

UDC 532.5.072.15

Design of processes of thermal bloating of silicates



Anatoliy Pavlenko

Dr. sci, professor,

Poltava National Technical Yuri Kondratyuk University, Poltava (Ukraine)



Hanna Koshlak

Ph.D., associate professor,

Poltava National Technical Yuri Kondratyuk University, Poltava (Ukraine)

Abstract

In the article mathematical model of formation of pores of raw material mixture is resulted with the purpose of receipt of porous heat-insulation material on the basis of soluble hydrosilicate. The developed mathematical model and its decision enable to forecast the basic technological indexes of process of taking into account forming of necessary structure of porous material. All thermophysical properties depend on the structure of material.

Keywords: PORES OF RAW, WARMLY EXCHANGE, POROUS HEAT-INSULATION MATERIALS.

Introduction

Prevalence of natural deposits of siliceous rocks in many regions of Ukraine, cheap and environmentally friendly raw materials is a strong argument for further research, development and implementation of new technologies of insulating porous materials based on hydrosilicate. Research in receiving such materials aimed at improving their thermal and structural properties.

For insulating materials, depending on the geometrical structure and the internal temperature applications, there are optimal values of porosity and specific pore number at which the greatest effect is achieved by reducing the intensity of heat transfer. In turn, the structure is functionally associated with swelling methods and technological modes.

The mechanism of swelling of hydrosilicate materials was studied in detail in

works [1-4]. When heating hydrocolicate by high-temperature coolant primary gas bubbles (pores) are formed. Viscosity of fluid decreases with time, while increasing the volume of the gas phase with a corresponding increase in its pressure. When the pressure of the gas phase (steam) exceeds the viscous drag forces and surface tension, swelling solution is implemented. Optimum conditions are controlled swelling viscosity of environment, due to the formation of low-temperature eutectic solutions, and reduced surface tension, which depend on the chemical composition and temperature, i.e. the last settings can create optimum material structure with desirable thermal properties.

The purpose of work

Completed laboratory studies allow you to pick the required processing temperatures. The objectives of future research is the choice of the method of effective heat transfer, modeling of these processes, the experimental testing of the data and creating methods for determining the main technical parameters of technologies of new material [5].

Material and research results

As established experimentally, essential factors of controlled effect on the kinetics of gas production and the formation of the porous structure of the temperature and composition of medium components. The process of swelling to optimal stage of plastic and viscous properties of the mixture in conjunction with the proposed blowing agent intensifies gassing process that occurs uniformly throughout the volume of raw material, ensuring the formation of closed pores. Swelling by gassing suggests that the gas which is released during gas production remains gel plastic tight phase. The mixture is crystallized at 100-120 °C to form a cellular structure of the material.

In previous drying of pellet by air temperature 100-120 °C active gas production is observed, which contributes to the presence in the initial mixture hydration water, sodium bicarbonate and clay. This increases the viscosity of the material, balancing gas pressure in the bubbles. The intensity of this process is regulated by temperature and time of action of the coolant, which are chosen so that the gas cell, increasing to a given size, not blended and retain their shape. In this case, the internal surface of the gas cells is stabilized by surface forces and pressure inside the pores, and the outer surface of granules - is covered solid film. Time of temperature action determines the structural characteristics (porosity and pore size)

and durable properties of the material and its thermal stability. With increasing duration and intensity of action strength characteristics of the material are getting worse, porosity is increasing, but at the same time the thermal conductivity is decreasing. So, for a material with the desired strength characteristics and durable thermal conductivity it is necessary to find the optimal technological mode of processing porous insulation material.

Consider the growth model of vapor phase of boiling water drops in gel multicomponent mixtures based on heat input part of the raw mix.

For computational models assume that the raw mass is saturated with water, the evaporation of steam bubbles are formed radius R , which are surrounded by fluid. At the initial time the system is under some pressure p_0 ($Eg p_0 > p_a$) and at temperature T_0 .

Increasing the volume of steam and water evaporation will occur because the raw material mixture is heated by an external source at a temperature of 500 °C. The movement of the interface liquid-vapor will be under pressure difference inside the steam volume p_n and pressure environment p_c [6].

