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THE HEAT-AND-MASS TRANSFER DURING FILTRATION DRYING OF FEEDSTOCK FOR SLAG GRAVEL PRODUCTION. RESEARCH OF CHANGE OF TEMPERATURE OF THERMAL AGENT IS ON HEIGHT OF LAYER OF MATERIAL

In the article the results of experimental and theoretical researches are presented heat- and mass-transfer during the filtration drying of feedstock for slag gravel production. Time-history of temperature of thermal agent is experimentally investigational on the height of layer of dry and moist raw material materials and dependence of speed of moving of mass-transfer zone is certain on a temperature.

Key words: filtration drying, slag, clay, raw granules, heat - and - mass transfer, heat agent.

Подано результати експериментальних і теоретичних досліджень тепло- і масообміну під час фільтраційного сушіння сировинних матеріалів виробництва шлакового гравію. Експериментально досліджено зміну температури теплового агента в часі по висоті шару сухих та вологих сировинних матеріалів та визначено залежність швидкості переміщення зони масообміну від температури.

Ключові слова: фільтраційне сушіння, шлак, глина, сирцеві гранули, тепло- і масообмін, тепловий агент.

Actuality of problem

At the modern world tendencies of increase of consumption of products of building industry and crisis ecological situation actual is a task of the rational use of secondary raw material resources, in particular slag wastes of thermal power-stations (TPS) for the production of building goods of necessary amount and set quality. These wastes it is expedient to apply in the production of slag gravel which is used in the production of easy heat-insulation, construction, chemically resistant concretes, as a fine-grained filter (adsorbent) in gas-cleaning installations, systems of aspiration of housing apartments and others like that [1-4]. The prime of slag gravel is largely determined by power expenses on the process of drying of raw materials; in fact it is known that expenses on his drying present approximately 30% of all production inputs [5-7]. One of high-efficiency methods of drying filtration, advantages of which is that a process takes place in a stationary layer through which a thermal agent is filtered and, as a result: presence of the mechanical expulsing of moisture, maximal satiation of thermal agent by the pair of moisture, high coefficients heat- and mass- transfer, which are limited to only financial viability of process, which enables to use low temperature thermal agent, and also does not require establishment of additional cleansing equipment. Thus, theoretical and experimental research of process of the filtration drying of feedstock for slag gravel production is an actual task.

Analysis of the last publications

Basic conformities to law heat-and mass-transfer during the filtration drying of moist materials in detail described in the advanced studies [8-10].

By an author [8], the experimentally-analytical methods of research are presented heat- and mass-transfer during the filtration drying of dispersible materials. The coefficient of heat- transfer a is certain for dry and moist materials and experimental data are generalized from heat- and mass-transfer on the basis of functional dependence between the criteria of similarity. However the author does not set to influence of temperature on the coefficient of heat- transfer a for moist materials, but accordingly and to his influence on speed of moving of mass-transfer zone.

In-process [9, 10], by the author got results of experimental researches which explain the difficult mechanism of the filtration drying of dispersible materials and enable to optimize the technological parameters of process of the filtration drying the cake of clay. The author investigated the temperature field of thermal agent in a layer of dry clay to the cake at the certain set temperature of thermal agent and fictitious speed. From the received results it is evident; that distribution of temperatures on the height of the investigated material is different and in understates a temperature is considerably below, especially at the beginning of process of heat exchange. Obviously, that this factor must be taken into account during research and analysis of kinetic dependences of change of moisture in time. Calculation dependence is offered for determination of size of speed of moving of mass-transfer zone:

$$\frac{dl}{dt} = \frac{u \cdot (x_{нас} - x_n) \cdot r}{w_n^c \cdot (1-e) \cdot r_s} \cdot e^{-h \cdot h}, \qquad (1)$$

where h is a coefficient which depends on a temperature. However the author did not identify unknown coefficient h in dependence (1).Thus, further researches must be sent to establishment of difficult dependence of temperature of thermal agent as functions of time.

The purpose of work is research heat- and mass- transfer during the filtration drying of feedstock for slag gravel production.

