

EFFECT OF THE APPLICATION OF MICROWAVE ENERGY ON THE REGENERATION OF THE ADSORBENT

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ABSTRACT. Today, energy conservation is a priority. This is due to the shortage of energy resources, the growth of their cost and global environmental problems. The production of compressed air is a very costly and power-consuming process. One of the areas of energy saving is to improve the quality of the air preparation equipment, in particular, to increase the energy efficiency of this type of devices such as adsorption dryers for compressed air. Reduction of unnecessary energy losses in this sphere is possible due to the use of innovative technologies. The functioning of the adsorption dryer is associated with the consumption of compressed air, which is consumed during the periodic regeneration of the adsorbent. The practical value of the research includes an explanation of the regularity of the influence of the temperature drop, at which the adsorbent regeneration process takes place, on the reduction of the airflow loss during the proceedings of the dryer.

KEYWORDS: air dryer, regeneration, microwave energy, adsorbtion, modeling.

1. INTRODUCTION

Dehumidifiers with a hot regeneration of the adsorbent are currently the most economical means of producing dried air. The development and the design of this type of equipment is the most crucial in improving the energy efficiency of an industrial production.

The main attention of developers of a drying equipment with a hot regeneration is focused on the problems of the heat energy recovery, which is used in the desorption process. Also, engineers are striving to maximally reduce the unproductive costs of thermal energy for heating the combined components of the equipment, up to the transfer of the heating source directly to the cavity of the adsorption columns [1].

Meanwhile, the use of alternative types of energy can become a serious alternative to traditional technologies of regenerating adsorbents. The present study is devoted to the study of the effect of microwave energy on the temperature rising of the adsorbent's desorption process. This has been studied in terms of increasing the energy efficiency of the mentioned process.

2. RESEARCH PROBLEM

The process of regenerating the adsorbent serves to remove the moisture desorbed from the porous structure of the adsorbent.

Consider the process of regenerating the adsorbent by purging the volume of the adsorbent with pre-heated air. From the point of view of changing the temperature of the adsorbent during the regeneration process, this method of regeneration is carried out in two stages. In the first stage, during the purging with the heated air, the adsorbent temperature rises to the

purge air temperature. The first stage of regeneration continues until the moisture content of the adsorbent reaches a predetermined value. The duration of the first stage of the regeneration process is reduced in the event that the intensity of the removal of moisture from the volume of the adsorbent increases. The consumption of purge air with a predetermined temperature, which is required for the regeneration of a certain mass of the adsorbent, are determined by the total heat balance:

$$Q_p = \frac{M_w((c_p)_w(T_1 - T_2) + H_a)}{\rho_0(c_p)_p t_h(T_3 - T_2)} + \frac{M_d(c_p)_d + M_v(c_p)_v(T_3 - T_1) + q_1}{\rho_0(c_p)_p t_h(T_3 - T_2)}, \quad (1)$$

where Q_p — amount of purge air; M_w — mass of adsorbed water, kg/column; M_d — mass of adsorbent, kg/column; M_v — mass of purge air, kg/column; H_a — heat of adsorption, J/mol; c_p — specific heat; q_1 — external heat loss; ρ_0 — air density (at sea level, at 75 °C = 1.225 kg/m³); T_1 — initial temperature of the adsorbent, °C; T_2 — purge air temperature at the inlet, °C; T_3 — purge air temperature at the outlet, °C; t_h — heating regeneration time, s.

It should also be taken into account that silica gel loses its useful properties when it overheats above 200 °C. From this it follows that an increase in temperature above this limit in order to intensify the process of regeneration of the adsorbent is unacceptable. Thus, an unlimited increase in the parameter T_2 is not possible in order to increase the intensity of the regeneration process. In the second stage, the volume of the adsorbent is cooled to a temperature not exceeding the temperature of the air being drained.

The duration of this stage also affects the duration of the regeneration process. The second stage of regeneration should not affect the moisture content of the adsorbent dried during the first stage. Cooling the adsorbent to the temperature of the dried compressed air is the final stage of the regeneration process. This is an integral condition for the subsequent adsorption process, since the hot adsorbent is not capable of actively adsorbing the moisture from the dried air. The amount of cooling air required to reduce the temperature of the adsorbent volume to the operating adsorption temperature is about 1.25 times the mass of air per unit mass of the adsorbent.

$$A_c = \frac{Q_c \rho_0 t_c}{1.25 M_d}, \quad (2)$$

where A_c — amount of cooling air; M_d — mass of adsorbent, kg/column; Q_c — cooling air consumption, m^3/sec ; ρ_0 — air density (at sea level, at 15°C , $1.225 \text{ kg}/\text{m}^3$); t_c — cooling time, s.

