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DEPENDENCE OF THE SAWDUST DENSITY ON THE SIZE OF ITS PARTICLES AND HYDRAULIC PRESS COMPACTION PRESSURE

In the process of timber processing large volume of waste products is formed, they constitute more than 17 % of energy potential of biomass in Ukraine. This enables to obtain annually while their usage energy effect equivalent to burning more than 1.5 mil. tons of coal. The paper contains the results of the determination of regression dependence of the sawdust density on the size of its particles and pressure, performed by the hydraulic press by means of rotatable central compositional planning of the experiment, using Wilson-Box method of the second order. Adequate regression dependence of the sawdust density on the size of its particles and hydraulic press compaction pressure is obtained. Adequacy of regression model was verified according to Fisher criterion and significance of the regression coefficient – by the Student`s criterion. The suggested mathematical model can be used for modeling the compaction process and for compaction drive design. It is established that according to Fisher criterion the hypothesis regarding the adequacy of the obtained regression model can be considered correct with 95 % validity. Correlation factor was 0.95829, this proves the sufficient validity of the obtained results. Using the Student`s criterion it was established that among the studied factors the hydraulic pressure exercises the greatest impact on sawdust density and the least impact – average size of sawdust particles. Response surface of the efficiency function – sawdust density in the plane of impact parameters is constructed, it enables to demonstrate the above-mentioned dependence.

Key words: *timber waste, sawdust, density particles size, compression pressure, hydraulic press, mathematical modeling, experiment planning, multifactor dependence, impact factors, response surface.*

Introduction

Biomass is one of the alternative sources of energy, its involvement into energy generation process may be a variable contribution in the solution of the primary energy sources shortage in Ukraine [1]. In the process of wood processing large volumes of waste are formed. More than 17 % of energy potential of Ukraine is occupied by wood biomass. In modern conditions production of biofuel from wood working waste and timber processing is a priority direction for timber industry, this is stipulated not only by the desire of the enterprises to get maximum profit but also by a general trend of transition to alternative, renewable sources of energy, growth of energy efficiency of the production [2]. In Ukraine approximately 50 mil. tons of wood working waste is formed annually, the energy of the waste is equivalent to 10…20 billion cubic meters of natural gas [3]. In many countries wood working waste is used for obtaining energy, as heat transfer of the fuel, obtained from wood biomass corresponds to the conventional fuel. One ton of coal may be replaced by 4.2 m^3 of such waste.

Problem set up

Law of Ukraine "On the alternative sources of energy" [4] determines legal, economic, ecological and organizational fundamentals of alternative sources of energy usage and promotes their application in fuel-energy complex, in particular, notes that the energy of biomass (including waste and residue of logging industry) is one of the types of the alternative sources of energy. In Ukraine the potential of the wood waste is more than 6 mil. m^3, this enables to obtain annually, if this potential is used, energy effect equivalent to burning more than 1.5 mil. tons of coal. But the usage of some materials as the source of energy is impossible in their primary state. That is why, these materials must be recycled to obtain briquettes to make them usable as a fuel. That is why, determination of the dependence of sawdust density on the size of its particles and compaction pressure by the hydraulic press is urgent scientific-technical problem.

Analysis of the recent research and publications

In the materials of the paper [5] compression ability and shearing strength of municipal solid waste (MSW) were investigated in laboratory conditions. Compression test, dry and non-dry triaxial compression was performed in the restored samples of large-size waste and with specific weights of the saturated samples and samples, tested at natural moisture content.

Dependence between the compaction pressure of MSW and process parameters: relative deformation and natural density without the account of the initial relative humidity of MSW is determined in the study [6].

In the paper [7] the impact of the relative humidity of MSW on the process of waste pressing is studied. Optimal content of the moisture during MSW pressing is – 10...12 %. Higher moisture content in the briquette led to the increase of compression process duration, lower density of the briquette in the internal layer, lower strength, there appears the possibility of briquette layering and swelling. The advantages of low moisture content is the lack of adhesion of MSW particles to the walls of matrix and more uniform distribution of the density over the briquette thickness, for obtaining of such briquette compression equipment with the hydraulic drive is used [8, 9].

The dependences of MSW density on the moisture content, joint effort and seasonal effects at compaction in laboratory and field conditions are determined in the materials of the study [10], mechanisms of waste compaction are analyzed. Duration of MSW hydration of 16...24 hours resulted in more uniform compaction curves than for the waste, compressed without hydration.

