About New Type of Multiplicity of Steady States in the Recycle System: Reactor - Separating Unit.

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1. Summary.

The conditions of the existence of the various continuums of steady states for the operational mode which complete utilization of feed and intermediate reactants are proposed. A continuous stirred tank reactor in which the second-order reactions A+B→2C and A + B → C, A + B ↔ P proceed with complete utilization of the feed reactants A and B is shown to be characterized by continuums of steady states in which the concentrations of reactants and temperature in the reactor can take an infinite of steady-state values lying within a bounded region (interval). This region (interval) is limited by the condition of the existence of the operational mode with a full use of the feed reactants.

Keywords: Recycle system: reactor – separation unit, multiplicity steady states, stability.

2. Extended Abstract.

An efficient way to solve the problem of minimizing chemical industrial wastes is recycling unreacted feed materials. For this purpose the reactor-separator recycle system can be used (Fig. 1). However a feedback causes an appearance of multiplicity of the steady states in the reactor. A problem of the steady states multiplicity in chemical reactor has been examined for a long time by van Herden (1953), Frank-Kamenetski (1955) and other. Also there are numerous articles in which the problem of the steady states multiplicity and stability of the reactor with recycle has been analysed (Lass and Amundsen (1967), Perlmutter (1972) and other). The existence of the finite set of steady states (odd number) in the reactor was indicated in all these works. But an appearance of qualitatively new properties in the reactor taking place in the recycle system: reactor – separating unit is possible. It is shown as an existence of continuum (infinite set) steady states in the reactor Boyarinov, Duev (1980,2002,2003,2004). Continuum of the steady states is possible to be only in recycle system for the operational mode with a complete utilization of feed and intermediate reactants. Necessary conditioons of the existence of operational mode with a complete utilization of feed and intermediate reactants are: an input of feed reactants in the system at a stoichimetric relation; full recycling of non reacting feed and intermediate reactants and the value of the recycle R must be greater than minimum value of the recycle R_{min}, where R_{min} is minimum value of the recycle, under which the operational mode with a complete utilization of feed and intermediate reactants is possible.

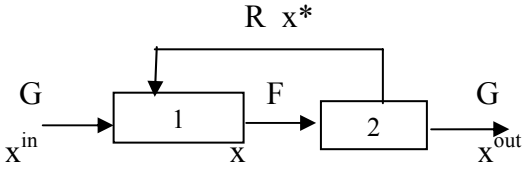

Figure 1. Reactor-separator recycle system: (1)-reactor, (2) - distillation column.

The conditions of the existence of the various continuums of steady states for the operational mode which complete utilization of feed and intermediate reactants are proposed. A continuous stirred tank reactor in which the second-order reactions $A+B \rightarrow 2C$ and $A + B \rightarrow C$, $A + B \leftrightarrow P$ proceed with complete utilization of the feed reactants A and B is shown to be characterized by continuums of steady states in which the concentrations of reactants and temperature in the reactor can take an infinite of steady-state values lying within a bounded region
(interval). This region (interval) is limited by the condition of the existence of the operational mode with a full use of the feed reactants.

The multiplicity of the temperature can be of two types: there may exist either a finite (discrete) number of steady – states values of the reactor temperature or an infinite number (continuum) of the reactor temperatures; i.e., the temperature may take any values within a certain interval (T_{min}, T_{max}).

Numerical calculations of a recycle system consisting of the continuous stirred tank reactor and a distillation column are done. The column distillate in which all components were present was used as recycle and the final product P, whose volatility is the least, was drawn off
via the column recoiled. Because the separation process is not perfect, the feed reactants A and B were present in insignificant amounts in the recoiled of the distillation column.

Continuum steady states is shown as a dependence of the calculated values of the concentrations A and B of initial approximation of the iterative procedure of the calculation of the system: reactor – distillation column. These steady states can not by of asymptotic stability. They can at best be on the boundary of the stability region at the state of neutral balance. Therefore it is necessary to carry out an automatic control to keep this operational mode.

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