It should be noted that if the first stage of the regeneration process takes place at a lower temperature, this reduces the time of the regeneration process by reducing the cooling time of the adsorbent in the second stage. Also, this reduces energy expended to cool the volume of the adsorbent to the temperature of the dried compressed air.

Desiccated compressed air is cooled in pipelines along the route to the desiccant and typically have an ambient temperature.

Also, taking into account the fact that the cooling of the adsorbent in adsorption dryers is carried out by purging with purging air at ambient temperature, which uses pre-dried air, the reduction of the regeneration temperature of the adsorbent in the first regeneration stage is particularly important in terms of reducing the losses of the pre-dried compressed air and, accordingly, increase the energy efficiency of the dryer [2].

As the mandatory and basic conditions for increasing the intensity of the regeneration process, we can distinguish the following:

- (1.) Intensification of the regeneration process should not lead to deterioration of the properties of the regenerated adsorbent and reduce its adsorption capacity;
- (2.) The regeneration process should not lead to a destruction of the adsorbent granules and its porous structure;
- (3.) Improving the efficiency of the regeneration process should not cause an increase in the duration of the regeneration period beyond the duration of the adsorption period, as this leads to the need for additional design solutions to ensure the continuity of the adsorption dryer.

If additional energy is applied to the adsorbent, the methods used should be technologically feasible and the components used should be accessible in terms

of their volume of production and availability on the market, as well as price characteristics, thus ensuring the equipment maintainability.

Considering the aforementioned conditions, it has been decided to propose a variant of an additional effect on the adsorbent, which would allow optimizing the process of the adsorbent regeneration. This is the energy of the microwave radiation. If the energy used for the drying of the adsorbent will act directly and only on the water molecules in the outer microporous layer of the silica gel and act with an intensity that is necessary and sufficient for the water molecules to leave the micropores and effectively evaporate from the surface of the adsorbent, in this case the energy losses of the desorption process will be minimal.

The advantage of heating the wet adsorbent using microwave is the possibility of a practical application of selective, uniform, ultra-pure, self-regulating heating of the adsorbent [3]. If water is contained in the adsorbent as free (hygroscopic) moisture, then its dielectric constant is about 80.0. For water adsorbed as a monolayer, the dielectric constant is 2.5. The high moisture content in the adsorbent increases the permittivity [4], as a result of which, the water absorbs most of the energy of the microwave radiation, heats up and begins to evaporate intensely. Since inside the porous structure of the adsorbent the water is in a space confined by the walls of the pores, an excessive pressure is created at the beginning of its boiling, so that the boiling point of the water rises. The distribution of temperature in the volume of the material under the action of microwave radiation creates the most favorable conditions for accelerating the diffusion of the vapor-air mixture from the inner layers of the adsorbent to the peripheral layers, since the temperature, pressure, and concentration gradients that determine the rate of diffusion here are directed in one direction [5]. Thanks to this, the effective drying of the wet adsorbent occurs at lower energy costs, since it does not require heating of the entire mass of the adsorbent to achieve an intensive evaporation of the water. Also the working conditions of the adsorbent are improved, since the risk of overheating of the adsorbent during the regeneration process is reduced [6].

The thermodynamic forces due to the electromagnetic field are:

$$\begin{aligned} X_e &= (\text{grad } E)\pi_e \\ X_m &= (\text{grad } E)\pi_m, \end{aligned} \quad (3)$$

Thus, in the electromagnetic field, the transfer of the moisture is due to the action of not only the diffusion forces (∇u) and thermal diffusion (∇T) but also by the action of forces X_e and X_m , and the moisture flux will be determined in an accordance with the Onsager equation

$$j_n = L_{n_1} X_1 + L_{n_2} X_2 + L_{n_3} X_3 + \dots + L_{n_n} X_n \quad (4)$$

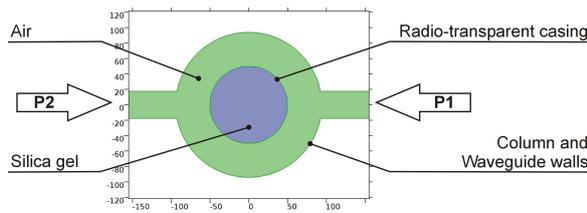


FIGURE 1. 2d model. Horizontal section of the adsorption column.

by the relation

$$j = -u_m p_0 \nabla u - u_m^T p_0 \nabla T - a_m^e p_0 (\nabla E) \pi_e - a_m^m (\nabla B) \pi_m, \quad (5)$$

The first term of this formula determines the amount of diffusion of moisture, the second term — the thermal diffusion of moisture, the third term corresponds to the transfer of moisture under the action of the electric field, and the fourth — to the transfer under the action of the magnetic field. Coefficients a_m^e and a_m^m — are the coefficients of electrodiffusion and magnetodiffusion of the moisture in the material [7].