Possibility of MSW disposal at available municipal thermal power plants, with generation capacity of 12 MW, which can operate on energy fuel (mixture of MSW, desiccated to 20 % of relative humidity and coal with weight part of 16 %) with calculated low heat value 10.99 MJ/kg [11].

In the paper [12] it is determined that the content of moisture and compaction pressure of the combustible materials of MSW were two key parameters for obtaining quality fuel briquettes, having calorific value of not less than 20 MJ/kg, equivalent to calorific value of the lignite and can be burnt together with the coal at thermal power plants. The studies were carried out at room temperature without using binding at the pressure of 69...138 MPa and relative humidity of MSW 6...20 %, the research carried out, enabled to determine that the content of moisture must not exceed 15 % for obtaining high quality briquettes from the mixture of paper and other combustible materials available in MSW.

The installation for briquetting the wood working waste was proposed in the study [13], it enables to enhance the specific heat of the waste, using as a solid fuel. Increase of the pressing degree is achieved as a result of the vibrating hydraulic drive application. The dependence between the pressure of sawdust compaction and its relative deformation in the process of briquetting is established, the dependence is used for the development of the mathematical model, enabling to describe adequately the process of vibration briquetting of the sawdust and allows to determine necessary efficient duration of this process.

Studies, performed [14] showed that promising method of wood working waste disposal is fuel briquettes pressing, using sulfate soap – waste, formed in the process of lysine boiling out from the wood pulp in cellulose pulp production, as a natural binding substance. This allows to minimize the ecological hazard as a result of polluting the environment with wood waste and cellulose pulp production waste and obtain quality biofuel. Usage of binding substance resulted in the reduction of the engine power by 40 % and increase the density of the produced fuel briquettes by 10 %. Pressure, due to which the formation occurred without adding binding substance was more than 1 GPa, with addition of binding substance – from 500 to 990 MPa.

Technological modes of fuel briquette production from a number of technogenic waste, which are not suitable by the aggregate state for direct usage in the technological processes and installations, are considered in [1]. Application of the considered technology in practice enables to use production waste as fuel briquettes. Such briquettes can be used for any type of combustion chambers, in the boilers of any power – from private houses heating systems to large thermal power

plants. It is noted that the inclusion in energy circulation the alternative sources of energy may become an important contribution in the solution of the problem of primary energy carriers shortage, improve ecological situation in the country.

It is substantiated in the study [15] that the application of the used wood (UW) is an alternative additional resource of the raw materials on the condition of its disposal and processing into wooden products: pieces of the curved shape, edge glue panels, wood panels and wood boards as well as fuel pellets and briquettes. Technique of UW potential calculation and its balance by categories was developed. The potential of the wood biomass – wood working waste and UW in Ukraine is calculated, in 2012 it was 6.438 mil. tons, in particular, UW – 2.0 mil. tons. On the base of cluster analysis monitoring of UW by regional centers of Ukraine was carried out. Basic physical-mechanical properties of the obtained production according to the developed technologies are determined. Proceeding from the obtained mathematical models the regularities of UW usage impact on physical-mechanical indices of the obtained production are established. Mode parameters for the implementation of the results of the research into production process are suggested.

Paper [16] contains the results of the process of the biomass pressing, in particular, woodworking waste, in order to obtain fuel pellets, briquettes, the impact of pressure and pressing temperature on the density of the obtained product is determined . The results of the studies showed that increase of the pressing temperature above (90 – 100) °C and pressure above (120 – 140) MPa is inefficient as it does not influence greatly on the increase of biofuel density and leads to the increase of energy consumption for its production. The results obtained can be used for the determination of optimal construction-technological parameters of the compaction process of dispersive materials.

Monograph [17] contains the generalized results of the development and systematization of the technological fundamentals of solid biofuel production from plant waste and composites of this base. The technique of spring coefficients assessment of two -component composite biofuel on the base of plant waste is proposed. The impact of the constructive parameters of die orifice on the quality parameters of the produced biofuel and energy characteristics of the pressure equipment is determined. Technological solutions regarding the production of the pellets of the improved quality from the fallen leaves, composite fuel on the base of plant PETF municipal waste are suggested and experimentally studied.

Authors of the paper [3] obtained regression dependences of the compaction pressure of woodworking waste on the compaction coefficient both in the form of the sixth order polynomials and by means of the exponential function. It is established that the exponential function provides better validity of the approximation with fewer quantity of the regression coefficients. Conditions of the briquettes of the sufficient strength formation for transportation and burning in energy units are determined. The impact of sawdust material density of the compaction pressure is studied, however the impact of sawdust particles was not taken into account.