Experimental part

A physical picture of process of external heat and mass exchange in the layer of material is following: thermal agent with a set temperature t_n, contacts with the epiphase of particles a temperature of which is even to the temperature T_n, and saturated by moisture. Filtered through the stationary layer of material his temperature goes down, as he gives the warmth of material, which is spent on evaporation of moisture, convectively. The epiphase of particles of material is dried out quicker all, in fact he contacts with a thermal agent which has the greatest temperature t_n. Obviously, content of moisture in an epiphase will attain a value $w_{кр}^c$ for some time t_1 which is named sometimes forming of front of mass-transfer. Time t_1 can be defined from dependence, resulted in [8]:

$$t_1 = \frac{w_n^c \cdot (1-e) \cdot r_c}{b \cdot s\,(x_{нас.} - x_0) \cdot r}, \qquad (2)$$

where w_n^c - initial moisture of hard material, $kg\ H_2O / kg\,dry\,material$; r_c, r - a closeness of material which is dried out and thermal agent, kg/m^3; s - is a specific surface of particles, m^2/m^3; e - is porosity of layer of material, m^3/m^3; b - is a coefficient of mass transfer, m/s; $x_{нас.}$, x_0 - is a water content satiation and initial water content of thermal agent, $kg\ H_2O/kg\ air$.

To this time t_1, a height $h_{\min}$ answers, where forming of front of mass- transfer is, and changes moisture material from initial w_n^c to critical $w_{кр}^c$, and the temperature of thermal agent diminishes from t_n to $t_{м.т.}$ as a result of evaporation of superficial moisture. Below heights $h_{\min}$ a thermal agent is fully saturated by moisture and in mass-transfer does not take part. A height $h_{\min}$ was determined from dependence:

$$h_{\min} = \frac{2 \cdot u_0 \cdot r \cdot c}{a \cdot s}, \qquad (3)$$

where u_0 - is fictitious speed of thermal agent, m/s; c - is a heat capacity of thermal agent $J/(kg \cdot K)$; a - coefficient of heat transfer, $W/(m^2 \cdot K)$.

Preliminary defining experimentally the coefficient of heat-transfer a (for the certain terms of experience) for the investigated materials we are find a value $h_{\min}$ (table. 1):

Table 1

Time and height of forming of front of mass- transfer (t_1, $h_{\min}$, $t_n = 80^oC$)

Material	t_1, s	$h_{\min}$, m	$u_0, m/s$	$b, m/s$	$a, W/(m^2 \cdot K)$
Slag	12,46	0,0065	1,33	0,15	142
Clay	72,68	0,0121	1,33	0,18	154
Granules	320,32	0,0443	0,57	0,10	97

During drying of moisture of epiphase of particles after moving away of external moisture changes from critical $w_{\kappa p}^c$ to level w_p^c and in the layer of material simultaneously there is drying both in the first and in second periods. The layer of dry material appears after some time, and a mass-transfer h zone moves in direction of motion thermal to the agent to the perforated partition. During the filtration drying the temperature of material grows from initial T_n to T_κ what part of warmth of thermal agent is spent on. Hereupon the temperature of thermal agent diminishes on the height of layer.

We were investigate the temperature field of thermal agent in the layer of feedstock for slag gravel production at the set temperature of thermal agent $t_n = 80 \pm 0{,}5^oC$, in obedience to methods resulted in [11]. The set temperature of material folded $+20\,^oC$ .Time-history of temperature of thermal agent on the height of layer of raw material materials is brought around to fig.1, 2.

