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Ant Colony Algorithm based Prediction Model for Signal Reconstruction Fluctuation Operating State Parameters of Submarine Oil Pumps

Lu Lu

Software institute,Zhengzhou Railway Vocational & Technical College, Henan 451460, China
lulu48293@126.com

The research in this article is conducted to analyze the prediction model for signal reconstruction fluctuation operating state parameters of submarine oil pumps. The prediction model for signal reconstruction fluctuation operating state parameters is established in this article based on the ant colony algorithm, which is then analyzed by taking certain submarine oil pump for vehicle manufacturing as an example. Based on research findings, the model proposed in this article plays roles in research and application, which can be utilized to predict parameters of related devices in an accurate way. The model proposed in this research is applicable to prediction to related operating state signal parameters of submarine oil pumps, which can be taken as a reference.

1. Introduction

The facility automation in fields such as oil, electric power and mechanical engineering changes mature day by day and the facilities are more and more accurate and complicated during the development and application of science and technology. Although mechanical equipment automation contributes to human resource optimization for enterprises, it may lead to faults and problems in practical utilization, which may give rise to influence on production and processing of products. Today, with constant development in science and technologies, it is difficult for traditional facility maintenance and detection methods to adapt to current social market circumstances, with long time for maintenance and unfavorable detection effect. Therefore, it is necessary to conduct predicted maintenance to mechanical equipment for equipment maintenance in advance, so as to reduce faults and economic losses of enterprises to the minimum level. Related operation and maintenance departments are required to have certain professional basis and detection equipment for predicted maintenance, to conduct accurate detection with scientific methods, so as to improve product quality. Submarine oil pumps involve in fields such as vehicle manufacturing, petrol stations and oil depots, and equipment quality is closely related to life safety of related personnel; therefore, it is needed to conduct predicted maintenance before operation of submarine oil pumps.
Therefore, the research and analysis on applications of prediction model for signal reconstruction fluctuation operating state parameters of submarine oil pumps with the ant colony algorithm are conducted in this article. Firstly, research and analysis are conducted on prediction model for parameters of the ant colony algorithm and the signal reconstruction fluctuation operating state, which is analyzed on the application effect in an empirical way.

2. Literature review

With the development of China's petroleum industry and the deepening of oilfield development, the electric submersible pump has become one of the main mechanical oil recovery equipment in the oilfield. The electric submersible pump has the characteristics that other mechanical oil production equipment does not have and plays a more and more important role in the exploitation of the oil field. It is one of the important means of long-term stable production of the oil field to select the large displacement oil extraction of the electric submersible pump. The electric submersible pump, called the electric submersible pump, is a kind of rod

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pumping equipment with large displacement lifting oil. It is suitable for oil wells, high water cut wells and low gas oil than oil wells. The electric submersible pump is composed of two parts: ground equipment and underground equipment. As the submersible pump has many advantages, such as large displacement, high lift, wide use, convenient management, long pump cycle and good economic benefit, the proportion of the submersible pump is on the rise. In recent years, many experts in many countries have devoted themselves to the research and improvement of the adaptability, economy, reliability and advanced nature of the submersible pump. Many new technologies and new achievements have appeared, and good economic benefits have been achieved in the oil production practice. With the continuous increase in the depth of oil field and the widening of the application range of the submersible pump unit in the oil field, the new specifications and new types of units have appeared one after another, and a relatively complete series of products have been formed. Submersible pump units have become an important means of stable crude oil production, and many high temperature and high pressure submersible pumps have come out one after another. But at present, compared with the rapid development of new products, the detection means are relatively backward, which cannot fully meet the requirements of production, especially the performance testing of the high temperature and high-pressure type electric submersible pump unit.

At present, using the submersible pump in our country, from the amount of equipment and the amount of mining, it has become the fourth largest country next to the former Soviet Union, the United States and Canada in the world, and has made great achievements in the research field of submersible pump. According to the prediction of technology development, oil submersible pumps will be used more widely in the future. The use of electric submersible pump oil production can achieve high oil production. Now many oil fields in China have entered the middle and late mining stage, and water injection and intensive mining are needed. Electric submersible pump is a good pumping equipment for water injection and strong production, so its application prospect is considerable. In addition, the electric submersible pump can be used in the land oil recovery and can also be used in the offshore oil field, the desert oil field and the polar oil field for oil recovery. It has the same good use effect and economic benefit.

