MEASUREMENT THE VOID OF WOODEN CHIPS BY GAS DISPLACEMENT METHOD

Václav KŘEPČÍK[1], František KUMHÁLA[1], Jakub LEV[2]

[1]*Department of Agricultural Machines, Czech University of Life Sciences in Prague, Faculty of Engineering, Kamýcká 129, 165 00 Praha 6 – Suchdol, Czech Republic*
[2]*Department of Physics, Czech University of Life Sciences in Prague, Faculty of Engineering, Kamýcká 129, 165 00 Praha 6 – Suchdol, Czech Republic*

Abstract
The void of wooden chips is very important factor which significantly affects properties of wooden chips, i.e. dielectric properties, speed of combustion. This paper is focusing for void measurement of pure wooden chips by apparatus for measurement the volume of particular material. The principle of measuring apparatus is based on the gas displacement method. The volume between the parts of wooden chips is calculated on the basis of decreasing pressure by Boyle-Mariott's law. The pressure operating range was from 1000 to 1500 Pa. The moisture content of the wooden chips was reduced by hot-air oven with temperature 105 °C. The difference of measurement volume of wooden chips by displacement method and real volume was determined. The difference between real volume and volume which was measurement by displacement method was change during the drying the samples of the wooden chip. The effect of the internal porosity of the material was detected.

Key words: *Boyle-Mariott's law; void; wooden chips; moisture content.*

INTRODUCTION

Wooden chips are used for the production of heat energy in various devices. Wooden chips are burned in facilities that serve for heating individual houses or in very sophisticated facilities for the heating of a large number of buildings. According to *Díaz-Yáñez, et al. (2013)* in a number of countries, the use of wooden chips for energy purposes can be doubled. The most important characteristic of wooden chips is the moisture content, which clearly influences the heating capacity of the material during combustion *(Nyström & Dahlquist, 2004; Swisher, 1976)*. The moisture content of wooden chips ranges from 20% to 55%. With legislative changes, heating companies for the production of heat energy by combustion of wood chips are forced to reduce the content of pollutants in the combustion gases. The regulation of combustion process based on the moisture content before the entry of wooden chips into the combustion chamber can bring about a reduction in the content of pollutants in the combustion gases. *Nelson (2005)* demonstrates in his studies that the dielectric properties of the material are significantly influenced by the moisture content. *James (1975)* published the results of his measurements of dielectric properties of wood and hardboard at various temperatures, frequencies, moisture content ratio and fibre orientation. From the results of experiment (*Nelson, 1991*), it's evident that volume density is another important parameter affecting dielectric properties.
The void can significantly influence the measurement of the moisture content of wooden chips. There are several methods for determining the volume of particular particles, it means their void. One of these methods is the gas displacement method *(Sahin & Summu, 2006). Thompson & Issacs (1967); Fang & Campbell (2000)* used the gas displacement method to measure the volume of the seed in their research. From the results they achieved, it is evident that the porosity of the material influences the results of the measurement of volume by the of gas displacement method. *Křepčík et al. (2017)* carried out the calibration of the measuring apparatus for the measurement of the volume of particulate material respectively the void in their research. From the measured data it was found that the moisture content of the material influenced the results of the measurement of the void because the measuring medium penetrated into the internal pores of the material.
This paper is focused to measurement of volume respectively the void of pure wooden chips by apparatus based on the principle of Boyle-Marriot's law.

MATERIALS AND METHODS

The measuring apparatus for measurement of void of wooden chips (Fig. 1) is composed from two chambers with the same volume and the connection conduit for the displacement of measuring medium (the air in this case). The connection conduit includes the three manual valves for displacement of measuring medium between the comparative and measuring chamber and the pressure values were displayed on the digital pressure gauge. The principle of gas displacement method is used for the measuring the samples with irregular shape and this method using Boyle-Mariott's law (*Sahin & Summu, 2006).*

