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VIABILITY ANALYSIS OF PINE SAWDUST DRYING IN A FOUNTAIN DRYER

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Abstract

This article presents an analysis of the physico-chemical properties of pine sawdust originating from the area of the Knyszyńska Forest, in the context of the possibility of the sawdust drying in a fountain dryer. Several tests were carried out on dry pine sawdust with 45% moisture, including chemical composition, calorific value, ash content as well as morphological changes of wet and dried material. The water storage mechanism in chips and the mechanism of formation of a fountain bed were also discussed. Based on the obtained results, several technical solutions and modifications of the fountain dryer were proposed. These modifications enable sawdust of heterogeneous size and shape to be dried in a fountain dryer as well as additional functional properties.

Nomenclature

A – is the content of volatiles in the analytical sample [$\%_{max}$]
m_1 – is the mass of the crucible
m_2 – is the mass of the crucible with the raw material being burnt
m_3 – the mass of crucible with ashes
N – the Avogadro's number

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w_p – the surface occupied by a particle in the surface of the test sample
a_p – the amount of the gas absorbed
S_p – specific surface area
S – airflow [dm^3/h]
t – time [s]
Y – humidity [%]
T – temperature [°C]
V – sample volume [ml]

Introduction

Forest and agricultural materials are used for the production of fuel biomass. In the case of biomass from the forest, one can obtain sawdust with different morphology (size and shape), moisture content and physicochemical properties. The problem is also the content of solid impurities and the elemental composition, e.g. the content of chlorine which emits dioxins which are hazardous to health during combustion. The raw material in the form of sawmill chips can be processed into a specific final product, e.g. pellets. The process involves chip thickening under the action of external and internal forces applied to obtain a fixed shape and size of the pellet. Before the granulation, the chips must have adequate humidity, calorific value, colour, purity (free from such contaminants as bark, large pieces of wood, stones, or pieces of metal), as well as low ash content.

Drum and belt dryers are often used for drying sawdust. Each dryer for structural reasons has its limitations and disadvantages, e.g. their efficiency or use of exhaust gases for drying materials (WITROWA-RAICHTER 2009, STRUMIŁŁO 1983). Drying with exhaust gases causes colour changes in the sawdust and its demineralization and a higher ash content, which adversely affects the pelleting process (BERGSTRÖM 2008). This problem can be solved by drying sawdust with a hot air stream.

Fountain dryers with a vertical drying chamber allow the material to be dried in a very efficient way and dispersing the material by creating a fountain effect. The scattered, detached material can also be dried with hot air instead of exhaust gases. However, fountain dryers are mainly used for drying granular materials of equal size and weight, e.g. cereal grains. Hence, during drying sawdust in a typical fountain dryer, there are several process difficulties, particularly the formation of a slugging effect, limiting the amount of dried material.

The main aim of this work is an analysis of the possibility of using a fountain dryer to dry pine sawdust for pellet production. This paper presents the results of research work on selected physicochemical properties of pine shavings obtained from various sawmills in the Knyszyńska Forest and proposes an improved fountain dryer for drying wet sawdust.

Material and methods

Two measurements presented in this article relate to the fountain drying process, i.e. the stand for testing the flow of loose materials and the sawdust drying process characterization (drying curves). The rest of the measurements and tests refer to the sawdust material. The tested sawdust was collected from various pine trees, i.e. from wood that was fresh, rotten and exposed for a long time for different weather conditions. Trees were also cut at different seasons.

In the case of pellet production, a large amount of sawdust is needed. Therefore, the authors in this work wanted to represent the real conditions encountered in granulate production.

Sawdust material

Sawdust resulting from the machining of wood has a shape and size mainly dependent on the cutting tools, process parameters and the physicochemical properties of wood.

In general, chip morphology is mainly dependent on the type of machining tool used, an example of which is presented in Figure 1. Due to its high availability, pine sawdust obtained from a band sawmill was chosen for this study (Fig. 1*a*). Figs. 1*b* and 1*c* show chip morphology obtained using a frame sawmill and a wood milling machine, respectively.

Due to an increased tooth size in the frame sawmill and the reciprocating movement of the tool, these chips are much larger compared to the chips obtained from a band sawmill. Such sawdust has the shape of sticks of varying lengths. The shape of the chips obtained on the wood milling machine is defined by the geometry of the milling cutter and they are thick and twisted.

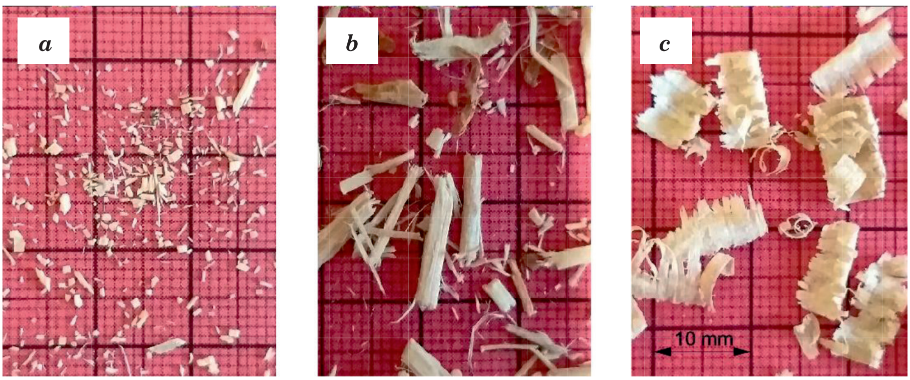


Fig. 1. Examples of the morphology of pine sawdust obtained from various cutting devices: *a* – sawdust from a band sawmill, *b* – sawdust from a frame sawmill, *c* – sawdust from a milling machine