With the continuous updating of the type and performance of the submersible pump, the performance detection technology of the submersible pump has also been developed continuously. Many scholars have put forward some technical problems in the detection system successively. According to the fluid heat transfer theory and the characteristics of the submersible motor, Yu and others have determined the cooling medium of the submersible motor, summed up the characteristics of the temperature rise calculation of the submersible motor and calculated the surface heat dissipation coefficient. The temperature field of the submersible motor was calculated by the network topology method, and the temperature rise range of the submersible motor was obtained (Yu et al., 2017). Korobiichuk uses water as the test medium for the performance testing of the high temperature and high pressure electric submersible pump. It is proposed that the research on the temperature control of the medium is mainly the establishment of the system mathematical model. The system is simplified, the heating power is used as the input of the system, the increase of the temperature of the medium in the well is used as the output, and the electric pump unit is protected. The mathematical model of the electric submersible test system is set up, and the control law of the medium temperature is simulated based on simulation (Korobiichuk, 2016). Panfilova and others developed a multifunctional automatic control test system for electric submersible pumps. The system is composed of four parts: automatic control, parameter testing, pipeline flow and electrical control. It cannot only carry out comprehensive detection of the electric submersible pump unit, but also manage and track the test data. It has the characteristics of complete test parameters, fast speed, high precision, easy operation, strong security, wide measurement range and large capacity (Panfilova et al., 2017). Zhu and others introduced a method of testing the viscosity temperature characteristics of the submersible pump by using emulsion as a mobile medium. It can test the influence of crude oil viscosity on the characteristic parameters of submersible pump under different water content and temperature conditions and establish the viscosity temperature relationship of the submersible pump (Zhu et al., 2016). Zarubin begins with the basic theory principle of heat transfer, expounds the calculation and application of the critical heat insulation diameter of the pipeline, emphatically describes the optimization calculation method of the heat preservation of the circular pipe, analyses the main common factors that affect the optimization results, and points out that the key factors affecting the thermal conductivity of the thermal insulation material and the fluctuation of the energy price are the key to the optimization results (Zarubin et al., 2016). Strakhov and others have optimized the adiabatic structure of high temperature steam pipeline. The density of the adiabatic coating is larger. With the increase of the medium temperature and the increase of the thermal conductivity, the thickness of the designed adiabatic layer also becomes larger, which aggravates the weight of the pipe and increases the total cost of the pipeline design (Strakhov et al., 2017). Balunov and others analysed the structure and heat transfer process of steam thermal recovery wellbore. Some of the energy injected into the steam will pass through the insulation tube, casing and cement sheath along the radial direction to the formation, causing radial heat loss. In the longitudinal flow

of steam along the wellbore, the energy of the steam itself changes because of the friction loss and the loss of gravitational potential energy (Balunov et al., 2017). Based on the hypothesis of stratified stratigraphy, Debbabi and others approximate the vertical heterogeneity in the actual situation, and on this basis, a mathematical model for heat conduction in porous media is established (Debbabi et al., 2017).

To sum up, the basic concept and structure of the submersible pump, the theory of fluid heat transfer, various fluid media and the assumption of stratified stratum are studied in the above research work, but the research on the fluctuation of signal reconstruction is very little. Therefore, based on the above research status, this paper mainly studies the ant colony algorithm. Ant colony algorithm is the dynamic process of evaluating the self-knowledge constantly according to the income scheme, and the algorithm is the algorithm of the positive feedback mechanism of information, that is, in the process of generating the tree, it tends to select the edge with more pheromone on the edge. By doing this, in the search process, ant colony algorithm only searches for the scheme that satisfies the motion state of the signal reconstruction of the submersible pump, reduces the search range, and then improves the efficiency.

3. Methods

3.1 Ant colony algorithm

Ants do not know accurate positions of foods when they are seeking for them. Once an ant finds foods, it releases a kind of volatile secreta known as pheromone to surroundings, which gradually volatilizes with time. Concentration of the pheromone indicates distance of paths. The ant attracts other ants with the pheromone, so that more and more ants can find foods. At the same time, different from some ants, some other ants seek for new paths. They will release pheromone if they find shorter paths, so that more ants are attracted to the shorter paths, until the shortest path is found after repeated such processes. The shortest path will be adopted by most ants, and this is the whole process for ants to seek for foods. The ant colony algorithm is a biological nature based simulation evolutionary algorithm established according to foraging behaviors of ant colonies in the natural world, which is applied to solution for complicated combination problems, with favorable effect. Ants release a kind of chemical substance on their way seeking for foods, which is known as pheromone. The substance is felt by other ants within certain reanges; in addition, ants tend to move to places with relatively high concentration of the substance. The path selection process of ants is known as the autocatalysis behavior, and such collective behavior is a positive feedback phenomenon. The behavior can be known as the enhanced learning system; at the same time, the pheromone will gradually weaken or even disappear with time.

