Research of the process of regeneration of activated carbon during filtration drying

Volodymyr Atamanyuk, Iryna Huzova, Zoriana Gnativ, Mykola Hrynkiv, Mykola Bodnar

Department of Chemical Engineering, National University «Lviv Polytechnic», UKRAINE, Lviv,12 Bandera str.,

E-mail: iryna.o.huzova@lpnu.ua

***Abstract* – Heat-mass exchange processes during drying of regenerated activated carbon was to study and determine minimum height of heat-mass exchange zone and time of termination of hot heating agent supply based on criterion equations and heat balance calculations.**

Keywords – adsorbent, adsorption-desorption processes, heat-mass exchange, heating agent

I. Introduction

In chemical technology considerable part of technological processes proceeds in fixed bed of disperse material. Such processes include adsorption-desorption processes widely used in chemical, food, pharmaceutical and other industries.

Regeneration of adsorbent can be carried out by steaming with saturated water vapor or by treatment with hot water [1]; by electrical [2] and electrochemical methods [3]; by SHF irradiation [4]; by thermal [5], chemical [6] or ultrasonic methods [7]; by means of catalyst addition [8].

In consideration of the fact that much more energy is consumed by adsorbent regeneration process compared to the adsorption process itself, theoretical and experimental studies of drying and cooling processes are very urgent.

In industry adsorbents are multiple use materials. After adsorbent saturation with an adsorbate adsorption process is stopped and the adsorbent used is regenerated with the aim of removing the components adsorbed. Water steam or hot water with temperature 100°C are most often used as desorbing agents, and regeneration of the adsorbents without their consequent drying leads to considerable decrease of their adsorption capacity. According to [10], adsorbent regeneration consists of the following stages:

– heating of the bed by hot air;
– steaming of the bed by saturated water vapor;
– drying of the adsorbent;
– cooling of the adsorbent bed to 20°C.

It is stated in [11] that after finishing the adsorbent drying its adsorption capacity can become equal to the capacity of fresh adsorbent. Such phenomena depend on size of pores and capillaries and on the amount of moisture condensed in them.

II. Experimental

Activated carbon, used in this study as the research object, supplied by Sigma–Aldrich, was Carbotrap Adsorbent matrix, 20-40 meshgrade.

Activated carbon, was loaded into a cylindrical container (fig. 1). The research container made of thermal insulating material (Polytetrafluoroethylene (PTFE), film, thickness 0.005 mm, L 0.1 m, coil width 450 mm was purchased from Sigma–Aldrich), consists of six 30 mm high sections with perforated bottoms. Thermocouples were put into each section. Another two thermocouples was used to measure temperature in the inlet and the outlet of the container. Temperature was registered by eight-way thermoelectric transducer ПТ-108 (by CEM R&D, China) capable of displaying measured values on computer after 1.8 s. Change of mass of the container filled with activated carbon during drying was measured by electronic balance AXIS-3000 (by AXIS, Poland) to within 0.01 g. Gas flow rate was measured by rotameter PM–II (PM-02-0,016ZhUZ by Arzamas instrument-making plant, Russia).

