Application research of adaptive fuzzy control in the treatment device of drilling fluid wastewater

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Abstract. Aiming at the problem of energy consumption and efficiency in the treatment process by the treatment device of drilling fluid wastewater, this paper puts out an adaptive fuzzy control method. The fuzzy controller is based on the real-time online monitoring data of water quality and make rules based on engineering practice experience. The adaptive algorithm based on the real time online data of Do, pH and SS can treat drilling fluid wastewater in pertinence by selecting the specific processing module from aeration, filter presses, de-oiled, activated carbon, and adjusting the temperature of the Mechanical Vapor Recompression (MVR) processor. The experimental results show that the method of fuzzy control can decrease energy cost and improve treatment efficiency. The device with the optimized control can save energy consumption per hour 0.6 kw.h, and save 1 hour in a single workflow.

1. Introduction
The treatment device of drilling fluid wastewater which based on Mechanical Vapor Recompression (MVR) takes the low temperature negative pressure evaporation as the core and combined with the physical treatment technology such as pressure, filtration and adsorption [1]. The device solves the traditional treatment process (recovery and reuse method, curing method, biological treatment, evaporation and concentration treatment) which is difficult to apply to different components of the drilling fluid, the terminal treatment and high cost engineering problems, so it is very suitable for China's limited space drilling a large number of drilling fluid treatment. Because of the water quality parameters are complicated and changeable, and the working conditions are changed, so the device cannot verify whether it will work during the treatment of drilling fluid wastewater. At present, the device used a fixed process which based on the engineering experience. In this way, the treatment device of drilling fluid wastewater has low work efficiency and high energy consumption.

The fuzzy adaptive controller has nice robustness which based on the engineering experience of operators, it is especially suitable for the control of complex nonlinear systems and unknown mathematical model [2]. Suoqing Liu et al. [3] received the good application effect in the pH value control system for waste water treatment with the fuzzy adaptive controller; Galluzzo et al. [4] applied the rule-based fuzzy multi-level controller to the aeration process of sewage treatment plants, which was proved the method an effective method; Hongbiao Zhou [5] applied the neural network with fuzzy control to the dissolved oxygen control in the process of wastewater treatment, which obtained a good effect.

In this study, the adaptive fuzzy controller is applied to the control system of the drilling fluid wastewater treatment device, which based on the real-time online monitoring data of water quality and make rules by engineering practice experience, the adaptive algorithm is achieved treating drilling
fluid wastewater flexibility and diversity, and the device with the adaptive fuzzy controller can improve the intelligence and the efficiency, and which can reduce the energy consumption of unit operation.

2. The treatment device of drilling fluid wastewater
The treatment device is composed of several processing modules, such as aeration, demulsification, pressure filtration, MVR processor, de-oiled and activated carbon adsorption. The purification process is shown in Figure 1.

![Figure 1. Purification process of drilling fluid wastewater treatment plant based on MVR.](image)

Drilling fluid wastewater was pumped into the aeration tank by centrifugal pump; after 30min, it is transported into the demulsification tank; after 30min, it is transported to MVR processor by pressure filter; the condensed water by MVR processor degreasing for 10 minutes in the de-oiled tank, then it is transported to activated carbon tank, after treatment for 10 min, and finally the water was discharged.

The device had obtained the good processing effect in treating the drilling fluid wastewater from Beibei, Suining, Jiangyou in the company of Chuandong drilling. But in the treatment process, reducing the operating time and reducing the operating costs is an urgent problem to be solved by optimizing the control process. The flow chart of fuzzy controller is shown in Figure 2.

![Figure 2. The flow chart of fuzzy controller.](image)
3. Adaptive fuzzy controller
Fuzzy controller is a control method based on the basic idea and theory of fuzzy mathematics, first, the fuzzy controller summarizes people's operating experience based on the way of people's thinking, then the fuzzy controller makes rules by fuzzy language and fuzzy conditional statements, finally these rules are implemented by computers or special modules. The fuzzy controller does not rely on the mathematical model of the controlled object, its robustness is well [6]. The treatment device of drilling fluid wastewater with the adaptive fuzzy controller can treat drilling fluid wastewater flexibility and diversity which based on the quality of effluent, and which makes treating wastewater smarter. The control flow is shown in the diagram.

