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Modeling temperature of pellet press matrix for wood pellets

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Abstract: *Modeling temperature of pellet press matrix for wood pellets.* On the basis of active industrial experiments on industrial equipment mathematical dependence is obtained, showing the change in temperature of the matrix during the granulation of wood pellets. This dependence, adequate to real conditions, can be effectively used to control this important parameter that provides stable operation of the equipment. Minimum temperature of the matrix, determined from the results of presented research, increases service life of matrix and reduces the probability of emergency situations.

Keywords: adequacy, biofuel, dependency, matrix, management, modeling, parameter, pellet, process, temperature, wood

INTRODUCTION.

Production of wood pellets in the Russian Federation develops very rapidly due to the large number of available raw materials at wood processing enterprises in the form of waste from the processing of timber and lumber and demand for this type of biofuel in the world market. These wastes are generated annually by the statistical data of many researchers in the amount of about 70 million m^3 , at generally quite low, in comparison with other advanced forest powers, useful output of 40-60%, they have zero or negative value [1]. This is explained by the necessity of their recycling that without doubt requires considerable financial expenses.

Accumulating wastes of wood processing damage the environment, litter territory of enterprises, require significant production area for storage. At the same time, having a significant energy potential, sufficiently high hydrocarbon content, such waste can be a source of additional income for any wood processing enterprise. This profit can be obtained as a result of the organization of production of wood pellets, using sustainable and steadily increasing demand in the market of the European Union and Russia in the areas where there is a deficiency of fossil hydrocarbons.

Constructive design of production process of biofuel in the form of pellets, briquettes of different shapes and contents is already developed by many engineering companies, major manufacturers of machine tools, tools, technological equipment. It is known that in many kinds of such equipment there are very important components that determine the rhythm of the machines, the frequency of routine and preventive services, unscheduled repairs. So in the pellet presses for the production of wood pellets, press matrices are important and crucial units, determining the nature of the process, product quality, the probability of an emergency. They are usually made of high strength stainless steel or alloy steel by using vacuum quenching technologies. Due to the advanced design of matrix the productivity of pellet press can be increased to some extent, pressure on the pressure element can be reduced.

MATERIALS.

The most important indicators characterizing not only the pressing process of wood pellets, but also the efficiency of the individual pieces of equipment are the following mode parameters: amount of supplied wood raw material X_1, humidity of the wood raw material X_2, fractional composition of supplied wood raw material X_3, lignin content of wood, determined by species composition X_4, the distance between the rollers and the matrix X_5, rotation speed of matrix X_6, steam temperature X_7, cooling temperature of pellets X_8. The above mentioned parameters along with such objective changing factors as air temperature F_1, air humidity F_2, raw material temperature F_3 determine effective service life of matrix. Indeed, such number of controlled or regime indicators and uncontrolled factors, in varying degrees, define one of the most important output indicators characterizing the duration of operation of the matrix, its operating temperature. In real production conditions, the temperature of the pressing matrix can be adjusted by these parameters. However, for the formation of an adequate control action mathematical modeling of this indicator is necessary, which allows calculating the numerical values of mode parameters at certain levels of objective factors. In this case numerical values of mode parameters must maintain minimum temperature of the matrix.

This problem can be completely solved by modern methods of system analysis, planning active industrial experiment, statistical processing of results and mathematical modeling with the help of specialized software applications packages [2]. As a result of active industrial experiments, reliable information about the properties of the control object was received, confirmed by sufficiently adequate obtained mathematical dependence.

RESULTS.

In general form matrix temperature dependence t_m is expressed by Taylor series, taking into account, including, quadratic and pair interactions of controlled parameters at the appropriate levels of uncontrolled disturbing effects:

$$t_m = B_0 \cdot X_0 + B_1 \cdot X_1 + \ldots + B_n \cdot X_n + B_{11} \cdot X_1^2 + \ldots + B_{nn} \cdot X_n^2 + B_{F1} \cdot F_1 + \ldots$$
$$+ B_{Fk} \cdot F_k + B_{12} \cdot X_1 \cdot X_2 + \ldots + B_{n-1} \cdot X_{n-1} \cdot X_n \qquad (1)$$

where $B_0 \ldots B_{n-1}$ - regression coefficients, obtained by the least squares method

The table shows the numerical values of the regression coefficients included in the equation (1), which describes the temperature of pellet press matrix after normalization of this function.

