COMMAND AND REMOTE CONTROL OF A CHEMICAL REACTOR

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Abstract

The paper presents some aspects of command and remote control systems of a reactor Use automatic adjustment of concentration. It further shows a way to implement business systems for regulating concentration.

1. General problems

It is considered an isothermal chemical reaction type *A* → *B (A)*, which takes place in a reactor volume *V* (substance *B* was converted partly into the reaction speed constant *k*). The determining of mass conservation equations for reagent *A* and *B* reaction product, with the observation that the amount of the substance consumed and produced by reaction give an interpretation of the output mass streams respectively input into the system. Then for the stationary we have:

$$F_0 c_{A1} - kVc_{A2} - F_0 c_{A2} = 0 \qquad (1)$$

$$kVc_{A2} - F_0 c_{B_0} = 0 \qquad (2)$$

Daca intereseaza, spre exemplu, dinamica canalului de executie de la variatia debitului de alimentare *F* la variatia concentratie de substanta reziduala c_{A2} se poate scrie ecuatia:

If you are interested, for example, channel dynamic execution flow from variation to variation in supply *F* residue concentrations c_{A2} can write equation:

$$F(t)c_{A1} - kVc_{A2}(t) - F(t)c_{A2}(t) = V\frac{dc_{A2}}{dt} \qquad (3)$$

It is believed that depend on time measurements, expressed by the equation:

$$\begin{aligned} F(t) &= F_0 + \Delta F(t) \\ c_{A2}(t) &= c_{A_{20}} + \Delta c_{A2}(t) \end{aligned} \qquad (4)$$

From (3) and (4) after extraction of inpatient and product regime $\Delta F(t)\Delta c_{A2}(t)$, result:

$$F(t)\left(c_{A1} - c_{A_{20}}\right) - \left(F_0 - kV\right)Ac_{A2}(t) = V\frac{d\Delta c_{A2}(t)}{dt} \qquad (6)$$

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Such measurements are standardized variations:

$$y(t) = \frac{\Delta c_{A2}(t)}{c_{A_{20}}}$$
$$m(t) = \frac{\Delta F(t)}{F_0} \qquad (7)$$

The notation (7), to obtain the final model, dimensionless:

$$F(t) c_{A1} - kVc_{A2}(t) - F_0 c_{A2}(t) - c_{A_{20}} \Delta F(t) = V \frac{d\Delta c_{A2}(t)}{dt} \qquad (5)$$

or:

$$Vc_{A_{20}} \frac{dy(t)}{dt} + \left(F_0 + kV\right) c_{A_{20}} y(t) = F_0 \left(c_{A1} - c_{A_{20}}\right) m(t) \qquad (8)$$

If shares in (8) the coefficient $\left(F_0 + kV\right) c_{A_{20}}$ to obtain:

$$\frac{V}{F_0 + kV} \frac{dy(t)}{dt} + y(t) = \frac{F_0}{F_0 + kV} \frac{c_{A1} - c_{A_{20}}}{c_{A_{20}}} m(t) \qquad (9)$$

and deduce the transfer function:

$$H_P(s) = \frac{k_P}{\tau_P s + 1} \qquad (10)$$

where:

$$k_P = \frac{F_0}{F_0 + kV} \frac{c_{A1} - c_{A_{20}}}{c_{A_{20}}} \qquad (11)$$

$$\tau_P = \frac{V}{F_0 + kV} \qquad (12)$$

2. Systems for automatic adjustment of concentration

Consider a system with transfer function fixed part:

$$H_F(s) = k_T \frac{k_E}{\tau_E s + 1} \frac{k_P}{\tau_P s + 1} \qquad (13)$$

resulting in serial connection for the sensor element concentrations considered proportional to the gain k_T, actuators approximated by the transfer function $\frac{k_E}{\tau_E s + 1}$ with transfer function and $\frac{k_P}{\tau_P s + 1}$ the previously calculated.

Given the relatively large time constant of the process can thus neglecting τ_E with τ_P, instead it is necessary to introduce the effect of transport of the sample to be analyzed from the transducer to the concentration plant, the dead time $\tau = \frac{L}{V}$, where L is the length of pipe and V the velocity of the fluid.