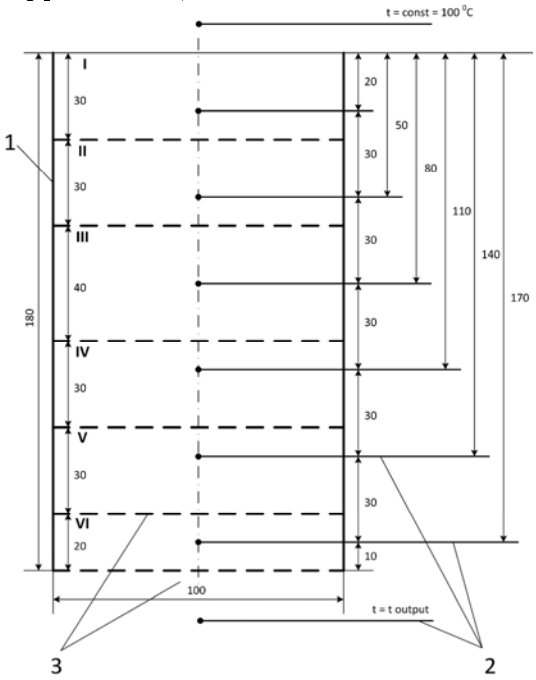

Fig.1. Arrangement of thermocouples mounting into sections of container for disperse adsorbent: 1 – container, 2 – thermocouples, 3 – perforated partitions.

The research was carried out as follows. Wet adsorbent, regenerated by steaming with saturated water vapor, with temperature 100°C was loaded into six sections of the cylindrical container (fig. 1). Total height of the adsorbent bed in the container is 180 mm. The heating agent was filtered through the bed at rate of 2 m/s. Researches were carried out at the heating agent temperature equal to 100°C, which was kept constant in the container inlet. Time change of heating agent temperature across the adsorbent layer height during filtration drying was registered by thermocouples situated in the middle of each section and in the container outlet.

Mass of the container with activated carbon was measured with fixed time intervals (30 s). If mass of the container with adsorbent remained constant for 120-180 s and if the heating agent temperature in the container outlet was 100 K, the experiment was stopped. Mass of dry carbon after drying was 640 g.

III. Results and Discussion

So, the experimental data show, that heat-mass exchange zone moves in heating agent flow direction. After certain time intervals there appears an adsorbent layer, which does not take part in heat-mass exchange process and accumulates heat energy in itself.

Thaking this into consideration, it is reasonable to use the energy accumulated by dried layer to dry remaining wet material by filtration of cold air through hot dried layer. Thus, due to such organization of the process part of heat energy can be saved and total duration of the adsorbent regeneration can be reduced.

New concept of regeneration of a layer of activated carbon grade is suggested in the paper. The essence of the concept consists in drying of hot layer of adsorbent with temperature 100°C by heating agent with the same temperature. The driving force in this case is difference of partial pressures of saturated water vapor on the adsorbent particles surface and in the heating agent.

The mechanism of suggested method is as follows: because of pressure difference the moisture from the activated carbon particles is evaporated and moved out by the flow of the heating agent. Complex heat-mass exchange process proceeds during this. The activated carbon particles are cooled because of moisture evaporation and, at the same time, heated up by the heating agent. So, the temperature of the first layer in heating agent flow direction is kept constant and equal to 100°C.

Further heat-mass exchange proceeds only because of cooling of wet particles of lower layers of the adsorbent. Due to the heating agent cooling and its saturation with moisture the evaporation intensity steadily decreases in the heating agent flow direction until its complete saturation with moisture. Thus, the mass exchange zone is expanded. After complete saturation of the heating agent with moisture corresponding its temperature at certain height h_{min}, it is heated up when filtrating through wet layer of the adsorbent with temperature 100°C. Thus, heated heating agent “gets its second wind”, so its extra saturation of water vapors becomes possible. Moisture content of the heating agent when coming out from the adsorbent layer is determined by its temperature.

Conclusions

Based on experimental researches and grounded drying mechanism, the reasonability of using the energy accumulated by dried layer for drying the remaining wet material by filtration cold air through it, has been demonstrated.

Minimum time of the hot heating agent supply termination τ , as well as minimum height of hot layer h_{min} , energy of which would be enough to dry the lower wet layers, have been determined based on experimental data and criterion equations.

Exact time of the hot heating agent supply termination has been calculated based on heat balance, and under the experimental conditions is equal to 540 s.

Amount of energy consumed for conventional process of adsorbent regeneration and amount of energy consumed for the regeneration process suggested in the paper have been calculated.

It has been proved that suggested regeneration method allows to reduce the amount of consumed specific energy by 1066.95 kJ/kg $_{\text{of dry adsorbent}}$.

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