Most methods of calculating of radial fluid motion on the verge of a spherical cavity using Rayleigh equation, which was first considered in a perfect fluid collapse vacuumed cavity formed suddenly, without capillary effects. Rayleigh equation has the form

$$\frac{d^2R}{d\tau^2} = \frac{p - p_c - \frac{3}{2}\rho \left(\frac{dR}{d\tau}\right)^2}{\rho R}, \quad (1)$$

where: R - radius of the vapor bubble; τ - time, p - pressure in the fluid, p_s - vapor pressure; ρ - viscosity materials.

This equation can be obtained using the equations of fluid motion together with the continuity equation. Equation (1) expresses the law of conservation of mechanical energy in the liquid at relaxation system in thermodynamic equilibrium.

In this case, it is accepted that the vapor layer already exists and the initial pressure in it constant, as well as the pressure acting on the volume of water. As the Rayleigh equation (1) can be obtained from the equations of fluid motion and continuity, that describes the change in acceleration of the fluid in a spherical boundary gas-liquid, it can be used to describe the processes of sobs or steam segments that are directly on the spherical volume, which over

Thermal technology

time has the same pressure as the vapor layer. This model involves consideration of motion interface vapor bubbles, which is a certain amount of water, the liquid that surrounds it.

The equation of motion for the case when the bubble is not in infinite volume of fluid in the middle and a limited amount of spherical outer radius, such as inside a drop of liquid has the form

$$\frac{dw}{d\tau} = \frac{p - p_r - 1.5\rho_l \left(\frac{dR}{d\tau}\right)^2}{\rho_l R} \quad (2)$$

As is shown in equation (2) the rate of growth of bubbles in a limited volume always exceeds the growth rate in the infinite volume by an amount determined by the second member of the right-hand side of this equation is always positive. It is clear that $R_r \rightarrow \infty$ Equation (2) becomes (1).

The pressure in the fluid on the edge of the bubble is balanced pressure environment that is inside the bubbles. If the medium is steam-gas mixture, except that water vapor is still some gas, the total pressure of the mixture is determined by Dalton's law

$$p_{\Sigma} = p_n + p_r, \quad (3)$$

where p_n, p_r - Partial pressure of steam and gas, respectively.

Pressure p is always less p_{Σ} the magnitude of capillary pressure and pressure shear stresses arising directly on the spherical surface due to the interfaces of adjacent layers of fluid motion.

$$p_{\Sigma} = p + \frac{2\sigma}{R} + \frac{4\mu_l \cdot w}{R}, \quad (4)$$

where σ - surface tension, μ - viscosity; w - velocity of the interface liquid - vapor.

As is shown in (4), component $\frac{2\sigma}{R}$, is called Laplace pressure, depends on the radius. As a result, the greatest impact is the pressure at small radius R , so when $R \leq 10$ μm pressure inside the steam volume is significantly higher than the pressure at the interface steam-liquid. Component $\frac{4\mu_l w}{R}$ can be obtained by examining of rheological equations of Newton. Its influence is most manifested at small radius and large values μ_l and w . Thus, the greatest impact of these two components of (4) will increase at the beginning of the vapor phase. With increasing radius R , i.e. an increase in the volume of steam, their influence will decline.

If at the interface is intense evaporation or condensation, then

$$\frac{dR}{d\tau} = w + \frac{j}{\rho_l} \quad (5)$$

Accepted lack of a gas in the vapor volume is present volume consists only of steam.

To determine the temperature inside the steam volume, you can use the first law of thermodynamics, which can be written as

$$\frac{dU}{d\tau} = Q - p_n \frac{dV_n}{d\tau} \quad (6)$$

Performing differentiation, we finally obtain

$$\frac{dT_n}{d\tau} = \frac{1}{c_{n,m_n}} \left[Q - c_{n,T_n} j S_M - p_n \frac{dV_n}{d\tau} \right] \quad (7)$$

where $S_M = 4\pi R^2$.

Considering the heat and mass transfer through the interfacial interface of water-vapor, can write the equation

$$Q_w = Q_n + Q_m, \quad (8)$$

Where Q_w - Amount of heat that comes from the water;

$Q_n = \alpha_n \cdot \Delta T \cdot S_3$ - The amount of heat that goes to heating the steam;

$Q_m = j \cdot L \cdot S_3$ - The amount of heat which carries a mass flow;

ΔT - Temperature difference between steam and interface between water-vapor.

We assume that the temperature of the steam volume T_n is not equal to the temperature of the interface water-vapor T_M , so the process will take place in the presence of a temperature jump at the interface, not quasi-equilibrium. Thus we believe that the temperature inside the steam volume is homogeneous.

