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Physical properties of wastes from furniture industry for energy purposes

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Abstract. The aim of the study was to determine the physical properties such as moisture content, particle size distribution, density and calorific value of wastes from wood-based boards and to determine their suitability for energy purposes. The tested material included wastes from tooling fibreboards (MDF) and raw (PWP) and laminated (PWO) chipboards. Tests were conducted according to the standards. The materials from wastes after mechanical boards tooling were characterized by a similar low moisture content. The geometric mean of particle size values were 0.38 mm, 0.64 mm and 0.57 mm, respectively for MDF, PWO and PWP. The particle size distributions were right-hand skewed and non-aligned. It was found that the prevailing share had the smallest fraction and its largest share had wastes from MDF. Regarding to the high calorific value and low moisture content and high bulk density, it could be stated that the wastes from furniture industry are a good raw materials for energy purposes. These wastes can be combusted at proper conditions of this process.

Key words: wastes, furniture industry, fibreboards, chipboards.

INTRODUCTION

The intensive development of new technologies conducive to modern composite materials production such as wood-based boards that have a majority share of wood raw material in a different form. Other materials used in board production are i.e. flax, bagasse or straw (Thoemen et al., 2010). In the furniture industry the production of boards includes shredding and binding lignocellulose particles with organic or synthetic binders throw bonding and compressing at high pressure and temperature values. Products made of wood or boards are produced according to high standards under quality control of each raw material (Kaputa, 2004). These products have to meet restrictive requirements of standards and quality and safety certificates.

Popular boards used in the furniture industry are chipboards and fibreboards (Fierek, 2013). They contain about 90% of pure biomass in the form of wood chips and also because of the low moisture they have a high calorific value (at least 17 MJ kg^{-1}). They should be a great source of energy in the plants that produce a large amounts of chips, sawdust and dust during cutting of wood-based boards. Although these residues meet all the criteria of biomass, in Poland they are regarded as wastes another than hazardous (Dz.U. 2013 poz. 21), due to the share of synthetic ingredients, adhesives and other additives. Disposal of waste products from furniture plants is not yet sufficiently resolved, however, it can be done by burning, which also provide valuable energy (Kajda-Szcześniak, 2013). Boilers for burning such waste are different from standard boilers to biomass and, above all, they should be equipped with exhaust gas cleaning system, and additionally at least one auxiliary burner for each combustion chamber (Wasilewski & Hrycko, 2010). During the combustion process the minimum temperature of the gases in the plant must be at least 850°C, and in the case of hazardous waste, where the proportion of chlorinated compounds is more than 1%, the minimum temperature is 1,100°C. Moreover, slag and ash may not contain more than 3% organic carbon.

The energy use of wood residues incudes processing of dust and sawdust is similar to biomass conversion and properties of the raw material should be comparable. The main property of biomass is the moisture content. A high moisture content of raw material affects negatively on the calorific value of biomass (Dzurenda et al., 2011) and worsens the mechanical properties, which has an impact on the process of combustion – can results in lowering the temperature of the process (Głodek, 2010). The bulk density depends on type of biomass and affects the transport and storage. A property inversely proportional to the density is the particle size (Bitra et al., 2009). The mean value of particle sizes and standard deviation depend on the type of material and setting of machines technical parameters (Hejft, 2002).

Therefore, a thermal processing of such wastes requires knowledge of the characteristic physical parameters and properties of the raw materials that could be used for energy purposes. For that reason, the aim of the study was to determine the moisture content, particle size distribution, density and calorific value of the wastes from wood-based boards.

MATERIALS AND METHODS

For tests the material from three types of wood-based boards after tooling were used. The raw material were obtained from furniture manufacture BOMA Ltd. in Poland. Samples were collected from tooling the fibreboards by milling machine (marked in the manuscript as MDF), laminated chipboard (PWO) and raw chipboards (PWP) (Fig 1).

