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Data Analysis of Magnetic Flux Leakage Detection Based on Multi-Source Information Fusion

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Abstract. For the analysis of the magnetic flux leakage detection data in pipelines, a single information source data analysis method is used to determine the pipeline characteristics with uncertainty. A multi-source information fusion data analysis technology is proposed. This paper makes full use of the information collected by the multi-source sensors of the magnetic leakage internal detector, and adopts distributed and centralized multi-source information fusion analysis technology. First, pre-analyze and judge the information data of the auxiliary sensors (speed, pressure, temperature) of the internal magnetic flux leakage detector. Then, the data of the main sensor, ID / OD sensor, axial mileage sensor, and circumferential clock sensor of the magnetic flux leakage detector are analyzed separately. Finally, the RBF neural network + least squares support vector machine (LSSVM)fusion analysis technology is adopted to realize the fusion analysis of multi-source information. The results show that this method can effectively improve the quality and reliability of data analysis compared with traditional single information source data analysis.

Keywords. Magnetic flux leakage, in-line inspection, multi-source, data fusion, data analysis

1. Introduction

Magnetic flux leakage detection is an effective method to detect pipeline defects and identification features. How to improve the quality and reliability of data analysis in magnetic flux leakage is the key issue to ensure the results of pipeline testing [1]. Yang Lijian et al. [2] used the finite element method to analyze the characteristics of the leakage magnetic field signal to make a preliminary judgment on the defect shape parameters. Shao Weilin et al. [1] adopt the principle that the characteristic curves are relatively consistent to judge the special stolen oil hole signal. Wang Fuxiang et al. [3] can identify the pipeline features by using the triaxial leakage magnetic field pseudo color map. The above literatures all use the data analysis of a single information source to judge the results of the leakage magnetic field signals, while the data analysis using single information sources has certain limitations and uncertainties [4].

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2. Structure and working principle of multi-source information magnetic leakage internal detector

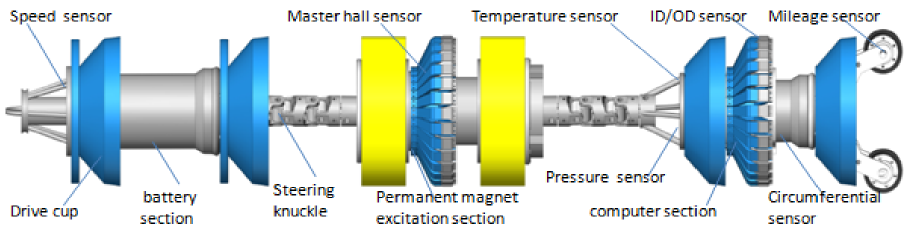


Figure 1. Structure of the magnetic flux leakage detector

The structure of the magnetic flux leakage detector is shown in Figure 1. It is mainly composed of a front-end battery-driven section, an intermediate permanent magnet excitation section, and a rear-end industrial computer section, and each part is connected through a knuckle. The pipeline magnetic flux leakage detecting device is a multi-source information collecting system. Sources of collected information mainly include main sensors, ID/OD sensors, axial mileage sensors, circumferential hour sensors, and auxiliary sensors (speed, pressure, temperature).

The principle of magnetic flux leakage detection is shown in Figure 2. The magnetic field of the leakage magnetic field signal of the wall to be inspected is collected by the main sensor array between the two magnetic poles through the excitation tube body and the permanent magnet thereon, the steel brushes on both sides, and the wall of the tube to be inspected to form a closed loop saturation magnetic circuit. If the material of the wall to be inspected is uniform or the electromagnetic characteristics have not changed, the magnetic field signal of the back is relatively constant; otherwise, the signal of the magnetic flux leakage changes. Through the analysis of the signal signals of each information source, the correlation analysis of the detection data is completed, and the type, shape and size of the relevant features of the pipeline are obtained through the inversion of the signal[1、3].

