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Study of the technological process parameters basis on a mathematical model

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Abstract. The results of modeling of parameters of technological process are presented in this article. By means of data processing of an experiment the mathematical expressions connecting values of input and output parameters of process are received. On the basis of the regression analysis the system from three equations has been calculated. The check of the constructed model on suitability of application is executed. The received results will allow operating the process parameters so that to minimize the amount of discrepancies in the studied parameter that will lead to increase in production efficiency, decrease in level of marriage, decrease in grade of production, reduction of number of the controlling operations.

1. Introduction
Control and product quality are the main problems of modern production. The quality of modern products is considered as a complex indicator, which depends on the general scientific level of development, the quality of products, the perfection of technology and metrological support of production. Therefore, the problems of product quality should be solved at the earliest stages and stages of development of the technological process.

Any control system includes entrance, current and output control [1, 2]. The entrance control provides with big reliability of assessment of production quality shown on control; prevention of start in production or repair of production which isn't conforming to the established requirements. On the production which isn't conforming to requirements of standard documentation the act of defective production is made out. The current control represents the control of course of process by operators on each site of production which is carried out in the automated way [3–5]. The output control of finished production is carried out in production laboratory of the enterprise on compliance of quality indicators [6]. Unfortunately, the presence of automatic control does not guarantee 100% quality control of the assembled products. There are hidden defects in the joints (microcracks, air bubbles, unreliable contact of the hidden conclusions of the components BGA etc.), which are manifested in the operation of the nodes.

We will consider the line of impregnation of decorative paper with the melamine pitches as a result of which the high-quality melamine film applied for the lamination of the wood-shaving plates is made.

For the purpose of prevention of production of inappropriate products, we will exercise control of production process [7, 8]. For this purpose, we use mathematical model of process.

2. Research description

This article is the continuation of works [9, 10] in which stages of studying of this process are presented, namely:

- technological process is investigated;
- the correlation dependence between factors is constructed;
- the most significant factors are revealed;
- the plan of an experiment is developed.

The purpose of the following stage of this work was drawing up a system of the equations with use of the regression analysis on the basis of processing of the obtained data.

The object of a research is the technological process of the chipboard's production.

The subject of a research is the system of communications between adjustable parameters of technological process of the chipboard's production.

When studying aprioristic information, the analysis of data with use of the following tools of quality was carried out: control card; histogram; Pareto's analysis; Isikava's chart; control leaf; chart of dispersion of [11,12].

Baseline data is given in [10].

Considering the coefficients we will make the system of the equations:

$$\begin{cases} y = 687.88 - 2.75 \cdot x_1 + 2.38 \cdot w_2 + 6.13 \cdot w_4 + 1.75 \cdot x_1 \cdot w_2 + 1 \cdot x_1 \cdot w_4 + 2.38 \cdot w_2 \cdot w_4 + \\ + 0.25 \cdot x_1 \cdot w_2 \cdot w_4; \\ y = 686.70 - 3.8 \cdot x_2 + 0.9 \cdot w_5 + 1.8 \cdot x_2 \cdot w_5; \\ y = 686.83 - 1.42 \cdot x_3 - 0.83 \cdot w_1 + 4.42 \cdot w_3 + 1.92 \cdot x_3 \cdot w_1 + 3.17 \cdot x_3 \cdot w_3 - 0.42 \cdot w_1 \cdot w_3 + 0.33 \cdot x_3 \cdot w_1 \cdot w_3. \end{cases}$$

Some of the equation coefficients are insignificant, i.e. they have no significant effect on formations of a process response. In this regard, these coefficients which reflect the influence of a factor or the effect of factors' interaction are excluded from the equations. An inspection of the importance of coefficients was carried out by Styudent's criterion.

Therefore, it is possible to draw a conclusion that all factors have a significant effect on formation of density value. Coefficients only at one pair interaction of humidity of shaving and the temperature of pressing are insignificant and at threefold interaction of all factors – humidity of shaving, a ratio of layers, pressing temperature.

Insignificant coefficients are excluded from the equations. Thus, the final option of system of the equations has this form:

$$\begin{cases} y = 687.88 - 2{,}75 \cdot x_1 + 2{,}38 \cdot w_2 + 6{,}13 \cdot w_4 + 1.75 \cdot x_1 \cdot w_2 + 2{,}38 \cdot w_2 \cdot w_4; \\ y = 686.70 - 3.8 \cdot x_2 + 1.8 \cdot x_1 \cdot w_5; \\ y = 686.83 - 1.42 \cdot x_3 + 4.42 \cdot w_3 + 1.92 \cdot x_3 \cdot w_1 + 3.17 \cdot x_3 \cdot w_3. \end{cases}$$

After the calculation of model's coefficients, it is required to check the model for suitability. Such check is called check of model's adequacy.