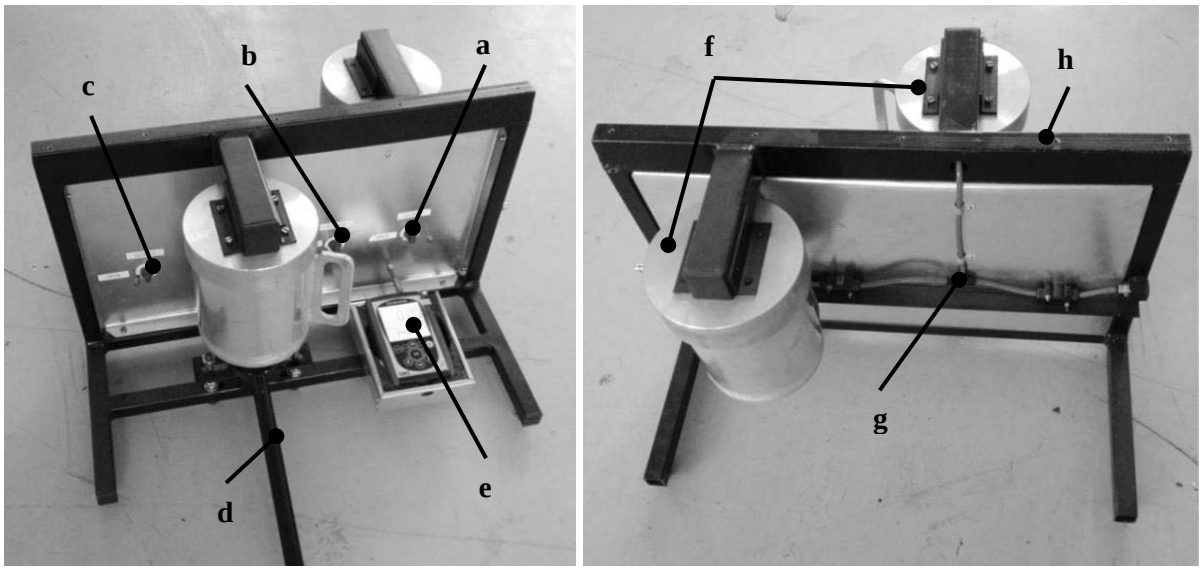


Fig. 1 Measuring apparatus: a) closing valves no. 1; b) closing valves no. 2; c) closing valves no. 3; d) pressure mechanism of measuring chambers; e) digital pressure meter; f) measuring and comparing chambers; g) connecting line; h) bearing frame of the measuring apparatus

The samples were sorted to three fraction of beech wooden chips (Fig. 2). The samples were inserted into the cold water and they were in the water for 24 hours for achievement of the maximal moisture content in the samples. After taking samples out of water they were inserted into the plastic bags for homogenization of the moisture content in all particles of wooden chips. The samples were inside the plastic bags for 24 hours and the excess water was removed in the step, too. The samples were filled to the measuring chamber by gravitational method without mechanical pressuring. The samples were aligned with the top edge of the measuring chamber by ruler. The measuring chamber with the samples were inserted to the pusher mechanism.

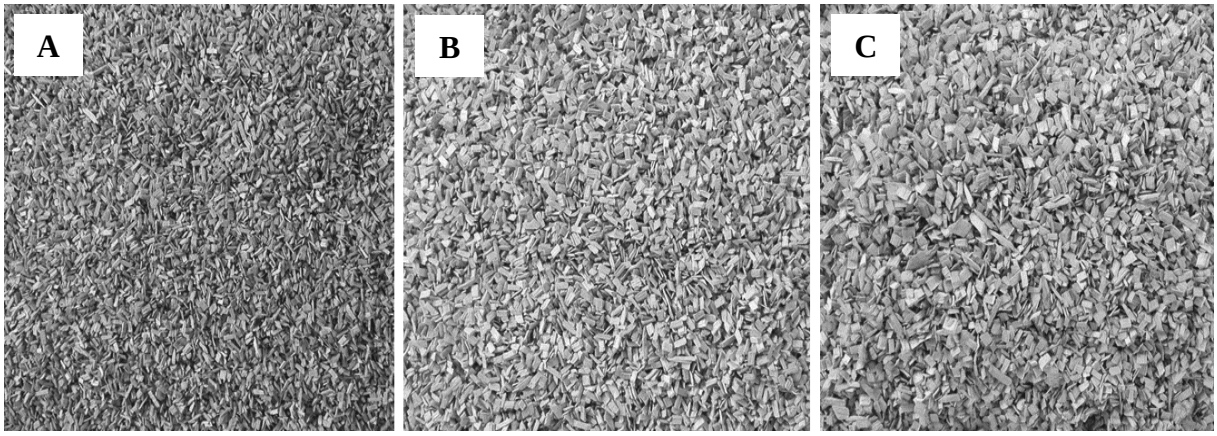


Fig. 2 A) Fraction x < 3.15 mm; B) – Fraction 3.15 mm < x < 5 mm; C) Fraction x > 5 mm

The measuring medium (the air in this case) was pushed into the first part of the connection conduit and the pressure was between 1000 Pa to 1500 Pa. The manual valves no. 1 and 2 were closed. After the

pressure settled in the first part of connection conduit, the value of the pressure in the first part of connection conduit was deducted from the pressure gauge and recorded like pressure P_1. After the pressure recording (P_1) the manual valve no. 2 was opened and the manual valve no. 3 was in the closed position. After the pressure settled in the all connection conduit, the value of the pressure in the all connection conduit was deducted from pressure gauge and recorded like pressure P_2. The manual valve no. 3 was opened for remove the pressure from connection conduit. This measurement was repeated ten times. The volume of the sample can be counted with the help of the following equation. The equation is based on Boyle-Mariot's law *(Sahin and 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).