3. MATERIALS AND METHODS

We will study the process of regenerating the adsorbent in the cavity of the adsorption column using simulation modeling, taking into account the additional influence of the electromagnetic field.

The calculation carried out using the mathematical model of a desiccant adsorption tower with a capacity of $1.5 \text{ m}^3/\text{min}$. The adsorption column is a metal cylinder connected to a microwave source through rectangular waveguides. Waveguides operate in the TE_{10} mode with a frequency of 2.45 GHz. Action of radiation are made through two opposing ports with a capacity of 370 W each. In the figures, the ports are denoted by the letters P_1 and P_2 . Inside the column, there is a radio-transparent enclosure. There is an air gap between the radio-transparent casing and the column wall. The volume of the silica gel, which undergoes the heating in the process of regeneration, is inside the radio-transparent case.

At the initial stage of solving complex physical tasks, it is legitimate to use 2d models [8–10]. After that, the solution is completed on a 3d model. Our 3d model is based on the 2d model (Fig. 1) used in previous calculations [1]. The configuration of the model has been previously optimized in terms of minimizing microwave energy losses. Linear dimensions of the model are given in the Table 1.

The physical properties of the silica gel are shown in Table 2. The properties of the silica gel [11, 12] are corrected taking into account the moisture content and the bulk density of a wet silica gel. The model uses a copper material for the column walls and waveguides. The purge air, which has a zero moisture content, moves from the top down along

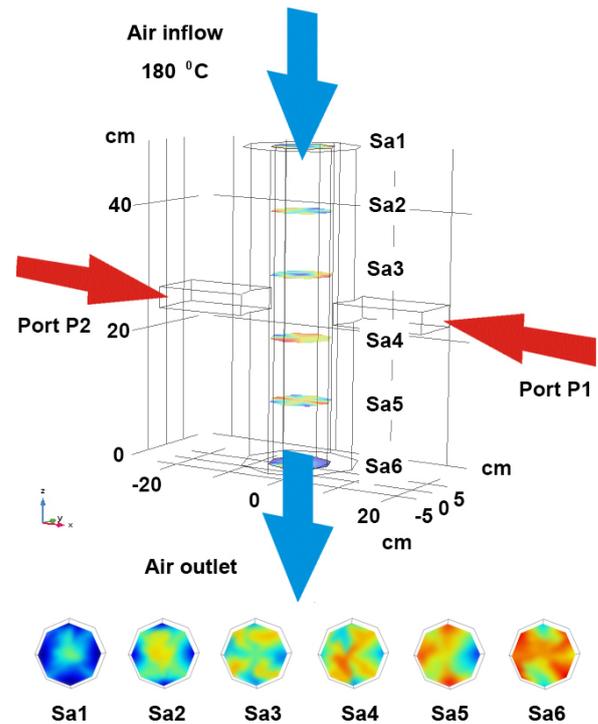


FIGURE 2. The control surfaces Sa_1 , Sa_2 , Sa_3 , Sa_4 , Sa_5 , Sa_6 of parameters measurement.

the axis of the adsorption column [13]. The initial temperature of the adsorbent is the same at all points in the volume of the adsorbent - 20°C .

The air in the cavity of the radio-opaque outer wall of the adsorption tower also has an initial temperature of 20°C . The same temperature is conventionally considered the adsorption temperature. The study was carried out in the time interval 0–1200 s, step 10 s. Measurements of the moisture content and temperature were carried out in 6 control surfaces (Fig. 2).

The control layers Sa_1 , Sa_2 , Sa_3 , Sa_4 , Sa_5 , Sa_6 (Fig. 2) are horizontal sections of the volume of the adsorbent located at a distance of 10 cm apart from each other.

The presented computer model is built using the COMSOL Multiphysics software. This allows us to consider the pattern of the distribution of the electromagnetic field intensity and the temperature of the silica gel statically and dynamically and visualize and evaluate the results. Two regimes of the adsorbent regeneration process were studied:

- (1.) The process of regeneration by purging the volume of the adsorbent with air, which is pre-heated to a temperature of 180°C .

