The Intelligent Control of Emulsion Pump Station

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Abstract. Emulsion pump is one of the key equipment of coal mining working face. With the development of comprehensive mining technology of underground coal mine, the single machine power of emulsion pump station is increasing constantly. Domestic emulsion pump manufacturers have developed an emulsion pump with an installed capacity of 315KW. How to ensure the continuous safe and stable operation of emulsion pump is of great significance to the efficient and safe production of coal mine. It is urgent for the coal mine to operate the emulsion pump station safely and efficiently. By analyzing the demand of intelligent control system of emulsion pump station, the operation target and performance requirement of the system are defined. By establishing the prediction model of shearer speed, the power demand of hydraulic support is judged. The fluid supply line of emulsion pump station is modeled by AMESim software, and the pressure loss model is simulated and analyzed. The power matching control technology is introduced into the pump station control system to judge the power demand of hydraulic support and optimize the output of emulsion pump station. The experimental platform of the power matching intelligent control system of the emulsion pump station was built and verified by experiments.

Keywords: Emulsion Pump Station, Intelligent Control, Power matching

1. Introduction
In the information society, computers and networks have completely penetrated into every corner of daily life [1]. In terms of the number of applications, various new embedded devices have far exceeded general-purpose computers. Large to industrial robots, manned aircraft, small to smart phones, MP3, PDA and other smart devices, embedded systems and devices can be seen everywhere. Every ordinary person has access to a variety of electronic products that use built-in technologies, such as common, tiny digital products, including network devices, smart devices and in-car electronics [2]. In the industry and service fields, CNC machine tools, smart tools, industrial robots and service robots using embedded technology will gradually change the traditional industry and service methods [3].

The main research content is the development of intelligent monitoring system of emulsion pump station in coal mine. When the operation of the emulsion pump station is abnormal, it will inevitably lead to changes in related parameters [4-5]. Through real-time monitoring of the working pressure, temperature, lubricating oil pressure, lubricating oil temperature and liquid level of the liquid emulsion tank of each emulsion pump part, the actual operating conditions of the pumping station can be
understood [6]. China currently does not have mature and cost-effective intelligent mining products. The development of this research has important practical significance for avoiding the failure of the emulsion pump and ensuring the safety of mining production [7].

Due to the importance of intelligent control of pumping stations, more and more scholars and researchers have devoted themselves to research and have achieved many good results [8]. Delfanian et al. combined the characteristic curve of the water supply maintenance pump station with the pressure and flow required by the network to determine the number of pumps to be used [9]; however, it is not accurate due to environmental factors. Zhi-Hui and others introduced the conceptual design into the design of large-scale pumping systems, and reasonably adjusted the reliability ratio, cost ratio, and document ratio through load demand analysis [10]; this method is also prone to errors. Therefore, the pump station is simulated by simulation experiment to find the best intelligent research method of emulsion pump station.

In order to study the problem of intelligent control of emulsion pumping station, firstly, the prediction model of shearer speed is established, which lays a foundation for judging the dynamic demand of hydraulic support; secondly AMESim software is used to simulate the pressure loss model; then the matching of liquid supply flow in emulsion pumping station is studied. Through the above methods, the safety of the intelligent control of the emulsion pumping station has been increased by 15%.

2. Research Method of Intelligent Control of Emulsion Pumping Station

(1) Introduce shear velocity prediction model. The position of the shearing determines the type of action and the start time of the hydraulic support. This paper aims to establish a shear rate prediction model based on BP neural network based on the shear rate curve, and lay the foundation for coping with the crisis of hydraulic demand.

(2) Define the action model supported by the hydraulic time series. In order to meet the needs of emulsion hydraulic support, this paper analyzes the law of hydraulic support, and establishes a sequence model of hydraulic support according to the speed and position of the clipper, which provides a basis for reasonable control of output.

