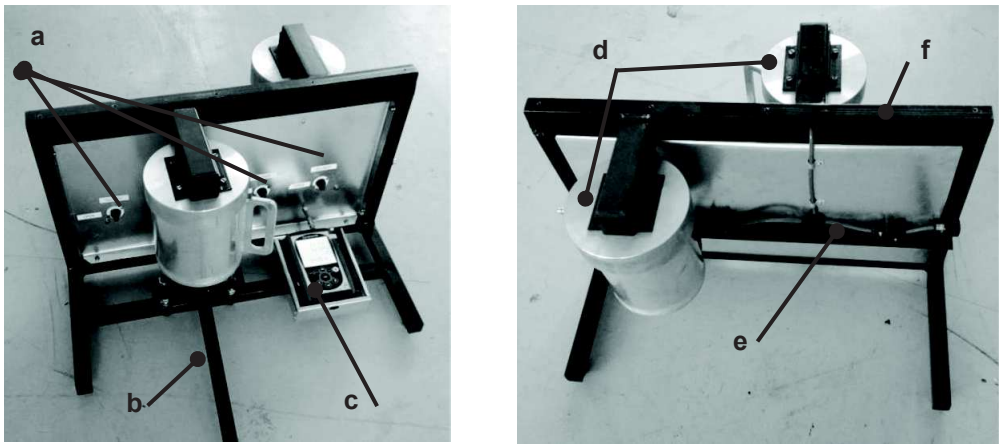

Figure 1. Measuring apparatus: a) closing valves; b) pressure mechanism of measuring chambers; c) digital pressure meter; d) measuring and comparing chambers; e) connecting line; f) bearing frame of the measuring apparatus.

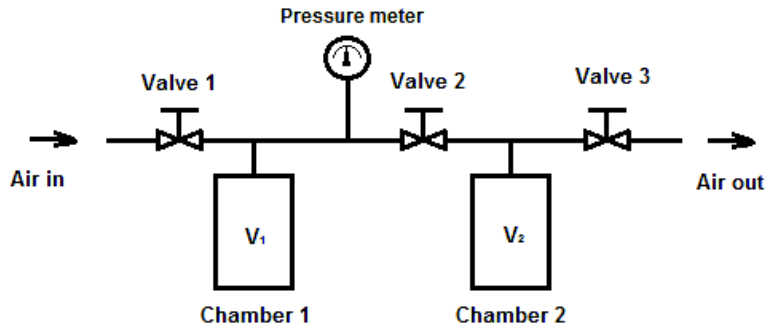

Figure 2. Linking conduct of the measuring apparatus.

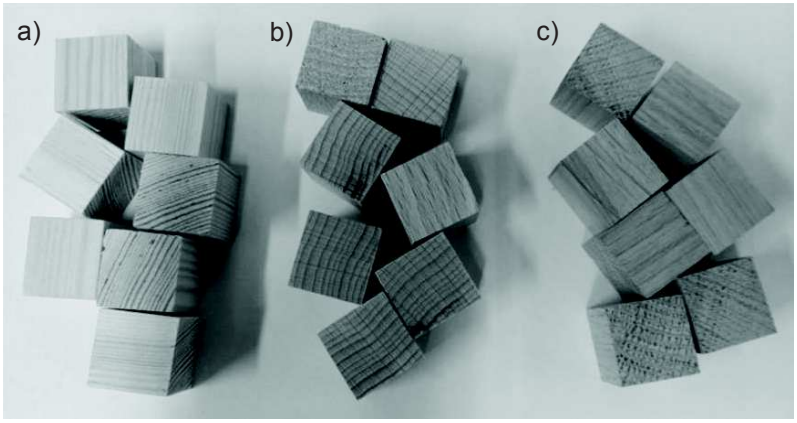

Figure 3. Testing samples: a) pine, b) beech, c) oak.