In the process of mathematical modeling of the regeneration process using the convection method, the following equations were used for the heat transfer equation (6):

$$Q_{\text{heat}} = \rho C_p \frac{\partial T}{\partial t} + \rho C_p u \nabla T - \nabla(k \nabla T) \quad (6)$$

where ρ — the density, kg/m^3 ; C_p — the specific

Property	Dimension	Value
The height of the waveguide	mm	34
The width of the waveguide	mm	88
The length of the waveguide	mm	142
The radius of the adsorption column	mm	94
The radius of the radio-transparent case	mm	50
Initial temperature	°C	20

TABLE 1. Parameters of the computer model.

Property	Dimension	Value
Density	kg/m ³	2900
Bulk density	kg/m ³	780
Heat capacity	J/kg m ³	5.2
Relative permeability	1	1
Relative permittivity	1	5.1
Electrical conductivity	S/m	0

TABLE 2. Properties of Silica gel material.

heat capacity at constant pressure, J/kg K; T — absolute temperature, K; u — the velocity vector, m/s; q — the heat flux by conduction, W/m²; p — pressure, Pa; τ — the viscous stress tensor, Pa; S — the strain-rate tensor, 1/s; Q — contains heat sources other than viscous heating, W/m.

The heat of desorption is expressed by the following equation:

$$Q_{\text{evap heat}} = H_{\text{vap}} K \left(\frac{p_{\text{sat}}(T)}{RT} - c \right) \quad (7)$$

where p_{sat} — saturation pressure, Pa; K — the evaporation rate; c — the current concentration, 1/s; H_{vap} — the latent heat of evaporation ideal gas constant, J/mol ($R = 8.314$ J/kg K).

(2.) The process of regeneration by purging the volume of the adsorbent with air at a temperature of 20 °C using the energy of microwave radiation.

In the process of mathematical modeling of the process of regeneration by microwave energy, additionally the equation of the electromagnetic field distribution was used:

$$\nabla \times \left(\frac{1}{\mu_y} \nabla \times E(x, y) \right) - k_0^2 \varepsilon_\gamma E(x, y) = 0 \quad (8)$$

where μ_y — complex relative permeability; $E(x, y)$ — complex amplitude representing an oscillating electric field; ε_γ — complex relative dielectric permeability; κ_0 — phase constant of free space.

The equation, expressing the amount of heat of deperization is

$$Q_{\text{desorption convection}} = cm\Delta T, \quad (9)$$

where Q — quantity of heat; c — specific heat, J/kg m³; m — mass of adsorbent volume, kg; ΔT — temperature change, °C.

4. RESULTS AND DISCUSSION

4.1. RESULTS

The change in the moisture concentration in the volume of the adsorbent in the layers Sa_1 , Sa_2 , Sa_3 , Sa_4 , Sa_5 , Sa_6 during the regeneration in modes I and II are displayed in the comparative graph (Fig. 3).

Let us consider the dynamics of the change in the moisture concentration in the adsorbent during the regeneration process by purging with heated air (Fig. 3, pos. I). The motion of the desorption front from the upper layers of the adsorbent to the lower ones is characterized by the shape of the concentration curves in the planes of the section (Fig. 3 pos. I). So, from the start of the regeneration process (point K , see Fig. 4, pos. I), the concentration of moisture in the Sa_1 layer begins to decrease, while during the first 100 seconds, a parallel decrease occurs with a lower dynamics of the moisture concentration in the Sa_1 layer, separated from the layer in the layer Sa_1 by 100 mm. This is explained by the fact that the volume of purge air passed through the adsorbent layer Sa_1 is not completely saturated with the moisture. Passing through the adsorbent in the Sa_2 layer, the purge air continues to be saturated with moisture, reducing the moisture concentration in the adsorbent layer Sa_2 .

Then, after a certain length of time, in an order of 100 seconds, the level of moisture concentration in the Sa_2 layer under the Sa_1 layer begins to increase sharply (point L_1 , see Fig. 3, pos. I). This is explained by the beginning of the process of a secondary adsorption of moisture by the adsorbent of the layer Sa_2 from the flowing air. This is because the purge air is now saturated with moisture, which is adsorbed from the Sa_1 layer. Thus, the accumulated moisture is displaced from the upper layers of the adsorbent to the lower layers. After 100 seconds from the start of the regeneration process, a decrease in the level of moisture concentration in the Sa_2 layer is observed. Then follows a gradual increase in concentration in the Sa_2 layer from point L_1 to point M_1 (see Fig. 4, pos. I). The smoothness of the transition from a decrease to an increase in the concentration is explained by the gradual saturation of the purging air with moisture, followed by the transfer of moisture to the lower layer of the adsorbent.