In this model, the assumption of homogeneity of gas pressure in the vapor layer and bulk water drops, uniformity and temperature steam, which significantly simplify the examination of the dynamics of growth segments of steam.

As is shown in [7] the first assumption may not take place only in the last stages of destruction steam volume when the radial velocity of the fluid at the interface between the liquid-vapor above the speed of sound in the gas, and the change of the velocity of the interface significantly higher than the passage sound pulse from the surface to the center of the bubble. But these stages even under quite short compared with the period of oscillations bubbles are destroyed.

In the case of pure steam bubbles the dominant role is played by external heat conduction problem, and the heterogeneity of the temperature inside the bubble can be neglected.

As a result, the density of the vapor phase in the vapor volume ρ_n is homogeneous,

i.e. $\frac{d\rho_n}{dR_n} = 0$, function of density changes over

time vapor can be written as

$$\frac{d\rho_n}{d\tau} = \frac{1}{V_n} \left(\frac{dm_n}{d\tau} - \rho_n \frac{dV_n}{d\tau} \right). \quad (9)$$

For the above conditions Rayleigh equation (1) takes the form

$$\frac{dw}{d\tau} = \frac{p_n - p_c - 1.5\rho_w w^2 - \frac{2\sigma}{R} - \frac{4\mu w}{R}}{\rho R}. \quad (10)$$

To solve the mathematical model of the process of vapor phase growth is used the method of nets.

The end result is given by solving the equation by which the value of "next" temperature at a given point (node) is a function of time, its "current" temperature and "current" temperature adjacent nodal points.

The solution of differential equations will seek to explicitly scheme in which the desired radius clearly expressed through the values of the radii at the same point in the previous point in time.

The peculiarity of the swelling process is that the process of formation, growth of steam bubbles occur simultaneously with crystallization frame material as rheological material properties (viscosity, surface tension, density) are variable in time.

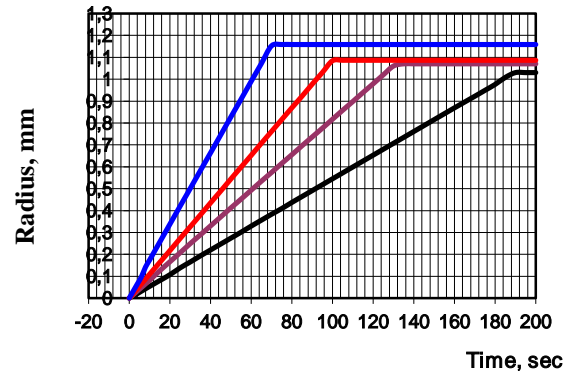
Based on the experimental data there were obtained equation viscosity, surface tension and density of time in MathCad program using static regression functions. There was obtained the following relationship:

$$\begin{aligned} \sigma &= 0.453 - 4.066 \cdot 10^{-4} \cdot \tau + 9.673 \cdot 10^{-5} \cdot \tau^2 - \\ &- 2.432 \cdot 10^{-6} \cdot \tau^3 + 2.12 \cdot 10^{-8} \cdot \tau^4; \\ \mu &= 1992 + 10.84 \cdot \tau - 0.718 \cdot \tau^2 + 0.022 \cdot \tau^3 - \\ &- 2.746 \cdot 10^{-4} \cdot \tau^4 + 1.242 \cdot 10^{-6} \cdot \tau^5 \\ \rho &= 800 - 2.5 \cdot \tau. \end{aligned} \quad (11)$$

We accept that in the initial time there is a layer of steam radius of 1 mkm, surrounded by a continuous liquid medium to unlimited resources. The entire system is at an initial pressure of 101 325 Pa (1 atm) and the corresponding saturation temperature of

100 °C. Increase the volume of steam and water evaporation will occur because the raw material mixture is heated by an external source at a temperature of 500 °C

Calculations performed FDTD method for different values of the heat flux supplied to the raw mix outside. The results are shown in Figures 1 - 3.



a)

Temperature, °C

b)

