Intensification of the commercial run of deriving of isobutylene

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The optimum control of the process of dehydrogenation of isobutene has been analysed. In order to increase productivity of the process and also obtain of additional economic effect, it has been developed the mathematical model of this process due to regard of temperature, consumption of raw material and the catalyst.

Keywords: isobutene, intensification, optimization, mathematical, model

With the purpose to obtain isobutene in industrial scale isobutene dehydrogenation in pseudocondensed bed of the catalyst IM - 2201 circulating in reactor-regenerator system is widely used. The specified process has high selectivity and an output of a target product as an inherent characteristics. However opportunities of this process in industrial conditions completely is not realized, mainly because of reactor-regenerator system working in not optimum mode, caused not taking into account the influence of the reactionary environment and conditions of regeneration on activity of the catalyst. Optimum conducting of the process is interfered by absence of more convenient and simple mathematical model, and also discreteness of applied chromatographical methods of the analysis of the contact gas, thus complicating the organization of the continuous analytical control of process parameters.

The performed work is connected to the resolving of the specified actual and up today stubborn problems and includes development of dynamic mathematical model of process of dehydrogenation of isobutane into isobutene in view of influence of the reactionary environment and conditions of regeneration on activity of the catalyst, creation of a method and a way of the continuous analytical control and automatic control of technological parameters of process according to measurement of physical parameters.

Earlier [1] functional connections between the basic technological parameters of process (a degree of conversion α and selectivity S) and the data on density ρ and heat conductivity λ of contact gas have been established. This connection has been established on the basis of the experimental researches of the process which has been carried out on laboratory flow-type installation in the intervals of control parameters variation - temperature of reaction (580-680^{0}C), volumetric speed (150-750 h^{-1}), temperature of regeneration (600-650^0 C), at (5-30 minutes) of time of regeneration. For an estimation of structure of reaction products it was used the chromatographical method of the analysis.

According to the conducted analyses it was determined a degree of conversion α and selectivity S of the process, and also value of density of received products of reaction according to the account (ρ) and without taking into account (ρ_0), of the hydrogen consistence in them. In last two cases tabulared ρ values of all components of products of reaction were used, and additive character of connection between concentration of corresponding components in a mix and their density was assumed.

Despite of appreciable changes of structure of products of reaction in the investigated intervals of a variation of temperature in a reactor and speeds of isobutane inlet on the installation, found dependences of α from ρ and S from ρ_0 within the limits of probable mistakes of measurement have linear character [2].

Thus, by the comparative analysis of products of reaction of isobutane dehydrogenation, obtained in the specified way and according to chromatographical method measurement, it was established the linear dependence of conversion α and selectivity S of process from contact gas density (ρ) with the account and (ρ_0) without taking into account of hydrogen in its structure.

$$\alpha = a\rho + b$$

$$S = c\rho_0 + d$$

where a, b, c, d-constant, and parameter ρ_0 is functionally connected with ρ and heat conductivity λ under the expression:

$$\rho_0 = \left(\rho - \rho_{H_2}\frac{\lambda - \overline{\lambda_i}}{\lambda_{H_2} - \overline{\lambda_i}}\right)\left(\frac{\lambda_{H_2} - \overline{\lambda_i}}{\lambda_{H_2} - \lambda}\right),$$

where ρ_{H_2} - density of hydrogen, $\overline{\lambda}_i$ - average size of heat conductivity of hydrocarbonic components of a mix, λ_{H_2} - heat conductivity of hydrogen - preset coefficients.

Then parameter ρ_0 can be determined by the measured value of density ρ and heat conductivity λ of products of reaction with the help of detectors of the continuous control of density and heat conductivity of a gas mix.

On the basis of the specified way of an estimation of the basic technological parameters of processes of dehydrogenation of the lowest paraffin hydrocarbons the scheme for optimum control of industrial process of dehydrogenation of isobutane in pseudocondensed bed of the catalyst with application of the automated system has been developed.

The technological scheme and control system of process of dehydrogenation of isobutane into isobutene contains a furnace 1, a reactor 2, a regenerator 3, the gauge 4 of consumption of raw material, the executive mechanism 5 on a line of loading of raw material in a furnace, a regulator 6 of consumption of raw material, the gauge 7 and a regulator of 8 temperatures of raw material on an input of a reactor, the executive mechanism 9 on a line of loading of fuel gas in a furnace, the gauge 10 and a regulator of 11 temperatures of the regenerated catalyst, the executive mechanism 12 on a line of loading of fuel in a regenerator, the gauge 13 and a regulator 14 of consumption of the regenerated catalyst, the executive mechanism 15 on lines of loading of the regenerated catalyst, the gauge of 16 and 17 density and heat conductivities of contact gas and a computer 18.