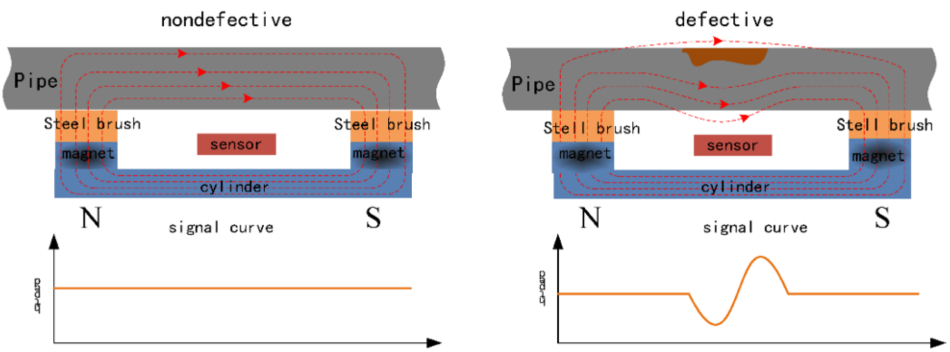


Figure 2. Schematic diagram of magnetic flux leakage detection

3. Data analysis based on single source information

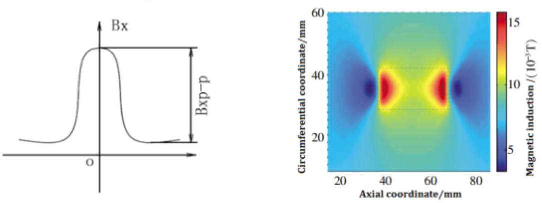
The pipeline magnetic flux leakage detector is a multi-source information acquisition system. By visualizing the detected data, the image of the feature is drawn, and the qualitative analysis of the data is realized by analyzing the signal changes in the image. The following data analysis of signals from different sensor information sources.

3.1. Data analysis of the main sensor information source

The main sensor is located on the permanent magnet excitation section of the detector. The multi-channel three-axis orthogonal Hall sensor array [5] is used to measure the component Bx along the axial direction, the component of the radial direction By and the component Bz of the circumferential direction. Used to identify the type, shape, size, etc. of the feature. The following is a data analysis of the time domain features of the signals in these three directions.

3.1.1. Data analysis of main sensor axial information source

Using the finite element method, the graph of the axial component [6]and the pseudo color map are shown in Figures 3(a) and 3(b). It can be seen from Figure 3(a) that the Bx component is parallel to the axis of the pipe, has a maximum value at the center and is bilaterally symmetric, and has a maximum peak and two valleys. It can be seen from Fig. 3(b) that the contour of the Bx component mainly reflects the inflection point of the bottom contour of the defect, and the valley points are respectively located at the left and right edges of the defect opening, and the peak region is located at the center of the defect opening. The difference between the peak value and the trough value of the Bx component of the feature quantity is defined as the Bx peak-to-valley value [7] (Bxp-p) to evaluate the radial depth of the feature.



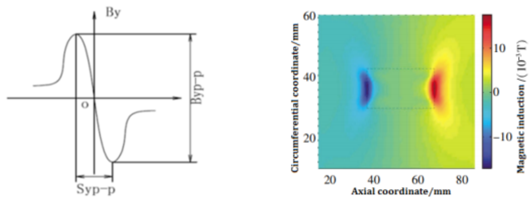
(a) (b)

Figure 3. Schematic diagram of the axial component of the leakage magnetic field signal

3.1.2. Data analysis of the main sensor radial information source

The finite element method shows that the radial component [6] has a graph and a pseudo color map as shown in Figure 4(a) and 4(b). It can be seen from Figure 4(a) that the By component is perpendicular to the axis of the pipe, which is symmetrical about the center of the defect and zero at the center, and the left and right edges of the defect have a positive value and a negative value, respectively. It can be seen from Figure 4(b) that the contour of the By component mainly reflects the shape of the opening of the defect, and the peak and valley points of By are located at the left and right edges of the defect opening. The difference between the positive peak and the negative peak of the

By component of the feature quantity is defined as the peak value of the By peak [7] (Byp-p) to evaluate the radial depth of the feature. The axial distance between the positive and negative peaks of the By component is defined as the peak-to-peak distance value [7] (Syp-p) to evaluate the axial length of the feature.