Sawdust testing methods

A representative sample of pine sawdust from a band sawmill (Fig. 1*a*) with a mass of 10 kg and an average moisture content of 46±2% was collected and secured. The chips were sealed in hermetic containers and then used for further testing of their properties. To determine the morphology and selected physicochemical properties of the pine sawdust, the following tests and observations were carried out:

– calorific value, using a caloric bomb (Parr 6100);

– ash content, by burning samples in the oven (Nabertherm P330);

– microscopic observations, using an SEM equipped with an EDS device (Hitachi 3000N) and an optical microscope (Olympus 2000);

– chip-specific surface area, using the BET method;

– sawdust drying process (for establishing drying curves as a function of temperature), using a dryer (Radwag MA 50R);

– size distribution of wet sawdust and after drying, using the ImageJ program;

– sawdust sieving analysis.

In addition, sawdust was fed to various thermal treatments, in a thermal furnace and in a drum dryer at 400°C, where the drying agent was exhaust gas.

A selected sample of 0.4 kg was used to determine the calorific value of pine sawdust. The sawdust sample was placed on trays and dried until the mass stabilized. The mass of the sample was measured every 1 h. Then, after stabilization, moisture was measured using a moisture analyser and was 8.2±0.1%. Further, 15 representative 0.01 kg specimens were selected again and were ground in a small kit mill and pressed into a pellet with a diameter of 20 mm and a height of about 14 mm. The specimens were precisely weighed and then tested with a calorimetric bomb (Parr 6100). The operating parameters of the calorimetric bomb are given: oxygen for combustion – O_2 = 99.95%; working pressure – P = 30 bar; weight of separated water – m_w = 2 kg.

For the ash content testing, 30 samples of dried sawdust, with 0.5% of humidity and 0.001 kg mass were used for a single sample. Sawdust samples were placed in pre-weighed crucibles. The crucibles were placed in a laboratory oven (Nabertherm P330) and allowed to burn. After cooling, the samples were weighed with a laboratory balance with an accuracy of 0.001×10^{-3} kg. The ash content was determined indirectly using formula (1).

$$A = \frac{m_3 - m_1}{m_2 - m_1} \cdot 100\% \quad [\%_{\max}] \tag{1}$$

where:

A – is the content of volatiles in the analytical sample [$\%_{\max}$],

m_1 – is the mass of the crucible,

m_2 – is the mass of the crucible with the raw material being burnt,
m_3 – the mass of crucible with ashes.

A scanning electron microscope (SEM) and optical microscope (OM) were used to study the microstructure of both wet and dry sawdust samples. Samples of varying humidity (from 5% to 46%) were observed. Due to the scattering of light in the water contained in the samples during OM observations, to increase the contrast of the chips, they were dyed blue with ink.

Examinations of the specific surface area of the sawdust were also performed using the BET method. The sawdust samples were inserted into a chamber with nitrogen penetrating the surface of the material. By knowing the pressure, temperature and gas volume, one can calculate how much gas has been absorbed on the chip surface based on the mass difference. Using formula (2), the specific surface area of the wet and dry sawdust was calculated.

$$S_p = a_p \cdot \mathrm{N} \cdot w_p \tag{2}$$

where:
N – the Avogadro's number,
w_p – the surface occupied by a particle in the surface of the test sample,
a_p – the amount of the gas absorbed.

Three humid (46% of moisture) samples of 0.01 kg each were used for the sawdust drying tests, to dry them by 5±2%. For the analysis of phenomena occurring during the drying process of sawdust, so-called drying curves were used, as a function of drying time and temperature. A moisture analyser (AGS200) was applied for the tests. The tests were carried out for three temperatures 100°C, 125°C and 150°C, repeating each of them three times.

Measuring the size of sawdust, using computer image analysis method, the change in the equivalent diameter of chips before and after drying was determined. An example image of the sawdust before drying and after drying is presented in Figure 2. A series of sawdust images were taken. The best quality photos were then selected, scaled, converted and automatically analysed by the computer program (ImageJ). 500 wet chips and 500 dry chips were analysed.

Observations of sawdust motion kinematics in the fountain stand (Fig. 3) were performed. This study was intended to visualize and analyse the processes occurring in the fountain bed. The fountain test stand (Fig. 3) consists of a glass pipe 1 through which air was pumped at a given speed by a fan 6, controlled using an inverter and a throttle valve 5. The amount of airflow was measured by rotameter 3, so it was possible to precisely set the flow. The single test duration was 10 minutes. The entire fountain process was recorded with camera 4.

