Research on Ultra-precision Technology for Fault Law and Operation Trend Prediction of Machinery and Equipment

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Abstract: Mechanical equipment is the key to ensure industrial production, which determines whether industrial production links can operate efficiently and continuously, but the occurrence of mechanical failure is an important factor hindering its stable operation. Therefore, accurate diagnosis and prediction of mechanical faults has become a hot research topic in the field of industrial production. In this paper, a fault diagnosis and operation trend prediction model of mechanical equipment will be established by combining vector regression and full vector technology. Compared with the traditional time domain model, the model built in this paper mainly uses spectrum structure to predict the model. Finally, this paper establishes the prediction model of fault operation trend based on gear trend development. The results show that the prediction model proposed in this paper can realize the prediction of gear fault trend development.

1 INTRODUCTION

Industrial production determines the industrial and economic level of a country, and mechanical equipment, as an extremely important factor in industrial production, determines whether industrial production can operate efficiently, safely and steadily (Wang Y, Wei Z, Yang J, 2018; Shi M, Lu J, Fu Y, 2018). The occurrence of mechanical failure to a certain extent restricts the service life of mechanical equipment, but also affects the production efficiency of industrial production. Therefore, efficient and reasonable technology of mechanical equipment fault detection and operation trend prediction is the key to effectively solve the above problems, and it has also become a hot and difficult point in industrial research (Zhou Z Q, Zhu Q X, Xu Y, 2017; Yang H L, Yang Y L, Yu C, et al, 2018; Rathore S S, Kumar S, 2017; Wei J, Wang L, 2017; Rajagopalan R, Litvan I, Jung T P, 2017).

At present, fault detection and operation trend prediction technology of mechanical equipment mainly concentrates on rolling bearings and gears. Based on a large number of scholars and research institutes in the above-mentioned fields, this paper carries out research and Analysis on it. American scholar (Pyo S, Lee J, Cha M, et al, 2017; Kumar M, Parmar K S, Kumar D B, et al, 2018) has proposed fault diagnosis technology based on spectrum analysis method, which mainly carries out uninterrupted spectrum analysis for bearings and gears, and takes timely measures once spectrum abnormalities occur. Relevant scholars (Hake A, Pfeifer N, 2017; Michiels B, Nguyen V K, Coenen S, et al, 2017) have proposed the prediction and analysis of mechanical fault based on vibration signal, which mainly uses the cut-off frequency of the peak value of vibration to judge the fault, but there are a lot of noise hazards in the collected signal, so it needs to increase the signal pretreatment link in the actual analysis. Relevant scholars (Chaudhuri D, 2017; Bahrami M, Bazrkar, Samira, Zarei, Abdol Rassoul, 2018; Lin Y, Zhang J W, Liu H, 2018) proposed fault prediction based on precise diagnosis. Although this method can achieve certain results to a certain extent, it actually requires a lot of manpower and financial resources.

In order to solve the above problems and put forward an efficient and reasonable mechanical fault prediction model, this paper proposes a fault diagnosis and operation trend prediction model of mechanical equipment based on vector regression and full vector technology. Compared with the traditional time domain model, the model built in this paper mainly uses spectrum structure to predict the model. Finally, this paper establishes the prediction model of fault operation trend based on gear trend development. The results show that the

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The structure of this paper is as follows: In the second section of this paper, the combination algorithm of vector regression method and full vector technology proposed in this paper will be analyzed concretely, and the prediction model of mechanical equipment fault and operation trend based on this algorithm will be constructed; in the third section, the gear fault prediction model based on this algorithm will be analyzed concretely, and the experimental conclusion will be given; in the last section, this paper will do a summary.

2 COMPREHENSIVE ANALYSIS OF VECTOR REGRESSION AND FULL VECTOR TECHNIQUES

This section will mainly analyze the comprehensive analysis and research based on vector regression and full vector technique proposed in this paper, and discuss and analyze the vector regression method and full vector technology in detail.