Table – Numerical values of regression coefficients

№	Element name	Regression coefficient	№	Element name	Regression coefficient
1	B_0	-0.0599079130	25	$X_1 \cdot X_6$	-0.0000001742
2	X_1	-0.0000110581	26	$X_1 \cdot X_7$	0.0000003889
3	X_2	-0.0266452827	27	$X_1 \cdot X_8$	0.0000003483
4	X_3	-0.0422823767	28	$X_2 \cdot X_3$	0.0077665714
5	X_4	0.1024840704	29	$X_2 \cdot X_4$	0.0003895691
6	X_5	-0.2025929794	30	$X_2 \cdot X_5$	-0.0048179478
7	X_6	-0.0046212494	31	$X_2 \cdot X_6$	0.0000436543
8	X_7	-0.0008365595	32	$X_2 \cdot X_7$	0.0001340958
9	X_8	0.0505752600	33	$X_2 \cdot X_8$	0.0001115801
10	F_1	0.0001434521	34	$X_3 \cdot X_4$	-0.0007550481
11	F_2	0.0001919646	35	$X_3 \cdot X_5$	-0.0002093571
12	F_3	-0.0015151231	36	$X_3 \cdot X_6$	0.0000052549
13	X_1^2	0.0000000288	37	$X_3 \cdot X_7$	-0.0001894872
14	X_2^2	0.0004842243	38	$X_3 \cdot X_8$	-0.0000702415
15	X_3^2	-0.0036302298	39	$X_4 \cdot X_5$	-0.0457858462
16	X_4^2	-0.0030307134	40	$X_4 \cdot X_6$	0.0005283434
17	X_5^2	-0.0845384967	41	$X_4 \cdot X_7$	0.0000339085
18	X_6^2	-0.0000552387	42	$X_4 \cdot X_8$	-0.0000411715
19	X_7^2	0.0000047974	43	$X_5 \cdot X_6$	0.0105174029
20	X_8^2	-0.0008816559	44	$X_5 \cdot X_7$	0.0017233347

21	$X_1 \cdot X_2$	-0.0000242863	45	$X_5 \cdot X_8$	0.0004474948
22	$X_1 \cdot X_3$	0.0000215260	46	$X_6 \cdot X_7$	-0.0000115723
23	$X_1 \cdot X_4$	0.0000021497	47	$X_6 \cdot X_8$	-0.0000098858
24	$X_1 \cdot X_5$	-0.0000026039	48	$X_7 \cdot X_8$	-0.0001588935

The resulting equation was tested on adequacy to the real process of pelletizing. Deviation of the measured values of the matrix temperature of pellet press from the values, calculated by the formula (1) for each industrial experiment was determined by the following formula:

$$\Delta_i = \frac{|t_{mc} - t_{me}|}{t_{me}} \cdot 100\ \%, \qquad (2)$$

where t_{mc}, t_{me} – calculated and experimental temperature values of the matrix for i-th experiment respectively, °C.

Value of Δ_i for each industrial experiment in a series of 81 experiments was within 0.009 ... 1.66%, and the average value for the entire series of experiments was 0.55%. This level of deviation is acceptable to wood processing in which permissible deviation should be $\Delta_{perm} \leq 5$ %.

CONCLUSION.

Of course, monitoring and control of the temperature of the matrix should be in consistency of other equally important output parameters describing both technological and economic component [3]. It would be inappropriate, providing the desired temperature of the pressing matrix, not to take into account or to pay less attention to the calorific value and the mechanical strength of the produced pellets, performance of pellet press, unit cost of biofuel.

This requires consolidated or integrated control solution that satisfies in this or that extent all output technical and economic parameters and provides the best or extreme values of characteristics of pelletizing process at different levels of objectively changing factors.

This problem will be solved in the future by multiobjective optimization method with predetermined coefficients of weights of all objective functions of the process, their normalization and obtaining generalized additive utility function.

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Streszczenie: Model temperatury prasy do peletowania drewna. Na bazie eksperymentów o skali przemysłowej znaleziono zależności matematyczne opisujące temperaturę matryc w peleciarce. Zależności te, zbieżne z warunkami praktycznymi, mogą być użyte przy sterowaniu procesem produkcyjnym zapewniając ciągłość i wysoką jakość produkcji peletu. Utrzymywanie możliwie niskich temperatur matryc zwiększa ich żywotność i zmniejsza prawdopodobieństwo awarii.

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