MODELLING OF MULTIFACTOR PROCESSES WHILE OBTAINING MULTILAYER HUMIC-MINERAL SOLID COMPOSITES

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Abstract. The mathematical model of continuous process of formation of multi-layer humic-mineral composites from the liquid systems on the basis of the fuzzy set theory for achieving steady kinetics of granulation process is proposed.

Keywords: multi-layer humic-mineral solid composites, granulation new centers function, quality losses function, fuzzy sets, membership functions, equivalent diameter, product dispersion composition

The industrial technology development of granular humic-mineral fertilizers with predetermined properties from wastes of chemical and mining industries for ecological balance preservation is an important task of the national economy. The authors [1] developed a method of obtaining humic-granular fertilizers with variable nutrient composition and stimulating substances in accordance with agro-climatic conditions of their application region. The technology essence lies in dehydration and granulation of process solutions in a fluidized bed apparatus and obtaining a granulated product of the predetermined dispersion composition and physical and chemical properties of the components uniform distribution. This can be achieved due to the multiple layer mass crystallization of mineral particles and precipitation of colloidal particles of humic substances. To sustain the formation of multifactor process steady kinetics of solid organic-mineral composites with a strong stochastic nature is needed to change the process parameters in a time manner.

Problem setting

The objective of the investigation is to create a mathematical model that describes influence of the stochastic nature factors on kinetics stability of the continuous formation process of humic-mineral composites with predetermined properties.

Basic approaches to the mathematical model creation

Studies [2,3] are the closest solutions of the problem but the proposed models do not fully take into account the nature of the formation process of crystal-amorphous structures. To take into account the stochastic nature of the process is appropriate to use a fuzzy logic method which is based on application of fuzzy sets and linguistic variables [4]. For this purpose MatLab environment with FuzzyLogicToolbox adds-on of fuzzy sets is applied.

Two blocks – basic and intermediate ones were proposed to designate in the model taking into account the nature of the processes. The structure of the model is shown in Fig. 1.

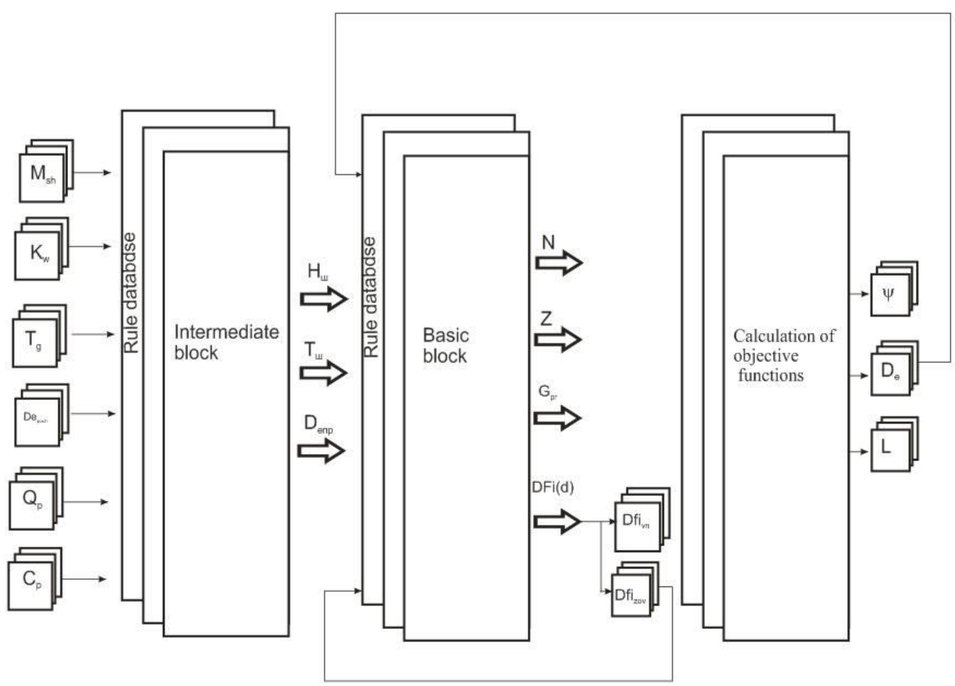

Fig. 1. Structure of dehydration and granulation model with using fuzzy sets method

With due consideration of the full-scale investigations described in [5,6], there were defined the following basic input parameters for the intermediate block: the loaded material mass (*M*sh), the fluidization number (K_W), the gas coolant temperature (*Tg*), the equivalent diameter of the granulation primary centres (De_{poch}), the working solution expenses supplied to the apparatus (*Q*p) and its concentration (Cp), Fig. 1. The output variables of the intermediate unit are: the layer height (*H*sh), temperature (*T*sh) and the current equivalent diameter of particles in the layer (De_{pr}).