3.2 Ant colony algorithm based prediction model for signal reconstruction fluctuation operating state parameters

There is an important concept of pheromone concentration in ant colony algorithm, which is updated after passing by of ants. Therefore, it is available to train sample data during data prediction, and the change on data indicates selection of ants. In this way, ants have different selections according to different data. Different concentrations of pheromone on different paths in each selection give rise to different selections of ants. That is to say, in condition of training the history state of equipment, the development trend of the state at the next moment will form the “pheromone” of the current state. That is to say, the state in the future is related to the concentration of the “pheromone” of the state. In this way, it is available to predict the development state of the next moment of the equipment which is the most close to practical conditions theoretically. Therefore, aiming at increasingly grown data with fluctuation, firstly, it is needed to process it to a fluctuation image within certain ranges based on the signal reconstruction thought, i.e., the image similar to sine wave image with linearly increment. This process achieves better regularity for the fluctuation data within certain ranges. Prediction research on fluctuation iamges within certain ranges are conducted based on ant colony algorithm, so as to detect rules of data in sample training, achieving better accuracy in prediction results, with higher credibility. The measured data of fluctuation operating state of mechanical equipment within certain period is taken as the sample data, and an original data sequence is composed as per time sequence: X=[x(1),x(2),…,x(n)] A fitting is conducted by utilizing the origin software, with the primary fitting principle of the least square method, and the equation acquired from the fitting is listed as follows: y=0.000117375i+0.05367. Table 1 shows the related fluctuation data processed by signal reconstruction.

The ant colony algorithm is adopted to predict the fluctuation data processed by signal reconstruction. According to the ant colony algorithm, the paths selected by ants every time is divided into five ones, and the above data processed by signal reconstruction is divided into five groups, i.e., five paths, which are listed successively as follows: [-10.570, -4.082), [-4.082, 2.406), [2.406, 8.894), [8.894, 15.382) and [15.382, 21.870), with the unit of g×10-3. Considering that the values within the first period are within range 1, it is

assumed that the pheromone concentration of each path is 0 since the second period. Facing with the five paths, ants select as shown in Figure 1.

Table 1: Wave data processed by signal reconstruction (part)

cycle	1	2	3	4	5	6	7	8
Processed data ($g\times10^{-3}$)	-4.874	-1.048	-6.221	10.395	-10.569	-9.743	-5.916	-6.090

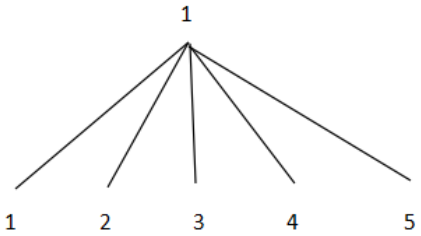

Figure 1: Ant selection diagram

3.3 Process of failure prediction realized in the system

The determination of the spot check items of the equipment and the detailed procedures for analysis and understanding of the equipment are not introduced considering that they are not tasks of the author. This article mainly introduces the realization of the prediction process in the system. It introduces the establishment of the spot check standard of the equipment and determines the state according to qualitative indexes or quantitative detection with instruments aiming at the bottom events of typical actions of the equipment. Different detection methods and detection periods are adopted aiming at different detection indexes for real-time supervision. In the system, the spot check standard is established as per the positions of parts of the equipment. (Figure 2 shows the prediction flow diagram in the system.)

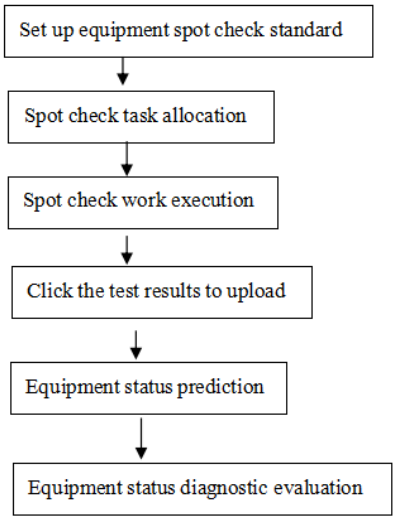

Figure 2: Flow chart in the system

4. Results and discussion

4.1 Ant colony algorithm based prediction model for signal reconstruction fluctuation operating state parameters

Among all the 8 state points predicted, the trend predictions for all points except for the 7th point and the 8th point are accurate, realizing the prediction to fluctuation data trends in a favorable way. According to the comparisons, although there are differences between the predicted trend and the actual trend on the 7th point and the 8th point, the grey prediction results corrected by Markov are closer to actually measured data of