2.1 Vector Regression Method and Full Vector Synthesis Technology Analysis

This section will abandon the shortcomings of the original mechanical equipment fault prediction algorithm, and propose a mechanical equipment fault prediction algorithm based on vector regression algorithm and full vector synthesis technology. First, the regression function used in the vector regression algorithm is shown in Equation 1, where the corresponding x and w are the algorithm samples, and the corresponding b is a constant.

$$f(x) = (w.x) + b \tag{1}$$

In this paper, taking the gear as an example, according to the mechanical characteristics of the gear, the corresponding linear regression function of the mechanical equipment fault can be obtained, as shown in Equation 2, where the corresponding C is the penalty factor of the regression function, which mainly depends on the complexity of the gear. The corresponding function Q represents the optimal constraint solution of the linear regression problem.

$$Q(w) = \frac{1}{2}(w.w) + CR_{emp}(f) \tag{2}$$

The corresponding Remp in the formula of the above optimal constraint solution depends on the loss function L (f, y), and the corresponding loss function selected in the algorithm is an insensitive loss function, and its corresponding function expression is as shown in Equation 3.

$$L(f, y) = \begin{cases} |f - y| - \varepsilon & |f - y| > \varepsilon \\ 0, & others \end{cases} \tag{3}$$

An image of the insensitive loss function is shown in Figure 1:

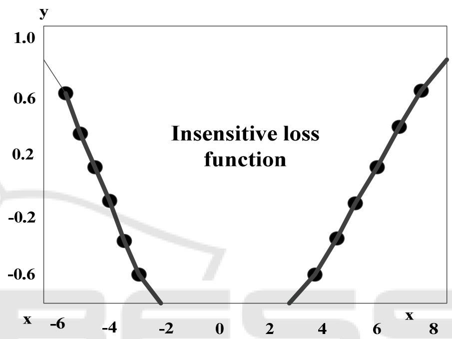

Figure 1. Insensitive loss function image.

In the practical application of the algorithm in this paper, it is mainly considered that the empirical risk of mechanical equipment needs to be minimized, so it is assumed that its ideal state is f-y=0. At this point, the corresponding loss of the mechanical device is considered to be lossless, and the corresponding linear regression image is shown in Figure 2:

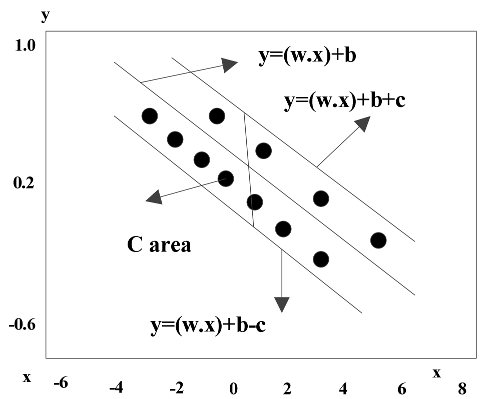

Figure 2. Linear regression function image of insensitive loss function.

Based on Fig. 2, the empirical function of mechanical equipment loss corresponding to the gear studied in this paper can be further obtained, as shown in Equation 4:

$$Q(w) = \frac{1}{2}(w.w) + C\frac{1}{l}\sum_{i=1}^{l}\left|y_i - f(x_i)\right| \quad (4)$$

The corresponding constraint condition is as shown in Equation 5, wherein the corresponding related parameters A and B are corresponding slack variables, and the corresponding C is a strip region of the regression function.

$$\begin{cases} y_i - w.x_i - b < C + A_i \\ w.x_i - y_i + b < C + B_i \quad i = 1,2,3,4,5...n \\ A_i.B_i \end{cases} \quad (5)$$

Based on the above formulas 2, 3, 4, 5, the corresponding gear prediction function based on the regression algorithm can be obtained as shown in Equation 6. The acquisition technique used in this equation is a time interval sample acquisition technique, and its core principle lies in the interval. Data acquisition takes a certain amount of time and is used as a basis for prediction of the next collection point. The corresponding m in Equation 6 is the predicted target acquisition quantity value.