Objective and task of the paper

Objective of the paper is determination of the regression dependence of sawdust density on the size of its particles and compaction pressure by the hydraulic press, it can be used for modeling the compaction process and in the process of pressing drive design.

Methods and materials

Determination of the regression dependence of sawdust density on the size of its particles and compaction pressure by the hydraulic press was carried out by means of rotatable central composite experiment planning of the second order using Box-Wilson method [18]. Determination of the coefficients of regression equation was performed by the developed computer program "PlanExp", protected by the Certificate of the state registration of the rights to the copyright object [19] and is described in details in the work [20, 21].

Results of the research

Table 1 contains the values of pine sawdust for different sizes of its particles and compaction pressure by the hydraulic press, obtained at raw material moisture of 7...10 % [2].

Table 1

Values of pine sawdust density for different sizes of its particles and compaction pressure by the hydraulic press [2]

Compaction pressure by the hydraulic press, MPa	Pine sawdust density, g/cm^3, for different sizes of its particles, mm				
	>5	3...5	2...3	0,5...2	<0,5
0	0.18	0.19	0.19	0.21	0.20
50	0.54	0.70	0.75	0.73	0.54
75	0.75	0.90	1.00	0.90	0.75
100	0.80	1.00	1.10	1.05	0.80
125	0.86	1.10	1.20	1.08	0.86
137,5	0.93	1.14	1.25	1.16	0.93
150	0.96	1.20	1.38	1.20	1.10

Using experiment planning by means of rotatable central composite planning of the second order, applying the developed software, after disposing nonsignificant effect of interaction by the Student`s test the following regression dependence is obtained:

$$\rho = 0.1479 + 0.01027p + 0.06349d - 2.845 \cdot 10^{-5} p^2 - 0.01243d^2 \text{ [g/cm}^3\text{]}, \quad (1)$$

where ρ – is sawdust density, g/cm^3; p – is compaction pressure by the hydraulic press, MPa; d – is an average size of sawdust particles, mm.

Verification of the adequacy of the regression model (1) was performed by Fisher`s criterion, according to this criterion it was established that the hypothesis, regarding the adequacy of the obtained regression model can be considered to be correct with the validity of 95 %.

Correlation factor was 0.95829, this proves the sufficient validity of the obtained results.

According to Student`s criterion it was determined that among the studied factors of influence the compaction pressure by hydraulic press has the greatest impact on the sawdust density and the least impact is carried out by the size of the sawdust particles.

Fig. 1 shows the response surface of the objective function – sawdust density ρ in the plane of impact parameters, this enables to illustrate the above-mentioned dependence.

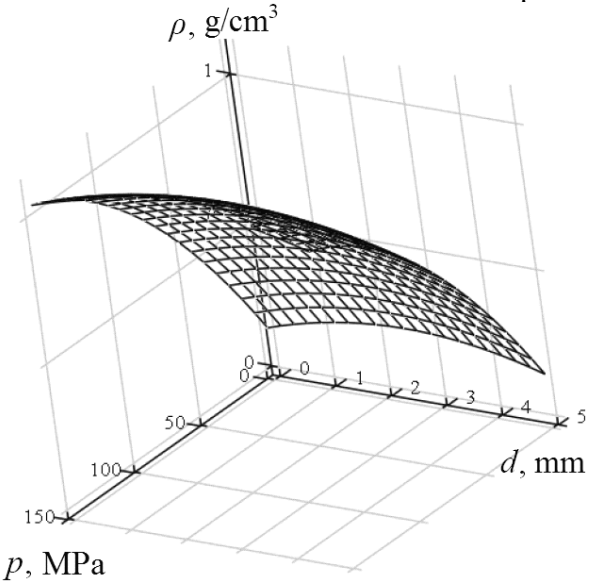

Fig. 1. Response surface of the objective function – sawdust density ρ in the plane of the impact parameters

$$\rho = f(p,d)$$

Conclusions

Adequate regression dependence of the sawdust density on the size of its particles and compaction pressure by the hydraulic press is obtained, it can be used for modeling the pressing process and design of the pressing drive.

By Student`s criterion it is determined that the compaction pressure by the hydraulic press exercises the greatest impact on the sawdust density and average size of the sawdust particles exercises the least impact.

Response surface of the objective function – sawdust density in the plane of impact parameters is constructed, it enabled to illustrate the above mentioned dependence.

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