Research on pH Value Control for Sewage Treatment

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Abstract　Take a model sewage treatment plant as an example, the mathematic model of sewage acid/alkali deviation is figured out oriented by combined oxidation ditches. The relationship between pH measuring value and acid/alkali deviation is built up by means of non-linear transformation. According to these results, the adaptive algorithm is given out for digital discharge valve control. The algorithm adopted Restricted Least Square Method to estimate the parameter $\boldsymbol{\theta}_0$ and realized estimating on-line. The control system has been used in that model plant and the controlling results are proved good.

Key words　sewage treatment;　pH value;　control;　algorithm

污水处理过程中pH值控制方法的研究*

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【摘要】以某污水处理示范工程为例，依据一体化氧化沟的工艺流程建立了污水酸碱偏离度的数学模型，通过非线性变换确定了pH测量值与污水酸/碱偏离度的关系。在此基础上，推导了以数字式流量阀为控制对象的pH值控制算法，运算中采用带约束条件的最小二乘法对参数 θ_0进行估计，实现了参数的在线辨识。该控制方法已经在示范工程中进行了实验，控制效果理想。

关　键　词　污水处理;　pH值;　控制;　算法

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1　The Combination of Sewage pH Value Control System

There are few closed-loop pH value control solutions to be adopted in usual sewage treatment processing [1~4]. Most sewage treatment plant simply uses manual way to adjust sewage pH value. Comparing with the past ten years, the acid/alkali deviation of live sewage has increased obviously. It is necessary to control sewage pH value in order to guarantee the sewage treatment quality to meet drain-off standard. This paper reports a closed-loop pH value control system for model sewage treatment plant in Sichuan. In the process, the sewage first is introduced to neutral pool to adjust its pH value (to keep neutrality) and then is pumped into the Combined Oxidation Ditches. The control system is combined by digital discharge valve, pH value sensor, neutral pool and digital regulator and as shown in Fig. 1.

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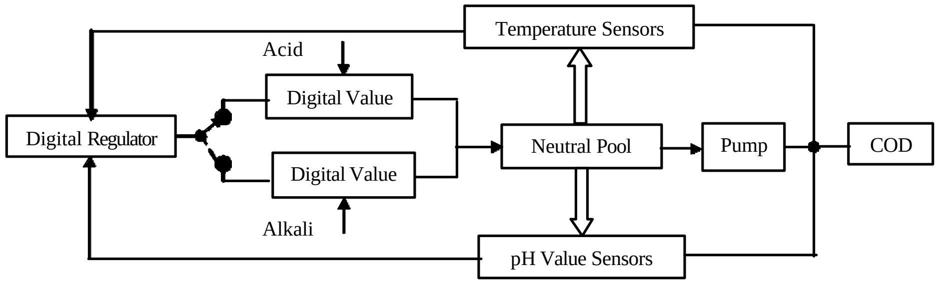

Fig.1　The combination of pH value control system

2　The Adaptive Algorithm

According to Ref.[5], the sewage neutral deviation function $y(t)$ could be expressed as follow

$$V(\mathrm{d}y/\mathrm{d}t) = F(t)[a - y(t)] - u(t)[b + y(t)] \tag{1}$$

where $y(t) = [H^+] - [OH^-]$, which is sewage neutral deviation, and V is volume of COD, $F(t)$ is flowing velocity of acid, a is concentration of acid, $u(t)$ is flowing velocity of alkali, b is concentration of alkali.

According to experimental results and real condition, the concentration of acid and alkali are fixed and known, $F(t)$、$u(t)$ could be measured on-line. The pH value in neutral-pool is time related and can be estimated by parameter estimating method.

From experiment results, the proximate dispersing model (including measuring and driving errors) is

$$y(t+1) \approx y(t) + (T/V)\{F(t)[a - y(t)] = u(t)[b + y(t)]\} = F(t)^T q_0 \tag{2}$$

where $y(t)$ denotes the degree of deviation, T denotes the space of sampling.

$$F(t) = \{y(t), -F(t)y(t) - u(t)[b + y(t)], F(t)\}^T \tag{3}$$

$$q_0 = [q_1, q_2, q_3] = [1, T/V, aT/V] \tag{4}$$

Using Restricted Least Square Method (RLSM) method to estimate è$_0$, we can keep $\hat{q}_2(t)$ constant positive[6].

The output sequence are $\{y^*(t); t = t_0 + nT\}$, we can obtain input sequence $u(t)$ from Eq. (2)

$$u^*(t) = \left[\hat{q}_1(t)y(t) - \hat{q}_2(t)F(t)y(t) + \hat{q}_3(t)F(t) - y^*(t)\right] \Big/ \{\hat{q}_2(t)[b + y(t)]\} \tag{5}$$

where when $0 < u^*(t) \leq u_{\max}$, taking $u(t) = u^*(t)$; when $u^*(t) \geq u_{\max}$, taking $u(t) = u_{\max}$; when $u^*(t) \leq 0$, taking $u(t) = 0$.