After a period of time, in an order of 150 seconds, saturation of the adsorbent in the Sa_2 layer is observed

and the rate of the growth of the moisture content level in this layer slows down, reaching its maximum at the point M_1 (see Fig. 4, pos. I). The moisture content level at the specified point depends on the location of the layer under consideration. The further the layer is located far from the inlet of the purge air, the higher the maximum level of moisture concentration that will be reached in it during purging of the volume of the adsorbent by the purge air flow (points M_1, M_2, M_3, M_4, M_5 , see Fig. 3, pos. I). This is explained by the accumulation of the desorbed moisture in the region of the desorption front.

After reaching the maximum moisture content level in some layer n of the adsorbent, the moisture concentration starts to decrease with an increasing intensity from point M_n to point N_n . At this time, the moisture concentration in the previous layer is already low, which reduces the transfer of moisture by the flowing air flow from the upper layers to the lower layers.

There is an increase in the distance on the time axis of the line segments formed by pairs of points $L_n - M_n$, ($cA_1 < cA_2$). This indicates the accumulation of desorbed moisture in the region of the desorption front, which causes a more intense secondary adsorption of the lower layers of the adsorbent in comparison with the upper layers. There is a slight increase in the distance of the line segments formed by pairs of points $M_n - M_{n+1}$, ($cB_1 < cB_2$). This indicates a high intensity of the desorption process due to the speed of the purge air flow. An increase in the distance of the line segments formed by pairs of points $N_n - N_{n+1}$ is observed, in which the intensity of regeneration reaches a minimum ($cC_1 < cC_2$). This indicates an increase in the saturation of the moisture of the drying air, which increases the duration and intensity of the secondary adsorption of moisture by the adsorbent, because a lot of moisture is contained in the volume of the flowing purge air.

Consider the dynamics of the change in the moisture concentration in the adsorbent during the regeneration process using microwave energy (Fig. 3, pos. II). This process correlates well with the regeneration process by blowing with heated air (Fig. 3, pos. I). But there are differences in the dynamics of the processes. When regenerating with microwave radiation 2×370 W, the desorption time is 30 s less, and the residual moisture concentration is 1.5 Kmol/m^3 higher.

When regenerating by microwave radiation, the inhomogeneity of the moisture content level in the volume of the adsorbent is noticeable. These heterogeneities are indicated by the letter D on the gradients of the vertical plane of the cross section of the volume of the adsorbent and the graphs of the concentration of moisture in the control surfaces (Fig. 3, pos. II). This is due to the relatively large heterogeneity of the heating of the adsorbent volume, due to the uneven distribution of the electromagnetic field strength in the volume of the adsorption column (Fig. 5, pos. II).

To confirm the assumption of the positive effect of

microwave radiation [14–17] on the drying intensity, not directly related to the growth of the temperature of the substance to be dried, a thermal mathematical model of the adsorption column was calculated.

The graph (Fig. 5, pos. I) shows the dependence of the temperature of the adsorbent on the time of the regeneration process in the layers $Sa_1, Sa_2, Sa_3, Sa_4, Sa_5, Sa_6$ during the regeneration by a flowing air, which is preheated to a temperature of 180°C .

The large heating temperature of the Sa_1 layer, compared to $Sa_2, Sa_3, Sa_4, Sa_5, Sa_6$ (Fig. 5, pos. I) is explained by the direct contact of the surface of the layer with the flow of the heated purge air entering the region of the column. The graph (Fig. 5, pos. II) shows the dependence of the temperature of the adsorbent on the time of the regeneration process in the layers $Sa_1, Sa_2, Sa_3, Sa_4, Sa_5, Sa_6$ during the regeneration process by purging the adsorbent with an air, having temperature of 20°C , and using microwave energy.

By comparing the graphs (Fig. 5, pos. II), it is concluded that the adsorbent layers Sa_1 and Sa_6 are heated more intensively, compared with the heating dynamics of the Sa_2, Sa_3, Sa_4 , and Sa_5 layers, which is explained by the appearance of zones with an increased electromagnetic field intensity at the upper and lower boundaries of the adsorbent volume. The heating dynamics of the Sa_2, Sa_3, Sa_4 , and Sa_5 layers are fairly uniform. This indicates a good configuration of the adsorption column in terms of the propagation of the microwave energy in it.

The graph (Fig. 4) shows the increase in the average temperature of the entire volume of the adsorbent during the regeneration process in the first and second modes. Analysis of the graphs (Figs. 3, 4 and 5.) shows that in both regeneration regimes, there is a 6-fold decrease in the moisture content of the adsorbent, from a value of 9.1 Kmol/m^3 to a value of about 1.5 Kmol/m^3 (Fig. 3). The average temperature of the adsorbent volume reaches a maximum value of 100°C during the regeneration process in the I-th mode and 78°C in the II-th mode (Fig. 5).