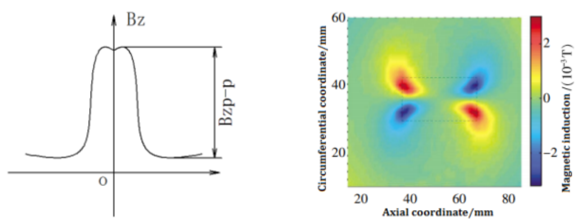


(a) (b)

Figure 4. shows the radial component of the leakage magnetic field signal

3.1.3. Data analysis of the main sensor's circumferential information source

The finite element method is used to simulate the curve of the circumferential component of the main sensor [6]. From Figure5 (a),it can be seen that the Bz component has two peak points, two valley points, and two antisymmetric planes[13].It can be seen from FIG. 5 (b) that the outline of the Bz component mainly reflects the inflection points of the side boundaries of the defect, the peak points are located at the upper left and upper right edges of the defect opening, and the valley points are located at the lower left and lower right edges of the defect opening. The difference between the peak value and the valley value of the Bz component of the feature amount is defined as the Bz peak and valley value[7] (Bzp-p) to evaluate the circumferential width of the feature[8].



(a) (b)

Figure 5. Schematic diagram of the circumferential component of the leakage magnetic field signal

3.2. Data analysis of ID / OD sensor information sources

The ID / OD sensor is located in the industrial computer section of the detector. The multi-channel Hall sensor array is used to identify whether the feature is located on the inner or outer wall of the tube. It uses the permanent magnet localized Hall measurement method to magnetize a certain depth using a weak magnetic field. The distance between the inner surface of the pipeline and the absolute magnetic flux leakage vector field in the radial direction follows the principle of magnetic flux leakage. The signal fluctuation is used to determine whether the defect is within the magnetization range to distinguish the features located on the inner and outer walls of the pipeline [9]. First, a certain method is used to extract the characteristics of the curve data, and then the polarity curve comparison consistency principle [1]is used to judge, which can only evaluate the inner and outer wall distribution of the feature in a limited way.

3.3. Data analysis of axial mileage sensor information source

The axial mileage sensor is located at the end of the detector's industrial control computer section. It uses a multi-channel switch-type Hall sensor for characteristic mileage information positioning. It cooperates with a mileage wheel and a counter to form a redundant mileage positioning system for the detector. The element receives the magnetic signal of the mileage wheel, generates a pulse voltage signal and sends it to the counter to judge the number of revolutions of the mileage wheel, and then calculates the axial mileage based on the circumference of the mileage wheel multiplied by the number of pulses. First, the optimal algorithm is used to extract the features of the triangular wave curve data, and then the time-domain signal alignment analysis is used to locate the feature points. It can only obtain the absolute mileage and relative mileage of the characteristic signal to a limited extent.

3.4. Data analysis of clockwise sensor information source

The circumferential clock sensor is located inside the industrial computer section of the detector. A hammer encoder is used to determine the position of the feature in the circumferential direction of the cross section of the pipeline. The circumferential position adopts the pipe cross-section to align the clock dial to define the clock position. When rotating, the weight always outputs the code disk value to its relatively fixed position to reflect the position of the encoder's circumferential rotation [9]. First, by calculating the two-dimensional curve of the code disk value generated by the initial fixed tip probe, the code disk value corresponding to the characteristic point is selected. Then it is converted into the corresponding hour, and then the hour of the circumferential position of each channel given to the multi-sensor curve is realized. It can only obtain the circumferential clock position of the characteristic signal in a limited manner.

3.5. Data analysis of auxiliary sensor information sources

Auxiliary sensors (speed, pressure, temperature) are located at different positions of the detector, which are used to record the operating parameters and judge the validity of the test data. Each parameter (speed, pressure, temperature) sensor uses the set parameter thresholds to determine whether the operating parameters exceed the working parameters of the detector, thereby realizing the validity of the collected data. When the pressure and temperature parameters exceed the limits, the detection data will be invalid. However, if the speed parameter exceeds the limit within a certain range, a data compensation identification model based on the speed effect must be adopted. First, extract the eigenvalues through the adopted parameter curve, and then use the time domain signal alignment to judge the validity of the data. It can realize the validity of the collected data and the establishment of the recognition model of the compensation model.