The gantry is then rendered by:

$$H_F(s) = \frac{k_F e^{-\tau s}}{\tau_P s + 1} \tag{14}$$

For automatic control systems concentration recommended a PID.

When designing the controller are taken into account by this time dead and therefore the equity method is attempted continuous system meshed with an equivalent system which performs data required by answering clues, sampled with a period $T_e = \frac{\tau}{m}$ (the choice is here to ease calculation, thus $T_e = \frac{\tau}{m}$ $\mathrm{m} \in \mathrm{N}$).

So the answer must be transformed Z:

$$Y_d\left(z^{-1}\right) = \sum_{j=1}^{l} \beta_j z^{-j} \tag{15}$$

where β_j coefficients are samples taken from the response required, and l is the total number of samples is calculated using the equation:

$$l = \frac{t_r}{T_e} \tag{16}$$

t_r the response time continuous closed loop system.
Next step response of the system to calculate real:

$$Y(s) = \frac{1}{s} H_0(s) \tag{17}$$

where:

$$H_0(s) = \frac{H(s)}{1 + H(s)} \tag{18}$$

whith:

$$H(s) = H_R(s) H_F(s) = \frac{k_R\left(T_i s + 1\right)}{T_i s} \frac{kFe^{-\tau s}}{\tau_P s + 1} \tag{19}$$

Prin compensarea constantei de intarziere cu constanta de timp de integrare *Ti* se obtine:

The delay compensation τ_P constant integration time constant T_i is obtained:

$$H(s) = \frac{k_R / T_i k_F e^{-\tau s}}{s} \tag{20}$$

Result

$$H_0(s) = \frac{k_R k_F / T_i e^{-\tau s}}{s + \frac{k_R k_E}{T_i} e^{-\tau s}} \tag{21}$$

Entering in (37) is obtained:

$$Y(s) = \frac{1}{s} \frac{k_R k_F / T_i e^{-\tau s}}{s + k_R k_F / T_i e^{-\tau s}} \tag{22}$$

Utilizing relationships meshing below:

$$s^{-1} = \frac{1 + z^{-1}}{1 - z^{-1}} \frac{T_e}{2} \tag{23}$$

$$s^{-2} = \frac{1+10z^{-1}+z^{-2}T_e^2}{\left(1-z^{-1}\right)^2 12} \qquad (24)$$
$$e^{-\tau s} = e^{-mT_e s} = z^{-m}$$

meshed response is obtained (in *z*) the real system:

$$Y\left(z^{-1}\right) = \sum_{j=1}^{l} a_j\left(k_R\right) z^{-j} \qquad (25)$$

in that the coefficients aj depends on the gain of the controller.

It builds a function that depends on the square criterion discrepancies that exist between the desired response coefficients and real response coefficients:

$$F\left(k_R\right) = \sum_{j=1}^{l}\left[b_j - a_j\left(k_R\right)\right]^2 \qquad (26)$$

and minimizes *F* variable in relation to k_R a possible restriction imposed it.

The solution of the problem:

$$\min\{F(k_R) = \sum_{j=1}^{l}\left[b_j - a_j(k_R)\right]^2\} \qquad (27)$$
$$k_{R\min} \le k_R \le k_{R\max}$$

It can be obtained relatively easily, if using a numerical method of optimization is the value k_R^*.

3. The implementation of the business systems to adjust the concentration

SRA for concentration are made practically in structures similar to those regulating temperature control.

Thus, industrial automation, especially in chemistry, SRA for concentration are made as control systems by error (deviation), but more frequently as a cascade control structures (Figure 1) and the control structures complex after error after disturbance (Figure 2).

Waterfall serial connection is made through the main loop concentration control secondary loop of diluent flow control F_d which is the size of the system execution. In this configuration, the system designed with such a structure is invariant perturbation due to random variations in flow F_p.