Thus, the increase in the temperature [18] during the course of the regeneration process in the I-th mode, using the heated purge air, was $\Delta T_2 = 100^\circ\text{C} - 20^\circ\text{C} = 80^\circ\text{C}$. In the second mode, using the energy of microwave radiation, the temperature increase was $\Delta T_2 = 78^\circ\text{C} - 20^\circ\text{C} = 58^\circ\text{C}$ (Fig. 3). The amount of heat that is released by cooling the body, calculated by the formula (8), is directly proportional to the mass of the body and the change in its temperature.

Since the mass of the adsorbent in the cavity of the adsorption tower is unchanged, the ratio of the amount of heat K , released during the cooling of the adsorbent to the adsorption temperature (20°C) in the I and II regimes is about $K = \Delta T_1 \div \Delta T_2 = 80^\circ\text{C} \div 58^\circ\text{C} = 1.4$, which will further save the cooling air at K times. Thus, the use of microwave energy for the purpose of regenerating the adsorbent results in a reduction in the cost of the expensive purge air consumed during

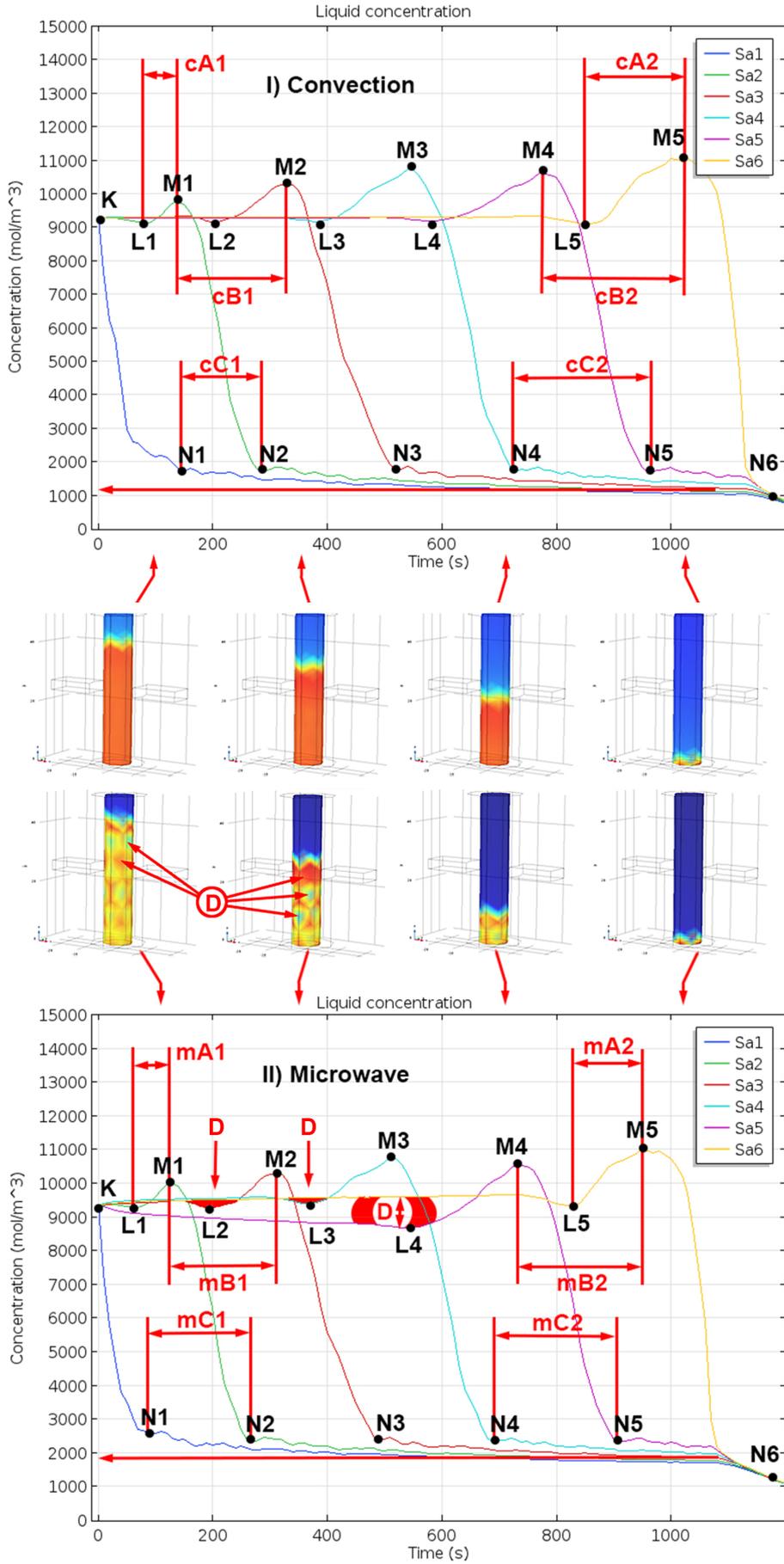


FIGURE 3. Change in the moisture concentration: I – Convection; II – Microwave.