These parameters together with the parameters of mass y-distribution of granules masses sized n and z, the power function of granulation new centres dFi (D) and weight of the obtained products *G*pr determine the granulation coefficient (Psi) and quality function of the granular product (*L*), Fig. 1.

The model input variables are chosen as membership functions of the bell-shape form (gbellmf), Fig. 2.

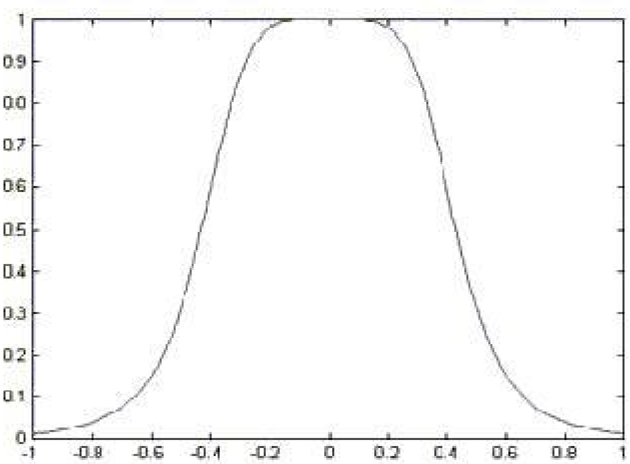

Fig. 2. General view of bell-shaped membership function

The peculiarity of these functions is that they can change not only its shape but also the width of the maximum value of the plot, as shown in Fig. 2.

Increasing the model compliance to real process is the creation of rule database and selection of suitable number of membership functions for the experimental results.

Particularly for the processes of obtaining humic-mineral solid composites of the following composition 1 – H:N = 1:20, II – H:N: Ca = 1:15:12 and III – H:N:K:Ca = 1:15:8: 5 [5,6] for variables M_{SH}, K_W, Tg, Qr, Wed, Hsh, Tsh types of membership functions were proposed, shown in Fig. 3.

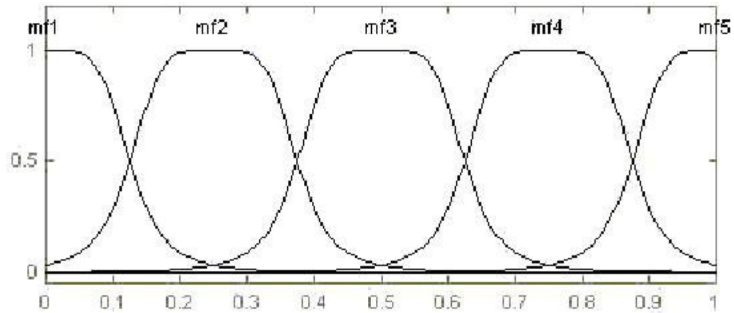

Fig. 3. Distribution of membership functions for variables M_{SH}, K_W, Tg, Qp, Cp, Hsh, Tsh

According to De_{poch}, De_{pr}, n and z variables with taking into account their greater variability degree [4,5] membership function was offered, shown in Fig. 4.

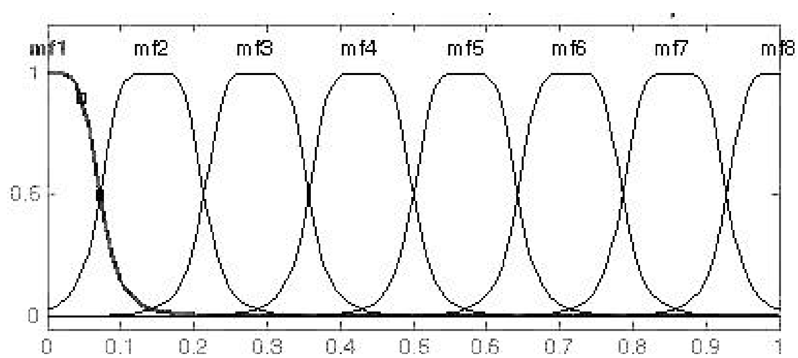

Fig. 4. Distribution membership functions for variables De_{poch}, De_{pr}, „n“ and „z“

In addition, it was established a rule database which describes qualitative changes in output variable changes of input parameters.