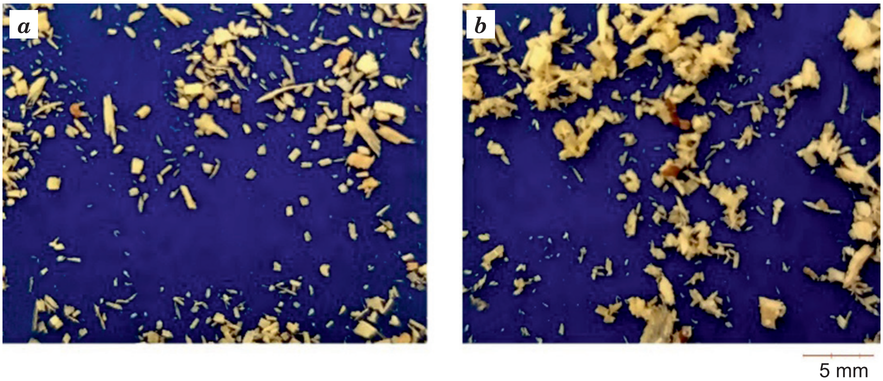


Fig. 2. Image of samples of sawdust: *a* – dry sawdust of 5% humidity, *b* – wet sawdust of 46% humidity

1 – glass pipe with an internal diameter of 50 mm, *2* – perforated baffle, *3* – rotameter, *4* – camera, *5* – throttle valve, *6* – fan
Fig. 3. Research stand for testing the flow of loose materials at the Faculty of Civil Engineering, in BUT

Samples with three different humidity levels (46%, 37%, 28%) were prepared for the testing. In the first phase, a flow rate of 600 dm^3/h was established for sawdust volume of 100 ml. The parameters of the stand are presented below: testing time – t_1 = 10 min; flow rate – S = 600 dm^3/h; sample volume – V = 100 ml; air temperature – t_2 = 22,5°C; air humidity – Yp = 50%. Sawdust moisture before drying: $Y1$ = 46%, $Y2$ = 37%, $Y3$ = 28%. Sawdust moisture after drying: $Y1$' = 22%, $Y2$' = 7%, $Y3$' = 5%.

The sieving analysis of chips with different humidity was also carried out using the Multiserw LPzE-2e laboratory shaker. Sieves were set up in accordance with PN-EN-ISO 3310. Three 0.01 kg samples obtained after drying in the fountain bed were used.

Results and discussion

Calorific value

The calorific value for the dried pine chips was 18.07 MJ/kg, which is similar to the data described in the literature (NINGBO 2015). Using a low vacuum SEM-EDS analysis, the chemical composition of the pine chips was detected. The pine sawdust consists of: C – 53.9%, O – 40.1%, K – 0.01%, S – 0.005%, Cl – 0.005%. Similar chemical composition was reported in the literature (KAJDA-SZCZEŚNIAK 2013). A slightly different composition was obtained from other regions of Europe (DOS SANTOS VIANA 2018).

Ash content

The average ash content after drying the sample in the stand presented in Figure 3 was 0.504±0.15. This is a similar amount of ash obtained by other authors (GLIJER 2011, JIRJIS 1995, BRYŚ 2016). Ash content was also tested for dried sawdust in a conventional drum dryer, where the drying medium is exhaust gases. The ash content was 0.743±0.12 (Fig. 4).

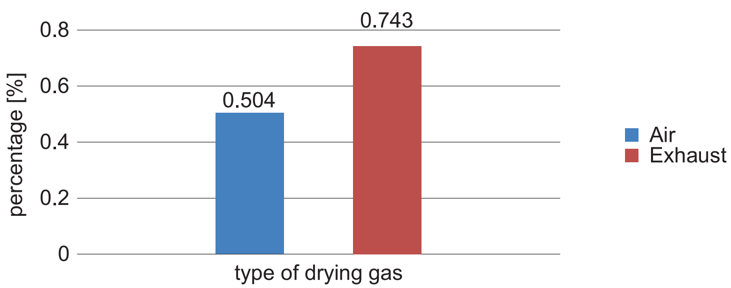


Fig. 4. Ash content depending on the method of drying with dried air and exhaust fumes