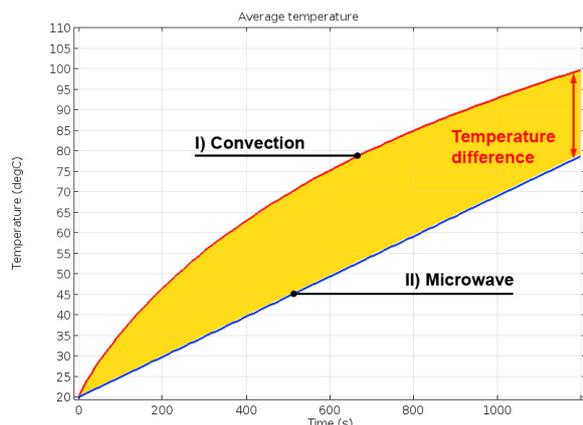


FIGURE 4. Average temperature difference.

the stage of cooling the adsorbent to the adsorption temperature.

4.2. DISCUSSION

It is necessary to pay attention to the peculiarity of the character of the course of the desorption process.

To describe the graphs of the course of the desorption process, which have a pronounced wave character, we use the terminology of the crest and trough of the wave, which is the most applicable here.

After the valley of the wave formed by the points with the greatest negative deviation L_n from the initial state of equilibrium K corresponding to the initial level of the moisture content, an increase in the moisture content level in the n -th adsorbent layer was noted (Fig. 3).

The set of points M_n in the plot sections, where the moisture content level reaches the maximum positive deviation from the initial state, form a comb of the desorption wave.

Attention should be paid to the peculiarity of the flow pattern. The very first wave, which separates the area of the graph from point K to point L , captured by the wave process, from the regions unperturbed up to this instant of time, forms a wave front. The graph shows how the wave front moves from the upper layers to the lower ones. The velocity of this motion is the phase velocity of the wave and is determined from the formula (9). It is clear that the phase velocity can differ from the velocity of the particles of the medium in the wave.

$$l_w(t) = v_p + \frac{1}{2}k_w t^2, \quad (10)$$

where l_w - wave front coordinate, m ; k_w - coefficient of front movement acceleration, m/sec^2 ; t - desorption time, sec .

Note that the displacement of the crest of the desorption wave occurs in the direction coinciding with the direction of the movement of the purge air through the volume of the adsorbent. Consider the construction of the desiccant adsorption tower in which, during the regeneration of the adsorbent, the purge air flow

moves through the adsorbent bed from top to bottom, as does the flow of dried air passing through the volume of the adsorbent during adsorption. In case of the termination of the regeneration process at the time when the desorption front did not overcome a distance equal to the length of the adsorption column, this circumstance will result in a saturation with moisture of the lower layers of the adsorbent, point M_5 (Fig. 3).

The lower layers of the adsorbent in this case are closest to the outlet of the adsorption column, these layers are the last ones along the path of the drained air. Thus, at the beginning of the process of the adsorption of the moisture from the dried air, dried by the upper layers of the adsorbent, the air enters the lower layers of the adsorbent with a high level of moisture content. In this case, the reverse process of the moisture transfer from the lower layers of the adsorbent to the volume of the dried air takes place.

This leads to an increase in the humidity of the air that is being dried at the dryer outlet at the time when the desiccant regeneration stage of the adsorption column is changed to the adsorption stage.

Let us consider another variant of the design of the desiccant adsorption column in which, during the regeneration of the adsorbent, the purge air flow moves through the adsorbent bed from top to bottom, but, during the adsorption process, the flow of the dried air moves through the adsorbent in the reverse direction, from bottom to top. In this case, the moisture saturation of the lower layers of the adsorbent, associated with the early termination of the regeneration process, will transfer moisture from the lower layers of the adsorbent to the volumes lying above. This leads to an increase in the moisture content of the entire volume of the adsorbent and, accordingly, to an increase in the humidity of the air that is being dried at the desiccant outlet during the entire adsorption period.