The samples were subsequently inserted into the hot-air oven and they were dried at the temperature 105 °C (ČSN 72 1012). The drying of the samples continued until the weight of the refuel sample was decreased to determine the moisture content by 10 to 15 g. The samples were mixed every 15 minutes to ensure uniform drying of the sample throughout the profile. After the drying samples, they were inserted into the plastic bags for homogenization of the moisture content in all particles of wooden chips and were left for 24 hours to homogenize the samples and to cool down. The samples were measured by the same system which is described above, after this step.

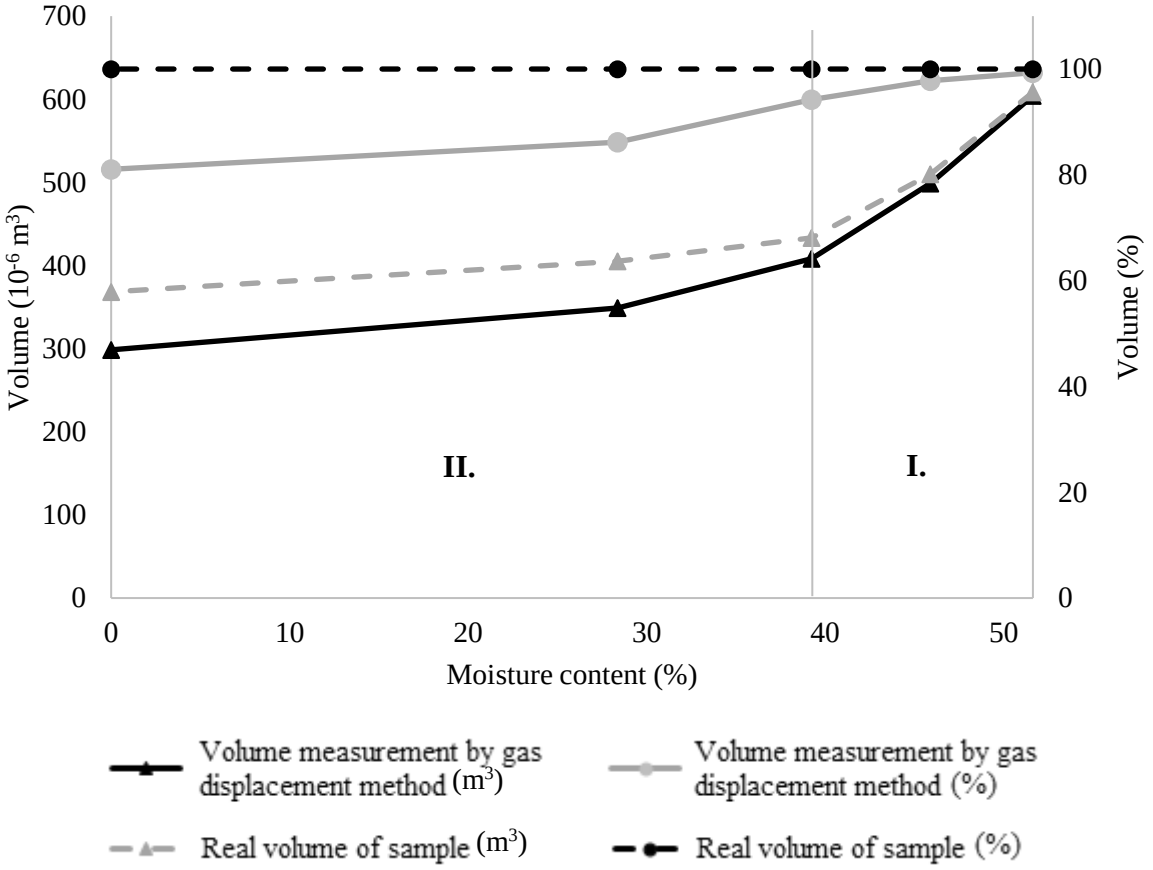
RESULTS AND DISCUSSION

Results of the measurement are displayed in the Fig. 3. Each of the three diagrams contains four curves. The first curve always presents volumes which were measurement by gas displacement method. The second curve presents the real volume of samples the wooden chips. The third and fourth curves represent the percentage of real sample volume and the volume measured by the gas displacement method.