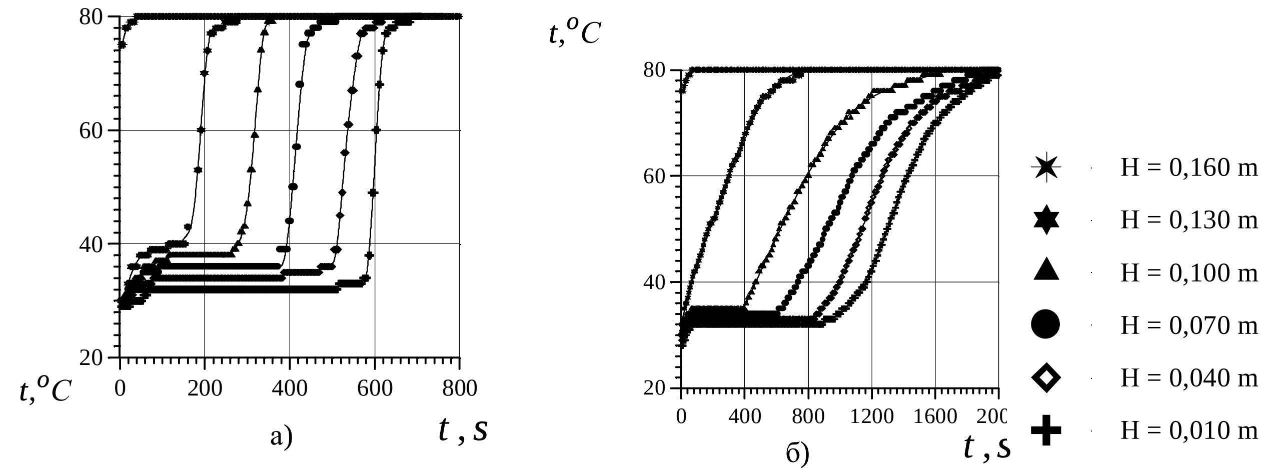

Fig. 1. Changing of temperature of thermal agent on the height of layer of moist materials for: to the a) slag; b) clay

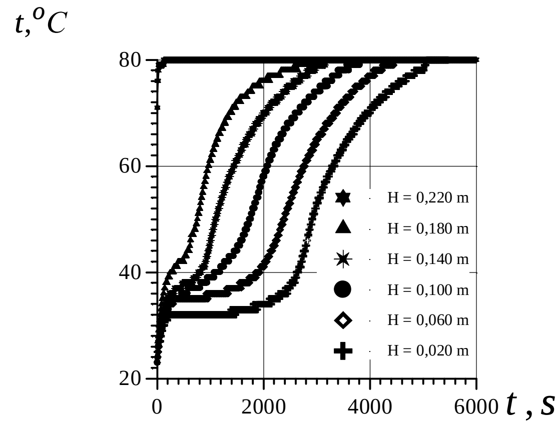

Fig. 2. Change of temperature of thermal agent is on the height of layer moist materials for raw granules

Analysis of fig. 1, 2 shows, that distribution of temperatures on the height of layer of moist materials changes in time, in understate a temperature is below, especially at the beginning of process of heat exchange. On the basis of fig. 1, 2 the built dependence of change of temperature of thermal agent on the height of layer of moist material for the certain interval of time (fig. 3, 4).

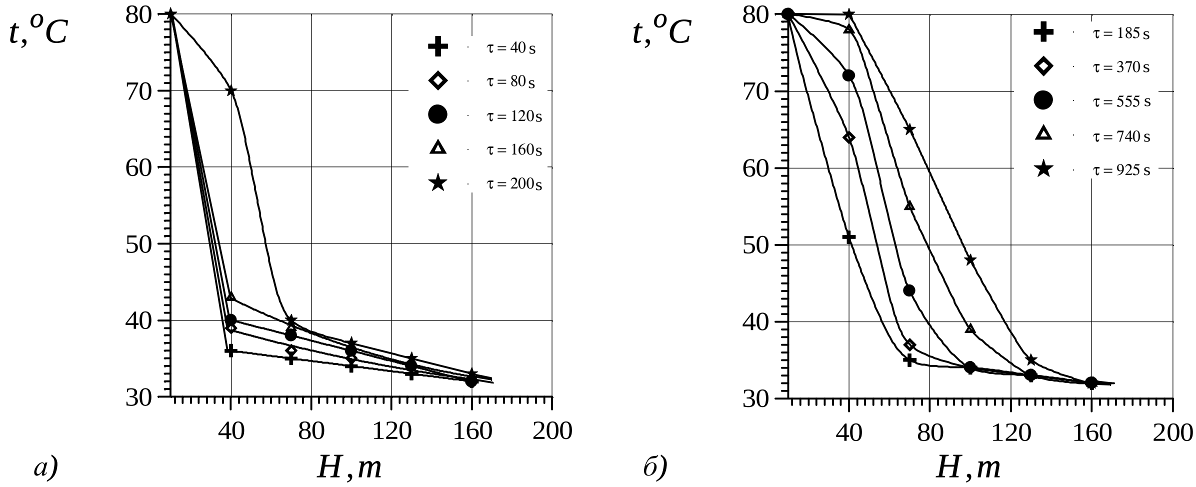

Fig. 3. Change of temperature of thermal agent on the height of layer moist to the: a) slag; b) clays