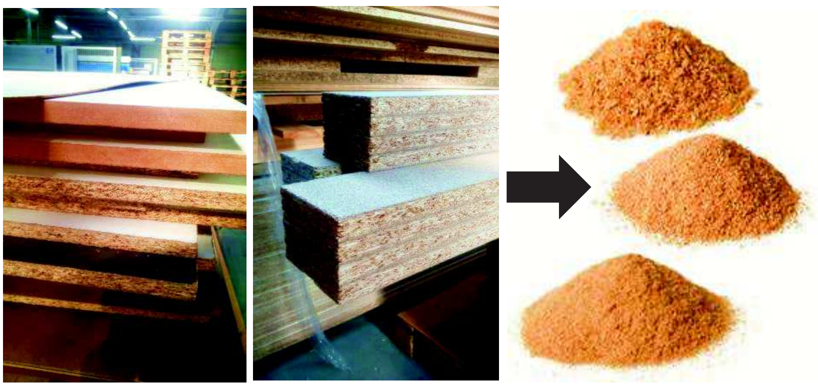

Figure 1. Chipboards and fibreboards and their residues (wastes) after tooling.

MDF boards were made of 88% of wood from pine and fir, 10% of amine glue and 2% of water and emulsion. Chipboards were made of 85% of chips from pine and spruce, the rest were resin, repellents and in the case of PWO the decorative paper. The products were produced without the addition of chlorinated compounds and wood preservatives and they can be burned for energy.

Studies of physical properties of these wastes were carried out at the Department of Agricultural and Forest Machinery, WULS. The waste material was analysed regarding to its usefulness not only for direct combustion, but also to its suitability for the pressure agglomeration and production of pellets.

The scope of research included determination of parameters of random chosen samples of biomass in the form of wastes from wood-based panels: moisture content, particle size distribution, bulk density and gross calorific value. The all tests were performed according to standards. To sieve analysis the separator with oscillatory motion in the vertical plane was used. Each type of tested material was sieved five times and a single sample was 50 g. All parameters of particle size distribution were calculated according to the standards and formulas described by Rosin & Rammler (1993), Folk & Ward (1957) and CFI (1982). The heating value was measured using the standard KL-10 calorimeter. The milled sample of 1 g of the material was weighted with accuracy of 0.0001 g on the electronic scale RADWAG WPA 40/160/C/1 and combusted. Each trial was repeated five times.

RESULTS AND DISCUSSION

The tested material from MDF, PWO and PWP had a low similar moisture 4.95%, 5.18% and 5.2%, respectively. The MDF was characterized by the lowest bulk density and it was 321 kg m^{-3}. Wastes from chipboards had clearly higher bulk density. The PWP material was characterized by the highest density 361 kg m^{-3} and the density of PWO was 351 kg m^{-3}. The bulk density of tested materials were similar to the density of other raw materials used for energy purposes. It was similar to chips from spruce 328 kg m^{-3} and higher than sawdust 160 kg m^{-3} but in turn, the pellets i.e. from straw has higher bulk density 620–650 kg m^{-3} (Komorowicz et al., 2009).

The appropriate structure of particles length is one of the most important parameters characterizing the material to be used for energy purposes. Uniformity and fineness of waste from wood-based panels affect the quality of the material to be burned or used for other purposes, eg. production of pellets. On the basis of results obtained from sieve analysis it could be stated that the particle size distributions were non-aligned (Fig. 2). The percentage mass share of fraction decreased with diagonal screen opening size increase. That indicates that in all cases, most of the material remained on the sieves with the smallest dimensions and at the bottom. Whereas the least material was on the sieves 2.81 mm, 3.99 mm and 5.65 mm. For MDF and PWO on the two highest sieves was no material but the PWO and PWP particle size distributions had similar characteristics. It follows from this that, regardless of the type of tooling and laminating, chipboards had similar particle size distributions, in contrast with the MDF waste, which had considerably more fine particles and dust. The longest particles (0.64 mm) had PWO material and the smallest had MDF (0.38 mm) (Fig. 3).

Particle size distributions shown in the Fig. 2 were asymmetrical with right-hand skewness. This is evidenced by the value of skewness, on the basis of which it can be concluded about the prevalence of the share of fine particles and by the value of inclusive graphic skewness (*GS*) with values from 0.32–0.43. According to Folk & Ward (1957) all of particle size distributions were fine skewed ($0.3 \leq GS \leq 1.0$) and mesokurtic ($0.90 \leq K \leq 1.11$).