The range of the input error e1 and e2 is \{NB Z PB\}, and the range of the input error e3 is \{NB NS Z PS PB\}, and the range of the output u3 is \{NB NS Z PS PB\}, which based on the process of treating drilling fluid wastewater and the requirements of control system. The monitoring interface of PC WINCC is shown in Figure 3.

First, targeted experiments were carried out for aeration, demulsification, pressure filtration and activated carbon adsorption treatment module in the paper. It was found that the dissolved oxygen content in the drilling fluid was less than 2.55mg/L, and the aeration treatment was carried out for 20min minutes. When the concentration of suspended solids is higher than 20mg/L, it needs to be filtered into the filter before entering the MVR evaporator. In the post-processing stage, when the COD content in the drilling fluid was greater than 188.2mg/L, de-oiled and activated carbon adsorption both worked on the drilling fluid; when the COD content in the drilling fluid was greater than 120mg/L and less than 188.2mg/L only the activated carbon adsorption worked on the drilling fluid; when the COD content in the drilling fluid was less than 120mg/L, the drilling fluid was carried to the tank. In the activated carbon adsorption stage, the amount of activated carbon is 112.2g/ml and the COD 188.2mg/L drilling fluid wastewater, adsorption treatment time 20min to meet the "Integrated Wastewater Discharge Standard" (GB8978-1996) secondary standard (120mg/L), COD content decay rate of 40.12%.

Secondly, the fuzzy rules are made by the experience of engineering practice. During the process of treating drilling fluid waste water, if the effluent quality exceeds the standard, the drilling fluid sewage needs the specific processing module to be treated, else the drilling fluid wastewater does not need any module to be treated. So the fuzzy controller has developed a set of procedures and strategies to follow;
such as the aeration module is selected by the content of Do, the filter press module is selected by the content of SS, the MVR evaporator is adjusted by the content of SS, pH, Do, the de-oiled module and the activated carbon adsorption module are selected by the content of SS, pH, Do.

Figure 4. Look-up table of fuzzy controller rules in ladder program.
4. The implementation of control system

During the process of treating drilling fluid waste water, the fuzzy controller controls the module such as aeration, filter press, MVR evaporator, de-oiled, activated carbon adsorption by detecting the content of Do, SS and pH in the drilling fluid sewage.

The device adopts Siemens WINCC configuration software. The upper-computer software of control system is designed, which mainly includes operation module, monitor interface and parameter setting.

The fuzzy controller uses modular design of function in the PLC control programs, and the function modules can be invoked in the main program. So that's the basic flow: firstly, the fuzzy rule table is established in PLC register according to the control rules; then, the input quantity is collected into PLC and converted into digital quantity by EM231; finally, the output of fuzzy controller is obtained in fuzzy rule query table. In the PLC control program, the key to the realization of fuzzy control is the fuzzy inquiring tables, so the fuzzy inquiring tables is the key to the realization of the lower computer PLC.

The basic address of the fuzzy control variable is 100. When researching on the fuzzy inquiring tables, the address of the output variable of the fuzzy controller is obtained by the input values of $e_1$, $e_2$, $e_3$ in the formula of $F = [100 + (e_1 - 1) \times 15 + (e_2 - 1) \times 5 + e_3 - 1] \times 20$.

In the PLC program, the fuzzy controller rules can start and stop the module of aeration, filter press, de-oiled, activated carbon adsorption by the value of VD16, VD17, VD19, VD20; and the fuzzy control rules can adjust the temperature of MVR evaporator by the value of VD18. The look-up table of fuzzy controller rules in ladder program is shown in Figure 4.

5. The study of the experiment

The treatment device of drilling fluid wastewater treats the drilling fluid wastewater which comes from hetan1#. The drilling fluid system based on MVR is shown in Figure 5. In process of wastewater treatment, the sample were taken in every processing module. Then the sample were determined of water quality. The result is as follows in the Figure 6.