After the connecting the source of pressure medium, the first valve was opened and the other two valves were closed. The pressure from 1,000 to 1,500 Pa was put into the first part of the connecting line and, subsequently, the first valve was closed. After the pressure was ballanced in the first part, the value of the pressure in the first part of connecting line was recorded from digital pressure meter.

Then the second closing valve was closed and the pressure was released into the second part of connecting line when first and third valves were still closed. The value which was at the pressure gauge after the connecting both branches of connecting line was recorded from the pressure meter. The volume of the sample was counted with the help of the following equation (Sahin & Sumnu, 2006):

$$V_s = V_2 - V_1\left(\frac{P_1 - P_2}{P_2}\right) \quad (1)$$

where: V_s – calculated volume of the sample (m^3); V_1, V_2 – volume of the chambers (m^3); P_1, P_2 – measured pressures (Pa).

Then, samples were inserted into water with the temperature 15 ± 3 °C for one hour. After this time, samples were taken out and inserted into the hermetic plastic bag where they were kept for 12 hours in order to balance the moisture content of all samples at the same level. After the balancing the moisture content, the samples were weighed again and its dimensions were measured in order to determine its moisture content and volume. After that, the measurement described above was repeated.

Volume measurements by the GDM method was 15 times repeated. All together the samples were macerated four times. First three times for one hour and within the forth maceration, for 36 hours. The samples from pine reached moisture content 6.4%, 20.6%, 28.0% a 35.6%. The samples of oak reached moisture content 12.7%, 15.6%, 30.3% a 53.9%, and the samples of beech reached moisture content 6.1%, 26.2%, 39.1% a 43.7%.

RESULTS AND DISCUSSION

Results of the measurement are charted in the graphs in Fig. 4. Each of the three graphs contains three curves. First curve presents the real volume of measured samples as it was determined by hand measurement. From all three diagrams, obvious effect of samples swelling can be seen. The degree of volume change for individual materials approximately coincided with an increase of moisture content. However, the response of individual materials was different. The second curve presents the course of volume which was measured by our measuring apparatus. Volumes measured corresponded with the volume of samples, without pores in the material. The difference between both measured values present a part of pores volume in the material. In Fig. 4, these data are displayed as percentage share from the real volume of the samples.