In statistics a very convenient way of check of a hypothesis of model's adequacy is developed [13, 14].

The received value is compared to the tabular one. If the calculated value doesn't exceed the tabular one with the set confidential probability, the model can be considered as adequate. Therefore, the hypothesis of model's adequacy is accepted.

3. Interpretation of results

Each of the equations shows certain results of influence of entrance factors on plate density at a stage of formation of a wood-shaving carpet.

1. The considered factors: humidity of shaving (x_1), ratio of layers (w_2) and temperature of pressing (w_4):

$$y_1 = 687.88 - 2.75 \cdot x_1 + 2.38 \cdot w_2 + 6.13 \cdot w_4.$$

In this equation all coefficients are significant, i.e. each of factors has significant effect on changes of a density indicator of chipboard. The coefficient at x_1 shows that at increase in humidity at one unit from value 2.25, density decreases by 2.75 kg/m^3 and vice versa, at reduction of humidity of shaving by each 1 % of 2.25%, plate density every time will increase by 2.75 kg/m^3.

At increase in value of a factor of a layer's ratio by 1% of 20.6% density of a plate will increase by 2 kg/m^3, at reduction of value of a factor of a ratio of layers by 1% of 20.6% density of a plate will decrease by 2 kg/m^3.

At increase in temperature of pressing on 1^{0}C from 197^{0}C, density will increase on 6 kg/m^3. At reduction of pressing temperature on 1^{0}C from 197^{0}C, density will go down on 6 kg/m^3.

2. The considered factors: tarring of an inside layer (x_2), pressure on the press (w_5):

$$y_1 = 686.70 – 3.8 \cdot x_2.$$

In this set the pressure on the press has no significant effect on values of density.

As for tarring of an inside layer, at increase in this parameter by 1% of 7.1% density decreases by 4 kg/m^3, and respectively on the contrary.

3. The considered factors: tarring of an external layer (x_3), speed of formation of a wood-shaving carpet (w_1), weight of a carpet (w_3):

$$y_1 = 686,83 – 1.42 \cdot x_3 + 4.42 \cdot w_3$$

In this case, the speed of carpet formation influences density indicator not significantly. At the same time, increase in tarring of an external layer by 1% from 11.6 leads to reduction of density of a plate by 1 kg/m^3. Increase in weight of a carpet by 1 kg from 131 kg corresponds to increase in density by 4 kg/m^3.

To determine the optimal conditions for the process, the gradient motion method is applied to each of the equations found. The Table 1 presents the optimal parameters of the production process.

Table 1. Optimal parameters of the production process

Input data \ Output data		Layer ratio, [%]	Pressing temperature, [^{0}C]	Density, [kg/m^3]
Chip Moisture, [%]	2.4	20.5	196	683
	2.2	20.7	197	693
	2.1	20.8	198	697

The Table 2 shows the parameters for optimizing the production process, obtained empirically.

Table 2. Parameters for optimizing the production process, obtained empirically

Input data \ Output data		Layer ratio, [%]	Pressing temperature, [^{0}C]	Density, [kg/m^3]
Chip Moisture, [%]	2.4	20.5	196	677
	2.2	20.7	196	697
	2.1	20.8	196	682

4. Conclusions

So, all technique of planning of an experiment which has been received in the practical way is described.

Before carrying out an experiment the aprioristic information by means of the analysis of process of chipboard production with use of statistical control methods has been studied. The financial losses connected with the production scrap have been as a result estimated. Stages of technological process of chipboard production at which there is the greatest number of defective plates are found. Types of defects which make 80% of all mass of defects are established. Types of defects which incur the greatest losses for the enterprise are found. Such defects are "short, friable plates". When studying these types of defects, the reasons of their formation in a production cycle are established.

On the basis of the regression analysis the system from three equations has been calculated. The check of the constructed model on suitability of application is executed.

Interpretation of results by the indication of interference of factors on a research object response in concrete numerical values is made.

This method has allowed establishing the influence of the chipboards of parameters regulated during the technological process of producti on on a quality indicator. Density of chipboard is taken for the quality indicator demanding the improvement and stabilization [15].

Due to the restrictions which are available in work the mathematical model has been developed for one stage of production – formation of a wood-shaving carpet. At the same time the studied parameters of technological process have been divided into three groups. Therefore, the constructed mathematical model represents system from three equations. With its help it is possible to improve the results received in work if to make an experiment on the production. At the same time one equation will be received that taking into account the interaction of all factors will fully reflect their influence on the chosen quality indicator.

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