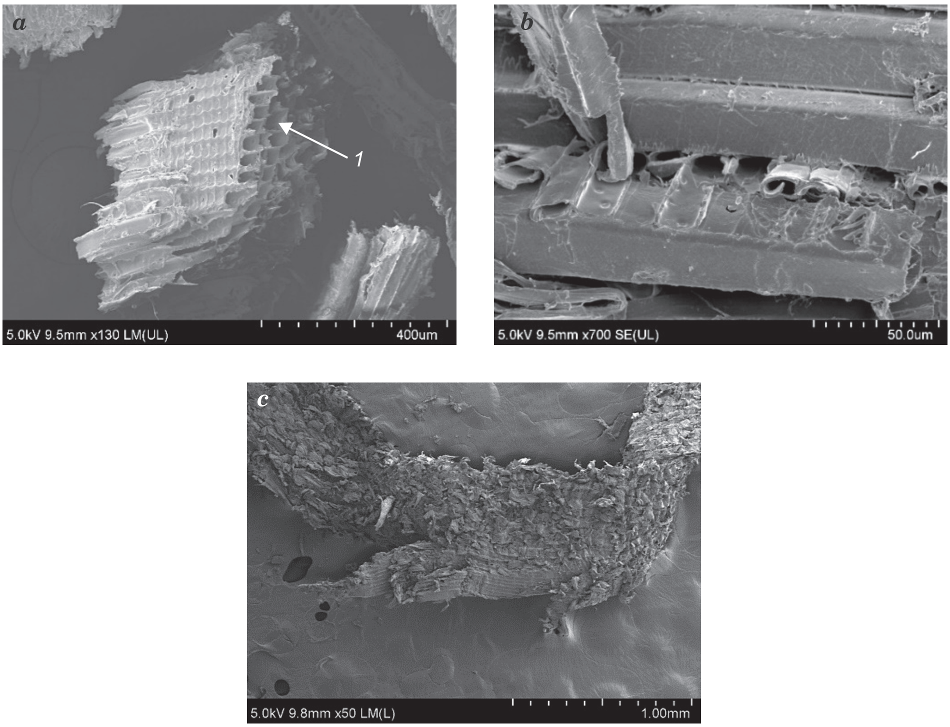
It can be noted that the ash content in sample dried in exhaust gases is 25% higher compared to sawdust dried in a fountain bed. This is because the exhaust gases contain ash particles that settle on the surface of the wood chip. Note that the pine samples used for these comparative tests were taken from an industrial drum dryer, which was equipped with firewalls with settling chambers for particle separation from the exhaust gases.

The percentage of ash content essentially affects the quality of the raw material. During the production of fuel pellets, the amount of hard ash particles should be as low as possible. Too much of them can lead to clogging the furnace burners in which solid fuel in the form of granules is burned.

Additionally, ash settling on the chip surface causes a colour change to darker pellets, which is not desired by customers and results in a lower price of the product. Therefore, hot air drying as opposed to exhaust gases is proposed.

Microscopic observations

To determine the water retention in the chips and the processes that occur during their drying, several microscopic observations of the samples were carried out. Literature reports (Strumiłło 2006, Kudra, Mujumdar 2009, Perre, Keey

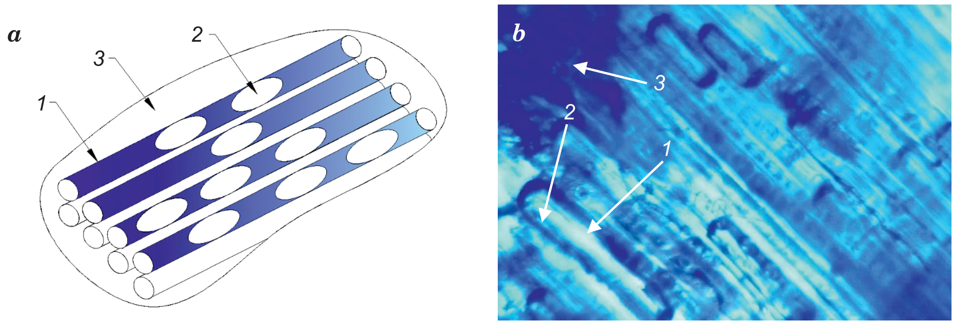


1 – capillary
Fig. 5. Chip structure (*a*, dry sawdust), channel permeability in a chip (dry) (*b*), SEM image of a surface of a single pine chip (dry sawdust) (*c*)

2006) show that the water in the wet material is located inside the growth cells, on the surface and between the wood chips.

Microscopic observations show that the water contained inside the wood cells (capillary 1, Fig. 5*a*) can lead to changes in chip morphology as a result of intensive drying. This phenomenon is observed during rapid heating of small pieces of sawdust.

Capillaries in a tree form channels where water and nutrients are transported. Depending on the degree of humidity, these channels may be partially filled with water or air (Figs. 6*a* and 6*b*). During the drying process, a rapid increase in gas pressure in the ducts can cause cracking (tearing) of chips, which leads to an increase in the amount of a small fraction. This process is desirable for pellet production because more small fractions result in better granule quality (BERGSTRÖM 2008).



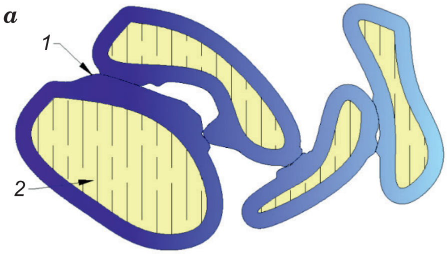
1 – capillary, *2* – air bubble, *3* – cell walls of the wet chip
Fig. 6. Schematic view of the water in the wet chip (*a*), OM image of a wet chip filled with water and air bubbles (*b*) (magnification ×50, description in the text)

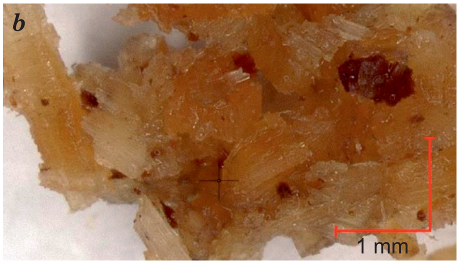
In Figure 6*b*, the light areas (*1*) show air bubbles inside the cells, while the dark areas are coloured water (*3*). The number (*2*) indicates the interface between water and air. Microstructure observations confirmed that the water inside the wood chip did not completely fill the internal cells.