$$x_{i+1} = f(x_i, x_{i-1}, ...x_{i-m+1}) \quad (6)$$

Based on the prediction formula of the above formula 6, the corresponding prediction result evaluation formula can be further obtained as shown in Equation 7, which mainly reflects the prediction accuracy of mechanical equipment failure. The corresponding x1 is the predicted value, and the corresponding x2 is the true value.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{x_2 - x_1}{x_2}\right| * 100\% \quad (7)$$

In order to make the proposed algorithm accurately predict the type of mechanical equipment, this paper creatively adds full vector prediction technology to the regression algorithm, which is mainly to calculate, select and analyze the spectrum in the frequency domain. In the practical application of this paper, this paper introduces the full vector technique to analyze the spectrum of the X and Y directions of the mechanical equipment, and based on the spectrum in these two directions, the corresponding full vector diagram is synthesized to further accurately predict the mechanical equipment. failure. Take the steam turbine unit as an example, as shown in Fig. 3, the corresponding spectrum structure diagram in the X and Y directions, as shown in Fig. 4 is the corresponding synthetic full spectrum diagram.

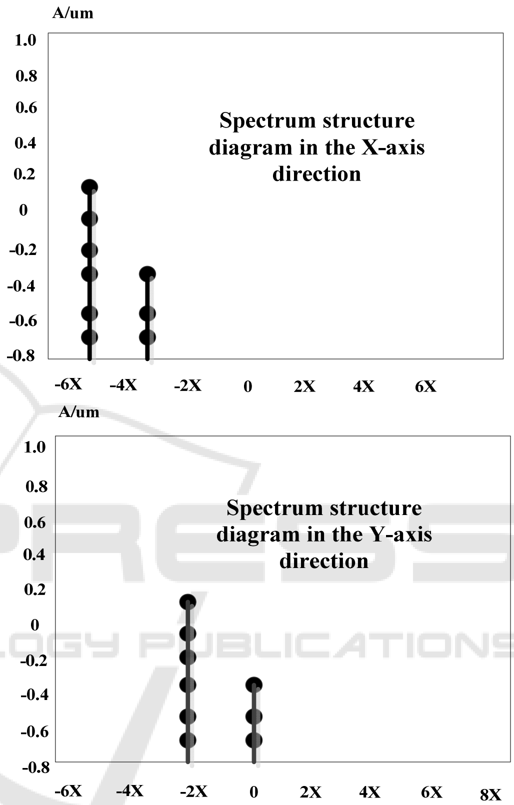

Figure 3. Spectrum structure diagram of the steam turbine group in the X and Y directions.

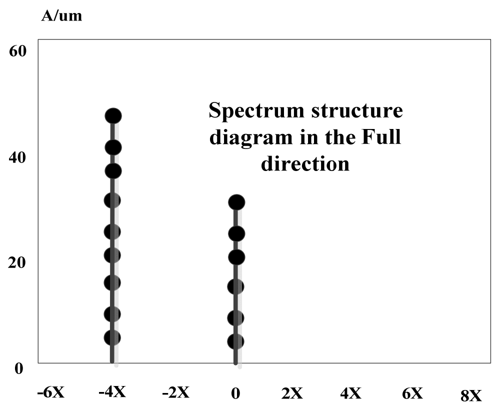

Figure 4. Turbine unit full vector spectrum structure diagram.

2.2 Predictive Model Establishment

Based on the analysis in Section 2.1 above, it can be concluded that the corresponding gear failure prediction model is constructed as shown in FIG. 5, wherein in the corresponding step 3, it is necessary to note that the extraction time interval is consistent when performing feature quantity extraction. At the same time, in the X and Y direction data acquisition, it is necessary to pay attention to the collected data to form a corresponding discrete sequence.