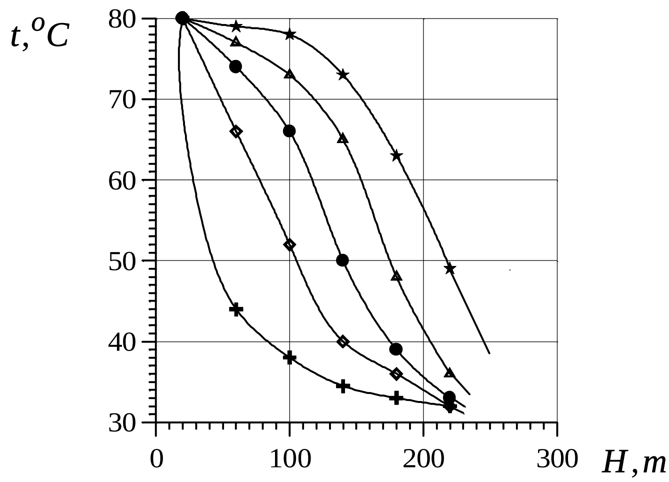

Fig. 4. Change of temperature of thermal agent is on the height of layer of moist granules:

✚ - *t = 580 s;* ◇ - *t = 1160 s;* ● - *t = 1740 s;* △ - *t = 2320 s;* ★ - *t = 2900 s*

Diminishing of temperature of thermal agent influences the value to the coefficient of heat transfer a [12, 13], dependence of coefficient of heat transfer a is therefore certain on the temperature of thermal agent and dependence $a = f(t)$ (fig. 5 a) is built. Analysis of fig. 5a shows that with the height of temperature the coefficient of heat transfer diminishes, in fact the increase of temperature results in the increase of viscidity and reducing of thermal agent, as a result grows thickness hydrodynamic, diffusive and thermal boundary layers.

On the basis of experimental data of brought around to fig. 5, a by us the built dependence of height of forming of front of mass-transfer on the temperature of thermal agent for feedstock for slag gravel production and it is brought around to fig. 5, b. By virtue of that the coefficient of heat transfer a in dependence (3) is included in a denominator, accordingly with the height of temperature the height of forming of front of mass-transfer will grow, that is explained by physical essence of process.

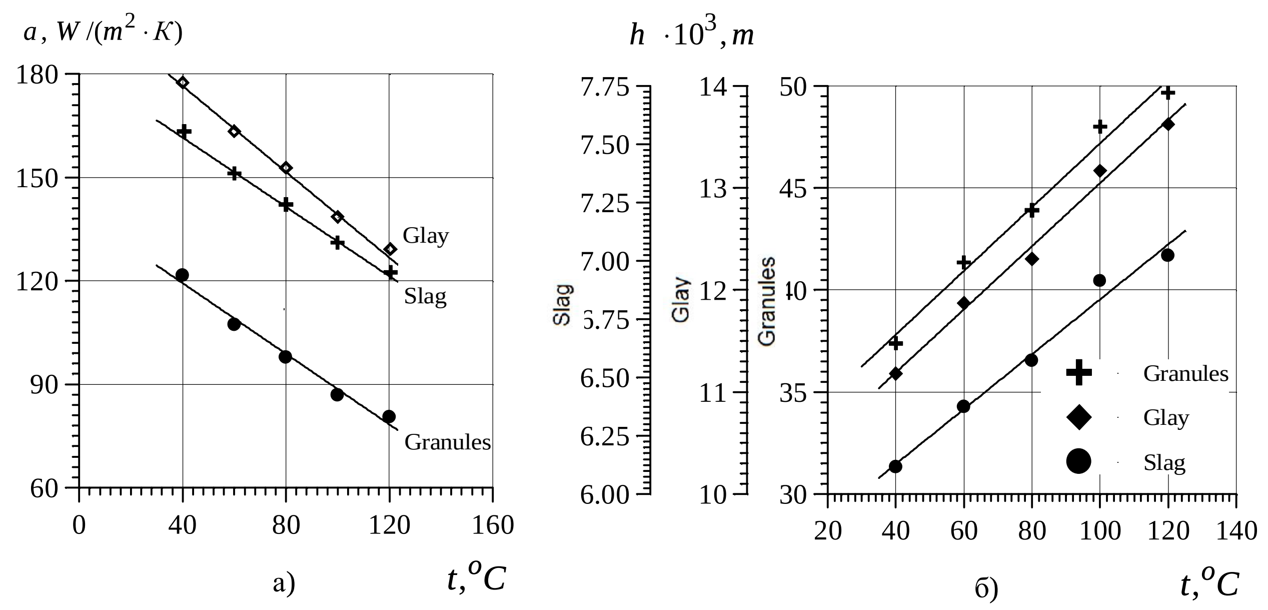

Fig. 5. Dependence to the coefficient of heat transfer a (a) and height of mass-transfer h (б) zone from the temperature of thermal agent through the layer of moist materials:

slag $(u_0 = 1{,}33\, m/s,\ H = 0{,}010\, m)$;

clay $(u_0 = 1{,}33\, m/s,\ H = 0{,}015\, m)$;

granules $(u_0 = 0{,}57\, m/s,\ H = 0{,}072\, m)$

The next stage is parallel transference of front of concentrations to the perforated partition in direction of motion of thermal agent. The dried up layer every particle of which begins to be heated by a heat-conducting is formed from above, increasing his temperature and taking away a heat from a thermal agent. The further moving of limit of front of concentrations reduces the temperature of thermal agent and speed of drying. It means that speed of moving of area $\frac{d\mathbf{l}}{dt}$ will diminish with the increase of height of area h, and time of drying to grow. The account of this factor can be conducted on the basis of determination of temperature in the process of drying on the height of layer of material and time of process (fig. 1 - 3).

On the basis of the higher brought experimental results over an unknown coefficient h (1) which is given as graphic dependence (fig. 6) is certain by us. Dependence from a temperature carries linear character a coefficient h and grows with the height of temperature which means diminishing of speed of moving of mass-transfer zone.

On the basis of generalization of experimental data dependence (1) was presented in a kind:

$$\text{for a slag - } dl/dt = 6{,}5 \cdot 10^{-4} \cdot \exp(1{,}5 \cdot 10^{-8} \cdot t^2 + 1{,}7 \cdot 10^{-4} \cdot t + 0{,}05)\,; \quad (4)$$

$$\text{for clay - } dl/dt = 1{,}9 \cdot 10^{-4} \cdot \exp(2{,}1 \cdot 10^{-7} \cdot t^2 + 5{,}8 \cdot 10^{-4} \cdot t + 0{,}17)\,; \quad (5)$$

$$\text{for granules - } dl/dt = 1{,}6 \cdot 10^{-4} \cdot \exp(1{,}9 \cdot 10^{-5} \cdot t^2 + 1{,}1 \cdot 10^{-2} \cdot t + 1{,}34)\,. \quad (6)$$

Semi empiric dependences (4) - (6) enable to define speed of moving of mass-transfer zone in direction of motion of thermal agent depending on the change of his temperature on the height of layer, and accordingly, and common time of drying of moist material.

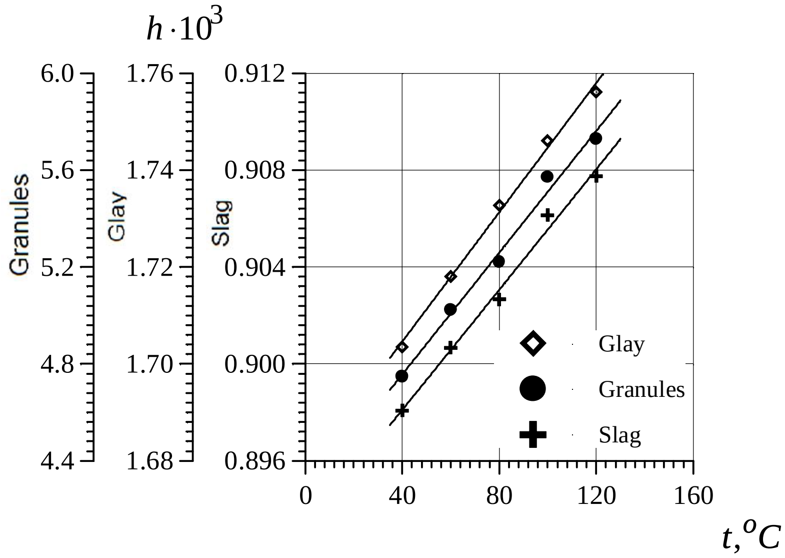

Fig. 6. Dependence to the coefficient h *from a temperature during the filtration drying*

Conclusion

Results received in course of experimental and theoretical researches heat- and mass-transfer during the filtration drying of feedstock for slag gravel production the difficult mechanism of the filtration drying of dispersible materials is explained to and enable to optimize the technological parameters of process of drying. Difficult dependence of temperature of thermal agent as functions of time and co-ordinate and accordingly speed of moving of mass-transfer zone is set in direction of motion of thermal agent depending on the change of his temperature on the height of layer.

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