The steps to estimate q_0 using RLSM method are given out as follows

$$\hat{q}(t) = \hat{q}(t-1) + \{[P(t-2)F(t-1)]/[1 + F(t-1)^T P(t-2)F(t-1)]\}[y(t) - F(t-1)^T \hat{q}(t-1) \tag{6}$$

$$P(t-1) = P(t-2) - [P(t-2)F(t-1)F(t-1)^T P(t-2)]/[1 + F(t-1)^T P(t-2)F(t-1)] \tag{7}$$

If $\hat{q}_2(t) > 0$, the algorithm continues, else changing the coordinate of parameter space and order(as Fig.2 shows)

$$r = P(t-1)^{-1/2} q \tag{8}$$

where $$P(t-1)^{-1} \underline{\underline{\Delta}} P(t-1)^{-1/2} P(t-1)^{-1/2} \tag{9}$$

Using $\overline{W}$ to indicate the phase space of W under $P(t-1)^{-1/2}$ linear transformation.

1) $\hat{q}(t)$'s phase $\hat{r}'(t)$ orthogonal casting to the border of $\overline{W}$ generated $\hat{r}(t)$ under the effecting of $P(t-1)^{-1/2}$, we obtain

$$\hat{r}(t) = P(t-1)^{-1/2} \hat{q}(t) \tag{10}$$

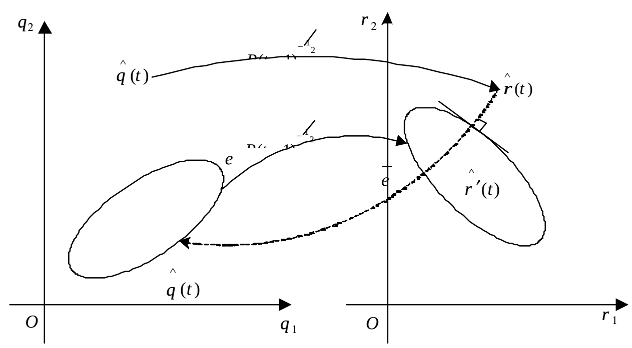

Fig.2 The algorithm of RLSM

2) Order

$$\hat{q}(t) = \hat{q}'(t) \underline{\underline{\Delta}} P(t-1)^{1/2}\, \hat{r}'(t) \tag{11}$$

The algorithm will continue till to next sampling period, we can take that estimated value and substitute the value into Eq.10 to obtain controller output.

3 Experiment Results

Using MATLAB5.3 simulation tool to simulate the algorithm, the simulation result is shown in Fig.3. The real measuring results of pH value regulating are shown in Fig.4.

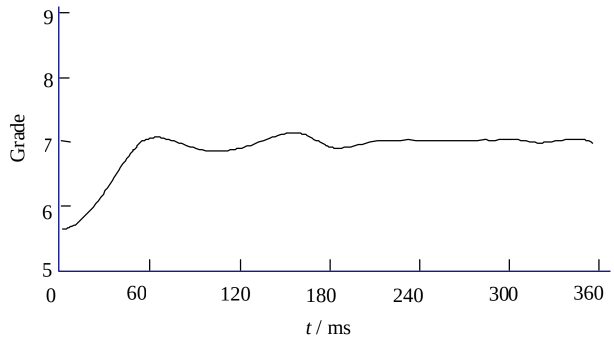

Fig.3 pH value simulating curve

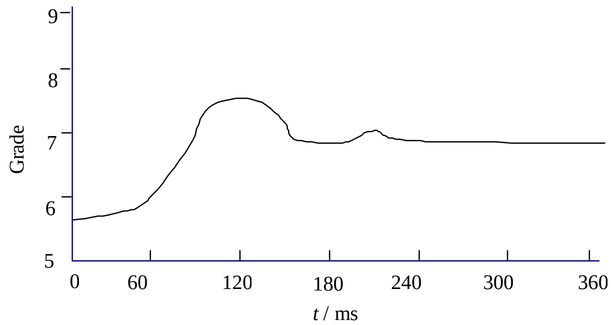

Fig.4 The real controlling result

4 The Control Program Design

When sewage pH value $p(t)$ changed, $y(t)$ also changed correspondingly. Meanwhile, the parameter vector $F(t)$ will change also. Using the RLSM to estimate $q_0(t)$ on-line, the controller's parameters are adjusted to optimize the controller output. This adoptive control process can be designed by program flow as Fig. 5 shows.

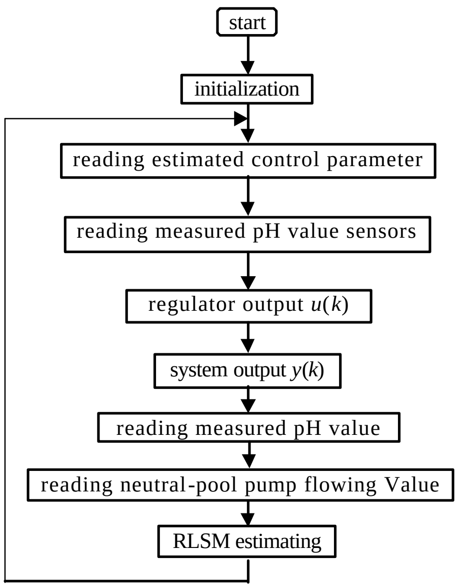

Fig.5 The program flow chart

5 Conclusions

According to the control efforts and the experimental results, it's possible to adopt closed-loop control system for sewage pH value control. The adaptive algorithm can improve the control quality and fulfill the pH value's long-time delay and wide-rang deviation. The adaptive algorithm is realized by estimating parameter q_0 using RLSM method based on real application, the results show that the control system design is reasonable and the algorithm is chosen properly.

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