Kinetics and mass transfer processes of thermal catalytic neutralization of gas emissions in modern waste processing complexes

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The method for calculation, design and manufacturing of the catalytic converters for waste processing complexes has been developed. The development of the method and mathematical model of heterogeneous catalytic process of harmful impurities are based on the experimental study of parameters of the process catalytic thermal purification.

Public life inevitably leads to generation of waste that negatively affects the environment. The problem of the accumulation of household waste appears especially acute in large cities in places of maximum number of congestion of people: car stations, sea and railway stations, airports. Acceptable solution to the problems is found through the creation of mobile and stationary waste processing systems of various productivity [1,2]. In Ukraine these systems operate at railway stations (Kharkiv city) and territories of seaports (Mykolayiv city).

Waste processing complexes for solids are made as stationary (block-container) or mobile units. Mobile units are assembled on rail or car platforms. Regardless of the complex type the units are equipped with the following protection systems that prevent harmful substances of any aggregate state to get into the human habitat: combustion chamber, post-combustion chamber, 1st catalytic purification unit, soda solution injection system, cyclonic separator for gas pre-treatment, 2nd low-temperature catalytic reactor, bag filter with impulse regeneration, adsorptive charcoal filter fabric. The most important stage of the protection system is the stage of gases purification which outflow of waste combustion facilities since gases may contain poisonous and carcinogenic compounds.

Existing methods of calculation and design of catalytic converters based on approximate, simplified approaches based on consideration of the process of catalytic conversion from chemical kinetics position or the position of mass transfer laws. It means that methods do not include a number of critical factors.

Design of blocks of catalytic converters should be based on consideration of dynamic thermal and physical loads, on diverse flow rate of catalytic reactions on different parts of the support surface which caused by diverse hydrodynamic and thermal conditions in a volume of converter. This requires a detailed study of the parameters of the thermal decomposition of harmful impurities in the gas emissions and creating a mathematical model of the impurities conversion process.

Controlling parameters of heterogeneous catalytic process of gas emissions thermal decomposition have been studied and identified. Controlling parameters have been identified for limiting stages of chemical kinetic and external diffusion by varying following parameters: surface concentration of catalytically active compounds on a carrier, the concentration of contaminants in the gas stream, contact time interacting phases, surface of the carrier occupied by catalytically active centers.

The formula for conversion degree of hydrocarbons for chemical kinetic limiting stage is proposed:

$$x_k = 1 - exp\left[-t_k \cdot \frac{273}{T} \cdot k_0 \cdot exp\left(\frac{-E}{RT}\right) \cdot C_k^n \cdot \frac{S_k}{V_p}\right], \qquad (1)$$

where S_k – surface of the carrier occupied by catalytically active centers, m^2; V_p – reactor volume occupied by catalyst; m^3; C_k^n – the concentration of catalytically active compounds, g/m^2; t_k – the contact time of the gas stream with a catalyst, sec; k_0 – pre-exponential factor; E – activation energy, kJ / mol; R – universal gas constant, к kJ / (mol·K^{-1}); T –the temperature in the reaction zone, K.

In the study of catalytic thermal oxidation process in the external diffusion limiting stage it is offered to assess the impact of catalyst concentration on carriers surface, concentration of hydrocarbons in the gas mixture and gas flow rate on the mass-transfer coefficient:

$$\beta = \frac{V_p}{t_k \cdot S} \cdot ln\left(\frac{C_0^{CH}}{C_k^{CH}}\right), \tag{2}$$

where C_0^{CH} – the concentration of hydrocarbons in the initial time, g/m^3; C_k^{CH} – the concentration of hydrocarbons in the end of reactor, g/m^3.

All research data of hydrocarbons catalytic decomposition process in the external diffusion limiting stage allowed to form a data set from which the dependence of the mass-transfer coefficient on the studied parameters is obtained:

$$\beta_\Sigma = e^{m_1} \cdot \Re^{m_2} \cdot E_1^{m_3} \cdot \frac{D}{d} \cdot ln\left(C_0^{CH}\right) \cdot C_k^{m_4}, \tag{3}$$

where m_1=-22,494; m_2=1,684; m_3=14,524; m_4=0,586.

With the use of equation (3) the dependence of the hydrocarbons conversion degree for the external diffusion limiting stage is obtained:

$$x_d = 1 - exp\left(-\beta_\Sigma \cdot t_k \cdot \frac{273}{T} \cdot \frac{S}{V_p}\right). \tag{4}$$

Resulting equations allowed to develop methodology for calculation, design and conclude recommendations for production catalytic gas cleaning equipment for waste processing facilities with productivity of 100 kg and 400 kg per hour for Kherson seaport and Kyiv railway station respectively.

References

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