![Figure 5. Drilling fluid system based on MVR.](image)

![Figure 6. Water samples in different treatment.](image)
Table 1. Water quality testing in different processes.

| Projects                  | COD (mg/L) | Do (mg/L) | SS (mg/L) | turbidity | PH  |
|---------------------------|------------|-----------|-----------|-----------|-----|
| drilling fluid wastewater | 17694      | 0.197     | 24.4      | 187.6     | 7.78|
| aeration                  | 13003.8    | 0.92      | 20.3      | 156.4     | 7.26|
| demulsification           | —          | —         | —         | —         | —   |
| pressure filtration       | 11617.7    | 1.13      | 14.8      | 113.5     | 6.88|
| MVR processor             | 64         | 3.66      | 7.2       | 6.1       | 7.53|
| de-oiled                  | —          | —         | —         | —         | —   |
| activated carbon adsorption | —      | —         | —         | —         | —   |
| first level of national discharge standard | 60 | — | 70 | — | 6~9 |
| second level of national discharge standard | 120 | — | 150 | — | 6~9 |

As shown in Table 1, the data from experiments has showed that the content of Do is obviously improved after 20 minutes’ aeration process, and the removal ratio of COD has a better result; and after the MVR evaporator treatment, the removal ratio of COD, Do, SS and turbidity were definite improvements, the content of COD meets the second level of national discharge standard and the SS meets the second level of national discharge standard. After the drilling fluid wastewater were treated by the treatment device of drilling fluid wastewater with the fuzzy controller, the effluent quality can reach the second level of national discharge standard, and the treatment device of drilling fluid wastewater with the fuzzy controller can meet the requirement of treating drilling fluid wastewater.

In process of wastewater treatment, compared with the original experiment, the aeration time in aeration stage is saved 10 min, and the modular of demulsification, de-oiled, activated carbon adsorption couldn't come into use. After the device run for 10 hours, the run data of energy usage in the Table 2.

Table 2. Comparison of energy consumption before and after optimization control.

| energy efficiency (kW·h)/h | Original data | optimized data |
|-----------------------------|---------------|----------------|
| Running for 10 hours        | 28.4          | 27.8           |

The device run for 10 hours, the amount of electricity used was 27.8 kW·h, every hour 0.6 kW·h was saved, and in the same processing flow, one hour was saved.

6. Conclusions
High energy consumption and long treatment time of the treatment device of drilling fluid wastewater were studied in the paper. The adaptive fuzzy controller was applied to the control system of the device, and it not only solved the problem of high energy consumption, but also reduced the runtime which based on the water quality to reach the national standard. Experimental researches find that the effluent quality can reach the second level of national discharge standard, every hour 0.6 kW·h was saved, and in the same processing flow, one hour was saved. The experimental results show that the treatment device of drilling fluid wastewater with the adaptive fuzzy controller is feasible and effective.

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References

[1] Miao Chunzheng, Zhou Chuande, Li Ruimin, Wang Kun and Meng Minghui 2015 Treatment of Waste Drilling Fluid by Negative Pressure Evaporation Technology *J. Environmental Protection of Chemical Industry* **35** 498-501

[2] Ernst Murnleitner 2002 State detection and control of overloads in the anaerobic wastewater treatment using fuzzy logic *J. Water Research* **36** 201-211

[3] Liu Suoqing, Liu Shaohong, Li Junhong and Peng Weijuan 2019 Wastewater Treatment PH Value Control Based on Fuzzy Self-tuning PID Cascade Control *J. Techniques of Automation and Applications* **38** 22-27

[4] Galluzzo M, Ducato R and Bartolozzi V 2001 Expert control of DO in the aerobic reactor of an activated sludge process *J. Computers Chemical Engineering* **25** 619-625

[5] Zhou Hongbiao 2017 Dissolved oxygen control of wastewater treatment process using self-organizing fuzzy neural network *J. CIESC Journal* **68** 1516-1524

[6] Zhang Rui, Ye Jianhua, Qian Hong and Xue Yang 2008 Application Methods of Multivariable Fuzzy Control in Engineering *J. Journal of Shanghai University of Electric Power* **24** 243-238