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Power-efficient mode of the electrolytic fluorine production process control

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Abstract

Generalized functionality of the fluorine production manufacturing efficiency developed for determination of optimum values of temperature and hydrogen fluoride concentration according to the method of multiparametric optimization allowed calculating the optimum process performance and develop the optimum fluorine production process control by maintaining electrolytic solution temperature and hydrogen fluoride concentration in the electrolyte depending on the value of the current load in the electrolyzer.

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Keywords: efficiency functional ; technological process control

1. Main text

Research of the causes of high energy consumption and search for new engineering solutions and modes for increasing operation efficiency of fluorine electrolyzers is very important nowadays[1–4]. The ranges of electrolyte optimum composition have been obtained experimentally by Caddy in 1934 [1]. With the increase of hydrogen fluoride content in electrolyte from 36% to 42 % wt, and temperature increasing from 90 to 120 °C, the efficient fluorine yield can increase from 27% up to 40%, while the content of hydrogen fluoride (HF) in the product grows from 6% to 18% vol. [4].

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As a result, the need to form a generalized criterion for optimality of the manufacturing process operational mode expressing efficiency in terms of the main technological control variables and to develop efficient control mode on its bases appeared.

Operational ranges of the electrolytic content experimentally obtained by Caddy have some limitations such as electrolyte crystallization and the HF vapor pressure above the melt of 50 mm Hg which corresponds to the upper permissible value of HF concentration in the manufactures fluorine. It is well known that when HF content in electrolyte C_{HF} increases from 36% to 42% wt, in the interval of the electrolyte temperature change T_E = 90 …120°C, the efficient fluorine yield can increase from 27% to 40% [3], and the content of HF in the product can grow from 6% to 18% vol. [1]. The production cost of fluorine is mainly determined by expenditures connected with HF (58%) and energy sources (16%), hence, cost savings, in case when 10 and more production units are used, is a very important task.

Electric power losses depend on the value of voltage drop on electrolyte and polarization[1,3,4]. The decrease of the electrolyte temperature results in the increase of the electric power cost. The decrease of HF concentration in the melt leads to the decrease of electrolytic conductivity. This also leads to the increase of energy costs.

The quality of the produced fluorine is characterized by the presence of admixtures. The main component is HF (up to 95%) which evaporates from the electrolyte surface in the anode portion of the electrolyzer. Concentration of HF above the electrolyte surface is conditioned by a saturated vapor pressure. HF, evaporating from the electrolyte surface in the cathode portion and hydrogen go to ventilation and get lost.

According to the above stated, the requirements and restrictions to the ranges of operation mode optimal values have been formulated. The bounds of this range determine: partial pressure of the saturated vapor of HF over the electrolyte melt which characterizes the product quality and raw material losses; electrolyte voltage drop which shows the power consumption; dissociation rate and electrolyte viscosity as the efficiency fluorine yield. According to the method of multi parametric optimization, the generalized efficiency functional F with weight coefficients takes the form of [5]:

$$F = \sum_{i=1}^{5} k_i \cdot f_i \tag{1}$$

Generalized functional the expert evaluation method has been used [6] to determine weight coefficients of the process efficiency. The functionality has been formed from the optimality criteria by using energy and materials resources and quality of produced fluorine which allows determining optimal values of controlled variables. Energy efficient mode of the fluorine production process means variability of controlled variables values depending on current load, specification of permissible quality of the produced fluorine, according to calculation results of the functional to achieve the minimum power costs.

The researches of the generalized efficiency criterion (1) in the range of working values of controlled variables have shown that the developed functional had been at its highest point in the range of 36…39% wt. of HF concentration and 99…103 °C of the electrolyte temperature.

The developed generalized efficiency functional can be used to determine optimal values of HF temperature and concentration from the point of view of the technology, resources conservation, product quality for the manufacturing process of technological fluorine production. The performed researches allowed developing the energy-efficient mode of the fluorine production process management.

While researching current voltage characteristic of the electrolyte (Fig. 1) [5], it turned out that when the values of HF concentration and temperature changed within the regulated range, the increment of voltage change begins with the current increase to 2.5V at maximum load.

Taking into account that the voltage drop on electrolyte can be explained by the HF concentration and electrolyte temperature can be described by a linear function with accuracy sufficient for control, and there is rather accurate temperature and HF concentration automated control, it is possible to adjust these variables at the load current change:

$$C_{HF} = 0.2 \cdot I + 35.9, \tag{2}$$