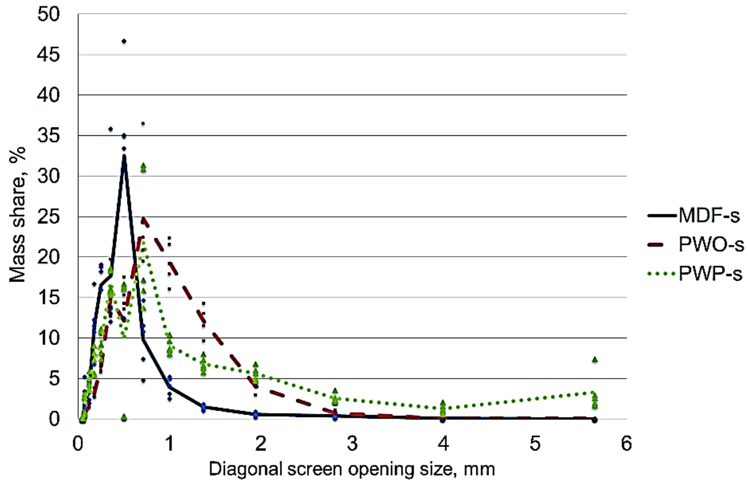

Figure 2. The MDF, PWO and PWP particle size distribution.

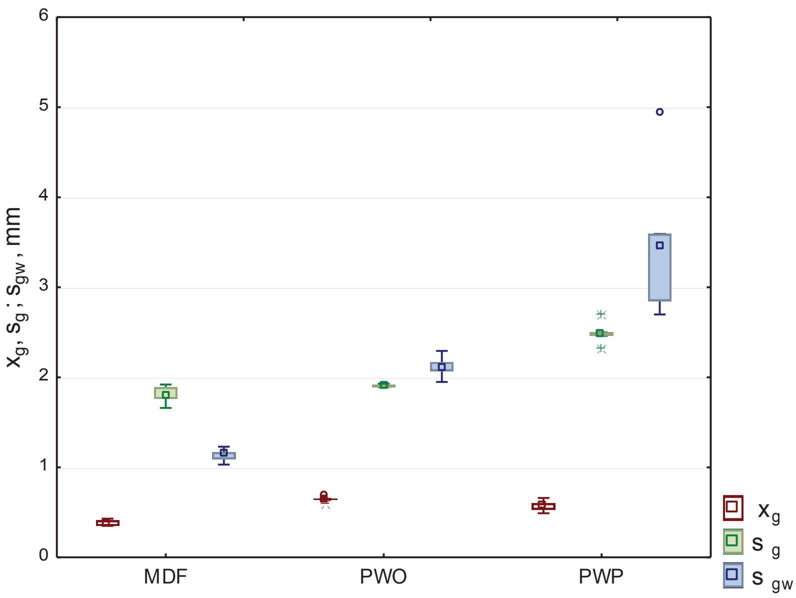

Figure 3. The MDF, PWO and PWP particle size distribution.

The Rosin-Rammler *n* parameter was inversely proportional to the kurtosis values (Table 1) what indicates the distribution width. Relatively high share of fine particles and dust in tested material is confirmed by high values of RS_m parameter which was inversely proportional to the Rosin-Rammler *n* parameter and that is consistent with other studies (Bitra et al., 2009).

The kurtosis coefficients in all cases were positive (Table 1). That indicates the distribution steepness and a slight predominance of slenderness in comparison to the normal distribution. The material of the most flat distribution was waste from tooling raw chipboard (PWP). The uniformity indexes (I_u) for wastes were differentiate and it could be stated that the type of tooling had the high influence on this indicator values.