The way of automatic control of process of dehydrogenation of isobutane is carried out as follows:

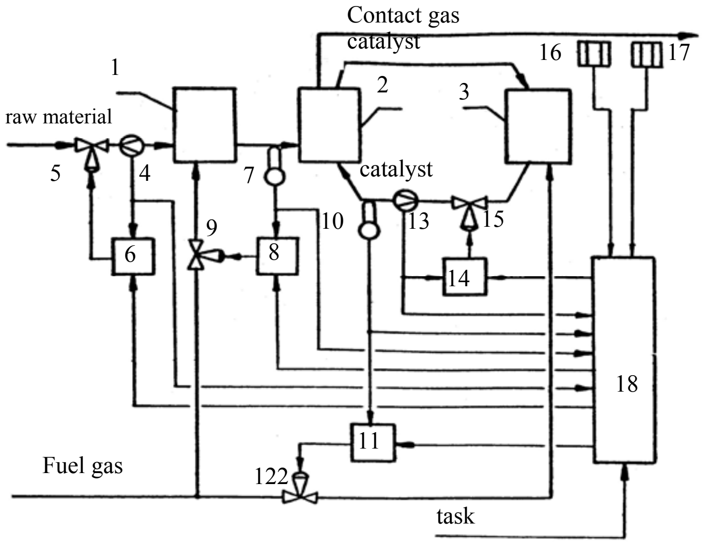

Fig.1. Isobutene dehydrogenation industrial process of automation control method flow diagram.

In a reactor 2 with pseudocondensed bed of the catalyst on the pipeline the raw material (isobutane fraction) is loaded. Heating of raw material is carried out in the furnace 1 due to fuel gas burning. The temperature of raw material in the entrance of the reactor 2 is measured by the gauge 7 and stabilized with the help of a regulator 8 and the executive mechanism 9, and the raw material consumption is measured by the gauge 4 and stabilized with the help of a regulator 6 and the executive mechanism 5. The task is established by a regulator 6 and 8 from an output of a computer 18. The catalyst from a reactor goes with the help of the pneumoconveyor to a regenerator 3 for restoration. In the last one there has been occurred a removal of a part of coke from a surface of the catalyst. The regenerated catalyst comes back in a reactor 2. The temperature of the regenerated catalyst is measured by the gauge 10 and adjusted with the help of a regulator 11 and the executive mechanism 12 established on the lines of loading of fuel gas in a regenerator. The consumption of the catalyst is measured by the gauge 13 and stabilized by a regulator 14 and the executive mechanism 15. Tasks to regulators 11 and 14 are established from an output of a computer 18.

The density and factor of heat conductivity of reaction are measured accordingly by gauges 16 and 17. The information from gauges on temperature of raw material and the catalyst, the consumption of raw material and the catalyst circulating in system, density and factor of heat conductivity of a product of reaction enter into computer 18. Thus the size of conversion (α), density (ρ_0)of contact gas without hydrogen taking into account, selectivity (S) of process and an output (α.S) of a target product is determined.

Besides in a computer 18 is entered as the help information the value of isobutane concentration in raw material, the common pressure of system, speed constants of isobutene formation and cracking products, constant factors, constants, fractions of the active centers, not had time to be deactivated in reaction to the beginning of regeneration, partial pressure of oxygen in gases of regeneration, factor of proportionality in the equation of speed of the active centers formation, preexponential factors of the equation of speed of the active centers formation, adsorption, speed of regeneration, energy of activation, absolute gas constant, heat of adsorption, energy of activation, regeneration.

After input of the specified information in a computer 18, last one run an computation on the measured values of density and factor of heat conductivity of the current values of conversion, selectivity and on their bases - sizes of an output of a target product (isobutene) in products of reaction. On the bases of these data and in view of other measuring information, and also taking into consideration the preset optimum values of conversion $\overline{\lambda}$, an output of a target component $\overline{\alpha \cdot S}$ it is made the computer based 18 comparison of measuring values α and αS with optimum sizes $\overline{\alpha}$ and $\overline{\alpha \cdot S}$ and at presence of a deviation from an optimum operating mode there are determined, in view of existing restrictions, values of controlled parameters (temperature and consumptions of raw material and the catalyst) by minimization of function.

$$F = \left(\alpha_\tau - \overline{\alpha}\right)^2 + \left[\left(\alpha \cdot S\right)_\tau - \overline{\alpha \cdot S}\right]^2,$$

where theoretical values of conversion α_τ and an output of isobutene $(\alpha S)_\tau$ are determined under the expressions, in which conditions of regeneration of the catalyst are taken into account.

The obtained calculation values of temperature and the consumption of raw material and the catalyst are transferred as the task to regulators 6, 8, 11, 14 which operate the executive mechanisms 5, 9, 12, 15 established on the lines of loading of fuel gas, raw material and catalyst.