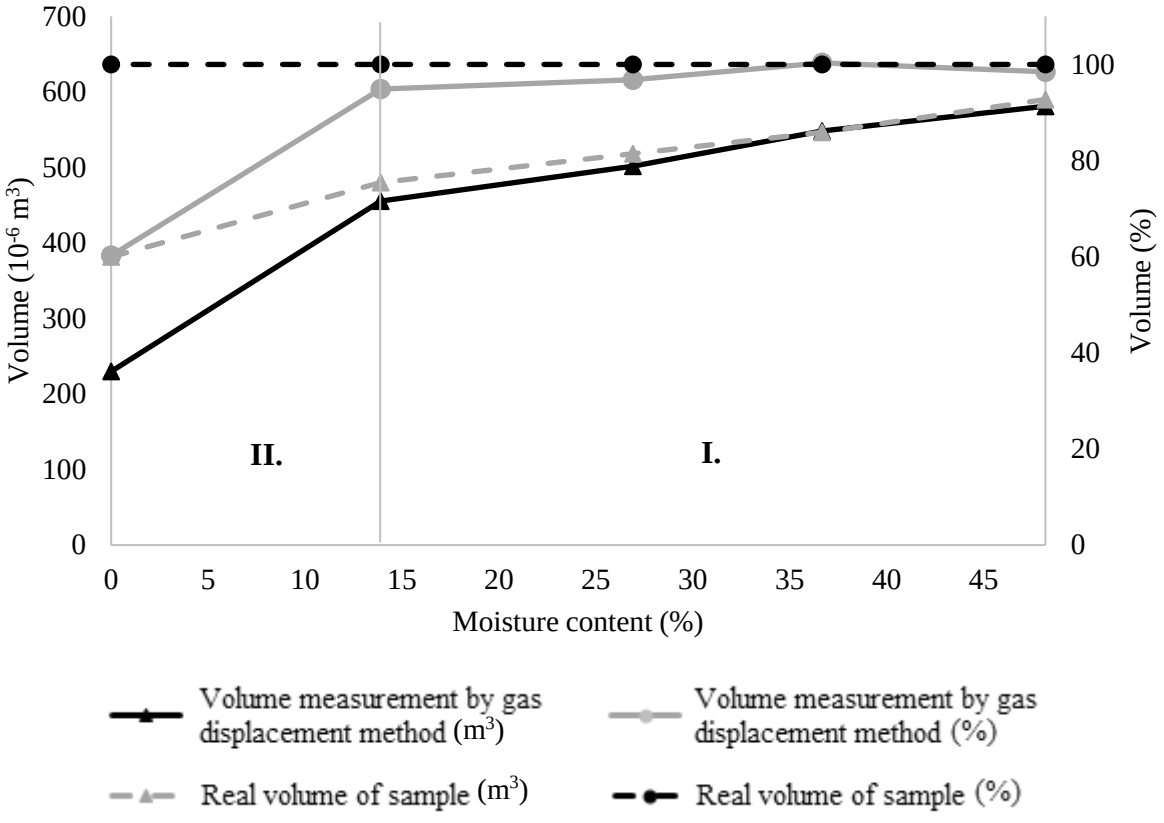
In the diagrams in the Fig. 3 it is possible to mark two different areas. For all three factions, it can be seen that the accuracy of the measurement of the volume of wooden chips by the gas displacement method increases with the increasing of moisture content the samples. In the first area, the internal pores of the wooded chips were filled with water and the proportion of measuring media penetrated into the internal pores was reduced. This area is different for each fraction by its length. For fractions where the particle size is less than 3.15 mm, this first area extends to a fraction of the moisture content of about 35%. The percentage increase in the volume measurement error for this fraction is almost linear. Very similar to the course is evident in the fraction, where the particle size is greater than 5 mm. The error of measurement of volume by gas displacement method is increased below the 35 % of moisture content. The water was removed from the internal pores of samples under this edge of moisture content and the measuring medium can be penetrate into the internal pores. For a fraction with a particle size of 3.15 mm < x < 5 mm, it is evident that the increase in the measurement error occurred only when the moisture content was below 15%.