4. Data fusion analysis based on multi-source information

4.1. Structure of multi-source information fusion analysis

This paper adopts a distributed and centralized data fusion analysis structure. First, perform independent data analysis on the collected data of each sensor's information source (based on the data analysis method of each sensor), then perform centralized data fusion processing, and finally make a comprehensive data analysis judgment. The data of each single information source sensor is firstly preprocessed by the respective data, and then the local data analysis of each information source sensor is performed according to the respective feature quantities. Before the auxiliary sensor information source data is sent to the fusion center, it needs to be sent to the local data analysis of the main sensor, ID / OD sensor, axial mileage sensor, and circumferential clock sensor information source. First, make a centralized judgment on the effectiveness of the proactiveness of each acquisition system. Then input the results from the local data analysis into the fusion analysis center, make decisions based on the information source sensors and other related information, and make the final comprehensive decision [10].

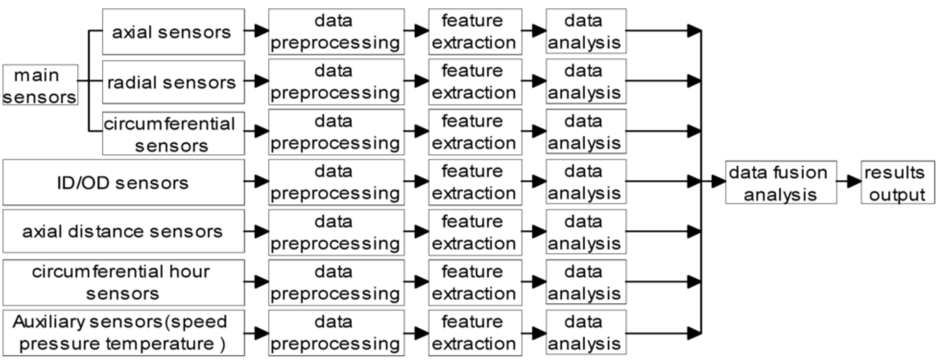


Figure 6. Fusion analysis structure of magnetic flux leakage detection data

4.2. Multi-source data fusion analysis method

The method of data fusion analysis is critical to the quality and results of data analysis. The comprehensive RBF neural network (RBF ANN) has the characteristics of fast convergence speed, fast network training, strong learning and approximation capabilities, and minimal support vector machine [11] (LSSVM) can solve small sample learning, structure selection, Local extremum, high-dimensional problems [7]. This paper adopts a two-way data fusion analysis model of RBF neural network + minimal support vector machine (Figure 7). That is, the RBF neural network is used to perform pre-data fusion on the auxiliary sensor information source data. Then use LSSVM for feature layer data fusion, the steps are as follows: First, the main sensor axial signal, radial signal, circumferential signal, and ID / OD sensor signal, as well as the time domain characteristic signal data set extracted from the axial mileage signal and circumferential clock signal as the input of magnetic flux leakage detection data LSSVM. Data analysis results as output. Second, normalize the input and output data so that they are between 1 and -1.Finally, determine the kernel function and related parameters of LSSVM, construct and solve convex quadratic programming, construct the decision function f (x) = sgn [g (x)], and train LSSVM.