Thus, a generalized block diagram of the continuous process model of solid humic-mineral composites formation is shown in Fig. 5: Module I – input variables that take into account technological parameters, chemical composition of the product etc.; Module II – taking into account peculiarities of kinetics, stabilization method of dispersion composition; Module III – qualitative and quantitative characteristics that determine the process effectiveness.

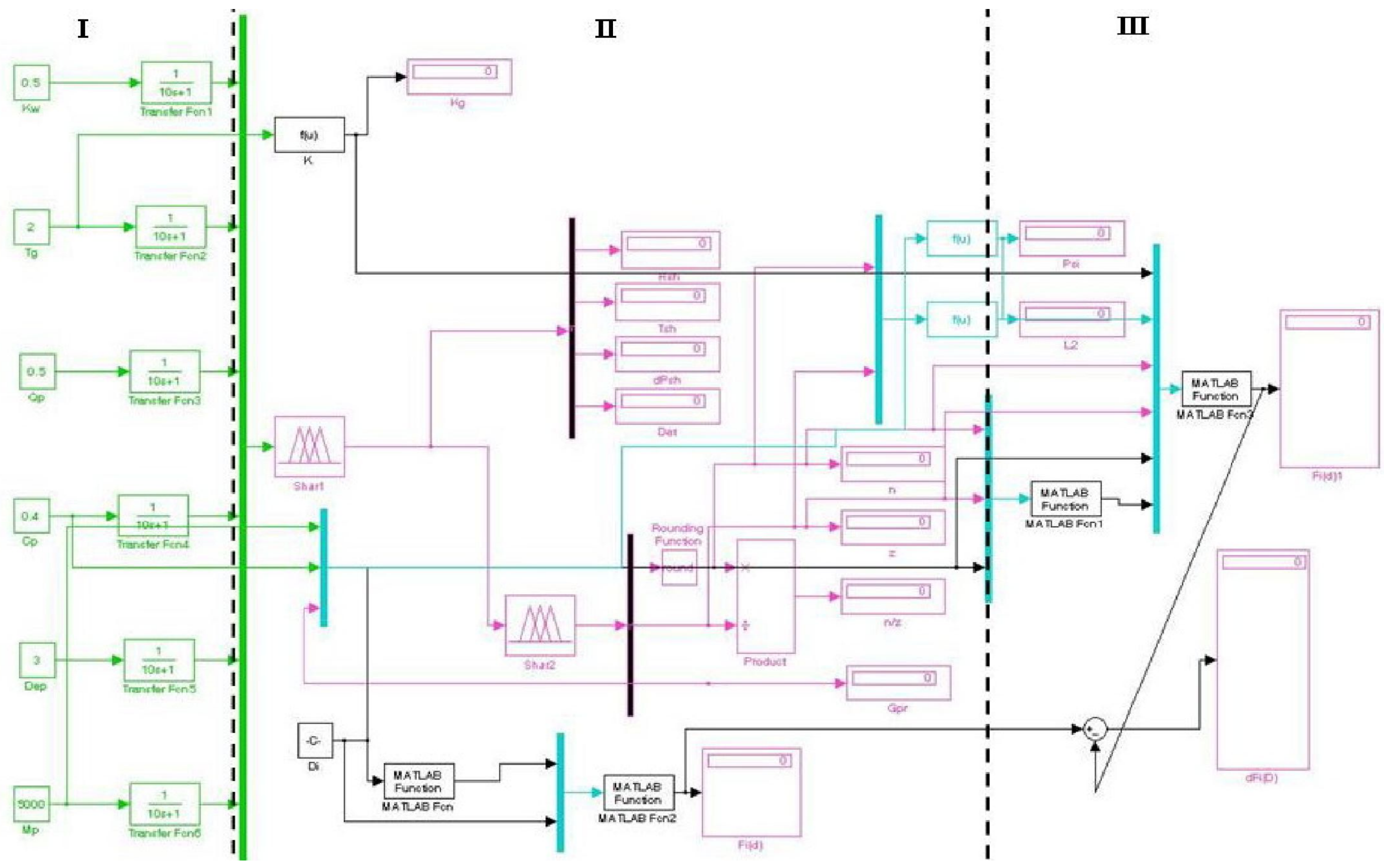

Fig. 5. Flowchart of model formation process of solid humic-mineral composites

The model is based on three modules: module I considers input variables, which include process variables, chemical composition of the product, etc., module II takes into account the kinetics peculiarities, the stabilization method of dispersion composition, module III takes into account qualitative and quantitative features that characterize the process effectiveness.