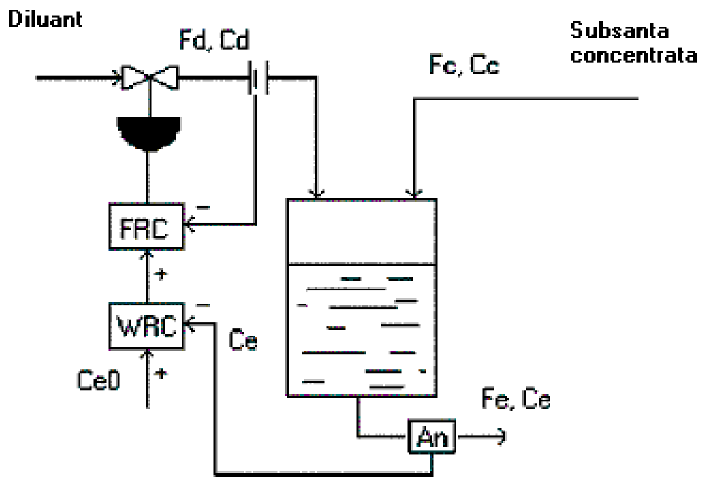

Figure 1. *Adjusting concentration of diluent flow cascade that*

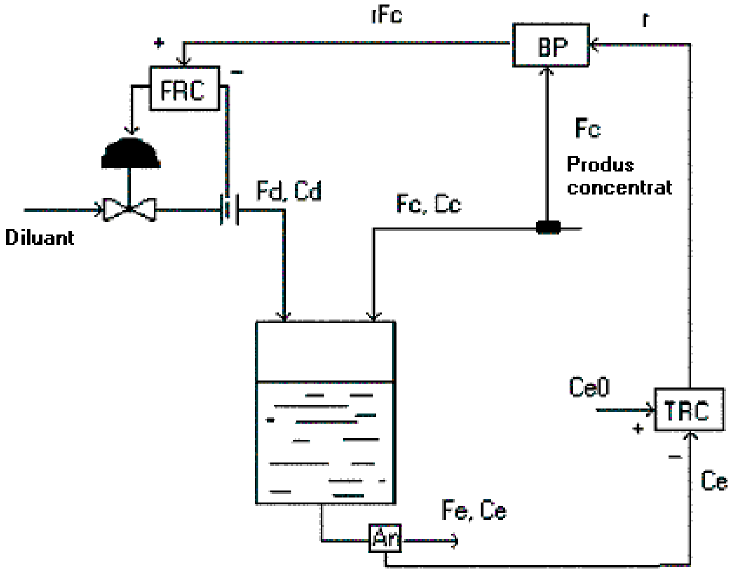

Figure 2. *Adjusting concentration after departure and after disturbance*

To further improve performance, we try to keep constant the ratio between flow rate of diluent and concentrate F_p. This is canceled and the disruptive effects due to variations in flow F_p by introducing additional transducer for measuring the flow and a block BP report.

Implementation cascade control structure, most commonly used in practice, it is possible either using the current unified signal devices (4 − 20 mA) as shown in Figure 3, or to the unified signal voltage equipment (0 − 10 V_{cc}).

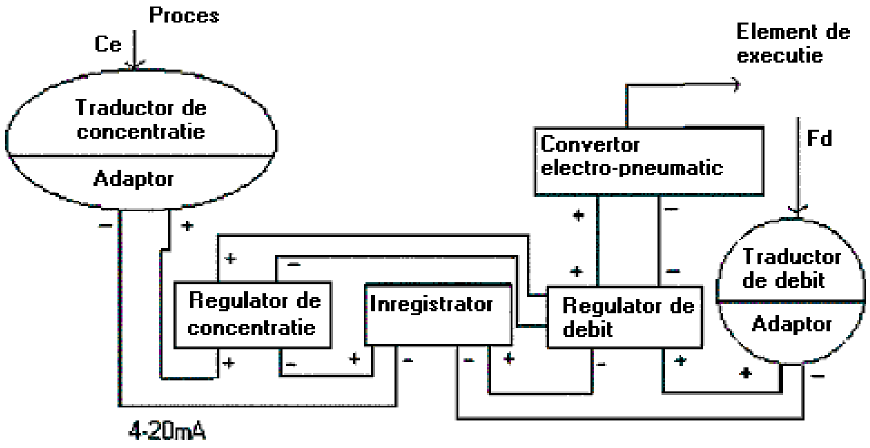

Figure 3. *Implementation of the SRA (cascade) for concentration with the current unified signal devices*

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