The temperature gradient on the chip, as a result of drying, can cause internal stress due to different thermal expansion of the chip. This causes chip twisting (warping) and wood shrinkage, which results in its structure changing during drying. This shrinkage is the greatest along the capillaries. Thus, the shrinkage will be different depending on the location of the tree trunk which the chip comes and the way how it is obtained.

Moreover, the chips resulting from cutting have channels with various levels of permeability (Fig. 5*b*) which makes it difficult to remove the water remaining from inside the crushed tubes. This also leads to the process of chips cracking described above. Water on the chip surface is also a significant reservoir that must be evaporated in the process of drying. Due to the highly developed specific surface area, numerous capillarity's and cavities, the chips accumulate water drops on the top layers. In the case of lower humidity, water does not fill the entire surface tightly but stays in the form of drops embedded in the insets. Water also occurs in a general mass of sawdust between individual particles of chips (Figs. 7*a* and 7*b*), which can be much more humid than the rest of the material. This water can get into the sawdust during rainfall or high humidity. Sawdust at high humidity sticks together, forming large agglomerations.

While the process of evaporation of this water from the chip surface is fast (GLIJER 2011), exposure of sawdust in high humidity conditions for too long causes water to enter. This is because the size of a single H_2O molecule is 0.28 nm (PANG 2014) and therefore it may easily penetrate the chips.





1 – water bridges, *2* – chip (wet sawdust)
Fig. 7. Drawing showing water accumulation between chips (*a*), water between the chips forms agglomerates (wet sawdust) (*b*)

Specific surface area

The specific surface area of sawdust measured for the dry sample, with 5±2% of humidity, and for the wet sample, with 46±2% humidity, is 0.5233 m^2/g and 0.5826 m^2/g, respectively.

In analysing these results, one can conclude that the dry sample has an approx. 10% smaller specific surface area compared to the wet sample. This is caused by the shrinking of wood, due to the evaporation of water, which during the drying process leaves the cells and thereby reduces their size. The wood shrinkage depends on the fibre direction, e.g. wood shrinks 1.7 times less in the radial direction and this is 20 times less in the longitudinal direction than in the tangential direction. It should be mentioned that this phenomenon occurs for sawdust of 30% and lower humidity, as it is reported in (GLIJER 2011, PERRE, KEEY 2006).

Determination of chip drying characteristics

The drying process of chips with a humidity of 46% as a function of time and temperature is presented in Figure 8. In the drying process, three characteristic stages can be distinguished.

Stage 1 is the period in which the heated chips have negligible weight loss. This stage includes the ranges: T_1, T_2, T_3, and for three temperatures, which are equal in time, lasts about 60 seconds and does not depend on the temperature.

Stage 2 with ranges of T_{21}, T_{22}, T_{23} are of different length (time axis) and depend on the drying temperature. The T_{21} section at 150°C is the shortest and lasts about 590 s. Compared with the drying time at 100°C, the drying time increases to 1,000 s and it is 59% longer.

Stage 3 shows a plateau, where no changes in chip mass were observed. This means that the process of water evaporation has been completed and only the dry mass of sawdust remained (STRUMIŁŁO 2006).

The drying curves show the starting parameters for the further comparative analysis of the drying process of the pine sawdust. They were made in heating conditions without airflow. Thanks to this, by comparing them with the drying curves on the test stand, we can see how other parameters, such as blowing speed, temperature or the type of bed affect the drying speed.

The obtained results may suggest that in certain weather conditions it is reasonable to pre-heat the sawdust before drying. Thus, in the autumn-winter period, when the sawdust is very moist, the drying time can be significantly reduced. Pre-heating of the sawdust can be carried out outside the drying

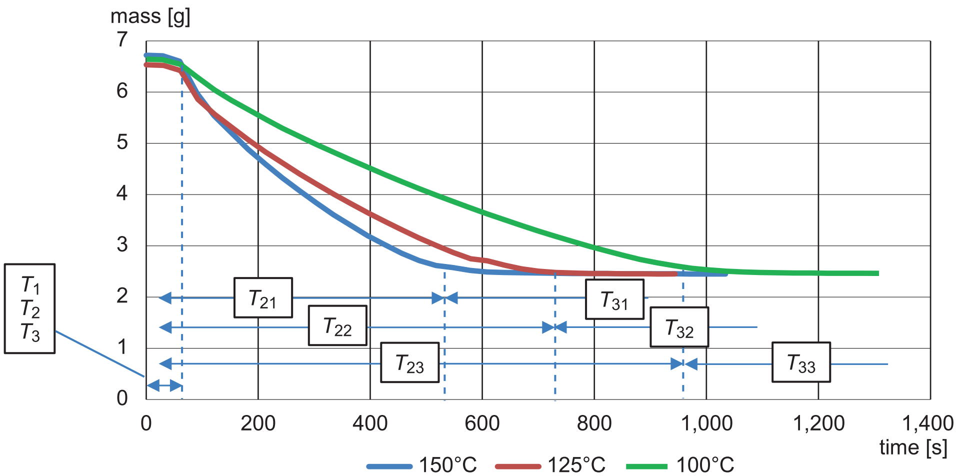


Fig. 8. Drying curves of the wet pine sawdust tested at 100°C, 125°C and 150°C, respectively, made with a moisture analyser

chamber, e.g. in screw feeders. The advantage of pre-heating has been confirmed by literature (WITROWA-RAICHTER 2009, KEEY 1991, DE LA FUENTE-BLANCO, DE SARABIA 2006, BRYŚ 2016).