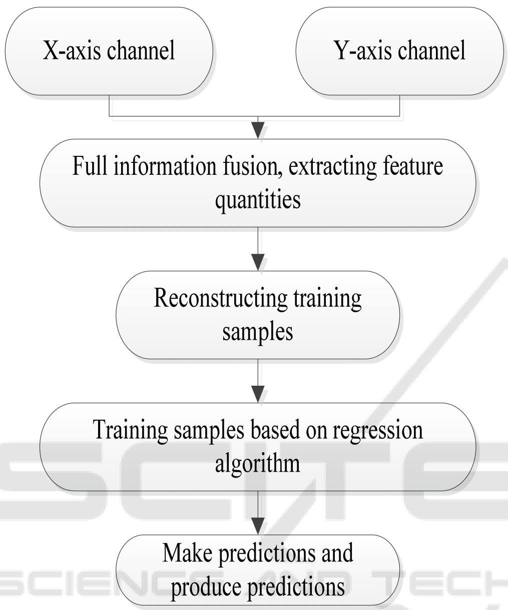

Figure 5. Flow chart of gear mechanical failure prediction model based on the algorithm of this paper.

3 EXPERIMENTAL ANALYSIS

In order to further verify the accuracy of the proposed algorithm in mechanical equipment failure prediction, this paper uses a certain type of gear as the prediction object. At the same time, when using the algorithm proposed in this paper, the insensitive loss function is used as the function of the prediction model. Gaussian radial is chosen as the base function of the algorithm, and its corresponding width coefficient w=3 is set. The corresponding single-step prediction results are shown in Fig. 6, and the selected training samples are 40. FIG. 7 is a corresponding single-step prediction graph obtained based on a conventional mechanical equipment failure prediction algorithm.

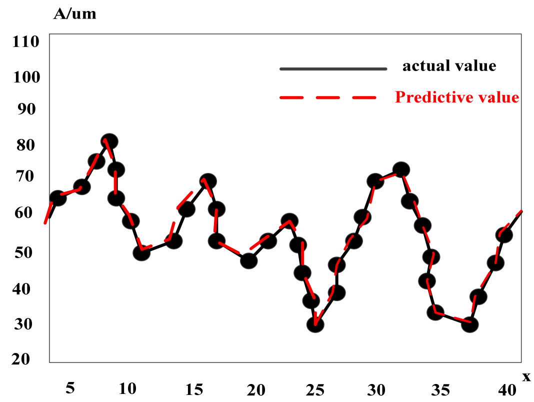

Figure 6. Single-step prediction result diagram of gear mechanical fault based on the algorithm of this paper.

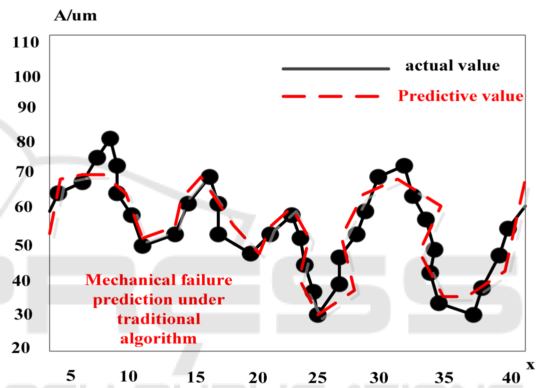

Figure 7. Single-step prediction result diagram of gear mechanical failure based on traditional algorithm.

Based on the above results, Fig. 6 and Fig. 7, combined with the accuracy calculation formula corresponding to Equation 7, it can be concluded that the prediction accuracy corresponding to Fig. 6 is 3.23%, and the corresponding prediction accuracy of Fig. 7 is 5.34%. It can be seen that the proposed algorithm has obvious advantages in prediction accuracy compared with the traditional regression vector method, and it also has stronger generalization ability.

4 CONCLUSIONS

In this paper, an in-depth analysis and research on the fault prediction of mechanical equipment that is urgently needed in industrial production is carried out. By analyzing the domestic and international research status and the related prediction schemes, this paper combines vector regression and full vector technology to establish a mechanical equipment fault diagnosis and operation trend prediction model. Compared with the traditional time domain model, the model established in this paper mainly uses the spectrum structure to predict the model. Finally, based on the trend development of gears, the prediction model of fault operation trend is established. The results show that the proposed prediction model can predict the development trend of gear faults.

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