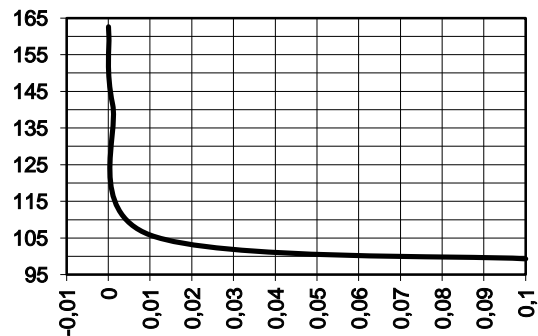
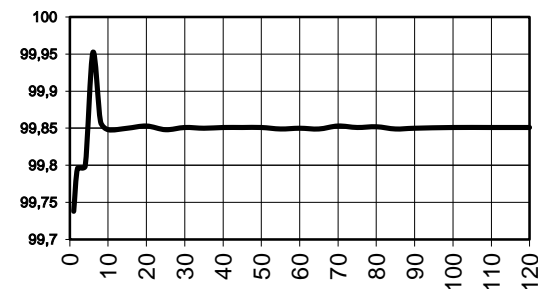


Figure 1. Change of the radius (a) the interface vapor-water and temperature (b) in time for the heat flow values q_3 : 1 – 10000 W/m²; 2 – 15000 W/m²; 3 – 20000 W/m²; 4 – 30000 W/m²

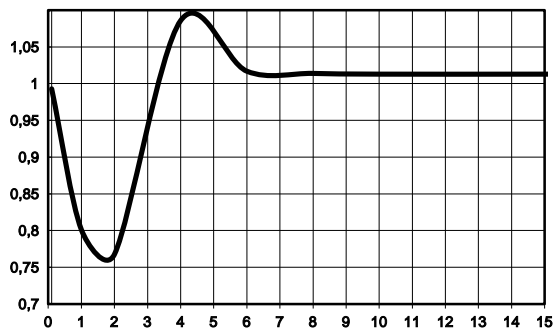
a)

Temperature of vapor, °C



Time, sec

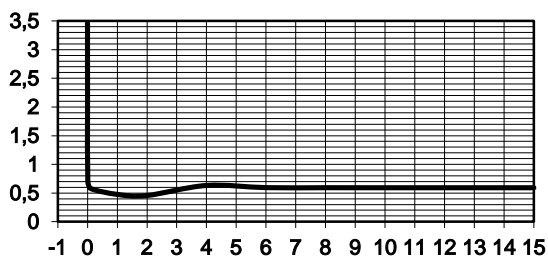
b)



Time, sec

Figure 2. The change in temperature (a) and pressure (b) of vapor at the time when the heat flow $q = 10000 \text{ W/m}^2$

Pressure of vapor 10^5 Pa



Time, sec

Figure 3. The change in pressure of fluid at the time when the heat flow $q_s = 10000 \text{ W/m}^2$

Conclusions

Analysis of literature data, dedicated to the study of vapor bubbles (pores) by heating showed, that accurate information about the regularities of heat and mass transfer processes and the role of these various processes, methods

of mathematical and physical modeling of phenomena that are studied.

There proposed, physically grounded and tested the equations of mathematical model of the dynamics of the vapor phase, which is formed by heating soluble in water of gel raw mass and hydro growing in volume, with further heating, allows detailed study of these processes.

References

1. Pavlenko A.M., Koshlak H.V., Usenko B.O. (2014). Peculiarities of controlled forming of propous structure, *Metallurgical and Mining Industry*, No 3, p.p. 60-65.
2. Pavlenko A.M., Koshlak H.V., Usenko B.O. (2014). The processes of heat and mass exchange in the vortex devices, *Metallurgical and Mining Industry*, No 3, p.p. 55-59.
3. Pavlenko A.M., Koshlak H.V., Usenko B.O. (2014). Thermal conductivity of the gas in small space, *Metallurgical and Mining Industry*, No 2, p.p. 20-24.
4. . Pavlenko A.M., Koshlak H.V., Usenko B.O. (2014). Heat and mass transfer in fluidized layer, *Metallurgical and Mining Industry*, No 6, p.p. 96-100.
5. Pavlenko, A.M., Basok, B.I. (2005). Regularities of boiling-up of emulsified liquids. *Heat Transfer Research*. 36, (5).
6. Pavlenko A.M., Koshlak H.V., Usenko B.O. (2014). Basic principles of gas hydrate technologies. *Metallurgical and Mining Industry*, No 6, p.p. 92-95.
7. Pavlenko, A.M., Basok, B.I. (2005). Kinetics of water evaporation from emulsions. *Heat Transfer Research*. No 36, (5), p.p. 425-430.