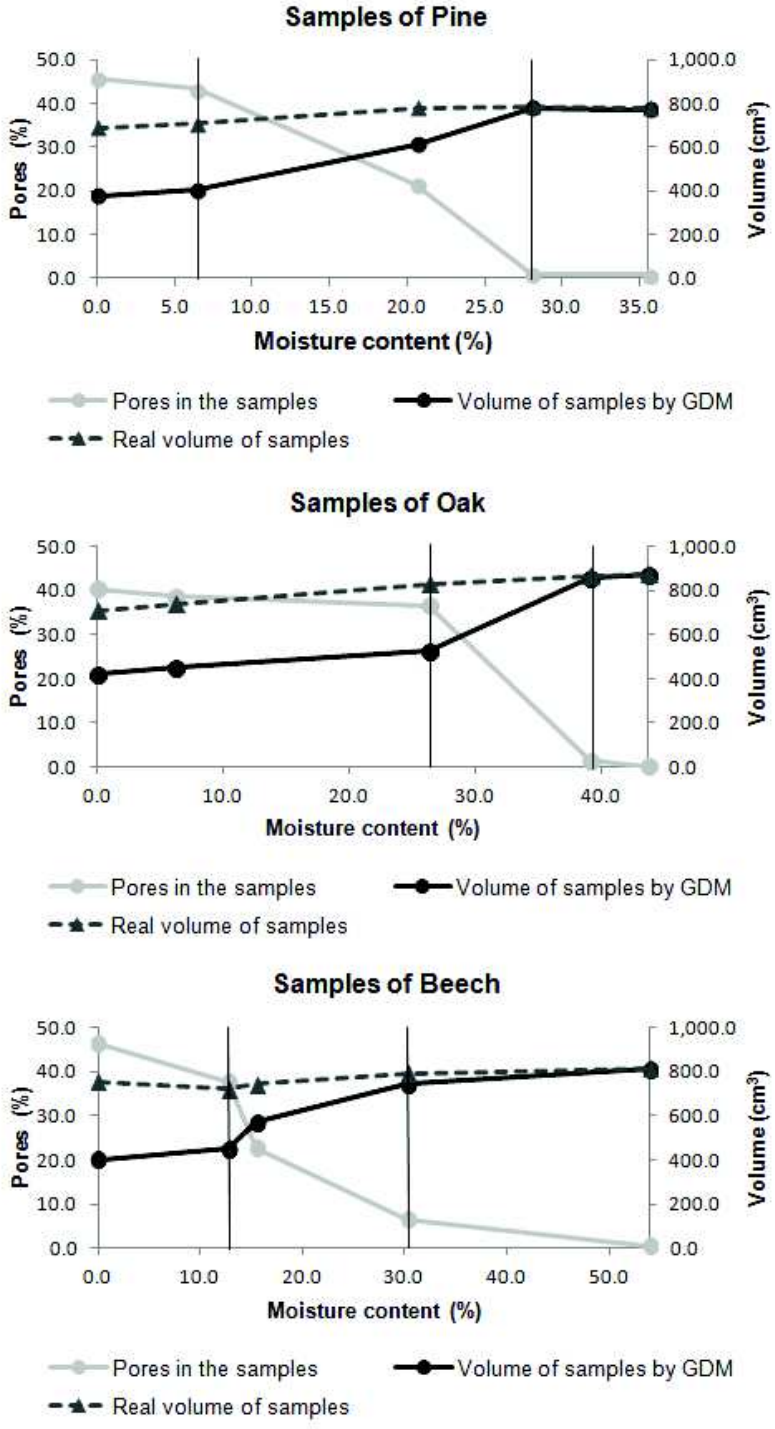

Figure 4. Graphs of the dependence of filling of pores by water,samples real and samples measured volume on material moisture content. GDM – gas displacement method.

It is possible to distinguish between three different areas in the graphs in Fig. 4. Slight change of proportional volume of pores during moistening was typical for the first area. This area was relatively short for pine and beech wood; nevertheless for oak wood it reached 30% of moisture content. In this area, water penetrated into the material but most of bigger pores still remained full of air. The second area was typical by fast change of pores percentage volume with the increasing moisture content. It can be assumed that, in this phase, the gradual filling of bigger pores by water was observed. The fastest change was observed for oak wood again. In the third area, most of the pores were filled with water and volumes measured by apparatus almost matched to the real volumes. In this area, it is possible to still expect the growth of moisture content. Nevertheless, the movement of water was determined by diffusion processes, which are considerably slower.

The Fig. 4 showed that from 40% up to 45% shares of the pores were observed for completely dry material. When using the method and the apparatus presented in this article, measured porosity values presented not only voids (space between particles), but also bigger part of inner pores volume. This fact can be evaluated as a positive one, because this volume also fundamentally influences dielectric properties of material (Nelson, 1991). Our results also indicated that the knowledge of the kind of material is important not only to explain different materials dielectric properties, but also different behaviour of water in material. Arrangement and shape in which water is located in the material influences its dielectric properties as well (Serdyuk, 2008; Paz et al., 2011).

CONCLUSIONS

New apparatus for wooden chips voids measurement, which function is based on gas displacement method, was developed.

Developed aApparatus was successfully tested on three types of samples and with different samples moisture content. Results indicated nontrivial behaviour of material with the change of moisture content. Three different areas of the curve describing the dependence of measured pores on material moisture content can be distinguished. These areas were different for different wood tested. This was probably caused by different structures of tested materials.

This behaviour is needed to be taken into consideration when developing methods for fast measurement of wooden chips moisture content made from different wood materials.

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