THE METHOD OF DETERMINATION OF THE OPTIMAL PARAMETERS OF DISPERSED MATERIALS GRANULATION THROUGH CONSOLIDATION

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Abstract: *The method of determination of the optimal constructive and technological parameters of dispersed materials granulation through consolidation is represented within the task of nonlinear mathematical programming. The method is based on mathematical modeling of dispersion materials extrusion through the granulator matrix holes. The method allows taking into account constructive features of technological equipment and rheological properties of the raw material.*

Key words: *extrusion, disperse materials, mathematical modeling.*

1.Introduction

Recently in food and processing industry appeared a problem of the rational usage of the offals, such as sunflower husk, straw, bagasse, beer pellet, wood shavings and other. According to the Ukrainian Law about the stimulation of biofuel production and considering the world energy crisis, such offals should be used as biofuel, compound feed and other. But because of the low bulk density, the transportation of such materials is not profitable. It stipulates increasing of bulk density of these materials with briquetting consolidation, baling, granulation and other. According to the analysis of different consolidation technologies we conclude that granulation is the most rational way since it is a continuous process that allows getting the product with the maximum density and provides versatility of further usage of granules (biofuel, compound feed of different factions.)

The analysis of the latest researches and publications [1] shows that effective realization of pressing technologies through extrusion depends a lot on constructive parameters of the equipment, which provide the required performance. Herewith the application of modern information technologies of design allows determining of quantitative and qualitative patterns of consolidation of disperse materials of different structural and mechanical characteristics. Considering the wide range of raw materials while determining the constructive parameters of the equipment there appears a new problem. It is the finding of interconnection between the basic constructive and technological parameters of a specific pressing node. Since the problem includes lots of parameters, it is important to find their optimal distribution.

2. Materials and methods

The goal of this paper is to create the method of determination of basic elements of technological equipment for disperse materials granulation through consolidation [2].

The method is schematically represented in Figure 1. Consolidation technology is implemented by raw material extrusion through matrix holes. Figure 1 shows, that to set the optimization task within the general mathematical programming theory, it is necessary to find the interconnection between all the parameters which describe the special granulation process. So there is a necessity to make a research to define quantitative dependences, which describe thermodynamic process and mass transfer in the material during its granulation through consolidation.

The effectiveness of granulating press is evaluated according to the granules quality (density), productivity and power consumption. So appear several optimization criteria:

1) Maximize granules density
2) Minimize power consumption
3) Maximize productivity

$$\rho(\alpha) \to \max; \quad W(\alpha) \to \min; \quad Q(\alpha) \to \max; \qquad (1)$$

where, $\rho(\alpha)$ – granules density, $W(\alpha)$ – power of granulator drive, $Q(\alpha)$ – granulator productivity.

Having analyzed the construction of granulator pressing node and granulation technology [4], we found out the following optimization restrictions:

$$40 \text{ mm} \le L \le 90 \text{ mm}, \quad 8 \text{ mm} \le d \le 28 \text{ mm}, \quad 50 \text{ mPa} \le P \le 300 \text{ mPa}, \qquad (2)$$

where L – length of matrix dies, d – dies diameter, P – shrinkage pressure.

Lets rewrite (1) considering (2):

$$\rho(L,d,P) \to \max; \quad W(L,d,P) \to \min; \quad Q(L,d,P) \to \max; \quad 40 \le L \le 90; \quad 8 \le d \le 28; \quad 50 \le P \le 300 \qquad (3)$$

So, the problem with three target functions is formulated. And we face the multicriterion problem – making the solution in the presence of number of target functions $f = \{f_i(a)\}$ (I = 1, 2, …, M), where α is some alternative implying continuous vector variable, which belongs to the convex closed range which is usually set by system of inequalities [3].

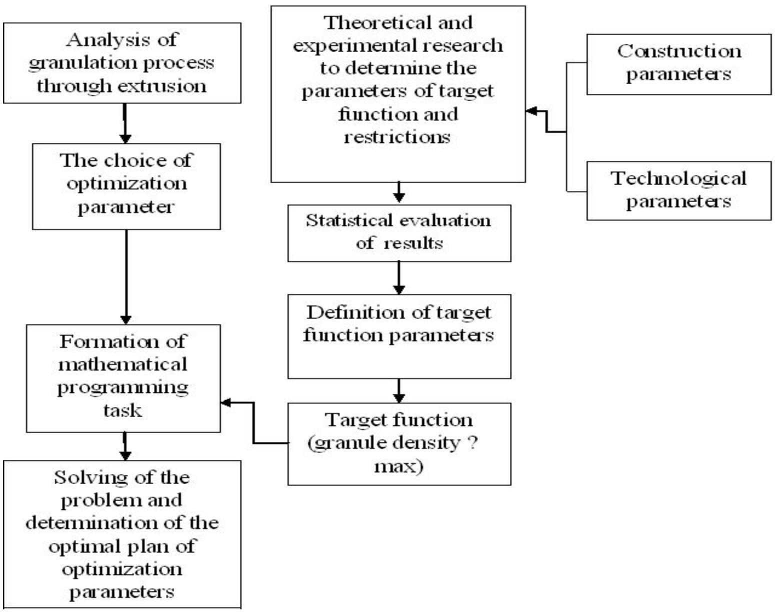

Fig 1. The scheme of determination of optimal constructional and technological parameters of disperse materials granulation through consolidation

It is clear that the optimum after each target function criteria can not always be reached with the same control parameter α value. That's why it is necessary to stipulate how to make a decision. There appears a problem of choice of one of the effective alternatives – search of compromise (compromise decision).