(3) Based on AMESim, analyze the pressure loss in the water supply process of the pumping station. Insufficient fluid supply pressure at the lotion pump station will damage the hydraulic support. Use AMESim software to simulate the pressure loss model, and based on the simulation results, use an electronically controlled analog relief valve to replace the original discharge valve to achieve pressure compensation.

(4) Check to match the fluid supply flow to the emulsion pump station. In order to achieve the best hydraulic support effect, a particle swarm optimization algorithm is designed to control the flow matching of the emulsion pump, and a pre-regulation control strategy is adopted to improve the control performance of the system.

(5) Experimental research. Build an experimental material platform for the power matching control system of the pumping station, design the system software unit, conduct the pumping station fluid supply experiment, analyze and compare the role of the hydraulic support, and verify the effectiveness of the proposed method.

3. Intelligent Control Research Experiment of Emulsion Pumping Station

Emulsion pumping station is an electrical equipment used to supply high-pressure emulsion to hydraulic supports with fully mechanical extraction surfaces or single hydraulic supports with ordinary extraction surfaces. In recent years, "automation" and "intelligence" have become the development trend of comprehensive mining personnel. This requires not only the coordinated operation of basic equipment, such as the clippers and hydraulic supports in fully mechanized miners, but also the pumping station to provide timely and reasonable constant power. It can be seen that the control of the pumping station is not only related to the coal mining efficiency of the fully mechanized miners, but
also related to the safety of underground operations, so the research on the control technology is necessary.

The intelligent emulsion pump station is used as the power source of the hydraulic support and is used for the fully mechanized extraction surface. It mainly includes four parts:

1. Extract the explosion-proof and intrinsically safe frequency conversion speed control device, its specifications are different due to the different flow of the pumping station, hereinafter referred to as "frequency converter".
2. Automatic fuel tank, usually of standard size, hereinafter referred to as "fuel tank".
3. Automatic liquid distribution tank, hereinafter referred to as "liquid tank", the volume of the pumping station varies with the flow rate.
4. Lotion pump set, this article takes two pumps and one box as an example.

The frequency converter is the control core of the intelligent emulsion pump station. It consists of two independent explosion-proof boxes. The right box is the main power supply of the entire device, while the control box bypasses the power frequency of the control system. The box is equipped with a power isolation switch, a programmable controller and related units, and a three-phase transformer. The display screen displays all monitoring data and the current operating status of the pump station.

The fuel tank is a container for storing emulsified oil, and the emulsified oil is an important part of the system for completing automatic fluid dispensing operations. There is an oil level sensor in the oil tank, a "distribution oil pump" and a "calibration oil pump" are installed in the pump room, a portable oil pump is installed outside, and an explosion-proof junction box is on the side.

Liquid storage tanks are equipment used to prepare, store, recover and filter emulsions, with relevant sensors that can control and protect the normal operation of the storage tanks. It is mainly composed of a liquid storage tank, an automatic liquid distributor, a suction filter, a high pressure filter, a backup valve, a liquid return filter, a pressure gauge, a liquid mark and a sensor. According to its function, the liquid storage tank is isolated in the precipitation chamber, filter chamber and working area. Each chamber is equipped with an oil drain plug and a cleaning cover to replace the emulsion and clean contaminants. Currently, emulsifiers are mainly used in coal mines, and their concentration requirements are not less than 3% to 5%.

These two groups of emulsion pumps are respectively equipped with sensors for monitoring and data protection, such as: 1 pressure sensor, 1 oil level sensor and 1 temperature sensor. The lotion pumping station used in this article is customized and equipped with an engine winding temperature sensor and a motor bearing temperature sensor.