The quality function „*L*" takes into account the deviation of mass distribution of the granular product from the predetermined values, the granulation coefficient „Psi" is determined by the ratio of masses of granular product to the dry matter mass, which comes with working solution. The range of desired values for these functions are: $L \to 0$, Psi $\to$ 0,99. To achieve the preset goal blocks „Psi" and „*L*" have feedback from variables „*T*sh", „*H*sh", „*De*pr".

The basic condition for sustainable kinetics of the formation process of solid composites with layer structure is stability provision of the particles total surface in the layer and the number of granulated product including unloading and recovery centres of granulation due to internal or external recycling. For this, in block II and III the preset and current value of new centres of granulation Fi (D) power functions are continuously calculated by employing the built functions of MatLab environment and their difference dFi (D). If the acquisition function dFi (D) range from 0 to 2,3 of negative values (insufficient intensity of new granulation centres) it needed to in addition to new centres of granulation apparatus from the outside. When values dFi (D) = 0 centres granulation are formed by crushing of large granules, i.e. an internal recycling is implemented. The presence of feedback from the previous blocks allows determining these parameters change by a special algorithm. Table 1 shows the values in their respective points of the process.

Table 1. Results of the model calculation

	Block I						***Block II***						***Block III***	
№	***Kw***	***Tg***	***Qp***	***Cp***	D_{en}	***Mp***	H_{sh}	T_{sh}	***n***	***z***	***n/z***	***dFi(d)***	***Psi***	***L***
1	0.5	2	0.5	0.4	2.2	5000	0.505	0.5	19	8.411	2.3	0	0.97	0
2	0.5	2	0.5	0.4	1.5	5000	0.505	0.5	12	8.572	1.4	2.17	0.9	24.51
3	0.5	2	0.5	0.4	2.6	5000	0.505	0.5	19	5.299	3.5	-2.93	0.86	4.809
4	0.5	2	0.5	0.4	3	5000	0.505	0.5	17	3.779	4.5	-3.958	0.89	12.68
5	0.5	2	0.5	0.4	3.5	5000	0.505	0.5	21	3.73	5.5	-4.305	0.81	12.89

As shown in Table 1 for different experiments and, consequently, for different set values of input variables different results were obtained. For Experiment 1 the objective function values appeared satisfactory, i.e. for these input values of the process can run relatively stable. In Experiment 2 functions dFi(d) take positive values, which specify necessity withdrawal of 3.0 mm granules size grading by separation unloading. Herein it is observed a decrease in the ratio n/z, leading to a sharp increase of the function L, which indicates a significant difference of current dispersion composition from the predetermined values and therefore specifies active adjustment of parameters in the intermediate unit (block), even at high values of granulation coefficient Psi = 0,9. For experiments 3,4,5 it is observed a significant increase of the ratio n/z, which leads to negative values acquisition of function dFi (d), i.e. for the process predetermined types for kinetics stabilization an external source of new granulation centres should be applied; granulation coefficient values decreased, but the quality loss function with respect to the second experiment are reduced, i.e. the ratio n/z influence upward from the optimum has less impact on the product quality than deviations upward increase.

Conclusions

The proposed mathematical model makes it possible to determine the initial characteristics influence on the basic technological parameters of the process – the fluidized bed height *Hsh*, its temperature *Tsh*, and as a result, the effectiveness of the granulation main characteristics of the granulated product (dispersion composition, equivalent diameter, and product quality).This will allow under the conditions of industrial implementation of granular humic-fertilizers production technology to determine the degree of automatic process control in case of disturbances due to stochastic changes of process technological parameters, and under force major situations promptly withdraw the unit from operation mode and determine the technical staff's procedure that will lead to lower energy costs and obtain maximum quantity of quality product with appropriate characteristics, defined in advance.

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