vibration when compared with the grey prediction results. It realizes the correction to the grey prediction results and improves the prediction accuracy. Compared with the other two prediction models, the grey-Markov fluctuation operating parameter prediction model can reflect the fluctuation change trend of the vibration data in a more accurate way. Considering that the grey prediction model is influenced mainly by the previous period changing trends, its prediction results are on a rise, which cannot reflect the changes on trend directions in an accurate way. There are similar problems in inflection points in trend changes of the rest points. (Table 2 shows the actual vibration data of some submarine oil pumps.)

Table 2: Actual vibration data of submarine oil pump (part)

cycle	1	2	3	4	5	6	7	8
Processed data ($g\times10^{-3}$)	0.0533	0.0538	0.0534	0.0531	0.0532	0.0534	0.0539	0.0540

4.2 Result analysis on ant colony algorithm

Data prediction is conducted after sample training. Considering that the 22nd ant is in path 2, the pheromone concentration of each path is 0.1352, 2.71, 0.9104, 0 and 0 for the rest ants facing with selections, and the pheromone concentration weight of each path is 0.036, 0.722, 0.242, 0 and 0. Verification is conducted in sequence after the period, so as to update the pheromone, to acquire the prediction results of signal reconstruction vibration as shown in the following Table 3.

Table 3: Prediction results of signal reconstruction based on ant colony algorithm

cycle	The measured values	Prediction of wave data after signal reconstruction	Actual predicted value	Percentage error (%)
23	0.0563	0.5012	0.05642	0.2131
24	0.0555	0.1955	0.05649	1.7838
25	0.0562	4.5790	0.05706	1.5303
26	0.0560	-1.3264	0.05659	1.0536
27	0.0564	-2.8729	0.05655	0.2660
28	0.0560	-4.4765	0.05651	0.9107
29	0.0568	-5.2924	0.05654	0.4577
30	0.0581	-2.5255	0.05694	1.9966
Average error percentage	0.4129			

In condition that it is not available for signal reconstruction processing, the ant colony algorithm is adopted directly for data prediction, the results of which are shown in Table 4:

Table 4: Shows the prediction results of ant colony algorithm directly

cycle	The measured values ($\times10^{-3}$)	Predictive value ($\times10^{-3}$)	Percentage error (%)
23	563	558.6	0.7815
24	555	559.3	0.7748
25	562	564.1	0.3737
26	560	558.1	0.3393
27	564	558.8	0.9220
28	560	559.4	0.1071
29	568	559.8	1.4437
30	581	567.7	2.8789
Average error percentage	0.8789		

With respect to the grey-Markov operating parameter prediction model and the ant colony algorithm based prediction model for signal reconstruction fluctuation operating state parameters, although the latter one has better prediction accuracy during the data prediction process, they have their own advantages in trend prediction, with favorable trend prediction results. Considering that the pheromone concentration of the ant colony algorithm based prediction model for signal reconstruction fluctuation operating state parameters keeps updating and changing, there are changes after each time of prediction. The continuous updating will keep increasing, leading to more and more accurate subsequent data.

5. Conclusions

By taking the ant colony algorithm as the foundation, research and analysis on the prediction model for parameters of fluctuation operating are conducted in this article. Conclusions are made on prediction model results based on the prediction results of signal reconstruction fluctuation. The prediction model for fluctuation operating parameters designed in this article is a prediction model integrated with the grey theory and the Markov method. The Markov prediction method is adopted to correct and modify the prediction accuracy. On the aspect of the ant colony algorithm utilization, this algorithm is taken as the research ideas for innovative research on the prediction model for signal reconstruction fluctuation operating parameters. Based on research findings, this research method has certain application and research value, which is utilized to provide data prediction method for vehicle manufacturing equipment such as submarine oil pumps. Considering that only part of pheromone though in the ant colony algorithm is adopted in this article, there may be some problems arising from the predication model for the signal reconstruction fluctuation operating parameters in practical utilization. In addition, further practical research shall be conducted to verify if the research method provides the research on submarine oil pumps for vehicle manufacturing departments with feasible data.

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