Data Preprocessing Based on MFL Inspection

Shao-xin SUN, Hua-guang ZHANG and Sen-xiang LU

School of Information Science and Engineering, Northeastern University,
Shenyang, 110819, P. R. China
*Corresponding author

Keywords: Magnetic flux leakage (MFL), Data preprocessing, Data processing, Imaging.

Abstract. It’s necessary for detected ferromagnetic material to do fault diagnosis to ensure it to operate safely, lengthen its service life, prevent leakage and environment pollution. Now, magnetic flux leakage (MFL) inspection method is widely recognized as one of the most effective nondestructive testing methods for ferromagnetic material.

In this paper, data preprocessing and data processing are the main research content. Data preprocessing makes data neater, which lays a solid foundation for accurate and fast defect localization, feature extraction and life prediction. Furthermore, data preprocessing and image rendering implement the data processing function rapidly and precisely and greatly reduce the difficulty of data processing.

Introduction

MFL is mainly used in defect detection of the ferromagnetic material such as pipelines, oil tank, steel wire rope, and so on. The signals of defects on the surface or near surface of ferromagnetic material are detected by Hall sensors. Furthermore, MFL also can locate the defect region [1]. MFL has many advantages, for example, testing sensitivity is high; probe is simple and convenient; preliminary quantification of defects is realizable; missing rate is low; realizing automation is easy.

The technology of quality control is developing rapidly, but the development of MFL technology in China is lagging behind, leading to the increasing market demand for MFL equipment in our country. Therefore, it is an important and urgent task for our country to catching up with the foreign equipment manufacturing technology of MFL.

Principle of MFL

When the magnetizer magnetizes the detected ferromagnetic material which is uniform and continuous, the magnetic induction line will be constrained in the detected ferromagnetic material [2]. The flux and material surface are parallel, uniform distribution, without leakage flux overflow. When there are defects in the material, the defects will cut the magnetic lines, and the permeability will change. Because of large magnetic resistance of the defects, permeability is very small, which leads to flux distortion in the magnetic circuit and affects the path change of magnetic induction line. Some magnetic induction line will go through the inner material by bypassing the defect. A part of magnetic induction line will directly go through the defect, and other magnetic induction line will penetrate the surface of the material, which leads to produce a magnetic leakage field on the defects parts of the surface of the material, as shown in Figure 1. The MFL signals is acquired and recorded the magnetic induction intensity value of the magnetic field by the Hall sensor [3]. Though the size of the defects is the same, the leakage magnetic field on the surface and subsurface is different: the MFL on the surface is large, and the leakage magnetic field is smaller under the surface.
Figure 1. The principle of MFL.

MFL detector is composed of magnetic device, yoke iron, iron brush, Hall sensor and related circuit. The whole detection process is as follows: firstly, magnetize ferromagnetic material to be detected in order to make the surface and the surrounding form the leakage magnetic field; secondly, use the MFL detector composed of Hall sensor to detect and acquire data; thirdly, do data preprocessing of signals according to the change of detected leakage magnetic field; finally, do data processing.

Data Preprocessing of the MFL

Baseline Correction

The multi-scale morphological baseline correction method designed in this paper mainly adopts the structure of circular type and cosine type to do multistage filtering by tandem way of multistage morphological opening-closing and closing-opening filter [4], and the last stage of the output signal is the desired baseline signal. The baseline signal is subtracted from the original signal is baseline correction signal. The method has excellent baseline extraction effect in the straight line type, arc type or wavy type. Select a long set of data with 17000 points to test the effect as shown in Figure 2. It can be seen that there is baseline drift in the data, the type of which is similar to straight line type, arc type and small wavy type, bringing great trouble to the defect waveform identification and data analysis. The method can be used to separate the useful signal and the baseline signal. Separation effect is shown in Figure 2. Standard deviation can be reduced to below 1.1 Gs after the multi-scale baseline correction.