Image analysis of sawdust before and after drying

This section presents the histogram (Fig. 9) of the dry and wet chip fraction distributions presented from images in Figure 2. From the graph, one can conclude that the highest percentage of the chip size is 0.5 mm, both wet and dry and that the total proportion of particles smaller than 0.5 mm is greater for dry chips with 5% of moisture. This confirms that crushing and cracking of the sawdust occurs during the drying process.

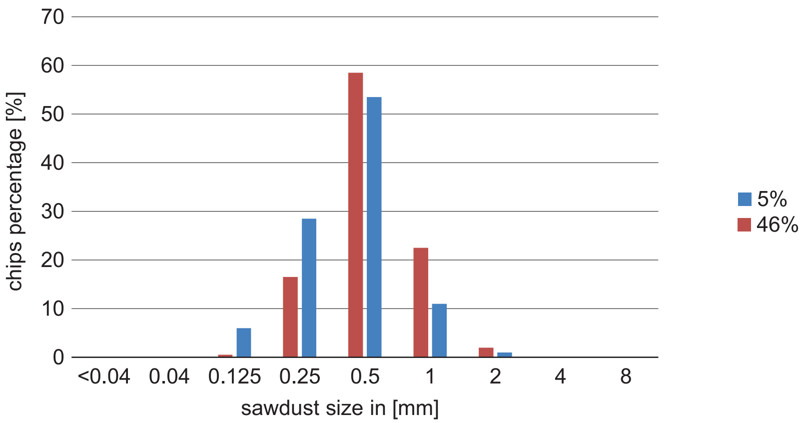


Fig. 9. Image analysis of the chip size distribution with different humidity: 5% and 46%, respectively

Analysing the results presented in Figure 9, it can be concluded that the average wet chip size is approximately 22% larger than the dry chip size. The average chip sizes are similar to those reported in the literature (GLIJER 2011, PERRE, KEEY 2006). Furthermore, after drying, the chips are in the range from 0.125 to 2.0 mm. Note that the large chips are undesirable, interfering with the drying process in a fountain dryer. However, they constitute only about 1% of the entire percentage of the vortices. However, the smallest chips constitute about 5% of the total value, and they are desirable during the granulation process. Although they may have a few percent higher humidity compared to larger chips, the water evaporates faster due to their lower weight.

Sieving analysis

Figure 10 presents images of the pine sawdust after sieving analysis of drying in the fountain bed, whereas Figure 11 presents a histogram of chip size distribution with different humidity (45%, 37% and 28%, respectively). Based on the obtained results, the data of the sieve analysis generally coincide with the results of the image analysis, in which about 90% of the chips are in the range of 0.125-1.0 mm, and chip moisture affects particle size distribution.

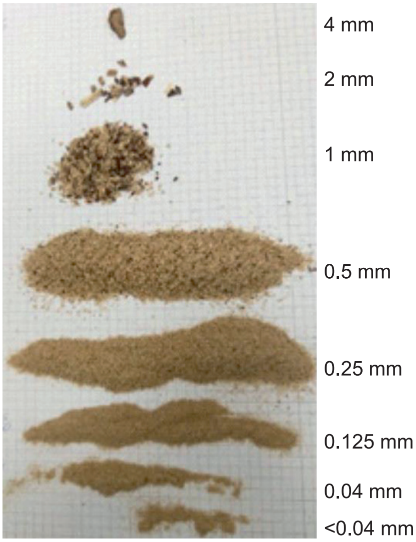


Fig. 10. Sawdust fractions obtained by sieving analysis of sawdust with an initial moisture content of 37%

