n-paraffins increases the *CP* of the DT samples, which clearly indicates a change in the onset temperature of crystallization and the earlier appearance of n-paraffin crystals.

Thus, the addition of heavy n-paraffins was found to increase the effectiveness of the depressant additive against CFPP and *PP*.

References

1. *Bogdanov I.A., Altynov A.A., Morozova Y.P., Kirgina M.V. // Oil Processing and Petrochemistry, 2020. – Vol. 9. – P. 27–33.*
2. *Mukhtorov N.Sh., Karpov S.A., Kapustin V.M. // Oil Processing and Petrochemistry, 2012. – Vol. 10. – P. 46–48.*
3. *USS 11851-85 "Petroleum. Method of paraffin determination". – Moscow: Standartinform, 2018. – 15 p.*

MATHEMATICAL MODELING OF SULFONATION REACTOR

M.A. Pasyukova, A.A. Solopova, I.O. Dolganova
Research supervisor – candidate of technical sciences, associate professor I.M. Dolganov
National Research Tomsk Polytechnic University
634050, Russia, Tomsk, 30 Lenin Avenue, maria.pasyukova11@gmail.com

Global demand for safe and effective detergents is driving the development of biodegradable anionic surfactant technologies. Alkylbenzenesulfonic acid is the base component for these surfactants. Alkylbenzenesulfonic acid is obtained by sulfonation with sulfuric anhydride of a thin film of linear alkylbenzene with a side chain of 10–13 carbon atoms. The most efficient technologies include sulfonation in multi-tube film reactors. The sulfonation reaction is exothermic, cooling is carried out by supplying water to the annular space. An increase in temperature in the reaction zone leads to the occurrence of side reactions, during which viscous tetralins and sulfones are formed, which settle on the inner surface of the reaction tubes and reduce the quality of the final product. To remove by-products, it is necessary to periodically shut down the reactor and rinse the reaction tubes with water.

The use of mathematical modeling for the selection of optimal technological parameters makes it possible to increase the duration of continuous operation of the reactor without deteriorating the quality of the final products [1]. At present, various versions of mathematical models are known for film reactors for the sulfonation of linear alkylbenzene. Early models assumed turbulent motion in the liquid and gas phases, as well as the absence of entrainment of liquid droplets by the gas phase or the capture of gas bubbles by the liquid. Later, other models were proposed. They assumed a laminar flow of the liquid phase, supplemented by assumptions about the diffusion of gas into the liquid, as well as the adsorption of SO_3 by the liquid phase.

This paper presents the results of calculations using the developed mathematical model based on the following assumptions: plug flow, the liquid film is located over the entire surface of the tubes and is symmetrical about the reactor axis, the reaction rate decreases due to the formation of a viscous component [3].

An important advantage of the mathematical model is that it allows you to calculate the quality indicators of the product flow depending on the concentration of aromatic compounds in the sulfonation feed.

Calculations using a mathematical model made it possible to establish the effect of the content of aromatic hydrocarbons in the feed on the mass fraction of alkylbenzenesulfonic acid in the product stream and the optimal consumption of sulfur supplied for combustion in the furnace to obtain a gas mixture of sulfuric anhydride and air used for sulfonating linear alkylbenzene. The calculated optimal consumption of combusted sulfur at different concentrations of aromatic hydrocarbons in the feed are presented in the table.

Thus, an increase in the content of aromatic compounds in the feed leads to a decrease in the yield of the target product and an increase in the optimal consumption of combustion sulfur. According to calculations carried out using a mathematical model, it was found that alkylbenzenesulfonic acid of the maximum concentration is 97 % wt. was obtained from raw materials with a concentration of aromatic substances entering the sulfonation reactor with linear alkyl benzene, not exceeding 5.9 % wt. According to the calculations, with an increase in the concentration of aromatic compounds in the raw material, it is necessary to increase the consumption of combusted sulfur.

Thus, the use of mathematical models to control and optimize the production of alkylbenzenesulfonic acid makes it possible to increase the duration of continuous operation of the reactor, reduce the cost of washing, increase the yield of alkylbenzenesulfonic acid in the product stream, and optimize the entire multistage process.

The reported study was funded by RFBR according to the research project № 20-38-90103.

Table 1. Dependence of the optimal consumption of combusted sulfur on the content of aromatic hydrocarbons in the feed

Optimal consumption of combusted sulfur, kg/h	376.4	377.1	378	379	380.1	381.1
Concentration of aromatic hydrocarbons, kg/h	252	288	310	337	352	389

References

1. *Optimal design of the film sulfonation reactor in linear alkylbenzene sulfonic acid manufacturing technology [Text] / I.O. Dolganova, I.M. Dolganov, M.A. Pasyukova, A.A. Solopova, A.A. Bunaev, E.D. Ivanchina // B: Petroleum and Coal, 2020. – V. 62. – №1. – P. 35–40.*
2. *Linear Alkylbenzenes Sulfonation: Design of Film Reactor and its Influence on the Formation of Deactivating components [Text] / E.D. Ivanchina, E.N. Ivashkina, I.O. Dolganova, I.M. Dolganov, A.A. Solopova, M.A. Pasyukova // Journal of Surfactants and Detergents, 2020. – Vol. 23. – №6. – P. 1007–1015.*

SYNTHESIS OF ZEOLITE MATERIALS AND STUDY OF THEIR PROPERTIES

М.О. Патз
д.т.н., профессор Е.Н. Ивашкина
National Research Tomsk Polytechnic University
634050, Russia, Tomsk, Lenin Avenue, 30, matheus_osmar@hotmail.com

Zeolites are porous materials with high adsorption capacity. This characteristic is the main, distinctive characteristic of them, thus explaining the widespread use of zeolites.

The synthesis of zeolites is carried in a basic solution. The synthesis can be performed in one or two steps. Nowadays, a two steps method is more suitable for higher conversion. The main components responsible for the synthesis are aluminum and silicon, as can be seen in Figure 1:

The compensation cation is usually referred as sodium (Na^+) or potassium (K^+) since the higher interaction between these components with silicon and aluminum is responsible for the stability of the desirable zeolite.

The two steps method consists in a variation of one step method – hydrothermal synthesis-, with the addition of an alkali fusion, where interaction between Silicon (Si) and Al (Aluminum) is increased. Thus, improving the conversion rate of the method.

Furthermore, according to the main components of the zeolite, a list of raw materials that have suitable qualifications is performed, encouraging the use of the ecological factor to reduce pollution.

One of the main sources of the raw materials are power plants which convert solids into energy. In the modern time, not only coal is used as a source of energy but also rice husk, or clay. But the main characteristics of the ideal source of minerals remain as high concentration of Si and Al, and lower concentration of iron and calcium. Within the reaction between NaOH, iron and calcium, if present in high quantity in the sample, compete with the