Algorithm of optimum control of the process by this model and the specified way of the control of technological parameters of process it is shown in figure 2 and it is consisted of the following. On measured values of density ρ and heat conductivity λ of contact gas it is conducted the calculation of the current values of conversion α, selectivity S and an output $X = \alpha S$ of a target product of process. Found values α and αS are compared to preset optimum values $\alpha_{опт}$ and $(\alpha S)_{опт}$. At deviation occurrence of α and αS from $\alpha_{опт}$ and $(\alpha S)_{опт}$ it is made updating of a mode of installation by change of sizes of the basic operating parameters of the unit: temperatures of reactor T and temperatures of regenerator T_R, and also the consumption of raw material G and consumption G_K of the catalyst. In this case, using the simplified model of process, in view of the preset restrictions there are selected such values T, T_R, G, G_R at which the values $\overline{\alpha}$ and $\overline{\alpha \cdot S}$ calculated by the model appear to be higher than measured values α and S. Found by this way values T; T_R; G; G_R, are printed and used by the operator for their transfer on corresponding regulators of installation.

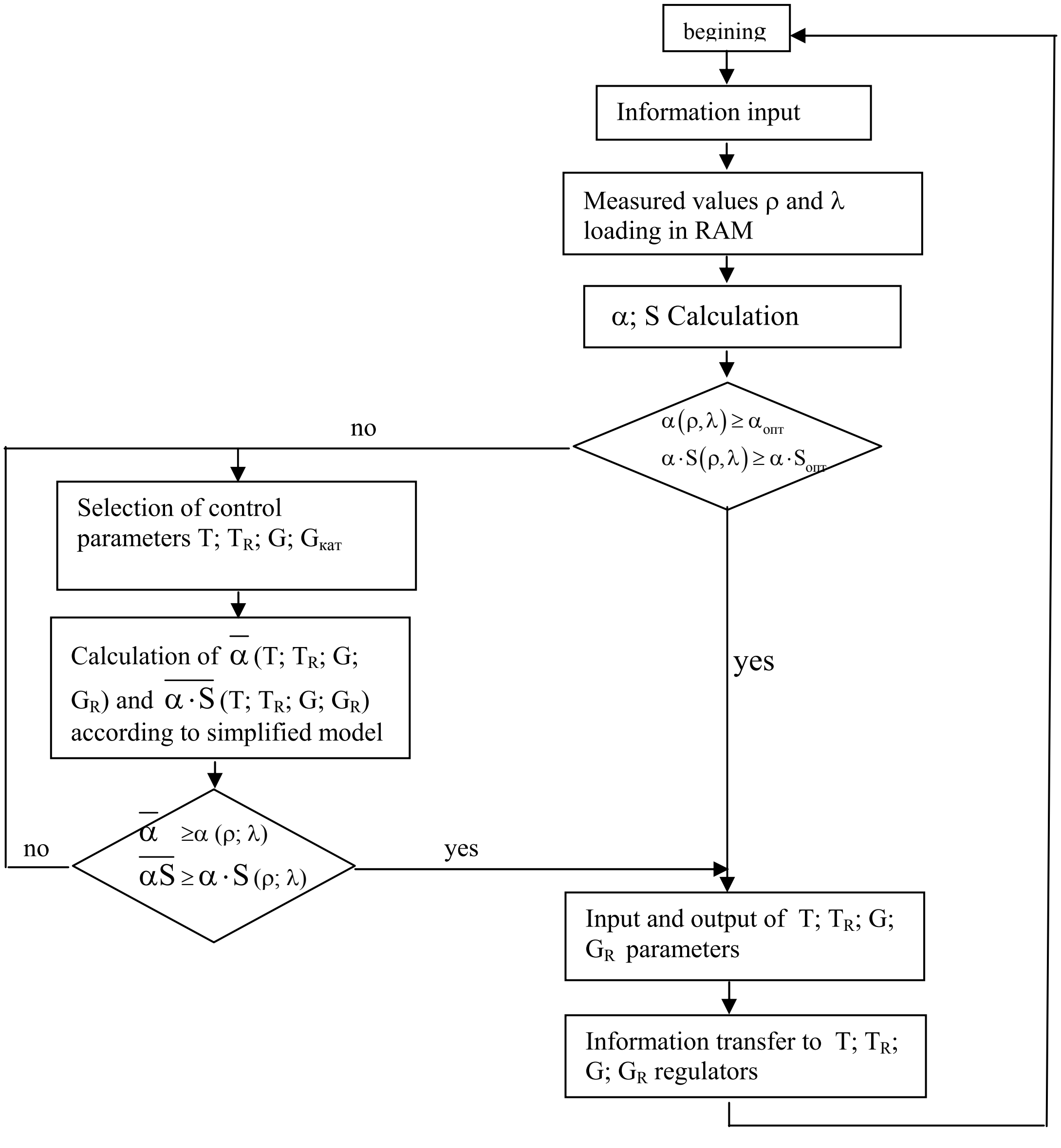

Fig. 2. The block diagram of algorithm of optimum control.

This way of automatic control of isobutane dehydrogenation process can be used in the chemical industry and will allow to increase productivity of process, to receive additional economic benefit due to simplification of a construction and reduction of expenses for service and repair of offered tools of measurement, control and optimum automatic operation.

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