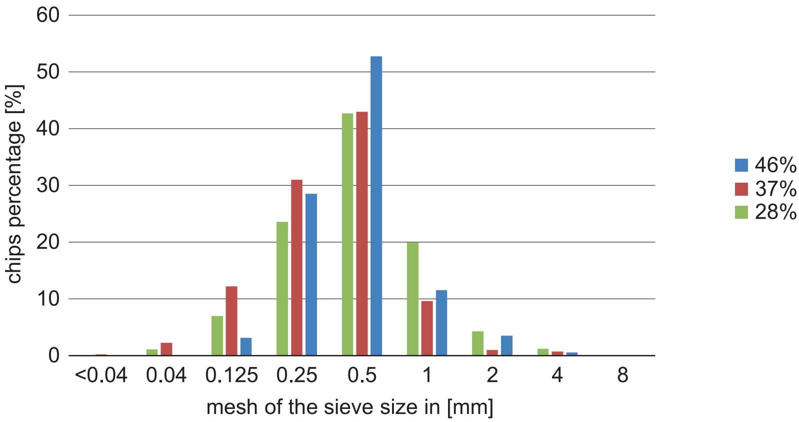


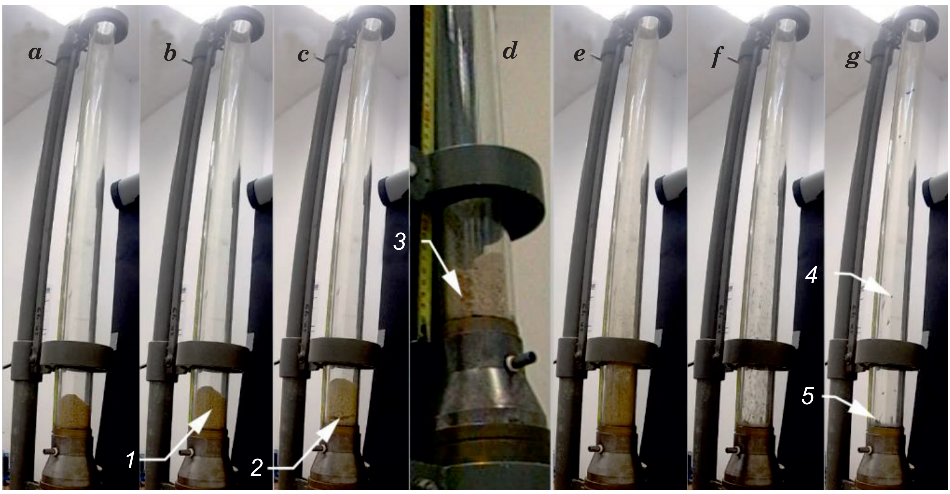
Fig. 11. Percentage distribution of wet chips after drying on the test stand

Figure 11 shows that there are ~ 45% of 0.5 mm chips, ~ 28% of chips are 0.25 mm in size, and ~ 8% of sawdust is 0.125 mm. There is also about 3% of the undesirable, coarse shavings fraction with an average particle size of 1, 2 and 4 mm (Fig. 10) which have bark and other impurities. The high content of the bark has a negative influence on the granulation process, e.g. increasing the ash content and changing the colour. Thus, a good solution is to use the bark for incineration in a furnace feeding a dryer.

Further technical solutions for the fountain dryer will be proposed to eliminate the coarse particles from the sawdust.

Motion kinematics research in the fountain bed

Figure 12 shows the stages of the formation of a fountain bed during the drying of the chips on the stand presented in Figure 3. Chips with a moisture content of 46%, 37%, and 28% were used. The moisture of the chips after the drying process ranged from 5-8%. When analysing the movement of particles (sawdust) in the fountain bed, several basic stages can be distinguished. Turning on the fan resulted in the bulging of the bed surface (the so-called "loosening") combined with an increase in volume (Fig. 12*b*). There is also the phenomenon



1 – volume increase, *2* -crack of the bed, *3* – channel interrupting the bed, *4* – levitating chips, *5* – chips not involved in the process of fountaining

Fig. 12. Stages occurring in the fountain bed during drying of the sawdust for 10 minutes: *a* – initial state, *b* – loosening, *c* – delamination, *d* – the interruption of stream continuity, *e* – the formation of a proper spouted bed, *f* – gradual reduction in the number of chips, *g* – residues after drying

of a further increase in the volume of the bed (Fig. 12*c*). The interruption of stream continuity and the formation of a trough inside the bed is the next stage of the process shown in Figure 12*d*. The formation of a proper spouted bed and a gradual reduction in the number of chips inside the pipe are shown in Figure 12*e* and 12*f*. Note, that "levitating chips" (*4*) in Figure 12*g* were also observed which were not able to leave the drying chamber even after a long drying period. These individual chips are not involved in the fountain process and eventually fell to the bottom of the pipe. From these observations, it appears that one can distinguish the stages: a fixed, bubbling bed (Fig. 12*a*, 12*b* and 12*c*) and a rapid transition to a turbulent bed, followed by rapid fluidization (Fig. 12*e*) (GUPTA, SATHIYAMOORTHY 1999).

Based on the obtained results, it can be concluded that the time needed to dry the chips in the fountain bed is much shorter than when drying the chips with a moisture analyser. During 600 seconds of fountain drying, a 0.1 kg sample of sawdust was dried to a moisture content of 5-8%, blowing the material with 25°C air. This is because there can a large volume of airflow in a short time in the fountain bed with very intensive turbulent chip mixing.