Elimination and Compensation of Abnormal Points

Sometimes, one or some consecutive points, the value of which is large, are produced at every fixed time due to the design of the data acquisition program. Sometimes, when data is in the process of acquisition, amplification, storage and transmission, one or some of the last points stored in the hard disk are usually wrong because of the ambient temperature, flow changes or equipment vibration and a series of other factors. The sample points different from general data in behavior or characteristics are called abnormal points. There are two kinds of common abnormal points. One is called signal singularity point. Its characteristic is that the amplitude of a point or several points increases a lot suddenly, as shown in the dotted circle of Figure 3. The other is called signal missing point. Its characteristic is that the amplitude of several consecutive points is missing, as shown in the dotted box of Figure 3.
In this paper, threshold segmentation method is designed to remove the obvious abnormal data. Firstly, the source data is grouped and computed difference. Then each area threshold is calculated according to the difference median of each group. The data value of each group and the threshold value in the region are transfinite judged. Finally, if the judgment data value is more than threshold value, the data value is recorded as outlier, and is compensated by three spline interpolation method, otherwise, the data value is judged as normal. The threshold segmentation algorithm runs fast and is intelligent. It can basically get rid of elimination of abnormal data by manual work, and is not limited by the number of abnormal points, which has good adaptability. As shown in Figure 3, it can be seen from the original signal that the signal has some obvious abnormal data. After correction algorithm, the obvious abnormal signal data is removed and re compensated on the interpolation data. The elimination and compensation of abnormal points are basically actualized.

**Adaptive Filtering**

Gaussian filter can significantly improve the NSR, make the signals smooth, and make distortion small [5]. Butterworth filter can ensure to smooth signal, at the same time, it can ensure that there is no distortion furthest, which results in the peak weakening is the smallest. Wavelet packet filtering method can analyze signals in time and frequency domain simultaneously, and can effectively distinguish the defect signal and noise signal. Therefore, firstly magnetic leakage signal is filtered by Gaussian filter algorithm. Then it is filtered by Butterworth filter algorithm. Finally, the Amplitude of the signal is further smoothed by Wavelet packet filtering. By selecting the appropriate parameters, the three methods are combined perfectly, and the adaptive filtering algorithm is realized. The comparison of adaptive filtering effect is shown in Figure 4. As shown in Figure 4, the filtering effect is ideal, and the signal distortion and signal recognition are both very good. The PNSR of the defect signal is increased, the SNIR is relatively high, and the waveform distortion factor is ideal. And the spectral analysis tends to the ideal state, the amplitude of the high frequency band is greatly reduced, and the low frequency band information is reserved.

**Defect Signal Feature Extraction and MFL Image Rendering**

**Defect Signal Feature Extraction**

When the ferromagnetic material is tested, the acquired MFL signals are generally relatively stable signals of low frequency, but at the same time, the acquired data which contains useful signals, contains noise of different degrees and different types which can’t be accurately identified by the
naked eye. And the amplitude resulted in noise is not large. Therefore, in the detection process, the MFL signal has a very small amplitude, so that the detected data curve is relatively flat, and there will be a small fluctuation in the vicinity of the base value [6]. But in the defective part, the amplitude of the MFL signal will suddenly become large, resulting in large distortion. Therefore, we need to identify the useful information of the MFL signals, which is called feature extraction.

The defect signals are divided into standard defect signals and nonstandard defect signals. The standard defect signal is divided into single peak defects and double peaks defects. Generally, the left peak value is higher than the right peak value in double peaks defects. The standard defects of single peak and defects of double peaks is shown in Figure 5. The curve display has a linear relationship with actual value of length, width and depth. The formation of nonstandard defects can be regarded as the superposition of many kinds of standard defects, which usually have multiple peaks. And the actual value of length, width and depth can’t be seen only from the curve display.

**Image Rendering of MFL Signals**

Data can be acquired and displayed in a variety of ways. There are three common ways in the field of MFL, which include A-scan, B-scan and C-scan. Each presentation mode is different from the display mode of the detected material area and the defect detection mode. Modern technology can simultaneously display the same magnetic leakage data in three display formats [7]. Corresponding to the three kinds of data presentation technology, there are three views of data acquired by MFL [8], which include curve view, gray view and color view, as shown in Figure 6. In this paper, curve view is used to do data preprocessing.

**Summary**

The principle of MFL is studied in this paper. According to the data characteristics acquired by MFL device, we analyze the characteristics of the defect signals, achieve the free switch of three kinds of views of magnetic leakage signals and design an adaptive algorithm for real-time data preprocessing on the MFL detector platform, which includes the baseline correction, elimination and compensation of abnormal points, and filtering.

**References**