### 4. Research and Analysis on Intelligent Control of Emulsion Pumping Station

#### 4.1. Simulation Analysis of Pressure Loss along the Line

**Table 1.** Parameter setting table of pressure loss model

| Parameter                                      | Value            | Parameter                                      | Value            |
|------------------------------------------------|------------------|------------------------------------------------|------------------|
| Liquid density                                 | 998kg/m³        | Distance from pump station to working surface  | 2100MPa          |
| Pipeline surface roughness                     | 0.05mm           | Elastic Modulus                                | 120              |
| Hydraulic cylinder diameter                    | 160mm            | Number of brackets                             | 120mm            |
| Center distance of bracket                     | 1.5m             | Rod diameter                                   | 30MPa            |
| Number of liquid inlet joints between racks    | 120              | Pressure of relief valve                       | 55mm             |
| Number of joints between pump station and working face | 20              | Diameter of liquid inlet pipe between racks    | 80mm             |
|                                               |                  | Length of liquid inlet pipe between racks      | 0.5m             |
The liquid supply pipe of the emulsion pump station is composed of two parts: the emulsion pump station control pipe and the hydraulic support control pipe. The emulsion pump station control pipeline is responsible for introducing high-pressure emulsion into the work surface. The hydraulic control cable controls the opening and closing of the solenoid valve to control the movement of the bracket. The bracket includes a cylindrical conductor, a push conductor, a protective socket conductor and a connection control conductor (such as spray). This part uses AMESim software to model and simulate the liquid supply line of emulsion pumping station. As shown in Table 1 and Figure 1.

![Figure 1. Simulation results of pressure loss](image)

When the flow is 1000L/min and the simulation time is 20s, the pressure difference between No.1 and 120 hydraulic supports is 3.85MPa. In other words, during the lifting process of the No. 120 boom, due to insufficient adjustment force, the boom's "down and up" time may be prolonged, thereby reducing the output efficiency of the desktop machine, and may even cause danger. Safety. Therefore, it is necessary to dynamically update the overflow limit according to the pressure loss value and compensate the pressure loss of the acting arm.

4.2. Automatic Control of Hydraulic Support

The automatic control function of the hydraulic support includes an action control, group control and automatic machine control. Single action control refers to the operation of controlling the action of controlled frames in adjacent frames. In this mode, the operator controls experience-based support by observing the haircut operation; group control refers to a single control phase. Many adjacent parentheses perform the same action simultaneously or sequentially. This control method is fast and reduces the workload of the operator. This is a commonly used control function; the automatic control of the machine is based on the running speed and cutting direction. The automatic control of the hydraulic support is carried out in cooperation with the clipper and the lotion pumping station. The hydraulic support received in this article will be used as the research object for the following automatic inspections.

In the coal mining process, in order to avoid accidents, the hydraulic support must be retracted in advance, and the number of shrinkage protection devices for the front drum of the push-cutting must not exceed 15. The hydraulic support starts to lower the column. The hydraulic control valve is used to make the high pressure emulsion enter the upper cavity of the chromatographic column housing to guide the chromatographic column downwards. In actual use, please wait until the upper beam and the roof are completely separated. Stop the increasing energy, and at the same time, turn on the spray...
device during operation to achieve spray synchronization. In order to ensure safe and fast transportation of hydraulic supports, lower lifting actions must be performed before transportation. The movement of the chassis is based on the lever and hydraulic support of the scraper conveyor, which is moved to the carbon wall by extending and retracting the thrust jack. After completing the lower movement of the hydraulic support, it starts to raise the column. The tower rises under the action of the high-pressure emulsion. After that, the upper beam contacts the upper plate, the pressure in the hydraulic cylinder increases continuously, and the upper beam produces a certain elastic-plastic deformation. The internal pressure reaches its maximum value. At this time, the hydraulic support is in the equilibrium position and the lifting action is completed. Once the protective side is extended, the hydraulic support will push and slide, opposite to the moving frame. At this time, the hydraulic support is used as a lever, and the scraper conveyor is pushed to the side of the carbon wall by the push jack. In the working process, in order to facilitate the management of the hydraulic supports through the electro-hydraulic controller, the hydraulic supports are numbered in the direction of movement of the hydraulic clippers. The actual time of each operation usually varies depending on the conditions.