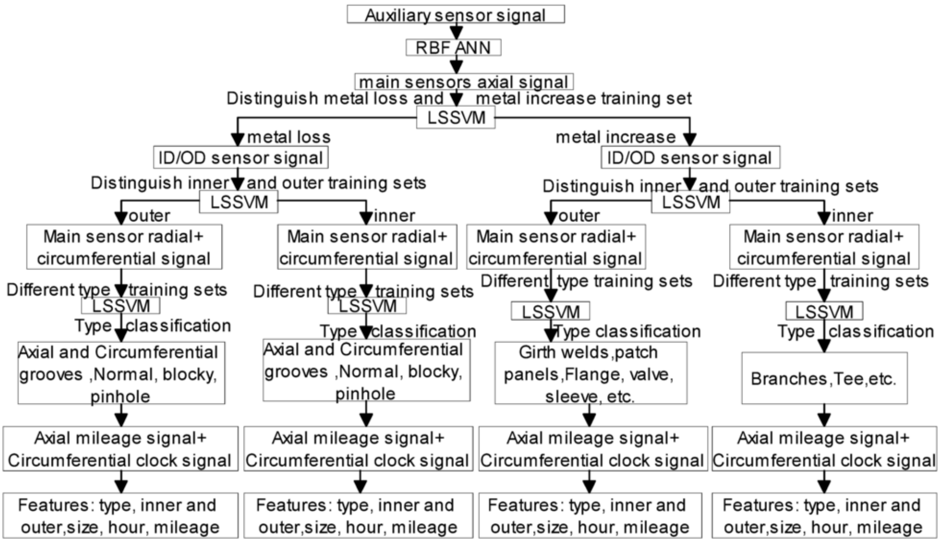
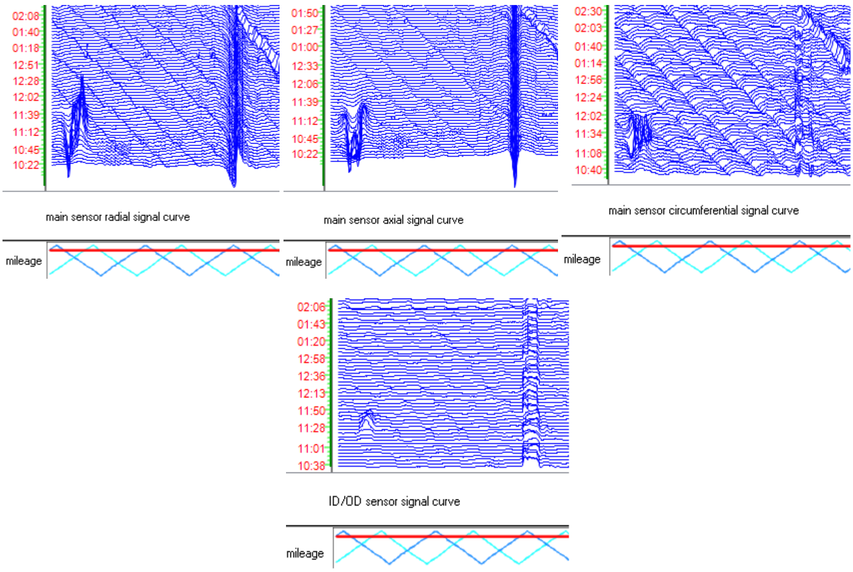


Figure 7. Two-way data fusion model

5. Multi-information source data fusion analysis application

Using multiple information source fusion analysis to analyze the offline data of a certain type of magnetic flux leakage detector, it can be seen that the auxiliary sensor information source signal is judged by RBF neural network fusion, and the data of each collected information source is normal. (A), (B), (C), and (D) of Figure 8 are the graphs of axial signal curve diagram of the main sensor, the graph of radial signal curve of the main sensor, the graph of circumferential signal curve of the main sensor, and the graph of ID / OD sensor signal curve, respectively. Using the LSSVM method to analyze the signals in Figures 8 (A), 8 (B), 8 (C), and 8 (D), it can be seen that this feature is basically directly above the pipe (11:40), and the length and width are basically the same 50mm, and belongs to the metal-addition board and metal loss hole complex. To sum up, it is an external branch pipe, which has been verified as an oil stealing valve after excavation (Figure 9), which shows that the method is feasible.

According to the above-mentioned data fusion analysis, it can be known that the use of multi-source information fusion analysis technology can avoid the limitations and one-sidedness of single-source data analysis when determining features, and can improve the redundancy and superiority of multi-source information systems. Finally, a comprehensive analysis of the detection data is achieved, which can better obtain information such as the type, size, shape, position, and orientation of features.



(A) Axial of main sensor (B) Main sensor axis (C) Circumferential direction of main sensor
(D) ID / OD sensor

Figure 8. Multi-source information acquisition signal curve

Figure 9. Actual picture of digging verification

6. Conclusion

The pipeline magnetic leakage internal detection equipment is a multi-source information acquisition system, and the sensor is the medium for information source acquisition. The acquisition of pipeline detection information depends on sensors of various information sources with different functions. Multi-source information collection can obtain detection information in all directions, and establishes the basis of complementarity and redundancy of multi-source information.

Multi-source information fusion analysis technology can effectively avoid the limitations and uncertainties of single-source data analysis, and can effectively establish the connection and globality between various sources. Using the RBF neural network + minimum support vector machine data fusion analysis method, compared with the traditional single information source data analysis, it can effectively improve the quality and reliability of the detection data analysis.

7. Acknowledgment

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