α^0 alternative can be considered as effective if there are no other alternatives better on at least one criteria and not worse on the others [3]. In our case *f* set criterion possess different physical content. Some are maximized and some are minimized. It should be noted that if α^0 is the effective alternative of criterion set $f = \{f_i(a)\}$ (I = 1, 2, …, M), than α^0 is an effective alternative of function set $\psi = \{\omega_i(f_i(a))\}$ $(I = 1, 2, \ldots, M)$, where $\omega_i(f_i(a))$ is a monotonic function $f_i(a)$.

To find the effective points it is necessary to transform the functions $\omega_i(f_i(a))$ on to dimensionless ones or such, when $\omega_i(f_i(a)) \rightarrow \min$. That's why the following monotonic transformations for maximizing criterion should be introduced:

$$\omega_i(f_i(a)) = \frac{f_i^0 - f_i(a)}{f_i^0 - f_{i(\min)}}, i = 1, \ldots, m. \qquad (4)$$

for minimizing criterion

$$\omega_i(f_i(a)) = \frac{f_i(a) - f_i^0}{f_{i(\max)} - f_i^0}, i = m+1, \ldots, M. \qquad (5)$$

f_i^0 – optimal value of the i-criteria

$f_{i(\min)}$ - the smallest value of maximizing criteria

$f_{i(\max)}$ - the biggest value of minimizing criteria

So the parametrical problem should be solved:

$$\text{man}\psi(\alpha) = \min_{\substack{\alpha\in U \\ \alpha\in V}} \{\sum_{i=1}^{m} \gamma \frac{f_i^0 - f_i(a)}{f_i^0 - f_{i(\min)}} + \sum_{i=m+1}^{M} \gamma \frac{f_i(a) - f_i^0}{f_{i(\max)} - f_i^0}\} \qquad (6)$$

for each $\gamma_i \in \gamma^+ \{\gamma_i \succ 0, \sum_{i=1}^{M} \gamma_i = 1\}$.

3. Results and discussion

Lets use such method when the compromise solution is considered as the one, which allows the minimal relative deviation from the optimum parameter values depending on weighting coefficient δ_i, such that

$$\delta_i \in \delta^+ \{\delta_i > 0, \sum_{i=1}^{M} \delta_i = 1\}.$$

Let's solve the problem using this method.

According to (2) and (3) let's deceive the obtained dependences to dimensionless and minimizing ones:

$$\rho^* = \frac{\rho_{opt} - \rho}{\rho_{opt} - \rho_{\min}},$$

where

$\rho = 58.04 + 9.8d + 15.72L + 4.25P -$
$0.049d \cdot P - 0.53d^2 - 0.09L^2 - 0.0065P^2$

ρ_{opt} – optimal value of ρ function,

$\rho_{\min}$ – minimal possible value of ρ function considering restrictions (2)

$$Q^* = \frac{Q_{opt} - Q}{Q_{opt} - Q_{min}},$$

where

$$Q = 1745.5 + 35.78d + 18.2L + 10.96P + 0.132d \cdot P - 0.0443L \cdot P - 0.298L^2 - 0.018P^2$$

Q_{opt} – optimal value of Q function,
Q_{min} - minimal possible value of Q function considering restrictions (2)

$$W^* = \frac{W - W_{opt}}{W_{max} - W_{opt}},$$

where
W_{opt} - optimal value of W function,
W_{max} - minimal possible value of W function considering restrictions (2).

So for (3) case having considered (4), (5) and (6) we get:

$$\min \psi(d, L, P) = \min_{\substack{d \in [8,30] \\ L \in [40,90] \\ P \in [50,300]}} \left\{ \gamma_1 \frac{\rho_{opt} - \rho}{\rho_{opt} - \rho_{min}} + \gamma_2 \frac{Q_{opt} - Q}{Q_{opt} - Q_{min}} + \gamma_3 \frac{W - W_{opt}}{W_{max} - W_{opt}} \right\}$$

where $\left\{\gamma_i > 0, \sum_{i=1}^{3} \gamma_i = 1\right\}$.

Basing on Levenberg–Marquardt algorithm, in Mathcad 14 pack was created a program to calculate compromise values of control parameters according to the proposed method.

4. Conclusion

The represented method allows formulating and solving of the problem of multicriterion optimization for the set of control parameters of pressing node within the nonlinear mathematic programming.
Solving of the problem allows getting the appropriate optimal parameters of the granulator pressing node in order to formulate the further project solutions.

5. References:

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