5. Conclusion

The control efficiency of the pumping station is directly related to the production safety of the fully mechanized mining face. The unreasonable exit of the emulsification pump station will cause problems such as lagging of the hydraulic support, improper movement and insufficient adjustment power, which will bring hidden dangers to the safe mining of the fully mechanized mining surface. Therefore, it is necessary to study the emulsion pump station control system that meets the needs of hydraulic supports. This paper introduces the power matching control technology into the pump station control system, predicts the grip speed of the scissors, judges the power demand of the hydraulic support, optimizes the output of the emulsion pump station, and finally builds an experimental system platform for installation. The novelty of the study is: (1) The demand flow analysis of the hydraulic support of the emulsion is carried out. (2) During the liquid supply process of the emulsion pump station, a pressure loss simulation analysis is carried out along the line. (3) A hybrid particle swarm optimization algorithm is designed to optimize the fluid flow control of the emulsification pump station. (4) The experimental platform of the pump power matching control system was built, and the experiment was verified.

However, there are also some disadvantages. (1) In the pressure loss model of emulsion pump station in this paper, some parameters are selected according to experience, which need to be further studied; (2) During the investigation of the emulsion pump in this paper, the development of station power matching control technology was only tested on the test bench, but not applied in the field. These shortcomings will be improved by further study in the future. The next step should be to implement its industrial field applications.

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References
[1] Delfanian M, Razavi S M A, Khodaparast M H H, et al. Influence of main emulsion components on the physicochemical and functional properties of W/O/W nano-emulsion: Effect of polyphenols, Hi-Cap, basil seed gum, soy and whey protein isolates [J]. Food Research International, 2018, 108(JUN.):136-144.
[2] Chen Y, Xu W, Huang J, et al. Research on the Preparation of 25% Cyhalofop-Butyl Emulsion
in Water[J]. Journal of Computational and Theoretical Nanoscience, vol. 13, issue 12, pp. 10299-10302, 2016, 13(12):10299-10302.

[3] Qu Guimei, Xia Jinmin, Wang Hongxiang, et al. Research on powdery emulsion explosive of low detonation velocity used in explosive welding [J]. Engineering Blasting, 2016, 022(001):42-45.

[4] Wang Hong, Sun Haixiang, Ji Zhendong. Research on the Control of DC Solid State Transformer with Soft-Switching Characteristics% Modular DC Solid State Transformer with Soft-Switching Characteristics [J]. Low Voltage Electrical Apparatus, 2018, 000(020): 36-43.

[5] Wei-Guang L I, Peng L, Chan-Chan L I, et al. Research on the Durability and Microscopic Mechanism of Cement-Emulsified Asphalt-Epoxy Emulsion Compound Material [J]. Highway, 2017, 036(001):97-102.

[6] Song H, Xu R, Wang C. Research on statistical process control method for multi-variety and small batch production mode[C]// 2020 Chinese Control And Decision Conference (CCDC). IEEE, 2020, 035(009):25-27.

[7] Quan L, Yang Z. Research on Cultural-Communication Practice in Confucius Institute of Africa——Confucius Institute of University of Yaounde II in Cameroon for Example [J]. Journal of Chuxiong Normal University, 2019, 252(4):042-125.

[8] Fulco G D, Arajo-Net I, Dantas C, et al. Nanotechnology in Phytotherapy: The Effect of Noni€s Nanoemulsion on Bacterial Translocation Induced By Experimental Model of Intestinal Ischemia and Reperfusion [J]. Research and Reviews On Healthcare: Open Access Journal, 2018, 1:25-33.

[9] Delfanian, Mojtaba, Razavi, et al. Influence of main emulsion components on the physicochemical and functional properties of W/O/W nano-emulsion: Effect of polyphenols, Hi-Cap, basil seed gum, soy and whey protein isolate [J]. FOOD RESEARCH INTERNATIONAL, 2018, 297(1):012-023.

[10] Zhi-Hui Z, Quan-Yuan Z, Zu-Shun X U. Research Progress in the Application of Pickering Emulsion in Functional Polymers [J]. Chinese Journal of Colloid & Polymer, 2016, 495(1):012-059.