The presented results, shows that there can be influence between the volume of wooden chips and the amount of pores in the particles of wooden chips by gas displacement method. This result is positive because the volume of internal pores influences fundamentally dielectric properties of material *(Nelson, 1991)*. Presented results corresponding the conclusions of calibration the apparatus for measurement of volume the particular material which achieved *Křepčík et al. (2017)*. The results of the measurements indicate that the results of the measurements may differ in the individual fractions of the same type of wooden chips.

Fraction x < 3.15 mm



Fraction 3.15 mm < x < 5 mm



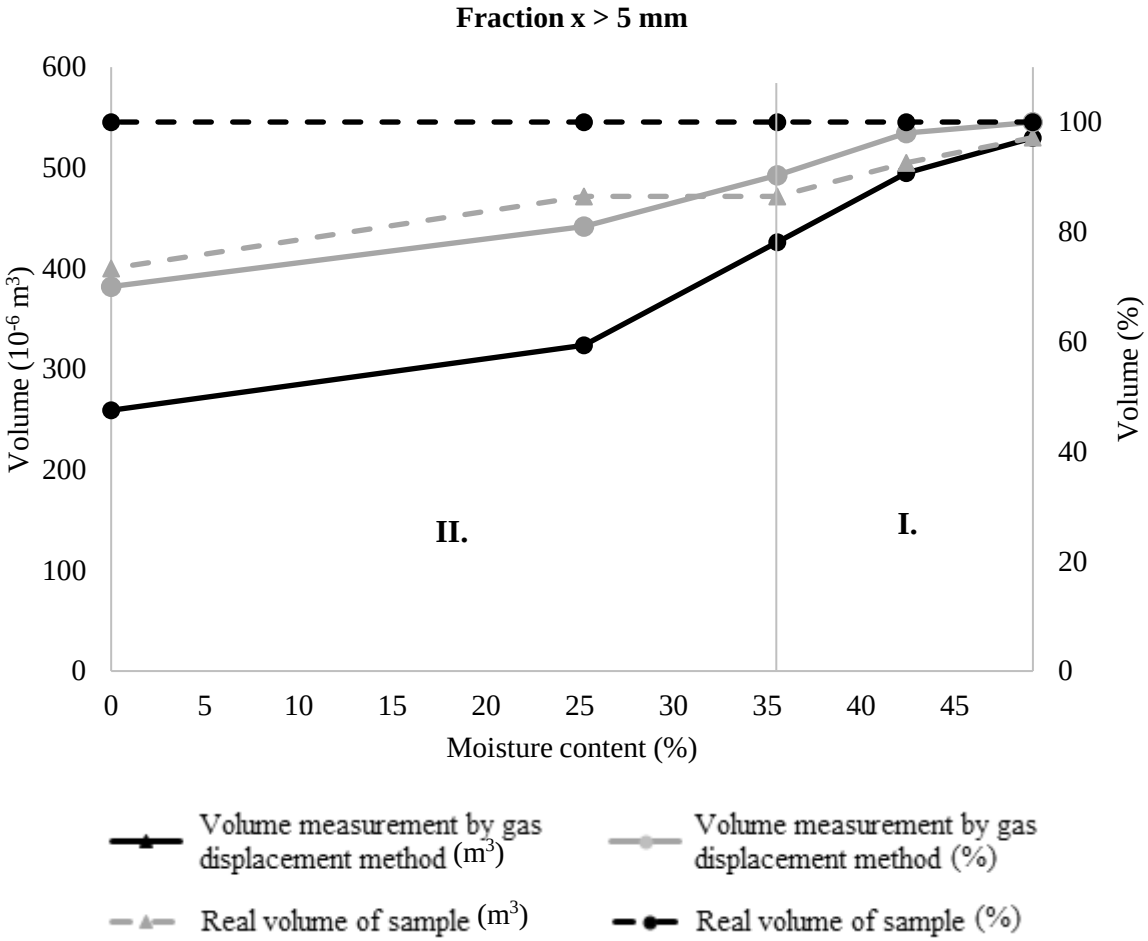


Fig. 3 Results of measurement the volume by gas displacement method for each fraction the pure wooden chips

CONCLUSIONS

The results of the measurements show that wooden chips are heterogeneous material, which can exhibit non-trivial behaviour even in individual fractions of the same type of wooden chips. This fact must be taken into account in the design of the method for continuous measurement of the moisture content of wooden chips. It is possible to use the measuring apparatus for the measuring the volume respectively void of wooden chips because the moisture content of the wooden chips is in the range from 20 % to 55 %.

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Corresponding author:
Ing. Václav Křepčík, Department of Agricultural Machines, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6 - Suchdol, Prague, 165 00, Czech Republic, phone: +420 732202607, e-mail: krepcik@tf.czu.cz