5. CONCLUSIONS

The presented work shows the possibility of achieving the goal of reducing energy costs by using the energy of microwave radiation during the regeneration of adsorbents of compressed air dehumidifiers. It is shown that the economic effect is achieved due to the intensification of evaporation of moisture from the porous structure at a lower temperature, compared with the purging with preheated air. A decrease in the temperature at which the regeneration process takes place makes it possible to reduce the consumption of the dried air necessary to cool the adsorbent heated during the regeneration to the temperature of an effective adsorption.

This will provide an additional saving of cooling air by 1.4 times. The loss of the purge air of the dryer with a hot regeneration will decrease from 3% to 2%. Considering that only 15% of the energy expended by the compressor passes into the potential energy of

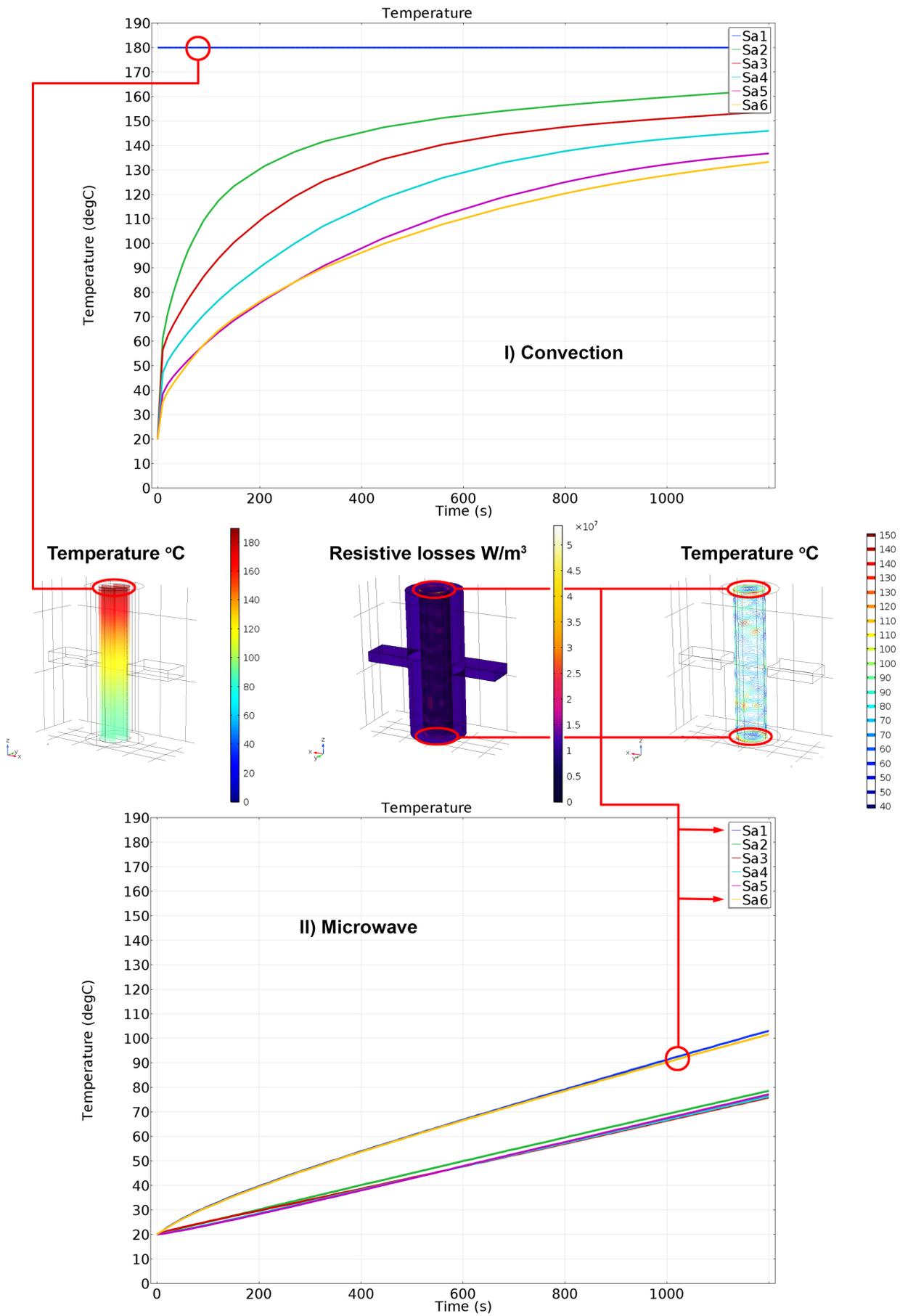


FIGURE 5. Change in the adsorbent temperature.

compressed air, the energy savings of the compressor will be up to 6.5 %.

The mathematical model, which was made to create a prototype of an industrial compressed air dryer with improved energy saving characteristics is presented.

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