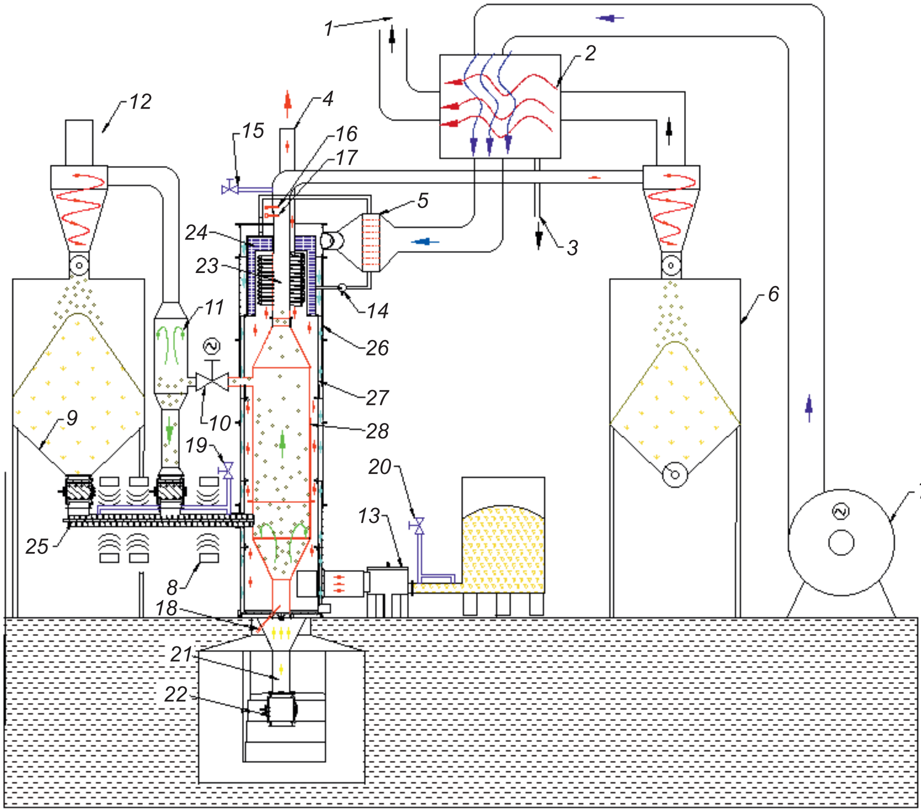
Improvements proposed in a foundation dryer

In analysing the process of drying chips in the fountain bed, the most significant problem discovered is sawdust pollution and large-size chips. To solve these problems, based on literature analysis (MUJUMDAR 2006, KUDRA 2004, LIU 2014, AZIZ 2011, ZHANG 2017) and on the results of preliminary research work, the authors proposed several modifications and improvements in the construction of a fountain dryer. Figure 13 shows a design solution for a fountain dryer to improve the drying process of heterogeneous materials, in this case, of pine sawdust. Note that such devices are usually used for drying homogeneous materials, e.g. powders, corns, etc.

The proposed device (Fig. 13) has the following modifications compared with a typical fountain dryer:

- bed adjustment valve 10;
- cone separator for removing stones, metal pieces, bark 22;
- an internal system of heating air by flue exhaust gas 27;
- water heater 24;
- ultrasound heating generators 8.

The introduced improvements are designed to obtain a dried product with appropriate technological properties, i.e. sawdust with parameters necessary for the production of fuel pellets. The next step is to improve the thermal and functional properties of the dryer.



1 – air outlet, *2* – recuperator, *3* – condensate outlet – dehydration, *4* – exhaust outlet, *5* – water heater, *6* – dry sawdust tank, *7* – fan, *8* – ultrasonic generator, *9* – raw material tank, *10* – air cushion adjustment valve, *11* – sawdust separator, *12* – cyclone, *13* – furnace, *14* – water pump, *15* – water inlet to extinguish (extinguishing system), *16* – flowmeter, *17* – thermocouple (temperature measurement at the output), *18* – thermocouple (input temperature measurement), *19* – water inlet for cooling the material in the screw feeder, *20* – water inlet to extinguish the raw material in the screw feeder, *21* – heavy debris discharge, *22* – rotary sluice, *23* – air outlet from the drying chamber, *24* – water heater with flue gas, *25* – screw conveyor, *26* – external case, *27* – inside case, *28* – drying chamber

Fig. 13. Scheme of the proposed fountain dryer

SUMMARY

This work aimed to propose a new design of a fountain dryer, to provide an optimal product for the production of pine pellets.

This article presents an analysis of pine sawdust obtained from the Knyszyńska forest and its drying process, which is the first stage of the pellet production. The drying process in fountain dryers of heterogeneous sawdust

materials is difficult due to non-homogeneous material. Different particle sizes hinder the proper functioning of the bed. They also have impurities which also affect the operation of the bed and cause the dry material to have worse technological properties in terms of further granulation. Therefore, the fountain dryer should be equipped with tools and devices that can separate the least valuable big sawdust particles, metal parts, bark, stones and other impurities. Thus, the basic parameters of the sawdust were determined, i.e. the chemical composition, calorific value, surface area analysis, sieve analysis and ash content for drying process performed by exhausted gases and hot air. Analysis of the ash content showed a significant reduction of the ash for the samples dried by warm air in comparison to the exhaust gases (drum dryer). The BET analysis revealed that after drying, the surface area of the sawdust decreased by approximately 10%. A series of microscopic observations were also carried out to analyse the manner of water accumulation in sawdust and the effect of water evaporation on the sawdust morphology. In analysing the kinematics of the sawdust sample movement in the fountain bed, it can be concluded that the bed movement during the fountain process is affected by the size and morphology of the particles.

Based on the literature, research work and the authors' own experience, a modification of a typical fountain dryer was proposed. Thanks to this modification, the fountain dryer will be able to dry the sawdust with exhaust gases without contaminating them with additional sorting of coarse fractions that often interrupt the fountain process.

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