Table 1. The average values of characteristics parameters of wastes particle size distribution

Material	x_g	x_R	n	x_{10}	x_{50}	x_{90}	RS_m	GS	K	I_u	N_{sg}	C_u	C_g	GSD_1	GSD_2	GSD_3
MDF	0.38	0.49	1.15	0.07	0.36	1.01	2.65	0.40	1.04	3.66	26.18	6.56	1.27	2.33	3.32	2.78
PWO	0.64	0.78	1.32	0.14	0.59	1.47	2.24	0.32	1.02	5.60	10.61	5.15	1.23	2.09	2.85	2.44
PWP	0.57	0.83	1.08	0.10	0.59	1.80	2.86	0.43	1.06	2.95	6.41	7.41	1.29	2.46	3.59	2.97

x_g is the geometric mean of biomass particle size; x_R is the parameter or geometric mean of Rosin-Rammler dimension; *n* is the Rosin-Rammler distribution parameter; $x_{10,}$ x_{50} and x_{90} are the corresponding particle lengths in mm at respective 10%, 50%, 90% cumulative undersizes, which are also known as percentiles; RS_m is the relative span based on length; *GS* is the inclusive graphic skewness; *K* is the graphic kurtosis; I_u is the uniformity index; N_{sg} is the size guide number; C_u is the coefficient of uniformity; C_g is the coefficient of gradation; GSD_1, GSD_2, GSD_3 are the distribution geometric standard deviation of the high, low and total regions, respectively.

The coefficient of uniformity with values of 6.56 (MDF), 5.15 (PWO), 7.41 (PWP) indicates the higher scatter of particle size values, which means that particle size distributions were poorly aligned. The coefficient of gradation were similar in the range of 1–3, therefore it couldbe stated that particle size distributions were well graded.The highest values of geometric standard deviations in all regions had PWO. The tests results were close to parameters of fine fraction from straw and hay biomass (Lisowski et al., 2016).

In Table 2 the regression coefficients and their statistical asessments were shown. On the basis of obtained results can be concuded that *t*-Student values were quite high and *p* values were significant for MDF and PWO. The exception was PWP, where the insignificance of constant b in the regression equation was found. The values of regression model were high too. The values of Fisher-Snedecor test exceeded 100 at the significance level at $p < 0.0001$ and the determination coefficient R^2 was above 83% for all of the wastes.

Table 2. The values of regression coefficients and their statistical assessments

Material	Regression coefficient	Rate	Error	*t*-Student value	*P*-value	F-test	P-value for regression	R^2, %
MDF	index *n*	1.15	0.09	12.66	< 0.0001	160.2	< 0.0001	83.78
	constant *b*	0.36	0.06	5.90	< 0.0001			
PWO	index *n*	1.32	0.10	12.75	< 0.0001	162.68	< 0.0001	83.98
	constant *b*	0.14	0.07	2.00	< 0.05			
PWP	index *n*	1.08	0.08	12.69	< 0.0001	160.94	< 0.0001	83.84
	constant *b*	0.09	0.06	1.58	0.12			

The highest calorific value had the residue after MDF board tooling and it was 18.22 MJ kg^{-1}. The calorific value of PWO and PWP were 17.59 MJ kg^{-1}and 16.61 MJ kg^{-1}, respectively. These values are comparable to calorific values of pure wood materials and energy plants (Komorowicz et al., 2009) and wood residues such as chips and sawdust (Dzurenda et.al., 2011). These parameter indicates good suitability of tested materials for energy purposes.

CONCLUSIONS

1. In all tested materials from wastes obtained from tooling the wood-based panels, the dominated fraction was the finest one and the particle size distributions were right-hand skewed and asymmetrical and non-aligned. The biggest share of the fine fraction was characterized by the material from fibreboard (MDF).

2. Wastes from tooling of chipboards and fibreboards contain too much fine particles and dust, so they cannot be used to the pressure agglomeration process and pellets production without additional treatment.

3. Due to the high calorific value and low humidity and relatively good bulk density, residues from mechanical tooling of chipboards (PWO and the PWP) and fibreboards (MDF) are a good raw material for energy purposes. According to their good physical properties they could be a good binder to the material for pellets what requires further studies.

4. Wastes from wood-based panels are characterized by physical properties similar to materials that are commonly used for energy purposes, therefore, can be used as a source of renewable energy if the relevant parameters of thermal processing of raw materials specified in the laws are respected.

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